NINTH JOINT MEETING
of the
SPACE RESOURCES ROUNDTABLE
and the
PLANETARY & TERRESTRIAL MINING SCIENCES SYMPOSIUM
with
LUNAR POLAR PROSPECTING WORKSHOP

Colorado School of Mines
Golden, Colorado, USA
June 12-15, 2018

SPACE RESOURCES ROUNDTABLE

PTMSS
Planetary & Terrestrial Mining Sciences Symposium

Message

Welcome to the Ninth Joint Meeting of the Space Resources Roundtable (SRR) and the Planetary and Terrestrial Mining Sciences Symposium (PTMSS) along with the Lunar Polar Prospecting Workshop.

This is undoubtedly an exciting time for the space resources community. Not since NASA's Vision for Space Exploration (VSE) initiative in 2004, has so much attention been placed in this field. However, this time is markedly different. In contrast to the VSE, interest is coming from a variety of participants with a wider set of objectives. New studies and projects incorporating ISRU technologies are being conducted for the Moon, Mars, and asteroids by space agencies around the world and the commercial space sector. Legislation has been advanced in the US and Luxembourg for commercial space-resource exploration and utilization, while a broader legal framework is being actively pursued at the international level. Several start-up companies have appeared in the past year positioning themselves in the various links of the space resources value chain, highlighting the growing interest and excitement around this topic. It is now sufficiently clear that the use of space resources is a critical-path activity for further exploration and commercialization of space.

This increased attention brings many unique opportunities, but also a call for greater involvement from our 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.

We invite all meeting participants to actively contribute to this discussion and to help make the years to come even more exciting and productive.

Sincerely,

Angel Abbud-Madrid
President & Chair, SRR XIX

Dale Boucher
Chair, PTMSS XV

Sponsors

On behalf of the SRR and PTMSS Steering Committee, we would like to express our appreciation to this year's sponsors.

Program Schedule

TUESDAY, JUNE 12, 2018

7:30 AM	**Continental Breakfast (Room 102, CTLM Building)**	
8:00	Opening remarks	Angel Abbud-Madrid & Sherry Schmidt
Technical Session 1 – Latest Developments in Space Resources		
Session Chair: Angel Abbud-Madrid (Colorado School of Mines)		
8:15	**Current Activities in the Advanced Exploration Systems ISRU Technology Project** Diane Linne, NASA Glenn Research Center	
8:35	**What Can We Learn from Centuries of Exploration, Mining, and Assessment on Earth to Better Utilize the Rest of the Solar System?** Larry Meinert, United States Geological Survey	
8:55	**NASA Innovative Advanced Concepts Program Explores ISRU concepts** Ron Turner, NASA Innovative Advanced Concepts	
9:15	**Towards the Development of a Planetary Resource Management System: Understanding the Why** Don Barker, MAXD, Inc.	
9:35	**Building a Space Development Industry in Luxembourg** Bob Lamboray, Ministry of the Economy, Luxembourg	
9:55	**Break**	
Technical Session 2 – Economics, Business, and Policy		
Session Chair: Sherry Schmidt (Deltion Innovations)		
10:15	**Transportation and Propellant Resources in the Cislunar Economy** Melissa Sampson, United Launch Alliance	
10:35	**A Business Case for Mining Propellant on the Moon** George Sowers, Colorado School of Mines	
10:55	**Five Phases of Technical and Financial Lunar Development** Doug Plata, The Space Development Network	
11:15	**Modeling Lunar Partnerships for the NASA Emerging Space Office** Brad Blair, NewSpace Analytics	
11:35	**Framework for Valuation of Asteroid Mining Options, Incorporating Strategic Knowledge Gaps, Market Demand and Temporal Dependencies of in Space Resource Availability** Eric Ward, Aten Engineering	
12:00	**Lunch (Atrium, Marquez Hall)**	

Technical Session 2 (continued) – Economics, Business, and Policy	
Session Chair: Sherry Schmidt (Deltion Innovations)	
1:00	**Space Commodity Trading on the Moon and with Other Solar System Locations** Jeff Greenblatt, Emerging Futures, LLC
1:20	**How Space Mining Missions will Disrupt Mineral Markets and Contracts** Ian Lange, Colorado School of Mines
1:40	**Policy Building Blocks for Space Resources Development** Ian Christensen, Secure World Foundation
2:00	**Economics, Business, and Policy Roundtable Discussion**
2:40	**Break**
Technical Session 3: Individual Poster Presentations (Short Talks)	
Session Chair: Angel Abbud-Madrid (Colorado School of Mines)	
3:00	**SRR Student Scholarships**
3:10	**A Case for Extraterrestrial Water Reserves and Resources** Gordon Wasilewski, Space Research Centre, Polish Academy of Sciences, Poland
3:15	**Using CT Scanning to Examine Lunar Regolith Porosity as a Function of Grain Shape and Depth** Ruby Patterson, Southwest Research Institute
3:20	**Cubesat-Minimoon Rendezvous Mission Synthesis and Analysis** Niklas Anthony, Luleå University of Technology, Sweden
3:25	**Modeling of JSC-1A Lunar Simulant Flow and Heat Transfer in the Helium Extraction & Acquisition Testbed** Aaron Olson, University of Wisconsin-Madison
3:30	**Economic Feasibility of Space Solar Power in Remote Mining Operations** Nicholas Proctor, Colorado School of Mines
3:35	**Increasing Lunar Propellant Delivery Capability with ACES Aerobraking** Nicholas Campbell, University of Colorado, Boulder
3:40	**Simulated Lunar High Land Rocks Using Japanese Igneous Rocks** Hiroyuki II, Wakayama University, Japan
3:45	**Concentrated Solar Energy for Manufacturing in Space** Andrew Brewer, Blueshift, LLC

3:50	**Robotic Prototypes for 3D printing with Lunar Regolith and Sunlight Developed in the RegoLight Project** Diego Urbina, Space Applications Services NV/SA, Belgium
3:55	**Production of Gravel from Lunar Soil Simulant by Rapid Microwave Sintering** Hiroshi Kanamori, Japan Aerospace Exploration Agency (JAXA)
4:00	**Poster Session and Break (Atrium, Marquez Hall)**
Technical Session 4 - Space Manufacturing and Processing Technologies	
Session Chair: Paul van Susante (Michigan Technological University)	
4:30	**Percussive Rotary Multi-Purpose Tool (PROMPT)** Sherry Schmidt, Deltion Innovations, Ltd., Canada
4:50	**Extraterrestrial Metals Processing** Mark Berggren, Pioneer Astronautics
5:10	**Cislunar Industries™ Space Foundry™: Recycling Space Debris into Refined Materials for In-Space Use** Gary Calnan, CisLunar Industries
5:30	**Self-Propagating Chemical Reactions for Making Materials and Structures from Lunar and Martian Regolith** Evgeny Shafirovich, University of Texas at El Paso
5:50	**Foam Structures for Encapsulating Regolith in Additive Manufacturing Applications** Gareth Morris, Colorado School of Mines

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WEDNESDAY, JUNE 13, 2018

7:30 AM	**Continental Breakfast (Room 102, CTLM Building)**
Technical Session 5 – Mars Resources	
Session Chair: Diane Linne (NASA Glenn Research Center)	
8:00	**Looking Ahead: Reconnaissance for Mars** Richard Davis, NASA Headquarters
8:20	**Mars Sample Return Objectives Relevant to Future In-Situ Resource Utilization** Julie Kleinhenz, NASA Glenn Research Center
8:40	**Informing the Selection of the First Human Landing Site on Mars – An Overview of NASA's Mars Water Mapping Projects** David Beaty, NASA Jet Propulsion Laboratory
9:00	**Martian Ice as a Resource for Exploration: Current Knowledge and Recent Results** Colin Dundas, United States Geological Survey
9:20	**Orbital Radar Assessments of Non-Polar Ice-Rich Terrains on Mars** Nathaniel Putzig, Planetary Science Institute
9:40	**Mars Pathfinder ISRU Modeling and Simulation** David Dickson, Georgia Institute of Technology
10:00	**Break**
Technical Session 5 (continued) – Mars Resources	
Session Chair: David Beaty (NASA Jet Propulsion Laboratory)	
10:20	**ISRU Technology Development for Extraction of Water from the Mars Surface** Julie Kleinhenz, NASA Glenn Research Center
10:40	**Electrostatic Precipitation for Cleaning Mars Atmospheric ISRU Intakes** Michael Johansen, NASA Kennedy Space Center
11:00	**Solid Oxide Electrolysis Calibration and Characterization Plan for the Mars Plan for the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)** Forrest Meyen, Draper
11:20	**Scroll Compressor for Mars Atmospheric Acquisition** John Wilson, Air Squared, Inc.
11:40	**Production of Methane and Oxygen on Mars Using Proton-Conducting Ceramics** Neal Sullivan, Colorado School of Mines
12:00	**Demonstration of a Piloted Mars Mission Scale RWGS System** Robert Zubrin, Pioneer Astronautics
12:20	**Lunch (Atrium, Marquez Hall)**

Technical Session 5 (continued) – Mars Resources	
Session Chair: Leslie Gertsch (Missouri University of Science and Technology)	
1:20	**Hard Rock Water Jet Mining, a Novel Method to Extract Water from Poly-Hydrated Sulphates on Mars** Paul van Susante, Michigan Technological University
1:40	**RedWater: Extraction of Water from Mars' Ice Deposits** Kris Zacny, Honeybee Robotics
Technical Session 6 – Small Bodies Resources	
Session Chair: Leslie Gertsch (Missouri University of Science and Technology)	
2:00	**Successful Demonstration of the Feasibility of Applying the USGS Resource Assessment Methodology to Near-Earth Objects** Colin Dundas, United States Geological Survey
2:20	**Risk Assessment of an Asteroid Mining Ventures Using Decision Modeling and Monte Carlo Simulation** Mike Jude, University of North Dakota
2:40	**Asteroid Regolith Model and Figure of Merit for Asteroid Simulants** Philip Metzger, University of Central Florida
3:00	**Break**
3:20	**Asteroid Mining Mission System Concept** Joel Sercel, TransAstra Corporation
3:40	**Dismantling Rubble Pile Asteroids with Area-of-Effect Softbots (AoES)** Jay McMahon, University of Colorado at Boulder
4:00	**Methane Production from Carbonaceous Chondrites Using Electromethanogenesis** Mihkel Pajusalu, Massachusetts Institute of Technology
4:20	**Mars and Small Bodies Roundtable Discussion**
5:30	**Banquet (Table Mountain Inn)**

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THURSDAY, JUNE 14, 2018

7:30	**Continental Breakfast (Room 102, CTLM Building)**
Technical Session 7 – Moon Resources	
Session Chair: Jerry Sanders (NASA Johnson Space Center)	
8:00	**Building Solar System Infrastructure with the OffWorld Industrial Robotic Workforce** Jim Keravala, OffWorld
8:20	**Commercial Exploration of Lunar Resources with ispace and the Polar Ice Explorer Mission** Julien-Alexander Lamamy, ispace Europe, Luxembourg
8:40	**"ALCHEMIST" - Lunar ISRU Demonstration Payload** Diego Urbina, Space Applications Services NV/SA, Belgium
9:00	**Applying the USGS Resource Assessment Methodology to the Moon: Three Very Different Cases** Laszlo Kestay, United States Geological Survey
9:20	**Strategic Knowledge Gaps I Have Known** Warren Platts, Groundhog GeoScience, LLC
9:40	**Lunar COTS Concept: A Public/Private Partnerships Approach for Lunar Resource Prospecting, Extraction and Infrastructure Development** Allison Zuniga, NASA Ames Research Center
10:00	**The Cislunar Autonomous Positioning System (CAPS)** Bradley Cheetham, Advanced Space
10:10	**Break**
Technical Session 7 (continued) – Moon Resources	
Session Chair: Julie Kleinhenz (NASA Glenn Research Center)	
10:30	**Progress toward Earth's Moon, Ongoing Moon Village Association's Efforts** John Mankins, The Moon Village Association
10:50	**Lunar Volatiles Mobile Instrumentation (LUVMI): Low-mass, Low-footprint, Payload and Robotic System for the Sampling of Volatiles at the Lunar Poles** Diego Urbina, Space Applications Services NV/SA, Belgium
11:10	**Lunar Soil Simulant in Japan 2018** N. Uyama, Shimizu Corporation, Japan
11:30	**Challenges of Designing a Tunnel Boring Machine (TBM) for Development of Underground Structures on the Moon** Jamal Rostami, Colorado School of Mines

11:50	**TRIDENT: The Regolith and Ice Drill for Exploration of New Terrains** Kris Zacny, Honeybee Robotics
12:10	**Ice Mining in Lunar Permanently Shadowed Regions** Christopher Dreyer, Colorado School of Mines
12:30	**Lunch (Atrium, Marquez Hall)**

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LUNAR POLAR PROSPECTING WORKSHOP

THURSDAY, JUNE 14, 2018

1:30	**Introduction** George Sowers, Colorado School of Mines
	Overview Presentations
1:50	**State of Knowledge of Lunar Polar Ice and Volatiles** Clive Neal, Lunar Exploration Analysis Group (LEAG)
2:20	**Mining Options in the Lunar Polar Craters** George Sowers, Colorado School of Mines
2:50	**Summary of Prospecting Technologies** Christopher Dreyer, Colorado School of Mines
3:20	**Break**
3:30	**Instructions for Working Groups**
3:45	**Working Groups Discussions** **(Teams and rooms to be assigned by discussion topic)**
6:00	**Workshop Reception (CSM Geology Museum)**

FRIDAY, JUNE 15, 2018

7:30	**Continental Breakfast (Room 102, CTLM Building)**
8:00	**Working Groups Discussions (continued)** (Workform Completion)
9:50	**Break**
10:00	**Briefing of Results by Working Groups**
11:30	**Open Discussion**
12:00	**Next Steps**
12:30	**Adjourn**

Credits

Joint Technical Steering Committee

Angel Abbud-Madrid, Colorado School of Mines
Dale Boucher, Deltion Innovations, Ltd.
Leslie Gertsch, Missouri University of Science and Technology
Stephen Mackwell, Lunar and Planetary Institute
Sherry Schmidt, Deltion Innovations, Ltd.
George Sowers, Colorado School of Mines

Session Chairs

Angel Abbud-Madrid, Colorado School of Mines
David Beaty, NASA Jet Propulsion Laboratory
Leslie Gertsch, Missouri University of Science and Technology
Julie Kleinhenz, NASA Glenn Research Center
Diane Linne, NASA Glenn Research Center
Jerry Sanders, NASA Johnson Space Center
Sherry Schmidt, Deltion Innovations, Ltd.
George Sowers, Colorado School of Mines
Paul van Susante, Michigan Technological University

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