WHAT ON

EARTH

FALL 2019

A PUBLICATION OF THE COLLEGE OF MINES & EARTH SCIENCES
AT THE UNIVERSITY OF UTAH

FORGING A SUSTAINABLE FUTURE

CMES Deans, Chairs, and Directors left to right, front row: Michael Simpson, Taylor Sparks, TJ McMullin, Cari Johnson, Samantha Davis, Marjorie Chan, Sivaraman Guruswamy; back row: Michael Free, Paul Jewell, Keith Koper, Darryl Butt, Brenda Bowen, John Horel.

Hello friends of the College of Mines and Earth Sciences (CMES). It's hard to believe this is the 2020 academic year! I hope you enjoy this edition of *What on Earth*. You will read about a few of the accolades, important work and inspiring stories of our faculty, students, and alumni, and about some very important new collaborations. My favorite story is on page 3, highlighting some of our more senior students. If it makes you feel old to think that we're two decades into the 21st century, take a look at our HB60ers for inspiration. They represent one of the important outcomes of higher education: a commitment to and appreciation for the value of life-long learning. Education keeps you young!

This issue of *What on Earth* is focused on sustainability and collaboration, two topics of strategic importance to our college, the university, and particularly this generation of students. CMES is engaged in critical research that is contributing to our understanding of and preparation for a changing planet with growing anthropogenic influences. The challenges faced by those of us blessed to live in this century are incredibly complex and can only be addressed by embracing diverse views and leveraging diverse skills in ways that make two plus two equal something greater than four.

Our faculty continue to be leaders on campus and in our community, bringing together diverse teams to address complex problems associated with water resources, air quality, availability of critical materials, recycling and reuse of materials, efficient and competitive manufacturing, and sustainable and resilient energy resources. Building fruitful collaborations across campus and within the college requires not only motivated faculty, but also thoughtful and proactive leadership. To that end, we are very fortunate to have a wonderful leadership team in the college, to whom I am grateful for their selfless dedication to the university and our community. -- *Dean Darryl Butt*

CMES DEANS, CHAIRS & DIRECTORS

Darryl Butt	Dean
Sivaraman Guruswamy	Associate Dean of Academics
Cari Johnson	Associate Dean of Research
Marjorie Chan	Associate Dean of External Relations
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Brenda Bowen	Dir., Global Change & Sustainability Center

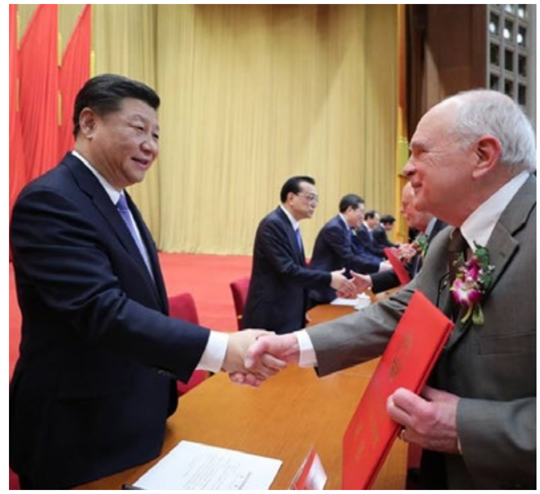
Department Chairs:

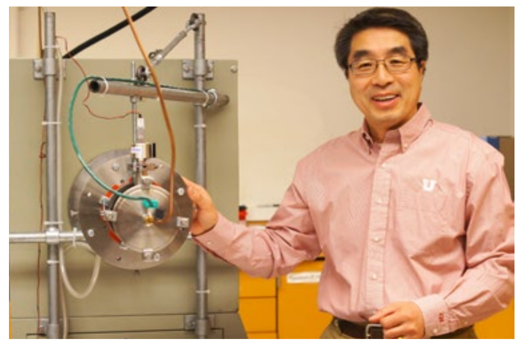
John Horel	Atmospheric Sciences
Paul Jewell	Acting Chair, Geology & Geophysics
Michael Simpson	Materials Science & Engineering
Taylor Sparks	Associate Chair, Materials Science & Engineering
Michael Free	Mining Engineering

Photo by Rebecca Ray

Photo by Bryce Wilson

ON THE COVER: *Metallurgical Engineering students Alex Wikstrom and Jano Farah (above) received the Most Resourceful Award in this year's TMS Bladesmithing Competition. They used 15n20 steel, 01 tool steel, Monel nickel, and etching with ferric chloride to give this sword its distinctive look.*





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Metallurgy & Materials Science Forge A New Relationship

Effective July 1st, the University of Utah's departments of Metallurgical Engineering (METE) and Materials Science & Engineering (MSE) have begun the process of merging into a single academic unit administered jointly by the College of Mines and Earth Sciences and the College of Engineering, pending all university approvals.

This change has been driven by the joint efforts of College of Mines and Earth Sciences Dean Darryl P. Butt and College of Engineering Dean Richard B. Brown and unanimously supported by the faculty of both departments.

"This merger will significantly elevate our programs in national rankings, but more importantly, creates important synergies and efficiencies that will allow us to better recruit and serve our faculty and students," says Dean Butt. "We are moving toward becoming one of the top materials and metallurgy programs in the country."

The new academic unit, called the Department of Materials Science and Engineering, will have strengths in metals, ceramics, polymers, electrochemistry, nanotechnology, biocompatible materials, semiconductors, hydro-, electro- and pyrometallurgy, and mineral processing.

Michael Simpson

Professor and Department Chair of the Department of Metallurgical Engineering, Michael Simpson, has become the chair of the new program. He actually earned degrees in chemical engineering and worked at Argonne National Laboratory and Idaho National Laboratory for a combined 16 years on nuclear engineering problems before coming to the U as an associate professor in 2013. His research is largely focused on chemistry and applications of molten salts. (Learn more about his research on page 12.)

"This merger will significantly elevate our programs in national rankings, but more importantly creates important synergies and efficiencies that will allow us to better recruit and serve our faculty and students."

"This merger is really the best possible path forward for the students and faculty of the two departments and the university. Together, we can elevate the University of Utah's materials program to be one of the best in the country — attracting new investments from industry and government while also attracting the best and brightest students," said Simpson. "Having the department connected to both the College of Engineering and College of Mines and Earth Sciences puts us in an excellent position to have strong impact over all of campus and promote the idea of One U," says Dr. Simpson.

Any faculty members who have adjunct or research professor appointments in either of these departments will have an adjunct or research professor appointment in the new program. Students will enjoy all of the benefits of being members of both COE and CMES and have the opportunity to complete their degrees under current requirements.

Taylor Sparks

Associate Professor Taylor Sparks accepted the position of Associate Chair of the new MSE program. An alum of the MSE department, Prof. Sparks returned six years ago and has been very successful at establishing a successful research program while also gaining enormous popularity with students for his teaching and service. He brings vibrant ideas and enormous energy to his new administrative position.

U. Isotope Camps Train Scientists From Around the World

Photo by Laurie Mecham

Christy Mancuso, PhD U Utah, leads a group project with students from Egypt, Peru, and China.

In 1996, University of Utah professors Jim Ehleringer and Thure Cerling, along with colleagues from around the country, welcomed 18 students to the U to teach them about the then-emerging science of analyzing stable isotopes to learn about biology and ecology.

Twenty-three years and 800 students later, "IsoCamp" has become an award-winning, internationally recognized short course for scientists looking to use stable isotopes in their research. Each June, IsoCamp welcomes 35 new participants ("isotopeteers", typically Ph.D. students) to the U campus for two weeks. Their instructors come from across the country, but the isotopeteers come from widely diverse backgrounds. This year's class included students from Egypt, Italy, Bolivia and Australia. In total, participants have come from 37 countries. Sixty percent of participants are women. A quarter come from groups underrepresented in science. Some participants have returned as instructors. Two have been elected to the National Academy of Sciences, of which Cerling and Ehleringer are also members.

The American Geophysical Union honored Cerling, Ehleringer and IsoCamp with the Excellence in Earth and Space Science Education Award. "Students advance rapidly from tentative newcomers, fueled by lectures, discussions, and growing experience in the field and lab," the citation reads. "By the second week, students have gained the ability to envision their own projects and decide how best to apply an arsenal of available isotope methods and have built a lasting esprit de corps as they scramble to complete their projects before presentation."

In 2013, U of U Geology & Geophysics Professor Gabe Bowen launched a companion two-week short course, SPATIAL, for researchers investigating more than a single study or field site. SPATIAL teaches participants how to manage large data sets, analyze data with spatial and statistical tools, and carry out computer modeling.

"Both camps are about creating an interdisciplinary community," Bowen says. "We hope, and the track record would suggest, that this grows the connectedness of the scientific community, helps our students build their identity and sense of belonging, and promotes innovation through the exchange of ideas between groups."

In 2020, IsoCamp will move to the Center for Stable Isotopes at the University of New Mexico. Center associate director Seth Newsome will lead the course. SPATIAL will remain at the University of Utah. *- Paul Gabrielsen*

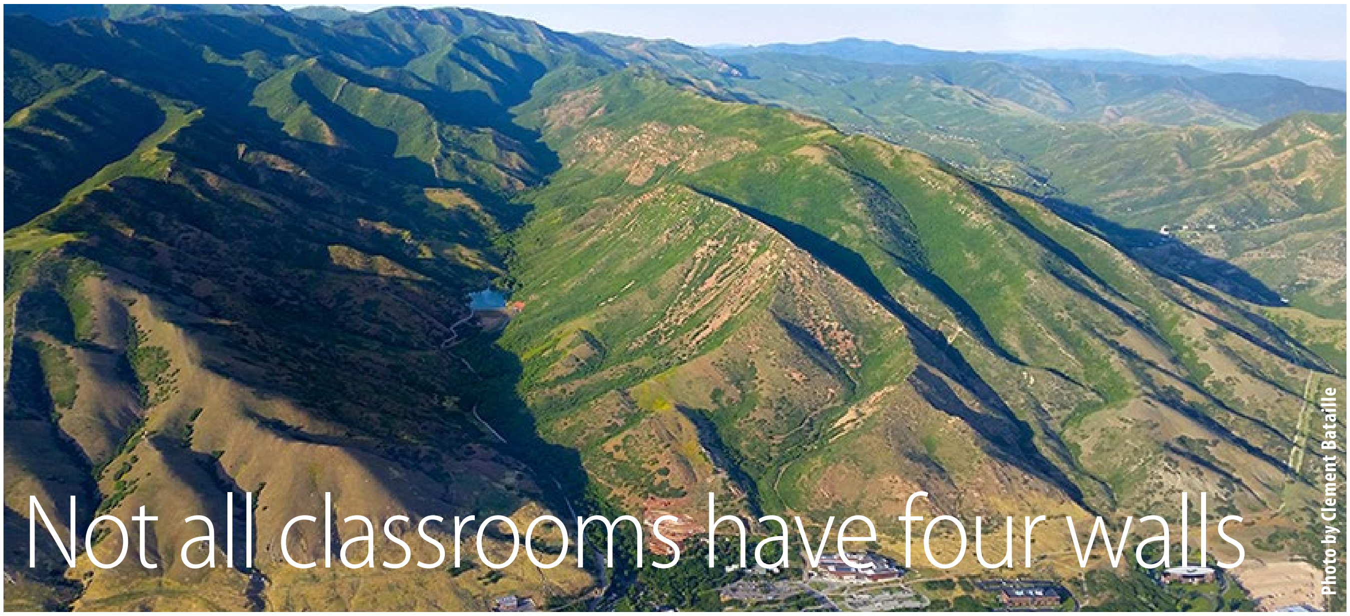
Lifelong Learners - CMES's Own Rock Band

It's common to see seniors (fourth-year undergraduates) roaming the halls of the Frederick Albert Sutton Building. But among them are a different kind of senior – adults 62 and older who, through an act of the Utah Legislature, gain the same access to the U's high-quality instructors and courses as other, ahem, less-seasoned students.

Since 1977, the provisions of House Bill 60 (abbreviated HB60) allow any Utah resident 62 and older to audit classes at the state's public universities for only $25 per semester. Retired geologist Alfred Oestreich, 90, has been attending classes for around 20 years. "To replace some of the marbles I keep losing," he says. "I have enjoyed the heck out of it." Oestreich advises his younger colleagues to not be afraid to ask questions. "I think it's foolish not to ask questions," he says. "If you don't know something, ask! You're dealing with a bunch of experts up there."
- Paul Gabrielsen

Photo by Anita Tromp

Rawlins Young (passed away on August 19, 2019), John Young and Art King



Aerial view of Red Butte Canyon Research Natural Area

Wasatch In the Field

Wasatch in the Field (GEO2500) is an exciting new course from the Department of Geology & Geophysics where the classroom is the Wasatch Range. With no pre-requisites, students gain first-hand experience on multiple aspects of geoscience – including geology, geological engineering, environmental geology, and geophysics. This year, the course immediately began with students hiking around Bells Canyon to find and map fault scarps. After exploring multiple nearby landscapes for faults and determining fault properties, students moved into deciphering an ancient massive landslide near the Alta ski resort. By gathering information on the historic landslide in our backyard, students were able to learn about the geology of the area and engineer current hazard analyses. From the ancient landslide and current risk assessments, students jumped in to local streams to gather multiple water samples that they later chemically analyzed to determine current water properties and origin of water within each stream. The course wrapped up with students applying gravity and seismology tools to gain insight to the subsurface structure deep beneath our feet. By providing students with a taste of a variety of geoscience disciplines, students are able to see what they are most drawn to and focus their undergraduate careers to expand their interests. Students also gain a variety of connections within and extended beyond the Department, allowing them to leap in to research and internships to further apply their newly gained skills. - *Elizabeth Berg*

Atmospheric Chemistry and Air Pollution Course

John Lin, Professor in the Department of Atmospheric Sciences, knew that a field-based experience would make air quality data more meaningful for students in his "Atmospheric Chemistry and Air Pollution" course.

Before having students work with trace gas and air quality data collected on the TRAX light rail by the Land-Atmosphere Interactions Research (LAIR) research group, in collaboration with the MesoWest group, Lin gave a unique assignment. Students were to ride the red line TRAX from the University of Utah all the way to Daybreak, taking notes along the way.

"I wanted the students to have a real appreciation for the physical environment they're living in, and to relate the pollution TRAX is monitoring to human activity," said Lin.

Lin collected the students' field notes from their TRAX rides and assigned initial experiments with this data set. Next, students began working with the research-grade data from instruments mounted on the trains to better understand spatial distribution and long-term trends for air pollution in the Salt Lake Valley. The course culminated in a final project where students used this dataset to answer their own air-quality related questions, exploring concepts like how pollution varies throughout the Salt Lake Valley, how weather is related to changes in pollution, and how various pollutants change throughout the seasons.

Lin was inspired to pair a ride on TRAX with his data during the Wasatch Experience, a year-long workshop at the U that supports faculty to incorporate the big ideas of sustainability into their courses. He hoped to help students already passionate about the local environment make a stronger connection to it through scientific data.

Lin found the experience to be rewarding for himself and the students. "It was very fulfilling to see the students relate the research-grade data we are collecting to our local environment and address questions that they found of personal interest. Hopefully it made them think about what is in the air as they travel through the Salt Lake area," says Dr. Lin . - *Liz Ivkovich*

2018-2019 YEAR IN REVIEW

STUDENT INVOLVEMENT

270 UNDERGRADS

157 GRAD STUDENTS

14 STUDENT CLUBS

GLOBAL REACH

65 COUNTRIES

OUTREACH

ON-CAMPUS EVENTS **30**

OFF-CAMPUS EVENTS **50**

FACULTY

$16.4 MILLION

$$$$$

AWARDED FOR RESEARCH

FACULTY : STUDENT RATIO 1:10

SCHOLARSHIPS

140 STUDENTS

275 SCHOLARHIPS

$537,000 AWARDED

Outstanding Undergraduate Research Awards

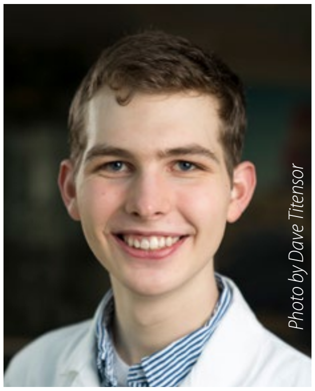


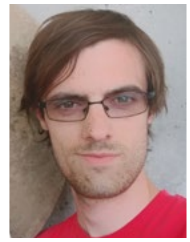
Photo by Dave Titensor

Alexander Reifsnyder is the recipient of the 2019 Outstanding Undergraduate Researcher Award for the College of Mines and Earth Sciences. Alexander, who recently graduated with a B.S. in Metallurgical Engineering, was nominated by Professor Krista Carlson. Alexander's research is concerned with the fabrication of silica aerogels that are used for the filtration of unwanted species from gases.

The previous winner (for 2018) was **Silvia Padilla** (B.S. Metallurgical Engineering '18). She was recognized as the top undergraduate researcher in the College of Mines and Earth Sciences for her work in Professor Michael Simpson's lab on electrodeposition of uranium and thorium for development of alpha spectroscopy sensors in spent nuclear fuel electrorefiners in Metallurgical Engineering. Silvia is now a research analyst in the Division of Epidemiology at the University of Utah. She says, "I went from metallurgy to epidemiology because it allowed me to continue to apply the research and data analysis skills I developed with my engineering degree while also letting me continue to learn new skills and do work that helps improve the lives of veterans."

Outstanding Teaching Assistant Award

Doctoral candidate **Nicholas Hebdon** received the 2019 CMES Outstanding Teaching Assistant Award. This award honors the teaching and educational service of one graduate student each year in the College of Mines and Earth Sciences and is considered one of the highest College honors. Hebdon has been the teaching assistant for three courses and their respective labs: Paleobiology, Sedimentology and Stratigraphy, and Natural Disasters. His faculty advisor is Dr. Kathleen Ritterbush.



Quantum Snow

Peter Veals and **Trey Alvey,** both recent Atmospheric Sciences Ph.D. graduates, were recently mentioned in an article from the Deseret News entitled, "8 Start-ups Transforming the Face of Entrepreneurship in Utah." The article states, "One of the eight most exciting to come from the University of Utah this year is Quantum Snow." Veals and Alvey founded Quantum Snow to bring what skiers in Utah crave: fresh powder on demand, without having to wait for Mother Nature to deliver it.

"Our thought was, why not make a man-made snow that is the same as the powder that falls from the sky?" said Peter. Current man-made snow production tends to be heavy and icy, while Quantum Snow seeks to blow powder that's as light and fluffy as natural snowfall. *(Read the rest of the story at cmes.utah.edu.)*

Photo by Rebecca Ray

Student Mine Rescue Team - The Mine Rescue Team at the University of Utah was formally organized last year. Since then, they have learned many valuable lessons and benefited from the leadership and involvement of the Society of Mining, Metallurgy & Exploration (SME) and the local mining community in or near Salt Lake City, UT.

The first lesson the team learned was how much they didn't know about mine rescue. Team members are currently learning and applying training standards, prescribed by the Mine Safety and Health Administration (MSHA) to gain a better understanding on how to effectively aid those in need during a mine catastrophe and return a mine to normal operating conditions. The team has been working hard to build a solid foundation focused on mine rescue training that follows a sound health and safety mentality. The team believes that the most important thing to come out of a mine is the miner and their well-being. As a result, they are very focused on supporting its individual members, most full-time mining engineering students with heavy loads.

Outstanding Faculty Teaching Award

Dr. Gannet Hallar, Associate Professor of Atmospheric Sciences, received the 2019 Outstanding Teaching Award. This student-driven award is considered the highest teaching honor in the College of Mines and Earth Sciences. The award was presented by Dean Butt at the spring convocation ceremony.

Sloss Award/Hintze Award

Dr. Marjorie Chan, newly named Distinguished Professor of Geology & Geophysics, received the 2019 GSA Sedimentary Geology Sloss Award and the 2018 Lehi Hintze Award.

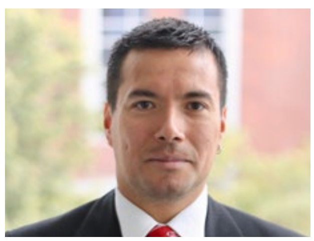
Celebrate U Awards

Dr. Courtenay Strong, Associate Professor of Atmospheric Sciences, was honored in the Celebrate U as a Researcher for "Climate Change and Atmosphere-cryosphere Interactions." Dr. Marjorie Chan, was honored as a Celebrate U Researcher Award for "Utah Geology: from Earth to Mars."

MPIF Award

Dr. Zhigang (Zak) Fang, Professor of Materials Science & Engineering, received the Distinguished Service to Powder Metallurgy Award from the Metal Powder Industries Federation (MPIF) for his outstanding career achievements.

Sustainability Leadership Research Award



Dr. Daniel Mendoza, Research Assistant Professor of Atmospheric Sciences, received the 2019 Sustainability Leadership Research Award from the University of Utah's Sustainability Program.

Dr. Mendoza writes, "Sustainability and equity have always been a primary foci of my research at the University of Utah. Large scale problems, such as climate change and rapid urbanization, are being tackled by multiple scientists, and while I am active in these research areas, I also chose to look in our own backyard. Twice a year I organize and host community events in Salt Lake City's West Side: Breathe Clean (Respira Aire Limpio) and Environment + You (El Medio Ambiente y Tú). In these bilingual events, we seek to educate and empower communities whose first priority may not be air quality or sustainability. We teach them about health impacts of poor air quality, provide free pollution masks, window insulation kits, LED bulbs, and low flow showerheads, and explain enactable measures they can do to improve the air quality around them and their neighbors."

Dr. Mendoza is also the co-director of the Consortium for Dark Sky Studies, editor-in-chief of the *Journal of Dark Sky Studies,* and part of the team developing the minor in Dark Sky Studies at the U (the first of its kind in the world). Light pollution has negative impacts in human and animal health, safety, tourism, and energy consumption, among others. They are working towards developing the field to not only advance scientific research, but also share knowledge and produce quantifiable results. He also served as a STEM Ambassador at the U in 2018.

General Education Teaching Award

Holly Godsey (BGL '95, PhD '12), Associate Professor (Lecturer) of Geology & Geophysics, was selected by the Office of General Education to receive the 2018-19 Innovation in General Education Teaching Award. This award recognizes successful innovation in curriculum or pedagogy in General Education teaching. Holly has created six new courses in her time at the Center for Science and Math Education, including The Nature of Scientific Inquiry, Science and Society, and Science Communication and Mentoring Skills for the Next Generation.

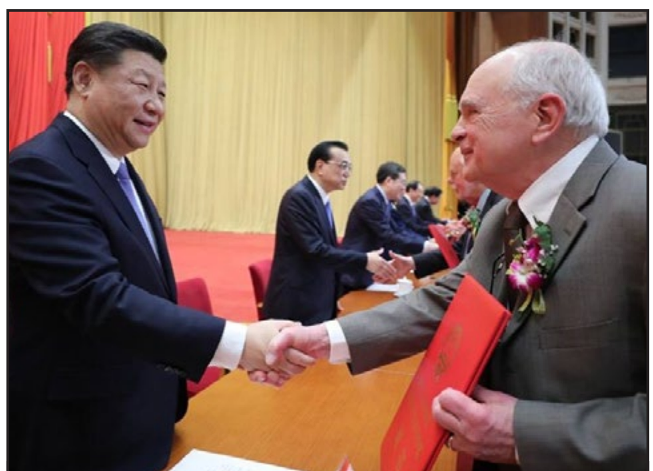
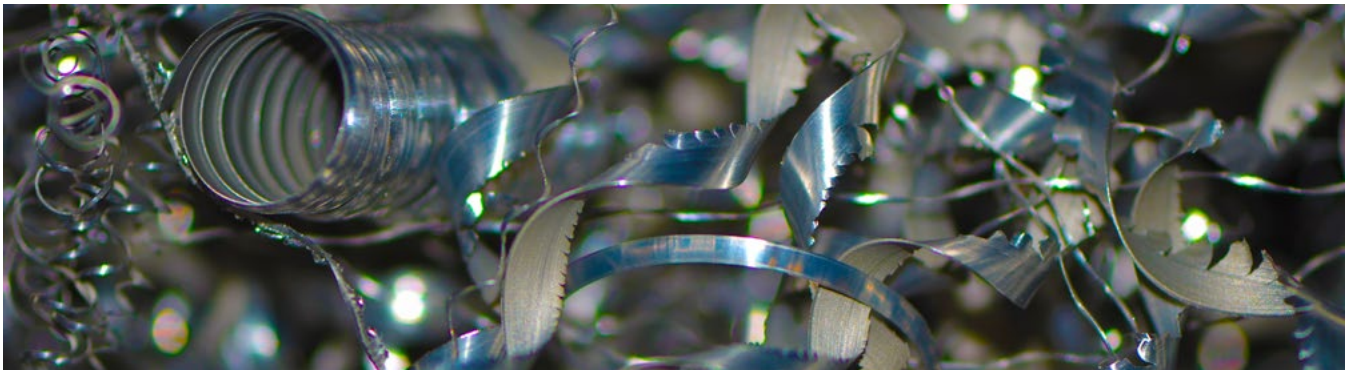


Photo by China Central Television (CCT)

Dr. Jan Miller, Ivor D. Thomas Distinguished Professor of Metallurgical Engineering, received the International Science and Technology Cooperation Award, which was presented by the President of China, Xi Jinping, at a ceremony in the Great Hall on January 8, 2019. He also received the 2018 International Mineral Processing Congress (IMPC) Lifetime Achievement Award. He is a world leader in the field of x-ray tomography in minerals processing.



A Game Changer for Recycling

U OF U METALLURGY RESEARCH GROUP INVENTS TECHNOLOGY TO SORT PREVIOUSLY UNSORTABLE METALS

By Lisa Potter, Science Writer, Marketing & Communications

The United States Department of Energy Advanced Research Projects Agency-Energy (ARPA-e) published a mandate to contain the millions of tons of metal scrap that Americans export every year. The metal recycling industry already produces tens of billions of dollars' worth of scrap by shredding cars, refrigerators, radiators — anything with metal components — but their material recovery is heavily limited by the sorting technologies currently available.

The Electrodynamic Sorting (EDX) Group, led by Raj Rajamani, Professor in the Department of Materials Sciences & Engineering, won the funding. His group has invented technology that can recover tiny pieces of scrap that were previously unsortable — red bits of copper, yellow flakes of brass and gray pieces of aluminum. These non-ferrous, or non-magnetic, metals that are extremely difficult to separate from one another, but are highly valuable once they are. The EDX system can sort them almost perfectly.

"Nobody else in the world, as far as we know of, has done anything close to this," says James Nagel, a research associate for the EDX Group.

The technology works by exciting an electromagnet with high frequencies of electrical current. When a piece of metal passes through the magnetic field, its conductive interior flurries with electrical eddy currents that repel the pieces off of a conveyer belt and into neat piles. The researchers can fine-tune the magnets to sort non-ferrous metals from each other, to sort metals from non-metals, or recover tiny metal pieces that most sorting methods miss. The group licensed the technology to form EDX Magnetics, a company that won a 2018 Utah Innovation Award in the Clean Technology and Energy category.

Rajamani's team has already tested the magnet in a real recycling facility. They are now testing a prototype that can likely process the volume of materials produced every day in scrap yards, the final step needed for the industry to buy in.

"In Utah, there's a metal recycling plant in Plymouth and two in Salt Lake City that could easily use this machine. Around the nation, there are hundreds of automobile shredders that would need this machine," says Rajamani. "The future potential of this technology is enormous."

The magnet has massive implications for the metal recycling industry and global sustainability. Extracting and refining metal ore uses lots of energy and leaves lasting impacts on the environment. Better methods for sorting material would allow companies to recycle, rather than to mine, more of the metals they need.

Sorting the scrap

The reusable nature of metal provides a boon for companies that turn metallic trash into untarnished treasure, but they could do better. In 2018, aluminum recycling in the U.S. only satisfied about 28 percent of our total consumption. The other 72 percent is either imported from overseas or produced directly from mined materials.

"Around the nation, there are hundreds of automobile shredders that would need this machine. The future potential of this technology is enormous."

Recycling facilities use giant magnets that easily recover steel and iron from the streams of waste, but they leave behind a jumble of non-ferrous materials. Most scrap yards use so-called "eddy-current" separation to recover the remaining metals, resulting in a common industry product known as Zorba—a messy mixture of aluminum, copper, brass and zinc.

The majority of U.S. recyclers would then ship their Zorba overseas, but recent trade disputes with China have heavily impacted that option.

"We wanted to develop a technology that can recover those materials at the end of the line, which creates real value for the recycler," says Dave Cohrs, associate researcher for the EDX Group.

Spoiler alert: They did.

Fine-tuning the magnetic field

The EDX technology works by exciting magnetic ferrite with an alternating electrical current. The magnetic field excites metal particles with electrical eddy currents that experience a powerful deflection force. Nagel used complex computer simulations to predict exactly how much magnetic field would emerge and how much force a metal particle would experience. Cohrs then built the magnet to perfectly execute the simulations and crafted the system to operate within the harsh environment of a scrap recycling facility.

Depending on a metal's properties, the researchers can fine-tune the current to repel different metals into separate containers. For example, the magnetic field kicks lightweight aluminum into one container, while heavier copper particles fall into another. The design can easily scale up by adding more magnets beneath larger conveyer belts. The team is testing a version that they predict will be able to handle the four tons of scrap per hour required by industrial facilities.

In 2014, Rajamani received a $3.6 million APRA-e grant from the U.S. Department of Energy to develop an electrodynamic metal sorting technology. Funding from the DOE's REMADE Institute, USTAR's Utah Technology Acceleration Grant, and the University of Utah has helped scale up the technology for potential commercialization. The Technology & Venture Commercialization Center helped facilitate licensing. Metallurgical Engineering undergraduate and now alumnus Jake Salgado (BML '18) also worked on the project.

Photo by Dave Titensor, University of Utah

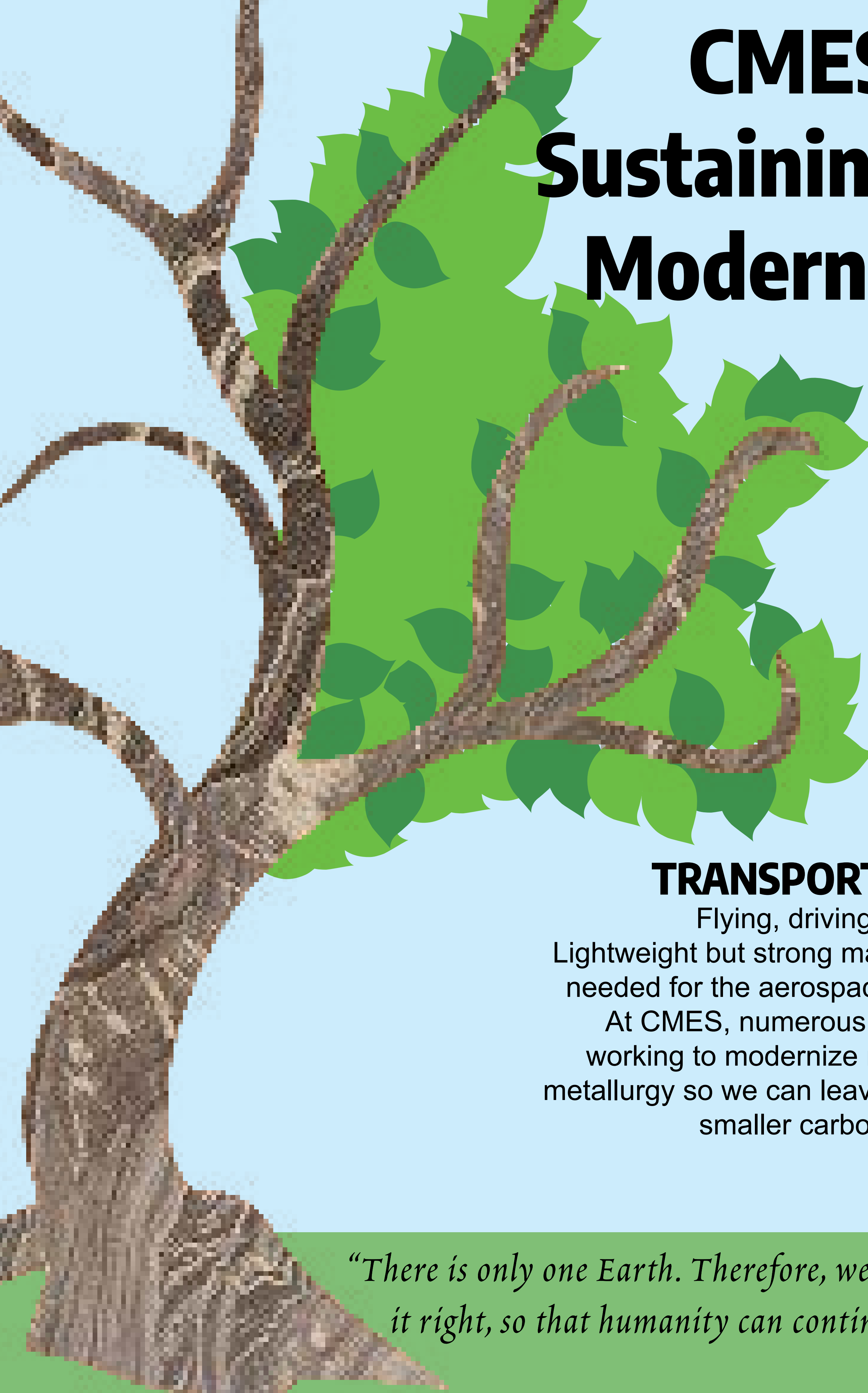
The University of Utah EDX Laboratory, a research group that has developed an electromagnet that can separate metals such as aluminum and copper that aren't naturally magnetic, but very valuable for metal recyclers.

Improving Sustainable Manufacturing Through Innovative Recycling Technologies

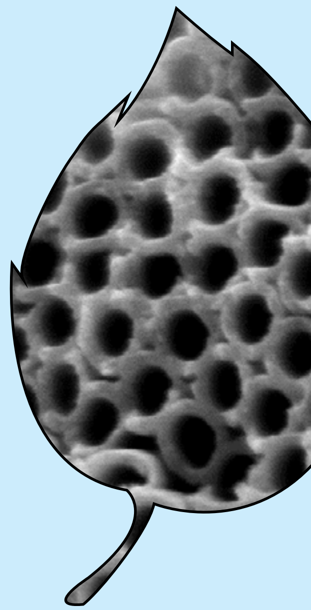
Recycling remakes used material into something new. As a key member of the United States Department of Energy's Reducing Embodied-Energy and Decreasing Emissions (REMADE) Institute since 2017, engineers at the University of Utah are creating innovative recycling technologies to reuse, recycle and manufacture materials such as metals, fibers, polymers and electronic waste at a lower cost.

The REMADE Institute is a national coalition of leading universities and companies that will forge new clean energy initiatives deemed critical to keeping U.S. manufacturing competitive. The Institute will leverage up a total of $70 million in federal funding that will be matched by $70 million in private cost-share commitments from industry, consortium members and partners. The mission is to fund early stages of research and development for key technologies that could dramatically reduce the energy and carbon emissions of industrial-scale materials production and processing.

Michael L. Free, Professor in the Department of Materials Science & Engineering, and now Department Chair of Mining Engineering, has served as the deputy node lead for the Recycling and Recovery unit at the REMADE Institute. Raj Rajamani, Professor in the Department of Materials Science & Engineering, was awarded a $1,100,000 research contract to develop his electrodynamic metal sorting technology that will enable more effective recycling of a variety of metals. Half of the funding came from the REMADE Institute, and the other half came from an industry partner called EDX Magnetics, the Utah Science Technology and Research Initiative and the University of Utah. York Smith, an Assistant Professor in the Department of Materials Science & Engineering, has a project designed to produce useful carbon from used tires. He will receive $100,000 through the REMADE Institute and $100,000 in cost-matching. Prashant Sarswat, a Research Associate Professor in the Department of Materials Science & Engineering was awarded a $200,000 grant to do research to recycle and recover copper and precious metals from electronic waste. – *Lisa Potter*



CMES: Sustaining Our Modern Life



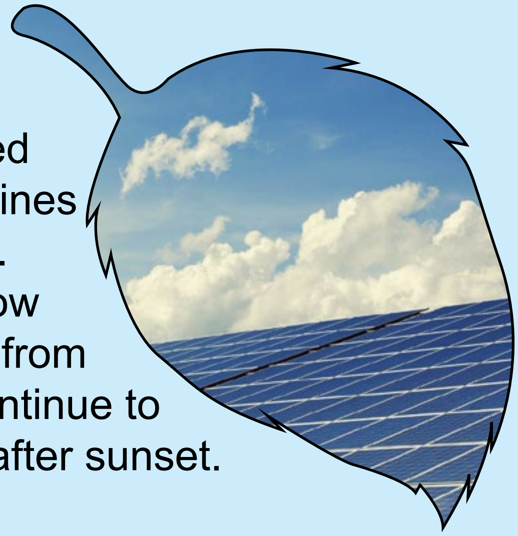
TRANSPORTATION

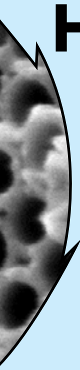
Flying, driving, bicycling. Lightweight but strong materials are needed for the aerospace industry. At CMES, numerous faculty are working to modernize mining and metallurgy so we can leave behind a smaller carbon footprint.

“There is only one Earth. Therefore, we are training the
it right, so that humanity can continue benefitting fr

ENERGY

Mining and metallurgy provides the metals needed for batteries and wind turbines essential for green energy. Our team is figuring out how to transfer maximum heat from sunlight to water so we continue to benefit from the sun long after sunset.





HEALTH & MEDICINE

Mining and metallurgy play a critical role in supporting health care needs. CMES faculty are researching ways to detect tuberculosis using titanium dioxide nanotubes.

ARTS

For thousands of years, humans have been inspired by minerals and metals to create beautiful art and music. The copper and zinc mined for brass instruments, the azurite crushed into blue pigments, and the kaolinite shaped into ceramics will continue to spark imagination for generations to come.

ELECTRONICS

Nothing screams modern life more than electronics. At CMES, we are working on ways to make more efficient use of minerals in modern life, improving Li-ion batteries and ways to recycle Rare Earth Elements.

next generation of mining, geological, and metallurgical engineers how to do
om modern technologies and lifestyles while sustaining life here on Earth."

- DR. RAJIVE GANGULI, MALCOLM MCKINNON CHAIR OF MINING ENGINEERING

Turning Nuclear Waste Into Ceramic Blocks

PROFESSORS KRISTA CARLSON AND MICHAEL SIMPSON DEVELOPED NEW PROCESSES FOR SAFE PERMANENT DISPOSAL

By Lisa Potter, Science Writer, Marketing & Communications

The Idaho National Laboratory is the leading national nuclear energy laboratory in the United States. For decades, INL has processed and stored a particularly reactive form of spent nuclear fuel in units called electrorefiners. But there's a problem — the electrorefiners are nearly full of the spent radioactive molten salt and they have no immediately available pathway to dispose of it safely in the near term. Even after the molten salt cools and solidifies, it poses an environmental risk because salt is highly soluble in water and could flow into the environment if it gets wet. A U.S. Department of Energy (DOE)-funded team led by Krista Carlson, Assistant Professor in the Department of Materials Sciences & Engineering (MSE), and supported by Michael Simpson, Chair of MSE, has developed a cheap, easy way to virtually eliminate the salt's solubility in water by dechlorinating it and incorporating the remaining metals into ceramic blocks that can be safely stored and transported for permanent disposal.

Simpson began his career working on this exact problem at Argonne National Laboratory-West (ANL-West) 23 years ago. The laboratory had just started to electrorefine about 25 tons of spent fuel from the Experimental Breeder Reactor II (EBR-II) and the Fast Flux Test Facility. EBR-II was used to demonstrate a new way to produce sustainable nuclear energy that would be viable for thousands of years. It also created used nuclear fuel consisting of metallic uranium, plutonium, fission products and sodium, a mixture too risky to dispose of or transport out of the facility. Metallic sodium reacts violently with water. If any water contacted the spent fuel, the reaction would generate heat and hydrogen, and could consequently explode. In 1994, DOE directed ANL-West to deal with this hazardous and unstable material. In 2005, ANL-West combined with Idaho National Engineering and Environmental Laboratory to form the new INL.

"They need something simple and cheap that is also going to make waste forms that are really safe to transport to safe waste repositories."

Krista Carlson

Idaho's Salt Waste Problem

"The salt in these electrorefiners is becoming more and more contaminated. And they have yet to decide what to do with it in the near term. The problem is that the original process to convert the salt into waste forms that I helped develop is too slow and expensive. Meanwhile, the salt just keeps on building up," said Simpson. "So, they need something simple and cheap that is also going to make waste forms that are really safe to transport to safe waste repositories."

Simpson and Carlson found a solution using a type of mineral known as zeolite. Zeolites form a nanoscale porous structure similar to a molecular sieve. They used a special kind of zeolite loaded with hydrogen ions. When the salt enters into the microporous H-zeolite structure, the hydrogen ions react with the chloride ions and make hydrogen chloride, a gas that quickly diffuses out of the zeolite. Manish Wasnik, a doctoral candidate in Simpson's lab, improved the process through his project so that it now eliminates 95% of the chlorides from the mixture. All metal ions in the salt, including the uranium and plutonium, will bond to the zeolite structure, so they are no longer soluble in water.

The waste still has a problem — the process generates a zeolite powder embedded with radioactive metal ions that could contaminate landscapes as far as the wind can blow it. Carlson and Levi Gardner, a doctoral candidate in her lab, discovered that heating the powder to 925°C turned it into concrete-like blocks that are resistant to leaching metals into water. The radioactive particles are essentially locked into the ceramic block structure and can safety be transported and disposed into waste facilitates.

"We have created a chemically durable ceramic with a higher waste concentration than previous ceramic waste forms. The higher concentration eliminates more than half of the volume of waste that needs to be stored in a radioactive waste repository," said Carlson. "Our synthesis method significantly reduces the complexity and footprint of the process so that we can perform the entire process in a single reaction chamber. This improvement is critical because the process has to occur in a space-limited shielded nuclear radiation containment chamber," Carlson said.

Wasnik will intern at INL in the fall to help evaluate how to scale up the process and implement it remotely. Simpson believes that INL could process all of the electrorefiner salt waste in just a couple of years — much faster than the original process that he helped to develop in the late-90s.

Photo by Dan Hixson, U. of U. College of Engineering

Metallurgical engineering doctoral students, Manish Wasnik (left) and Levi Gardner (right) pull a sample of ion exchanged zeolite from a rotary furnace, demonstrating a new and highly effective way of making radioactive molten salt stable for permanent disposal.

What is the Global Change & Sustainability Center?

The Global Change & Sustainability Center (GCSC) is an interdisciplinary hub catalyzing research on global change and sustainability. In 2009, united by a shared interest in interdisciplinary research and graduate training, faculty from four colleges founded the center, with the goal of bridging colleges, departments, and disciplines to promote environmental research and training. The Center initially included ~20 faculty, and membership has expanded continuously. The ten affiliated colleges today represent more than 140 faculty interested in a broad spectrum of research in air quality, built environment and communities, climate change, ecological and environmental change, energy, food systems, justice, equity and diversity, nature and culture, and water. This number includes 36 faculty affiliates from CMES in Atmospheric Sciences, Geology & Geophysics, and Materials Science & Engineering. The GCSC is now the research arm of the University of Utah's Sustainability Office and serves to unite multiple interdisciplinary environmental research efforts on campus including the Center for Ecological Planning + Design, the U Water Center, the Wasatch Environmental Observatory, and the Society, Water & Climate Research Group. Last year, the GCSC's research and education activities included awarding $132,000 in seed grants to nine new interdisciplinary faculty collaborations, supporting graduate research and education with nine fellowships and 52 small student research grants, assisting with the submission of multiple large multi-investigator research grants, launching a searchable inventory of faculty research in sustainability, and hosting a bi-monthly seminar series. The GCSC is an inclusive community and invites all University of Utah scholars working in this area to participate. -- Learn more at environment.utah.edu. - *Liz Ivkovich*

WEO Unites Environmental Instrumentation Network

U scientists keep a close eye on the air, water, earth and life along the Wasatch Front. The new Wasatch Environmental Observatory (WEO), administered by the Global Change and Sustainability Center (GCSC), aims to broaden and improve that scientific vision through tying together research infrastructure.

WEO combines current and future environmental monitoring instruments into one distributed, large-scale scientific observatory. "We have all this infrastructure," says Brenda Bowen, GCSC director. "We thought: How can we pull this together in a new way to study the whole Wasatch Front as a living lab? We're pulling together systems that were initially funded by individual researchers or through large grants to make it into something more than the sum of its parts."

Nearly 40 U researchers from 13 departments (including 13 faculty from CMES) are participants in WEO, sharing their data to encompass the interconnectedness of environmental issues in the west. Geology & Geophysics Professor Paul Brooks, a WEO leader, says that the U is uniquely positioned to study issues of mountain water supply right alongside issues of urbanization. "Instead of addressing these issues piecemeal we have the ability to address them in concert," he says.

WEO is also funding two technical research staff, Dave Eiriksson and Ryan Bares, to maintain the instrumentation. Watch for more updates from WEO at https://environment.utah.edu/weo. - *Paul Gabrielsen*

Photo courtesy of Rio Tinto Kennecott

FROM MONGOLIA TO UTAH - BONNIE'S MINING ENGINEERING ADVENTURE

Bonnie Erdenekhuyag is not your average student. She came to Utah from Mongolia after finishing high school. She had a limited working knowledge of English, but she knew she wanted to be a Mining Engineer. As an undergraduate student, Bonnie overcame challenging language barriers and she is now working towards a Master of Science degree in Mining Engineering with Dr. Jessica Wempen.

Bonnie is interested in everything and one of her hobbies is flying drones. Leveraging her interests and her abilities, Bonnie pursued an internship with the Remotely Operated Vehicle (ROV) program at Rio Tinto Kennecott Utah Copper where she had an opportunity to work with U of U alum Andrew Carey (B.S. Mining Engineering '13), the Director of Drone Operations. As part of her experience at Rio Tinto, Bonnie has developed proficiency as a professional remote pilot, and she has had the opportunity to work with developing technologies including drone born LiDAR and hyperspectral imaging.

Bonnie feels that this is just the beginning for ROVs in the mining industry. "There are so many other things that we can do with ROVs. I look forward to trying other aspects, like a thermal camera on a drone to help the reclamation crews determine how much water is in each area so they will know what type of plants will thrive there, or a hyperspectral camera to review the mineral makeup of soil samples. As the technology improves, so does the ROVs' future in mining."

Bonnie wasn't planning to get a masters degree, but she has created the opportunity in collaboration with Andrew, Jessica, and Rio Tinto. Bonnie believes ROV technology is the future of the mining industry and that this technology will continue to develop with a focus on safety, cost savings, and efficiency. Bonnie has been an amazing asset to the ROV group, and both Andrew and Jessica feel privileged to be able to participate in Bonnie's education.

"Even though my mother would like to know when I will be getting a real job and stop playing with toys," Bonnie said with a smile, "I truly believe this technology is the future generation in mining and will continue to grow and focus on safety, cost savings, and efficiency." - *Jessica Wempen*

Photo by Luke Leclair-Marzolf

"I wasn't planning on getting a Master's degree. It was because of the amazing partnership between my university mentor Jessica Wempen, Andrew (my leader) and Rio Tinto, I was really encouraged to take my interest to the next level."

A SUSTAINABLE IRONMAKING TECHNOLOGY

By Lisa Potter, Science Writer, Marketing & Communications

Dr. Hong Yong Sohn, Distinguished Professor of Metallurgical Engineering, is ready to upend the steel industry. Over the last decade, he has developed innovative technology that would radically reduce steelmaking's pollution and energy consumption. Steelmaking is one of the most carbon dioxide (CO_2)-producing industries in the world, but demand for steel is increasing. Sohn's Flash Ironmaking Technology (FIT) transforms the most CO_2-heavy step in "blast furnace" steelmaking; producing the iron that gets refined into steel. If the United States and Canada switched to FIT to produce all of their steel, CO_2 emissions would drop by 54 million tons per year. Worldwide, FIT would reduce CO_2 emissions by 2 billion tons per year, according to Sohn's calculations.

"My goal is to replace the blast furnace with this technology. At this point, it's almost pie-in-the-sky," said Sohn. "But you gotta dream big, right?"

Ditching the blast furnace

Over 90 percent of the world's primary iron is made using blast furnace technology. The blast furnace has two major issues: it consumes tons of energy and produces lots of pollution. Blast furnaces turn raw, iron oxide (Fe_2O_3 or Fe_3O_4) minerals into a crude iron metal, which is then refined into steel. To make iron, you must isolate and concentrate the iron oxide, then remove the oxygen (O) from the iron element (Fe). Metallurgists and chemists call the process of removing oxygen "reduction," and the tool they use to steal the oxygen a "reducing agent."

In North America, 70 percent of iron oxide used for steelmaking comes from taconite, a low-quality ore that contains less than 30 percent iron in the form of magnetite Fe_3O_4 mixed with silica. Ironworkers grind taconite into very fine powder, then use a magnet to separate Fe_3O_4 from non-magnetic impurities. They press the powder into pellets and fire them, like ceramics. This "pelletization" requires lots of energy and produces CO_2.

Ironmakers "charge" the blast furnace with alternating layers of pellets and another material called coke, a nearly-pure carbon made from coal. Coke serves two purposes: it fuels the furnace to high temperatures and it produces carbon monoxide (CO), an essential reducing gas. Coke is a major source of pollution—making coke produces toxic coal dust, organic wastes and the oxide-reducing reactions produce large volumes of CO_2.

Sohn's technology eliminates coke. Rather, FIT uses oxygen to partially burn hydrogen (H_2) or hydrogen-containing natural gas to heat the furnace as well as reduce the iron. Unlike CO, H_2 steals O to form water vapor (H_2O), not CO_2. FIT is the only method in the world that uses Fe_3O_4 concentrate powder directly, avoiding the energy-intensive pelletization process.

Ditching the carbon

Sohn's state-of-the-art, computer-controlled facility is the largest laboratory on campus. Inside, the FIT furnace looms 12 feet tall, topped with a cylindrical reactor in which he injects natural gas with just the right amount of oxygen. The oxygen does two things: it oxidizes the natural gas, generating the necessary 1,200° C to 1,600°C temperatures, and the produced gas serves as a reducing agent. Then, he adds the very fine Fe_3O_4 concentrate powder into the top of the cylinder. The particles flow together with the gas under extreme heat, where it reduces the iron oxide. In this method, reduction happens in two to seven seconds. The traditional blast furnace takes two to eight hours. The end result is a pure iron-powder that he presses into briquettes to be melted down into molten iron and refined into steel.

FIT has some challenges before it can be implemented in industry. Until now, Sohn has worked on validating that the technology will be able to handle the required materials at the industry scale. The member companies of American Iron and Steel Institute and Department of Energy have shown much interest in commercializing FIT. Now, Sohn is preparing to do a pilot with an industry partner, with an emphasis on coupling FIT with an emerging technology for hydrogen production. Currently, hydrogen prices are too high to compete with the blast furnace. However, due to recent shale gas development, natural gas prices are at historic lows.

"Right off the bat when we started ten years ago, hydrogen prices were pretty expensive. I always maintained that this process would work with natural gas, as well. I'm proud of myself, actually, because I was very clairvoyant. Natural gas prices have dropped by a factor of at least two," said Sohn. "With natural gas right now, FIT has a high economic feasibility."

Sohn further notes that much progress is being made to develop hydrogen economy in the U.S. and elsewhere, largely aimed at its utilization in automobile and transportation sectors. When this happens, hydrogen prices will be sufficiently low to make its use in FIT economical, with environmental and other associated benefits.

Hong Yong Sohn, Distinguished Professor of Metallurgical Engineering, has developed innovative technology that would radically reduce steelmaking's pollution and energy consumption.

The Department of Atmospheric Sciences showed the ACCESS students a Google car now equipped with mobile air monitors.

ACCESS PROGRAM A SUCCESS

The College of Mines and Earth Sciences was happy to host the students in the ACCESS Program for Women in Science and Mathematics for three days of their program this summer. The women are entering freshman and transfer students to the University of Utah that are interested in STEM majors. The students attended a welcome breakfast with faculty and staff from CMES and took a tour of the Atmospheric Sciences Department. The young women learned about the kestrels, anemometers, and thermal imaging used in atmospheric sciences, learned about the pollution sensors on Google Cars, and pretended to be weather forecasters in front of the Ute Weather Center green screen!

Staff and faculty from CMES then took the ACCESS students on two field trips to industry partners. First, Rio Tinto Kennecott gave a tour of the Visitor Experience at the Mine, a presentation with a panel discussion, and had a "speed dating" rotation for questions with a wide range of leaders. This set the stage for some great questions on the research, roles, and the fun that happens every day at Kennecott. The panel discussion covered a variety of career paths, the support that Rio Tinto provides in diversity, and the many opportunities that Rio Tinto offers. Next, the ACCESS students went to FLSmidth where they met with industry leaders and research scientists to learn about the many paths that lead to careers in exploration geosciences, metallurgical engineering, and mining engineering. As well as a discussion with women from FLSmidth, the students participated in a cupcake mining activity and received a tour of the facilities.

Thank you to everyone who participated and helped make the week a success! - *Laura Meyer*

NATURE MASTERCLASS

In support of a new Energy Frontier Research Center (EFRC) that was established last academic year by DOE, Dean Butt was the driving force behind bringing editors from the prestigious journal *Nature* to Salt Lake City to deliver a masterclass on technical writing and publishing last May. If one looks closely in the photo, one can see an uninvited attendee to the workshop looking in the window. She must have heard that *Nature* was coming!? It's not often we have the opportunity to discuss original journal abstracts with editors from such a journal, and seats were limited to graduate students, postdoctoral researchers and early-career scientists from our EFRC, as well as students from the College of Mines and Earth Sciences. The doe did not have an abstract to review, but she did keep an eye on us for an hour or so.

Our EFRC includes researchers from several other universities and the Idaho National Laboratory, as well as a number of research groups from CMES and other departments at the University of Utah. We are investigating the interaction of solids and liquids in very confined spaces, where macroscopic properties are often not observed, and the EFRC is named Multi-Scale Fluid-Solid Interactions in Architected and Natural Materials (MUSE). The center hopes to make significant strides toward understanding such phenomena, concentrating on the basic science of these systems. Advancements in this area of study would lay the groundwork for improving a range of practical applications, including carbon sequestration, water filtering and energy production. - *Mark Koopman*

Photo by Mark Koopman

Hassnain Asgar, a PhD student from Cornell University and a member of MUSE, pitches his research topic to editors from the journal Nature and his fellow participants, during a masterclass on scientific writing and publishing. Can you spot the uninvited guest on the other side of the window?

WELCOME NEW FACULTY & DEPARTMENT CHAIRS

Sarah Lambart

Dr. Sarah Lambart joined the Department of Geology & Geophysics as an Assistant Professor in March 2018. She received her bachelors, masters and PhD in Earth Sciences from Blaise Pascal University, France. Sarah says, "I'm an experimental petrologist. When I was a kid, I wanted to be a car mechanic. Growing up, my love for nature, and volcanoes in particular, drove me towards geology. Experimental petrology is a great way for me to combine mechanical work and my passion for understanding how magmas are formed." At the U, Dr. Lambart uses high pressure-high temperature apparatuses to reproduce conditions of the deep Earth. "Having the opportunity for a geologist to work in the middle of such a beautiful state is a dream coming true."

Dr. Lambart's work was highlighted in a new paper published in May 2019 in *Nature Geoscience* which paints an intricate picture of the mantle as a geochemically diverse mosaic, far different than the relatively uniform lavas that eventually reach the surface. Even more importantly, a copy of this mosaic is hidden deep in the crust.

Rajive Ganguli

The Department of Mining Engineering research and teaching opportunities expanded this year with the addition of

Dr. Rajive Ganguli as new McKinnon Chair in Mining Engineering in May 2019. Dr. Ganguli is an experienced mining engineering professor with a large research group and a wealth of experience in research, teaching, and service that will have an immediate, positive impact on the Department.

He came to the University from the University of Alaska Fairbanks (UAF), where he directed the Mineral Industry Research Laboratory. Additionally, he led the accreditation efforts of the mining engineering program for two cycles. Dr. Ganguli has been working on artificial intelligence for mining industry applications for the last two decades. In addition to computational intelligence, he acknowledges mining as a truly interdisciplinary industry and recognizes the many opportunities afforded to interdisciplinary teams. He is hoping to partner with colleagues to tackle some of the grand challenges in mining, from exploiting big data, to tackling the various issues that make mines difficult to permit.

John Horel

Dr. John Horel is now the Chair of the Department of Atmospheric Sciences.

Professor Horel is a world-class atmospheric scientist with a focus on observation and analysis of weather and climate processes in mountainous regions.

Much of his research has been of import to Utah, including work on the 2002 Winter Olympics, fire-weather applications, the Great Salt Lake climate, and air quality along the Wasatch Front and in the Uinta Basin. *(See his Foster Camp story on page 21.)*

Michael Simpson

Dr. Michael Simpson is the new Chair of the intra-college Department of Materials Science & Engineering. This administrative assignment allows Dr. Simpson to oversee both the Metallurgical Engineering and Materials Science & Engineering Departments as the merger processes proceed. "This is an exciting time for the metallurgists and materials scientists at the University and we are pleased to have such a capable captain at the helm," says Dean Butt. (Read about Dr. Simpson's research on page 12.)

Michael Free

Dr. Michael Free was named Chair of the Department of Mining Engineering on July

1st, succeeding Dr. Michael Nelson who served in that capacity for eleven years. Dr. Free is a Professor of Metallurgical Engineering (and now Materials Science & Engineering) with a strong background in extractive methods. Dr. Free has a very strong research group with mining-related research project experience that includes collaborations with other mining engineering departments. He has a great teaching record that includes teaching one of the required mining engineering courses, and extensive experience in advising, recruiting, and administering. Dr. Free's expertise and breadth of knowledge of both the front end and back end of mineral processing will allow our college to develop additional collaborations and interactions with other complimentary disciplines on and off campus as well as expand our research opportunities, strengthen our undergraduate program, increase our enrollment, and build upon the tradition of excellence in Mining Engineering.

Our educational opportunities have been expanded with the new MS program in Earth Resource Management, which is largely the result of Mike Nelson's efforts, and we welcomed the first students into this program fall 2019. We are also finalizing plans to expand our safety center, and pursuing some new educational and training collaborations with the School of Business.

As we look toward the future, the College of Mines and Earth Sciences will continue to be committed to and will be investing in the faculty and students in the Department of Mining Engineering to ensure their success as we educate, elevate, and empower the next generation of mining engineers to do great things to benefit our society.

A Conversation with Alumna, Crystal Tulley-Cordova

Crystal Tulley-Cordova recently graduated with a Ph.D. in Geology in 2019. Crystal was a US EPA STAR Fellow. She received a M.W.R. in Water Resources and a B.S. in Earth and Planetary Sciences from the University of New Mexico. Her research focused on using historical records and isotope geochemistry to better understand water resources of the Navajo Nation and their susceptibility to climate and land use change. Recently, TJ McMullin, CMES Development Director, spoke with Tulley-Cordova about her career and her experiences at the University of Utah.

TJ: Could you please tell us what you are currently doing in your career?

Crystal: As principal hydrologist for the Navajo Nation, I participate as a technical expert in water rights meetings with tribal, city, state, and federal governmental agencies. I am a Navajo Nation representative and a Coordination Committee member for the San Juan River Basin Recovery Implementation Program. I also participate in watershed and ground water studies currently being conducted on the Navajo Nation.

TJ: What do you enjoy most about the work you do?

Crystal: I love that I am working for an organization, Navajo Nation Department of Water Resources - Water Management Branch, whose main goal is "to protect and manage water resources of the Navajo Nation." I enjoy working with my co-workers and allies (academic institutions, foundations, non-profits, tribal, state, and federal agencies) on various water-related projects.

TJ: How did your time at the College of Mines and Earth Sciences prepare you for your career?

Crystal Tulley-Cordova

Crystal: My time spent in the College of Mines and Earth Sciences allowed me to learn about managing multiple research projects located on the Navajo Nation. My Ph.D. research consisted of three different projects that allowed me to learn about budget management, communicating with research collaborators, conducting field work, dealing with unexpected set-backs, and writing journal articles describing my research findings.

TJ: What was your most meaningful experience at the University of Utah/College of Mines and Earth Sciences?

Crystal: The turning point in my Ph.D. and most meaningful experience at the University of Utah was when I decided I needed to tell my advisor I wanted to work on a different project than the one I was assigned. When asked, "What would you like to work on instead?" I felt like my brainstormed ideas could materialize. I knew I had a lot of work to do, but the comforting thought was that I had the support to do it.

TJ: What advice would you give current students?

Crystal: I have two points of advice: 1) have a mentor and be a mentor. I am the first in my family and extended family to receive a Ph.D. Mentors in my life have helped me navigate through my undergraduate and graduate years; 2) be the best you that you can be. I'd unknowingly compare myself to others, and I'd get frustrated with my grades, my research progress, etc. I finally realized I'm unique, and I don't need to compare myself to others because it only made me feel bad about where I was.

TJ: What is something unique about you that other alumni or current/future students might find especially interesting?

Crystal: I was a flamenco dancer trained by Eva Encinias-Sandoval, founder of the National Institute of Flamenco.

NEWMONT GOLDCORP INVESTS IN SAFETY WITH $500,000 GIFT

Newmont Goldcorp generously pledged $500,000 to fund a renovation of space on the east side of the 5th floor of the William Browning Building. The space will be used for group work, classes, workshops and activities focused on proactively building a culture of safety. The space will be named the Newmont Goldcorp Safety Classroom and will also serve as the physical home for the Center for Mining Safety and Health Excellence. We look forward to opening up the space to students, faculty, campus partners and friends from the community in spring 2020. Thank you to Newmont Goldcorp for investing in safety and education.

BARBARA NASH RETIRES

Dr. Barbara P. Nash retired this year from the Department of Geology & Geophysics after 50 years of service. She was trained in geochemistry and mineralogy at the University of California, Berkeley. She has been a leading analyst using electron microprobe methods at the University of Utah during that time. She came in 1970 and has only left for field and research visits, and to paint! She has characterized alkaline rocks to understand their formation, studied the volcanism of the Yellowstone region to understand the geological history of the Rocky Mountain and Great Basin regions, been a key analyst in work involving the correlation of obsidian in human occupation in East Africa, and characterized minerals unique to the Anthropocene. In all, she has been associated with the discovery and characterization of 74 newly recognized minerals on Earth. A few years ago, one of these minerals was named Nashite in her honor.

Some of her career highlights include:

- Associate Dean for Research, College of Mines and Earth Sciences
- Professor, Department of Geology & Geophysics, University of Utah, 1978-present
- Director, Electron Microprobe Laboratory, University of Utah, 1970-present
- Chair, Department of Geology & Geophysics, University of Utah, 1980-85
- Fellow, Geological Society of America
- Outstanding Faculty Research Award, Department Geology & Geophysics, University of Utah, 2016.
- "Mineral of the Year" award, 2015, by the International Mineralogical Association.
- Outstanding Faculty Research Award, Department Geology & Geophysics, University of Utah, 2010.

CMES RANKED #2 ON GIVING DAY

This past spring the College of Mines and Earth Sciences participated in the University of Utah's first annual Giving Day. During the event, 160 of our generous friends and alumni contributed over $40,000 which was the second highest fundraising total on campus. Thank you to all who participated and to the many others who made gifts large and small to the College throughout the year. The next Giving Day will be February 25-26. We hope you will join us in supporting CMES! If you would like to make a contribution in the meantime, you can call TJ McMullin at 801-581-4414 or give online at cmes.utah.edu/giving.php.

A Life of Invention

By Lisa Potter, Science Writer, Marketing & Communications

In Dec. 2017, the National Academy of Inventors (NAI) elected Zhigang Zak Fang as part of the newest cohort of NAI fellows. The Professor of Metallurgical Engineering was an obvious choice; he has over 50 issued patents, several more pending and multiple new projects in the works.

Fang's research focuses on the metallic materials used in energy efficiency, energy storage or energy production, specifically, on the processes and mechanical properties of metals made from metal powder. Lately, he has focused on titanium, a so-called "wonder metal" that is strong, lightweight, corrosion resistant, bio-compatible and abundant but not widely used due to its cost. Fang invented a process that can reduce the cost of producing titanium powder by half, and the processing energy of the primary titanium metal by 40 percent.

What on EARTH sat down with Fang to talk about his prolific research and how he stays motivated.

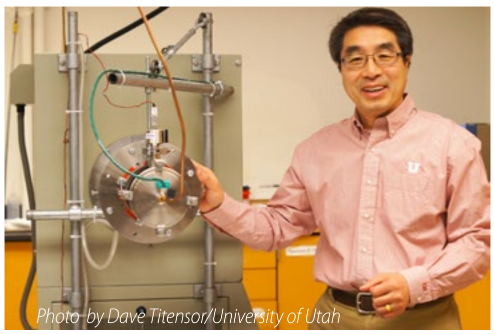


Photo by Dave Titensor/University of Utah

What drives you to keep innovating?

I worked in industry for 11 years before joining this faculty, and that shaped the way I work as an academic. So, my career has been focused on working to solve industrial and practical problems.

It takes a lot of energy to produce primary metals from minerals and to manufacture with metals to make auto parts, airplane parts, and computer parts. No matter how much high tech we have, we rely on metals to build it, so metals will never go away. My research group has deliberately defined our focus on energy efficiency, energy production, or energy storage. We're not working directly on solar or wind or electric batteries, but on the metal powders that are often the source materials for those products.

Your recent work focuses on making titanium more efficiently. Why titanium?

Titanium is a wonder metal, or a metal of the future. I like to think of titanium as a metal of the present. It can have the same strength or toughness as steel, but with half the weight. If automobiles used titanium instead of steel, they would be more lightweight, consume so much less fuel and produce fewer emissions.

However, Ti is not used nearly as much as steel because it's too expensive. It's not rare, but it's expensive to extract, to process, and to make things from. That makes it a good area and challenge for us.

You discovered an efficient, less expensive way to reduce titanium oxide, the main component in titanium ore, into pure titanium powder. How did you do that?

The current method, called the Kroll process, is very energy intensive and expensive. It relies on a chlorination process to prepare titanium tetrachloride ($TiCl_4$) as the raw material for the reduction process to make pure metal. We came up with an approach to reduce titanium dioxide (TiO_2) directly, without the chlorination.

We discovered that when magnesium is used together with hydrogen to reduce TiO_2, something magical happens. We revealed a new chemistry. It's not a complex science; put titanium dioxide and magnesium powder into the blend and heat it up in a hydrogen atmosphere, and pure titanium metal is produced.

So far, it's very effective, and we believe this process has a lot of potential. We predicted that the titanium metal powder was going to be half of the current cost of Ti powder in the market. It cuts the processing energy of the reduction of $TiCl_2$ or TiO_2 by 40 percent compared to the Kroll process.

What stage is the research in now?

We partner with the companies Boeing and Arconic. In 2017, we received additional funding from the Department of Energy to do the pilot production. In 2018 and 2019, we have produced a few hundred kilograms for evaluation and validation by Boeing, Arconic, and other industrial entities. Then it will be on its way to become commercial.

The titanium powder process is just one of your many inventions, and you have multiple new projects in the works. How do you stay inspired?

Everyone has something that makes him or her tick, so to speak. To me, the gratification comes from solving problems, from seeing something work because of my ideas and hard work. I am fortunate to have worked in several interesting and challenging fields, including the hard materials for energy exploration, metal hydrides for hydrogen, thermal energy storage, and light metals for structural applications. There are plenty of challenges in all these fields. Keeps me busy.

I appreciate the environment that the University of Utah provides for faculty inventors. I received assistance from the U's Technology & Venture Commercialization Office with patents and two spin-off companies.

What's your newest endeavor?

In May 2019, I accepted a three-year appointment as Program Director in the Advanced Research Project Agency for Energy (ARPA-E) of the U.S. Department of Energy (DOE). ARPA-E's mission is to develop research programs for breakthrough technologies that will have transformative impact on energy efficiency, renewable energy, and reduced emissions.

WITHSTANDING THE TEST OF TIME


Photo by J. P. Oleson

Romacons drilling at a marine structure in Portus Cosanus, Tuscany, 2003. Drilliing is by permission of the Soprintendenza Archeologia per la Toscana.

Roman author Pliny the Elder wrote in his *Naturalis Historia,* published between 77-79 AD, that concrete structures in harbors, exposed to the constant assault of the saltwater waves, become "a single stone mass, impregnable to the waves and every day stronger."

He wasn't exaggerating. While modern marine concrete structures, made of Portland cement concrete crumble within decades, 2,000-year-old Roman piers and breakwaters endure to this day, and are stronger now than when they were first constructed. Romans made concrete by mixing volcanic ash with lime and seawater to make a mortar, and then incorporating chunks of volcanic rock aggregate into that mortar. The combination of ash, water, and quicklime produces a pozzolanic reaction. University of Utah geologist Marie Jackson studies the minerals and microscale structures of Roman concrete as she would a volcanic rock. Jackson says that while researchers have answered many questions about the mortar of the concrete, the long-term chemical reactions the aggregate materials remain unexplored. She and her colleagues have found that seawater filtering though the concrete leads to the growth of interlocking minerals that lend the concrete added cohesion. The results have been published in *American Mineralogist*. Jackson intends to continue the work of Pliny and other Roman scholars who worked assiduously to discover the secrets of their concrete. "The Romans were concerned with this, " Jackson says, " If we're going to build in the sea, we should be concerned with it too."

The Graduate Certificate Program in Hydrology and Water Resources is entering its third year with increasing enrollment and now integrates courses from six colleges (Mines & Earth Sciences, Science, Engineering, Social & Behavioral Science, Architecture & Planning, and Law) to prepare students to become leaders in research and applications related to water resources. The program is a collaboration between the Graduate School, the Sustainability Office, and the Global Change and Sustainability Center which explicitly recognizes that water is directly or indirectly involved in most aspects of sustainability. Program Director Paul Brooks states that "concurrent exposure to cutting edge research across disciplines in the academic setting combined with interaction and internships with a range of working professionals is a unique aspect of the program that allows students to envision how and where they can put their knowledge to work". Additional information can be found at https://environment.utah.edu/hydro-certificate/

FOSTERING COMMUNITY AT KIDS CAMP

Professor John Horel, the chair of the department of Atmospheric Sciences, is a world-class atmospheric scientist with a focus on observation and analysis of weather and climate processes in mountainous regions. Much of his research has been of important to Utah, including work on the 2002 Winter Olympics, fire-weather applications, the Great Salt Lake climate, and air quality along the Wasatch Front and in the Uinta Basin.


Having a swinging time at camp.

It's hard for Professor Horel to unplug from his cell phone. For five days this summer his cell phone and those of roughly 70 other volunteers were off limits so that they focus on helping 42 children ages 7-11 have an amazing time at a summer Bible camp in the Wasatch Mountains. He has been helping at one of the three Royal Kids Camps (RFK) in Utah for the past 17 years. The RFK program began nearly 30 years ago to create positive, life-changing moments for innocent children who have been victims of neglect, abuse, and abandonment. Other Department alumni who have helped at this Camp include Sarah Bang, Erik Crosman, Matt Jeglum, and Leigh Jones.

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Google Street View Cars Join the U's Air Quality Team

The first step toward fixing air quality challenges in the Salt Lake Valley is understanding how air pollution levels vary across the city. To that end, U researchers have previously placed air sensors in a van, on light rail trains and on a news helicopter. But to get an even finer view of Salt Lake's air quality, they're getting help from the people who turned block-by-block driving into an art—Google's Street View cars.

Since April, the Street View cars, brought to Salt Lake City through the efforts of research assistant professor Logan Mitchell, professor John Lin, Google Earth Outreach and Environmental Defense Fund (EDF), will weave through Salt Lake's streets, collecting real-time air quality data. Mitchell, Lin and their colleagues will then use the data to identify pollution sources and how they affect different kinds of neighborhoods.

"In the end it's going to enable better utilization of mobile data," Mitchell said. "That's going to give more accurate science-based information to policymakers and stakeholders so we can make better informed decisions about how to clean up the air."

The end goal is to provide is to provide information that will help residents and leaders of the Salt Lake Valley make science-based decisions to improve Utah's air quality.

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