2024 Lunar Development Conference

book of abstracts

Presentations and Authors

Author	Presentation (subject to change)	Abstract available
Adam Williams	**Lunar Agriculture: Transformation of Lunar Regolith into Soils to enable space agriculture**	X
Alastair Browne	**Building a Lunar Civilisation**	X
Ben Smith	**One Standard Lunar Homestead**	X
Cengiz Toklu	**Use of Cable-Strut Structures on Space Bodies**	X
Colin Lennox & Mikayla McCord	**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**	X
Erika Nesvold	**A quick survey of environmental justice considerations in lunar development**	
Greg Baiden	*Tentative: Establishing a lunar underground outpost: shifting the paradigm for future space exploration, settlement, and commerce*	
James L Burk	**Opportunities for Collaboration between Moon and Mars**	
Madhu Tangiaveli	**PLUTONS: Pits & Lunar Lava Tube Exploration for Potential Habitation & Settlement**	
Madison C. Freehan	**Space Copy: Technology For ISRU Enabled Lunar Manufacturing**	X
Melodie Yashar	*Tentative: Concrete 3D printing*	
Nadia Khan	*Tentative: Waste recycling*	
Niklas Järvstråt	**Production flow breakdown for human survival: Base on the Moon and Moonbase Lappträsk analogue**	X
Randall Severy	*Artemis Society International*	
Saba Raji	**The LEADER: Lunar Equatorial Daylight Exploration Rover Mission Architecture**	X
Ulf E Andersson	*Tentative: Circular Economy*	

Program (preliminary outline)

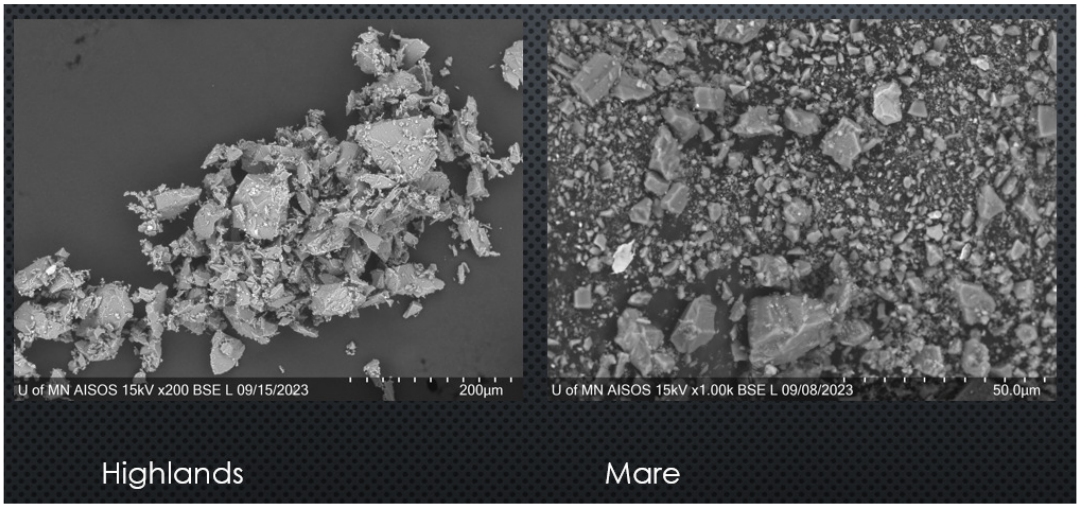
Saturday, 20th July						
GMT	PDT	EDT	CEST		Title	Speaker
15	8	11	17		Opening	TBD
				Session 1	Keynote	TBD
16	9	12	18			
					Presentation 1	TBD
17	10	13	19		Presentation 2	TBD
					Presentation 3	TBD
18	11	14	20		Presentation 4	TBD
				Session 2	Presentation 5	TBD
19	12	15	21		Presentation 6	TBD
					Presentation 7	TBD
20	13	16	22		First lunar landing + footprints in Regolith	Niklas Järvstråt, (and/or VIP/surprise)
					Panel discussion, theme TBD (Historic?)	Panel + All
21	14	17	23			
					Closing reflections, day 1	TBD

Sunday, 21st July						
GMT	PDT	EDT	CET		Title	Speaker
15	8	11	17		Opening, day 2	TBD
				Session 3	Presentation 8	TBD
16	9	12	18		Presentation 9	TBD
					Presentation 10	TBD
17	10	13	19		Presentation 11	TBD
					Panel discussion, theme TBD (Current?)	Panel + All
18	11	14	20			
				Session 4	Presentation 12	TBD
19	12	15	21		Presentation 13	TBD
					Presentation 14	TBD
20	13	16	22		Presentation 15	TBD
					Panel discussion, theme TBD (Future?)	Panel + All
21	14	17	23			
					Closing reflections	TBD

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.

Building a Lunar Civilization

Author and Presenter: Alastair Storm Browne

Alastair Storm Browne
Co-Author of Cosmic Careers (with Maryann Kaninch)
Durham, North Carolina
alastair11@gmail.com

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.

One Standard Lunar Homestead

Ben Smith – 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 over an indefinite time.
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.

This presentation will address these concerns and show that there are only a few viable options for space settlement breathing gases. And why the One Standard Lunar Homestead Atmosphere is the best choice.

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. Ben is working on developing the Frontier-Enabling Technology and Techniques these Homesteaders will need to thrive on the Lunar frontier. And anywhere else in the Solar system.
Lunar Homestead's current primary project is Shielded Pressurized Oxygen Resource Extraction (SPORE). SPORE combines resource extraction with habitable space creation, while avoiding or minimizing the hazards of Lunar surface operations. Other projects include extracting oxygen and iron from Lunar basalt and using Lunar iron to create habitat pressure hulls.
You can learn more, and get involved, by going to the Lunar Homestead website (www.lunarhomestead.com).

USE OF CABLE-STRUT STRUCTURES ON SPACE BODIES

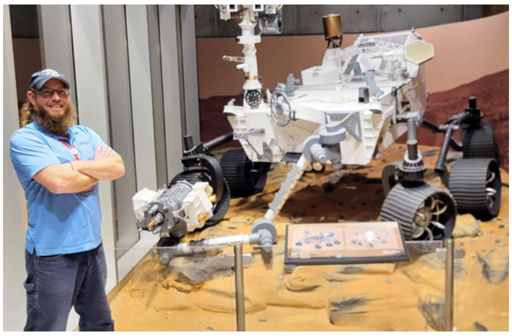
Y. Cengiz TOKLU
Istanbul Aydin University, cengiztoklu@gmail.com, https://cengiztoklu.com

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 10th 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.

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

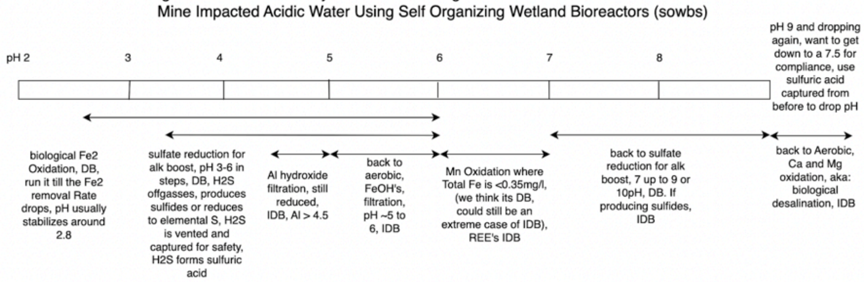


Mikayla McCord, ArcologyX
Altoona, PA
mikaylamccord16@gmail.com
Mikayla is a recent graduate of Johns Hopkins University with a Masters in BioTech and has several years of microbiology laboratory experience.

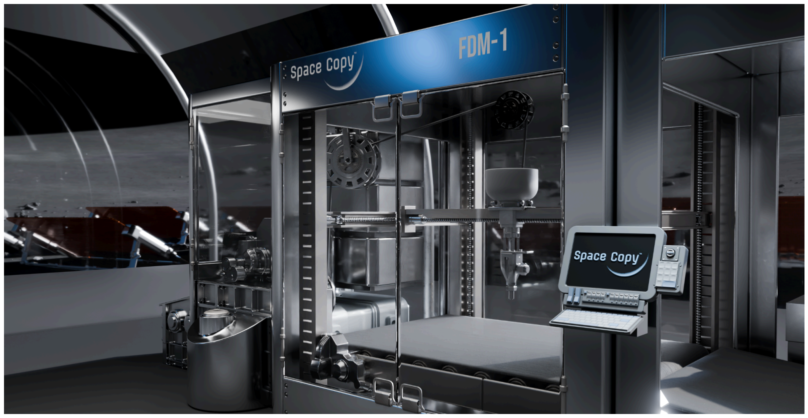
Colin Lennox, CEO and PI of EcoIslands
Altoona, PA
colin@ecoislandsllc.com
Colin has been building and investigating self-organization in open and semi-enclosed ecological systems for 15 years.

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)



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.

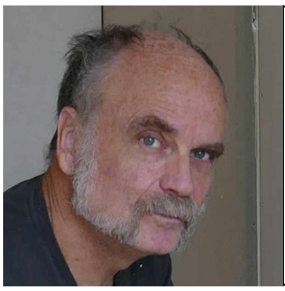
Production Flow Breakdown for Human Survival: Base on the Moon and Analogue in Lappträsk

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.

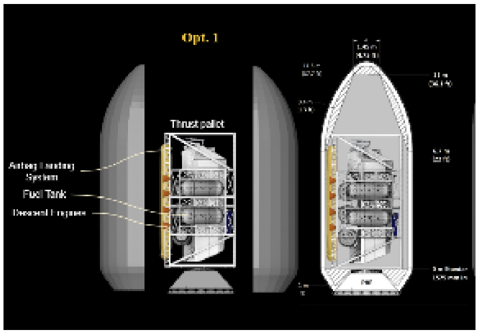
How is anything of that different on the moon? Not much, actually, and we are pretty good at all of it, really. There are a few things that will be trickier on the moon than here, such as exposing plants to air and light. But people have been pushing boundaries of what is possible to produce and how 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.

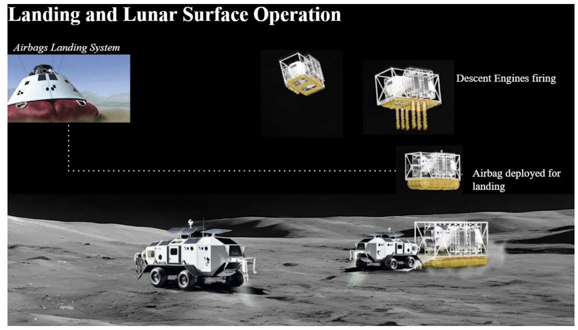
What is missing for putting that to work on the moon? Again, not much, actually. But everything needed is scattered over the world, in different companies and known by different people. At Moonbase Lappträsk we are trying to bring together that knowledge and try it out safely in a scale relevant to a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

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)



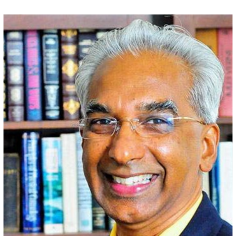


The LEADER Lunar Equatorial Daylight Exploration Rover traverse mission concept proposes an exciting alternative to Artemis lll. The LEADER proposal plans to return crew to the Mare Tranquillitatis region to explore the pits and conduct a traverse to the Apollo 11 site to survey the landing site in order 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.