Resources: Natural, Energy, Water, for Society (ReNEWS)

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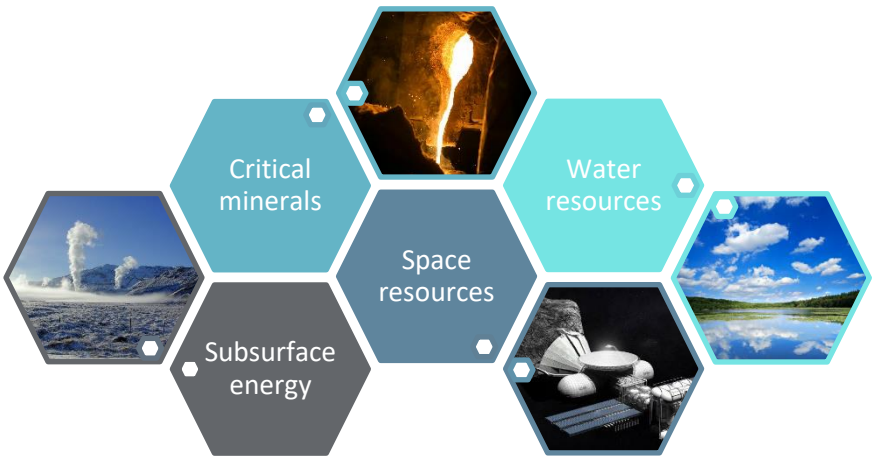
1 BACKGROUND AND RATIONALE

Both renewable and non-renewable natural resources play an essential role in the economic development and national security of the United States and many other countries in the world. As the premier technological research university of the State of Missouri, Missouri S&T is home to numerous research groups with research themes related to various aspects of natural resources, such as their accurate exploration, economical and environmentally friendly extraction, safe storage, and sustainable management. Improving the communication and collaboration among all the research groups has the potential to dramatically improve S&T's capability to respond to funding opportunities, and conduct cutting-edge interdisciplinary research projects that raise S&T's visibility and reputation.



The Resources: Natural, Energy, Water, for Society (ReNEWS) research constellation will focus on the exploration, extraction, and management of the following natural resources: water, oil & gas, minerals, geothermal and other renewable energy, and space resources (minerals and volatiles) in asteroids, the Moon, and other space objects. In addition to traditional key natural resources such as water and fossil fuels, this constellation includes some emerging areas addressing future national needs for our society with numerous funding opportunities, including

critical minerals, space resources, geothermal energy, and application of artificial intelligence in various fields.

There are several reasons for establishing the ReNEWS research constellation. Firstly, many of the research areas in ReNEWS are a perfect fit for the Center for Resource Sustainability within the new Kummer Institute. The Center for Resource Sustainability aims to reduce the footprint of mineral and fuel extraction, increase access to clean drinking water, and leverage regional resources for resilient energy, water and materials utilization. These goals directly overlap with the efforts of the researchers in the ReNEWS constellation. The ReNEWS constellation will provide the faculty and student expertise and other resources to facilitate the success of this important Kummer Center. ReNEWS is also poised to support the educational mission of the Kummer School of Innovation, Entrepreneurship, and Economic Development. The group's distinct expertise enables it to create novel interdisciplinary programs to train tomorrow's entrepreneurs and innovators in responsible resource development, equipping them with specialized competencies derived from the engineering disciplines, the natural and social sciences, and public and business administration.

Secondly, some techniques commonly used for one type of natural resource research can be readily applied to other types. Examples of such common techniques include rock characterization using geochemical analyses, remote sensing, geophysical inversion, digital signal analysis, advanced materials, data mining, and artificial intelligence, especially machine learning. Additionally, numerical simulations of coupled physical processes of fluid flow and rock deformation (from grain to plate scale) are used across these fields. The ReNEWS constellation can build on a vast set of expertise currently present amongst researchers at S&T (both in academic departments and research centers such as EMRGe, HPCC, CREE, and MRC).

Thirdly, some of these natural resources are intrinsically connected and, thus, knowledge can easily be transferred and these resources can be studied together. For instance, effective water management is an important component in oil and gas extraction. Geothermal energy production relies on the same subsurface technology from drilling to production to well abandonment initially developed for hydrocarbon resources. Water resource assessment and management can benefit resiliency related to water crises, flooding and drought, and contribute to efficient

utilization in energy production and natural resource extraction. Carbon capture and storage (CCS) and alternative natural subsurface resources such as geothermal energy have become the focus of the traditional oil and gas energy industry as well as federal and state agencies.

Finally, the different disciplines required to study these natural resources can share techniques and instruments to gain synergies. For example, techniques used for seismic monitoring of hydro-fracturing and waste water disposal are easily adapted for monitoring in mines. Sample analysis instrumentation for water quality can also be used for analyzing oil/gas samples.

In summary, ReNEWS has great potential to improve S&T's visibility in the natural resource area related to human welfare, increase our chance to win interdisciplinary large proposals, and help recruit and retain outstanding faculty. It will make S&T more attractive to outstanding applicants for our many graduate programs that span this broad area.

2 ORGANIZATION

S&T already has a solid foundation of interdisciplinary research expertise and skills residing in many academic programs and research centers, such as Geology and Geophysics, Petroleum Engineering, Geological Engineering, Mining Engineering, Explosives Engineering, Metallurgical Engineering, Civil and Environmental Engineering, Chemical Engineering, and Aerospace Engineering. Researchers in the ReNEWS focus area are divided into four groups, including critical minerals, space resources, subsurface energy, and water resources. Additionally, the cross-cutting themes of societal impacts, science communications, high performance computing, and data science will serve as connectors for all of the constellation's work.

2.1 CRITICAL MINERALS.

In the last few years, critical minerals (those minerals "critical" to national security or economic development of a particular country) have received significant attention from governments, industry, and other stakeholders. This attention is the result of supply chain vulnerabilities, national security concerns, and the general shift towards green energy technologies. For example, the World Bank estimates that the global mining sector will have to

significantly increase the supply of several products including aluminum, cobalt, copper, lead, lithium, nickel, manganese, the platinum group of metals, rare earth metals, silver, steel, titanium and zinc to facilitate a low carbon future (World Bank Group, 2017). From the perspective of the United States, the United States Geological Survey (USGS) in response to a Presidential Executive Order defined 35 critical minerals, 31 of which the US relies exclusively on imports to meet its needs. Consequently, there is a dire need for research and innovation to ensure a secure and reliable supply of critical minerals to safeguard our national security and facilitate the sustainable transition to green energy.

The critical minerals research challenges are: 1) public policy development related to encouraging the recovery of critical materials from existing and new process streams; 2) development of new processes to recover critical minerals as byproducts from existing processes and new sources; 3) identifying new domestic sources of critical minerals; 4) life cycle-based criticality assessment of existing and new processes for critical mineral recovery; and 5) sustainability assessment and environmental mitigation of potential hazards of existing and new processes.

The critical minerals subarea is connected to all the other ReNEWS subareas. Mining and processing of minerals requires significant amounts of water and has potential to negatively impact surface and ground water resources. Thus sustainable extraction of critical minerals requires assessing its impacts on water and addressing clean water challenges as mining competes with other uses for clean water. While society's immediate needs for critical minerals are likely to be met by resources on our planet, in the near future some critical minerals will be supplied by mining space resources either to meet needs on earth or to support space exploration missions. Research to address the space resources challenges will both rely on and improve mining techniques on our planet. In addition, subsurface energy recovery relies on some of the same techniques used in mineral exploration and exploitation (geophysics, drilling, water management etc.).

Missouri S&T has strong relationships with government agencies (Defense Logistics Agency, USGS National Mineral Information Center, DOE's Critical Minerals Institute, National Renewable Energy Laboratory and National Energy Technology Laboratory, etc.),

multi-national institutions (e.g., World Bank), mining companies, foreign universities (University of Botswana, Chongqing University, USFQ, etc.), and several international organizations (e.g., Copper Refineries Group). We will leverage all these relationships to move Missouri S&T toward success in this area.

2.2 SPACE RESOURCES.

"Space resources" are natural materials found and processed extra-terrestrially to support human endeavors in space as well as on Earth (NASA calls this ISRU, for *in situ* resource utilization). Government agencies and public and private companies working in this area face significant new opportunities, challenges, and decisions in policy, governance, and business strategy. This sub-area focuses on transdisciplinary research in the responsible use of natural resources found in space.

Many of the approaches and technologies that can be adapted for use in space originated in the millennia of human experience locating and extracting critical minerals, subsurface energy sources, and water resources from the Earth. Therefore, the space resources sub-area will work closely with the other sub-areas to achieve synergies that would be much less likely with a "siloed" approach.

The ongoing space exploration effort, nationwide and globally, is spurring many commercial, government, and private entities to become more active in areas related to space resources. Several faculty in this sub-area are members of the Lunar Surface Innovation Consortium established in 2020 and the Space Resources Roundtable established in 1998. S&T faculty already have worked with Colorado School of Mines, Michigan Technological University, the University of New South Wales, Australia, the Harvard-Smithsonian Center for Astrophysics, and King's College London, in this sub-area. We have links to active researchers at eight of the ten NASA centers, as well as NASA Headquarters. Potential partners that have not been approached yet include Washington University-St Louis, Georgia Tech, Notre Dame, and the University of North Dakota. Relationships have been / are being established also with the European Space Resources Innovation Centre, the Luxembourg Institute for Science and Technology, and the Canadian Space Agency. Commercial enterprises interacted with include SpaceX, Boeing, Lockheed Martin, Honeybee Robotics, Sierra Nevada Corporation (Orbitec), Deep Space Industries, various NASA contractors, and a number of startup companies. A

paradigm shift is underway in this very active area of research, and the number of participants is increasing rapidly. With the right focus and investments, Missouri S&T can become a global leader in space resources research.

2.3 SUBSURFACE ENERGY.

Subsurface energy sources account for >80% of the United States (US) energy needs, including oil & gas, coal, geothermal and nuclear energy. In addition to using energy resources from the subsurface, various critical storage and disposal activities, which are necessary to ensure energy sustainability, rely on subsurface activities, such as CO_2 sequestration, waste water disposal, and nuclear waste storage. We also store a myriad of products (e.g. natural gas, critical materials stockpiles, secure facilities etc.) in subsurface "structures" to facilitate economic development and national security. The Department of Energy (DOE), recognizing this need, has established a focus area in Subsurface Science, Technology, Engineering, and R&D (SubTER). At the same time these subsurface activities have grown in significance, stakeholders have become more aware of the health and environmental impacts of subsurface activities, such as hydraulic fracturing (fracking), and are demanding better protection from potential environmental and health impacts.

It is necessary to provide a hub for a large number of researchers at Missouri S&T who have expertise in subsurface research to facilitate more effective communication and collaboration. This group will address the grand challenges in subsurface sciences and engineering, such as wellbore integrity, fluid flow/fluid-rock interaction, health and safety, and environmental impacts. It is our intention to create a unique subsurface research consortium at Missouri S&T to become a premier, nationally-recognized team.

The subsurface research sub-area is closely related to the other sub-areas. For example, in the petroleum industry in the USA, seven barrels of contaminated water has been produced for every barrel of oil production from conventional reservoirs. Also, tremendous amounts of freshwater have been used in hydraulic fracturing jobs each year. The sustainable and secure use and treatment of such huge volumes of water are critical to the economy, society and the environment.

We have collaborated and will continue to expand our collaborations with experts in other universities to develop winning proposals, such as the University of Texas-Austin, University of Alaska Fairbanks, Colorado School of Mines, Berkeley National Lab, University of Missouri-Columbia, University of Missouri-Kansas City, and so on. Chevron, Conoco-Philips, Occidental Oil Company, PetroChina have supported our research in the past in Mechanical Earth Modeling and Enhanced Oil Recovery projects. It is our intention to grow industry support from more companies to address this important research issue that continues to plague the entire industry.

2.4 WATER RESOURCES.

The availability of useable freshwater is a fundamental requirement for drinking water, food production, power generation, and the extraction and processing of natural resources such as oil, gas, and minerals. Global demand for water is expected to rise by 60% by 2050. On a global scale, the availability and access to clean drinking water is also the single largest factor affecting human health. As a result, providing access to clean drinking water has been identified by the National Academy of Engineering as one of the 14 grand engineering challenges and also one of the prime UN Millennium Development Goals (MDGs). We also experience many water-related challenges in the state of Missouri. Water-related disaster resilience has become a growing topic of interest in the US, with the past decade being the costliest in terms of disaster damages and relief. The National Oceanic and Atmospheric Agency (NOAA) commented "2019 is the sixth consecutive year (2015-2020) in which 10 or more billion-dollar weather and climate disaster events have impacted the United States." Water resilience in the Missouri is of particular interest, with the 2019 floods causing damages in excess of $6.2 Billion, with projections of over $10 Billion in economic loss. Water quality is also of prime concern as harmful cyanobacteria algal blooms and *E. coli* contamination in lakes and drinking water reservoirs, and increasing numbers of emerging pollutants are identified in surface waters, in runoff of agricultural lands, and impacted from resource extraction (mine drainage, processing waters, fracking solutions, and residuals management such as tailings impoundments). Missouri has exceedingly complex hydrogeology, with unpredictable flow pathways within the bedrock impacted by caves and sinkholes.

Our water resources focus also provides direct linkages to the other research sub-areas, expanding our combined capabilities for large projects. For example, efficient water

management and water re-use technologies are a crucial part of the processing of critical minerals, space resources, and oil and gas. In addition, water itself is a primary “space resource”, and new technologies will be necessary to extract it from reservoirs on the moon and other planets. Water also serves as the conduit for heat in geothermal systems, so its role in subsurface energy is multifaceted.

As a state leader in the water resources area, there will be ample opportunity to connect and collaborate with stakeholders in Missouri and elsewhere. Our small community is already connected with and hosts a number of federal and state agencies, including the US Geological Survey water science center, the Missouri DNR, US Army Corps of Engineering, State Emergency Management Agency, and the Missouri Geological Survey. A targeted focus on water resources at Missouri S&T will further strengthen these relationships and spur new growth in this critical field.

3 EXPERTISE

In order to for the ReNEWS area to be competitive, S&T needs a critical mass of faculty with key expertise within these focus areas and connecting them to facilitate a focused and comprehensive effort. Some of the expertise needs to be in-house, while other areas can be addressed by collaborating with researchers from other institutions.

Tackling the critical minerals research challenges requires research expertise from disciplines such as geosciences and mining, metallurgical, environmental, and geological engineering. Additionally, expertise in data science, high performance computing, mineral and resource economics, policy analysis, other social sciences, and communication are required for a comprehensive approach. Missouri S&T has expertise in most of these disciplines with a 150-year history in minerals education and research starting with the Missouri School of Mines, and over 100 years of experience in Geology and Geophysics and Petroleum Engineering. S&T’s reputation as a global leader in minerals, our relationships with global mining companies, and relationships with several government agencies and national laboratories place us in a unique position to tackle this challenge. Globally only a handful of institutions can match the breadth and depth of expertise of Missouri S&T in critical minerals.

Missouri S&T can address the growing field of space resources with its unique combined legacies in mining engineering, aerospace engineering, chemical engineering, materials science and engineering, and civil engineering, as well as history, technical communication, and political science.

Missouri S&T is poised to become a nationally-recognized leader in addressing the grand societal challenges associated with water resources. Our existing research strengths in this area can be subdivided into the areas of surface water and groundwater hydrology, water infrastructure engineering, water quality and aquatic ecosystems, and water remediation. These skills position us to address most water sustainability and security challenges. The water resources focus area also pairs nicely with our campus' educational objectives, including existing online graduate certificates in *Surface Water Resources* (via Civil Engineering) and *Subsurface Water Resources* (via Geosciences and Geological and Petroleum Engineering), as well as an interdisciplinary pending new graduate program in Water Science and Engineering.

A critical mass of faculty members in GGPE, Mining, and Chemical Engineering have a long track record of research in subsurface research. Moreover, this can be integrated with faculty members in mechanical engineering and civil and environmental engineering to provide transformative research in areas such as the characterization of fluid flow and the control of subsurface fractures. Faculty members in material science, chemistry, chemical engineering and civil engineering can also develop novel materials to solve subsurface drilling and well performance problems related to subsurface energy production and carbon storage. Faculty working on geophysics and sensors can also develop breakthrough tools to map subsurface features. Therefore, this subarea will provide an excellent opportunity for collaboration by a large and diverse group of researchers inside and peripheral to this core area.

Our survey of expertise shows that S&T has significant expertise in the ReNEWS research areas. The detailed results are shown in Appendix B. The results show broad expertise in all areas necessary for a sustained research effort in the subareas that define ReNEWS. There are a few areas such as resource economics, policy, and communications that have very few faculty with expertise. The needs of the ReNEWS area are discussed in section 5.

4 FUTURE FUNDING OPPORTUNITIES & STRATEGIES

There are a multitude of collaborative funding opportunities within each of our subareas; however, the ultimate goal is for each subarea to work towards attracting engineering research center type funding to cement S&T as a national leader within these areas.

Since 2017, the US Government has issued two presidential executive orders on critical minerals. The first one resulted in several initiatives including an inter-agency report, headed by the Department of Commerce that put forth a federal strategy to ensure a secure and reliable supply of critical minerals (U.S. Department of Commerce, 2019). The second executive order issued on September 2020, required all US government agencies to submit plans to address the challenges posed by critical minerals and provide ongoing reporting to the White House. Even before this last executive order, several government funding agencies (NSF, DOE, DOD etc.) were already funding significant research on critical minerals. The latest executive order only ensures that all agencies will focus on critical minerals and fund appropriate research. Besides the US Government, there are multi-national companies that have a stake in ensuring the sustainable supply of critical minerals that are looking at ways to improve efficiency, safety, environmental and societal performance, and economic viability of critical minerals extraction.

Funding agencies such as the NSF, NASA and DARPA have significant funding opportunities in the space resources area. These include programs such as NSF-CASIS Collaboration on Transport Phenomena on the ISS; NASA's Solar System Exploration Research Virtual Institute (SSERVI), Maturation of Instruments for Solar System Exploration (MatISSE), and Development and Advancement of Lunar Instrumentation (DALI); and DARPA's Disruptive Capabilities for Future Warfare program. All these programs have funding limits exceeding $1M per solicitation.

Hundreds of millions of dollars of funding are available from U.S. government agencies each year for subsurface energy research. Our research team will seek large grants from government agencies such as DOE, EPA, NIH and so on. Solicitations from NSF and the Gulf Research Program, as well as the level of interest from major energy companies and service companies should result in additional funding opportunities. Examples of major opportunities include

DOE's Subsurface Technology and Engineering Research (SubTER) Initiative and opportunities in the Offices of Fossil Energy and Office of Basic Energy Sciences.

Funding opportunities for water resources research include large initiatives (a $100 million effort) within the DOE to improve water treatment and re-use of highly saline wastewater from oil and gas extraction. A wealth of opportunities for funding also exist within the NSF. In addition to individual program proposals, water resources research could be leveraged for the ERC and GOALI programs. Additional federal agencies such as the USDA, USEPA and USGS frequently fund water-related research. Collaborating with state and federal agencies is also viable and underway, including the governor's appointed Flood Recovery Advisory Working Group recommending funding improved water resource data collection and information platform. The US federal government is investing heavily in future research, such as Integrated Water Resources Science and Services (IWRSS) for interagency collaboration with NOAA / USACE / USGS / FEMA and research collaboration for water-crisis preparedness. The Department of Homeland Security's Flood Apex Program directs new programming and funds to address the specific topic and pending Flood Level Observation, Operations, and Decision Support (FLOODS) Act is poised to inject billions in new funding into this globally important topic. Opportunities for partnering with industry are also abundant. One of our collaborators has an existing industry consortium that focuses on developing technologies to control water inundation during subsurface drilling projects. Other researchers are working with industry partners on developing new water treatment technologies.

5 RESOURCE NEEDS

While S&T has existing expertise and resources to give it a competitive advantage, important gaps in our capabilities still remain. In particular, the group needs four new faculty positions to fill in some gaps. These faculty hires should have expertise in critical minerals, resource economics, space mission operations (all phases and destinations, including the International Space Station), and unconventional oil & gas recovery improvement and wellbore integrity. At least one of these faculty should be someone with a national pedigree (NAE level) who can lead the ReNEWS constellation.

The critical minerals subarea could benefit from a state-of-the-art critical minerals laboratory that houses equipment for mineral processing and extractive metallurgy. Currently, there is equipment scattered across Mining & Explosives Engineering and Material Science & Engineering (McNutt Hall and the Kennedy Experimental Mine), which supports the teaching and research needs of the faculty. A flagship laboratory that has all the mineral processing and extractive metallurgy equipment will significantly increase S&T's capacity in this area. At a minimum, the addition of several major equipment units such as a mineral liberation analyzer, electron microprobe, and high pressure autoclave would increase capacity and position S&T to move to the next stage.

The water resources and resilience area needs core leadership in the area of hydrologic data acquisition, integration across multiple platforms, and projective modeling through climate scenarios in water resources engineering and hydrology. Addition of demonstrated expertise and research interest in modeling of watershed hydrologic processes and water quality, eco-hydrology related to resource extraction and processing is also sought. Added expertise is also needed in use interdisciplinary use of informatics and AI-Machine Learning in hydrology, water quality, and flood hydrology.

The subsurface energy area needs to purchase some supporting instruments, such as a high pressure high temperature (HPHT) consistometer for cement material, and a spinning tensor meter, an instrument for the viscoelastic behavior of interfaces, to extend its research capability in the subsurface energy area.

6 CONCLUSIONS

Missouri S&T has active natural resources research spanning areas such accurate exploration, economical and environmentally friendly extraction, safe storage, and sustainable management. The Resources: Natural, Energy, Water, for Society (ReNEWS) research constellation will bring the researchers and facilities together to comprehensively address grand challenges related to the exploration, extraction, and management of water, oil & gas, minerals, geothermal and other renewable energy, and space resources (minerals and volatiles) in asteroids, the Moon, and other space objects. In addition to traditional key natural resources such as water and fossil fuel, this constellation includes some emerging areas addressing future national needs for our society with

numerous funding opportunities, including critical minerals, space resources, and application of artificial intelligence in various fields. Fifty faculty members from 11 departments in both colleges have expressed interest in contributing to this research effort. Based on documented expertise and facilities, S&T is equipped to address the grand challenges associated with finding, safely exploiting and managing critical minerals, subsurface resources, water resources, and space resources. With minimal investments in new faculty lines and laboratory equipment, S&T can position itself to be a national leader in resources research and education.

7 REFERENCES

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8 APPENDIX A: LIST OF PARTICIPATING FACULTY

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9 APPENDIX B: EXPERTISE SURVEY RESULTS

- **Kwame Awuah-Offei**: Critical minerals, Mining methods, Mineral economics, Sustainability, Mineral policy, Social license to operate, Societal implications, Environmental impacts, Reclamation & rehabilitation, Mine safety, Capacity building, Energy minerals, Workplace safety and health
- **Phillip Mulligan**: Mining methods, Mine safety, Space mining, Workplace safety and health, Human factors
- **Stephen Gao**: Mine safety, Seismic imaging, Digital signal analysis, Gravity exploration, Magnetic exploration, Hydro-fracturing monitoring, Seismic while drilling, Mine seismic monitoring, Data mining
- **David Duvernell**: Environmental impacts, Biodiversity monitoring and assessment.
- **Xinhua Liang**: Water remediation
- **Leslie Gertsch**: Mining methods, Space resources, Moon, Mars, or asteroids science or engineering, Space mining, In-situ resource utilization (ISRU), Excavation/construction on planetary surfaces, Surface water hydrology, Groundwater hydrology
- **Guang Xu**: Environmental impacts, Mine safety, Workplace safety and health
- **Andreas Eckert**: Oil & gas, Drilling, Geothermal resources, Geomechanics, Seal integrity, Structural permeability, Wellbore integrity, Carbon storage, Carbon sequestration, Hydraulic fracturing, Enhanced geothermal systems, Subsurface energy, Science communication
- **Mark Fitch**: Sustainability, Environmental impacts, Water control, Water contamination, Water quality, Water remediation, Water and ecosystems
- **Mahalet Fikru**: Mineral economics, Resource economics, Sustainability, Cost-benefit analysis, Economic impacts, Natural resource markets, Data science, Data analytics, Decision science
- **V. A. Samaranayake**: Data science, Data analytics, Data mining, Machine learning
- **David Borrok**: Sustainability, Mineral exploration, Environmental impacts, In-situ resource utilization (ISRU), Oil & gas, Groundwater hydrology, Water contamination, Water quality, Water quantity, Water security, Water resources, Produced water
- **Michael Moats**: Critical minerals, Mineral processing, Extractive metallurgy, Sustainability, Capacity building, Cost-benefit analysis, Economic impacts

- **Jonathan Obrist Farner**: Environmental impacts, Oil & gas, Seismic imaging, Water and ecosystems
- **Francisca Oboh Ikuenobe**: Earth history
- **Mingzhen Wei**: Oil & gas, Water control, Conformance control, Enhanced oil recovery, Unconventional oil & gas, Data science, Data analytics, Data mining, Machine learning
- **Daoru Han**: Moon, Mars, or asteroids science or engineering, Space instrumentation
- **Dev Niyogi**: Sustainability, Environmental impacts, Reclamation & rehabilitation, Carbon sequestration, Surface water hydrology, Water contamination, Water quality, Water quantity, Water security, Water resources, Water remediation, Water and ecosystems, Water and disease
- **Thomas Schuman**: Sustainability, Environmental impacts, Natural resource markets, Water control, Conformance control, Enhanced oil recovery, polymer science and technology Renewable ag products
- **Abdulmohsin Imqam**: Environmental impacts, Oil & gas, Drilling, Geothermal resources, Wellbore integrity, Carbon storage, Carbon sequestration, Water control, Conformance control, Enhanced oil recovery, Unconventional oil & gas, Hydraulic fracturing, Enhanced geothermal systems
- **Henry Pernicka**: Space resources, Moon, Mars, or asteroids science or engineering, Space mining, Orbital mechanics, Space instrumentation, Space manufacturing
- **Jeremy Maurer**: Sustainability, Societal implications, Geomechanics, Data science, Data analytics, Data mining, Machine learning, natural hazards and resilience
- **Baojun Bai**: Oil & gas, Geothermal resources, Seal integrity, Wellbore integrity, Carbon storage, Carbon sequestration, Water control, Conformance control, Enhanced oil recovery, Unconventional oil & gas, Shale oil, Shale gas, Tight oil, Tight gas, Hydraulic fracturing, Enhanced geothermal systems, Subsurface energy, Water remediation, Produced water
- **Wan Yang**: Oil & gas, Carbon storage, Carbon sequestration, Enhanced oil recovery, Unconventional oil & gas, Shale oil, Shale gas, Tight oil, Tight gas, Seismic imaging
- **Ryan Smith**: Sustainability, Surface water hydrology, Groundwater hydrology, Water contamination, Water quality, Water quantity, Water security, Water resources, Water and disease, Data science, Data analytics, Data mining, Machine learning

- **Kelly Liu**: Mineral exploration, Oil & gas, Geothermal resources, Unconventional oil & gas, Hydraulic fracturing, Seismic imaging, Digital signal analysis, Hydro-fracturing monitoring, Seismic while drilling, Mine seismic monitoring, Data science, Data analytics, Data mining, Machine learning
- **Suzanna Long**: Critical minerals, Resource economics, Sustainability, Societal implications, Cost-benefit analysis, Economic impacts, Flooding hazards, Data science, Data analytics, Decision science, natural hazards, resilience
- **Yue-Wern Huang**: Water contamination, Water quality, Water quantity, Water resources, Water and ecosystems, Water and disease
- **Joel Burken**: Sustainability, Societal implications, Environmental impacts, Reclamation & rehabilitation, Carbon storage, Carbon sequestration, Water control, Surface water hydrology, Groundwater hydrology, Water contamination, Water quality, Water quantity, Water security, Water resources, Industrial water, Water remediation, Produced water, Flooding hazards, Water power generation, Water and ecosystems, Water and disease, Data analytics, Machine learning, Science communication
- **Audra Merfeld-Langston**: Intercultural competence & communication, Language acquisition
- **Alanna Krolikowski**: Space resources, Space policy, law or regulation, trade policy
- **Taghi Sherizadeh**: Critical minerals, Mining methods, Mineral exploration, Mine safety, Capacity building, Moon, Mars, or asteroids science or engineering, Space mining, Space instrumentation, Excavation/construction on planetary surfaces, Energy minerals, Drilling, Geothermal resources, Geomechanics, Seal integrity, Structural permeability, Wellbore integrity, Carbon storage, Carbon sequestration, Unconventional oil & gas, Hydraulic fracturing, Enhanced geothermal systems, Subsurface energy, Hydro-fracturing monitoring, Seismic while drilling, Mine seismic monitoring, Machine learning, Workplace safety and health
- **David Wronkiewicz**: Critical minerals, Sustainability, Societal implications, Mineral exploration, Environmental impacts, Energy minerals, Carbon storage, Carbon sequestration, Water contamination, Water quality
- **Lana Alagha**: Critical minerals, Mineral processing, Extractive metallurgy, Energy minerals, Machine learning