Science, Technology, Infrastructure, and Commerce

MATRICES Campaign: Manufacturing Materials and Processes for Sustainability in Space

John Vickers | October 9, 2024

The Problem

Everything that we do on the moon we've got to figure out how to dispose of it or it's there forever…I'd like to emphasize that the recycle/reuse and sustainability model has to extend throughout the solar system, especially to the surface of other planets."

Pam Melroy, Deputy NASA Administrator

The space ecosystem is expanding rapidly - More people, More destinations, Longer durations, More activities, More commercialization… ***National Academies***

NASA’s Moon to Mars Strategy and Objectives:

Objective-based Approach – Architect from the Right - Artemis Campaign Research

RT-5: Maintainability and Reuse

RT-6:Responsible Use and Behavior in Space

RT-9: Commerce and Space Development

OP-11: In-Space Resources to Reduce Mass

OP-12: Minimize Disturbance to the Environment, Maximize Reuse/Recycling

LI-4: Lunar Surface Advanced Manufacturing and Construction

LI-7: Demonstrate industrial scale ISRU capabilities

PPS-2: Understanding Physical Systems

AS-6: Understanding Environmental Effects

TH-4: In-Space and Surface Habitation

Moon-to-Mars Architecture Definition

- What waste/trash management, disposal, repurposing, recycling, reuse, or other approaches should be utilized for sustainable exploration?
- Initial approaches and capabilities for addressing trash and waste management include inventory management, trash, waste disposal, and storage functions necessary to meet planetary protection requirements.
- As the technologies mature, the capabilities will continue to grow.
- Almost every element in the architecture is being designed to take advantage of some level of reuse, but understanding of risks associated with maintainability and reuse and their impact on safety, science, and long-term sustainability goals will be vital as the Moon-to-Mars architecture is refined and matured.

https://ntrs.nasa.gov/citations/20230002706

Tech Base Functional Domains

GO
Space Transportation

- Advanced Propulsion
- Nuclear Propulsion
- Flight Vehicle Systems (including Ascent Systems)
- Cryogenic Fluid Management

LAND
Space to Surface Operations

- Deceleration Systems
- Guidance & Nav Systems
- Landing Systems & Environments
- Entry Modeling & Instrumentation

LIVE
Surface Infrastructure/ Exploration

- Surface Power
- In Situ Resource Utilization
- Surface Structures & Construction
- Dust Mitigation & Environments
- Surface Mobility & Transportation
- Surface Habitation Systems
- Surface Sustainability & Logistics

EXPAND
In-Space Infrastructure/ Discovery

- Observation Systems
- In-Space Sustainability
- Communications, Positioning, Navigation, & Timing
- In-Space Servicing, Assembly, & Manufacturing
- Small Spacecraft & Distributed Systems

ENABLE
Foundational Capabilities

- Avionics & Sensors
- Robotics & Autonomy
- Advanced Materials, Structures, & Manufacturing
- Advanced Power & Thermal

❖ Capability Portfolio

CATALYSTS
Innovative Mechanisms

- NIAC/CIF/ECI
- STRG
- PCC
- Tech Transfer
- SBIR/STTR
- Flight Opportunities
- TP/ACO
- Inclusive Innovation

Enabling Key Moon-to-Mars Lunar Infrastructure Objectives

LI-1^L: Develop an incremental lunar power generation and distribution system that is evolvable to support continuous robotic/human operation and is capable of scaling to global power utilization and industrial power levels.
MI-1^M

LI-2^L: Develop a lunar surface, orbital, and Moon-to-Earth communications architecture capable of scaling to support long term science, exploration, and industrial needs.
MI-2^M

LI-3^L: Develop a lunar position, navigation and timing architecture capable of scaling to support long term science, exploration,
and industrial needs.
MI-3^M

LI-4^L: Demonstrate advanced manufacturing and autonomous construction capabilities in support
of continuous human lunar presence and a robust lunar economy.

LI-5^L: Demonstrate precision landing capabilities in support of continuous human lunar presence and a robust lunar economy.

LI-6^L: Demonstrate local, regional, and global surface transportation and mobility capabilities in support of continuous human lunar presence and a robust lunar economy.

LI-7^L: Demonstrate industrial scale ISRU capabilities in support of continuous human lunar presence and a robust lunar economy.
MI-4^M

LI-8^L: Demonstrate technologies supporting cislunar orbital/surface depots, construction and manufacturing maximizing the use of in-situ resources, and support systems needed for continuous human/robotic presence.

LI-9^L: Develop environmental monitoring, situational awareness, and early warning capabilities to support a resilient, continuous human/robotic lunar presence.

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LunaRecycle $3 Million Centennial Challenge

- Administration priority to develop a challenge aimed at climate change/sustainability
- Public interest and focus on sustainability
- Potential for terrestrial applications that could disrupt the recycling industry
- Develop and demonstrate novel recycling technology and/or systems
- Teams will address specified waste categories for a permanent lunar settlement of eight people for 365 days
- Design and code a high-fidelity “digital twin” to holistically address the waste management needs by converting the identified waste into useable products
- Design and build a ”working prototype” for recycling one or more more waste categories into useable products

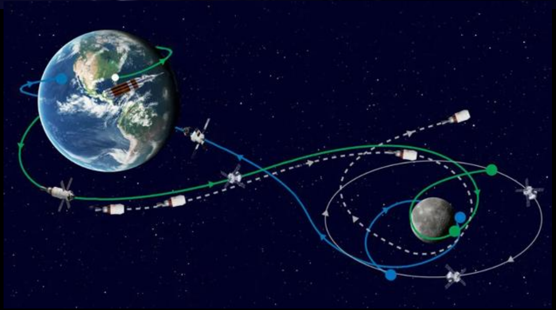
NASA's LUNARECYCLE CENTENNIAL CHALLENGE

FOR THE CRATER GOOD

Waste Management Policies in Antarctica

- Antarctica has strict waste management policies to protect its unique ecosystem. These policies are outlined in the Protocol on Environmental Protection to the Antarctic Treaty.
- All activities in Antarctica must aim to minimize waste generation. This includes reducing packaging, reusing materials, and recycling whenever possible.
- Recycling and disposal: Non-hazardous waste, such as paper, plastic, and metal, is typically recycled or transported back to other countries for disposal.
- Environmental impact assessments: Any new activity or project in Antarctica must undergo an environmental impact assessment to evaluate potential risks and mitigation measures.

Recycling Energy Resources

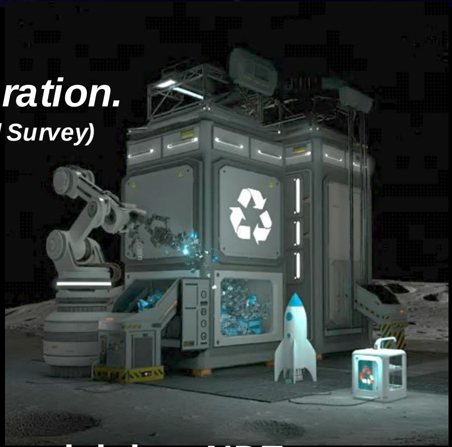


re·cy·cle: verb
convert (waste) into reusable material

- Two-thirds of the aluminum ever produced is still in use today.
- Over 80,000,000,000 aluminum soda cans are used every year.
- A used aluminum can is recycled and back on the grocery shelf as a new can, in as little as 60 days.
- The energy you save by recycling a single aluminum can will run a TV for three hours.
- An aluminum can is worth about 1 cent on earth. The cost of transportation to the lunar surface is about $1,200,000 per kg.

Science and Technology

The combined vision for use of materials found in space and circular lifecycle for materials is vital to Earth-independent, long-duration exploration.
(National Academies. Thriving in Space: Ensuring the Future of Biological and Physical Sciences Research: A Decadal Survey)



Develop the science and technology to enable in-space manufacturing for long term sustainment during future exploration missions (STMD, InSPA, BPS, Multi-Agency, Commercial)

Key focus areas include:

- **ICME/AI/Digital Twins: modeling approaches for manufacturing, construction, joining, NDE, recycling and more with recycled and in situ materials in microgravity.**
- **Materials: Understanding processing, structure, properties in the space environment.**
- **Additive Manufacturing/In-Space Welding: Offers the most utility of any process for a broad range of in-space manufacturing resilience. Despite its potential, AM is new and faces several challenges when applied to critical in-space applications.**
- **Recycling and Reuse: circular material and process design, materials science challenges, remedial materials and processes, economic benefits.**

QUESTIONS?

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