2024 Lunar Development Conference

book of abstracts

Program, with Presentations and Authors

GMT	PDT	EDT	CEST	Topic	Title	Author-s (Presenter in bold)	Abstract available
					Saturday, 20th July		
14.45	7.45	10.45	16.45	Start	**Opening**	**Philip Crume**, Moon Society President	-
15	8 AM	11 AM	17	Keynote 1	**Keynote 1: Establishing a Lunar Underground Outpost Shifting the paradigm for future space exploration, settlement and commerce**	**Greg Baiden**, Louis L. Grenie, Brad Blair, Dale Tietz, and James S. Logan	Yes
16	9 AM	12 AM	18	Exploration	Lunar Lava Tubes and Chambers: Optimum Sites for Permanent Lunar Settlement	David Schrunk and **Madhu Thangavelu**	Yes
					The LEADER: Lunar Equatorial Daylight Exploration Rover Mission Architecture	**Saba Raji** and Madhu Thangavelu	Yes
17	10 AM	1 PM	19		The SLINGER Mission: Sampling Lunar Interior Natural Geology for an Earth Return Mission	**William Crowson**	Yes
					Space Habitation in the Interior by Robotic Exploration (SHIRE)	**Morgan Farrier**, Brendyn Byrne, and Nibin Nithyanandham	Yes
18	11 AM	2 PM	20	ISRU 1	One Standard Lunar Homestead Atmosphere	**Ben Smith, Lunar Homestead**	Yes
					General Overview on Water Existence in Lunar Regolith	**Ibrahim Bay**, Yusuf Kaya, and Cengiz Toklu	Yes
19	12 AM	3 PM	21		The Basics of Space Radiation and the Challenges It Presents	**James H Sloan**	Yes
					Space Copy: Technology For ISRU Enabled Lunar Manufacturing	**Madison C. Feehan**	Yes
20	1 PM	4 PM	22	Artemis Anniversary	Lunar landing celebration + footprints in Regolith	**Niklas Järvstråt**	-
					Artemis Society International and the founding of the Moon Society	**Randall Severy**, Moon Society	Yes
21	2 PM	5 PM	23		**Panel discussion, What got us here and what do we need to stay on the Moon?**	**Panel + Attendees** Moderator: Randall Severy	-
22	3	6	24	End	**Closing reflections, day 1**	TBD	-

GMT	PDT	EDT	CEST	Topic	Title	Speaker	Abstract available
					Sunday, 21st July		
14.45	7.45	10.45	16.45	Start	**Opening, day 2**	**Philip Crume**, Moon Society President	-
15	8 AM	11 AM	17	ISRU 2	Tentative title: Waste recycling	**Nadia Khan**	Not yet
					Lunar Agriculture: Transformation of Lunar Regolith into Soils to enable space agriculture	**Adam Williams**	Yes
16	9 AM	12 AM	18		Self-Organizing Wetland Bioreactors (SOWBs) Application to Mining on the Moon: Direct and Indirect Bioremediation of Regolith Slurry as a Design Tool for Mine Influenced Water (MIW) Benefaction	**Colin Lennox** and Mikayla McCord	Yes
					How to Mine Icy Regolith combining a Slusher, a Hoist, and IoT Technologies in a Lunar Crater excavated in our own backyard	**Victor O Tenorio**	Yes
17	10 AM	1 PM	19		Use of Cable-Strut Structures on Space Bodies	**Cengiz Toklu**	Yes
				Keynote 2	**Keynote 2, Tentative title: Sustainable Lunar Settlement Design: Off-world Anthropological Space Infrastructure Settlement (OASIS)**	**Gary Barnhard**, Moon Village Association	Yes
18	11 AM	2 PM	20	The long game	Production flow breakdown for human survival: Base on the Moon and Moonbase Lappträsk analogue	**Niklas Järvstråt**	Yes
19	12 AM	3 PM	21		Building a Lunar Civilisation	**Alastair Browne**	Yes
					Environmental justice considerations in lunar development	**Erika Nesvold**	Yes
20	1 PM	4 PM	22		A circular economy, new tech and smart systems thinking on the Moon – and on Earth	**Ulf E Andersson**	Yes
					Opportunities for Collaboration between Moon and Mars	**James Burk**, Mars Society	Not yet
21	2 PM	5 PM	23		**Panel discussion, The role of a Moon colony in an interplanetary society**	**Panel + Attendees** Moderator: James Burk	-
22	3	6	24	End	**Closing reflections**	TBD	-

Establishing a Lunar Underground Outpost

Shifting the paradigm for future space exploration, settlement and commerce

By

Dr. Greg Baiden
President
Penguin Automated Systems Inc.

Louis L. Grenier ing., M.Sc. CD [1]
Mission Manager, International Space Station Utilization
Space Exploration
Canadian Space Agency

Brad Blair
NewSpace Analytics
Dale Tietz
CEO/LTC USAF (Ret) Shackleton Energy Inc.

James S. Logan, MD
NASA Space Medical Officer (Ret)
Space Enterprise Institute

Abstract

The first generation of space entrepreneurs and their acolytes have grown weary of standard '*flags and footprints*' space exploration missions/programs historically sponsored by nation states. They are pondering more profound questions: What are the potential value propositions of space-based activities? How can *known* off-planet resources be leveraged to create vast new wealth, permanently expand the global economy into cis-lunar space, solve current real-world problems and facilitate humanity's transition from a constrained terrestrial civilization to a theoretically unlimited celestial one.

[1] The views expressed by the author are based on thirty-six years of professional engineering experience in both the aerospace and space sector and do not constitute necessarily an official endorsement from the Canadian Space Agency or Government of Canada on current established space policy and future directions of the space program. The content of this paper are reflections from a group of multi-disciplinary experts providing guidance material for future potential strategic directions.

The range of promising economically feasible *commercial* space applications range from the mundane (tourism - space hotels) to the transformational (carbon-free energy beamed to earth by space solar power satellites). The ultimate success of such applications depends on four critical assets, which must all be *space-based* rather than resupplied from Earth: (1) Propellant; (2) Energy; (3) Mineral and Chemicals and (4) Space Industrial Manufacturing Capabilities (SIMC).

The cold hard physics of the Rocket Equation and the Laws of Economics mandate these assets come from non-terrestrial sources. Other than energy from the sun, the only non-terrestrial resource repository in the *local planetary neighborhood* is the moon.

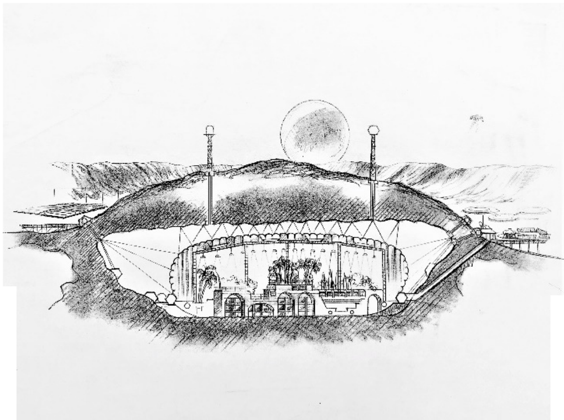
Fortunately, the moon is relatively rich in the resources required to build a cis-lunar industrial base. Unfortunately, the moon is an extremely unforgiving environment. Its resources may or may not exist in significantly concentrated deposits as on earth. Huge technological and operational hurdles exist to the application of proven terrestrial approaches to finding, extracting, separating, purificating and manufacturing.

The collection of raw materials and their conversion into usable materials for expansion of the human realm is the purview of exploration, prospecting, mining and processing known as the *mining process*. This paper describes the creation and evolution of a Concept of Operations (CONOPS) consistent with known *severe* lunar constraints leading to permanent industrial presence (PIP) on the moon, how such facilities might be constructed and relevant terrestrial technologies that could enable the first of many operational mines on the moon.

Lunar Lava Tubes and Chambers: Optimum Sites for Permanent Lunar Settlement

Madhu Thangavelu, USC, mthangav@usc.edu
David Schrunk, Science of Laws Institute, david.schrunk@scienceoflaws.org

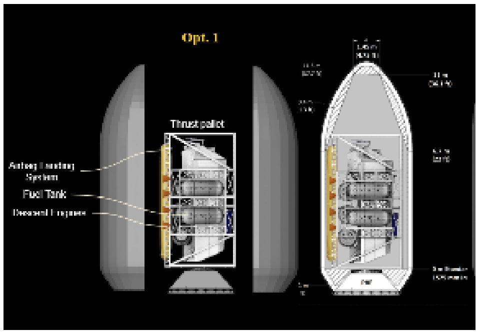
David G. Schrunk is an aerospace engineer and medical doctor with board certifications in the medical specialties of nuclear medicine and diagnostic radiology.

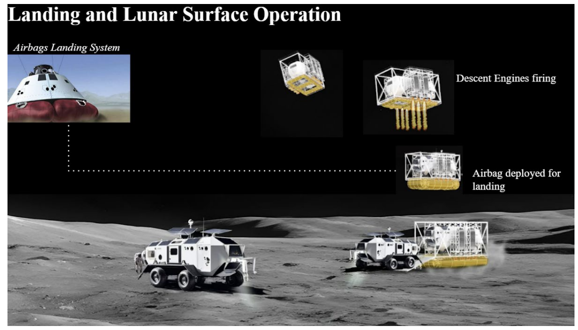


Madhu Thangavelu has a background education in Engineering and Architecture. He conducts the ASTE527 graduate Space Exploration Architecture Studio at the University of Southern California.

The next stage of international missions to the Moon will focus on the south polar region for further evaluation of water and organic compound resources needed to support permanent human settlements. The harsh lunar surface conditions, including radiation and constant bombardment from micrometeor showers make the environmental conditions at the surface of the Moon too hazardous for long term human survival and it would be necessary to excavate and build extensive shelters, covered with protecting layers of regolith, to establish safe and functional permanent human settlements in the south polar region. Rather than undergoing this extensive – and disruptive – terraforming effort, a simple and sturdy solution to safe shelters for human habitation already exists: lava tubes, pits and chambers. This presentation discusses the structure, location, and significant advantages of ancient lava tubes as sites for the development of large-scale human settlements. The combination of future robotic resource recovery efforts in the south polar region connected, e.g., by a rail system, to human activities in protected large lava tubes in the equatorial region would enable the rapid buildup of self-sustaining human settlements before the end of this century. Furthermore, a growing lunar base within a large lava tube could involve virtually all Earth governments in a cooperative effort to establish the permanent second home in space for humankind. The functioning "Planet Moon" would then have access to the unlimited resources of Space, and large-scale scientific, exploration and beneficial development projects would become possible.

The LEADER: Lunar Equatorial Daylight Exploration Rover Mission Architecture. A. B. Madhu Thangavelu [1] and C. D. Saba Raji [2], [1] University Of Southern California, mthangav@usc.edu, [2]University Of Southern California, Sraji@usc.edu. (Contact: mthangav@usc.edu)



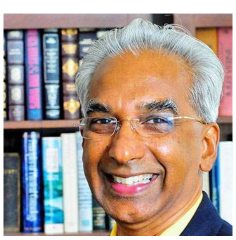


The LEADER Lunar Equatorial Daylight Exploration Rover traverse mission concept proposes an exciting alternative to Artemis lll. The LEADER proposal plans to return crew to the Mare Tranquillitatis region to explore the pits and conduct a traverse to the Apollo 11 site to survey the landing site in order to assess, protect and preserve the historic site and its contents. The LEADER mission is proposed as a phased, evolutionary dress rehearsal to test the capabilities and performance of commercial space transportation systems as well as lunar surface operations systems before attempting a much more complex polar landing and associated activities.

The LEADER mission is built around certain core principles. They include Low Earth Orbit (LEO) integration and staging at ISS, enhancing safety through integrated design, simplifying crew transfer EVA needs between transit, lunar lander and surface vehicles that also provides instant mobility and flexibility upon lunar landing, emphasizing efficiency in lunar surface exploration. Innovative systems proposed for the LEADER mission include modular, fully reusable propulsion systems and the use of a thrust pallet for cislunar transport stages and controlled rupture airbag landing systems for final descent and touchdown stage to curtail debris production by the heavy LEADER lunar rover.

Integration of the LEADER mission in LEO, assisted by the crew of ISS has several benefits including enhanced global participation and crew adjustment period in the LEADER mission that outweigh the Earth-Moon celestial alignment limitations. The ability of the LEADER pressurized rover to serve both as a habitat module and a rover during the entire 2-weeks mission will enable astronauts to explore sites along the mare traverse while being monitored from orbit, without the need to frequently return to a lander, maximizing the productive output of the LEADER mission and paving the way for a sustainable human presence on the Moon.

This is an ongoing study and several trades among the elements are being assessed. Aspects of the LEADER mission plan and profile along with systems and operations being studied are outlined.

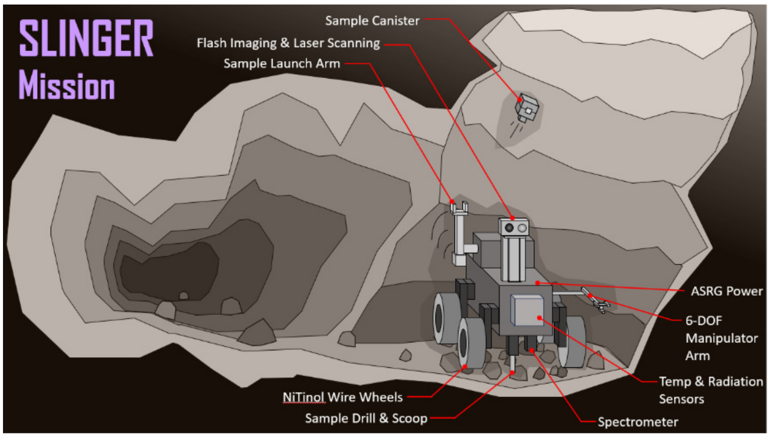


Madhu Thangavelu
"Conducts the ASTE527 graduate Space Exploration Architectures Concept Synthesis Studio in the Department of Astronautical Engineering within the USC and he is also a graduate thesis adviser and teaches the graduate Space Architecture seminar in the School of Architecture at USC."

Saba Raji
Creative Architectural Designer | Building Performance & Technology Student at School of Architecture at USC | Assoc. AIA | LEED Green Associate.

The SLINGER Mission: Sampling Lunar Interior Natural Geology for an Earth Return Mission

William Crowson, University of Southern California, wilcrowson@gmail.com



Abstract:
Collecting lunar samples for analysis is a critical step in helping scientists develop theories on the origin of the Moon and the history of the inner solar system. Bringing the samples back to Earth allows for much more powerful and sensitive science equipment to be used to help unlock these mysteries. In addition, lunar samples help calibrate remote sensing data from lunar orbiters to improve their results.

Exploration of lunar lava pits has gained renewed interest in recent years. Samples from lunar pits and lava tubes like the Mare Tranquillitatis Pit are of high scientific value because they offer the chance to sample rocks from different layers in the Moon's geological history that have been largely unaltered by surface weathering from micrometeorites and solar radiation. Also, because lunar lava tubes could offer natural protection for future human habitats, collecting samples can help evaluate the tubes for the suitability of a lunar base.

In addition, direct measurements of parameters like temperature and radiation levels of the Moon's subsurface environment have yet to be done and become possible through sensor emplacement in the lava tube interior.

SLINGER is a concept for a commercial robotic lunar sample collecting mission from the Mare Tranquillitatis Pit and is aimed at making basic parameter measurements as well as collecting lunar samples from inside the Mare Tranquillitatis Pit to be directly returned to Earth for analysis.

The SLINGER Mission strives to minimize possible contamination of the samples when accessing and returning samples from the lunar pit. The mission also tries to avoid potentially complicated surface structures assembled on site after landing to access the pit.

This presentation will outline facets of the SLINGER Mission plan, as well as some of the systems being evaluated in the ongoing study for the mission.

William Crowson has a B.S. in Mechanical Engineering from Iowa State University and is a recent graduate from the University of Southern California with a M.S. in Astronautical Engineering. William works for The Boeing Company in Saint Louis, Missouri where he is rotating through a variety of programs and engineering functions as part of the Engineering Career Foundations Program. Before joining the rotation program, he supported the F/A-18 program as a Structural Engineer for five years.

Space Habitation in the Interior by Robotic Exploration (SHIRE)

by Morgan Farrier, Brendyn Byrne, and Nibin Nithyanandham

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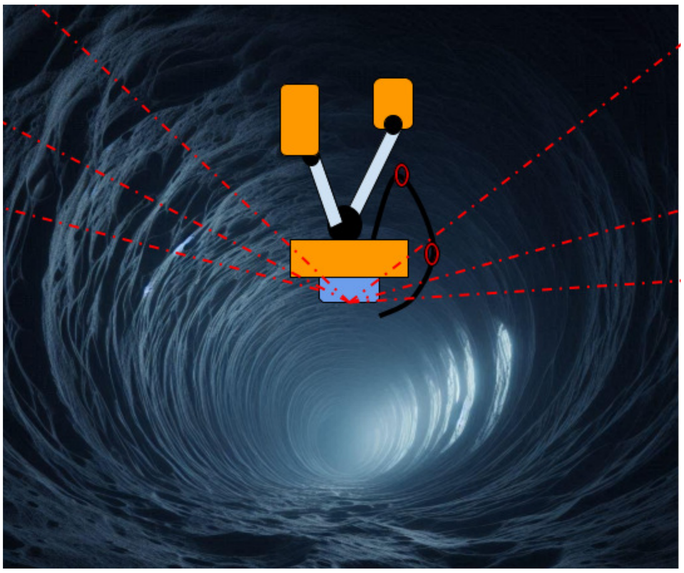


As humans return to create sustainable habitations on the Moon, there is a need to develop robotic systems to survey and prepare lunar habitations prior to manned missions. Lunar Plutons, geologic features observed from the Lunar Reconnaissance Orbiter, are a prime location for the first human settlements. Current data show that meteoritic impact has breached these Lunar Plutons, forming skylight pits that lead to ancient lava tubes. We propose the SHIRE mission to augment these missions to explore and demonstrate habitation feasibility inside Plutons.

The first part of SHIRE is an inflatable mat that will lay over the approximately 60 m funnel at the entrance of skylight pits. This will minimize the risk of a rock avalanche occurring while robotic explorers are approaching the edge of skylight pits by providing a solid surface for them to grab onto instead of loose lunar regolith. The mat will be attached to a projectile hook that will be pneumatically fired into the skylight pit from the landing module. The hook will then be connected to a winch system that will add tension to the mat once the hook has secured itself into the side of the skylight pit. The mat will then use left over cold gas from the lander to inflate its rims to prevent regolith from shifting onto the mat. This mat will provide a safer method for robots to enter Plutons while avoiding causing an avalanche.

Then, SHIRE proposes deploying a new robotic concept named ELI (Explorer of Lunar Interior). Inspired by Georga Tech's Tarzan and Honeybee's Draco drill, ELI will deploy climbing anchor bolts into the ceiling of lava tubes by drilling. As ELI swings from its anchor bolts on the ceiling, it will provide lidar imaging of the lava tube. ELI will also utilize an umbilical cable connected to the landing module. The anchors and the umbilical cable that ELI leaves behind will be the first public infrastructure inside Plutons, providing power, surface communication, and ceiling fixtures for future water and oxygen lines.

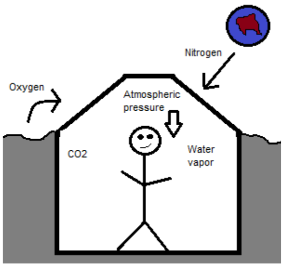
Presenting Author: Morgan Farrier

Morgan Farrier is a recent USC graduate, earning a BS in Astronautical Engineering. She has done mission operations work for small sat and satellite constellations for USC Space Engineering Research Center (SERC) and Northrop Grumman.

One Standard Lunar Homestead Atmosphere

Ben Smith – Founder of Lunar Homestead

The most critical feature of a Lunar Homestead (and any space settlement) pressure hull is that it safely and effectively contains the atmosphere of the habitat. We need to decide on what that atmosphere is before we can start designing the actual habitats. This presentation will cover the basic parameters for determining atmospheric composition and pressure and will explain why the One Standard Lunar Homestead Atmosphere (78% nitrogen/21% oxygen at 70.11 kPa – equivalent to 3000 meters elevation) is the optimal solution.



The 4 primary drivers in deciding on an "ideal" atmospheric pressure and composition for space settlements are:

1. Human physiology – Not only does our breathing gas have to keep our Homesteaders alive, it must also keep them comfortable and safe indefinitely.
2. Fire – In addition to the health of the Homesteaders, the other major safety concern is fire. Changes in oxygen partial pressure and concentration have a direct impact on the flammability of everything in the habitat.
3. Logistical concerns – Lunar Homesteaders will have plenty of oxygen once mining and refining operations are underway. Nitrogen (or any physiologically inert gas), carbon, and water (all necessary ingredients for a breathable gas mix) are another story. Decisions made now will have a direct impact on the initial and ongoing expenses of every Homestead.
4. Engineering requirements – Building a sustainable, long-term human (and other life forms) life support system is a huge engineering challenge. Selecting a breathing gas is the first part of the puzzle.

Ben Smith is an Independent Lunar Settlement Scientist and Founder of Lunar Homestead. Lunar Homestead operates from the viewpoint that governments and corporations are not going to settle the Lunar frontier; groups of motivated individuals (with the right Frontier-Enabling Tech) will. Lunar Homestead is developing that tech.

You can learn more, and get involved, by going to the Lunar Homestead website (www.lunarhomestead.com).

GENERAL OVERVIEW ON WATER EXISTENCE IN LUNAR REGOLITH

BAY, İ.[1], KAYA, Y.[2] TOKLU, Y.C.[3]

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2. Beykent University, İstanbul, Turkiye, yusufkaya@beykent.edu.tr,
3. Istanbul Aydin University, İstanbul, Turkiye, cengiztoklu@gmail.com,

Existence of water on the Moon has been one of the topics that researchers have focused on for the last few decades. Some studies conducted in recent years have changed the view that there is no water on the Moon. Latest researches have shown that water on the lunar surface is present in either hydroxyl (OH) or water ice forms. So the dilemma in between the old and recent indicators leads this study be conducted.

Present study investigates five subtitles that are existence, sources, amounts, detection and location of the Lunar Water.

Missions of NASA and other Space Foundations those were focussed on existence of the water on the Moon regolith have been scrutinised thoroughly. This review summarises alternative sources of activities that may indicate the existence of water in different forms. The key to get closer to the main goal lies on detection of the Lunar water. Methods for detecting the Lunar water such as Spectroscopy, Neutron Spectroscopy, Radar Mapping, Thermal Analysis and Mass Spectroscopy and all of them have been scrutinised.

Within the scope of this presentation, the studies carried out with respect to parts were mentioned. Each parts have been detailed and the ongoing developments from past to present have been tried to be revealed.

Asst. Prof. Dr. İbrahim BAY

He achieved his BSc in Civil Engineering, MSc in Hydraulics from Eastern Mediterranean University and, PhD in Coastal Engineering from the University of Liverpool. He worked as an engineer and modeller for a DEFRA funded research project at HR Wallingford in the UK for a year and a half during his PhD. He worked as a Project Engineer, Project Manager and Consultant at WSP Development and Transportation Plc in the UK. As of 2010, he started to work as an academic at Cyprus International University and moved to European University of Lefke in 2014. He was the Chairperson of the Civil Engineering Department for 8 years and still offering consultancy to Turkish Embassy for investments on infrastructure projects in TRNC.

Yusuf KAYA, MSc.

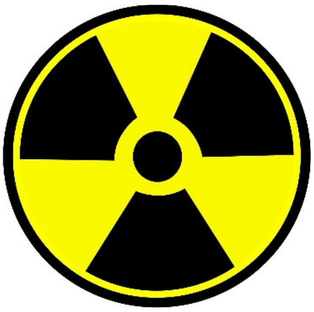
Yusuf Kaya obtained his BSc in Civil Engineering from Zonguldak Bulent Ecevit University and MSc in Civil Engineering (specialised in Geotechnical Engineering) from Yıldız Technical University. He is continuing for his PhD in Hydraulics in Civil Engineering. He works as a Research Assistant at Beykent University, Istanbul. He is enthusiastic in topics: soil behaviour, foundations, hydraulics, artificial intelligence application in Civil Engineering, space searches and droughts.

Professor Y. Cengiz TOKLU, Ph. D.

Professor Toklu obtained his BS and MS degrees in Civil Engineering from Middle East Technical University, Ankara, Turkiye and his doctorate from Universite de Pierre et Marie Curie (Paris VI), Paris, France. He directed and/or supervised numerous giant projects in Turkiye and taught in several universities as Department Head or Dean. Currently being affiliated to Istanbul Aydin University, he considers himself a space civil engineer and conducts research on possible construction activities on space bodies. He is the leader of a research group that made Turkiye the 10th country on Earth in producing lunar regolith simulants.

The Basics of Space Radiation and the Challenges It Presents

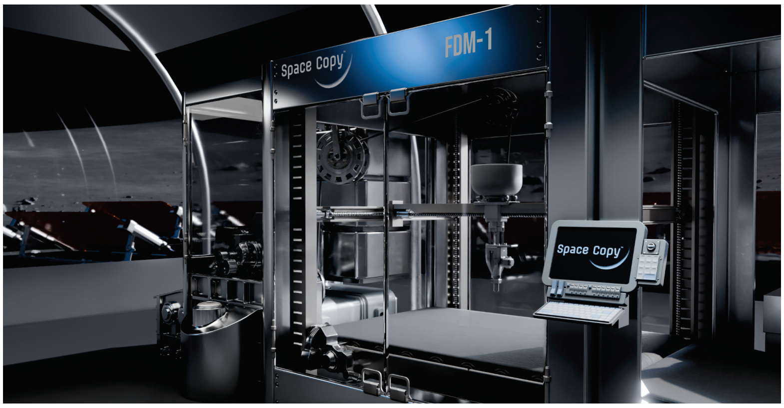
James H. Sloan, Information Universe, Jsloan12@Earthlink.net



There are two sources of particle radiation in space, Solar Proton Events (SPEs) of which Coronal Mass Ejections (CMEs) are considered a subset and Galactic Cosmic Rays (GCRs). These sources of radiation are then reduced by physical shielding of 0.25 grams per square centimeter (g/cm^2) for a space suit, 20 g/cm^2 for a deep space vessel, and 1,000 g/cm^2 for lifetime protection at a base. The purpose of this paper is to provide an understanding of radiation and to see how it will influence our future designs and activities on the Moon. Limits on the amount of radiation that we can receive vary by age and sex. These radiation limits will determine how much work time we will have in space suits and will require burying our living quarters under six meters of regolith or placement in lava tubes.

In 1964 as a ten year old, James H, Sloan looked at the space activity around him and decided that he would join the settlers of the Moon when he reached adulthood. To this aim he received a Batchelor's degree in electrical engineering and joined the growing Air Force Space Program as an Air Force Officer . He was privileged to work in the Air Force's Advanced Plans Office and served on Project Forecast II. The downturn in the aerospace industry led him to a Masters Degree in International Relations. Released from military service in the 1990s, he struggled to return to Federal service as a civilian analyst and retired in 2014 to pursue his passion for space settlement.

SPACE COPY: TECHNOLOGY FOR ISRU ENABLED LUNAR MANUFACTURING



Abstract: The use of additive manufacturing for in-space manufacturing (ISM) of infrastructure, and precision tooling are of interest to lunar colonization efforts pioneered by space agencies and the greater science community from both a scientific merit perspective, and an economic perspective for reducing lunar resupply payload cost, and frequency. The development of advanced lunar hardware introduces an improved method for additive manufacturing, and the integration of autonomous powered material characterization, beneficiation, and qualification sub-systems, allows for the identification, handling and effective use of lunar resources for off-world construction activities. In order to successfully shape the next generation of space hardware technologies, it is essential to explore the development of technologies that will serve as the foundation for lunar colonization and to provide support through funding, facility access, and global partnerships to ensure the safe, rapid, and responsible development of the Moon as both exploration sites and protected areas of natural importance. As additive manufacturing serves as a precursor to future technology enablement and long-term sustained human presence on the lunar surface, we aim to explore 3D printing as a core method of infrastructure production using regolith and lunar-derived materials as resources for off-world construction. UN COPUOS identifies various sustainable development goals that coincide with the invention of technologies to support lunar colonization, with the aim of visibly demonstrating successful prototyping, testing, and initiation of these technologies to ensure a thriving lunar economy. Space Copy serves as an example of private industry leaders striving to conceptualize lunar manufacturing using ISRU. With validation of the company's technology well underway, the future development of lunar hardware for regolith-based manufacturing holds potential for both crewed and uncrewed missions, and extends itself to applications for terrestrial manufacturing in extreme environments for defense applications. This discussion centers around education of current initiatives and technologies being developed for lunar-enabled additive manufacturing, chronicling historical and current traction, while also highlighting the need for developing an internationally upheld framework for initiating development, testing, launch, and operation of core space hardware that will significantly contribute to Artemis and the goal of sending humans back to the Moon on a permanent basis on a visible recognizable scale.

Author Biography: Madison C. Feehan is the founder and CEO of Space Copy and co-founder and CFO of Moon Trades. As an early career professional based in Edmonton, Alberta, Canada with a background in Commerce and advanced lunar instrument development for NASA's Planetary Science, Heliophysics, and Astrophysics divisions, Madison's initiatives are focused towards combining deep-tech development for in-situ resource utilization with entrepreneurship; while serving as a Subcommittee Advisor for UN COPUOS, and the G100 Region Chair of Space Technology and Aviation for the Province of Alberta.

Artemis Society International and the founding of the Moon Society

Randall Severy
Mount Airy, MD
severy@severy.net

Randall was one of the founders of the Moon Society and served as the organization's first Chairman of the Board from July 2000 to August 2003 and also served as Vice President of the organization from July 2000 to December 2001. He remained on the Board of Directors of the Moon Society until 2011. Randall has also served as a Director of Artemis Society International since June 1996, and has been a member of the National Space Society since the founding of that organization and a member of the L5 Society before that since the 1970s. Randall has also served on the boards and as a member of numerous other space organizations.

This presentation will provide a history lesson on the early days of Artemis Society International, from shortly after the founding of the organization up until the founding of the Moon Society in 2000. It will include a review of key events in the Society's early history, including the Future Fantastic episode featuring the Moon Society from August 1996, the First Annual Lunar Development Conference in 1999 in League City, Texas and other conferences, and the French E=M6 TV segment from January 2003.

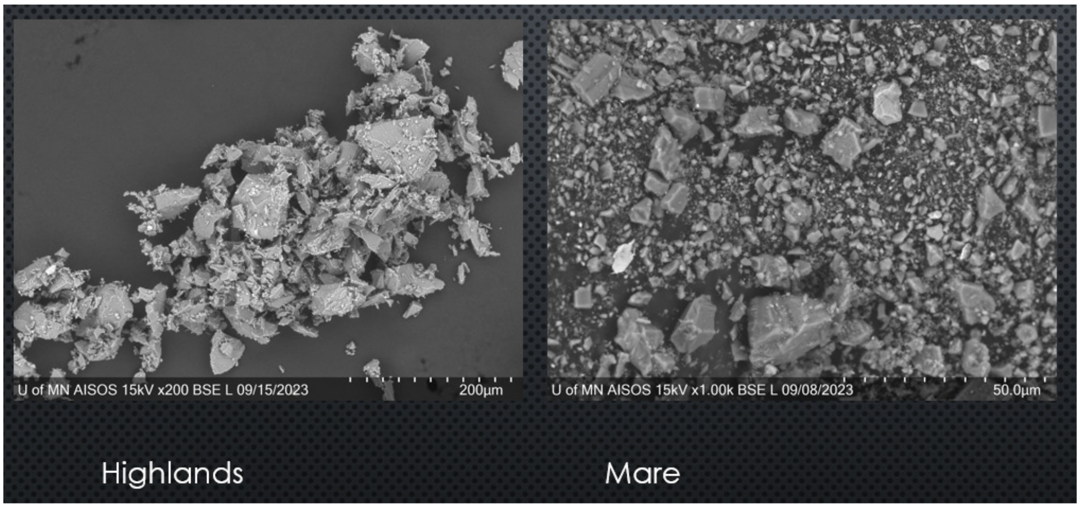
Nadia Khan	**Tentative: Waste recycling**

Abstract not received, 24/6 2024

Lunar Agriculture: Transformation of Lunar Regolith into Soils to enable space agriculture

Adam Williams, University of Minnesota, adam@oeac.space

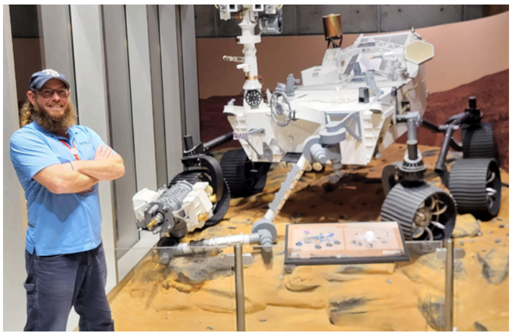
This presentation will explore the current state of the Lunar Regolith transformation research, explore upcoming projects, and present new findings since the LDC 2023 presentation. Topics covered will include key factors for lunar regolith and agriculture. Transformation strategies. Test Results including Soil, Carbon, Nitrogen, pH. It will also explore pioneer plant species and promising results.



Adam Williams is a PhD Student and professional engineer with 15+ years' experience as an engineer specializing in test and product development. Adam's PhD research is focused on Lunar Agriculture. In addition, Adam has a Bachelors in Economics and Philosophy, Masters degrees in both Software Engineering Bioinformatics (agriculture robotics focused), a Grad Certificate in Space Resources from Colorado School of Mines, and a Masters in Space Resources from Colorado School of Mines (focus on lunar geology and agriculture). Adam is also an active volunteer including community service organizations as well as serving as a Space Ambassador for the National Space Society.

Self-Organizing Wetland Bioreactors (SOWBs) Application to Mining on the Moon: Direct and Indirect Bioremediation of Regolith Slurry as a Design Tool for Mine Influenced Water (MIW) Benefaction

Authors: Colin Lennox (presenter) & Mikayla McCord

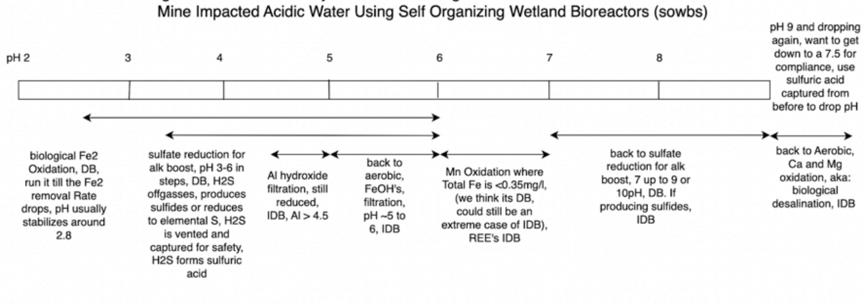


Mikayla McCord, ArcologyX
Altoona, PA
mikaylamccord16@gmail.com
Mikayla is a recent graduate of Johns Hopkins University with a Masters in BioTech and has several years of microbiology laboratory experience.

Colin Lennox, CEO and PI of EcoIslands
Altoona, PA
colin@ecoislandsllc.com
Colin has been building and investigating self-organization in open and semi-enclosed ecological systems for 15 years.

Self-organizing wetland bioreactors (SOWBS) provide a designer of mine influenced water (MIW) treatment systems a tool to harness ubiquitous microbiological processes in methodical and novel layouts for a variety of MIW load reclamation and beneficiation. SOWBs efficacy comes from the ability to grow and maintain very high masses of attached biofilms that are self-selecting dependent on the MIW load entering any portion of a SOWB treatment system. As the MIW load is sequestered or remediated, the net water biochemistry changes, developing new, selective pressures on the predominant, but ever shifting, biofilm metabolisms found throughout the treatment train. Depending on the MIW's load, influences such as iron, aluminum and manganese are either directly or indirectly remediated by the self-organized biofilms. Direct bioremediation (DBR) is when a microbe uses the influence in its metabolic triplet to respire, grow and reproduce. Indirect bioremediation, or IBR, are processes such as biofilms "stickiness" and the tendency to colonize and coat all surfaces in the SOWB, including precipitating matter, that leads to capture and sequestration in the SOWB of influences that are not part of a metabolic triplet. This knowledge can be applied to other waste streams beyond mining.

Figure 1. In-Situ Alkalinity Production Driving Direct and Indirect Bioremediation of Mine Impacted Acidic Water Using Self Organizing Wetland Bioreactors (sowbs)



How to Mine Icy Regolith combining a Slusher, a Hoist, and IoT Technologies in a Lunar Crater excavated in our own backyard

Author and Presenter: Victor O. Tenorio, Ph.D., University of Arizona, vtenorio@arizona.edu

Among the diverse techniques for extracting Icy Regolith to be chosen for mining the Lunar surface, the conventional method using Slushers with a Hoist, enhanced with Internet-of-Things (IoT) technologies becomes a promising option. Based on equipment traditionally utilized in underground mines for confined stopes and short-scale operations, the present proposal includes the steps required for opening a 10-meter diameter prototype excavation in a testing area at San Xavier Mine Laboratory in Sahuarita, AZ, with the shape of a Lunar Crater as found at the South Pole of the Moon, modernized with mechanical accessories, load-haul-dump equipment, a wireless mesh, digital cameras, IoT sensors, and regulators, to allow automation functions, teleoperation, surveillance and production control. The objective is to start production with manual operators, and gradually increase the levels of automation, while monitoring the continuous extraction of color-coded regolith simulant and defining ad-hoc key performance indicators. Procedures for keeping the continuity of operations and its repeatability are also included.

Victor Tenorio is a Mining Engineer from PUCP (Lima, Perú), with an M.S. from University of Alaska Fairbanks. He obtained a Ph.D. from University of Arizona (2012). His research interest is focused on Smart Mining and Decision Support Systems for optimizing productivity. Worked on several engineering projects in Peru and Chile. Currently Professor of Practice at the University of Arizona, teaching: Introduction to Mining Engineering, Underground Mine Design, Mine Examination & Valuation, Digital Mining, and Introduction to Moon Mining. Participated in the Autonomous Mining Program with Freeport-McMoRan until Dec 2008. Founder of the Wildcat Moon Miners (2021), a research team dedicated to participating in Space Mining-related projects and competitions.

USE OF CABLE-STRUT STRUCTURES ON SPACE BODIES

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There are many possibilities for constructing habitats on space bodies, one possibility is the use of cable-strut structures. As the name indicates, cable-strut structures are formed by cables and struts. The main properties of these structures are that the struts carry compressive forces while the cables carry tensile forces. Cables and struts are the simplest materials that can be transported from the Earth to space with the least difficulty and cost. These properties make them very convenient for applications on Moon when one considers that weight and volume are very important negative factors in the transportation from Earth to Moon. Cable-strut structures may be used in the form of towers, beams, closed structures, bridges, and many other types. Tensegric structures, that are also called tensile-integrity structures, are a sub class of cable-strut structures. In general cable-strut structures are not closed but using for example membranes reinforced by other construction materials, closed structures may also be formed by employing them. On Moon and Mars, the main stresses will be coming from the internal pressure, thus the real structural problem for cable-strut habitats will be to make them resistant to internal pressure. Other loads acting on these structures will be coming from moonquakes, and the shielding against environmental effects and meteorites on and around them made by regolith or other construction materials. The design and analysis of cable-strut structures cannot be performed with well-known techniques due to their highly nonlinear behavior. In the presentation, brief information will be given as to analysis of these structures including the new technique known as Finite Element Method with Energy Minimization (FEMEM) and form finding.

Professor Toklu obtained his BS and MS degrees in Civil Engineering from Middle East Technical University, Ankara, Turkiye and his doctorate from Université de Pierre et Marie Curie (Paris VI), Paris, France. As a civil engineer, he directed and/or supervised numerous giant projects in Turkiye. As an academician he conducted research on application of optimization techniques to engineering, space civil engineering, nonlinear analysis of structures, engineering education and construction scheduling and made numerous publications. Dr. Toklu is the developer of the method "Total Potential Optimization using Meta-heuristic Algorithms (TPO/MA)" and its more general version "Finite Element method with Energy Minimization (FEMEM)" which is shown to be more successful than classical methods in analyzing non-linear structural systems, under-constrained structures, unstable structures, degenerate structures, and structures with non-unique deformed shapes. Dr. Toklu formed a group that made Turkiye the 10^{th} country in the world to produce simulants for the lunar soils brought by Apollo missions, and the first group to produce simulant for the lunar soil sample brought by the Chinese mission Chang-5. He is a member of the Aerospace Division of American Society of Civil Engineers (ASCE) and a member of the Board of Directors of The Moon Society.

Sustainable Lunar Settlement Design:
Off-world Anthropological Space Infrastructure Settlement (OASIS)

Gary Barnhard (et al? Presenter and co-authors tba)

The Off-world Anthropologic Space Infrastructure Settlement (OASIS) project is a Kepler Space University (KSU) initiative to develop a prototype simulation analog for a sustainable lunar settlement buildable within a ten-year time horizon. The OASIS project began as an ideation exercise to ask and begin to answer fundamental questions concerning how science, systems engineering, and architectural design would drive a program where the desired outcome is a sustainable, scalable lunar settlement where the inhabitants would thrive, not just survive, thereby maximizing the probability of mission success.

The OASIS postulate is that the signatories to the Artemis Accords achieve a confluence of interest whereby:

(1) Developing sustainable offworld human settlements is deemed a priority outcome.

(2) The endeavor to accomplish the same is best served by fostering cooperation, collaboration, and competition.

(3) Our evolving understanding of science, systems engineering, and architectural design fosters our ability to survive and thrive as a species.

(4) We must translate all we learn into being the best stewards of our Earth and life as we know it.

The OASIS Project consists of three phases:

- Phase 0 -- OASIS Earth and flight analog testing for required elements & distributed systems
- Phase 1 -- OASIS in-situ checkout and evaluation of required elements & distributed systems
- Phase 2 -- OASIS Main Buildout & Operations

The process of suspending disbelief, learning how to build the future, and the relevance of different perspectives are integral to the design process. The definition and flow down of the Program and Systems level requirements to the elements and distributed systems must be accomplished. The overall management of the program's cost, schedule, technical risk, and the orchestration of all available program resources to maximize the probability of mission success (a.k.a., “herding” cats) are critical workflow considerations. Interface accommodation requirements, as well as interface standards, must be defined, tested, and applied as an integral part of the design, build, and test processes to ensure the integrated system can function properly (i.e., in a manner that meets or exceeds the requirements in terms of performance, availability, and safety/security). The resulting flow down and definition of verifiable functional requirements into the elements and distributed systems and the flow up of the evaluated efficacy of their implementation by testing, verification, and validation are part of orchestrating the systems engineering processes. This paper provides a top-down introduction and overview of the OASIS project.

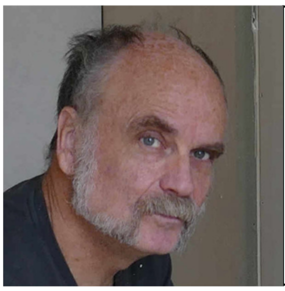
Production Flow Breakdown for Human Survival: Base on the Moon and Analogue in Lappträsk

Niklas Järvstråt, ISRUtech Sweden AB

What do humans need to survive? Air, water, food, clothes, a place to sleep (warm and safe), means to produce or acquire previous items, means to make the tools to produce or acquire previous items, the raw materials required as input to the last couple of items. And of course, the know-how and enough skilled people to put all of that to work.

How is anything of that different on the moon? Not much, actually, and we are pretty good at all of it, really. There are a few things that will be trickier on the moon than here, such as exposing plants to air and light. But people have been pushing boundaries of what is possible to produce and how cheap materials can be used for a long time. Dropping the economies of scale involved in buying things from the other side of the globe, the self-sufficiency vital for survival on the moon may also reduce environmental impact of production and transport in local Earthwhile circular economies.

What is missing for putting that to work on the moon? Again, not much, actually. But everything needed is scattered over the world, in different companies and known by different people. At Moonbase Lappträsk we are trying to bring together that knowledge and try it out safely in a scale relevant to a small society.



Niklas Järvstråt is a rocket scientist of sorts and specialising in high temperature behaviour of materials, with experience not only from the type of superalloys that make up rocket and aircraft engines, but also more common steel and aluminium alloys, as well as wind turbine composites. He is sure some of that will somehow be useful in rebuilding an old wooden schoolhouse into a small-scale analogue of modern society, striving towards self-sufficiency using only resources found on the moon.

Building a Lunar Civilization

Author and Presenter: Alastair Storm Browne

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Alastair Browne holds an M.S. in Space Studies from the University of North Dakota, and has done presentations at the International Space Development Conference, the Global Initiative Field Trip, and the Mars Society. He has also written various articles on space development. He has recently completed a series of podcasts on his book, Cosmic Careers, and can be accessed at https://www.buzzsprout.com/2280512/episodes.

This presentation covers the development of the Moon in incremental steps, all described in great detail, sometimes scientifically, from the very beginning, and how the resources can be developed and sold at a profit, leading up to new industries.

The establishment of a lunar base has been proposed for one of three different functions:
1. Scientific investigation of the Moon and the application to research problems.
2. Exploitation of Lunar resources for space-based industries.
3. Development of a self-sufficient and self-supporting lunar base, becoming the first extra-terrestrial space colony.

The first proposal seemed the most likely when NASA first planned a lunar base.

The second proposal covers developing lunar resources. This can be accomplished by mining minerals, extracting oxygen from the lunar soil, and manufacturing goods from these resources, to sell at a profit, to insure a payback of initial investments and to pay for the expansion of the lunar base. Space industries can then be set up to support the settlement of space. This process can also help fund research.

The third proposal has been simply to build a lunar settlement, use its resources for expansion, establish an agricultural system, and, with the use of its oxygen, minerals, and food supply, make the settlement expandable and completely independent of Earth, with an ever expanding population base. This would later evolve into a city and then a lunar civilization.

All three are interdependent upon one another, so in order to have a self sufficient base, all three of these proposals must be utilized simultaneously. A self sufficient lunar settlement must have an expanding industrial base, to support it and make it grow. These industries also need new ideas stemming from scientific research. This lunar base is to be built in several stages. This presentation is a detailed discussion of the three separate proposals and their benefits, and how a lunar base, and eventually, a civilization, can evolve from this process.

Environmental Justice Considerations in Lunar Development

Erika Nesvold, JustSpace Alliance, ernesvold@justspacealliance.org

As we continue to search for solutions to the technological and economic questions facing us on the moon, we must also ask: What are the ethical and human rights challenges of lunar development? This presentation will provide a brief survey of critical questions in environmental justice that must be considered by planners, researchers, and regulators as we increase human activity on the lunar surface.

For example: How can we share the lunar environment and its resources between groups with diverse motivations, from science to profit to exploration to national interests? What can we learn from the history of land use conflicts on Earth, especially in similar environments like Antarctica or international waters, to avoid violent or disruptive conflicts on the moon? And can we uphold the Outer Space Treaty's vision of space exploration "for the benefit and in the interests of all countries" during a potential lunar gold rush for the finite valuable resources and useful locations on the moon's surface?

Simultaneously, how can we share the moon's environment with future generations by incorporating intergenerational justice into our lunar development plans? How much of the moon's resources and undeveloped surface should be preserved for our descendants? What infrastructure and policies can we put into place now to ensure that humans living and working on the moon in the future have the greatest opportunities?

And finally, to what extent should we protect the lunar environment from ourselves? Is there intrinsic value in the lifeless wilderness of the surface that demands consideration and protection from potentially harmful human activities?

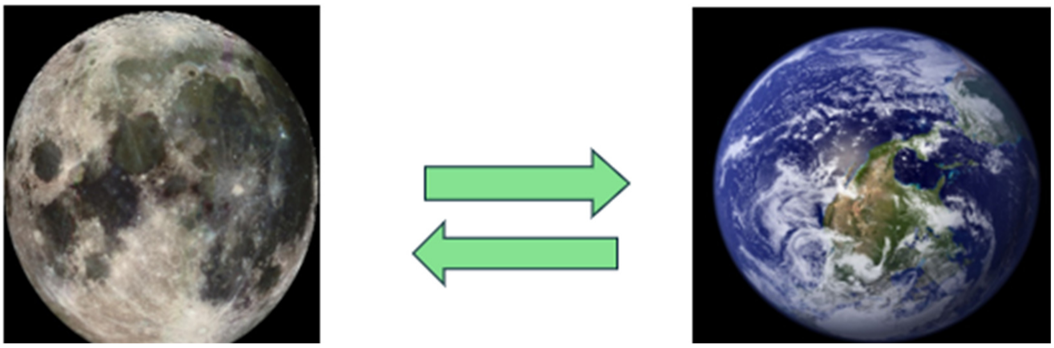
These questions must be considered by everyone working in lunar development to ensure a better future for our interaction with the moon's environment. To that end, this talk will also present useful parallels and case studies from the history of environmental justice on Earth that can be applied as we expand our civilization into space.

Erika Nesvold (ernesvold@justspacealliance.org) is an astrophysicist who has worked as a researcher at NASA Goddard and the Carnegie Institution for Science. She is an Astrophysics Engineer for Universe Sandbox, a physics-based space simulator; cofounder of the nonprofit organization the JustSpace Alliance; and the creator and host of the podcast Making New Worlds. She is also the author of *Off-Earth: Ethical Questions and Quandaries for Living in Outer Space* and co-editor of *Reclaiming Space: Progressive and Multicultural Visions of Space Exploration*.

A circular economy, new tech and smart systems thinking on the Moon – and on Earth.

Ulf E Andersson, Swedish Future Scanning

What types of technologies and smart systems do we need to have a permanent human presence on the Moon? In particular, for providing those working and living there with food, water and air. The answer is very similar to the tech and systems we need to have for creating sustainable cities on Earth, based on a circular economy. Those who work for the circular economy and sustainability on this planet can learn a lot from those who work for crewed bases and settlements outside the Earth. But the space sector should learn much more from the much larger number of people working for sustainable circular solutions for food, water and other resources on Earth – solutions that might be applied for the benefit of the humans that soon will work and live on the Moon.



Ulf E Andersson is Vice President of the national NGO Swedish Space Society (Swedish: Svenska Rymdsällskapet) – working to promote the space sector and human presence in space. We arrange seminars, technical visits, publish a newsletter, publish opinion materials newspapers and on social media. http://www.svenskarymdsallskapet.org/.

He is also CEO of the consultancy Swedish Future Scanning (Swedish: Svensk Framtidsbevakning) – focusing on urban food production, wastewater recycling and urban greenery. We are scanning of the world for good tech, biological solutions and smart systems in these areas. Personal mail ulferikanderssson@gmail.com

James L Burk	**Opportunities for Collaboration between Moon and Mars**

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