SAMPLE

Cosmic Explorers: In-Situ Resource Utilization

Living Off the Land in Space

Aira Astralis

Free sample: Introduction & Chapter 1

putrabooks.github.io

Buy the full book:

Carousell carousell.sg/p/cosmic-explorers-in-situ-resource-utilization-ebook-pdf-1468078108

Ko-fi

Payhip

Contents

Introduction

Chapter 01: The Discovery of In-Situ Resource Utilization

Chapter 02: Understanding In-Situ Resource Utilization

Chapter 03: Key Characteristics of In-Situ Resource Utilization

Chapter 04: The Science Behind In-Situ Resource Utilization

Chapter 05: Observation and Measurement of In-Situ Resource Utilization

Chapter 06: Important Features of In-Situ Resource Utilization

Chapter 07: In-Situ Resource Utilization in Context

Chapter 08: Modern Understanding of In-Situ Resource Utilization

Chapter 09: Research and Exploration of In-Situ Resource Utilization

Chapter 10: Significant Discoveries About In-Situ Resource Utilization

Chapter 11: Challenges and Mysteries of In-Situ Resource Utilization

Chapter 12: Future Directions in In-Situ Resource Utilization Research

Chapter 13: Fun Facts and Trivia About In-Situ Resource Utilization

Chapter 14: The Significance of In-Situ Resource Utilization

Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

In space exploration, in situ resource utilization (ISRU) is the practice of collection, processing, storing and use of materials found or manufactured on other astronomical objects (the Moon, Mars, asteroids, etc.) that replace materials that would otherwise be brought from Earth. ISRU could provide materials for life support, propellants, construction materials, and energy to a spacecraft payloads or space exploration crews.

It is now very common for spacecraft and robotic planetary surface mission to harness the solar radiation found in situ in the form of solar panels. The use of ISRU for material production has not yet been implemented in a space mission, though several field tests in the late 2000s demonstrated various lunar ISRU techniques in a relevant environment.

ISRU has long been considered as a possible avenue for reducing the mass and cost of space exploration architectures, in that it may be a way to drastically reduce the amount of payload that must be launched from Earth in order to explore a given planetary body.

According to NASA, "in-situ resource utilization will enable the affordable establishment of extraterrestrial exploration and operations by minimizing the materials carried from Earth." In the context of ISRU, water is most often sought directly as fuel or as feedstock for fuel production.

Applications include its use in life support, either directly for drinking, for growing food, producing oxygen, or numerous other industrial processes, all of which require a ready supply of water in the environment and the equipment to extract it.

In the context of ISRU, water heads nearly every prospecting list, valued either directly as a propellant ingredient or as the feedstock from which propellant is made.

Such extraterrestrial water has been discovered in a variety of forms throughout the Solar System, and a number of potential water extraction technologies have been investigated. For water that is chemically bound to regolith, solid ice, or some manner of permafrost, sufficient heating can recover the water. However this is not as easy as it appears because ice and permafrost can often be harder than plain rock, necessitating laborious mining operations.

Where there is some level of atmosphere, such as on Mars, water can be extracted directly from the air using a simple process such as WAVAR. Another

possible source of water is deep aquifers kept warm by Mars's latent geological heat, which can be tapped to provide both water and geothermal power. Rocket propellant production has been proposed from the Moon's surface by processing water ice detected at the poles.

The likely difficulties include working at extremely low temperatures and extraction of water from the regolith. Most schemes electrolyse the water to produce hydrogen and oxygen and cryogenically store them as liquids. This requires large amounts of equipment and power to achieve.

Alternatively, it may be possible to heat water in a nuclear or solar thermal rocket, which may be able to deliver a large mass from the Moon to low Earth orbit (LEO) in spite of the much lower specific impulse, for a given amount of equipment. The monopropellant hydrogen peroxide (H_2O_2) can be made from water on Mars and the Moon.

Aluminum as well as other metals has been proposed for use as rocket propellant made using lunar resources, and proposals include reacting the aluminum with water. For Mars, methane propellant can be manufactured via the Sabatier process. SpaceX has suggested building a propellant plant on Mars that would use this process to produce methane (CH_4) and liquid oxygen (O_2) from sub-surface water ice and atmospheric CO_2.

Historically, oxygen has been one of the primary extraction targets when considering space ISRU.

The main source of oxygen in space is planetary regolith which, when chemically reduced to extract oxygen also leads to the production of metals as a byproduct. Slightly preceding the announcement of the Artemis program by NASA, the study of processes specifically targeting metal extraction started to become more prevalent.

Many use cases have been suggested for metals extracted from off earth resources including as construction materials (Si, Al, Fe, Mg, Ti, Mn, Cr), solid rocket fuel (Al, Mg), energy storage (K, Na, Mn, Ti, Mg, Fe, Al, Si), and thermal fluids and coolants (NaK).

Chapter 01: The Discovery of In-Situ Resource Utilization

Many processes that have been investigated for metal extraction in space are already established processing routes on Earth, with the exception that space ready designs need to account for the significantly different conditions found in space including gravity, pressure, radiation conditions, supply chain issues, water availability, and need for automation/remote operation. It has long been suggested that solar cells could be produced from the materials present in lunar soil.

Silicon, aluminium, and glass, three of the primary materials required for solar cell production, are found in high concentrations in lunar soil and can be used to produce solar cells. In fact, the native vacuum on the lunar surface provides an excellent environment for direct vacuum deposition of thin-film materials for solar cells.

Solar arrays produced on the lunar surface can be used to support lunar surface operations as well as satellites off the lunar surface.

Solar arrays produced on the lunar surface may prove more cost effective than solar arrays produced and shipped from Earth, but this trade depends heavily on the location of the particular application in question. Another potential application of lunar-derived solar arrays is providing power to Earth. In its original form, known as the solar power satellite, the proposal was intended as an alternate power source for Earth.

Solar cells would be launched into Earth orbit and assembled, with the resultant generated power being transmitted down to Earth via microwave beams. Despite much work on the cost of such a venture, the uncertainty lay in the cost and complexity of fabrication procedures on the lunar surface. The colonization of planets or moons will require obtaining local building materials, such as regolith.

For example, studies employing artificial Mars soil mixed with epoxy resin and tetraethoxysilane, produce high enough values of strength, resistance, and flexibility parameters. Asteroid mining could also involve extraction of metals for construction material in space, which may be more cost-effective than bringing such material up out of Earth's deep gravity well, or that of any other large body like the Moon or Mars.

Metallic asteroids contain huge amounts of siderophilic metals, including precious metals.

ISRU research for Mars is focused primarily on providing rocket propellant for a return trip to Earth-either for a crewed or a sample return mission-or for use as fuel on Mars. Many of the proposed techniques use the well-characterised atmosphere of Mars as feedstock.

Since this can be simulated on Earth, these proposals are relatively simple to implement, though it is by no means certain that NASA or the ESA will favour this approach over a more conventional direct mission.

Another reaction proposed for the production of oxygen and fuel is the electrolysis of the atmospheric carbon dioxide,

$2\ CO_2 \rightarrow 2\ CO + O_2$

It has also been proposed the in situ production of oxygen, hydrogen and CO from the Martian hematite deposits via a two-step thermochemical CO_2/H_2O splitting process, and specifically in the magnetite/wustite redox cycle.

The summarised reactions in this two-step splitting process are as follows:

$Fe_3O_4 \rightarrow 3FeO + 1/2\ O_2$

$3FeO + H_2O \rightarrow Fe_3O_4 + H_2$

$3FeO + CO_2 \rightarrow Fe_3O_4 + CO$

Ethylene is used to make plastics such as polyethylene and polypropylene and can be made from carbon monoxide and hydrogen:

$2CO + 4H_2 \rightarrow C_2H_4 + 2H_2O.$

ISRU solar cell manufacture

ISRU on the Moon

The discipline's institutional debut came late, long after the idea itself. Space-agency studies of the 1980s folded local-resource use into lunar-base planning, a presidential spaceflight initiative of 1989 carried the first serious line items for surface propellant plants, and the 1990s evangelized the logic in mission proposals that argued a Mars expedition could fly on a single small booster if it made its own return fuel. What had been a speculative footnote became, within a decade, a named discipline with program offices, and the naming mattered: once the practice had an acronym, budgets could carry it, and a research community could form around the letters.

The idea's true lineage is older than the acronym by nearly a century. Nineteenth-century observers of the Moon already speculated that future travelers might tunnel into it rather than haul everything upward, and the

engineering visionaries of the early twentieth century wrote plainly about using other worlds' materials as the basis for expansion beyond Earth. Their arguments were the same ones this book makes: gravity costs, mass rules, and the difference between a visit and a residence is whether the destination supplies its own inhabitants.

A third root is military and industrial rather than visionary. Rocket engineers have always traded propellant for range, and mid-century missile and launch programs accumulated the tanks, pumps, and cryogenic handling that lunar oxygen and hydrogen plants would later claim as inherited capital. The discipline's hardware has never been exotic; its vats, compressors, and heat exchangers are chemical-industry stock dressed for vacuum, and the field's fast progress in any given decade tracks how readily it can borrow that terrestrial stock rather than invent from first principles.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.