SPACE RESOURCES ROUNDTABLE

XXIV SPACE RESOURCES ROUNDTABLE

CONFERENCE PROGRAM

Colorado School of Mines
Golden, Colorado, USA
June 4-7, 2024

Message

On behalf of the Steering Committee of the 2024 Space Resources Roundtable, welcome to the twenty-fourth edition of this conference that started back in 1999 with just a few enthusiasts in the space resources field. As we can see from the record attendance, number of presentations and posters, and variety of topics at this meeting, this is undoubtedly the most exciting time so far for this community.

Interest is now coming from a variety of players with a wider set of objectives. New studies, projects, and missions incorporating space resources objectives are being conducted for cislunar space, the Moon, Mars, and asteroids by government agencies around the world and the commercial space sector. Just this year, the Moon will be visited by several countries and companies demonstrating their landing and surface mobility capabilities, as well as deploying prospecting equipment.

The Artemis Accords now include more than 40 countries that have agreed to extract and utilize space resources to support safe and sustainable space exploration, while a broader legal framework is being actively pursued at the international level. Most large aerospace companies and dozens of start-ups that have appeared in the past few years are positioning themselves in the various links of the space resources value chain, highlighting the growing interest and opportunities in this field. As current plans focus on the Moon as a destination for renewed robotic and human exploration, while paving the way to small bodies and the Red Planet, it is now abundantly clear that space resources are moving ever closer to enabling future exploration, expanding economic activity beyond our planet, and increasing societal benefits on Earth.

This increased interest calls for greater involvement from our rapidly growing community. Our expertise is needed more than ever to provide the scientific, technical, economic, business, legal, and policy guidance to integrate space resources into public and private space initiatives in an efficient, fair, and responsible way. We invite all meeting participants to actively contribute to this discussion to ensure an exciting and productive future in this field.

– Angel Abbud-Madrid
President & Chair SRR XXIV, 2024

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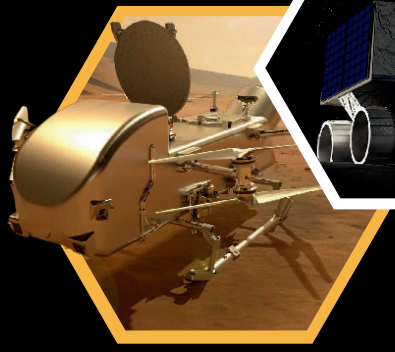
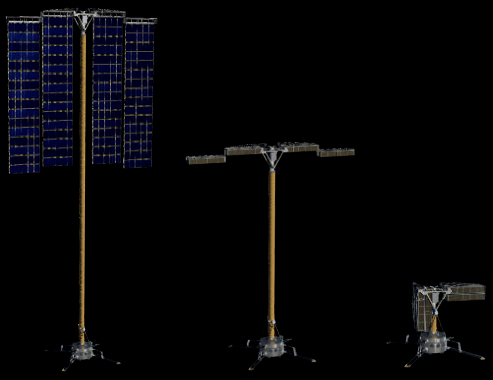


DrACO on Dragonfly



Lunar Array Mast and Power System (LAMPS)

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LOCATIONS

Altadena, CA

Greenbelt, MD

Longmont, CO

Keynote Speaker

Wednesday, June 5, 8:00 AM

Morgan Hendry
BLUE ORIGIN

Space Resources for the Benefit of Earth

Abstract: A key part of Blue Origin's vision is the harnessing of space resources for the benefit of Earth. The Space Resources Program within Space Systems Development has been established to address the challenges required for opening space resources to humanity and to use them in-situ starting with the Moon. Scientists and engineers in this program across various disciplines work together to design, build, and maintain resource prospecting, processing, and manufacturing systems in space. The core technology in development is Blue Alchemist, an end-to-end scalable autonomous and commercial solution that produces solar cells, wire, and oxygen from lunar regolith. This presentation will give an overview of the Space Resources Program, the Blue Alchemist technology development in partnership with NASA, and a description of Blue Origin's Center for Excellence for Space Resources, which will provide key technology to support a vivid lunar economy in this decade and beyond.

Biography: Morgan Hendry earned his Bachelor's and Master's degrees in Aerospace Engineering (Astronautics) from the University of Southern California. He spent 15 years at NASA's Jet Propulsion Laboratory in roles spanning formulation, technology development, and flight projects. He delivered flight hardware used on the Curiosity and Perseverance rovers and earned a NASA Early Career Public Achievement Medal for his work as the Project Mass Properties Engineer on the Soil Moisture Active Passive Mission. In addition to serving as the Team X Mechanical Chair on over 50 studies, Morgan developed technology for extraterrestrial material sterilization and containment, Venus surface missions, and icy world excavation. Before leaving JPL, he was the Break the Chain Domain Lead for the Mars Sample Return Campaign responsible for the technical success of all engineering efforts to prevent the uncontrolled transmission and release of unsterilized Mars material into Earth's biosphere. Morgan joined Blue Origin in April 2022 and is the Program Systems Engineer for the Space Resources Program. His present focus is leading systems engineering efforts on the Blue Alchemist development.

Program Schedule

TUESDAY, JUNE 4, 2024

7:30	**Continental Breakfast (CSM Ben Parker Student Center)**	
8:00	**Opening Remarks**	Angel Abbud-Madrid, SRR President
Session 1 – National Plans & Priorities Panel		
Session Chair: Angel Abbud-Madrid, Colorado School of Mines		
8:20	**NASA ISRU – Closer to Reality** Gerald Sanders, NASA Johnson Space Center	
8:30	**The Lunar Surface Innovation Consortium In-Situ Resource Utilization Group: Status Update and Path Forward** Jodi Berdis, Johns Hopkins University Applied Physics Laboratory	
8:40	**European SRU Program Update** Kathryn Hadler, European Space Resources Innovation Centre, Luxembourg	
8:50	**JAXA's Study of a Lunar ISRU Pilot Plant** Jun Shimada, Japan Aerospace Exploration Agency (JAXA)	
Session 2 – Economic, Legal, and Policy Considerations		
Session Chair: George Sowers, Colorado School of Mines		
9:10	**Setting the Stage for the Future Lunar Commercial Economy** Daniel Kulp, Colorado School of Mines	
9:30	**Determining Appropriate Investment Hurdle Rates for Commercial Space Resource Projects** Ben McKeown, University of New South Wales, Australia	
9:50	**Coffee Break**	
10:10	**The European Space Resources Innovation Center: A Unique Excellence Center with Commercialization Programmes Dedicated to Early-Stage Ventures** Lari Cujko, European Space Resources Innovation Centre, Luxembourg	
10:30	**Engaging the Mining Industry in ISRU** Dale Boucher, Interstellar Mining, Canada	
10:50	**Adapting Oil and Gas Geoscience Best Practices for Planetary Exploration and Prospecting** David T. Butler, SLB	
11:10	**Space Nuclear Safety and Regulation for Space Resources Activities** Alexander Gilbert, Zeno Power Systems, Inc.	

11:30	**If You Do Not Deal with Space Law, Space Law Will Deal with You** Antonino Salmeri, Lunar Policy Platform
11:50	**Lunch (CSM Ben Parker Student Center)**
	Session 3 – Resource Prospecting & Exploration
	Session Chair: Leslie Gertsch, NASA Glenn Research Center/Missouri S&T
1:10	**Progress at the United States Geological Survey Toward Quantitative Resource Assessments of Lunar Resources** Laszlo Keszthelyi, U.S. Geological Survey, Astrogeology Science Center
1:30	**Update on the Prospects for Finding Ice on the Moon** Norbert Schörghofer, Planetary Science Institute
1:50	**Descriptive and Genetic Models for Lunar Ice Deposits Consistent with Current Remote Sensing Data** Kevin Cannon, Ethos Space/Colorado School of Mines
2:10	**Lunar Surface Missions for Resource Reconnaissance: NASA's PRIME-1 and VIPER** Julie Kleinhenz, NASA Glenn Research Center
2:30	**Commercial Exploration, Extraction, and Reporting of Lunar Resources** Carlos Espejel, ispace
2:50	**The International Lunar Resource Prospecting Campaign: Growing the Collaboration** Clive Neal, University of Notre Dame
3:10	**Coffee Break**
	Session 4 – Lunar Access Missions
	Session Chair: Robert Moses, Tamer Space
3:30	**CAPSTONE: An Ongoing Demonstration of Navigation and Autonomy Technologies in the Cislunar Domain** Thomas Gardner, Advanced Space, LLC
3:50	**Sustained Low-Altitude Lunar Orbital Mission (SLALOM) Navigation System** Jeffrey Parker, Advanced Space, LLC
4:10	**Roundtable Discussion**
5:10-7:00	**Poster Session & Reception (CSM Ben Parker Student Center)**

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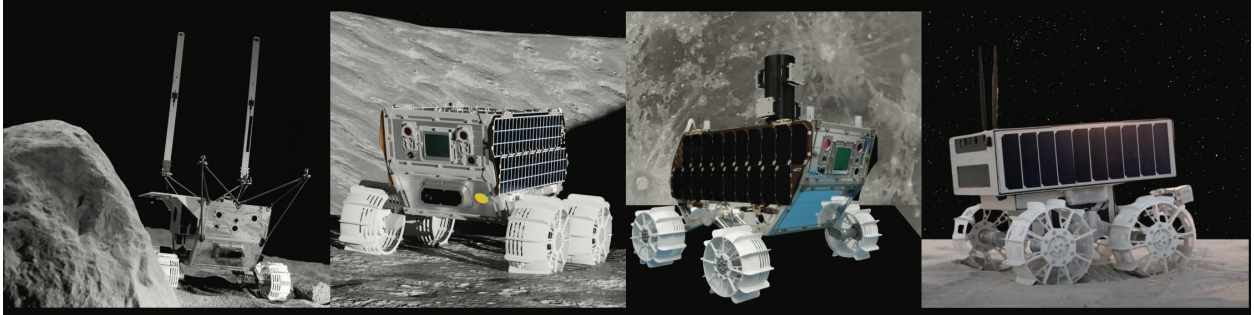

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WEDNESDAY, JUNE 5, 2024

7:30	**Continental Breakfast (CSM Ben Parker Student Center)**
8:00	**KEYNOTE PRESENTATION** **Space Resources for the Benefit of Earth** Morgan Hendry, Blue Origin
Session 5 – Prospecting Instruments & Platforms	
Session Chair: Julie Kleinhenz, NASA Johnson Space Center	
8:40	**Exploring Resources on the Moon: Tsukimi Mission and Associated Activities** Hirdy Miyamoto, The University of Tokyo, Japan
9:00	**Progressive Resource Prospecting Campaigns for Lunar-Derived Resources** A. J. Gemer, Lunar Outpost
9:20	**Field and Lab Testing with TRIDENT Drill to Help Prepare for Future Missions** Carol R. Stoker, NASA Ames Research Center
9:40	**Cryogenic Vacuum Testing of a Heated Cone Penetrometer for Thermal Detection and Quantification of Water in Icy Lunar Regolith Simulant** E. L. Zimmermann, Michigan Technological University
10:00	**Coffee Break**
10:20	**Hyperfluorescence for Real-Time Mineral & Material Identification: Update** Nigel Spooner, The University of Adelaide, Australia
10:40	**Laser-Induced Breakdown Spectroscopy Instrument for Accurate In-Situ Prospecting of Space Resources** Inna Uwarowa, Lightigo Space
Session 6 – Lunar Water Ice	
Session Chair: Kevin Cannon, Ethos Space/Colorado School of Mines	
11:00	**Using the TRIDENT Drill to Assess Geotechnical Properties of Probable Icy Lunar Regolith on Upcoming South Pole Missions** Isabel King, Honeybee Robotics
11:20	**Experimental Results of Ice Formation at Low Temperatures and Pressures** Timothy Krause, USRA at NASA Glenn Research Center
11:40	**Sintered Icy Regolith Simulants and their Implications for Lunar Subsurface Modification on Geologic Timescales** Daniel Johnson, Colorado School of Mines
12:00	**Lunch (CSM Ben Parker Student Center)**

Session 7 – Lunar Surface Infrastructure	
Session Chair: Laurent Sibille, Engineering & Research Consulting, NASA KSC	
1:20	**EURO2MOON: Leverage Lunar Resources Exploration to Foster International Collaboration and Benefit Sustainability in Space and Earth** Pierre-Alexis Joumel, Airbus Defence and Space, Germany
1:40	**Utilization of LUNARSABER for Lunar Exploration** Vishnu Sanigepalli, Honeybee Robotics
2:00	**Requirement Definitions of Deployable Structures and R&D of Unmanned System on Lunar Surface** Yasuhiro Fuchita, Obayashi Corp., Japan
2:20	**Development of the TEthered Mechanism for Persistent Energy Storage and Transmission (TEMPEST) System for the Watts on the Moon Challenge** T. Wavrunek, Michigan Technological University
2:40	**Commercial Radioisotope Power Systems for Space Resources Missions** Alexander Gilbert, Zeno Power Systems, Inc.
3:00	**Coffee Break**
Session 8 – Regolith Excavation and Conveyance	
Session Chair: Paul van Susante, Michigan Technological University	
3:20	**Computational Modeling of IPEx Drum-Lunar Regolith Interaction – Discrete Element Method and Control Mechanisms** Qiushi Chen, Clemson University
3:40	**Space Resources Handling Systems for Lunar, Martian and Space Missions** Süleyman Salihler, Polimak Process Technology, Turkey
4:00	**Effect of Vacuum on Force Response of an Ultrasonic Penetrator** Erin Rezich, NASA Glenn Research Center
4:20	**Roundtable Discussion**
5:30-8:00	**Banquet (Friedhoff Hall, Green Center)**

THURSDAY, JUNE 6, 2024

7:30	**Continental Breakfast (CSM Ben Parker Student Center)**
8:00	**SPACE RESOURCES INDUSTRY PANEL** • Christie Iacomini, Lockheed Martin Space • Benjamin Bussey, Intuitive Machines • Daniel Faber, Orbit Fab • Kevin Cannon, Ethos Space • Gary Lai, Interlune Panel Chair: George Sowers, Colorado School of Mines
Session 9 – Robotics & Autonomy	
Session Chair: Frances Zhu, University of Hawaii at Manoa	
8:50	**A Robotic Arm and Generic Payload Interface for the Lunar Surface** Cameron S. Dickinson, MDA Space
9:10	**Lunar Underactuated Arm (LUnA) Project** Alejandro Levi, Maxar Space Robotics
9:30	**2024 NASA Lunabotics University Competition: Site Preparation with Bulk Regolith** Robert P. Mueller, NASA Kennedy Space Center
9:50	**The Australian Rover Challenge (ARCH): Bringing Competition to Lunar Rover Simulation Missions** Daniel Ricardo, The University of Adelaide/Swinburne University of Technology
10:10	**Coffee Break**
10:30	**An Overview of Lunar ISRU Operation Research with an Uncertainty Consideration at Imperial College London** Joshua Rasera, Imperial College London, United Kingdom
10:50	**Field Demonstration of Gaussian Process Active Learning of Rover Mapping Spectral Composition in Hawaii's Lunar Surface Analog** Sapphira Akins, University of Hawai'i at Manoa
	Session 10 – Regolith Properties & Beneficiation
	Session Chair: Christopher Dreyer, Colorado School of Mines
11:10	**NASA Lunar Regolith Simulant Update** John Gruener, NASA Johnson Space Center

11:30	**De-Oxygenated Regolith as a Potential Advanced Material for Lunar Construction Exploration** Eliran R. Hamo, Helios-project Ltd.
11:50	**Testing of a Novel Lunar Regolith Compaction Device for Site Preparation** C. L. Carey, Michigan Technological University
12:10	**Lunch (CSM Ben Parker Student Center)**
1:30	**An Approach to Dust Handling and Mitigation for Lunar Habitats** Joshua Rasera, Imperial College London, United Kingdom
1:50	**Conceptual Design of the Regolith Size Separation Device** Damian Pietrusiak, Wroclaw University of Science and Technology
2:10	**Beneficiation of Lunar Regolith Simulants through Electrostatic and Magnetic Separation: Concept of Operations** Daoru Han, Missouri University of Science and Technology
2:30	**ISRU Advancements: Regolith Beneficiation & Propellant Production Overview** Kunal Kulkarni, German Aerospace Center, Germany
2:50	**Coffee Break**
Session 11 – Resource Extraction & Processing	
Session Chair: Koorosh Araghi, NASA Johnson Space Center	
3:10	**Towards Ranked Impurity Inventories of Water Resources on the Moon and Mars** Dennis Harries, European Space Resources Innovation Centre, Luxembourg
3:30	**Research Development for Lunar Volatile Extraction at KIGAM** Kyeong Ja Kim, Korea Institute of Geoscience and Mineral Resources, South Korea
3:50	**A Fully Automated, Demonstration Scale Carbothermal Reactor** Brant White, Sierra Space
4:10	**Roundtable Discussion**
5:10-7:00	**Poster Session & Reception (CSM Ben Parker Student Center)**

FRIDAY, JUNE 7, 2024

7:30	**Continental Breakfast (CSM Ben Parker Student Center)**
8:00	**SPACE RESOURCES MISSIONS PANEL** • Julie Kleinhenz, NASA • Michael Hecht, MIT Haystack Observatory • Justin Cyrus, Lunar Outpost • Thomas Gardner, Advanced Space • Demyan Lantukh, AstroForge Panel Chair: Kevin Cannon, Ethos Space/Colorado School of Mines
Session 12 – Metals Processing	
	Session Chair: Jodi Berdis, Johns Hopkins University Applied Physics Laboratory
8:50	**From Lunar Regolith to Aluminum Additive Manufacturing: Bench-Scale Demonstration of Metallic Aluminum Production from a Highland Simulant and its Utilization as Feedstock for 3D Printing on the Moon** Xavier Walls, Carleton University, Canada
9:10	**Modular Space Foundry Experimental Design for Metal Casting on the International Space Station** Joseph Pawelski, CisLunar Industries
Session 13 – Asteroid Resources	
	Session Chair: Jodi Berdis, Johns Hopkins University Applied Physics Laboratory
9:30	**The UAE's Emirates Mission to Explore the Asteroid Belt (EMA)** Heyam Al Blooshi, UAE Space Agency
9:50	**High Frontier: The First Asteroid Excavation Mission** Daynan Crull, Karman+
10:10	**Coffee Break**
10:30	**Rapid Mission Design to Enable Asteroid Mining** Demyan Lantukh, AstroForge
10:50	**Optical Mining – A Spallation Mining Model** Timofey Broslav, Colorado School of Mines
Session 14 – Mars Resources/Life Support Systems	
	Session Chair: Angel Abbud-Madrid, Colorado School of Mines
11:10	**MOXIE: Epilogue** Michael Hecht, MIT Haystack Observatory

11:30	**International Mars Ice Mapper Mission: Concept Mars Mission to Characterize the Subsurface Water Ice for Resource Utilization and the Future Human Mars Exploration** Richard Davis, NASA Headquarters
11:50	**Comparing Hydroponics and Regolith Growth and Evolution (CHRGE)** Laura Fackrell, NASA Jet Propulsion Lab
12:10	**Final Roundtable Discussion**
1:00	**ADJOURN**

LUNAR AND PLANETARY INSTITUTE

POSTER PRESENTATIONS

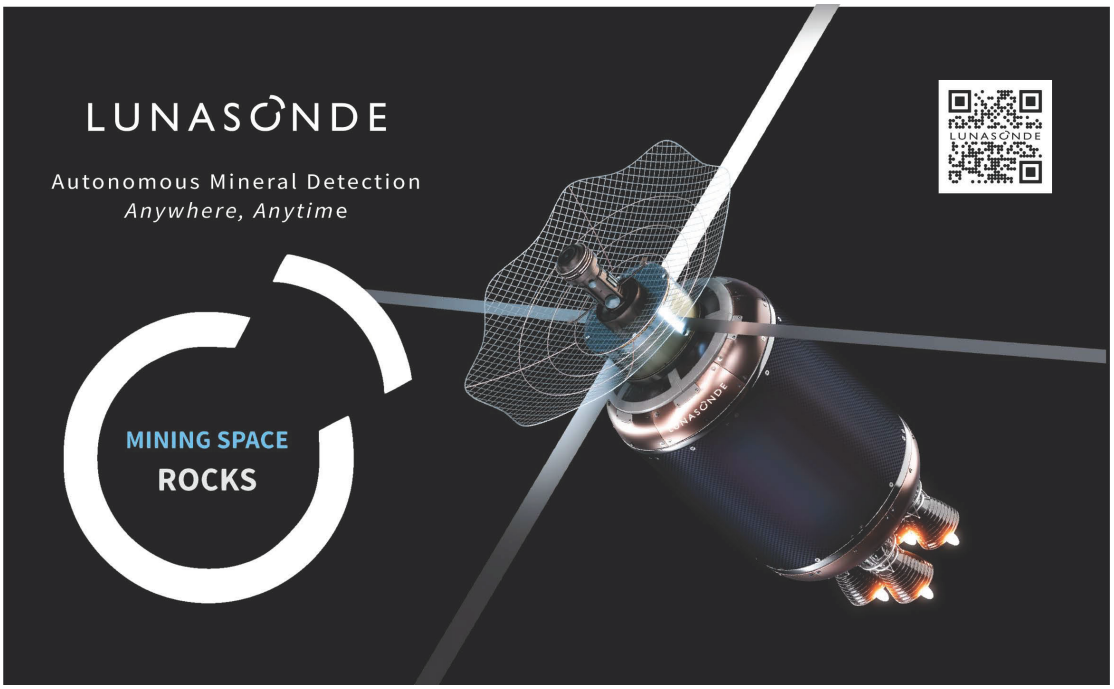
Poster presentations will be divided into two sessions on Tuesday and Thursday evenings

Tuesday, June 4, 2024 (5:00-7:00 PM)	
Location: Ballrooms D&E (CSM Ben Parker Student Center)	
1	**Commercial Services and Guiding Principles to Enable the Next Generation of Martian Exploration** Richard Davis, NASA Headquarters
2	**Modular Tool for Robotic Construction on the Lunar Surface** Nathen Blas, Independent Researcher
3	**Atypical Small Crater Morphology in the Shackleton PSR: Indicative of Subsurface Volatile Destabilization?** Hunter A. Danque, Colorado School of Mines
4	**Characteristics of an Artemis Lunar Construction Modular Toolkit** Cameron S. Dickinson, MDA Space
5	**Abrasion Resistance of Hardfacing Materials and Techniques for Lunar Applications: Introduction to Lasercladding** Natalia Fulton & Jean-Baptiste Crepin, Technogenia Lasercarb Oklahoma, Inc.
6	**Development of a Reusable Lunar Environment Electrical Connector: The Dust Tolerant Connector** Stephen Indyk, Honeybee Robotics
7	**Determination of Maximum Operating Temperature of Enstatite** Evan Karavolos, De Astris Generation LLC
8	**Predictive Modeling for Phased Infrastructure Buildup on the Lunar Surface** Joshua Menges, Colorado School of Mines
9	**Lunar Dawn: How Lunar Outpost's Lunar Terrain Vehicle Will Usher in a New Era in Lunar Surface Exploration and Space Resource Utilization** Forrest Meyen, Lunar Outpost, Inc.
10	**Lunar Infrastructure Development** Douglas Morrison, Centre for Excellence in Mining Innovation
11	**Lunar Surface Power for ISRU Applications** Ian Jakupca, NASA Glenn Research Center
12	**Examining the Reserve Potential of Lunar Polar Volatiles** Hannah O'Brien & Ruby Patterson, NASA JSC & Astralytical Consulting
13	**Review of Processes Influencing the Form and Morphology of Ice on the Moon** Daniel Ricardo, Swinburne University of Technology
14	**Metal Oxidation Heating Enabling a Closed-Loop Lunar Economic Cycle** Jon Slavik, Astrobotic Technology

15	**Nuclear Fission and Fusion Microreactors for Lunar and Planetary Tunneling Applications** John C. Smith, Jr., Colorado School of Mines
16	**Towards an Understanding of Rover Technology Needs for Future Lunar Applications** Angela Stickle, Johns Hopkins Applied Physics Laboratory
17	**Lunar and Mars ISRU, Excavation and Construction Test Capabilities and Project Progress at the MTU-PSTDL** Paul J. van Susante, Michigan Technological University
18	**ROCKETM – A Propulsive Excavation System for the Moon and Mars** Travis Vazansky, Astrobotic Technology
19	**OffWorld Prospector: Lunar Oxygen and Hydrogen Production Demonstration** Dallas Bienhoff, OffWorld, Inc.
20	**Maturing Aluminum Production from Lunar Regolith: Status of the MAGMA Project** Kevin Cannon, Colorado School of Mines
21	**ISRU Lunar Infrastructure – Darpa LUNA 10 Team Metal Discoveries** Joseph Pawelski, CisLunar Industries
22	**Engineered Living Building Material (LBM) Formed by Binder Jetting under Martian Temperature and Air Pressure** Ning Liu, Hong Kong University of Science and Technology
23	**A Proposed Framework for Astroagronomy as a Space Resources Discipline** Jerry V. Drew II, U.S. Army Command and General Staff College

Thursday, June 6, 2024 (5:00-7:00 PM)	
Location: Ballrooms D&E (CSM Ben Parker Student Center)	
1	**Semi-Autonomous Framework for Completing Contact Tasks in the Presence of Latency** Emmanuel Akita, The University of Texas at Austin
2	**Durability Testing of a Lunar Surface Excavation Rover** R.D. Austerberry, Michigan Technological University
3	**Toxicity of Lunar Volatiles on Human Health** Nicholas Barnett, University of New South Wales, Australia
4	**Modular Interface for CLPS-Scale Excavators (MICE) – Feasibility Testing of a Modular Disconnect System for Regolith Manipulation Implements Focused on Excavation and Site Preparation Activities** Evan Bell, NASA Kennedy Space Center
5	**Development of the Volatile Monitoring Oxygen Measurement System** Deborah E. Essumang, NASA Kennedy Space Center
6	**Soft Robotics for Space Applications: Embracing Flexibility for Extreme Environments** William Foster-Hall, The University of Adelaide, Australia
7	**In-Situ Resources Production of Hydrogen Peroxide and Hydrogen Using Nano-enabled Optical Fibers** Han Fu, Arizona State University
8	**Fundamental Regolith Properties, Handling, and Water Capture (FLEET) Project Update** Leslie Gertsch, NASA Glenn Research Center/Missouri University of Science and Technology
9	**Space Resource Utilization Considerations for a Lunar Habitation Customer** James E. Johnson, Colorado School of Mines
10	**Experimental Study on Carbothermal Reduction of Lunar Regolith Simulants for Metal/Metalloid Production** Shaspreet Kaur, Georgia Institute of Technology
11	**Lunar Regolith Simulant Figures of Merit: A System of Quantitative Characterization for the Direct Comparison of Analog Granular Materials to Apollo Soil Samples** Rostislav N. Kovtun, Jacobs/NASA Johnson Space Center
12	**LHS-2E and LSP-2: Novel 2mm Minus Lunar Regolith Simulants** Anna Metke & Levi Baum, Space Resource Technologies
13	**Quantifying the Need for Advanced Computational Tools for Lunar Excavation Analysis** Jared M. Long-Fox, University of Central Florida
14	**H_2O Sublimation Extraction for Mars and Lunar ISRU** Gregory Mungas, Freshare LLC
15	**Off Earth Resources (OER) – Shattering Paradigms and Creating Space Mining 2.0** Mark Sonter, Off Earth Mining Pty Ltd, Australia

16	**ASPECT LuSTR Lunar Testbed** Christopher Dreyer, Colorado School of Mines
17	**Acid Leaching and Electro-Deoxidation of Lunar Regolith Simulants to Produce Aluminum Metal** Jacob N. Ortega, Missouri University of Science and Technology
18	**Carbothermal Reduction Demonstration Prototype Design** Koorosh Araghi, NASA Johnson Space Center
19	**The Brazil Nut Effect (BNE) for Particle Size Classification in ISRU** Joshua Rasera, Imperial College London, United Kingdom
20	**Regolith Simulant Selection and Preparation for Technology Tests: An Updated NASA User's Guide** Laurent Sibille, NASA Kennedy Space Center
21	**Measurements of Silicosis Factors in Lunar and Martian Simulants** Ane Slabic, Jacobs/NASA Johnson Space Center
22	**A Concept of Lunar Beneficiation Test Bed** Mark Tolton, Orbital Mining Corporation
23	**Medicines for Moon Outpost: Cosmic Ray Stability of Space-Developed Ibuprofen Formulations on Earth and the International Space Station** Quy Don Tran, University of Adelaide, Australia
24	**Extended Reality Simulation Platform (ESP) for Humanoid Robots in the Loop (HRITL) & Humans in the Loop (HITL) for ISRU and ISAM** Bo Varga, Prefixa, Inc.
25	**TaRO-SCM: An Open-Source Terramechanics Simulation for Gazebo** Bret Witt, University of Hawai'i at Manoa



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Kevin Cannon, Ethos Space/Colorado School of Mines
Christopher Dreyer, Colorado School of Mines
Leslie Gertsch, NASA Glenn Research Center/MS&T
George Sowers, Colorado School of Mines

Session Chairs

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