Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2017

MECHANICAL ENGINEERING

RESEARCHERS DISCUSS THE FUTURE OF BIO-INTEGRATED TECHNOLOGY

Co-hosted by Northwestern Engineering and the National Academy of Engineering, "The Networked Body" symposium took place May 16.

Touching something might seem like a simple activity, but it's actually a fairly complicated process. When we touch an object, the skin on our fingers either vibrates or is stretched or deformed. That information is collected by a network of sensors and then processed by the brain. When we touch a flat, glass touchscreen, there is not much to feel.

"That rich network of sensors has almost no role," said professor **Ed Colgate**. "A touchscreen isn't, to my mind, really a touchscreen."

But Colgate, the Allen K. Johnnie Cordell Breed Senior Professor of Design, and **Michael Peshkin**, the Bette and Neison Harris Professor in Teaching Excellence, are working to put touch into the touchscreen. They presented their research on haptics technology as a part of a symposium co-hosted by Northwestern Engineering and the National Academy of Engineering.

Called "The Networked Body: How Wearables and Bio-Integrated Electronics Will Impact Our Future," the event took place May 16 in the James L. Allen Center.

During the public symposium, researchers from academia, athletics, and industry discussed advances in wearable and bio-integrated technologies and the sports, health, and wellness areas they promise to impact. "It's an honor to host this event," said Julio M. Ottino, dean of Northwestern Engineering. "The speakers we have are all leaders in their fields — in academia and industry."

"The topic of bio-integrated technology is very exciting," said C.D. Mote, president of the National Academy of Engineering. "Attendance today ranks among the highest of all our symposiums, so that shows you the level of interest in this topic."

Ed Colgate and Michael Peshkin

Much of Colgate and Peshkin's work involves manipulating friction on glass by modulating electric or ultrasonic signals below the surface. Their technology can make smooth glass feel and sound like sandpaper, metal, or ceramic. Their work is being commercialized through Tanvas, one of the startup companies which showcased its technology during a demo session after the symposium.

Also at the symposium, **John Rogers**, a pioneer in the field of wearable electronics, delivered the opening lecture. In his talk "Electronics for the Human Body," Rogers discussed his work at the intersection of science, engineering, and medicine. The Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering, and Neurological Surgery (with a courtesy appointment in mechanical engineering), Rogers develops bio-integrated technologies, which fall into three categories: soft, tattoo-like electronic sensors; millimeter-scale wireless wearables; and skin-integrated microfluidic systems.

FROM THE CHAIR

Dear friends,

As chair, one of the things I am proudest of is our faculty's commitment to excellence in teaching, while also undertaking world-class research that shapes our collective future. One of our faculty who exemplifies this commitment is **Yonggang Huang**. Last year I was pleased to report that Yonggang had received the Cole-Higgins Award as the teacher of the year in the McCormick School of Engineering and Applied Science. This year I have the honor to report that Yonggang was elected to the National Academy of Engineering (NAE) for "pioneering work on mechanics of stretchable electronics and mechanically guided, deterministic 3-D assembly" (page 6). Congratulations, Yonggang!

While our faculty are regularly selected for the top teaching awards offered by McCormick and the University, this June **Michael Peshkin** was honored for his teaching at a national level, receiving the American Society for Engineering Education's (ASEE) 2017 Ralph Coats Roe Award for outstanding teaching (page 6). The ASEE cited Michael's "sustained efforts to provide students with design/build/debug experiences, particularly in the context of practical electronics for mechanical engineers." The $10,000 award was presented at the ASEE annual conference in Columbus, Ohio.

Perhaps the most significant recognition of Northwestern's leadership in engineering education was the awarding of the NAE's 2017 Gordon Prize for Innovation in Engineering and Technology to **Dean Julio M. Ottino**, courtesy faculty in mechanical engineering. Dean Ottino was recognized for Northwestern's Whole-Brain Engineering philosophy, and specifically "for an educational paradigm that merges analytical, rational left-brain skills with creative, expansive right-brain skills to develop engineering leaders."

Mechanical engineering is at the center of Northwestern's efforts in Whole-Brain Engineering and creative design. This summer Northwestern again hosted the Design for America (DFA) Leadership Studio, under the leadership of **Liz Gerber**. More than 100 students from 33 universities spent a week at Northwestern learning about design, social innovation, and creative leadership, all around the theme of "accessible cities."

Northwestern also hosted the annual Student Shop Manager's Conference, focusing on makerspaces and innovative support of undergraduate mechanical design. This conference was organized by **Dan Brown** and **Mike Beltran**, who also played a leadership role in the recent expansion and reorganization of our makerspaces and prototyping shops, as summarized by the new make.northwestern.edu website (page 7).

Finally, exciting new research initiatives continue to come out of our department, including the establishment of a new research collaboration with BICI led by **Wing Liu** (below), the construction of a new robotics center due to be completed in fall 2019, and a new collaboration with Ben-Gurion University on water insecurity. **Neelesh Patankar** and **Kyoo-Chul Park** are investigating one-way nets for use in arid regions that minimize evaporation of water while allowing rain water to enter the soil.

I am pleased to present this newsletter highlighting some of the achievements of our students and faculty. Thank you for taking the time to look through it, and I wish you a healthy and fruitful 2017-18.

Kevin Lynch
Department Chair

Global Partnership to Enhance Northwestern Innovations

The agreement will result in at least $1 million in annual research funding for five years

By Roger Anderson

Northwestern and the Beijing Institute of Collaborative Innovation (BICI) signed a Master Research Agreement in December that will bring at least $5 million in sponsored research to the University. The partnership will fund key research initiatives in areas of material systems and simulations, with emphasis on energy materials, advanced manufacturing, medical devices and diagnostics, water treatment, and optoelectronics devices and materials.

BICI is composed of more than a dozen Chinese universities and 100 industry-leading companies. The nonprofit organization employs collaborative and innovative approaches to bring university technologies to market.

The Northwestern partnership was largely attributed to the long-term collaboration that **Wing K. Liu**, Walter P. Murphy Professor of Mechanical Engineering and Civil Engineering, has developed with Peking University and the effort of various Northwestern units led by **Jian Cao**, associate vice president for research and the Cardiss Collins Professor of Mechanical Engineering.

"This BICI center will be an active element in the large ecosystem of the Northwestern Initiative on Manufacturing Science and Innovation (NIMSI) by stimulating the integration of basic sciences and global innovation through product realization and manufacturing," said Cao, NIMSI director.

THE PARTNERSHIP WILL BRING AT LEAST $5 MILLION IN SPONSORED RESEARCH TO THE UNIVERSITY.

NEW TEXTBOOK EXAMINES MODERN ROBOTICS

Free to download, the textbook also includes video tutorials and accompanying software

Professor **Kevin Lynch** wants to make it easier than ever to learn the fundamentals of robotics.

In July, Cambridge University Press published *Modern Robotics: Mechanics, Planning, and Control*, a new textbook written by Lynch, chair and professor of mechanical engineering, and Frank C. Park, chair and professor of mechanical and aerospace engineering at Seoul National University.

Inspired by years of notes developed by Lynch in the ME 449: Robotic Manipulation course offered at Northwestern, *Modern Robotics* addresses fundamental topics like kinematics, mechanics, motion planning, and control using modern geometric tools that are destined to become standard in robotics education. While many robotics textbooks are written for graduate students, Lynch's book is tailored to students with freshman-level backgrounds in physics, linear algebra, ordinary differential equations, and computing.

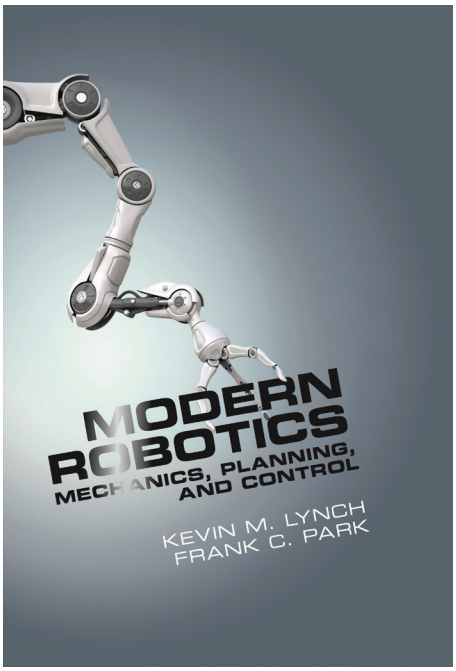
"Robotics has experienced rapid growth over the last ten years, but textbooks originally developed in the 1980s are still commonly used," Lynch said. "We wanted to develop a textbook that presents the field's core topics in a more unified way using modern geometric tools. At the same time, we saw an opportunity to make the material more accessible to undergraduates early in their studies."

Another major driver in the development of *Modern Robotics* was to eliminate cost as a barrier to getting started in robotics, particularly for students in developing countries. While students have to pay for a print version of the book, the preprint version is free to download. Lynch and his team developed free software to accompany the book, written in multiple programming languages, including free languages like Python and MATLAB clones. Chapter-ending exercises use a free robot simulator that runs on all major operating systems. Finally, the book is accompanied by free YouTube video lectures, filmed using the Northwestern Lightboard developed by Professor **Michael Peshkin**.

MODERN ROBOTICS WILL BE USED AS PART OF A NEW NORTHWESTERN MOOC AVAILABLE THROUGH COURSERA IN FALL 2017 THAT WILL DIVE DEEP INTO TOPICS PRESENTED IN THE TEXTBOOK

"We wanted to give back to the robotics community, and I'm very grateful for the financial and other support that Northwestern has given to this project," Lynch said.

In addition to incorporating the textbook into Northwestern Engineering's curriculum beginning in the 2017-18 academic year, *Modern Robotics* will also be used as the foundation of a new Northwestern MOOC specialization that will be available through Coursera starting in fall 2017. The specialization's suite of six courses is equivalent to a year-long university-level course and will dive deep into the topics presented in the textbook.



Modern Robotics presents an updated perspective of the robotics field for a larger audience, including undergraduate students.

"Students will receive a serious engineering experience in the MOOC specialization," Lynch said. "The final project will provide authentic robot programming experience by challenging students to develop a motion planner and controller for a simulated mobile manipulator."

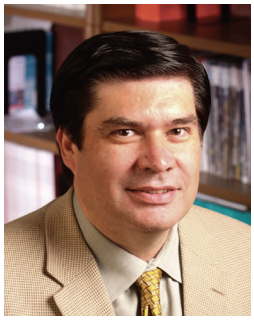
Visit http://modernrobotics.org for more information about the textbook and to download a free preprint version.

DECIPHERING THE BEETLE EXOSKELETON WITH NANOMECHANICS

Researchers employed a creative way to identify the geometry and material properties of the fibers that comprise a beetle's exoskeleton.

Understanding exoskeletons could lead to new, improved artificial materials

Many insects and crustaceans possess hard, armor-like exoskeletons that, in theory, should weigh the creatures down. But, instead, the exoskeletons are surprisingly light — even allowing the armor-wearing insects, like the beetle, to fly.



Horacio Espinosa

Professor **Horacio D. Espinosa** and his group are working to understand the underlying design principles and mechanical properties that result in structures with these unique properties. This work could ultimately uncover information that could guide the design and manufacturing of new and improved artificial materials by emulating these time-tested natural patterns, a process known as bio-mimicry.

Supported by the Air Force Office of Scientific Research's Multidisciplinary University Research Initiative, the research was featured on the cover of *Advanced Functional Materials*. Postdoctoral fellows Ruiguo Yang and Wei Gao and graduate student Alireza Zaheri, all members of Espinosa's laboratory, were co-first authors of the paper. Cheryl Hayashi, professor of biology at the University of California, Riverside, was also a co-author.

Though there are more than a million species of beetles, the team is first studying the exoskeleton of the *Cotinis mutabilis*, a field crop pest beetle native to the western United States. Like all insects and crustaceans, its exoskeleton is composed of twisted plywood-like structures, known as Bouligand structures, which help protect against predators. Fibers in this Bouligand structure are bundles of chitin polymer chains wrapped with proteins. In this chain structure, each fiber has a higher density along the length than along the transverse.

"It is very challenging to characterize the properties of such fibers given that they are directionally dependent and have a small diameter of just 20 nanometers," said Espinosa, the James N. and Nancy J. Farley Professor in Manufacturing and Entrepreneurship. "We had to develop a novel characterization method by taking advantage of the spatial distribution of fibers in the Bouligand structure."

To meet this challenge, Espinosa and his team employed a creative way to identify the geometry and material properties of the fibers that comprise the exoskeleton. They cut the Bouligand structure along a plane, resulting in a surface composed of closely packed cross-sections of fibers with different orientations. They were then able to analyze the mechanics of the fibers.

By correlating the mechanical properties with the exoskeleton geometries from diverse beetle species, Espinosa and his team plan to gain insight into natural selection and better understand structure-function-properties relationships.

RESEARCH HIGHLIGHTS

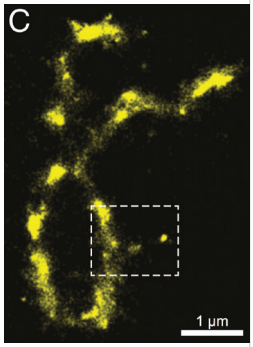
Researchers Discover that DNA Naturally Fluoresces

Discovery opens door for stain-free, super-resolution imaging

Cheng Sun

For decades, textbooks have stated that macromolecules within living cells, such as DNA, RNA, and proteins, do not fluoresce on their own. Technology instead relies on special fluorescence dyes to enhance contrast when macromolecules are imaged.

But now Professors **Vadim Backman**, **Hao Zhang**, and **Cheng Sun** have discovered that macromolecule structures in living cells do, in fact, naturally fluoresce. This finding could open the next frontier of biological discovery by paving a new way for label-free, super-resolution nanoscopic imaging and expanding the understanding of biological processes.



The reason why no one spotted the fluorescence before? The molecules were in the "dark state," a condition in which they do not absorb or emit light. The team discovered that when illuminated with visible light, the molecules get excited and light up well enough to be imaged without fluorescent stains.

New Tool Promotes Collaboration and Productivity

Pair Research is now available online

Elizabeth Gerber

Professors **Elizabeth Gerber** and **Haoqi Zhang** have developed a new online platform that simplifies the process of asking and receiving help. Launched in January, Pair Research is free and available at pair.meteorapp.com. The tool helps its users overcome productivity blocks and build teams.

After visiting the online platform, a user types in a request for help and how much time is needed to accomplish the task. The user might need someone to, for example, proofread a paper, test computer code, or motivate them to stop procrastinating. Other users then respond to the request, rating their ability to help with the task on a scale of one to five. A matching algorithm then recommends the optimal pairings for collaboration, informal learning, and productivity.

The idea behind Pair Research was formed in Zhang and Gerber's Delta Lab, an interdisciplinary research lab and design studio that aims to improve the way people design, work, learn, play, and interact. Along with colleagues at MIT and Georgia Tech, Zhang and Gerber coined the term "pair research" to describe a new type of interaction in which students were paired up weekly to work together on each other's projects.

Teaching Robots to Adapt to Human Unpredictability

NSF's *Science Nation* showcases Professor Todd Murphey's work to develop more helpful robots.

Todd Murphey

Professors **Todd Murphey** and **Jules Dewald** are collaborating to usher in a paradigm shift of how we understand robots, from large, monolithic machines used to complete repetitive, mechanical tasks, to models that are interactive and adaptable toward humans. Their latest work was featured in a video in the National Science Foundation's online magazine, *Science Nation*.

Before robots can assist humans in everyday settings, they must first learn how to respond to humans' unpredictable nature. Murphey and Dewald are building these skills through an algorithm-run robot that is programmed to draw. They believe the development of similar human-like behaviors holds potential in the physical therapy space, where robots can seamlessly cater to patients with unique needs and abilities, such as those recovering from a stroke or rehabbing an injury.

"One of the reasons we started looking at drawing is that the same drawing can be created lots of different ways," Murphey said in the video. "The order in which you do things can change, what you focus on can potentially change, yet each one of them would be considered a drawing."

Watch the *Science Nation* video at http://bit.ly/2nxXE00

FACULTY NEWS

Brenna Argall was named to *Crain's Chicago Business*' 2016 40 Under 40 list for her work bringing robotics to rehabilitative medicine.

Tanvas, a company founded by **Ed Colgate** and **Michael Peshkin** that is working to commercialize tactile display technology, received a 2016 Tibbetts Award from the US Small Business Administration. The startup was also recognized by *WIRED* magazine as one of the 2017 Consumer Electronics Show's "10 Sharpest Designs."

Horacio D. Espinosa received the Murray Medal from the Society for Experimental Mechanics.

Mitra Hartmann and **John A. Rogers** were among 145 engineers elected to the American Institute for Medical and Biological Engineering's (AIMBE) College of Fellows. The Class of 2017 was formally inducted during AIMBE's annual meeting in March in Washington, D.C.

Sinan Keten received the Presidential Early Career Award for Scientists and Engineers, the highest honor bestowed by the United States government on science and engineering professionals in the early stages of their careers. Keten will use the award to further his research in materials-by-design approaches to bioinspired systems.

Kevin Lynch was awarded the 2017 Intelligent Robots and Systems (IROS) Harashima Award "for his pioneering contributions to robotic manipulation." He is also currently serving as editor-in-chief of the IEEE International Conference on Robotics and Automation and is the incoming editor-in-chief of the *IEEE Transactions on Robotics*.

Michael Peshkin received the 2017 Ralph Coats Roe Award from the American Society for Engineering Education's (ASEE) mechanical engineering division. The award recognizes outstanding teachers in mechanical engineering.

Michael Rubenstein was awarded a 2017 Sloan Research Fellowship from the Alfred P. Sloan Foundation to advance his research in multi-robot systems.

John Rudnicki was elected fellow of the American Rock Mechanics Society.

Yonggang Huang Elected to National Academy of Engineering

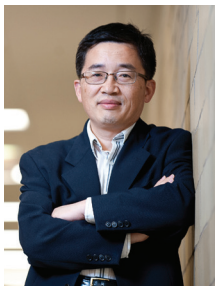
Huang recognized for pioneering wearable electronics

Professor **Yonggang Huang**, whose work has led to major advancements in stretchable and flexible electronics with biomedical applications, was elected to the National Academy of Engineering (NAE), one of the highest professional distinctions accorded to an engineer. Huang was one of 84 new members and 22 new foreign members announced by the NAE in February.

Huang, whose recent work includes a wearable electronic device for on-the-spot health monitoring, was cited by the NAE for "pioneering work on mechanics of stretchable electronics and mechanically guided, deterministic 3-D assembly."

"We are tremendously proud of Yonggang," said **Julio M. Ottino**, dean of the McCormick School of Engineering and an NAE member. "He exemplifies research excellence at the highest level, a strong commitment to education and outstanding collegiality."

Huang is the Walter P. Murphy Professor of Civil and Environmental Engineering and Mechanical Engineering.



Yonggang Huang

Huang develops mechanical models for stretchable and flexible electronics for use in biomedical devices and energy harvesting. Potential applications of his technology include thin "tattoo-like" sensors placed on the skin; implantable devices, such as pacemakers, defibrillators and heart-rate monitors; and electrocardiograms and electromyography.

Huang has earned several prestigious honors in the past year, including the Nadai Medal from the American Society of Mechanical Engineers (ASME), the William Prager Medal from the Society of Engineering Science, and McCormick's Cole-Higgins Award for Excellence in Teaching.

Jian Cao Receives Charles Russ Richards Memorial Award

Award honors Cao's outstanding achievement in mechanical engineering

Jian Cao

Professor **Jian Cao** was selected to receive the 2017 Charles Russ Richards Memorial Award, a joint award from the American Society of Mechanical Engineers (ASME) and Pi Tau Sigma National Mechanical Engineering Honor Society.

The award recognizes one individual each year for demonstrating outstanding achievement in mechanical engineering. She will officially accept the award in November at the ASME annual meeting and will become the first woman to receive the award since it was established in 1947.

The Cardiss Collins Professor of Mechanical Engineering and founding director of the Northwestern Initiative on Manufacturing Science and Innovation, Cao is internationally recognized for her broad impact on the fundamental understanding of process mechanics. Last year, she received the prestigious Frederick W. Taylor Research Medal from SME for her pioneering research on innovative manufacturing processes.

STUDENT NEWS

Car Teams Race in International Competitions

Baja and Formula teams unveil their 2017 cars.

With newly redesigned cars, Northwestern's **Baja and Formula SAE** (Society of Automotive Engineers) teams took part in three competitions this spring.

The Baja team raced in Baja SAE Kansas, an international competition in Pittsburg, Kansas, while the Formula team competed at FSAE on the Michigan International Speedway and again at Formula SAE Lincoln in Lincoln, Nebraska.

Advised by Associate Professor **Oluwaseyi Baolgun** and **Michael Beltran**, Northwestern's SAE teams give students hands-on experience in the entire research, design, and manufacturing process. They also learn about the skills required to raise funds, stay within budget, and promote their projects.

Northwestern Launches 'Make' Site

This spring, Northwestern launched MAKE Northwestern (make.northwestern.edu), a new one-stop information hub for all of its fabrication facilities and resources, including the 3D Printing and Rapid Prototyping Lab, Mechatronics Lab, Segal Prototyping and Fabrication Lab, and more.

GE Aviation to Prototype Student Project

Project selected from more than 150 entries

Students designed a smarter way to inspect airplane turbine engines.

Airplane inspections have used an optical device called a boreoscope to inspect turbine engines for the past 70 years. Inspectors have to manually position the device and eyeball the engine to evaluate it. The old-fashioned, time-consuming technique relies on manual data and image collection for further review and analysis.

Aiming to upgrade this inspection technique, GE Aviation challenged engineers around the world to design a better system. GE Aviation — from more than 150 entries — selected a project from Northwestern Engineering students enrolled in the ME 398 capstone course and plans to prototype and test their inspection solution in its facilities.

The student team, composed of **Zachary Fenske**, **John Harris**, **Jonathan Hoffman**, **Elizabeth McTighe**, **Matthew O'Hagan**, **Jacob Schneider-Martin**, and **Jay Welch**, calls their solution "SearchEYE." The segmented device enters an aircraft engine's combustion chamber, conforms to the chamber's interior geometry, then collects visual inspection data for aircraft technicians.

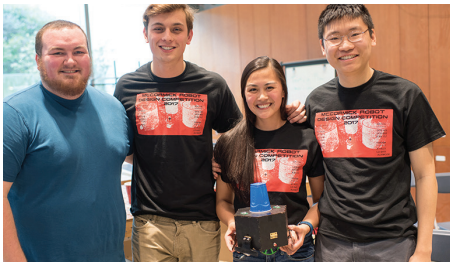
NUSTARS Soars High

Northwestern University's Space Technology and Rocketry Society (NUSTARS) completed a successful 2016-17 competition season after it consistently placed in the top five in several competitions.

Among the highlights, the NUSTARS rocketry team took second place at the 2017 Battle of the Rockets altitude target competition and fourth place in the competition's Advanced Planetary Lander Event, in which rockets are judged by their ability to deploy landing equipment. The rocket also placed fourth out of 60 teams in the NASA Student Launch in Huntsville, Alabama.

"Our designs were much more mature this year," said **Shawn Sobel** ('17), former president of NUSTARS. "We used to have things go crazy wrong, but now we're better organized and have more design experience. Our designs are super robust and tested."

2017 Design Competition



Winning team (left to right): Colton Colwell, Blake Strebel, Bailey Kuhn, and Matthew Li

A student-designed, autonomous robot named "I Can't Believe It's Not Better!" outmaneuvered the competition to win a game of "Robot Hide-and-Seek" during Northwestern's 26th annual Design Competition in May. In each round, one team commanded a remote-controlled vehicle using a virtual reality mask to find the opposing team's robot. When the human-controlled robot jousted a cup off the autonomous robot, the time was recorded. The winning robot triumphed by hiding for the longest amount of time.

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Mechanical Engineering

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Inaugural Student Advisory Council Celebrates Graduating Class

To enhance feedback and communication between students and department leadership, the Department of Mechanical Engineering students formed the Advisory Council of Mechanical Engineering students (ACME). Composed of undergraduate volunteers, ACME hosts advising, professional, and social functions throughout the year, including the Senior Sendoff Celebration event in June. The following graduating seniors received this year's departmental awards:

Bridget Popovic, who will join Boeing's Engineering Career Foundation Program, received the Leadership and Service Award. She was also named a co-winner of the Research and Innovation Award with **Adam Cyrus Farsheed**, who plans to join Teach for America before pursuing a PhD in mechanical engineering.

Elizabeth Anne McTighe, who will work for Boeing on advanced materials product development, received the Undergraduate Academic Achievement Award given to the graduating senior with the highest GPA.

The inaugural Ted Belytschko Outstanding Research Award, honoring a graduating PhD student, was awarded to **Demeng Che** in June.

Find us on Facebook: facebook.com/NorthwesternUME/

From left: Adam Cyrus Farsheed, Bridget Popovic, Elizabeth Anne McTighe, and Department Chair Kevin Lynch