

MINES MAGAZINE

COLORADO SCHOOL OF MINES ALUMNI MAGAZINE

Spring 2019 Volume 110 Number 2



MOONSHOTS

Mines made significant contributions to the 20th century space race and now plays a central role in a new race to learn more about the resources on the Moon and beyond.

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LEADING LIKE A BOSS

Many Mines alumni are in executive positions at oil and gas companies, guiding the industry toward a bright future.

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Cover image: This issue's cover is a composite image of a prospector created by Lunar Outpost pictured as if it were on the Moon's surface. (Prospector photo by Joe DelNero; Moon photo courtesy of NASA)

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MOONSHOTS

After making noteworthy contributions to space research in the last 50 years, Mines now plays a central role in a new space race to learn more about space resources.

LEADING LIKE A BOSS

20

Like many Mines graduates before them, alumni are taking on executive positions at oil and gas companies, leading the industry to a whole new level.

WEB EXTRAS | MULTIMEDIA

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AN INSIDE LOOK AT PROSPECTING ON THE MOON

In collaboration with the Center for Space Resources, Lunar Outpost developed a prospector to collect and analyze soil samples on the Moon. Check out the video on our website to see the prospector in action and learn more about the multidisciplinary collaboration that's driving cutting-edge space research at Mines.

HOMESTEADING THE FINAL FRONTIER

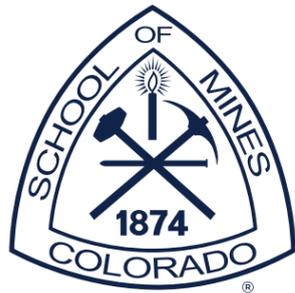
Mines is leading the next space race to develop the resources in space, as detailed on pages 14-19. For a more in-depth look at the space research currently underway at Mines, visit our website to check out the story featured in our recent research publication.

CELEBRATING ANOTHER E-DAYS

As always, this year's E-Days celebration was one for the books. The Mines community gathered to kick off a weekend of events that have become a signature part of the Mines experience. Check out photos on our website and look for a full recap in our summer issue.

THE BENEFITS OF A MINES DEGREE

Your degree offers you more than a rewarding career. As a Mines graduate, you have access to the Mines recreation center, discounted insurance and travel programs and more. You can even get a Mines license plate in Colorado and Texas. Visit minesalumni.com to check out how you can take full advantage of your degree.



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Comments and suggestions are welcome. Contact us via our contact form at minesmagazine.com/contact-us or via mail at *Mines Magazine*, 1500 Illinois St., Golden, CO 80401. To update your address, go to minesalumni.com/update or email minesalumni@mines.edu.

OPENING REMARKS



RIISING TO MEET NEW CHALLENGES

Mines has a long history of looking to the future, developing and delivering the degree programs, knowledge, technological innovations and the scientists and engineers that industry and society need to move forward.

This year marks the 50th anniversary of Apollo 11 landing on the Moon, and the dreams of space travel and the engineering and scientific research the Apollo program inspired continue today. NASA is currently conducting the Mars InSight mission to collect soil samples from the planet's subsurface, and humankind is taking aim at exploring farther and farther from Earth.

This poses new engineering and scientific challenges, including the need to locate, extract and process the resources we need for fuel, food and parts as we travel deeper into space. We cannot launch everything we need for deep space exploration from Earth—we will have to be creative and locate it out in space and develop new chemical and manufacturing processes that work far from home.

No university is better positioned to contribute to this exciting future than Mines. No one else has our unique combination of expertise in geoscience, extractive engineering and processing, energy, manufacturing and material sciences. Our students and faculty are already applying their expertise to figure out how to transform water mined in space into rocket fuel. Others are designing new rovers and other machinery with complex characterization tools for more efficient in situ testing in space environments. Mines also just launched the world's first space resources degree program to educate the next leaders in this developing field.

You can always count on Orediggers to meet the challenges our society puts in front of them, and I'm excited to see how far Mines innovations and graduates travel in space and which endeavors we tackle next.

Go Orediggers!

Paul C. Johnson, PhD
President and Professor



AT THE FOREFRONT OF THE FUTURE

Many of us are familiar with the saying, "Change is the only constant in life." Orediggers have long embraced those words and are known to meet the challenges that change creates. As evidenced in each issue of *Mines Magazine*, Mines alumni continue to make advancements in every industry to adapt to the changes our society demands.

In day-to-day life, consumer and product safety demands are among many things in our lives that necessitate change. Inspired by the need for safer automobiles, a Mines alumnus invented the explosive trigger for airbag deployment, and another alumnus is currently developing a safer tailgate step for pickup trucks. The leaders on pages 20-23 are tackling the changes in the oil and gas industry to ensure an ambitious and promising future.

Other changes have propelled us into fields that we'd never thought possible and helped advance us as a society. With the first lunar explorations in the 1960s came innovations in math, computing, mechanics and materials that have allowed us to better understand how the world—and the larger universe—works and our place within it. These breakthroughs, among others, have benefited from the creative and innovative minds of Orediggers.

These same kinds of innovations are happening today on the Mines campus and in every industry with Mines alumni leading the charge. Mines taught us the processes involved in scientific evaluation, thinking and design and developed those ideas into a skill set that still resonates in the workforce today. Mines uniquely prepares us for success and emboldens us with the ability and know-how to lead the way to places where others have not yet been.

Damian Friend '75
Executive Director, Mines Alumni Association

NEW CAMPUS LEADER

**RICHARD C. HOLZ
NAMED AS MINES' NEXT PROVOST**

Mines has named Richard C. Holz its next provost. Holz is currently dean of the Klingler College of Arts and Sciences at Marquette University and will join Mines in June 2019.

As provost, Holz will serve as Mines' chief academic officer, responsible for leading the faculty and staff to achieve the vision for the university's academic programs. He will work closely with President Paul C. Johnson and other members of the executive cabinet, providing leadership on strategic initiatives that ensure Mines is a top-of-mind and first-choice university for preeminent engineering and science students, industry partners and world-renowned faculty and staff.

"We are excited to have Rick join Mines as our next provost," Johnson said. "Rick brings skills and experience that we identified as critical to achieving our MINES@150 strategic plan—he is a great listener and is entrepreneurial, he highly values impactful teaching, research and industry partnerships, and he has experience and new ideas related to expanding the reach and impact of our unique programs. This is an exciting time to be joining Mines as we look toward our 150th anniversary in 2024 and work to position Mines for its next 150 years of success and global impact."

At Marquette, Holz led the largest of the university's nine colleges and schools, guiding 12 academic departments, 40 undergraduate majors, 14 interdisciplinary programs and 18 graduate degree programs. During his tenure as dean, he oversaw the establishment of five new entrepreneurial centers of excellence—including the Northwestern Mutual Data Science Institute, made possible by a \$6.25 million corporate donation—launched multiple innovative interdisciplinary degrees and more than tripled the number of student internship opportunities.

Prior to joining Marquette in 2013, Holz spent seven years at Loyola University Chicago, where he served as associate dean for resources and planning in the College of Arts and Sciences (2011-2013) and as chairman of the Chemistry and Biochemistry Department (2006-2011).

"I am extremely honored to join such an accomplished faculty at a world-class university," Holz said. "Mines has such a bright future, and I can't wait to begin working with faculty, students and alumni to bring the university's strategic plan to fruition and raise the profile of Mines to the next level."

A bioinorganic chemist by training, Holz's research work focuses on structure/function studies of metalloenzymes,



Richard C. Holz was named as Mines' new provost and will lead strategic initiatives for the university's academic programs.

Photo courtesy of Marquette University

including the design, synthesis and characterization of small molecules that function as potent inhibitors. He continues to maintain an active research group and is currently funded by the National Science Foundation.

Holz holds a PhD from Pennsylvania State University, MS from University of Minnesota-Duluth and BS from Bemidji State University, all in chemistry. He was a National Institutes of Health postdoctoral research fellow at the University of Minnesota from 1989 to 1992 and a faculty member at Utah State University from 1992 to 2006.

"I am extremely honored to join such an accomplished faculty at a world-class university."

Thomas Boyd has served as Mines' provost since 2015. In June, he will move into the role of associate provost through the end of 2019 to support Holz in the transition, after which Boyd plans to retire.

"I want to thank Tom Boyd for his outstanding service to Mines," Johnson said. "During his four years as provost, we have hired amazing faculty, seen the growth of new degree options and research programs, launched our first fully online degree program, seen increases in student graduation rates and created new professional development opportunities for our academic faculty and staff. Mines would not be where we are today without Tom's leadership and dedication."

By **Emilie Rusch**

ENGINEERING MOBILITY

BRAIN-CONTROLLED WHEELCHAIR WINS AWARD AT HACKATHON



A group of Mines students won a hackathon for a device that allows those paralyzed from the neck down to control a wheelchair by detecting brain activity.

Photo courtesy of BrainAble

A team of Mines students earned honors at a hardware-based hackathon for their project to create a device that allows those paralyzed from the neck down to control a wheelchair by detecting brain activity.

The team, BrainAble, won the MakeHarvard Originals award, given to the best project built entirely during the 30-hour hackathon and designed solely with materials provided at the event, hosted by Harvard University.

Mechanical engineering student Parker Steen led the team, which included fellow mechanical engineering majors Van Wagner and Peter Wilson and computer science major Joshua Rands.

The team's plan was to use penetrating infrared light emitters and receivers to track brain activity—infrared light of a certain wavelength is absorbed by blood and can provide information on the location of blood concentrations in the brain. Changes in brain activity would be correlated to forward movement, while an accelerometer that detects head tilting would control turning.

The team used a 3D printer to create a headset to hold the emitters and detectors, built a model wheelchair and developed the code for translating data into movement.

The team hopes to get more reliable data from their infrared sensors and create a consistent method for testing its brain monitoring system. "If our data is coherent, we would like to implement this on a full-scale prototype as soon as possible so that this technology can help those who are paralyzed," the team said on the webpage detailing their project.

"We are extremely proud of how we overcame adversity this weekend," the team said. "Even with a variety of setbacks, our team still managed to create a prototype and get farther than we thought was even possible. We were able to create a prototype with working infrared emitters and transceivers that was able to store a data stream on a local computer."

By **Mark Ramirez**

TACKLING THE WORLD'S CHALLENGES

Each year, nearly 100 private companies, nonprofit organizations and government entities work with Mines students to sponsor Capstone Senior Design projects. These projects push students to address realistic, multidisciplinary challenges and apply the skills and knowledge they've learned during their undergraduate education.

These projects are often generated by alumni who had positive outcomes from their own senior design project involvement, leading to new career interests or connections. Students are matched to a project by their preference, creating an engaged and inspired team with a genuine interest in the sponsor's organization and its mission.

The collaborative nature of senior design projects means that these opportunities are mutually beneficial. Sponsors have said that working with a team of students allows fresh perspectives on challenging projects and provides access to the world-class facilities and faculty at Mines. It also offers alumni the opportunity to mentor students and opens up a direct pipeline to recruit the next generation of engineers.

► If you have an idea for a senior design project, email design@mines.edu. For more information, visit capstone.mines.edu.



Current senior design students and project sponsors, Michelle Roark '15 and Mike Hormell, in Guatemala in February 2019, working with the Itzá community—the last descendants of the Mayans in the Petén forest—to create sustainable eco-cottages for volunteers and workers at the Itzá preserve.

Photo courtesy of Michelle Roark

AUGMENTED REALITY

COMPUTER-GENERATED IMAGERY OR REAL LIFE?

You've decided you're in the market for a new couch but are not sure how it will look in your living room. You also can't afford to purchase a couch, have it delivered and then decide if it is the right size and color for your space. Instead, you take out your smartphone and open the furniture app. When you point the camera at your living room wall, the new couch you are considering appears on screen, a simulation of what it would look like in your home. It looks like you've already bought the couch, and it's a perfect fit.



Augmented reality (AR) is not a new technology—from the first-down line in a football broadcast to the ads displayed along the baseline of a basketball court, AR has been utilized for years. But now, the proliferation of smartphones and cameras has brought the technology into the hands of everyday consumers. AR lies at the intersection of computer vision (learning the three-dimensional geometry from a two-dimensional image) and computer graphics (creating a two-dimensional image from a three-dimensional model).

One of the challenges in AR is using a two-dimensional screen to interface with a three-dimensional world. Apps must create a two-dimensional representation of an object that fits in a three-dimensional world to properly trick the mind and match the user's perspective. There are two steps to this process:

1. Computing the 3D space of the real world from the 2D camera image (i.e., mapping 2D space to 3D space—the computer vision problem)
2. Modeling an object in 3D and displaying it as 2D on top of the camera image (i.e., mapping 3D space to 2D space—the computer graphics problem)

The illusion only works if the 3D space in both steps is the same and the mapping in Step 2 is the reverse of Step 1. Therefore, the challenge is in computing the 3D transformation in Step 1.

There are several potential solutions to this problem. When available, two cameras can be used simultaneously, mimicking our own human stereo vision. But most smartphones only have a single camera available, so a different solution is needed.

Marker-based AR addresses the single-camera problem by placing a pre-scaled object in view of the camera. This pre-scaled object allows the camera to know the orientation of the room. Since a user may not have access to the special marker, enter Markerless AR, where everything about the world is learned from the world itself. Instead of using a single camera image, the video stream is analyzed to find flat planes and straight lines in the real world. The orientation of the room can then be computed using geometry and creating triangles between detected feature points.

Mines students are tackling all aspects of the augmented reality problem. The Intro to Computer Vision course teaches students how to compute the 3D space from a 2D image. The Computer Graphics class teaches students how to draw a 2D image from a 3D model. Mobile Application Development teaches students how to combine everything they've learned and create an app. Several students have even successfully deployed their app in the Google Play store. See examples at cs-courses.mines.edu/csci448/homework/appstore.html.

By **Dr. Jeffrey Paone**
Teaching Associate Professor, Computer Science

A NEW PLAN

SUPPORTING A DIVERSE, INCLUSIVE AND ACCESSIBLE COMMUNITY FOR ALL

The Mines community is made up of people from every state in the U.S. and from countries across the globe, and it's clear that a diverse and inclusive campus environment inspires creativity and innovation, which are essential to the engineering and scientific processes. With collaboration from faculty, staff, students, alumni and corporate partners, Mines launched its first Strategic Plan for Diversity, Inclusion & Access this year. The plan will help ensure Mines is a place that welcomes, respects and supports people of all backgrounds, a mission that is critical to the school's future success as one of the top universities in the world. To launch this initiative, Mines held a two-day celebration on campus with a lineup of activities, lectures and events that brought the community together under this important cause.

- Visit mines.edu/diversity to learn more about how this plan is being implemented on campus.



Photo by Colorado School of Mines

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ATHLETICS

A STRONG FINISH



Mines Wrestling celebrates winning its first-ever RMAC Championship after a win over Colorado Mesa University on February 6, 2019, in Volk Gymnasium. Joining the team was long-time coach and RMAC Hall of Famer Jack Hancock (second from right), the namesake of Mines' wrestling training complex.

Photo by Tim Flynn

A WIN 96 YEARS IN THE MAKING

The 96-year history of the Mines wrestling program has seen plenty of success. The Orediggers have had seven national champions, five national top-10 team finishes, 50 all-Americans and numerous Mines and RMAC Hall of Famers go through the program. But one historic win always eluded the team: a conference championship.

That all changed on February 6, 2019, when the Orediggers defeated rival Colorado Mesa 23-11 to clinch a share of the Rocky Mountain Athletic Conference Championship. The accomplishment came as Mines finished 11-3 in dual meets (their most wins in the modern era) and 6-1 in the RMAC. The Orediggers shared the title with a team it had previously beat—Western Colorado University—as both ended up with the same record.

The success didn't stop there. Mines went on to earn a #13 national ranking from the National Wrestling Coaches Association and finished fifth at the NCAA Super Region VI Championships to mark an incredible eight-place improvement over their 2018 finish. In the process, Mines qualified four wrestlers to the NCAA Division II Championships—Noah Ottum (149 pounds), Skyler Lykins (157 pounds), Robert Gambrell (174 pounds) and Weston Hunt (285 pounds)—which represented the first time in more than a decade that Mines had sent multiple grapplers to nationals.

The postseason awards reflected the team's in-season success. Five Orediggers were named All-RMAC, with head coach Austin DeVoe earning both RMAC and NWCA regional coach of the year honors. Hunt won the NCAA Super Region VI championship at heavyweight, while a conference-best 16 team members were named to the RMAC All-Academic teams, including four First-Team Academic All-RMAC honorees.



Heavyweight Weston Hunt (center) won the 2019 NCAA Super Regional VI championship and was one of four Orediggers to advance to the national championship meet.

Photo courtesy of Nebraska-Kearney Athletics

THE 2018-19 WRESTLING SEASON AT A GLANCE

96 YEARS BETWEEN THE PROGRAM'S FOUNDING AND ITS FIRST RMAC CHAMPIONSHIP

11 WINS THE MOST IN MODERN HISTORY

4 NCAA CHAMPIONSHIP QUALIFIERS

THE MOST IN MORE THAN A DECADE AT MINES

16 RMAC ALL-ACADEMIC TEAM HONOREES

MEN'S BASKETBALL

Chalk up another Rocky Mountain Athletic Conference Championship for the Mines men's basketball team. The Orediggers tore through the regular season with a dominating 21-1 conference record to win their fifth RMAC regular-season title this decade under head coach Pryor Orser. Led by RMAC Player of the Year Ben Sonnefeld and Co-Defensive Player of the Year Ben Clare, the Orediggers set a program record with a 22-game win streak during the season and reached as high as #11 in the national polls. Mines earned its sixth consecutive bid to the NCAA Tournament, thanks to a 25-5 overall record in the regular season.



Photo by Stefanie Brunello



Photo by Tim Flynn

MEN'S AND WOMEN'S SWIMMING

The men's swimming team finished third and the women fourth at the 2019 RMAC Championships meet in Lewisville, Texas, and both teams found plenty of individual success in the process. For the men, Peyton Scherschel capped off a terrific season by being named the RMAC Swimmer of the Year, and Jonathan Donehower won the RMAC championship in the 400 IM event. The women's team was led by Mia Wood (pictured), who swept all three distance gold medals at RMAC Championships (in the 500, 1000 and 1650 freestyle) and went on to become an all-American at NCAA Championships for the third consecutive year. Daphne Williams also repeated as an All-American at NCAAs in the 100 butterfly.

INDOOR TRACK & FIELD

The Mines indoor track & field teams had another successful winter, capped by 13 all-American performances at the 2019 NCAA Division II Championships in Pittsburg, Kansas. That meet saw the men finishing 12th nationally and the women 27th, highlighted by national bronze medals for the men's distance medley relay of Vincent Workman, Triston Sisneros, Miller Kettle, Luke Julian and Josh Hoskinson (pictured) in the men's 5,000-meter run. Chloe Cook led the women's individual performances with a fourth-place mile finish.

Photo by Tim Flynn



Photo by Zachary Walsh (Western Colorado University)

WOMEN'S BASKETBALL

With an exciting young core in place, the Mines women's basketball team finished fourth in the RMAC regular-season standings, going 18-11 overall and 14-8 in RMAC play. Guided by RMAC Freshman of the Year Denali Pinto (pictured), Mines advanced to the semifinals of the RMAC Tournament for the first time in a decade. Nicole Archambeau and Raven Herrera were also named all-RMAC after the season, and Pinto, who led the team in scoring with 14.2 points per game as a rookie, also earned a First-Team All-RMAC nod.

By **Tim Flynn**

► For more on Mines athletics, visit minesathletics.com.



A BETTER UNDERSTANDING OF WATER FLOW

MINES IS LEADING AN EFFORT TO DEVELOP A CONTINENTAL WATER MODEL FOR ALL

Understanding the movement and availability of water locally and across the country is of paramount importance to both economic productivity and the human health of the nation.

Decades of hydrology and computer science advances have allowed researchers to simulate U.S. water flow at high resolution on a continental scale for the first time, and a new \$3.8 million National Science Foundation project led by Mines aims to put those state-of-the-science hydrologic models into the hands of a much broader audience.

Not only will HydroFrame allow field hydrologists to seamlessly test their own observations against national research and operational models—no software engineering background or supercomputer required—but farmers, city planners, forest managers, teachers and others will also be able to access the best hydrologic information available today through an easy-to-use online portal.

The grant from NSF's Office of Advanced Cyberinfrastructure brings together computer scientists and hydrologists from seven institutions, forming a research team of experts in hydrologic processes, hydrologic model development, uncertainty quantification, data and workflow management, high-performance computing, performance portability and education and outreach.

"Having access to decadal, national-scale simulations is an unprecedented resource for both the hydrologic community and the much broader community of people working in water-dependent systems, whether that's biological systems, energy or food production," said Reed Maxwell, Rowlinson Professor of Hydrology at Mines and principal investigator on the project. "All hydrology builds on itself, and these simulations will enable the community to address research and operational questions about water availability and dynamics from the watershed to continental scale."

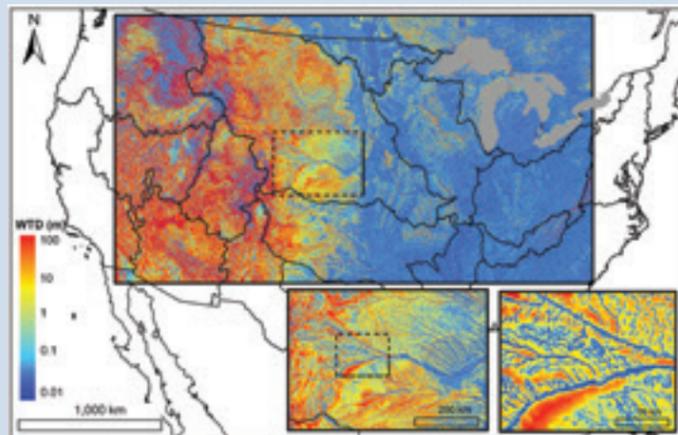
The research team is focusing its efforts on two specific modeling systems. The Weather Research and Forecasting Hydrologic (WRF-Hydro) system, managed by the National Center for Atmospheric Research, can be configured to represent hydrological processes at continental, regional and local scales, depending on the questions being asked and purpose being addressed. It also serves as the basis for the National Water Model, which simulates streamflow over the entire continental U.S. and is run by the National Oceanic and Atmospheric Administration.

The other system, ParFlow, can also be scaled to run at the local, regional or continental scale but uses a more general subsurface flow solution scheme optimized for parallel computing and operates in a research capacity. Both are run on industry-leading science and research supercomputers, the complex systems requiring thousands of cores to operate.

Over the four-year project, researchers plan to both improve access to the models and further improve the models themselves, through additional computer science research as well as additional input from the larger hydrologic community.

"These modeling systems are the best reconstruction of the hydrology of the whole continent over the past decade we have," Maxwell said. "We've already shown proof of concept—now, we want to bring the hydrologic community together and provide seamless access to not only just the results of these simulations but also input into how the simulations could be used in science or even shape how these models work."

By **Emilie Rusch**



A ParFlow map shows the water table depth over a large swath of the U.S., with insets zooming into the North and South Platte River basin, headwaters to the Mississippi River. The image is from the paper, "A high-resolution simulation of groundwater and surface water over most of the continental U.S. with integrated hydrologic model ParFlow v3," published in *Geoscientific Model Development*.

Image by Reed Maxwell

STEPPING UP

MINES ALUMNUS IS NEW MANAGER OF EDGAR EXPERIMENTAL MINE

The new manager of the Edgar Experimental Mine knows the unique educational and research facility perched above Idaho Springs well.



Lee Fronapfel '96 is the new manager of the Edgar Experimental Mine.

Photo by Colorado School of Mines

Mines alumnus Lee Fronapfel '96 spent a lot of time up at Edgar, both as part of his coursework en route to a bachelor's degree in mining engineering and as a student employee of the mine.

"That experience helped in my own career. It gave me an idea of what's out there and what might be needed," Fronapfel said. "What a great lab—you can't beat it."

His career in the mining industry includes 19 years with mining giant Freeport-McMoRan, the last five of which he managed Colorado's Henderson Mine, one of the largest primary producers of molybdenum in the world.

"Mines could not have found a better person to take the Edgar on," said Priscilla Nelson, professor and head of the Mining Engineering Department. "Lee is a graduate of Mines and knows Edgar well. His experience in managing major mines—including the Henderson Mine—clearly supports the excellence of his preparation for the challenge of managing Edgar into the future."

Named after the Edgar mineral vein that runs along the hillside above the mine, the Edgar Mine was a working operation in its early days, producing high-grade silver, gold, lead and copper in the 1870s. Today it provides a valuable hands-on experience for Mines students, operating as both a classroom and research facility.

"There's a lot more that can be done—it's not just for mining," Fronapfel said. "There are opportunities for petroleum engineering, robotics, geology. There are many fields out there that could utilize the mine and give students, researchers, grad students that hands-on experience."

By **Emilie Rusch**

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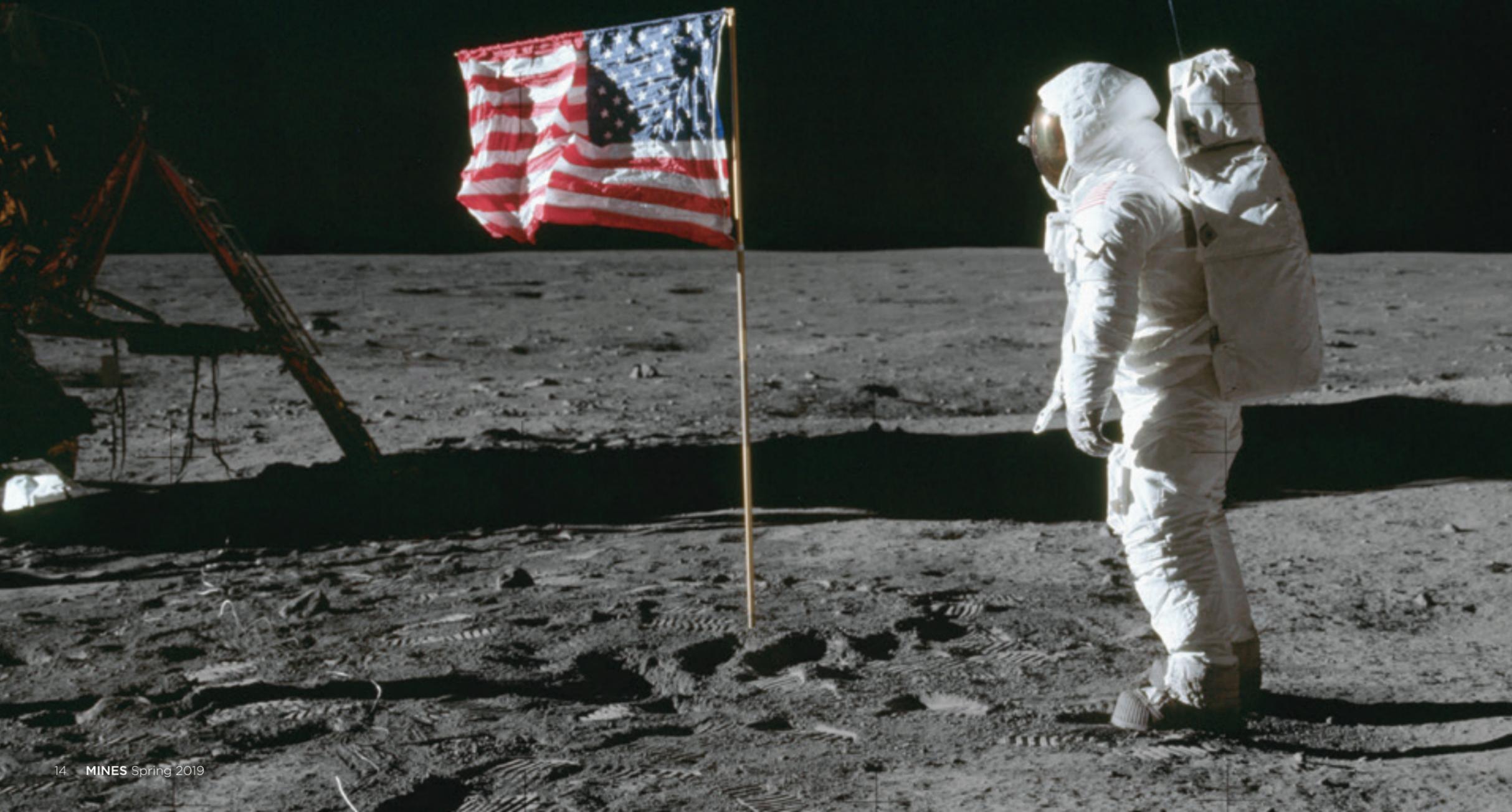
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MOONSHOTS



Mines made significant contributions to the space race of the 20th century and now plays a central role in a new race to learn more about space resources

By **Teresa Meek**

On July 20, 1969, at 10:56 p.m. Eastern time, astronaut Neil Armstrong touched his foot to the Moon's surface, famously declaring, "That's one small step for man, one giant leap for mankind."

Minutes later, Armstrong was joined by fellow Apollo 11 astronaut Buzz Aldrin. A camera recorded their progress, their tentative steps turning to leaps and bounds as they gained confidence negotiating the lunar surface.

For the next two hours, 600 million people around the world sat glued to their televisions as the astronauts bounced through the dusty, rocky terrain, collecting samples and recording their observations. "It has a stark beauty all its own," Armstrong said of the Moon's surface.

Though it was conceived as a Cold War rebuttal to the Soviet Union, the first lunar landing united the world with excitement for a feat people had never thought possible. Since then, researchers around the world have been actively studying the Moon and the seemingly unlimited expanse of outer space, and Mines is at the forefront, making giant strides in our knowledge of this new frontier.

In one of the most famous photographs of the last 50 years, astronaut Buzz Aldrin, lunar module pilot of the first lunar landing mission, poses for a photograph beside the United States flag during Apollo 11 extravehicular activity on the Moon's surface.

Photos courtesy of NASA

SPACE RESOURCES AT MINES: THEN AND NOW

From the aerospace industry's infancy to the present day, Mines experts have made vital contributions to space research.

The Apollo program went on to achieve five more successful lunar landings in the 1960s and '70s, and Mines researchers joined NASA scientists in analyzing rock samples the astronauts collected to discern their electrical and magnetic properties. The school was also involved in early discussions about lunar bases and was one of the few academic institutions invited to participate in NASA's first meeting, in 1962, about using extraterrestrial resources to support space missions.

The Apollo program came to an end in 1975, and over the years, the space program's focus shifted to other areas of research. But Mines scientists continued their work with NASA, receiving grants for space shuttle and International Space Station projects and gaining a national reputation for expertise in space resources. Planetary geologist Michael Duke, NASA's first science curator of the Apollo lunar rocks, brought his expertise to Mines to direct the Center for Commercial Applications of Combustion in Space, which later became the Center for Space Resources. The school also received small amounts of lunar rocks, pebbles, sand and dust from NASA and used them to create simulants of regolith, or lunar soil, to use in experiments.

But Mines is poised to play an even greater research role as the space program changes its focus once again.

"Now we're entering a second race—to develop the resources in space," said Angel Abbud-Madrid, director of the Center for Space Resources. This means harnessing new fuel sources—such as water and solar energy—and using materials that are readily available in space, rather than transporting resources from Earth, making astronomically expensive expeditions more economically feasible. With that possibility in mind, space fever is making a comeback and Mines is leading the charge.

"For 145 years, we've been focused on identifying and extracting resources on Earth. Now we want to do the same thing in space. From very early on, we were aware that resources from space would be important," Abbud-Madrid said.

Professors and students in every department at Mines are involved in some dimension of space research, Abbud-Madrid said. Geological and geophysical engineers decide how to look for large concentrations of resources. Mining, petroleum, mechanical and electrical engineers design rovers, excavators and drilling systems suited to the unique soil and low-gravity conditions of the Moon. Chemical engineers work on ways to extract water and gases from the

Moon, asteroids and Mars. Materials engineers design space manufacturing systems. And economists carry out analyses to make sure all projects are more than just dreams.

"Mines gives students a broad education in the field. They know geology and engineering but also economics and policy implications," Abbud-Madrid said.

Although its research involves multidisciplinary knowledge, Mines developed two formal entities to propel space resources into the future: the Center for Space Resources and the new space resources graduate program, the first of its kind in the world.

Researchers in the Center for Space Resources have been studying how to identify and extract the water, gases, metals and minerals in space for more than 20 years and host a yearly roundtable attended by renowned engineers and scientists from around the world to discuss ideas and developments in their research.

Classes in the new space resources graduate program started in fall 2018, and the online program now has 45 students from 10 countries, including many professionals in aerospace and mining, as well as scientists, economists, entrepreneurs and policy analysts. In addition to taking classes and listening to experts, they network via videoconferences and work on joint projects, connecting the dots in a multidimensional field with no central information clearinghouse.



At the dawn of the space age in 1959, John S. Rinehart, former director of the Mining Research Laboratory at Mines, proposed one of the earliest designs of a lunar base.

Photo courtesy of Mines Center for Space Resources

Lunar Outpost's prospector is a lightweight rover capable of collecting samples from the Moon's surface that can help researchers take the next steps in developing lunar resources.

Photo by Joe DelNero



PROBING THE MOON

Beyond the graduate program and the Center for Space Resources, professors and students have received numerous grants and regularly win NASA competitions. Space research clearly remains an attractive pursuit with seemingly endless opportunities.

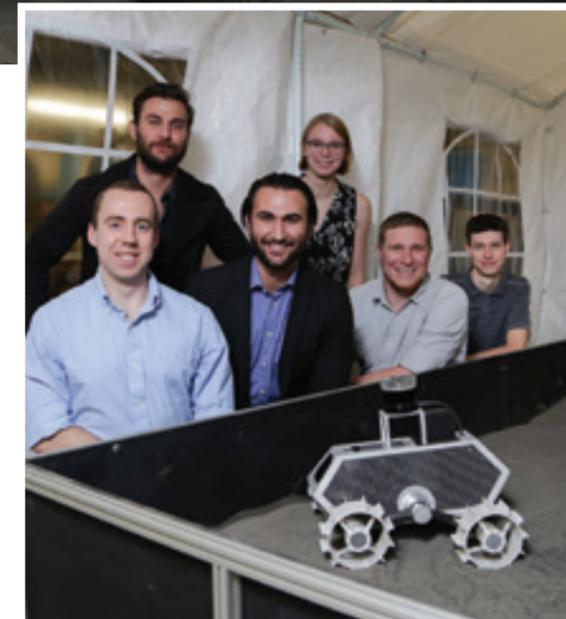
PhD student Justin Cyrus MS '16 took the next step, creating the startup Lunar Outpost, which has developed a lunar prospector—an autonomous vehicle with an attached drill to probe the Moon's surface and on-board mass spectrometers to analyze the samples it collects.

Cyrus uses Mines' lunar testing facility, located at the school's Excavation Engineering and Earth Mechanics Institute, to carry out trial runs for the prospector and has received support from other researchers in the Center for Space Resources. "The last space resources roundtable was all about lunar prospecting. They had some of the world's leading researchers, and I bounced ideas off them and picked their brains," Cyrus said.

Mines' broad academic expertise proved invaluable in helping him refine his ideas. "There are many strong professors in robotics, mechanical and electrical engineering and computer science," Cyrus said. "There's no department on campus that's not cutting-edge."

Cyrus recruited some of his 19 employees from the school, including a few from the space resources graduate program. "Mines trains really good future engineers. It's a direct pipeline," he explained.

Cyrus expects to make an announcement sometime this year about a future Moon landing. He also hopes to work with NASA, which is soliciting lunar surface technology. "They're looking for low-cost commercial landers, and we believe our lightweight prospector is a good fit," he said.



Lunar Outpost, a company created by Justin Cyrus MS '16, developed an autonomous lunar prospector to drill into the Moon's surface and analyze the soil samples it collects. Members of the Lunar Outpost team, pictured left to right: Colby Moxham, robotics engineer and current Mines student; Julian Cyrus, chief operating officer; Justin Cyrus MS '16, chief executive officer; Claire Thomas, intern and current Mines student; AJ Gerner, chief technology officer; Jeffrey Stenerson, software engineer and current Mines student.

Photo by Joe DelNero

TAPPING MINES RESOURCES

Cyrus is by no means the only employer to notice Mines students' aptitude for aerospace-related skills. Aerospace is the third-largest employment sector for Mines graduates, who are highly sought-after, even though the school doesn't offer a formal aerospace degree.

Caroline Ellis '18, who was recently hired as a flight controller at NASA's Johnson Space Center in Houston, is one such graduate. She remembers stretching her brain in Abbud-Madrid's Intro to Space Exploration class. "He posed big, open-ended questions, and we had to engineer through problems no one has solved," she said. "You have to reach into the boundaries of your mind and figure out how to do things no one has ever done."

The class and a NASA competition, in which she helped build a drilling system to extract water from the subsurface of Mars, led to her current job. "Working at NASA was my dream. I'm excited it happened so quickly," she said.

Ellis' dedication and problem-solving skills are qualities that many aerospace employers look for when recruiting new hires. "Mines engineers are broad-based problem-solvers, not just in technical fields, but in economics, social responsibility and entrepreneurship. They are phenomenal engineers, and they also have the ability to adapt," said Paul Anderson '85, an Orion program director at Lockheed Martin and co-chair of Mines' Aerospace Interest Group.

Lockheed Martin is currently working on multiple human and robotic exploration projects of its own, and is NASA's prime contractor for the Orion exploration spacecraft. It's

no surprise that Mines graduates are involved. "Right here in Denver, the next spacecraft capable of going to the Moon and Mars is being designed as we speak, and Mines graduates are a big part of it—today we have more than 30 Mines alumni working on the program," Anderson said.

The Aerospace Interest Group, which started in 2017 and now has more than 300 members, helps spread the word about the school's space expertise through its alumni network. Though Mines has a longstanding relationship with NASA and its contractors, new private companies like SpaceX and Blue Origin are becoming major players and embarking on projects of their own. Tapping Mines' talent pipeline could help them reach their goals, as well as enhance the school's reputation during the next generation of space missions.

Space research has come a long way since the first Moon landing 50 years ago, and Mines has played an integral part at every step along the way. With space resources viewed as the key to the future, the school is poised to play an even greater role.

"The Apollo program got a whole generation excited about space. Now people are seeing the value of space resources and that feeling is here again," Abbud-Madrid said. "Apollo ended abruptly because it was a matter of winning a race. We won't make that mistake again. We'll make space travel sustainable and keep going."

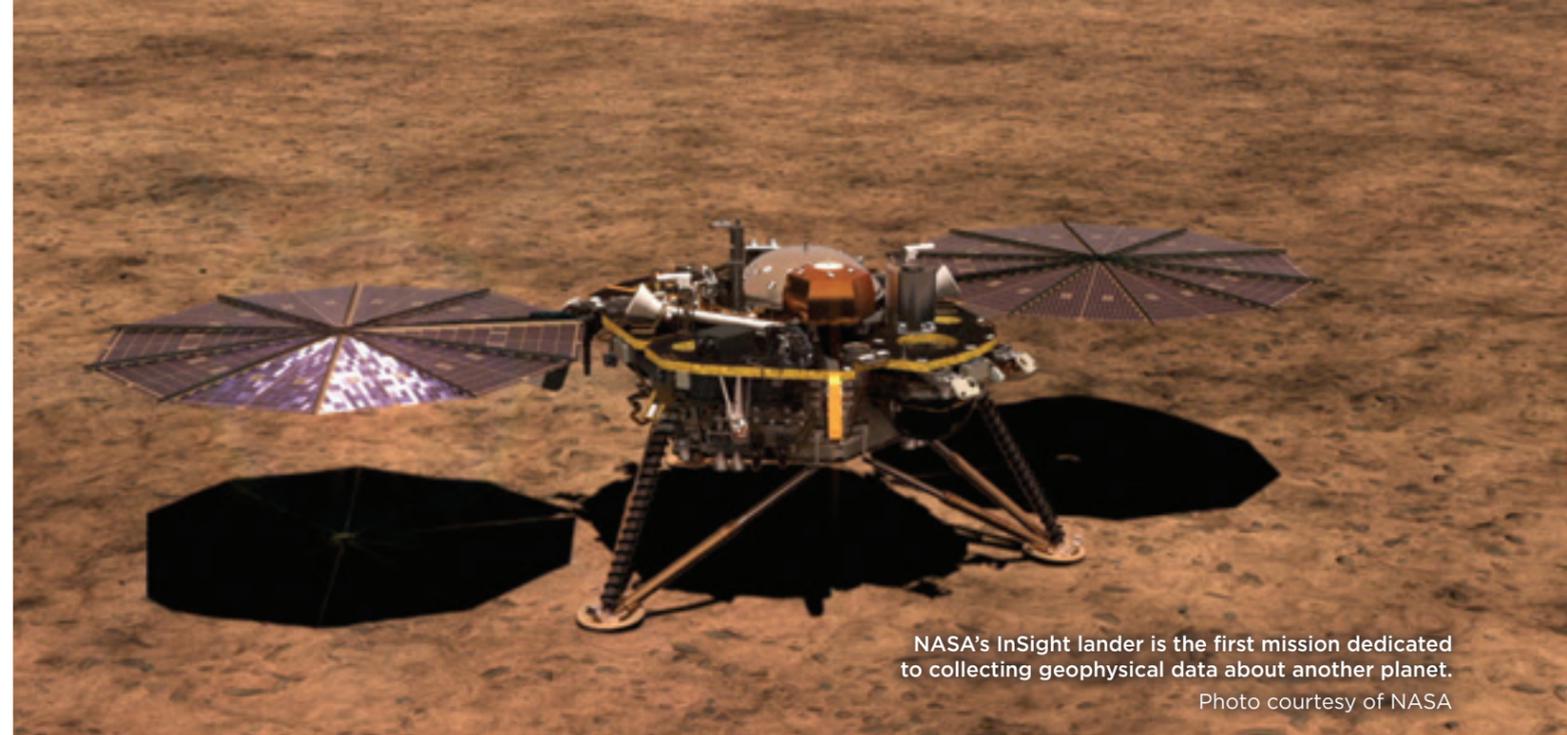
WHY SPACE RESOURCES MATTER

Mining resources in space will be a game-changer for exploration. Ninety percent of a rocket's weight consists of fuel, which must be used not only to overcome Earth's gravitational pull but sustain the mission and get the spacecraft back home. Under the current model, an extended stay on the Moon or a journey to Mars simply isn't possible. "That's fuel beyond the budget of any space agency in the world," Abbud-Madrid said.

Instead, astronauts may be able to obtain fuel, as well as building materials and life-sustaining water and oxygen, from space. The Moon's polar regions have an abundance of ice, and many asteroids contain large quantities of water.

In addition to being used for consumption, radiation protection and cleaning, water could be separated into hydrogen and oxygen and used as a propellant. Refueling at a space depot would lighten loads considerably, lowering the cost of landing a kilogram on the surface of the Moon from \$35,000 to \$11,000.

As Abbud-Madrid puts it, "Water is the oil of space."



NASA's InSight lander is the first mission dedicated to collecting geophysical data about another planet. Photo courtesy of NASA

NASA'S INSIGHT LANDER: EXPLORING THE INTERIOR OF MARS

If astronauts want to mine resources on other planets, they first need to understand extraterrestrial geology.

NASA's InSight lander mission, which landed on Mars on Nov. 26, 2018, is the first dedicated to seeking geophysical information about another planet. Paul Morgan, a senior geothermal geologist at the Colorado Geological Survey at Mines, is a member of the InSight lander's science team and helped build a probe that will measure the heat coming from Mars' interior.

Morgan and two other scientists created a Heat Flow and Physical Properties Probe (HP3) designed to burrow as far as 16 feet into Mars' surface—deeper than any probe or drill has gone before.

The probe will measure the heat coming from the planet's interior, providing clues about the resources it might contain. On Earth, ore deposits were formed over millions of years and brought up to the planet's crust by volcanoes and other geothermal activity. While these processes ceased long ago, they appear to be recent occurrences on Mars, Morgan said. Measuring internal heat flows will give scientists a better idea of where iron ore and other mineral deposits may be located.

It may also give them an idea of what Earth looked like in the past. "Our ore deposits and the early evolution of life happened at a time when Earth was completely different from the way it is now. We'd like to understand those processes. Mars may be able to help—it seems frozen in that earlier period," Morgan said.

The probe may also reveal a vital resource: water. Like Earth's moon, Mars has ice on its surface that might someday be separated into oxygen and hydrogen to be used as fuel. But

the water itself would be easier to work with. "There may be a depth at which water exists," Morgan hypothesized.

Answers could come soon. The probe was deployed in February 2019. "By the end of March, we should be down 16 feet—if we don't hit any rocks," Morgan said. Once it hits its lower limit, the probe will remain in place for 687 days—a full Martian year—to track temperatures over time for accurate measurements.

Also aboard the InSight lander is a seismometer, which will measure "marsquakes" and any seismic signal, including meteorite impacts and dust devils, giving scientists information about Mars' interior—for instance, the state of its core and the variations in its crust, known as the "crust dichotomy," which is thin in the northern hemisphere but thick in the southern one.

Ebru Bozdog, an assistant professor of geophysics at Mines, is a member of the InSight science team studying the Mars' seismology, which involves running 3D seismic wave simulations on supercomputers. The simulations will be used to explain the source of Martian seismic waves. Data from the InSight lander will help better constrain and update the models of Mars' interior.

"We do not know yet if Mars has an all liquid core or also has a solid inner core. If we get a high-quality signal, we may discover the state of the Martian core and better estimate its size," Bozdog said.

While the seismometer is being calibrated, scientists have already started receiving signals. "We're looking forward to the first quakes from Mars," Bozdog said. "Every wiggle we get from Mars will be precious and invaluable."



Center for Space Resources faculty and students pictured left to right: graduate student Hunter Williams, graduate student Ben Thrift, director Angel Abbud-Madrid and research assistant professor Chris Dreyer.

Photo by Joe DelNero



LEADING LIKE A BOSS

Many Mines alumni are in executive positions at oil and gas companies, guiding the industry toward a bright future

By **Lori Ferguson**

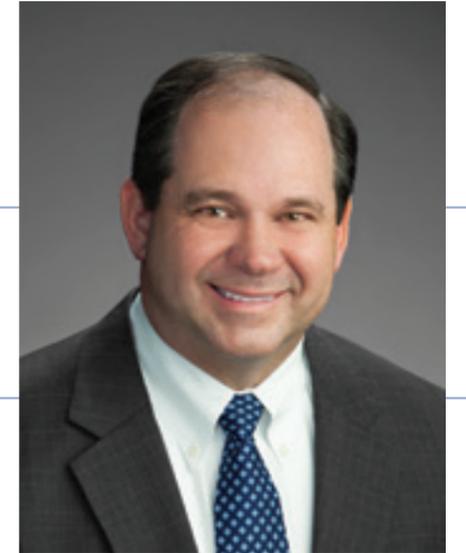
The oil and gas industry has changed dramatically over the past two decades. Competition for resource opportunities is fierce, new technology has transformed traditional exploration and extraction processes and the capacity to see opportunity where others don't is critical. Despite these changes, one constant remains: the need for leaders who can solve tough problems and work for the greater good. Mines alumni are well prepared for the challenge, as these four industry veterans demonstrate.

“

As a leader, I try to keep things simple, stay focused on our core values and never ask people to do anything that I wouldn't do myself.”

JOHN J. CHRISTMANN IV '88

PRESIDENT, CHIEF EXECUTIVE OFFICER AND DIRECTOR,
APACHE ENERGY



As the 11th member of his family to graduate from Mines, John J. Christmann IV '88 knew he'd receive a first-class education. But seeing the oil and gas industry on the ropes in 1986 made Christmann worry about his prospects, since he would be a freshly minted petroleum engineer two years later. He turned to his grandfather, John J. Christmann Jr. '36, for reassurance. "My granddad's advice was simple," he explained. "He told me, 'The best time to get in is when everyone is getting out, because the oil and gas industry isn't going away.'"

The elder Christmann was right. Today, his grandson is president and CEO of Apache Corporation, a thriving oil and gas exploration and production company with operations in the United States, Egypt and the United Kingdom.

Christmann joined Apache in 1997 and became CEO in 2015. The move into the corner office has been rewarding but not easy. "I quickly realized that we needed to do a hard stop and reset because our cost structure had become misaligned with the industry's new price environment. Our industry has changed dramatically in the last 20 years as a result of [new] technology," he said. "Today, we're exploring for source rock through techniques like horizontal drilling and multistage fracking—things that were never imagined when I was in school."

Due to hard work at all levels, Apache has emerged stronger and more capital efficient. "Navigating through such full-scale change is hard, but Mines taught me that there's not a problem that you can't solve if you break it down into its components and get after it," Christmann said. "As a leader, I try to keep things simple, stay focused on our core values and never ask people to do anything that I wouldn't do myself."

The approach is working. Apache has been recognized repeatedly for excellence in corporate social responsibility and earlier this year was named one of Fortune's most admired companies for the second year in a row for, among other things, its commitment to social responsibility and quality of management.

"We recruit smart people, earn their loyalty, give them the tools they need to succeed and turn them loose," Christmann said. "We want to leave the world a better place, and we're committed to giving back to the communities in which we operate. I embrace the word 'and'—it's powerful. We can have safety and production. We can be conservationists and develop oil and gas—it takes work, but it can be done."





“Mines teaches you everything about hard work and organization. If you’re going to make it through, you need to be determined. That’s why Mines engineers are so well prepared—we learn to be gritty.”

ADAM SAYERS '95, ME '00
PRESIDENT AND CO-FOUNDER, AXIA ENERGY II

Adam Sayers '95, ME '00 is no stranger to hard work. The petroleum engineer has spent more than two decades in the field and is leading the fourth private equity firm he helped found since the early 2000s. But after graduating from Mines, he confessed, “The first day at work was the easiest I’d had in the last four years. Mines teaches you everything about hard work and organization. If you’re going to make it through, you need to be determined. That’s why Mines engineers are so well prepared—we learn to be gritty.”

Grit is essential for survival in today’s oil and gas industry, according to Sayers. “Since 1995, we’ve witnessed massive resource plays that are leading the way to energy independence in the

U.S., something that was not imagined in the early 1990s or even 2000s,” he explained. “In the period from the late 1990s until now, the business has become much more about logistics, efficiencies and multiple rig plays. In fact, I can’t imagine another 20-year span in this industry where things have changed so drastically.”

Today, a company rises or falls on its ability to take data in, interpret it and then execute a plan. “There’s a lot of money in oil and gas right now and the competition is fierce—where you used to have one or two companies looking at an opportunity, you now have 10,” he said. “My biggest challenge as CEO is finding opportunities to develop.”

Another key to success: hiring the best educated, hardest-working people to

realize those opportunities. “We hire the best, then give them authority and ownership over their career,” Sayers said. “We have to create an atmosphere where people can speak their mind without fear of retribution.”

Living up to one’s word and doing the right thing is also critical. “Engineers are constantly working the numbers, trying to figure out an approach that is not only cost-effective but also responsible,” Sayers said. “As a student at Mines, you take ethics classes and the importance of doing the right thing is repeatedly made clear. The oil and gas industry is not without impact, but we need to be honest and up front about that impact. Mines helps students establish a good moral baseline for thinking those issues through.”



SANDY STASH '81
EXECUTIVE VICE PRESIDENT OF SAFETY, OPERATIONS, ENGINEERING AND EXTERNAL AFFAIRS, TULLOW OIL

Ten years after completing her degree in petroleum engineering, Sandy Stash landed a job running the Anaconda Mine, the largest Superfund site in the U.S. “It was a valuable experience—I had to learn to deal with an understandably angry public and then work collaboratively with people to come up with solutions to the problems they faced.”

Stash has continued to act as a problem-solver throughout her 30-plus years in the industry, working in safety, engineering and operations at Talisman Energy, BP, TNK-BP, ARCO and now Tullow Oil in London. For much of that time, she has worked internationally, an experience she describes as transformative. “The challenge of looking at issues through the lens of another culture has sometimes

JULIA GWALTNEY '93
VICE PRESIDENT OF STRATEGIC PLANNING AND DEVELOPMENT, GARY PERMIAN, LLC

As an industry veteran with more than 20 years of experience, Julia Gwaltney '93 understands that the only constant in oil and gas is change. “It’s a business that runs 24/7—there’s no mercy,” she said. “There’s an ever-changing set of problems to solve—sometimes financial, sometimes technical, sometimes personnel-related—and I love it. It keeps me on my toes and continuously learning.”

It’s ongoing change in the form of new processes that’s had the most profound impact on the industry during her tenure, Gwaltney observed. “Changes in communication have dramatically altered the face of our business. For example, phone service to rig locations used to be poor, necessitating a physical presence in the field, and activity reports used to be handwritten, then scanned and faxed,” she explained. “Today, we can transfer digital data from rigs via cellphones and utilize sophisticated software to sift through that data, which gives us a much better sense of

what’s going on. I can pull real-time drilling and production from a well and see how it’s doing from anywhere at any time—it’s a profound difference.”

But it’s her Mines background that really gave Gwaltney a leg up. “Mines is well recognized in our industry—alumni are known for having good heads on their shoulders and the capability to think things through,” she said. “Our professors expected excellence in execution and delivery on promises. There were no exceptions and no bell curve.”

It was an attitude that provided wonderful training for the real world. “In business, you quickly realize that at the end of the day, you’re delivering profits for investors or you’re not. There are always challenges, and if you don’t get it right the first time, you try again. Four years at Mines taught me that when the going gets hard, you don’t quit—you just keep going.”



“Mines is well recognized in our industry—alumni are known for having good heads on their shoulders and the capability to think things through.”

been difficult but also extraordinarily rewarding. I’ve been so lucky—I’ve had challenging jobs that have given me the opportunity to step up, which makes me proud.”

Stash credits Mines for instilling a strong work ethic and sense of resilience. “There’s something about the ethos at Mines—the programs are tough and students are competitive, but it’s not a cutthroat environment. There’s a sense of teamwork and shared experience that leads to lifelong friendships and networks.”

Stash also believes a sensitivity to the shared experience will be a defining factor for companies that succeed in the industry moving forward. “The hydrocarbon space

will be the site of a big change moving forward—with the transition to a lower carbon future front and center—and the companies that deal with this issue successfully will be the winners,” she explained.

But the way winning is defined will be more nuanced. “Industry leaders won’t just be concerned with investors—they’ll also be thinking about employees and the wider world,” Stash said. “That’s the essence of good business, and I think Mines is doing a beautiful job of educating students about this new reality.”

PAINTING THE SKY

THE E-DAYS FIREWORKS SHOW HAS BECOME A BELOVED TRADITION AT MINES

The crisp, mid-April air still hummed with excitement after the last notes of pop band Saint Motel's concert faded into Golden's foothills. The band had headlined the 2018 E-Days concert, but another exhilarating show was about to start.

With adrenaline still coursing through their bodies after a long day of events, including trips down Clear Creek in makeshift cardboard boats, students eagerly waited, eyes trained north, watching for a spark in the distance.

Their cheers rose to a fever pitch as the first bursts of fire erupted in the darkness, a stream of flame licking at a wooden structure in the shape of the trademark M that's become synonymous with Mines. The letter burned bright against the silhouetted hills, and the crowd howled in further anticipation.

Then, in a series of ear-ringing bangs and bright flashes, the M exploded, kicking off a bright display of fireworks trailing high into the indigo sky. For the next 15 minutes, the sky above the Mines campus was painted with light and color, captivating the audience below.

The E-Days fireworks show has become a tradition at Mines, first started by students in the Sigma Nu fraternity for the 1980 E-Days festivities. A group of them had an interest in fireworks and pyrotechnics, so it was a natural fit.

"The school recognized that a fireworks show would be a big draw for students," said Scot Anderson '79, one of the first students to start the fireworks show. "They gave us some money—it wasn't much, only a couple hundred dollars—and we went to Wyoming and bought as many fireworks as possible."

The show started out on Brooks Field—Mines' former football field—when it was still grass. In the early days, before the display could be controlled remotely, the pyrotechnicians had to light each firework by hand—a potentially risky job. "You never wanted to wear any nice clothes on those nights," Anderson said. "By the end of it, everything was singed."

The effects were set up close to the stands—allowing the audience to be up close and personal with the display. "We used to be really close to the audience," Anderson said. "Some people would swear the fireworks flew right over

their heads, but in reality, they were far off to the side and nowhere close to hitting anybody."

Because of its close proximity to the audience, the show was known for its use of ground fireworks in addition to aerial fireworks, a combination that provided enormous bursts of light and teeth-chattering booms that seemed to send shock waves all through campus. According to Anderson, the louder the fireworks, the better. "Mines was known for being loud, and that certainly held true," he said.

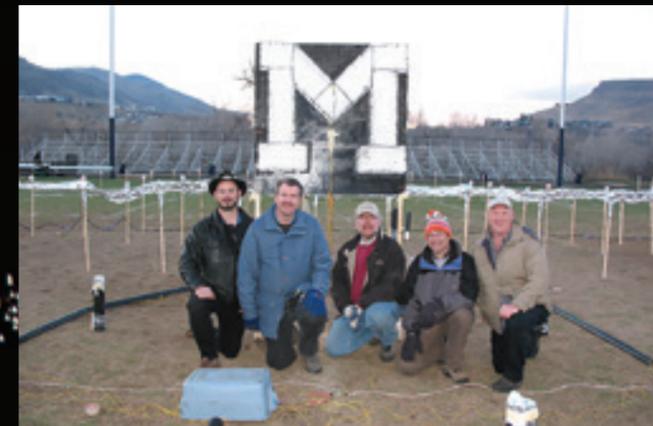
As the show got bigger and better as the years went on, there were a few times Anderson thought their ambitions were going to get the best of them. He recalled one year when a stray spark landed in a neighbor's front yard, setting a giant evergreen tree alight.

"We thought we were in for it," Anderson said. "We were prepared to buy her a new tree and plant it for her." But it turned out the woman who owned the tree had been trying to get rid of it for years. As long as Mines helped her remove the stump, she wouldn't think twice about the incident.

Eventually, the fireworks display had to be moved to the north parking lot near the intramural fields when the school laid artificial turf on Brooks Field—and later replaced the field with Marv Kay Stadium.

The location change altered the display slightly—with the audience farther away, it was harder to see the ground displays, limiting the show to more aerial fireworks. But the team in charge of the display was determined to still put on the best show possible that would make any Oredigger proud. "We still try to keep the same formula, with tall ground effects interspersed with aerial effects, and, of course, lots of noise," Anderson said.

Yet one aspect has remained a constant since almost the beginning: blowing up the M. "We got the idea to blow up the M," Anderson said of the early design ideas. "Not in a demeaning way—just for fun and to punctuate the next round of shells. And people loved it. Now it's become a tradition. It's even written into our contract that we have to blow up the M at the start of the show."



Chad Carr '91, Scot Anderson '79, Marc Williams, Chris Weege '84 and Ken Benkert have all had a hand in the E-Days fireworks show over the years, creating a signature event that Orediggers enjoy at every E-Days celebration.

Photo courtesy of Marc Williams

Today, the show is run by Marc Williams at Night Musick Inc., a fireworks display company, along with several Mines student interns and alumni with an aptitude for pyrotechnics, and they follow strict rules to ensure a safe show.

"It's a vocation for a bunch of geeks," Williams said, happily including himself under that term. "We train students throughout the year, and they often help me with other displays to learn about the process."

It takes several days to set up the show, and it's all computerized with safety measures in place to avoid prematurely setting off the show. "The computers are all encrypted so no one can set off the show too soon or when people are still setting up the display," Anderson said.

There is one myth, however, that Williams wanted to dispel about the show: the use of dynamite. "The giant explosions in the show are not dynamite—and never have been," he said. "We use low explosives that give you that satisfying thump in the chest—not the sharp and painful sound that dynamite would have."

But it's that myth that Anderson said they played on when designing the shows over the years. "We'd put fireworks in red cases that looked like dynamite," he said. "They of course weren't real, but that was part of the fun."

Since the first fireworks show, Anderson has only missed a handful of years due to business or other commitments that happened to fall during the annual celebration. He returns to campus every year to participate in a tradition that he still loves nearly four decades later. "I really like how we can take something so scientific and find the art in it," he said. "We are literally painting the sky."

By Ashley Spurgeon | Photo by Joe DelNero

IMPARTING TIME, TALENT AND KNOWLEDGE

MINES ALUMNI ARE THE BEST RESOURCE FOR BUILDING A STRONG INSTITUTION AND OREDIGGER NETWORK

The value of a Mines degree is measured in alumni successes. Graduates leave Mines with their silver diplomas in hand, prepared to launch exciting careers and put their newfound skills to work. No matter where their path leads them, each alumnus or alumna gains unique experiences and often becomes a key player in their industry. But those experiences are even more valuable when alumni return to their alma mater to share their successes—or lessons learned—and inspire and encourage their fellow Orediggers.

The time, talents and knowledge alumni share at Mines inspires and empowers the next generation of graduates to address society's grand challenges and to carry on the Oredigger legacy of making the world a better place. And the opportunities to give back are seemingly endless. A few alumni share the ways in which they volunteer with Mines.



“ I personally think Mines still has a lot more to offer the community outside of the school. I want to do more to connect Mines to new communities and new opportunities for outreach. Mines should be even more well-known than it is today, because it is such a great place for excellence. I think the greatest gift to a Mines alum is the Mines alumni network. We have a great history of alumni who have done so much in industry, communities and more. I think when you volunteer and are involved with the alumni office, you give yourself opportunities to learn from and network with Mines' great alumni.

► **NAHJEE MAYBIN '18**

Creator, Mines Black Alumni Network



“ I was approached with an excellent opportunity to be part of the alumni board. As an alumna in California, I was feeling detached from Mines and that my value as an alum was the money I could donate to the school. I wanted being a Mines alumna to mean more. I wanted to be able to lean on the alumni and the university throughout my entire career and life—a never-ending cycle of give and take based on what's needed at the time—and I wanted to be a part of making that possible.

Plus, being on the board allows me to be physically on campus a few times a year. There's no replacement for being on campus and feeling close to the university—the nostalgia, the student energy and the beauty of Golden.

► **TIFFANY BREWSTER '07**

Alumni Association Board member
Bakersfield M Club leader



“ My favorite part about being an M Club leader is when we get to spend personal time to get to know other alumni and hear about their Mines and life experiences. Everyone has something to share about their Mines experience. We can encourage others in that way. Getting to meet new or reconnected alumni is great—there's just something about the Mines bond that makes that connection special.

► **GEORGE PULS '75**

San Antonio M Club leader
Puls also started the Houston Golf Tournament and chaired the committee for eight years.



“ As a volunteer for the admissions department, I attend college and career fairs. I like answering key questions for students to help guide their decision-making toward a degree and institution. The passion and excitement I find in accepted Mines students (or even those applying) inspires me to help them make good decisions.

The Mines impact on my life and career was so dramatic and broad-reaching that I welcome the opportunity to give back to the school.

► **GARY HARRIS '84**

Volunteer for Mines Admissions office

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- Find your local M Club to stay connected to your fellow Orediggers long after graduation and continue to build a valuable network of support. Don't see one in your city? Start one!
- Join a golf tournament planning committee to help increase scholarship support for current and future Mines students.
- If you have a particular passion, join an existing interest group to connect with fellow enthusiasts and stay up-to-date on what's happening with that particular subject at Mines.

By **Anica Wong**

ALUMNUS PROFILE

A PIONEER IN AEROSPACE

Don Neuschwander '51 entered aerospace at an exciting time. In 1958, the Russians and Americans had just launched the first-ever satellites into space, and the aerospace industry was in its infancy. With a career spanning nearly four decades, Neuschwander worked at the forefront of space innovation, designing rocket launch technology, and was on the ground for more than 50 launches.

Neuschwander, who has a professional degree in mining engineering, found his way into aerospace when the diatomaceous earth mine he worked at in Lompoc, California, downsized and left him looking for work. The aerospace company Lockheed, newly contracted with the U.S. Air Force to design and manufacture Agena satellites, was looking for engineers of any kind. Neuschwander was soon hired and became the first salaried employee in Lompoc. His first task, he recalled, was to bring a hammer and nails from home to hang the Lockheed sign on a building assigned to the company at Vandenberg Air Force Base in April 1958.

Because the field was so new, virtually no one had experience launching rockets. The challenge, Neuschwander said, was to teach people from various backgrounds, then build up crews with a few launches behind them—meaning that for the first few launches, nobody really knew what they were doing. “We were building things that had never been done before,” Neuschwander said.

And it was his extensive background from Mines that enabled him to succeed. Lockheed needed experts in mechanics, physics, pneumatics, metallurgy and chemistry, Neuschwander said, and many engineers didn't have that kind of comprehensive knowledge. Except those from Mines. One of the first things Neuschwander did in his new role was hire more Mines graduates. When his boss asked why he had hired geologists for rocket science, he explained, “They came from Colorado School of Mines—they can do anything.”

After that, it was trial and error, successes and failures—and occasional fireworks. “It was a fun job. When things worked, it was great. When they didn't, it was like ‘run for your life,’” Neuschwander said.

He recalled running off a launchpad after one of the engineers initiated the launch too soon. Another time, he said, his entire family was present at a launch when an Atlas booster with 14,000 gallons of liquid oxygen and more than 5,000 gallons of RPI jet fuel, and more than 11,000 pounds of inhibited



Don Neuschwander '51 worked in aerospace for nearly four decades, beginning when the industry was in its infancy. Here, he is pictured in front of photos of different launches during his career.

Photo courtesy of Don Neuschwander

red fuming nitric acid and 6,000 pounds of unsymmetrical dimethyl hydrazine in the Agena was destroyed when the Atlas engines shut down at 30 inches after launch. “Boy, those were the biggest fireworks I've ever seen,” Neuschwander said.

It wasn't all error, though. Neuschwander worked on many successful projects, including the Agena vehicles, which launched reconnaissance flights. Neuschwander recalled that early recon satellites would eject one or more recovery capsules of film, which, remarkably, would have to be retrieved by pilots in midair. He was also involved in the Ranger and Lunar Orbiter programs, which obtained pictures of the Moon in preparation for the first landing vehicles, as well as a other launches from Cape Canaveral that were all exciting projects.

All in all, building a career alongside the beginnings of aerospace industry was full of excitement and innovation. Most of all, Neuschwander is proud of “the fact that we were breaking scientific barriers and doing things that no one had ever done before.”

By **Amanda Schuster**

SPRING 2019 ON OUR WALL

E-Days has become an annual signature event to celebrate the end of the academic year that creates lasting and unique memories for Mines students. What is your best E-Days memory?

E-Days was always about connecting with my friends and classmates. We'd meet up to go to the best fireworks show I've ever known or have brunch before watching the cardboard boat races. Lots of oohs, aahs and laughter!

Tiffany Brewster '07

My grandmother attended with me one year, and she loved the fireworks—she even stomped and screamed. She got caught up in the energy.

Melissa Laeser MS '03

A week of Coors beer, bonding with friends, bonfires. Making memories that last a lifetime!

Grzegorz Dewicki '91

Definitely doing the cardboard boat race. We won for the most people in a boat, but sadly it didn't win in our second heat. And always the fireworks—even if things catch on fire when they shouldn't.

Husni Mubarak MS '15, PhD '15

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OREDIGGERS GIVE BACK

GIVING VETERANS A LEG UP

Bud Isaacs '64 provides a scholarship for U.S. military veterans to cover education expenses that the GI Bill may not cover, supporting a new generation of leaders.

Photo by Joe DelNero



Bud Isaacs '64 is familiar with the rigors of military service and a Mines education. As a member of ROTC as a student and then as a U.S. Army officer during the Vietnam War, Isaacs learned how to work hard and how to lead. After completing his service, these attributes helped him build a successful career in the oil and gas industry. Now, Isaacs is helping those with similar backgrounds by providing a scholarship for veterans attending Mines that covers the education expenses the GI Bill may not.

"As a vet and a big supporter of Mines, it made sense to me to fill that need. I am a patriot and I believe in supporting those folks who come out of the military and have a desire to go on and get more education," Isaacs said. "I believe in giving a leg up, not a handout."

Isaacs views his time at Mines and in the military as complementary experiences. As a student, he learned how to solve problems, a core skill he would take with him when he volunteered to serve in Vietnam. In addition, as a combat engineer with the 101st Airborne, he learned how to manage people and established sound work habits, characteristics he wants to support in other veterans who pursue an education at Mines.

"I think the combination of military service and a Mines education creates strong leaders—not just engineers, not just scientists, but leaders who can go on and create something in the business world that supports many people," Isaacs said. "They've had the basic training and discipline that one needs to get an engineering degree. To me, it's leverage in the best sense. It's leveraging the youth's intellect and fire."

After Isaacs suffered the loss of two of his family members, he realized how important it was to take out his required minimum distribution to support Mines.

"I was the executor of their wills and they had all of their retirement funds tied up in an IRA, and that got taxed at the highest bracket," Isaacs said. "I became very cognizant of what would happen with my IRA when I passed. The required minimum distributions became the best vehicle to use to fund programs at Mines, because I don't have to pay income taxes on those funds."

By **Anica Wong**

"I worked as a fueller in the Marine Corps. While at home and abroad, I saw the impact that the oil and gas industry had on the world, and I decided I wanted to become a petroleum engineer. I liked the idea that I could be an engineer and still do hands-on field work, as I had come to love time in the field while in the military. I chose Mines because the culture of excellence found here is something that I had become accustomed to while in the Marines. To receive this scholarship from a fellow veteran is both humbling and motivating. I hope to one day be in a position to help veterans at Mines in the same way Mr. Isaacs has helped me."



—**Michael McGuiness**
Petroleum engineering, Class of 2019

MAY IS A MONTH **4** MINES!

TECHNOLOGY
Hareen Subramaniam
Class of 2019, Petroleum Engineering
Technology: Ruska Gas Permeameter

INNOVATION & RESEARCH
Amy Hegarty '13, MS '15, PhD '18
Research: Biomechanics for children with cerebral palsy

STUDENT LIFE
Bethel Tessema
Class of 2019, Computer Science
Activities: CASA tutor, National Society of Black Engineers, Society of Women Engineers and DECTech STEM instructor

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ALUMNA PROFILE

A BETTER WAY TO HEAL

Diana Hall '97 is living her dream. Using her chemical and software engineering background plus her passion for user-friendly medical treatment, Hall is making huge innovations in custom devices with 3D-printed casts and splints, improving efficiency for doctors and, more importantly, quality of life for patients.

Hall's company ActivArmor takes a 30-second scan of a patient's injury, then prints a custom-fit, waterproof, breathable orthosis. They can be used while bathing or swimming and are popular with doctors and patients alike due to the ease with which they can be produced and cared for, with minimal impact on daily activities.

Hall first got the idea for ActivArmor while volunteering with children in a low-income area of her hometown, Pueblo, Colo. She noticed children with injuries would often go for days without bathing or washing their hands to avoid getting their plaster casts wet. One child even ended up with permanent scarring due to a wet cast. Inspired by what she saw, Hall 3D-printed a custom splint for the boy and told him to ask his doctor if he could use it. She received a call from the doctor the next day, she said, asking if she could make more.

"It was then I realized I could make a viable business out of it, not just help people but have it be something there was demand for in the market and that could actually be revenue positive," Hall said. "After three years of field tests and commercial sales, that's where we're at right now."

Hall's technology has extended to more high profile patients—professional athletes. NFL players, an Ironman champion and an Olympic swimmer have used ActivArmor's gear, and a professional hockey player was even able to stay in shape on the ice while his arm healed, allowing him to return to the game sooner than he may have otherwise.

Though it's not only athletes who benefit from ActivArmor. The product is covered by insurance and thus widely available, and Hall thinks it will make a particularly big



Diana Hall '97 created ActivArmor, a startup that makes waterproof, breathable splints for athletes, children and other injured patients, to replace traditional plaster casts.

Photo by Jade Pitchford

impact in pediatrics, geriatrics and other populations where the proper care for a traditional cast can be challenging. But for Hall, the most important aspect of utilizing this technology is patient quality of life. Having witnessed the challenges her brother faced growing up with cystic fibrosis, Hall said she understood how hard it is for patients to adapt to things that aren't specifically made for them.

Now, Hall said, she finally understands how her varied background—including a degree in chemical engineering and a career in chemical and software engineering—comes together. "I didn't understand how all those experiences were leading up to what I was meant to do," she said. "And now I get up every morning, and I think, 'I would do this for free.'"

"The people who have degrees from Mines not only have sheer grit, but they have the tools they need to succeed. A degree from Mines is so valuable because you can build anything off of that."

Hall said that it was her experience at Mines that prepared her for this new step in her career. "The people who have degrees from Mines not only have sheer grit, but they have the tools they need to succeed," she explained. "A degree from Mines is so valuable because you can build anything off of that."

By **Amanda Schuster**

LEAVING A MARK

UNCOVERING MINES MEMORABILIA
IN A GOLDEN TIME CAPSULE

Fifty years ago, Golden residents buried a time capsule in front of City Hall, next to the city's Liberty Bell, with instructions that it be opened on Nov. 11, 2018.

On Veteran's Day 2018, as part of the city's celebration of the 100th anniversary of the end of WWI, officials unearthed the 1968 time capsule and discovered a treasure trove of documents that tell the story of Golden, Colorado, as it was 50 years ago.

Mines—a Golden institution since 1874—is an important part of that story, and Orediggers of yore made sure the time capsule included plenty of Mines memorabilia.

Among the Mines-related items that the Golden History Museum curators found inside the time capsule:

- ▶ Colorado School of Mines bulletin
- ▶ Edgar Mine brochure
- ▶ 1968–1969 general catalog

- ▶ Professional Contributions of the Colorado School of Mines leaflet
- ▶ Constitution of the Colorado School of Mines Dames Club and member directory. Founded in 1926 under the sponsorship of the faculty dames organization, the club furnished opportunities for the wives and mothers of students to socialize.

The time capsule and selected contents will be on display at the Golden History Museum through the end of April.

- ▶ For more information, go to goldenhistory.org.

By **Emilie Rusch**



Golden History Museum curator Mark Dodge displays one of the Mines brochures found inside the time capsule.

Photo by Joe DeNero

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WEDDINGS



TAKING THE NEXT STEP IN LOVE

Shannon Griep '08 and Christopher Lee were married in Oakland, Calif., on June 30, 2018. In attendance was Griep's Mines basketball teammate Angela (Pearson) Peters '08. Shannon works as a project manager for Bio-Rad Laboratories, and Chris works in student affairs for his alma mater, University of California, Berkeley.



AN UNDENIABLE CHEMISTRY

Seven years after meeting in their environmental chemistry class, Cristal Hibbard '10, MS '12 and Alex Wing MS '13 were married on Oct. 6, 2018, at Dead Horse Point State Park near Moab, Utah, during a rare desert downpour. Several alumni were in attendance, including Fiona (Meinert) Edge '09, Austin Edge '09, Amanda Johnson '10, David Manthei '10, Courtney Moore '10, MS '14, Bailey Smith '10 and Christophe Venot MS '09.



CELEBRATING WITH THE MINES FAMILY

Hannah Govett '16 married Austin Roberts '16 on Jan. 26, 2019, in Oklahoma City. The ceremony was officiated by close friend Ben Warren '16, and many Mines alumni were in the wedding party, including Max Ross '16, Jacqueline David '17, Laura Hughes '15, Kyle Jordan '15, Johanna Ratliff '16, Isabel Govett (current student), Anthony Fonte '16, Chris Pumford '16 and Mitchell Hinds '16. Other attendees included Hannah's grandfather, Raymond Govett '52, metallurgical and materials engineering professor Gerald Bourne and many other Mines alumni.



A GOLDEN COUPLE

Melinda Krebs '15, MS '16 and John Law '16 were married on Oct. 5, 2018, at the Boettcher Mansion in Golden, Colo. More than 40 alumni attended the wedding, with Katrina Ward '18, Jenny Wolicki '16, MS '17, Katie Schumacher '15, MS '17, Taylor Chott '16, MS '17 and Kevin Hartmann '16 serving as members of the wedding party. Meghan West '16 officiated the wedding. The couple met during their freshman year at Mines, both graduating with degrees in chemical engineering. They now work in the midstream natural gas and craft brewing industries and are happy to still call Golden home.



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BABIES



A NOVEMBER ARRIVAL

Jonathan Hodges '08 and Christina Hodges are excited to announce the birth of their daughter, Audrey Lynn, who arrived in November 2018.



TICKLED PINK FOR A LITTLE SISTER

Phil Lawlor '07 and Erica (Pribble) Lawlor '08 are tickled pink to announce the arrival of their baby girl, Edie Mae Lawlor, on Sept. 22, 2017. Her big brothers, Penn and Murray, are thrilled to have a little sister.

IN OTHER NEWS



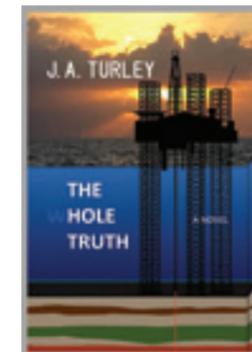
INTERNATIONAL SCIENCE AND TECHNOLOGY COOPERATION AWARD

Jan Miller MS '66, PhD '69 received the International Science and Technology Cooperation Award of the People's Republic of China in Beijing on Jan. 8, 2019. The award certificate, presented by China's president, Xi Jinping, at a special ceremony in the Great Hall of the People, recognized Miller's cooperation in education and research with Chinese universities and research institutions on the processing of energy and mineral resources. The award medal was presented subsequently in a separate ceremony by China's vice premier, Liu He. Additional special ceremonies were organized for subsequent visits to Kunming University of Science and Technology and Shanxi University.



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THE HOLE TRUTH

John Turley '65 published the technical thriller *The Hole Truth* in January 2019. The novel follows petroleum engineering professor Tony Zanatelli, who signs a summer job contract to manage the drilling of an exploration well in the Gulf of Mexico. Tony hopes to find a wealth of oil in the well, but the truth of what resides in the hole is targeted by conspirators. (The Brier Patch, 2019)

- ▶ To submit a wedding, birth or award announcement for publication in the magazine, visit minesmagazine.com/submit-an-announcement.

IN MEMORIAM

“When you are sorrowful look again in your heart,
and you shall see that in truth you are weeping for
that which has been your delight.”

-Kahlil Gibran



ROBERT E. CRUMB '61, MS '67 died Oct. 28, 2018. Born in 1938, Bob attended Mines on the Colorado Joint-Honor Scholarship and graduated with a professional degree in petroleum engineering in 1961. He served as a second lieutenant in the Army Corps of Engineers and taught for several months at the engineering college at Fort Belvoir in Virginia. Bob also volunteered to help improve the maintenance and construction of equipment at a U.S. military base in Seoul, South Korea. He then returned to Mines to complete his master's degree in petroleum engineering in 1967. Bob spent his career in the petroleum industry, working in Oklahoma, Texas, Alabama, Mexico, Libya and Indonesia.



ROBERT J. GOVERNSKI '64 died Nov. 14, 2018. Born in 1941, Bob graduated from Mines in 1965 with a professional degree in metallurgical engineering. As a student, Bob was a member of ROTC, played football and worked for the Rio Grande Scenic Railroad. After graduating, he served in the U.S. Army in Vietnam and as a member of the 82nd Airborne Division. Bob then worked for Kennecott Copper before becoming a sales engineer for Denver Equipment Company. He eventually left the mining industry to work for George Meyers Manufacturing and Wilfley Engineered Products. Bob started his own company, Denver Process Equipment Co., which later became Camber Process Equipment Company. Bob also served on the planning committee for the Society of Mining Engineers' mineral processing division and was on the board of the California Nevada Soft Drink Association. He later opened Crystalix of San Diego.



EUGENE C. MCMAHAN '49 died Feb. 5, 2019. Gene was born in 1926 and received a professional degree in geology from Mines in 1949. Gene went on to work for Shell Oil Company for the next 33 years. During his tenure, he worked as a junior geophysicist and seismic party chief. He was named senior staff geophysicist in 1969 and was promoted to geophysical advisor in 1981. Gene retired from Shell in 1982. In 1994, Gene started the Eugene C. McMahan Scholarship Fund at Mines, which provides a four-year award for an entering freshman who has graduated in the top 10 percent of his or her high school class. The first preference for award recipients is given to graduates of Wheat Ridge High School, Gene's alma mater.



DAVID E. PERRIMAN '49 died Feb. 8, 2019. David enrolled at Mines in 1943, but World War II interrupted his studies. He served as a merchant marine cadet on ships in the Pacific for two years before returning to Mines after the war. David earned a professional degree in petroleum engineering from Mines in 1949 and began his career working as a petroleum engineer and subsurface geologist for Shell Oil Company from 1949 to 1965. His second career was with New York state government, beginning with a task force in the oil and gas division that formed the Department of Environmental Conservation. David served in several managerial positions in the department until his retirement in 1983.



THOMAS A. WARFIELD '52 died Sept. 30, 2018. Tom was born in 1927 in Fort Collins, Colo., and joined the U.S. Coast Guard after graduating from high school. He served in the Pacific Ocean theater before returning home to earn a professional degree in mining engineering from Mines in 1952. After graduating, Tom went to work for Standard Oil of Indiana, working for the company until 1958 when he joined Frazier-Davis Construction. He worked on projects such as the spillway tunnels for the Glen Canyon Dam in Arizona, the Jaybird Tunnel near Placerville, Calif., the railroad relocation tunnels and diversion tunnels for the Oroville Dam in California, a shaft job for a mine in Ironton, Mont., and the Fryingpan-Arkansas Project in Colorado. Tom later joined Utah Construction and Mining, where he worked on the River Mountain tunnel project. When the company sold the construction division to Fluor Corporation, Tom became the corporate safety director. He also worked in the Democratic Republic of the Congo and Saudi Arabia, where he worked until his retirement in 1997.

ALSO REMEMBERED

Janice Nordby December 4, 2018



GEORGE C. WELCH III '59 died Jan. 21, 2019. A Denver native, George graduated from East High School before attending Mines to earn a professional degree in petroleum engineering in 1959. He worked in the petroleum industry for more than 50 years and was president of DartOil Company.

► To submit an obituary for publication in the magazine, visit minesmagazine.com/submit-an-obituary.

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MINER'S PIC



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WALKING AMONG GIANTS

In January 2018, Nathan Anderson '15 visited family in the San Francisco Bay area, expecting to spend some time with loved ones and take in the sights of the city and surrounding areas. He wasn't expecting, however, to run into giants.

While hiking through Redwood Regional Park, just east of Oakland, Anderson was blown away by the silent sentinels along the trail. Ancient coast redwood trees towered skyward to form an impressive canopy, captivating Anderson's attention, and he knew he had to pull out his camera.

"I had never seen one before," he said. "Walking so close to them and seeing their sheer height was incredible."

Anderson aimed his lens up into the canopy and snapped away, not wanting to forget the immensity of the trees and his experience of seeing them for the first time.

"I was lucky that day with the lighting and time of year, which allowed for bright, beautiful colors," Anderson said. "I have a thing for red, green and blue colors, as well as wickedly tall things."





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