MechSE News

MECHANICAL SCIENCE AND ENGINEERING / SPRING 2019

ILLINOIS

Groundbreaking marks "transformational moment" for MechSE

Breaking the ground: (front left) MechSE professor Placid Ferreira, MechSE Department Head Tony Jacobi, Provost Andreas Cangellaris, MechSE distinguished alumnus and guest of honor Sidney Lu (BSME '81), Chancellor Robert Jones, and Executive Associate Dean of Engineering Martin Wong.

MechSE students, alumni, faculty, campus officials, and special guests were in attendance on October 12, 2018 for the department's historic groundbreaking celebration of the Mechanical Engineering Building.

Under a tent at Green Street and Goodwin Avenue, one of the busiest intersections on campus, the ceremony kicked off the extensive renovation of 60,000 square feet of MEB and construction of a 25,000 square foot addition.

"This isn't just about laying a physical foundation," Illinois Chancellor **Robert Jones** told the crowd. "It is about the educational and scholarly opportunities for our students and our faculty, not only for the years to come, but for generations to come. This is certainly a transformational moment, both for this corner and for the future of innovation and discovery at this great university."

The project—"Transform MEB"—is MechSE's largest undertaking ever, with an estimated cost of $41 million. Construction will begin as soon as Spring 2019 classes end in May. The building is scheduled to re-open in time for the Fall 2021 semester.

The new MEB

Once completed, it is expected to bolster the department's place among the nation's elite engineering programs. The reconfigured MEB will feature active-learning classrooms and a state-of-the-art complex of integrated, instructional, and project laboratories. With nearly 7,000 square feet of makerspace, the new spaces will inspire creativity and foster teamwork, giving MechSE students greater opportunities to work, interact, and learn in an environment optimized for true innovation. The addition will include a 3,000 square foot open-design student center and will feature a coffee shop as well as dedicated space for projects, meetings, corporate events, and more.

CONTENTS

MechSE

Department Head
Anthony Jacobi

Editors
Bill Bowman
Julia Stackler

Advancement Office
Betsy Rodriquez
Alec Verone
Kendra Wolf

Contributors
Stefanie Anderson
Allie Arp
Heather Coit
Miranda Holloway
Veronica Holloway
Mike Koon
Amanda Maher
Joe Muskin
Brian Stauffer
Taylor Tucker

Join our social networks–
just go to mechse.illinois.edu!

Two more Illinois research centers launched in MechSE

Center for Autonomy

From self-driving cars to intelligent robotic assistants to remote surgical systems, autonomous technology will revolutionize the way we live, work, and play.

In order to enable this revolution, the university has allocated $2.1 million in funds to create a new Center for Autonomy that will conduct high-impact research and develop new educational programs for students and professionals. In addition, the College of Engineering is providing a $2.1 million match to recruit new faculty in robotics to continue growing expertise at Illinois.

Directed by MechSE professor **Geir Dullerud**, the Center's research team includes several other MechSE faculty members, including **Andrew Alleyne**, **Naira Hovakimyan**, **Amy LaViers**, **Tonghun Lee**, **Prashant Mehta**, **Hae-Won Park**, **Srinivasa Salapaka**, **Matt West**, and **Aimy Wissa**.

"MechSE has a central role to play in developing the engineering and science of current and future autonomous and robotic systems, which do and will rely on a cross-cutting interplay between the physical, mathematical, and computing sciences," Dullerud said.

The researchers are already pursuing distributed autonomous and robotic trustworthy systems for applications that are important to humanity and our economy, such as the farm of the future, information-rich IoT-driven autonomous manufacturing floors, and next-generation defense systems.

Center for UAS Propulsion

The newly launched Center for UAS Propulsion (CUP) is headquartered in the MechSE Department and is directed by Professor **Tonghun Lee**.

"The center will focus on discovery, innovation, and transition of Unmanned Aircraft System propulsion technologies," Lee said. "The collective synergy of government, academia, and relevant industry is expected to result in novel technologies that can propel next generation UAVs for our nation."

Primarily supported by the Army Research Laboratory as part of ARL-Central, the center will also benefit from the participation of several other DoD agencies (AFRL, AFOSR, ONR, and NRL) as well as academic institutions and industry. The list includes AMRDEC (ADD, AED), Argonne National Labs, PM UAS, PEO Aviation, GA-ASI, Northrop Grumman, GM, GE-GRC, Convergent Science Inc, UW-Madison, ISU, OSU, Northwestern, UIC, NASA GRC, SNL, ANL, UNSW (Australia), KAIST (S. Korea), ADD (S. Korea), and TAMU.

CUP research will focus on new advances in multi-fuel capable hybrid electric propulsion system and other novel propulsion technologies, including extreme fuel-ignition characterization; variable energy assisted compression ignition; reliable high-temp coatings/lightweight materials; tribological materials for extreme low viscosity; high-pressure compact air management; hybrid electric optimization/integration; power management; electric machines for hybrid power; and high-power advanced batteries.

CUP
CENTER FOR
UAS PROPULSION

MechSE welcomes four new faculty in Spring 2019

Nikhil Admal

Assistant Professor
Ph.D., University of Minnesota, 2014
Current research: Solid mechanics; computational mechanics with focus on materials defects in crystalline systems, and interaction between atomistic and continuum domains in multiscale modeling of materials.

Lili Cai

Assistant Professor
Ph.D., Stanford University, 2016
Current research: Combustion synthesis; nanoscale materials; energy storage and conversion; smart wearables; personal thermal management; thermal radiation.

Jie Feng

Assistant Professor
Ph.D., Princeton University, 2016
Current research: Fluid mechanics, soft matter physics, nanomaterials, drug delivery.

Jiajun He

Teaching Assistant Professor
Ph.D., Stanford University, 2016
Current research: Porous materials for clean energy applications; carbon capture; fluid phase and interfacial behaviors associated with oil and gas production.

Blackhawks physician credits success to ME education

"I went to medical school with an engineer's mind, and orthopedics was a very clear draw for me because of all the mechanics involved."

Dr. **Michael Terry** (BSME '94) faced a fork in the road when he graduated from Illinois. It led to him bypassing an engineering job at Motorola and heading to medical school at the University of Chicago.

Terry's work these days is three-fold: he is a team physician for Northwestern University's varsity athletics programs as well as for the U.S. Men's National Volleyball Team, and is the head team physician for the Chicago Blackhawks.

"I went to medical school with an engineer's mind and orthopedics was a very clear draw for me because of all the mechanics involved," Terry said.

Hawks head physician since 2005, Terry travels to games and attends all practices. Over the years, the games and practices have run the spectrum from being injury-free to major injuries occurring, sometimes with players rendered unconscious. He credits his engineering background with giving him a leg up in his work as a surgeon, stating mechanical engineering taught him how to think and challenged him to problem-solve.

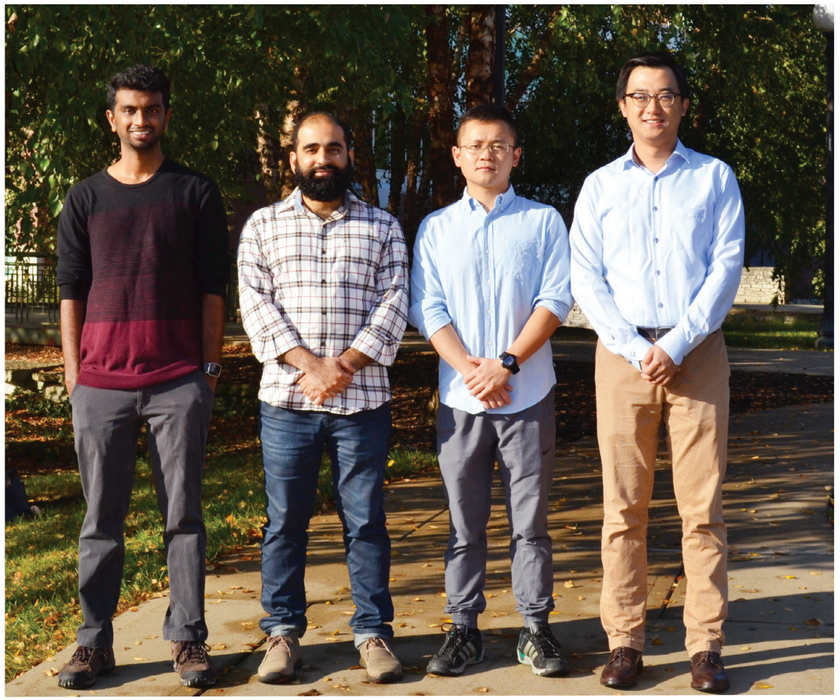
"I think (engineering) was a foundation for me that can't be beat," Terry said. "I've always told people that engineering at the University of Illinois was more challenging and thought-provoking than medical school."

Dr. Michael Terry (BSME '94) and wife Lynne (BS Accounting '94) celebrate the Blackhawks' Stanley Cup victory.

Pre-med track in MechSE

Mechanical engineering and engineering mechanics undergraduate students can now follow a prescribed track of traditional MechSE courses and newly recommended courses to qualify for medical school. It is an ideal time for students to consider this track, with the Carle Illinois College of Medicine now in its first year. Associate Professor **Amy Wagoner Johnson** is MechSE's pre-med advisor and can be reached by any interested students at ajwj@illinois.edu.

Mavis Future Faculty Fellows



Four MechSE graduate students have been named Mavis Future Faculty Fellows (MF3) for the 2018-2019 school year. The MF3 academy was developed in the College of Engineering to help prepare talented graduate students for their future transition into academia. The program focuses on research, teaching, and mentoring, offering professional development activities and workshops, a significant teaching experience, and mentorship of a less experienced student. From left to right, the students are **Chinnappamudaliar Rajagopal** (from Associate Professor **Sanjiv Sinha**'s group), **Umer Huzaifa** (from Assistant Professor **Amy LaViers**'s group), **Kaihao Zhang** (from Assistant Professor **Sam Tawfick**'s group), and **Jun Li** (from Research Professor **Pega Hrnjak**'s group).

Baja students, alumni unite for Drive Day

Drive Day is an annual Baja SAE event in which the team goes off-roading at South Fork Dirt Riders in Taylorville, Illinois. The team takes the Baja cars that have previously competed along with some tools for emergency fixes, and drive the cars on the trails.

Many alumni join the current students and bring older Baja cars and some other off-road vehicles, such as ATVs and Jeeps. This year was the biggest turnout yet, with more than 40 people participating, including 30+ current members.

"The purpose of this event is to get members excited about being on the team since they get to experience the end product of the year's work," said team member **Stef Anderson**. "The event allows members to bond with the team and create a fun community. It also lets members network with alumni who are now full-time engineers in industry."

HexNest aims to make gymnastics safer

Breaking two vertebrae in his spine as a high school gymnast turned out to be a big break for MechSE sophomore **Mark Van den Avont**.

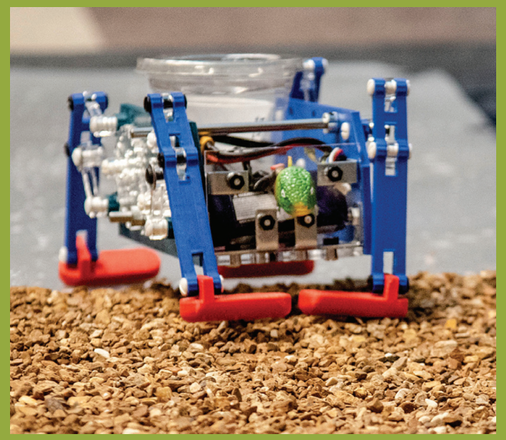
An Arlington Heights native, Van den Avont broke the T11 and T12 vertebrae during a backflip dismount while a senior at Hersey High School. The injury and crash led Van den Avont, who is fully healthy now, to create his company HexNest. The startup is developing mats that are safer and more cost-effective than the one he fell on as a 12th-grader.

Van den Avont has a provisional patent on a polymer composite that is an alternative to traditional foam used to fill mats. His first mat in development is a supplemental mat that covers much larger mats that fill gymnastics clubs and schools throughout the world. He said foam mats cost up to $400, while HexNest's expected sale price will be around $250.

"I never really thought of myself as an entrepreneur," he said. "If you told me two years ago that I would be an entrepreneur, I wouldn't have believed you."

Students' bots battle rocky challenge

In December 2018, student teams in ME 370, Mechanical Design I, created robots that could walk over both slick and rough terrain while spilling as little of their cargo (a cup of water) as possible.



The teams' entries took on a wide variety of personalities, typically animal-themed and silly, like this small-headed dinosaur.

Before reaching the rocky terrain, the robotic walkers needed to clear a Windex-coated slick surface while staying on track.

When all posed together, the walkers created a wide spectrum of colors, shapes, and mechanisms.

MechSE professors Placid Ferreira (pictured), Hae-Won Park, and Aimy Wissa were instructors for the class and final judges on how much water spilled.

MechSE outreach efforts leading students to STEM

> "It's a unique opportunity to distill the science down into something that is more digestible by a broader audience. Especially for students who are interested in science but don't get that much exposure to more interesting hands-on projects."
>
> – Gaurav Bahl

While often receiving less attention than education and research, outreach is a third integral part of the MechSE Department. Aiming to benefit the young people in the Champaign-Urbana community and beyond, these outreach efforts assist in the implementation of engineering curriculum in early education and empower young people to pursue a future in STEM.

With the leadership of MechSE and POETS Center Education Coordinator **Joe Muskin**, student societies, faculty, and other members of the department all do their part to make a positive impact on young students throughout Central Illinois. Dozens of programs are run each academic year.

"Starting out, I didn't think we would be able to have such a robust program and reach out to so many schools and so many teachers," Muskin said.

MechSE assistant professor **Gaurav Bahl** and his students have worked closely with Muskin, through outreach activities at local elementary, middle, and high schools.

"It's a unique opportunity to distill the science down into something that is more digestible by a broader audience," Bahl said. "Especially for students who are interested in science but don't get that much exposure to more interesting hands-on projects."

Members of Pi Tau Sigma and ASME run Family Engineering Night at Booker T. Washington Elementary School in Champaign to introduce students and their families to STEM concepts.

The connections Muskin has made helps more than just the young students in the classrooms he visits. Three of Bahl's graduate students have received National Science Foundation Graduate Research Fellowships, thanks in part to Muskin's programs.

"Without the outreach component, you can't win an NSF fellowship, and Joe has been indispensable in those outreach efforts," Bahl said.

Muskin's goal through outreach is to give students a fun and realistic view of what engineering is really like. Often, their only experience with engineering is through the guise of competition. In activities such as the egg drop and making mouse trap cars, students have one shot at coming up with a solution. Muskin said the stress of competition and the inability to learn from their mistakes often turns students away from engineering. He wants to show students the collaborative nature of engineering and combat the stereotype that it's a solitary profession.

"In fact, engineering is kind of the coolest job you can have," Muskin said. "You're paid good money to invent, and what kid doesn't want to invent something? We want to get more in line with what engineering really is."

MechSE makes outreach programs as accessible as possible, hosting events on campus like Engineering Open House as well as going to schools around Illinois, meeting with homeschool groups, and running events at the Orpheum Children's Museum or Champaign Public Library.

The department has a lot to offer young students. The opposite page showcases just a few of the many of events, clubs, and programs it offers.

Top: MechSE's Joe Muskin explains circuitry to a GAMES camper in Mechanical Engineering Laboratory.
Above: MechSE assistant professors **Chenhui Shao** and **Mattia Gazzola** show off their work from their Paper2Tree visit at King Elementary school in Urbana.

Assistant Professor **Leonardo Chamorro** teaches University Laboratory High School students about wind tunnels in his laboratory.

Assistant Professor **Shelby Hutchens** makes shoe sole-like materials to test mechanically with campers at the Fighting Illini women's basketball sports camp.

The MacPherson strut:
modern suspensions rooted in 1940s tech

Many modern cars can trace the technological roots of their suspensions back decades. One such example is the MacPherson strut front suspension, which is near ubiquitous on front-wheel-drive vehicles (and the Porsche 911). MechSE alumnus **Earle Steel MacPherson** (BSME 1915), born in 1891 outside Chicago, is to thank for this enduring bit of technology.

Working at General Motors, MacPherson worked up the corporate ladder to become Chief Engineer of Passenger Car and Truck Design. In 1945, he headed the design team for this advanced unibody "Light Car" concept, for which he personally tackled the new front suspension. MacPherson's innovative suspension would forever leave its mark on the automotive world.

His design incorporated a vertical strut attached to the wheel hub. The strut was composed of a coil spring with a tubular shock through the center, which acted as the upper anchor point for the wheel hub. The design differed radically from the standard straight axle front suspension, which often utilized leaf springs and knee-action shocks that required significantly more space and did not allow the front wheels to travel up and down independently.

With fewer parts, this system gives very similar performance to more complicated systems. With minimal modifications, it can also give very high steering angles—desirable among performance and drift drivers.

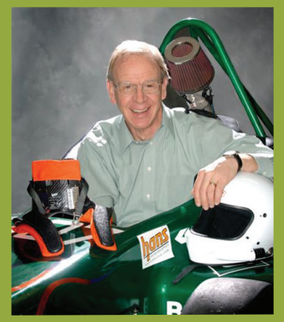
What else is so great about this 70-year-old suspension design that it's still in use? Low part count, simplicity, lighter weight, and compact packaging. All those details make it cheap to build as well.

Still, the overall package does require unibody construction, as the top of the strut needs to anchor to part of the chassis. Because modern cars are constructed almost exclusively in unibody form, and taller engines with dual overhead camshafts are now the norm, this time-proven solution is the suspension engineer's longtime best friend.

The MacPherson strut got it right 70 years ago. No reason to fix what ain't broke.

Article courtesy of Kyle Smith, Hagery.com.
Illustration courtesy of Casito.

HANS Device was game-changer for auto racing safety



MechSE alumnus Robert Hubbard (MSTAM '67, PhDTAM '70) worked alongside brother-in-law and IMSA racer Jim Downing to create the HANS device, revolutionizing driver safety in professional racing. Professor Hubbard died in February 2019 at the age of 75.

In the 1980s, Downing and Hubbard had reached the conclusion that racers were being killed in crashes because their heads were not properly restrained, leading to spinal injuries and basilar skull fractures. The death of Downing's friend, Patrick Jacquemart, in a Renault 5 Turbo at Mid-Ohio in 1981 was the seminal moment that propelled the project forward.

Hubbard was a professor of materials science at Michigan State University and needed a small business grant from the State of Michigan to launch what became the HANS device project.

It took a decade for the device to become as widely accepted as it is now, with the Formula 1 deaths of Ayrton Senna and Roland Ratzenberger at the 1994 San Marino Grand Prix, propelling the sport toward an increased focus on driver safety. But it wasn't until 2001 that the device became widely accepted with the death of Dale Earnhardt on the last lap of NASCAR's Daytona 500.

Primarily made of carbon fiber reinforced polymer, the HANS device is shaped like a "U", with the back of the "U" set behind the nape of the neck and the two arms lying flat along the top of the chest over the pectoral muscles. The device, in general, is supported by the shoulders. It is only attached to the helmet. Therefore, the HANS device is secured with the body of the driver, not the seat.

The purpose of the HANS device is to keep the head from whipping fore and aft in a crash, preventing excessive rotational movement as a secondary protection, without otherwise restricting movement of the neck.

The HANS device is now mandated in every NASCAR division and various racing sanctioning bodies across the globe.

Information courtesy of Autoweek.
Photo courtesy of Michigan State University.

Koe family doubles their impact through Grainger Matching Challenge

Linda and Bruce Koe

Scholarships created by Illinois alumni have long helped students fulfill their educational dreams. MechSE alumnus **Bruce Koe** (BSME '66) and his wife, **Linda** (BS, LAS '65), have turned to philanthropy to make college more affordable for students and to attract what is now the most diverse and most qualified classes of students in the history of the College of Engineering.

In 2001, the Koes established the Kirkwood Scholarship for Women in Engineering, named after Linda's grandmother, Flossie Kirkwood Massock. Flossie, born in 1892, was not an engineer. She was, however, one of the first women graduates of Bradley University and a trailblazer in her day. The scholarship is intended to motivate women in engineering to finish their degrees, and over the years, it has helped 22 women graduate from Illinois.

"Since we have retired, Linda and I have focused our efforts on supporting three of our passions: women in engineering, feeding the hungry, and helping immigrants to sustainability. We decided that rather than go on cruises or such that we wanted to give back. And we hope to be an example of giving back to our children, grandchildren and others, and inspire them to reach out and help others," Bruce said.

Witnessing the accomplishments of the women engineers who have benefited from their scholarship gives the Koes a great deal of personal satisfaction.

"We feel that each of us is called to give as we are able out of the many blessings we have received," the couple said. "Some of the [Kirkwood Scholar] graduates are already giving back to the university and some are now helping their siblings receive a college education. So the circle of giving goes on."

Find out more

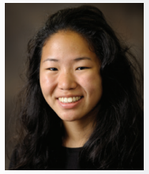
To learn more about the EVS Initiative and the Grainger Foundation's matching opportunity that lasts until the end of 2019, contact Betsy Rodriquez or Kendra Wolf in MechSE's Advancement Office.

Betsy Rodriquez
Associate Director of Advancement
217-333-9713

Kendra Wolf
Associate Director of Advancement
217-300-7297

Anthony Crawley, Jr.
Mechanical Engineering '22

"This scholarship makes it that much more important for me to fulfill my dreams so that the people that believed in me and have helped me in my academic journey can feel that their contributions did not go unanswered. They have helped to change not only my life, but also the world. Furthermore, it makes me want to do the same for the next generation after I leave this university."



Benita Ning
Mechanical Engineering '19

"This scholarship has allowed me to maintain a healthy and balanced life in college, which is an amazing feat to accomplish while at a highly competitive university like Illinois. I've been able to study abroad, conduct research domestically and abroad, and play a large role in clubs by volunteering my time to mentoring underclassmen."

Grainger to match at 100% through 2019

Five years ago, Illinois Engineering, in partnership with The Grainger Foundation, launched an ambitious initiative to raise $100 million in endowment support with a special emphasis on unrestricted scholarships. The Engineering Visionary Scholarship (EVS) Initiative has since paved the way for hundreds of deserving students to make their dreams of becoming an engineer a reality.

The EVS Initiative attracts the brightest students, ensures a diverse and talented class, and helps reduce debt. The college places a particular focus on highly qualified students from the State of Illinois. Gifts to EVS become the catalyst for access to education, for nurturing ambition, and for turning students' passions into possibilities. To date, the College of Engineering in total has raised $80.7M of the $100M goal, thanks to the help of more than 2,000 donors.

Through the end of 2019, all gifts made to the Engineering Visionary Scholarship Initiative will be matched dollar-for-dollar, up to $25 million. The Grainger Foundation, a longtime supporter of the College of Engineering at Illinois, is providing this matching opportunity. So far, The Grainger Foundation has matched more than $10.7 million in gifts. The Grainger Matching Challenge is a tremendous boost to achieving the goal of making Illinois's top engineering program more affordable for students.

Insects inspiring innovations in robot research

"We observe, model, and validate each stage of the jump with the hopes that we can later integrate them into a self-righting robot."

Robots perform many tasks that humans can't or don't want to perform, getting around on intricately designed wheels and limbs. If they tip over, however, they are rendered almost useless. Click beetles have a unique hinge-like mechanism between their heads and abdomens that makes a clicking sound when initiated and allows them to flip into the air and back onto their feet when they are knocked over—an ability researchers at Illinois would like robots to embody.

MechSE assistant professor **Aimy Wissa** leads an inter-disciplinary research team to study click beetles to inspire more agile robots. The team includes MechSE assistant professor **Alison Dunn** and entomology research scientist **Marianne Alleyne**, a research scientist in the Department of Entomology. The team is looking at several species of click beetles, ranging in size from just a few millimeters to several centimeters in length.

"Each insect goes through an assembly line of analyses that involve basic characterization, high-speed filming to observe the jump, and measurements to determine how much force it takes to overcome the friction of the hinge within an individual beetles jumping mechanism," Wissa said. "We observe, model, and validate each stage of the jump with the hopes that we can later integrate them into a self-righting robot."

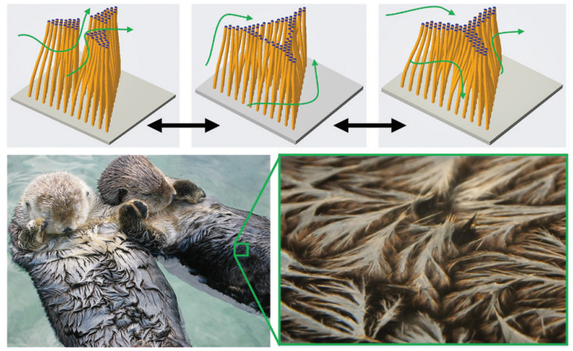
The group has already built several prototypes of a hinge-like, spring-loaded device that will eventually be incorporated into robots.

Route relays may optimize drone deliveries

While major commercial players—like Amazon, UPS, and the United States Postal Service—are developing their own network of cars and drones, their solutions that deliver one package to one customer at a time are not scalable, so they have vested interest in research seeking to solve the problem.

MechSE professor **Naira Hovakimyan** and colleagues at Stanford and the University of South Carolina recently kicked off a National Science Foundation-funded study to see if drones and existing ride-sharing vehicles (RSVs) can provide synergetic delivery service in urban areas. The much-anticipated project, "SYNergetic DROne delivery network in MEtropolis," (SYNDROME) will look into integration of parcel delivery drones with the ground vehicles on the road to optimize the time of delivery.

What Hovakimyan and her team are proposing is to develop a network of drones and existing RSVs to carry a package to the final destination. For instance, a drone might take off from a delivery center carrying a package, rendezvous with an Uber or mass transit vehicle using magnets to dock to the roofs of these vehicles even while in motion, and drop off the package. Another drone close to the final destination would then intercept the package and take it directly to the doorstep of the consumer. Because the ride-sharing vehicles are already on the road and use GPS to guide them on a specific route, the drones can coordinate with them to make the best flight plan for the package.



Hairy breakthroughs may solve tough Air Force challenges

For the U.S. Air Force, the characteristics of a surface are integral, and the ability to have an extra element of control in that respect would be game-changing. Thus their interest in the work of MechSE assistant professor **Sameh Tawfick**, who received a grant from the competitive Air Force Office of Scientific Research Young Investigator Program (AFOSR YIP) for his research attempting to develop transformable surfaces that are reconfigurable and self-healing.

"We're interested in novel active surface technologies and complex shape-changing textures, and hair is basically the ultimate texture seen in nature," Tawfick said.

Tawfick has always been inspired by the versatility of hair as a material. In nature, hair serves different purposes in different environments, from keeping animals warm in the winter to reflecting UV rays on leaves. Pairing hair with the capillary forces in a liquid expands its uses even further. When a person's hair gets wet, the hair's texture changes. The capillary forces from the water pull the hair together, morphing it from individual strands into bundles. When the water dries, the texture returns to how it was before.

Tawfick's lab already has the additive manufacturing technology necessary to print hair and the ability to create carbon fiber hairs. He will use funds from the grant to create a new technology to install various types of hairs onto any surface. Tawfick believes that the ability to create reconfigurable, transformable surfaces could add an additional dimension to design that changes every industry it touches.

"We're interested in novel active surface technologies and complex shape-changing textures, and hair is basically the ultimate texture seen in nature."

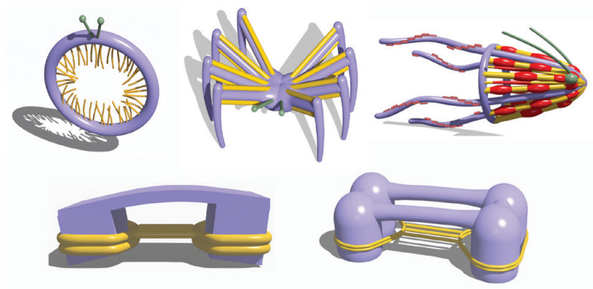
Living robots to aid internal healing

Research in the field of soft robotics and bio-hybrid robotics could improve the process for designing and building living robots for use in the medical field. Soft robotics is a field focusing on robots made of soft, highly compliant materials that are similar to those found in living organisms. These robots have more flexibility and adaptability than those made of rigid materials, but there are very few rigorous engineering methods used to design and manufacture them.

MechSE faculty **Mattia Gazzola** and **Taher Saif** recently received a $2M grant from the National Science Foundation to develop modeling and simulation software for these types of robots, while also improving fabrication protocol. Their team, which also includes Harvard Professor **George Lauder** and Northwestern Professor **John Rogers**, is focused on a subfield of soft robotics that includes integrating living matter onto artificial elements, also known as bio-hybrid robotics. The robots integrate these biological elements, such as muscle cells and neurons, with soft electronics and soft, bio-compatible materials to create a robot that is practically alive.

"We envision that these tiny robots swarm through your body and deliver a drug or are able to explore some parts of your body and send back diagnostics for prevention of a disease," Gazzola said. "We want to design them so that they are able to manipulate the environment around them, so they might even be able to perform microsurgery at some level, or simply to deliver some cargo cells used to patch an organ."

Bio-hybrid robots are very energy efficient since they are naturally equipped to extract nutrients and sugars to produce their own energy. They also can be completely bio-compatible with an individual, since they can be made from the individual's own cells. Thanks to these characteristics, they have a wide variety of potential applications.



Researchers unraveling keys to 'disgusting' hagfish defense

The hagfish dates back at least 300 million years. The secret of survival for these eel-like sea creatures can be found in the rate and volume of slime they produce to fend off predators. Today researchers at Illinois are beginning to uncover the mystery of how the hagfish uses this substance to choke its predators.

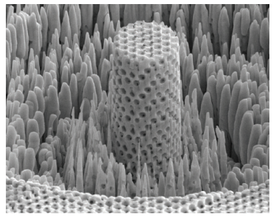
"Hagfish are both amazing and disgusting at the same time," noted MechSE associate professor **Randy Ewoldt**, who has studied the hagfish for about a decade. "The reason that they are disgusting explains how they have survived all this time."

His team's hagfish findings are receiving much interest, including features in *Newsweek, New Scientist, Ars Technica,* and *Science Magazine*. Only recently have researchers found evidence of the hagfish using its slime to clog up the gills of some suction-feeding predators, confirming the suspicions as to why the hagfish produces the slime.

"When the hagfish create this slime, they do so in an incredibly efficient way in that the amount of material they put into the water grows in volume by a factor of up to 10,000 to make the final slimy gel," Ewoldt explained. "The volumetric increase is astounding and as far as I know untouched by anything else in nature or anything we've done as engineers."

Ewoldt said a number of real-world applications will likely be designed in the future using the hagfish's method, with the United States Navy among the interested parties.

Wood-like metal boast titanium strength without the weight



Titanium is as strong as steel at half the weight, but scientists are determined to do better. In a paper published in the journal *Nature Scientific Reports*, a team from Illinois, the University of Pennsylvania, and the University of Cambridge describe building a sheet of nickel with nanoscale pores that make it as strong as titanium but four to five times lighter again. Shortly after publication, the breakthrough news was on the homepage of the U.S. Department of Energy.

The empty space of the pores, and the self-assembly process in which they're made, make the porous metal akin to a natural material, such as wood. And just as the porosity of wood grain serves the biological function of transporting energy, the empty space in this "metallic wood" could be infused with other materials, the researchers say. Infusing the scaffolding with anode and cathode materials, for example, would allow it to be used for a plane wing or prosthetic leg that's also a battery.

"The reason we call it metallic wood is not just its density, which is about that of wood, but its cellular nature," said Pennsylvania's **James Pikul**, who led the research. Pikul is a three-time alumnus of MechSE (BSME '09, MSME '11, PhDME '15), and was a graduate researcher in Professor **Bill King**'s group. King is co-author on the paper, along with MatSE professors **Paul Braun** and **Runyu Zhang**.

Coral reef engineering could have massive impact

On a global scale, coral reefs critically impact food security, shoreline protection, biodiversity, tourism, and jobs—yet huge portions of the world's major coral reef systems have not survived the last half century. MechSE faculty Amy Wagoner Johnson and Gabriel Juarez, with colleagues at Illinois and beyond, have received a National Science Foundation Convergent Research grant to work on coral reef recovery and propagation.

Not only does the disappearance of coral reefs severely limit the habitat for other ocean dwellers, but it greatly affects the stability of the lives and economies of shoreline communities. Despite biologists' best efforts to repopulate the reefs, currently only two percent of lab-cultured coral larvae survive for more than two years once introduced into the environment.

A significant issue for scientists introducing the larvae is its ability to settle when placed in the water. To counteract this, Juarez will quantify the swimming behavior of larvae in unsteady fluid environments, Wagoner Johnson is developing new materials to encourage larvae attachment, and the biologists are studying the response of the coral larvae to different materials and surfaces.

The team is also at the forefront of establishing the new field of coral reef engineering—giving researchers everywhere the foundation to invest in reversing what our current climate has done to coral populations and even lead to solving problems in antifouling, agriculture, bone repair, ocean robotics, extreme environment exploration, and terraforming.

"It's the beginning of really making a change, and when you look at it from that perspective it's really exciting," Juarez said.

New waterproof adhesive provides quick, lasting grip

Illinois researchers have introduced a new cutting-edge reusable adhesive that activates in seconds, works underwater, and is strong enough to deadlift 11 pounds: shape memory polymers (SMPs).

"Dry adhesives, such as those inspired by gecko feet, are believed to be inadequate to achieve high adhesion to a wet or submerged surface," said MechSE associate professor **Seok Kim**, who leads the project. "However, this belief has been nullified because of our SMP reversible dry adhesives."

The team has proved that SMPs can retain dry adhesion properties while submerged. Classified as a smart material, SMPs have the ability to manually transition between their original state and a deformed state. By manipulating the state of their SMPs, the team achieved successful adhesion to surfaces submerged in water as well as other liquid media such as oil.

"These findings will result in reusable high-strength adhesive fasteners for wet or submerged wall mounting," said Kim. "The next step for this technology will be to further explore SMP adhesive systems to enable reversible adhesive grippers."

Carbon nanotube research key to new paper products

The University of Illinois Research Park is home to Fresh Press, an agricultural fiber paper lab that produces and sells paper made from agricultural waste. The lab's initial goal was to eliminate campus farm waste by using it to make paper. In order to use the waste fibers to create three-dimensional packaging, the lab needed a strong understanding of the fibers' behavioral properties; enter MechSE assistant professor **Sameh Tawfick**.

"My core research program deals with processing, structure, and properties of synthetic fibers, known as carbon nanotubes," said Tawfick, who was excited about the prospect of using agricultural waste to construct sustainable materials. "These are comparable in size to nano-cellulose, which is the smallest constituent of plant fibers."

Eric Benson, chair of the university's graphic design program in the School of Art + Design, co-founded Fresh Press in 2012 with a grant from the Student Sustainability Committee.

"Agricultural residue is a more sustainable source for paper products than tree fiber," Benson said. "The most sustainable way to work is with the materials that are closest to you, and it also benefits the manufacturing and farming communities."

Soft robots could fill field labor shortages

In 2017, fruits and vegetables worth tens of millions of dollars rotted in California fields because of an ongoing labor shortage. A diverse group of researchers at Illinois is working to develop robots capable of reducing the agricultural industry's reliance on manual labor. Predicting how the robots will achieve their tasks and interact together is the job of MechSE assistant professor **Mattia Gazzola**, the team's computational modeling expert.

Whereas traditional robots are normally tested through trial and error, that wouldn't be an ideal approach when a robot is dealing with valuable growing plants. Unlike hard-bodied robots, soft robots have the additional challenge of body fluidity; when one part of the robot moves, it may affect another part. Gazzola is running hundreds of simulations in order to predict accurately how a robot's movements will impact the robot itself and the other robots around it.

"One of the challenges is to acquire data to determine how we should activate the robots and get them to move in the field," Gazzola said. "The goal is to do all of this on the computer. This way we can enhance the capabilities of these robots and develop them faster."

MechSE education leaping forward through SIIP programs

Liebenberg introduces redesign into ME 270 curriculum

A ME270 student team makes its final presentation.

In Fall 2018, Senior Lecturer Dr. **Leon Liebenberg** taught ME 270, Design for Manufacturability, and made big changes to improve the course and get students more engaged.

Instead of the traditional semester-long project in which students form teams to design a product from scratch, Liebenberg introduced a new project called *Redesign for Manufacturability*. He tasked students to find existing products to redesign for cost-efficiency and sustainability. After reverse-engineering their product, students redesigned one component or sub-assembly of the product, and then fabricated these redesigned components in MechSE's Innovation Studio.

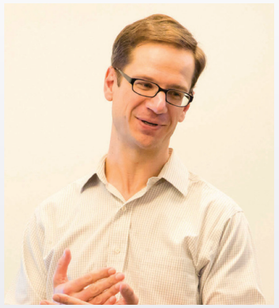
Liebenberg also introduced a series of 10 mini-projects to encourage students to engage even further with course material. They were asked to investigate products made using specific manufacturing techniques, often by acquiring the products from a scrap yard.

"I want students to engage at an emotional level with the subject contents," Liebenberg said. "I want them to feel the subject. It's not just a product, this thing interacts with the environment. They have cost aspects, human aspects, and environmental aspects. I want them to dig deep, and not just at a cognitive level. It's about empathizing with the client and empathizing with the product."

ABOUT SIIP

The Strategic Instructional Innovations Program (SIIP) competitively awards grants to enable faculty teams to accelerate best practices for teaching, develop new best practices, and reimagine what it means to educate Illinois students. The MechSE Department boasts by far the most faculty leading 2018-19 SIIP-funded projects. In addition to West and Liebenberg, Associate Professor Sam Tawfick leads Nurturing Design Thinking in Engineering Courses, Lecturer Blake Johnson leads Engineers SPEAK: Just-in-Time Delivery of Presentation Instruction, and Professor Elizabeth Hsiao-Wecksler leads iDesign: Integrated MechSE Design Curriculum.

West's programs making waves of change across campus



MechSE Associate Professor **Matt West**'s educational programs *PrairieLearn* and the *Computer-Based Testing Facility* (CBTF) have improved courses in the College of Engineering since their inception. Now, their influence has spread beyond the Bardeen Quad.

The PrairieLearn site provides online homework that uses mastery learning theory to adapt to a student's performance throughout an assignment and determine his/her proficiency in the material. This system is made to ensure that each student gets the practice they individually require for each problem.

West has repurposed an Engineering Work Station (EWS) lab as the first CBTF. A computerized examination center, the CBTF tests students, providing multiple tries at a problem, giving instant feedback, and opening up class time.

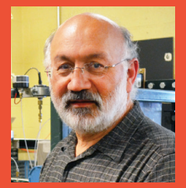
Initially only testing the TAM 251 sections, the CBTF has since expanded dramatically. It is now located in the Grainger Engineering Library, where it holds 80-85 seats and runs 12 hours per day, seven days a week. In Fall 2017, the CBTF ran 50,000 exams for 6,000 students across multiple engineering departments.

Universities around the world have experimented with computer-based testing, but West said that the CBTF at Illinois is the largest and most successful of its type. He has seen the number of A-grades on the TAM 251 final exam double and the number of failing grades decrease by 60 percent.

For faculty, the creation of PrairieLearn-compatible material opens up an opportunity for reevaluation of homework and exam questions. As they develop the material, they can turn a critical eye to how the course was previously tested to ensure that new questions are representing the desired takeaways from the course.

"I think that's one of the impacts—that it's made faculty rethink assessment in general," said **Laura Hahn**, Director of the Academy for Excellence in Engineering Education (AE3) in the College of Engineering.

Beyond engineering, PrairieLearn is used in a statistics course, and instructors of General Chemistry II (104) classes are developing PrairieLearn material to be used in the future. West said he hopes it spreads even further across campus.



Pega Hrnjak has been named the Stoecker Faculty Fellow in Mechanical Science and Engineering. Hrnjak is the Director of the Air Conditioning and Refrigeration Center.

Alexander Vakakis was awarded a Donald Biggar Willett Professorship of Engineering. His new appointment is the result of his exceptional research, teaching, and service.

Narayana Aluru was one of only four professors at Illinois to be elected 2018 Fellows of the American Association for the Advancement of Science.

Gaurav Bahl's article from *Nature Photonics* was chosen for the Optical Society's "Optics in 2018" list of the year's most interesting developments. Bahl and his team demonstrated that sound waves can be used to produce ultraminiature optical diodes that are tiny enough to fit onto a computer chip.

Joseph Bentsman and **Brian Thomas,** along with Nucor Steel Decatur metallurgist Madeline Rembold, completed an NSF-funded project that resulted in development of a mold oscillator control for Nucor. Their team applied bang-bang optimal control to continuous steel caster dynamics for fastest control under fault, work that won them the 2018 Computer Applications Best Paper Award from the Association for Iron and Steel Technology (AIST).

Harry Dankowicz was named one of the recipients of the 2019 Rose Award for Teaching Excellence from the College of Engineering. He was also honored with the DSWeb 2018 Software Award for his COCO software package upgrades.

Naira Hovakimyan gave the GNC Plenary Lecture at the American Institute of Aeronautics and Astronautics' 2019 Guidance, Navigation, and Controls Conference. Her talk, titled "Aerial Co-Robots of the Future," provided an overview of recent results in flight control development and applications in cooperative flight control.

Harley Johnson received the 2018 Larine Y. Cowan Make a Difference Award for Leadership in Diversity, in recognition of his efforts to promote diversity and inclusion through research, hiring practices, courses, programs, and events.

Richard Keane taught his last classes this past semester before retiring after more than two decades with the university. A native of Australia, Keane earned his PhD in Theoretical and Applied Mechanics at Illinois in 1993 and spent the next 25 years on the TAM (and subsequently MechSE) faculty as a lecturer specializing in fluid mechanics. Keane was also the coordinator for the fluid mechanics laboratory in Talbot Laboratory, and he contributed to the current laboratory manual required for TAM 335, *Introductory Fluid Mechanics*. For many years, he advised and supported students in the Society for Experimental Mechanics (SEM).

William King is Chief Scientist at Fast Radius, a company named a Manufacturing Lighthouse by the World Economic Forum. There were only nine companies worldwide selected for this honor, out of 1,000 companies considered. Fast Radius was selected because of its ability to accelerate new product development and production, using additive manufacturing and data analytics. It was the only company selected in North America; the others are in Europe and China.

Seid Koric, as part of a team of affiliates of the National Center for Supercomputing Applications (NSCA) at Illinois, was recognized with two awards at the 2018 International Conference for High Performance Computing, Networking, Storage and Analysis (SC2018). The team won Best Use of Artificial Intelligence and Best Use of HPC in Automotive in the annual HPCWire Editors' Choice Awards.

Kathryn Matlack was awarded the Haythornthwaite Foundation Research Initiation Grant from the Applied Mechanics Division of ASME.

Martin Ostoja-Starzewski coauthored a new book, *Tensor-Valued Random Fields for Continuum Physics*, in the highly acclaimed Cambridge Monographs on Mathematical Physics series.

Chenhui Shao has created a new course in mechanical engineering—Manufacturing Data and Quality Systems—one of the first of its kind in the U.S. The class's structure introduces students to industry environments, and its content prepares students for the future of the manufacturing industry. Manufacturing collects the largest dataset of any industry. That data, often high-dimensional or noisy, goes underutilized because of a lack of adequate tools to analyze it. Shao's course is designed to prepare Illinois students to take on this analysis.

Arend van der Zande won the prestigious Early Career Development Program (CAREER) award from the National Science Foundation for his research on two-dimensional material heterostructures. His project focuses on examining and understanding the mechanics at the interfaces between nanomaterials and how to take advantage of the emergent properties to engineer highly deformable electromechanical devices.

In Memoriam: Alva "Tad" Addy, former Department Head

MechSE professor emeritus and alumnus **Alva LeRoy Addy**, better known as Tad, died Nov. 16, 2018 at the age of 82. After completing his PhD in mechanical engineering at the University of Illinois in 1963, he joined the faculty at Illinois. Addy served as Department Head of Mechanical and Industrial Engineering from 1987 to 1998. His vision of a state-of-the-art teaching and research facility resulted in the multimillion dollar renovation and remodeling of Mechanical Engineering Laboratory. Throughout his career, Addy was recognized for his distinguished research in fluid dynamics and outstanding leadership of an academic department that influenced thousands of mechanical engineers, as well as his advocacy for the quality and innovation in education. In 1993, a college-wide committee of students selected him as an Honorary Knight of St. Patrick because of his support for undergraduate students. He was named as one of the College of Engineering's Distinguished Alumni in 2017.

ILLINOIS
Mechanical Science & Engineering
COLLEGE OF ENGINEERING

1206 W. Green Street
Urbana, IL 61801-2906

RETURN SERVICE REQUESTED

Non-Profit Org.
U.S. Postage
Paid
Permit No. 453
Champaign, IL

The challenge: build a robot that can walk over rough terrain without spilling a cup of water. Only the most worthy survived this ME 370 competition. See page 4.