RESEARCH, ENTREPRENEURSHIP AND INNOVATION AT COLORADO SCHOOL OF MINES

A new angle on cosmic research

Mines researchers send observatory 110,000 feet into the air via NASA super pressure balloon to detect ultra-high-energy rays

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Homemade energy

In-home fuel cell systems could cleanly generate electricity and hot water using natural gas COLORADOSCHOOLOFMINES

Spring-Summer 2017





SCIENCE BY THE ATOM

Metallurgical and Materials Engineering Associate Professor Brian Gorman leads the Atom Probe Tomography Laboratory at Colorado School of Mines, whose custom system is the first atom probe in the world with an integrated electron microscope.

The atom probe (a Cameca LEAP 4000 XSi) works by pulling individual atoms off a sample one at a time and analyzing each one. Repeating this process allows researchers to reconstruct a threedimensional image of the material at the atomic scale.

The system has been used to characterize photovoltaic materials for use in solar cells, oxides used in electronic devices, highstrength glass and a catalyst for liquefying natural gas, among other research projects.



COLORADO SCHOOL OF MINES has a long history of use-inspired research and innovation, and unique expertise in topics related to earth, energy and environment. Building on the strengths of that historic base, research at Mines has always reflected the changing needs of industry and society and the latest advances in the sciences and engineering. Today, research at Mines is increasingly interdisciplinary, drawing on expertise from across Mines to lead innovations in advanced manufacturing, health, energy production and storage, aerospace, security, information technology and even anthropological studies of communities connected to extractive industries.

We love sharing our success stories and the excitement our students and faculty feel for the research they pursue, and how their innovations are making an impact on society and furthering our understanding of the world, while always looking for new ways to make it better.

Our cover story details the innovation of a group of Mines researchers who are working with international partners on a technology to measure and gather information about cosmic rays. Other stories tell how our bioengineers are pursuing innovation in dentistry by developing a filling material that would encourage tooth regeneration, and how Mines researchers are finding innovative solutions to problems in robotics and the minerals industry. We also highlight the global recognition of our faculty and the impact they have on their fields.

But innovation doesn't just happen in the research labs or just with faculty—it happens all over Mines. Our undergraduates are entrepreneurial and creative, and have driven the launch of makerspaces at Mines. These facilities allow Mines students to learn and use new technologies that accelerate the transition from idea to prototype to possible start-up. We've seen evidence of this in our innovation challenge competitions and capstone course projects.

Each issue of this magazine provides an opportunity to shine a spotlight on some of the great work our faculty and students are driving, and that we are proud of here at Mines. To learn more about the research and innovation at Mines, please visit **MINES.EDU/RESEARCH**. 





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Balloon photos courtesy of NASA/ Bill Rodman







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Riding high: Physics team seeks cosmic rays from subspace

The Extreme Universe Space Observatory -Super Pressure Balloon takes off from Wanaka, New Zealand on April 24, 2017.

Just as you can see a huge slice of a city from atop a mountain or skyscraper, you can see an enormous swath of earth from 110,000 feet in the air. That's 21 miles above sea level and more than three times the 30,000-foot altitude of a typical commercial airplane flight.

This grand view of the planet is why Mines Physics Professor Lawrence Wiencke and his colleague Angela Olinto, a physicist at the University of Chicago, wanted their cosmic ray detection equipment aboard a super pressure balloon launched by the National Aeronautics and Space Administration (NASA).

The project puts a ray detection device into suborbital space, where it will look for extreme energy cosmic rays, the highest-energy subatomic particles known to exist in the universe.

Institutions from 16 countries developed the technology for the detector, which headed skyward on the Extreme Universe Space Observatory – Super Pressure Balloon (EUSO-SPB) mission. The detector and the balloon gondola it rides in were assembled at Mines and launched from Wanaka, New Zealand, on April 24, 2017 (April 25 local time).

TWINKLE, TWINKLE LITTLE PARTICLE

The cosmic rays under investigation by the EUSO-SPB mission are subatomic particles moving at nearly the speed of light, and light is how the researchers intend to observe them.

Wiencke says Einstein's famous E=mc²

equation comes into play: "This particle has so much kinetic energy that it can convert some of its energy into mass. By converting a lot of its kinetic energy into other particles, it creates a shower of particles that go through the atmosphere," he explains. The electrons in this air shower excite atmospheric nitrogen molecules, which then radiate fluorescent light. "The amount of light produced is proportionate to the energy of the original particle."

Just how much energy is packed into these particles? To answer that, Wiencke invites us to consider the piano. "The colors that you can see with your eyes represent about one octave of a piano," he says. "The total range in energy of radiation that's coming to us from the universe is not just one octave. It's not even one piano. It represents about



80 pianos, and these cosmic rays are up with the highest notes on the highest keyboard."

BUNDLE OF ENERGY

No source on Earth—or even within our own galaxy—could produce particles with this much energy, Wiencke says.

The unit measured is electron volts (eV), or the amount of energy gained by a proton or electron moving through a voltage difference of one volt. A molecule of oxygen in the air we breathe measures at 0.03 eV. A molecule at the temperature of the sun's surface has 0.5. Slap six zeros on the end of a 1, and you have 1 mega electron volt (MeV). The energy that a radioactive uranium 238 particle packs is 4.2 MeV.

Wiencke, however, isn't looking for particles that have eV measured with six zeros. He seeks particles energized in the range of 10^{18} electron volts (that's 1 followed by 18 zeros). Ultimately, he hopes to build a spacebased detector that will find particles in the 10^{20} electron volt range.

"The energy scale is extremely high," Wiencke says. "We don't know where these particles are coming from or what's producing them," although he adds that there are multiple theories about acceleration sources.

A supernova, for instance, might do the job, but Wiencke says it would only push the energy up to about 10¹⁷ electron volts, and the particles he's looking for go beyond that. "It's almost certainly not a supernova that makes these things," he says.

Candidate objects that could provide the necessary acceleration include a class of galaxies that have a massive black hole within them emitting particles. They're called active galactic nuclei. Pulsars—spinning, magnetized neutron stars—are another possibility. Neutron stars form when giant stars die in supernovas and their cores collapse.

"The object can be very small but, in that case, you need a very strong magnetic field. Or, it can have weaker magnetic fields and be much larger," Wiencke explains. To put this into perspective, he points to the Large Hadron Collider (LHC), the largest particle accelerator on Earth. It's a 17-mile ring of superconducting magnets plus accelerating structures built in to boost the energy of the particles along their way. "If you wanted to accelerate particles to the energies that we're looking at, the LHC would need to be about the size of the orbit of Mercury."

EVENT OF THE CENTURY

The particles under study may be energetic, but they're also quite rare. The rate at which they reach Earth is somewhere on the order of less than one particle per square kilometer per century.

According to Simon Bacholle, a postdoctoral research fellow with Wiencke in the Physics Department, this rarity contributes to the mystery of their origin. By searching for the particles from near space, the research team raises its chances of seeing them. "If we can detect them, we can become





more aware from which direction they come and then we can maybe—hopefully—identify what kind of source they came from," he says.

It is Bacholle's role to coordinate operation of the EUSO equipment. "We can't steer the flight, but we can control how our detector operates," he explains. "It has to be monitored 24/7."

The equipment looking for the particles includes an ultraviolet camera that takes 400,000 pictures per second. "This device, when it's running, consumes about 75 watts," explains William Finch, adjunct faculty in mechanical engineering and the man who designed the equipment Mines attached to NASA's super pressure balloon. "The balloon flies a large solar panel array and has 10 lead-acid batteries—essentially car batteries" to maintain power supply, he explains.

KEEPING IT COZY

It was Finch's job to design the gondola so that it would hold both the optical equipment and the batteries, a task he had well under control until the research team came to him one day and, as he puts it, said, "You know, we found out that these batteries are happier when they're a little bit warmer."

It's hard to stay warm in the stratosphere, where temperatures drop to -40 degrees on both the Celsius and Fahrenheit scales. At such chilly temps, batteries lose efficiency, which would leave the mission at risk. "It was my job to cram 400 pounds of batteries inside this precision optical device and capture some of the waste heat from the electronics to keep those batteries warm and happy," Finch says.

He also worked with the Columbia Scientific Balloon Facility, a NASA organization, to get the EUSO equipment certified for flight. "I did a lot of analysis that showed our design would handle all the cyclones and not get pulled apart during launch or recovery," Finch says.

IF YOU BUILD IT, THEY WILL COME

Among those who constructed Finch's designs

was Mines undergraduate Rachel Gregg, who is working on a combined bachelor's and master's degree in engineering physics. The project relates to her senior design class, she says. As part of her class deliverables, she wrote a manual on constructing the equipment as well as a comprehensive blog.

Gregg's role in the mission reflects her love of the hands-on building process, something first sparked when she helped her grandfather build birdhouses. For the EUSO mission, Gregg spent the better part of her fall semester fitting in hours of construction work alongside both staff and other student workers, and she remembers several visitors from the community and NASA coming to see their progress. When they'd ask what her role was, she'd explain that she was the main undergrad mechanic. "They were surprised shocked—to realize that I welded that. I built that," she recalls. Gregg and her teammates built the equipment quickly, too. Asked what the biggest challenge was on this project, Gregg joined Finch in saying the compressed timeline—a little more than a year—was tough to meet.

Another person pressed into fast service was Johannes Eser, a Mines doctoral candidate whose job it is to run the lasers the team will use to calibrate the detection device.

"I helped build and test two roving laser systems," he explains, adding that the lasers simulate the cosmic ray air showers, allowing the team to "make sure the detector actually sees tracks that are moving at the speed of light."



With his first laser system, Eser flew in a helicopter beneath a stratospheric balloon launched for a one-night flight from Timmons, Canada, in 2014. The second system was used to test and calibrate the EUSO-SPB detector against a dark, starry Utah sky in September 2016. That laser also attended the actual EUSO balloon launch, as Eser was in a plane below the balloon, once again validating the equipment.

UP, UP AND AWAY

NASA's high-pressure balloon carrying the detector is made with plastic as thin as a sandwich bag. Because the balloon contains no open ducts, helium doesn't escape once the vehicle is inflated. The balloon could conceivably fly for as long as 100 days, and that's the goal. So far, such balloons have achieved a 54-day flight record. In contrast, nonsuper-pressurized balloon flights average two days or less.

Inflated, the EUSO balloon measures some 150 meters in diameter—approximately the same size as a football stadium. To launch this beast, the team must have precisely the right weather conditions, a circumstance that had evaded the researchers from the time the launch window opened in late March. After seven attempts that were aborted due to unfavorable weather, the EUSO-SPB launched from Wanaka Airport the afternoon of April 24, 2017. The 10,000 pounds of balloon, parachute and payload rose nearly straight up and reached an altitude of 109,000 feet about three hours later.

Unfortunately, the balloon developed a leak a few days after launch; the flight was terminated by NASA controllers on May 7 after 12 days and four hours in the stratosphere, with the entire flight train splashing into the Pacific Ocean.

"Although this early termination is not what we had hoped for, we did operate the instrument successfully for 11 nights and we downloaded some 60 GB of data to analyze," Wiencke said. "We are in contact with NASA and planning for another payload and flight."

It will take the team some time to sort through its data, and Wiencke remains positive. "We have a good chance to see a cosmic ray or two, and perhaps something unexpected from this pioneering mission."

Aloft, the balloon provides a wide field of view, big enough that the team can "see hundreds of square kilometers of the atmosphere," Wiencke says. He adds that if the experiment shows promise, "it paves the way for a much larger experiment that would be higher up in space, perhaps aboard the International Space Station or a free-flying satellite."

BY BETSY LOEFF

High-energy research Ryan O'Hayre seeks to bring clean, high-efficiency fuel cells into homes

When Ryan O'Hayre was a high school student in Castle Rock, Colorado, he was already thinking big in terms of life goals: he wanted to work on something that would change the world. "My chemistry teacher would bring *Popular Science* and *Popular Mechanics* magazines to class and spice up his lectures with articles about cool cutting-edge science," recalls O'Hayre.

One day, when the article up for discussion was about fuel cells, O'Hayre was captivated. "The idea that you could combine hydrogen and oxygen and produce electricity to power a car, and the only pollution coming out the tailpipe would be some drops of water —I thought, wow, here's this new technology that could revolutionize the world," he says.

On the heels of his high school fascination with energy technology, O'Hayre was awarded a Boettcher Foundation scholarship, a merit-based full-ride grant to any four-year institution in Colorado. Although attending Colorado State University was a family tradition (both his parents and his sister graduated from CSU), O'Havre chose Colorado School of Mines, graduating in 1999 with a degree in metallurgical and materials engineering. He went on to earn a PhD in materials science and engineering at Stanford University, followed by a postdoctoral fellowship at Delft University of Technology in the Netherlands.

O'Hayre says a Mines professor from his undergraduate days inspired him to pursue a research career in materials. "Dr. John Moore had this amazing demonstration of a levitating magnet using superconducting materials, and he would tell me about all of the materials that went into it," says O'Hayre. "I thought, the world is full of materials, and here is this whole engineering discipline that will reveal to me the secrets of the universe. This is what I want to do."

Now, 20 years later, O'Hayre is a professor at Mines himself, and his most active research project is indeed helping him understand the universe's mysteries-at least the ones related to energy use. He and his students are working on a fuel cell system that could potentially run on natural gas and generate electricity and hot water for residential households. "You could pull out your water heater, stick a fuel cell system in there that's connected to the same natural gas supply you use for your water heater and that fuel cell system would make both electricity and hot water," says O'Hayre.

The advantage of the in-home fuel cell system is that it produces power onsite rather than at a central power plant, which drastically improves efficiency. "Right now you buy electricity from a utilities company, which is very inefficient because there are transmission losses as it's piped to your house," says O'Hayre. "With one of these fuel cell units supplied with natural gas that's already coming to your house, you could have a combined heat and power efficiency of greater than 90 percent. This would be a huge deal in terms of changing our energy economy."



"I thought, the world is full of materials, and here is this whole engineering discipline that will reveal to me the secrets of the universe. This is what I want to do."

- RYAN O'HAYRE

Because the system runs on an existing fuel source—natural gas—the technology is within reach in the near future. "Nobody has hydrogen coming to their house, so if you can make fuel cells that run on existing fuels, then suddenly you have a technology that people can actually use today without waiting for a hydrogen economy."

With multigenerational roots in Colorado (his great-great grandparents homesteaded part of what is now Applewood, just east of Golden) and as a father to two toddlers, O'Hayre says his decision to return to Mines as a professor was partly influenced by his desire to be close to family. But there was another big draw: the Colorado Fuel Cell Center, which had just been launched at Mines in 2006. "Here was this brand-new multimillion-dollar facility with all this equipment specifically for fuel cell research that I could walk into, and from day one start to do cutting-edge research and collaborate with other faculty in the fuel cell area," he says. These team efforts have involved faculty from various departments, such as Neal Sullivan, Robert Braun and Robert Kee in Mechanical Engineering and Jason Ganley in Chemical and Biological Engineering. "In terms of what I wanted to do, there really wasn't a better university in the United States."

In 2009, President Barack Obama named O'Hayre a recipient of the Presidential Early Career Award for Scientists and Engineers, the highest honor bestowed on young professional researchers by the U.S. government. "It was the one time in my life when it was good to be short, because they lined us all up by height, and I was smack-dab in the middle of the front row with the president right behind me," he says.

Prior to receiving the PECASE, O'Hayre was also awarded a Young Investigator Research Grant by the U.S. Army. There's a distinct humility when he talks about his awards, and he's quick to point out that he owes his success to teachers, colleagues and students. But even if he won't toot his own horn, others are happy to do it for him.

"Ryan is certainly recognized as a world leader in the field of fuel cell research. In fact, I think it's fair to say he's a rock star," says Tony Dean, senior vice president for research and technology transfer at Mines. "There is a legitimate aura of sustainability connected with his work, and it illustrates that faculty here are doing research in areas that people don't typically associate with Mines."

O'Hayre will soon begin a new fuel cell research project related to a potential fuel of the future: ammonia. The reversible ammonia fuel cell takes in nitrogen and water from wind power at night and converts it to ammonia through an electrochemical process. "Basically, we're using that cheap renewable energy and making ammonia fuel, and then during the day when everybody needs power, you can run the fuel cell the other way and consume that ammonia to make electricity," he says.

The enthusiasm in O'Hayre's voice when he talks about his work leaves no doubt that he will probably achieve that high school dream of changing the world. "Maybe 50 or 100 years ago, there were only a couple of options for energy and power, but the number of options is increasing exponentially," he says. "It's a really exciting time to be working in energy."

BY LAURIE J. SCHMIDT



Now a professor of civil and environmental engineering, Tissa Illangasekare was introduced to fluid mechanics growing up in Sri Lanka.

A lifelong fascination with water Tissa Illangasekare turns to interdisciplinary collaboration in search of supply solutions

It's not unusual to be fascinated by water when you're a kid, but Tissa Illangasekare did more than just jump in puddles to satisfy that youthful curiosity—he built miniature dams and learned the basics of fluid mechanics. Raised in a small village in the central hills of Sri Lanka, he says the landscape he grew up in provided the perfect opportunity to learn about water. "There were a lot of hills with mountain streams, and water was channeled from the top of the hills down to the terraced rice fields," he says. "So, actually without knowing at that time, I was introduced to the principles of hydraulics and hydrology by playing in the streams."

Those childhood fun-and-games sparked Illangasekare's passion for water and set the wheels in motion for his future career in hydrology and water engineering. Now a professor of civil and environmental engineering and the AMAX Endowed Distinguished Chair of Civil and Environmental Engineering at Mines, Illangasekare has spent his 40-year career trying to help solve global problems related to water availability, specifically focusing on groundwater. "Groundwater supplies about 35 percent of the water used by humans worldwide, so this is quite an important resource," he says.

Although many people think urban water comes mostly from rivers and lakes, less than 2 percent of the Earth's freshwater comes from those surface water sources. Groundwater provides about 30 percent of the Earth's freshwater, with the remaining 68 percent locked up in glaciers and ice caps. "Groundwater problems in the coming decade are going to be driven by increased demand for water and by climate change," says Illangasekare. "Humans already use 54 percent of available freshwater, and by 2023, available water for the global population will decrease by 30 percent."

Other threats, he says, relate to saltwater intrusion into coastal aquifers due to sea-level rise, and increasing levels of pollutants and toxins in groundwater introduced as a result of agricultural and industrial activity and natural causes. Some of these pollutants that were not known to exist in groundwater can now be detected at very low concentrations using advanced instrumentation. In his past and ongoing research, Illangasekare has taken a novel approach to studying aquifer remediation, the process of mitigating the effects of groundwater contamination from industrial solvents and petroleum waste products. By creating "test aquifers," Illangasekare and his students can study the long-term fate of contaminants in groundwater in a lab setting.

"These systems allow us to do very fundamental science that we can't do in the field, because the field is naturally very complicated," he says. "We study these things very carefully under highly controlled conditions in laboratory settings, and then we incorporate that information into numerical models, which can be applied in the field." In his recent work, he has extended these approaches to study technologies for storage of carbon dioxide in deep geologic formations and loading of greenhouse gases like methane to the atmosphere.

The ability to do innovative research, like the test aquifers, was a big part of

what drew Illangasekare to Mines nearly two decades ago. In 1998, while he was still a professor at the University of Colorado Boulder, he says he was contacted by Mines and invited for a visit. "I came down here and I was very impressed with their vision for the environment and water program because it sort of matched what I wanted to do in my career," he says. "Coming here was a bit of a risk I took, because the program here was small with very few faculty and nobody in my specific research area," he says. "But I thought this might be an exciting opportunity to build something new."

Despite the risk, Illangasekare says the idea of coming to a smaller school like Mines appealed to him because he thought it would allow him more opportunity for interdisciplinary collaboration, which he believes is essential to doing cutting-edge research. "I thought, this will be good, because the walls are not too high for me to be able to work across disciplines," he says.

The endowed position he was offered at Mines came with start-up funds to build a laboratory and infrastructure—now the Center for the Experimental Study of Subsurface Environmental Processes (CESEP), where he serves as founding director and oversees several research projects.

On November 2, 2016, Illangasekare had a pivotal moment in his career when he received the prestigious Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW), the highest international honor in the field of groundwater. The award recognizes innovation in water-related fields that contributes to sustainable potable



water availability and the alleviation of global water scarcity. "This award was very special for me, because they look not only at your publications, but also at your work in the context of how it impacts people," he says.

The PSIPW award came with a \$133,000 financial prize, which Illangasekare plans to donate to a charity organization that will help fund projects he is passionate about: projects that help people from parts of the world without access to educational opportunities and clean water. "Think about how many kids are dying because of lack of clean water. In distributing funds, we will look for places where there are health issues related to water," he says. "This will allow me to do the things I really believe in without having to rely on funding from traditional sources."

When it comes to future research, Illangasekare plans to move increasingly towards interdisciplinary work. "The exciting research opportunities in groundwater are not going to be in one core area," he says. "They're going to be at the interface of the different disciplines—looking at groundwater problems from the perspective of biological science, climate science, ecology, health and the social sciences.

"I think people should have a vision about their research and be willing to take some risks. This is what I believe will put Mines on the map, because we will be working on problems that are relevant to the world as a whole, rather than just working on one thing on our computers and in our laboratories."

BY LAURIE J. SCHMIDT

No more fillings

Once you have dental problems, they never seem to end. Fill a cavity and eventually the filling breaks down and you need a bigger one. Then a crown. And even crowns don't last forever.

Mines' Melissa Krebs, an assistant professor of chemical and biological engineering, has a better idea. With a grant from Delta Dental, Krebs, along with postdoctoral researcher Jacqueline Harding and graduate student Matt Osmond, is developing a natural, porous, mineralized material that can integrate with the body's own tooth cells. Once that happens, those cells can repair and regenerate the missing part of the tooth. The biodegradable filling material would dissolve over time as the tissue repairs itself. Instead of a permanent filling, the patient's tooth would ultimately return to its original healthy state.

"People will still get cavities, but this could bring the tooth back to its native state and prevent it from getting worse over time," Krebs said.

To make her material easy to handle, Krebs uses polymers to create a thick, honey-like liquid that can be injected directly into the cavity. Once in place, the material holds its shape. The repairs will occur over time without the patient even being aware, and before they know it, their tooth will be back to normal.

The material Krebs is developing contains a form of calcium phosphate that can be tuned to match the mineralized materials found in teeth and bones. Beyond dental applications, this type of material may also have use in bone grafts and bone putties as a kind of "glue." Current graft and putty materials don't always work, but these new materials being developed in Krebs' lab would be bioactive and porous, integrating better with surrounding bone tissue and making for a faster, better recovery for the patient.



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NSF CAREER Awards



Improving collaboration between humans and robots

Mechanical Engineering Assistant Professor Xiaoli Zhang has received an NSF CAREER Award for her project to improve the human-robot control interview during remote operation.

With a novel goal-guided control interface, instead of passively following an operator's motion input, the robot will understand the operator's high-level objective during an object-grasping operation and autonomously conform to task constraints to reduce control difficulties and ensure the success of subsequent manipulation.

Challenges in teleoperation include indirect visualization and manipulation, as well as the discrepancy between the robotic grip and the device being used to manipulate it.

"Even using a data glove, the physical structure of a human hand and the robot's hand are extremely different. If we want robots to do fine manipulations like a human can, we must solve this control problem," Zhang said. One of the most successful implementations of robotic teleoperations is in surgery, where it might be used to remove a gallbladder. Teleoperations are also extremely helpful in repairing or inspecting mines, space exploration, search and rescue operations and anywhere that is difficult or dangerous for humans to access.

"Ultimately, if we want a robot to think like a human, to be intelligent and have autonomy and the capability to regulate itself in order to work with humans, the robots have to first become more aware of how humans achieve those things," Zhang said.

"Even when it comes to something as simple as picking up a cup, there are multiple ways we approach it, depending on whether our goal is to pass it to someone else, place it on a shelf, drink from it or wash it," Zhang said. "We have to investigate our own behavior patterns in order to formulate a knowledge-based model through machine learning methods for a robot."

Zhang also seeks to improve distance learning by developing a system that immerses remote students in the classroom by allowing them to control a robot for object manipulation or interaction with classmates.

Applying machine learning to neurological diseases

Computer Science Assistant Professor Hua Wang has received an NSF CAREER Award for a research project to create a new machine-learning model for mining various kinds of data that could lead to easier, earlier and less-costly detection of neurological diseases such as Alzheimer's or Parkinson's.

The project, called "Robust Brain Imaging Genomics Data Mining Framework for Improved Cognitive Health," will receive \$409,641 over five years.

Wang will develop algorithms aimed at revealing the relationships between people's genetic information, how their brains appear in scans that measure volume and function and their performances in cognitive tests. "The algorithms can extract information from large amounts of data that cannot be directly analyzed by ourselves," Wang said.

Determining one person's full genetic profile can cost several thousand dollars. If Wang's project determines a link, for

example, between a disease and a small section of that long genetic chain, testing one's likelihood of developing the disease would be much cheaper.

The project could also determine which cognitive tests are most effective in diagnosing diseases, again saving patients and doctors money, time and effort. Early detection is important in Alzheimer's, for example, because while the disease is currently irreversible, there are therapies that can slow down its progress significantly. Discovering these relationships could also contribute to cures for such diseases down the road.

The project will contribute to the BRAIN (Brain Research through Advancing Innovative Neurotechnologies) Initiative, a public-private research partnership that includes numerous government entities, universities, corporations and other institutions. The initiative seeks to create a better understanding of how exactly the brain with its nearly 100 billion neurons and 100 trillion connections—functions.



Innovation in the minerals industry

Minerals and metals are at the foundation of modern technology-based societies. Each year, the average American uses about 25 tons of earth materials. Exploration for new resources is at the front end of the mining life cycle, with mining companies spending billions of dollars per year exploring for new metal and mineral resources yet often coming up empty.

Now, Colorado School of Mines researchers are teaming up with Virginia Tech researchers, bringing together over 250 years of experience in earth resource research, to develop an integrated approach to locating, characterizing and visualizing mineral resources. Their goal is to boost exploration success rates and advance mining operations while cutting costs and minimizing both financial risk and environmental impact.

The researchers have proposed a national cross-disciplinary Center for Advanced Subsurface Earth Resource Models, an industry-funded consortium that would provide exploration and mining companies worldwide with new 3-D subsurface geological models. The models would inform decisionmaking and risk management at all stages of the mining life cycle, from exploration to operations and including mine closure and environmental reclamation.

The center has received early support from the National Science Foundation through a \$15,000 planning grant to each institution. These planning grants will enable the Mines-Virginia Tech team and representatives from the exploration and mining industry to define a joint industry and university research agenda, consolidate support and develop a business plan under NSF's Industry/University Cooperative Research Center Program. Launched in 1973, the I/UCRC program supports research and workforce development in various industry sectors by establishing and fostering cooperative, long-term innovative university-industry-NSF partnerships.

"The purpose and long-term vision of this center is directed toward research challenges in the development of 3-D subsurface geologic models for mineral deposits, with the ultimate goal of informing decision-making and minimizing geological risk in mineral exploration operations," said Geology and Geological Engineering Professor Ric Wendlandt, Mines' principal investigator on the project.

The Mines team includes 14 researchers from the departments of Geology and Geological Engineering, Geophysics, Applied Mathematics and Statistics and Mining Engineering. Professor Wendy Harrison and Associate Professor Thomas Monecke, both from the Geology and Geological Engineering Department, are co-principal investigators. At Virginia Tech, Math Professor Matthias (Tia) Chung leads a team of 12 researchers.

The consortium represents an ideal cross-disciplinary effort, balancing geological and geophysical exploration methods with essential mathematical and computational approaches and risk analysis perspectives.

The research team will explore innovations in measurements of chemical and physical properties of rock materials and improvements to integrating and scaling of diverse geological and geophysical data types. These improvements will help mathematicians, statisticians and computer scientists build more accurate tools for 3-D imaging and visualization of the Earth's subsurface.

According to Monecke, who specializes in economic geology, the exploration

and mining sector is unlike other industries. The time between onset of exploration to resource production and recoup of investment often exceeds 10 years.

"The mining business is a complex process, taking many years to develop a project from exploration to production and finally mine closure and reclamation. Successful modern mining operations generate wealth and employment for several decades, yet because failure at any step is prohibitively expensive, companies are slow in developing and adapting new technologies and often rely on business strategies proven to have worked in the past," said Monecke. "Our center's vision is to advance the digital revolution of the global exploration and mining industry during all stages of the mining life cycle research in this area will be the stepping stone to transforming exploration and mining into an industry of the 21st century."

The center will need industry support to receive full funding from the NSF. During the initial yearlong planning phase, Mines will recruit companies to join the consortium. "There are already 28 companies interested in working with us, in the long run looking to fund innovative fundamental research that will accelerate the mining sector forward," said Wendlandt. "We're very encouraged."

Companies expressing interest in the consortium include those in mineral exploration and mining, software development, consulting, geochemistry and exploration geophysics and instrumentation. Federal agencies including the U.S. Department of Energy, the National Renewable Energy Laboratory and the U.S. Geological Survey may also participate. Research priorities are set by the consortium's members, who will establish an industry advisory board.

"Mining is intrinsic to modern society's transition to a sustainable existence," said Ramona Graves, dean of the College of Earth Resources Science and Engineering. "The center's projects will promote socioeconomic prosperity and help in reducing the environmental impact of the mining industry."

The center will also be a major effort to prepare college graduates at both the undergraduate and graduate levels to move directly into the industrial workforce, explained Harrison, helping students make essential contacts in the industry even before they graduate. There is an emerging need in the mining industry for professionals who provide expertise in advanced computer-controlled equipment, computer modeling and data analysis.

"The Center for Advanced Subsurface Earth Resource Models, if successful in attracting members, would be the first geoscience-based program started under the 44-year-old NSF program," said Harrison. Expectations for the planning year are to gain industry support for the center's operation plan, agree on research goals and initial projects and get individual companies to commit to joining the center.

Connecting defense contractors with **3-D metal printing research**

A Colorado School of Mines research consortium focused on 3-D metal printing technologies has been awarded about \$1.5 million by the Department of Defense to connect research and development centers with defense contractors via a centralized, artificially intelligent database, allowing manufacturers to respond more quickly to changing demands.

This first phase of the Mountain West Advanced Manufacturers Network (MWAMN) is a joint project with the University of Utah and was awarded a total of \$2.7 million by the Defense Department's Office of Economic Adjustment.

"Enabling manufacturers to efficiently deploy additive manufacturing processes helps diversify their product offerings, expand into non-defense markets and provide resilient employment and value to their communities and the economy independent of defense spending," said Aaron Stebner, ADAPT technical director and assistant professor of mechanical engineering.



"Additive manufacturing holds the promise of enabling manufacturers to quickly adapt to changing market needs compared to traditional manufacturing methods," said Heidi Hostetter, chair of ADAPT's industry board and vice president of Faustson Tool.

"Today, building new parts or switching materials with this technology takes too long," she said. "MWAMN is focused on radically shortening that time, lowering costs and reducing the negative economic impact on companies and communities when defense programs and spending changes."

ADAPT, since launching in 2016 with partners Faustson, Ball Aerospace, Lockheed Martin and Manufacturer's Edge and funding from the state Office of Economic Development and International Trade, has been building a database of materials, characteristics, processes and more to help industry qualify the parts they are manufacturing. ADAPT has since added numerous members, including Colorado and Utah manufacturers in the National Institute of Standards and Technology's Manufacturing Extension Partnership.

The MWAMN will leverage ADAPT's existing data framework to help companies change their products and materials, develop new products and reduce their reliance on military contracts.

Senthamilaruvi Moorthy, a graduate research assistant and member of the ADAPT group, is working on research focused on the optimization of additive manufacturing processes.

CERAMICS

O'Hayre, team recognized for paper on fuel cells in Science



Metallurgical and Materials Engineering Professor Ryan O'Hayre and his team will receive the American Ceramic Society's Ross Coffin Purdy Award for a paper that appeared in

O'HAYRE the September 18, 2015, edition of Science.

The paper, titled "Readily Processed Protonic Ceramic Fuel Cells with High Performance at Low Temperatures," focused on the development of affordable and efficient ceramic fuel cells that could be used to power homes.

It was based on more than five years of research to develop a new, higherperformance ceramic-based fuel cell device that might eventually be used to generate both electricity and hot water for residential households from natural gas. In addition to drastically increasing efficiency through reducing transmission losses, such a reliable, environmentally friendly distributed power technology would help guarantee greater energy security while also reducing energy costs for consumers.

The research team includes Mines graduate student Chuancheng Duan, former research professor Jianhua Tong, former postdoctorate researcher Meng Shang, former graduate student Stefan Nikodemski, research faculty Michael Sanders and Sandrine Ricote, as well as Ali Almonsoori of the Petroleum Institute in Abu Dhabi.

Brennecka named a fellow of the American Ceramic Society

Metallurgical and Materials Engineering Assistant Professor Geoff Brennecka has been named a Fellow of the American Ceramic Society, one of the highest levels of membership in the organization.

He is being recognized for his research in ferroelectrics and piezoelectrics, as well as his extensive service to the society, and is

one of the youngest members ever elevated to Fellow status.



Brennecka leads the **Functional Ceramics** Group at Mines, whose research explores the fundamental properties as well as practical issues of fabrication and integration of a variety

BRENNECKA

of ceramics in both bulk and thin film forms for electrical, electromechanical and optoelectronic functions.

Brennecka has been active in the American Ceramic Society since 1999, and has served as president of the National Institute of Ceramic Engineers and chair of the Education Integration Committee -helping to launch several studentfocused initiatives within the society, and has organized more than two dozen technical symposia and three full conferences. He currently serves as an associate editor of the Journal of the American Ceramic Society, chair of the Electronics Division and member of the society's board of directors.

CIVIL ENGINEERING

Lu, Griffiths recognized for geotechnical engineering work

Two Colorado School of Mines professors in the Department of Civil and Environmental Engineering have been recognized for their achievements in geotechnical engineering with national awards from the American Society of Civil Engineers.

Professor Ning Lu

Peck Award for his

multiyear case study

monitoring the

hydrological and

subsurface

mechanical

received the Ralph B.



ΙU

conditions leading to landslide occurrence on the coastal bluffs between Seattle and Everett, Wash., and for using the data collected to develop a new hydromechanical framework for slope-stability analysis.

The ASCE said Lu's research over the past decade has made significant contributions to the study of rainfall-induced landslides. The recurring landslides in Washington are a major concern for Burlington Northern Santa Fe Railway and Sound Transit, which operates a railway along the bluffs. Results from Lu's research are now being used to develop a comprehensive hazard mitigation strategy for the railway.



Professor D. Vaughan Griffiths received the H. Bolton Seed Medal for his innovative software developments, publications, textbooks and professional short courses on finite

elements and probabilistic methods.

According to the ASCE, "his highly cited work on finite element stability analysis has transformed the way engineers perform slope-stability analysis in practice." Griffiths' workshops have made him a de facto ambassador for the profession, according to ASCE.

INVENTION

Poate inducted as fellow of **National Academy of Inventors**

Emeritus Senior Vice President John Poate was inducted as a Fellow of the National Academy of Inventors on April 6, 2017, in Boston, Mass., during the NAI's annual conference.

The U.S. commissioner for patents, Andrew H. Hirshfield, delivered the keynote address during the induction, held at the John F. Kennedy Presidential Library and Museum.

Election as an NAI Fellow is a distinction accorded to academic inventors who have "demonstrated a highly prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development and the welfare of society."

Poate retired from Mines in 2014 after serving as vice president of research and technology transfer since 2006. He earned his PhD in nuclear physics from the Australian National University. He later



POATE (center)

headed the Silicon Processing Research Department at Bell Laboratories and is former dean of the College of Science and Liberal Arts at New Jersey Institute of Technology.

MINERALS

Faculty honored for contributions to industry, education

Two members of the Colorado School of Mines faculty were recognized at the Society for Mining, Metallurgy and Exploration's annual conference and expo, held in February in Denver. SME is one of the member societies under the American Institute of Mining, Metallurgical and Petroleum Engineers.

Mining Engineering Associate Professor Hugh Miller received the AIME-SME Mineral Industry Education Award for distinguished contributions to the advancement of mineral industry education.



Miller also received the AIME 2017 Honorary Member Award, given in appreciation of outstanding service to the institute or in recognition of distinguished scientific or

MILLER

engineering achievement in the fields embracing the activities of AIME and its member societies.

Metallurgical and Materials Engineering Research Professor Erik Spiller received the SME Distinguished Member Award,



given to individuals who demonstrate significant and sustained contributions to the minerals industry and to SME.

Metallurgical and

Associate Professor

named to a national

team of expert

educators charged

with identifying

Amy Clarke has been

Materials

Engineering

SPILLER

METALS

Clarke named to expert educators panel for lightweight technology



CLARKE

the knowledge and skills workers will need to deploy new lightweighting technologies and materials being developed by industry.

Clarke is one of six named to the Expert Educator Team by Lightweight Innovations for Tomorrow, the Association of Public and Land-grant Universities and the National Center for Manufacturing Sciences. The team members were selected from APLU's member universities and LIFT research partners for their significant knowledge of manufacturing technologies and experience within the manufacturing industry.

Before joining Mines in June 2016, Clarke was a scientist at Los Alamos National

Laboratory for seven years and spent a year at Caterpillar Inc. as a senior engineer. She is the site director for the Center for Advanced Non-Ferrous Structural Alloys and affiliated with the Advanced Steel Processing and Products Research Center at Mines.

The team began its work at a kickoff meeting February 23-24 in Detroit with LIFT's technology project leaders. The teams will review several technology projects underway and begin to determine where gaps in curricula exist.

POLYMERS

Williams receives Fulbright award to study new class of plastic

Chemistry Associate Professor Kim Williams has received a Fulbright award to conduct research with scientists in Dresden, Germany, into a new class of polyethylene plastic that may be better suited for biodegrading.



WILLIAMS

Williams will conduct research at the Leibniz Institute of Polymer Research and co-advise a graduate student at the Technical University of Dresden.

Polyethylene, or PE, is the most common plastic in the world,

primarily used in packaging such as plastic bags, films and bottles, as well as children's toys. It is also difficult to biodegrade. "People have been trying to make new types of PEs, and they need better analytical methods to help them figure out what has actually been made and connect this information with observed properties," said Williams. "I would like to bring this all the way to seeing whether this new type of PE is better suited for biodegrading."

Williams and her research group are focused on the separation and characterization of polymers, nanoparticles and other complex materials as well as biological systems using field-flow fractionation and other techniques.

A recent award supplementing an existing NSF grant will allow Williams to bring one or two of her Mines graduate students for a short research visit.

Taking on NASA's Mars Ice Challenge



A Mines team came in second of just eight finalists in a NASA competition to design and build a system to extract water from the subsurface of Mars, and their ideas have a chance of making it into space.

The Mars Ice Challenge is a special edition of NASA's Revolutionary Aerospace Systems Concepts – Academic Linkage (RASC-AL) brand of competitions. To celebrate the 100th anniversary of NASA Langley Research Center this year, the eight chosen teams were awarded \$10,000 each to construct prototypes and demonstrate them in Virginia.

Petroleum engineering majors Steve Benfield and Justin Kilb were in charge of the drilling subsystem. However, their prototype actually uses an auger, a drill that includes a blade to bring material up, unlike the systems used in oil drilling today.

Mechanical engineering major Michael Szostak, geophysical engineering student Kenneth Li and freshman Giorgio Cassata were tasked with designing and building the icebox, which collects the cuttings, melts the ice and filters out the dirt, all while the drill operates. "Seventy percent of the competition is how much water you deliver," Szostak said. "We'll also be penalized if any large particulates end up in the water."

Caroline Ellis, a student in engineering physics, led the electronics and programming subsystem team, which includes mechanical engineering students Tatjana Tschirpke and Taewoo Kim.

The team had originally planned on using a Raspberry Pi minicomputer to control the system, but after consulting with various experts, made the switch to a different device and programming language.

Mechanical engineering students Tyler Perko and James Wood translated theory they've learned in the classroom directly to the project as the mechanical subsystem team. "I've been taking machine design and advanced mechanics and materials, and we've been talking about the same things that we're working on," Perko said. The project revealed that learning about something and doing it isn't always an easy transition.

"Welding is a lot harder than you would think," Perko said. "We probably practiced welding aluminum for a month before we started trying to weld the chassis together."

Advising the group was Angel Abbud-Madrid, a research associate professor in mechanical engineering and director of the Center for Space Resources at Mines.



"The whole point of this competition is for students to suggest ideas that NASA might actually pursue and get to use," Abbud-Madrid said. The emphasis is on obtaining resources for astronauts who may travel to Mars in 2030 and beyond.

The final competition took place June 13-15, 2017, at NASA Langley.



Top PhD theses tackle challenges of alternative energy

PhD recipients Vinh Nguyen, chemical engineering, and Michael Wagner, mechanical engineering, received the Dr. Bhakta Rath and Sushama Rath Research Award for dissertations that demonstrate the greatest potential for societal impact.



Nguyen's thesis concerns the use of methane gas in fuel cells at low temperatures. Most processes that use methane require temperatures over 500 degrees—not

desirable for use in a car, for example.

In his first year, Nguyen, advised by Chemical and Biological Engineering Professor Andrew Herring, was able to extract about 30 times more energy than previous systems, at temperatures between 80 and 160 degrees. Nguyen achieved this by developing a platinum catalyst that is distributed more evenly, using more of its surface area, and developing an ionic liquid that allows the methane gas and the water it needs to oxidize to diffuse at the proper concentrations.

Wagner's dissertation

presents a model for

optimizing the

dispatching of

energy generated

from concentrating

solar power systems.

CSP systems use an



WAGNER

array of mirrors to focus the sun's rays on molten salt, heating it up to over 1,000 degrees Fahrenheit. The heat stored in the salt can then be used to drive steam turbines and generate electricity.

"Usually, you just run it until it's gone," Wagner said. Wagner wrote software that determines a dispatch strategy over 24 hours, considering various factors. Wagner's methods are already being applied to CSP facilities under development.

Advising Wagner were Professor Alexandra Newman and Associate Professor Robert Braun, both in the Department of Mechanical Engineering.

FULBRIGHT SCHOLARS

Reducing landslide risks in Guatemalan communities



Thanks to a Fulbright grant, geological engineering master's student David LaPorte is conducting research at the Universidad de San Carlos de Guatemala to evaluate landslide risk management

in precarious settlements of Guatemala

City's metropolitan area and develop cost-effective solutions. "These settlements are built on the slopes

of steep ravines and are populated by the area's most economically vulnerable population," explained LaPorte, whose ultimate goal is to help those who have little choice but to live in at-risk areas by studying ways to better manage these natural hazards.

To do this, LaPorte is evaluating the current landslide risk management initiatives put in place by Guatemalan government agencies and NGOs, such as risk-reduction tools and educational programs. Currently, there are no statistics in this field, which LaPorte's research is working to address. Communities will be surveyed before and after riskcommunication strategies are implemented, with the ultimate goal of improving initiatives to encourage riskreducing behavioral change.

Improving detection of engineered nanoparticles



RAND

Geochemistry PhD candidate Logan Rand has received a Fulbright grant to spend nine months at the Institut de Physique du Globe de Paris to analyze European river waters, compare them

to North American samples and improve methods for detecting the presence of engineered nanoparticles. Rand's research revolves around singleparticle inductively coupled plasma-mass spectrometry or spICPMS, a relatively new technique for detecting engineered nanoparticles that has been developed in the lab of his advisor, Chemistry Professor James Ranville, over the past decade.

While spICPMS has worked well in controlled laboratory environments, "the challenge we're looking at is improving our capability of detecting an engineered nanoparticle in natural systems," Rand said. "When it enters the water system, can we detect it, and can we distinguish it from the natural background of mineral nanoparticles?"

During his time in France, Rand will focus on trying to solve that background issue—"establish a baseline, what is normal for different water systems, so we can detect the anthropogenic input."

ROBOTICS

Mines team wins robot pentathlon

Colorado School of Mines' Robot Pentathlon team made history on March 18, 2017, becoming the first team from Mines to win the American Society of Mechanical Engineers' E-Fest West Student Design Competition.

Daniel Schmerge, a sophomore in mechanical engineering; Jacob Aas, a junior in physics and mechanical engineering; and John Wiens, a freshman in electrical



engineering and computer science, competed against 10 other teams at the conference, which took place at the University of Nevada Las Vegas.

Their remote-controlled robot competed in five events designed to test its speed, strength and ability, and the technical design skills of its creators: stair climbing, weightlifting, sprinting, throwing a tennis ball and hitting a golf ball. The team walked away with wins in the stair climb, weightlifting and throwing events, as well as the overall championship.

The team members, who are all in the Mines Robotics Club and worked in collaboration with the Mines student chapter of ASME, began working on their design in early October. The team will compete against the top teams from other regional E-Fests at the World ASME Conference this November in Tampa, Fla.

MINING

Exoskeleton for miners wins Innovation Challenge

A team of first-year students took the \$25,000 top prize in an annual challenge sponsored by Newmont Mining Corporation for a product inspired by a comic book hero.

Team ExoTech's proposal for an exoskeleton that protects and supports a mine worker's arms, legs and spine came out of mechanical engineering student Peter Wilson's suggestion that they "build an Iron Man suit."

The system includes a full-body harness that holds the miner's equipment, a spinal support system that encourages good lifting form and a knee brace. The team consulted with biomechanical, materials and mine safety experts and conducted market research to determine costs, selling price and target market.

Rounding out the ExoTech team are Joshua Rands, engineering physics; Parker Steen, mechanical engineering; Ben Topper, mechanical engineering; and Van Wagner, mechanical engineering. They were advised by Mirna Mattjik, teaching associate professor in the EPICS program. The \$25,000 prize will be used to further develop their idea. Team PipeWalker was named Most Innovative and received \$2,500 for its proposal for a device that detects stresses, leaks and breaks in pipelines.

Vader Technologies received \$2,500 and the award for Most Market-Ready for a lightweight and comfortable respirator that's an improvement on current devices.

MATERIALS

Students demonstrate materials knowledge, bladesmithing skills

Mines students took second place in the Materials Bowl and finished third in the Bladesmithing Competition during the annual meeting of The Minerals, Metals and Materials Society, held February 26 to March 2 in San Diego, California.

Undergraduate students Jordan Carson and Rachel English and PhD candidates Andrea Bollinger and Brian Kagay competed in the Materials Bowl, a materials-themed knowledge and trivia competition.

For the Bladesmithing Competition, undergraduate and graduate students forged and crafted a straight razor with a Damascus pattern.

Stuart Shirley, a blacksmith, and fellow undergraduate student Michelle Hoffman learned techniques from Denver knife maker Owen Wood and put them to use in blacksmith Dan McNeil's Golden shop. Iron from ore in Clear Creek was used as the handle spacer.

PETROLEUM

Mines papers take first place in regional student symposium

Mines petroleum engineering senior Manju Murugesu and master's student Jessica Iriarte both finished in first place in the Rocky Mountain North America Regional SPE Paper Contest, part of the Society of Petroleum Engineers North American Student Symposium.

Held February 1-4 in downtown Denver, the symposium is a massive conference put together by Colorado School of Mines, New Mexico Institute of Mining and Technology and the University of Texas at Austin.



Mines also competed in the Petrobowl Regional Qualifier, represented by students Joe Brady, James Blaney, Lydia Gillespie, Connally Reid and Zak Hartman. The team won 3-2 in pool play, but did not advance to the final round.

Murugesu and Iriarte will represent Mines and the region during the International Student Paper Contest at the SPE Annual Technical Conference and Exhibition, to be held in San Antonio, Texas, in October this year.

SUSTAINABILITY

Mines Tiny House prepares students for Solar Decathlon

A group of undergraduate students have spent nearly two years preparing for a competition to build a home that generates as much energy as it consumes, and their work is about to pay off in a "tiny" way. Mines Tiny House, which formed in the fall of 2015 as a way for students to prepare for the 2019 Solar Decathlon, is nearing completion of construction on a 220-square-foot tiny house.

"We thought of it like a pilot project," said engineering physics sophomore Katie Schneider, Mines Tiny House coplanning chair. "For the decathlon, the house will be full-size, so building a tiny house first was a great way for us to learn what a big project like that will take, while also showing knowledge and experience for our application into the competition."

The Solar Decathlon, which takes place every two years, challenges teams of students from universities around the country to build a "net-zero home." For the competition, this is accomplished primarily by the use of solar energy, through solar panels, passive solar heating and other methods.

The team also submitted a paper for the Race to Zero competition, which asks students to design a full-size, net-zero home, but not actually build it. The team presented at the National Renewable Energy Laboratory.

"We could not compete in the Solar Decathlon without having done either of these projects," Schneider said. "Both the tiny house and Race to Zero taught us a lot about time management, organization and preparation, which will be essential for our success moving forward as we submit our application to the Solar Decathlon in October and then hopefully build a full-size home over the next two years."





A Colorado School of Mines team of 14 undergraduate students has advanced to the final competition weekend in SpaceX's Hyperloop Pod Competition II in California later this summer.

Team DiggerLoop is made up of Mines seniors who are taking part in the competition for their CECS Senior Design Capstone project. They advanced after their design was reviewed for the final time by SpaceX engineers on March 21. This was one of several design reviews since November 2016.

The competition asked student teams from around the world to design a pod that can travel on SpaceX's high-speed transportation Hyperloop track. Over 1,000 teams began their work last fall, and only 24 of them, including the Mines team, advanced to the final competition weekend.

Hyperloop is a high-speed transportation system currently being developed by SpaceX that would move both passengers and freight in pod-like vehicles through a reducedpressure tube, allowing them to move faster than airplanes.

"We are definitely underdogs," said Austin Genger, the Mines team's project manager and lead electrical engineer. "We are facing off against teams from Princeton and Purdue, and

even a few international teams. Some teams are three times the size of ours and have nearly unlimited funding for their designs. We had to think and design uniquely to make sure we stood out from the rest and make our presence known."

The Mines team, which focused on workability, designed their pod using parts that can be bought off the shelf —not only to reduce costs, but also to increase confidence in performance.

"We're not reinventing the wheel," said Ryan France, Team DiggerLoop's chief draftsman. "We're using a hybrid motor from a Chevy Tahoe, and we've limited the custom parts we'll need for the frame, some electrical systems and motor stability additions."

France noted that other teams' designs include all-custom parts, setting up a "David vs. Goliath" encounter in August when the teams test their designs at SpaceX headquarters in Hawthorne, California.

At the August competition weekend, the team will send their life-size pod, along with a test dummy as a passenger, down a 1,400-meter tube of Hyperloop track. The competition is "judged solely on one criteria: maximum speed with successful deceleration (i.e., without crashing)," according to the competition rules.

"Conservatively, our pod will reach 235 miles per hour, but we're hoping for 260 mph," said Karl Grueschow, the team's chief engineer. The pod, starting from a standstill, has to reach a top speed and come to a complete stop within the 1,400-meter test track in order to be considered successful, all without crashing or breaking apart.

With the design phase of the competition over, the team must now begin construction of the pod, which could take over three months and cost up to \$70,000. The team is currently fundraising for the build.

"Team DiggerLoop's goal is to not only have the top-performing pod design in this competition, but also to help develop a transportation system that could potentially change the future," said Will Marquis, a team project manager. "However, none of this will be possible without financial support, and we are currently soliciting sponsorships and donations."

Team members include mechanical engineering students James

Bloomfield, Jacob Suter, Ryan France, Braiden Olds, Will Marquis, Christian Grundfor, Zach Melphy, Michael Lanahan, Jackie Knott, Karl Grueschow and Vincent Koch and electrical engineering students Jeremy Che, Tim Walker and Austin Genger.

Mechanical Engineering Teaching Professor Kristy Csavina serves as faculty advisor. Serving as technical advisors are Teaching Associate Professor Jered Dean, Assistant Professor Andrew Petruska and Teaching Associate Professor Robert Amaro in the Mechanical Engineering Department and Electrical Engineering Teaching Professor Jeff Schowalter.

"This team has worked extremely hard and effectively to iterate their design over the past six months, and they are one of the most professional student teams I have ever worked with," Csavina said. "They are proactive, selfdriven and they work well together as a team. I think all of those attributes, along with being incredibly smart, have helped them advance this far. Each student brings a different and important skill set to the team, and they have a unique synergy that has driven them forward since the start of this project."



Hope—and concrete—float

Senior civil engineering students Jonathan Henderson (right) and Grant Meehan (left) sand the sides of *Let It Row*, a 16-foot-long concrete canoe. The 11 members of Mines' concrete canoe senior design team put in more than 1,700 hours designing, mixing concrete, creating a mold, casting and sanding the vessel to prepare for the American Society of Civil Engineers' National Concrete Canoe Competition, hosted by Mines in 2017. The competition provides students with hands-on engineering experiences while broadening their knowledge of new concrete technologies and applications.

COLLEGE OF APPLIED SCIENCE AND ENGINEERING



MICHAEL BARANKIN

Teaching Assistant Professor, Chemical and Biological Engineering

Barankin studied chemical engineering with a focus on semiconductor manufacturing at the University of California Los Angeles, where he earned his BS and PhD. Barankin completed research on the use of atmospheric pressure plasmas for coating deposition, along with the production of nanoparticles and atomic clusters in plasma and spark discharges, respectively. Since then, Barankin's research shifted to renewable energy while working at EnTranCe and for the European Renewable Energy Research Centre master's program. Barankin was also a lecturer and researcher at the Hanze University of Applied Sciences in Groningen, Netherlands.



AMY CLARKE

Associate Professor, Metallurgical and Materials Engineering

Clarke is the site director for the Center for Advanced Non-Ferrous Structural Alloys and is affiliated with the Advanced Steel Processing and Products Research Center at Mines. She is also a guest scientist at Los Alamos National Laboratory. Her current research focuses on making, measuring and modeling metallic alloys during processing. This includes x-ray, proton and electron imaging of multi-scale solidification dynamics at national user facilities, the study of phase transformations and microstructural evolution and non-ferrous and ferrous physical metallurgy. Clarke earned her BS from Michigan Technological University and her MS and PhD in metallurgical and material engineering from Mines. Prior to joining Mines, she was a Scientist and Seaborg Institute Postdoctoral Fellow at LANL and Senior Engineer-Development/ Research at Caterpillar Inc. Clarke has received a U.S. DOE Office of Science Early Career Research Program Award and a Presidential Early Career Award for Scientists and Engineers.



KESTER CLARKE

Assistant Professor, Metallurgical and Materials Engineering

Clarke is engaging in research with the Advanced Steel Processing and Products Research Center and the Center for Advanced Non-Ferrous Structural Alloys. His interests include alloy development, material deformation and fabrication processes and the use of experimental and modeling methods to examine the effect of material processing history and microstructure on mechanical properties and performance. Clarke holds a BA in psychology from Indiana University, a BS in materials science and engineering from Wayne State University and a MS and PhD in metallurgical and materials engineering from Mines. He conducted postdoctoral research at Los Alamos National Laboratory, where he remains a visiting scientist, and has been an R&D scientist/engineer in the Materials Science & Technology: Metallurgy group, serving as the technical lead for thermal-mechanical processing of metals and metal component fabrication since 2011.



DIEGO GÓMEZ-GUALDRÓN

Assistant Professor, Chemical and Biological Engineering

Gómez-Gualdrón obtained his BS in chemical engineering from Universidad Industrial de Santander in Colombia and his PhD in materials science and engineering from Texas A&M University. During his PhD, he investigated ways to design "chiral selective" catalysts that could produce structurally homogeneous carbon nanotube samples during large-scale, chemical vapor deposition synthesis. For this work, Gómez-Gualdrón was granted the Silver Graduate Student Award from the Materials Research Society. As a postdoctoral fellow at Northwestern University, Gómez-Gualdrón applied his expertise in molecular modeling to develop new metal-organic frameworks for applications in storage of gas fuels, carbon capture and catalysis. For this work, he was granted the Outstanding Researcher Award from the International Institute for Nanotechnology. Gómez-Gualdrón also has contributed to the development of nanomaterials for applications in energy technologies and chemical processing, accomplished through the application and development of molecular modeling and other computational methods to investigate and predict the thermodynamic, kinetic and electronic properties of materials.



ANGUS ROCKETT

Professor and Department Head, Metallurgical and Materials Engineering

Rockett holds an ScB in physics from Brown University and a PhD in metallurgy/materials science and engineering from the University of Illinois. He is professor emeritus in the Department of Materials Science and Engineering at the University of Illinois and has won numerous awards for teaching and advising. He has studied the basic science of solar cell materials and the operation of solar cell devices, using virtually all of the common materials, microchemical and microstructural analysis techniques from SIMS and TEM to STM and photoluminescence. Rockett's research group also developed numerical models of photovoltaic and photoelectrochemical cells. He also worked on self-assembled nanostructures, MEMS devices, silicide reactions for VLSI contacts, Si-Ge oxidation kinetics for gate dielectrics, superconducting cavity resonators as temperature probes and optical spectroscopic analysis of combustion.



JOSEPH SAMANIUK Assistant Professor, Chemical and Biological Engineering

Samaniuk earned his PhD in chemical engineering at the University of

Wisconsin-Madison for his work investigating the rheological properties of lignocellulosic biomass. He earned his BS and MS in chemical engineering from Virginia Tech. After obtaining his PhD, he was awarded a Pegasus Marie Curie Postdoctoral Fellowship from the Belgium Science Foundation Fonds Wetenschappelijk Onderzoek to investigate the use of microrheological methods at fluid-fluid interfaces in the University of Leuven's Department of Chemical Engineering. He also completed a postdoc at ETH Zürich, with research focusing on the dynamics of soft matter systems at fluid-fluid interfaces for the purpose of developing advanced materials such as conductive thin films and 2-D polymer membranes. He also continued to work on interfacial phenomena with a greater focus on developing advanced materials from systems at fluid-fluid interfaces. His research interests focus on linking microstructure and material behavior-links that enable one to design new experimental methods for the laboratory, formulate novel advanced materials and propose new strategies for solving important industrial problems.



MEENAKSHI SINGH Assistant Professor, Physics

Singh's research targets the development of semiconducting quantum computers

with a focus on donor-based spin qubits. She graduated with

a PhD in physics from Pennsylvania State University with a thesis focusing on quantum transport in nanowires. In addition to research, she is interested in science education and outreach and has mentored five undergraduate students participating in NSF's Research for Undergraduates program. Her service record includes serving as treasurer for the Physics and Astronomy for Women Society at Pennsylvania State University, which provides a forum to discuss issues women face while seeking scientific degrees and careers. She also has research interest in superconductivity and macroscopic quantum phenomena, with a view toward hybridizing superconductors with other systems to access novel phenomena and applications.



BETHANY WILCOX Teaching Assistant Professor, Physics

Wilcox completed a BA in physics and astronomy and received a PhD in physics

from the University of Colorado Boulder. Her thesis research was in the field of physics education, with a specific focus on student learning in upper-division undergraduate physics courses. During her graduate career, she studied students' use of sophisticated mathematical tools during physics problem-solving to better understand the challenges that students encounter in this process. She also developed and demonstrated the statistical validity of a multiple-response conceptual assessment designed to measure students' reasoning around topics in upper-division electrostatics. After completing her PhD, Wilcox accepted a postdoctoral position, during which she was responsible for the statistical validation of another research-based assessment targeting students' views on the nature of experimental physics. Wilcox is a strong advocate for making physics a discipline that explicitly supports and encourages the participation of historically underrepresented groups, such as women and minorities.



JENNIFER WILCOX

Associate Professor, Chemical and Biological Engineering

Wilcox earned a BA in mathematics from Wellesley College and a PhD in chemical

engineering from the University of Arizona. Her research involves the coupling of theory to experimentation to test newly designed materials for sorbent or catalytic potential; within her research group, she focuses on trace metal and CO₂ capture. Wilcox received an ARO Young Investigator Award (Membrane Design for Optimal Hydrogen Separation), an ACS PRF Young Investigator Award (Heterogeneous Kinetics of Mercury in Combustion Flue Gas), and an NSF CAREER Award (Arsenic and Selenium Speciation in Combustion Flue Gas). She has served on a number of committees, including the National Academy of Sciences and the American Physical Society, to assess CO₂ capture methods and impacts on climate.

COLLEGE OF EARTH RESOURCE SCIENCES AND ENGINEERING



MELANIE BRANDT

Teaching Assistant Professor, Humanities, Arts and Social Sciences

Brandt received her MA in humanities from CU Denver. For her thesis, Brandt investigated the power of humor to affect political and social change. Her work necessitated multidisciplinary research and study, thereby creating a platform for understanding some fundamental elements of learning and communication that can be applied to many academic disciplines. She is interested in combining the humanities and STEM fields of study in innovative ways that bolster and enhance learning experiences for students. Brandt has taught a variety of writing and literature classes and has taught in Mines'Design EPICS program since 2011. Brandt will teach Nature and Human Values and an integrated pilot course combining NHV and Design EPICS.



BRANDON DUGAN

Associate Professor and Baker Hughes Chair, Geophysics

Dugan is a hydrogeologist who couples theory, experiments and models to understand the interactions of fluids and solids in Earth's shallow crust. Dugan's research group is using this approach to study natural resources (water, oil and gas), natural hazards (landslides, earthquakes) and carbon storage. To inform and to test theoretical models and to collect experimental samples, Dugan regularly participates in geophysical, geological and drilling field programs. Dugan is a member of the Environmental Protection and Safety Panel of the International Ocean Discovery Program and a member of the NSF's GeoPRISMS Steering and Oversight Committee. Dugan also served as a distinguished lecturer for Ocean Leadership to share ocean science with universities and communities. Dugan holds a BS in geoengineering from the University of Minnesota Twin Cities and a PhD in geosciences from Pennsylvania State University. He also completed a Mendenhall postdoctoral fellowship with the U.S. Geological Survey and was an assistant and associate professor of earth science at Rice University.



TÜLAY FLAMAND Assistant Professor, Economics and Business

Flamand received her PhD in Management Science from the University of

Massachusetts, Amherst, and holds a BS in mathematical engineering from Yildiz Technical University and an MS in industrial engineering from Istanbul Technical University. Her research interests lie at the interface of operations management and marketing science, with a strong methodological anchor in analytics and optimization. Specifically, her research focuses on retail analytics and novel optimization models for storewide shelf space allocation and the maximization of consumer impulse purchases.



RICHARD HUNT

Assistant Professor, Economics and Business

Hunt earned a BS from Rice University, an MA from Harvard University, an MBA

from Stanford University and a PhD from the University of Colorado Boulder. Previously, he held an appointment in Strategic Management and Entrepreneurship at the Virginia Polytechnic Institute in Blacksburg, Virginia, where he taught undergraduate and graduate courses in strategic management and entrepreneurship. He also served as VT's faculty research director at the Center for Innovation and Entrepreneurship. Hunt's research examines the intersection of entrepreneurship, innovation and strategy, including entrepreneurial environments, advantageous knowledge, new sector formation, modes of market entry and early-stage operational behavior. His approach employs transactions as the unit of analysis in order to capture meso-level effects, and he often juxtaposes contemporary data and distant, historical data in order to overcome proximity biases and inject a longitudinal dimension into the inquiry.



ADRIANNE KROEPSCH

Assistant Professor, Humanities, Arts and Social Sciences

Kroepsch is an environmental governance scholar with interdisciplinary training and a research focus on the relationship between extractive industries and communities in the American West. More specifically, she studies unconventional oil and gas extraction in Colorado with a focus on conflict and compromise between community, industry and state actors, as partly mediated by technology. She earned an MA in geology and a PhD in environmental studies from the University of Colorado Boulder, where she was also a graduate instructor and researcher at the Center of the American West and a cofounder of the Colorado Water and Energy Center. Her undergraduate degree is in science and technology studies from Cornell University. Between her undergraduate and graduate studies, Kroepsch worked for several years as a journalist, covering science and technology policy in Washington, D.C.



ALEXEI MILKOV Professor, Geology and Geological Engineering

Milkov received a PhD from Texas A&M University and worked for three

E&P companies, exploring conventional and unconventional oil and gas in over 30 basins on six continents while also participating in the discovery of four billion BOE (barrels of oil equivalent). He is also the director of the Potential Gas Agency. Milkov has expertise in exploration risk analysis, resource assessments, petroleum systems and oil & gas geochemistry. He has received several industry awards for his contributions to petroleum geosciences.



JENNIFER MISKIMINS

Associate Professor and Associate Department Head, Petroleum Engineering

Miskimins holds BS, MS and PhD degrees in petroleum engineering and has more

than 25 years of experience in the petroleum industry. Between her BS and graduate degrees, she worked for Marathon Oil Company in a variety of locations as a production engineer and supervisor. Miskimins taught at Mines from 2002 to 2013. From 2013 to 2016, she continued to hold a part-time appointment at Mines, advising research and graduate students, while working for Barree & Associates. She returned to Mines full-time in 2016. Miskimins specializes in well completions, stimulation, hydraulic fracturing and associated production issues. She is the founder and co-director of the Fracturing, Acidizing, Stimulation Technology Consortium and also co-directs the Center for Earth Materials, Mechanics and Characterization. Her research focuses on the optimization of stimulation treatments and the importance of such on associated recovery efficiencies. Miskimins is currently the completions technical director on the SPE International Board of Directors. She is a registered professional engineer in the state of Colorado.



ANDREW PEDERSON

Teaching Associate Professor, Economics and Business

Pederson received his BA in economics from Pacific Lutheran University and has

a master of taxation from University of Denver's College of Law. Pederson worked as an adjunct professor in the Division of Economics and Business at Mines, teaching engineering economics to undergraduate students. Pederson also served as a teaching assistant for the Division of Economics and Business and the Department of Chemical and Biological Engineering at Mines. He also worked with Investment Evaluations Corporation and lectured for Mines' Special Programs and Continuing Education short courses as well as in-house courses for over 20 companies, teaching economic evaluation and investment decision methods.



JAMAL ROSTAMI

Associate Professor and Alacer Gold/Haddon Chair, Mining Engineering

Rostami received his BS in mining engineering from the University of Tehran and graduated from Mines with a MS and PhD in mining engineering. He was a member of the Mines research faculty until 2000 and was simultaneously a faculty member at the University of Tehran. He then served as a full-time consultant with major A&E companies until he joined Pennsylvania State University as the Centennial Chair of Carrier Development in Mining in the Department of Energy and Mineral Engineering. Rostami has more than 26 years of experience in design, management, research and teaching in the field of mining, tunneling and underground construction. He is a registered professional engineer in Maryland, Pennsylvania and Virginia. Rostami is the founder of Professors Without Borders and a founding member of Iranian American Academics and Professionals.



GREG RULIFSON

Teaching Assistant Professor, Humanities, Arts and Social Sciences

Rulifson earned his PhD at the University of Colorado Boulder by studying how students' understanding of the relationship between social responsibility and engineering changed throughout college. Before his PhD study, Rulifson worked as a structural engineer in the San Francisco Bay area, where he earned his professional engineer license. Rulifson earned his BS in civil engineering with a minor in global poverty and practice from University of California, Berkeley, where he developed a strong desire to use engineering to facilitate developing communities' capacity for success. He brings significant global experience: with GeoHazards International, he helped coordinate design between stakeholders for the Tsunami Evacuation Raised Earthen Park in Padang, Indonesia; in western Nicaragua, he engineered the structure of a rammedearth community center in a rural village by collaborating with U.S. and Nicaragua-based NGOs, contractors and community. He co-advises the Mines Without Borders team and is a liaison to poverty alleviation organizations through the Posner Center for International Development in Denver.

COLLEGE OF ENGINEERING AND COMPUTATIONAL SCIENCES



ABD A. ARKADAN

Teaching Professor, Electrical Engineering

Arkadan's teaching and research interests include energy conversion, electric machines

and drives and design optimization using computation electromagnetics and artificial intelligence techniques. His research applications are in renewable and efficient energy and power systems, micro-grids, onboard aerospace and marine power systems and hybrid electric vehicles. He is a fellow of the Institute of Electrical and Electronics Engineers and a fellow of the Applied Computational Electromagnetics Society. Arkadan holds a BS from University of Mississippi, an MS from Virginia Polytechnic University and a PhD from Clarkson University, all in electrical engineering.



CHRIS COULSTON Teaching Associate Professor, Electrical Engineering

Coulston received a BA in physics from Slippery Rock University and earned a BS,

MS and PhD in computer engineering from Pennsylvania State University. He taught at the University Park campus from 1993 to 1998 and was granted tenure as an associate professor of electrical and computer engineering at Penn State Erie in 2006. Starting in 2005, Coulston served as chair of several departments, including Electrical Engineering, Computer Engineering, Software Engineering and Computer Science, leading the successful ABET accreditation of these programs over three review cycles. In 2013, Coulston led an interdisciplinary group of faculty to start a game development minor across the Penn State system. The following year, Coulston took a sabbatical and served as a distinguished visiting professor at the United States Airforce Academy in Colorado Springs.



KRISTINE CSAVINA Teaching Professor, Mechanical Engineering

Csavina received a BS in mechanical engineering from the University of Dayton

and a PhD in bioengineering from Arizona State University. Csavina's research interests include motion analysis of human motion in movement disorders, orthopedics and sports; human

motion aided by wearable technologies; and engineering education research in student learning and pedagogical approaches. She was formerly an associate director for engineering program innovation in The Polytechnic School of Engineering and Manufacturing Engineering in the Ira A. Fulton Schools of Engineering at ASU. She was the lead instructor for the senior capstone design experience, where she taught design and professional skills and managed over 20 student teams on eProjects (industry-partnered capstone experiences). She was also active with the ABET accreditation, helping to develop the course assessment and program evaluation process for the department. Prior to ASU, Csavina was a founding faculty in the U.A. Whitaker College of Engineering at Florida Gulf Coast University. As an assistant professor, she helped develop the curriculum for the bioengineering design courses and biomechanics and was involved in teaching courses from the sophomore to senior levels.



GREGORY FASSHAUER Professor and Department Head, Applied Mathematics and Statistics

Fasshauer spent the last 19 years at the Illinois Institute of Technology in Chicago, where he was a professor and associate department chair of applied mathematics. While there, he helped create an environment for excellence in teaching and learning as the director of undergraduate studies in the Applied Math Department and as a distinguished teaching fellow of the College of Science. Fasshauer holds Diplom and Staatsexam degrees in mathematics and English from the University of Stuttgart in Germany, as well as an MA and PhD in mathematics from Vanderbilt University. Fasshauer also spent two years as a visiting assistant professor in the mathematics department at Northwestern University. Fasshauer's research interests lie in computational mathematics with a particular focus on the theory and applications of kernel-based approximation methods.



KRISTOPH-DIETRICH KINZLI

Teaching Professor, Civil and Environmental Engineering

Kinzli graduated from Colorado State University with a BS in civil engineering. As an undergraduate student, he also studied at the Technische Universitaet Dortmund in Germany. He obtained an MS in civil engineering, an MS in fisheries biology and a PhD in civil engineering from Colorado State University. His dissertation focused on improving irrigation water use efficiency along the Middle Rio Grande. Kinzli has worked on research projects in Colorado with the Department of Fish and Wildlife and in New Mexico with the Interstate Stream Commission, the Bureau of Reclamation, New Mexico Tech and the Middle Rio Grande Conservancy District. His research interests include engineering teaching pedagogy, open channel hydraulics, river mechanics, stream rehabilitation, groundwater, water resources, agricultural water use, fisheries biology and ecological restoration.



KARIN LEIDERMAN Assistant Professor, Applied Mathematics and Statistics

Leiderman joined the faculty as an assistant professor in the Department of Applied Mathematics and Statistics. She worked as an assistant professor of applied mathematics in the School of Natural Sciences at the University of California Merced for the past four years. Prior to joining the faculty at UC Merced, she was a visiting assistant professor in the Department of Mathematics at Duke University and received her PhD in mathematics from the University of Utah. For her PhD thesis, she developed a spatial-temporal mathematical model of the formation of blood clots under flow and was awarded the SIAM student paper prize for this work. For her postdoc, she worked to develop numerical methods for fluid/structure interaction problems involving low Reynolds number and porous media flow. Leiderman's research aims at understanding biological systems through the use of mathematics, mathematical modeling and numerical computation. She also has general interest and expertise in computational modeling of blood clotting, biological fluid dynamics, biomechanics, biochemistry, flow through porous materials and scientific computing.



ASHLYN MUNSON

Teaching Associate Professor, Applied Mathematics and Statistics

Munson completed her PhD in statistics at Mines, where she studied efficient methods of case-control sampling under the advisement of Professor William Navidi. She spent the last seven years as an assistant professor in the mathematics department at Pacific Lutheran University in Tacoma, Washington, where she advised the statistics minor within the natural sciences. While at PLU, her research efforts mainly focused on the assessment and development of new curriculum methodology in the STEM disciplines.



OYVIND NILSEN

Teaching Associate Professor, Mechanical Engineering

Nilsen grew up in Tønsberg, Norway, where he earned a mechanical engineering

degree, and later earned his PhD in mechanical engineering from the University of Colorado. Nilsen's interests include product development and innovations, and his expertise is in design, manufacturing, advanced system integration, thermal and fluidic system design as well as optics and sensors. His research experience also involves mechanics of materials, optics, sensors, physical modelling and MEMS and microfluidics. Nilsen was the director of manufacturing and cofounder of BiOptix Diagnostics Inc., where he developed an optical biosensor system. He also has industrial experience, designing tools for the oil industry, and experience as a naval officer.



ANDREW PETRUSKA

Assistant Professor, Mechanical Engineering

Petruska graduated from Carnegie Mellon University with dual BS degrees in

mechanical engineering and physics as well as an MS in mechanical engineering. He worked as a design engineer at ATK Launch Systems in Utah and was responsible for designing, testing and qualifying solid rocket motor components. In 2010, he enrolled at the University of Utah and was awarded a National Science Foundation Integrative Graduate Education and Research Traineeship to study noncontact magnetic manipulation. He received his PhD after developing the first real-time reconfigurable magnetic manipulation system. Petruska joined the Multiscale Robotics Laboratory in the Institute of Robotics and Intelligent Systems at ETH Zürich and was awarded a Max Planck ETH Center for Learning Systems fellowship to investigate the magnetic manipulation of needles, endoscopes and catheters. His research interests are in the areas of complex system modeling and design, dynamics and control, advanced magnetic manipulation and search-and-rescue robotics.

Making room at MINES

A network of makerspaces fuels entrepreneurship and innovation across campus

BLASTER DESIGN FACTORY

The hub for all other makerspaces, the recently opened Blaster Design Factory in Brown Hall is the ideal place to start one's project. It has a 3-D printer, vinyl cutter, heat press and rapid prototyping supplies, plus whiteboards and software, all in support of designing and planning projects.

THE GARAGE

2 Current capabilities in this Brown Hall facility include plastic 3-D printing, laser cutting and etching, vacuum forming, 3-D scanning, thermal imaging and material testing. Additional tools, instruments and audio/video equipment are available for students to check out and use.

CECS MACHINE SHOP

3 This full-service shop in Brown Hall provides machining, assembly and fabrication services in support of research projects and instructional laboratories.

THE FOUNDRY

Located in Hill Hall, the Metallurgical and Materials Engineering Department's foundry holds Free Pour Fridays, which allows Mines students to create aluminum objects using sand casting techniques.

THE WOOD SHOP

Adjacent to the Digger Design Lab, the Wood Shop offers a wide selection of drills, drivers, saws, sanders and other hand and power tools.

DIGGER DESIGN LAB

Located in the Engineering Hall Annex, this space's specialty is lower-accuracy fabrication and messy assembly.

THE OUTLET

This student-run electrical engineering lab can meet any hardware needs a student may have, whether they're working on personal projects or finishing lab experiments outside of class. It has oscilloscopes, power meters, signal generators and a collection of components. COLORADOSCHOOLOFMINES. EARTH • ENERGY • ENVIRONMENT

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The ENGINEERING PHYSICS program at Colorado School of Mines provides students with a deep understanding of science fundamentals combined with the practical knowledge and skills of engineering practice and design.

The program is one of just 20 engineering physics programs in the country—and the only one in Colorado fully accredited by ABET.

Physics Professor and Department Head Jeff Squier designs and builds ultra-fast lasers that can cut, image and micro-machine in ways never before possible. His research team's creations have been used by everyone from neuroscientists wanting to peer inside the dense neuronal tangles of a fly's brain, to geneticists wanting to better understand, at the molecular level, how a corn plant grows. Through collaborations with private companies and other research institutions, they're also working to develop more affordable and accurate laser-based microscopes and safer laserbased surgical techniques.

PHOTO BY JULIAN LIU