



12th IAA/AIDAA Symposium on Future Space Exploration
09-11 June 2025, Torino, Italy

Space architecture and infrastructure design strategies for human space exploration: a systematic literature review

SIU – Spoke 8 - Task 8.4.3 | UNIFI - DIDA

*Prof. Arch. **Alessandra Rinaldi** alessandra.rinaldi@unifi.it*
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Space It Up | SIU

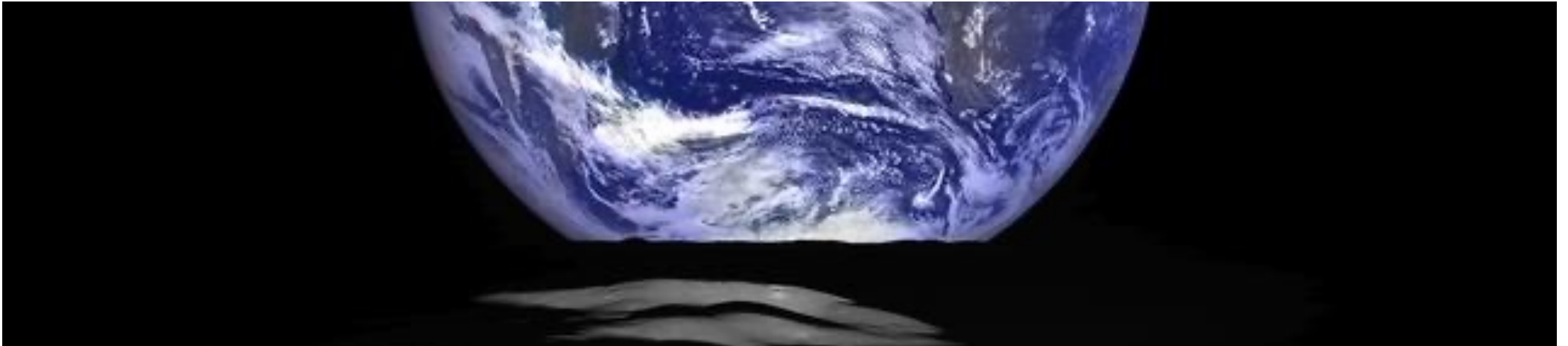
Project overview

Spoke 8

Robotic and Human Exploration of Extraterrestrial Habitats,
Architectures and Infrastructures

Task 8.4.3

Design of habitable space infrastructures for the human exploration



Space architecture and infrastructure design strategies for human space exploration: a systematic literature review

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Space it up | SIU

Project overview

Task leader 8.4.3

prof. Arch. **Alessandra Rinaldi** - Department of Architecture (DIDA), UNIFI

Research team

dr. **Sara Viviani** - Department of Architecture (DIDA), UNIFI

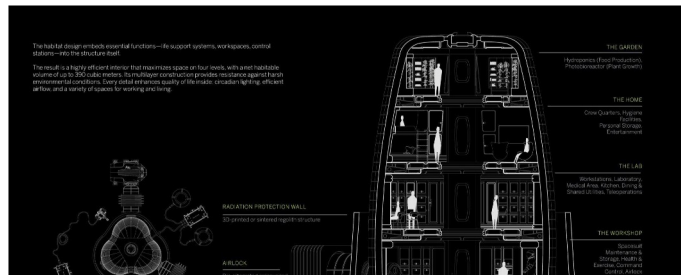
in collaboration with POLITO

Research objectives

Digital modeling of project design concepts for **extraterrestrial spaceports and sustainable settlements** *based* as much as possible *on available extraterrestrial resources*

Project **design concepts** options generation and performances' *parametric simulation*

Human-centered design



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Research activities overview

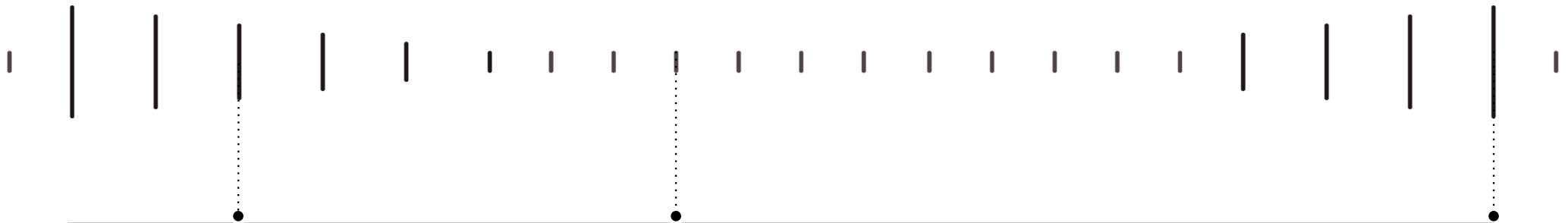
SIU - Spoke 8 – Task 8.4.3

March 2025

July 2025

January 2026

January 2027



March - July

August 2025 – January 2026

January 2026 – January 2027

State-of-the-art analysis, literature review

Analysis of design criteria (input of design): user needs, livable spaces, human factors, materials, and technologies etc

Design concept and design release; Proposal of habitation modules; Proposal of infrastructure for moon and mars.

July 2025

Dissemination

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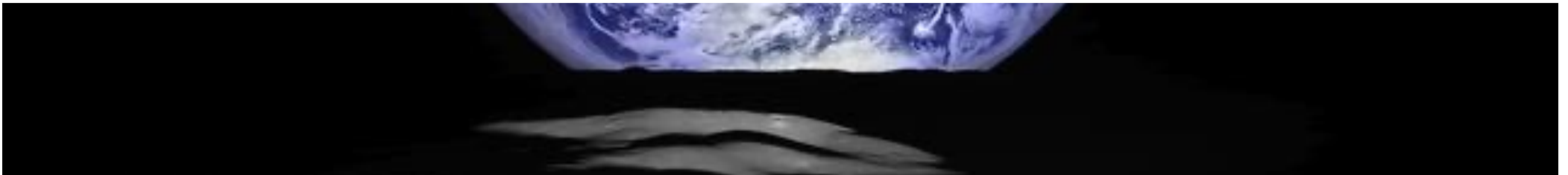
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Research questions

Project overview

-
- RQ1** What are the existing best practices for habitable spaces intended for human permanence in hostile terrestrial environments?
-
- RQ2** What types of housing solutions derived from a "nomadic" lifestyle in hostile environment could help broaden the perspectives of researchers?
-
- RQ3** What emerging ISRU-ISMU technologies, materials, and manufacturing processes could be adopted for the development of innovative habitable spaces?
-
- RQ4** **What architectural and technological solutions for long-term human survival on Moon have been developed internationally to date?**



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Methodology | PRISMA flow + HMW idea generation process

to collect, sort, and elaborate data

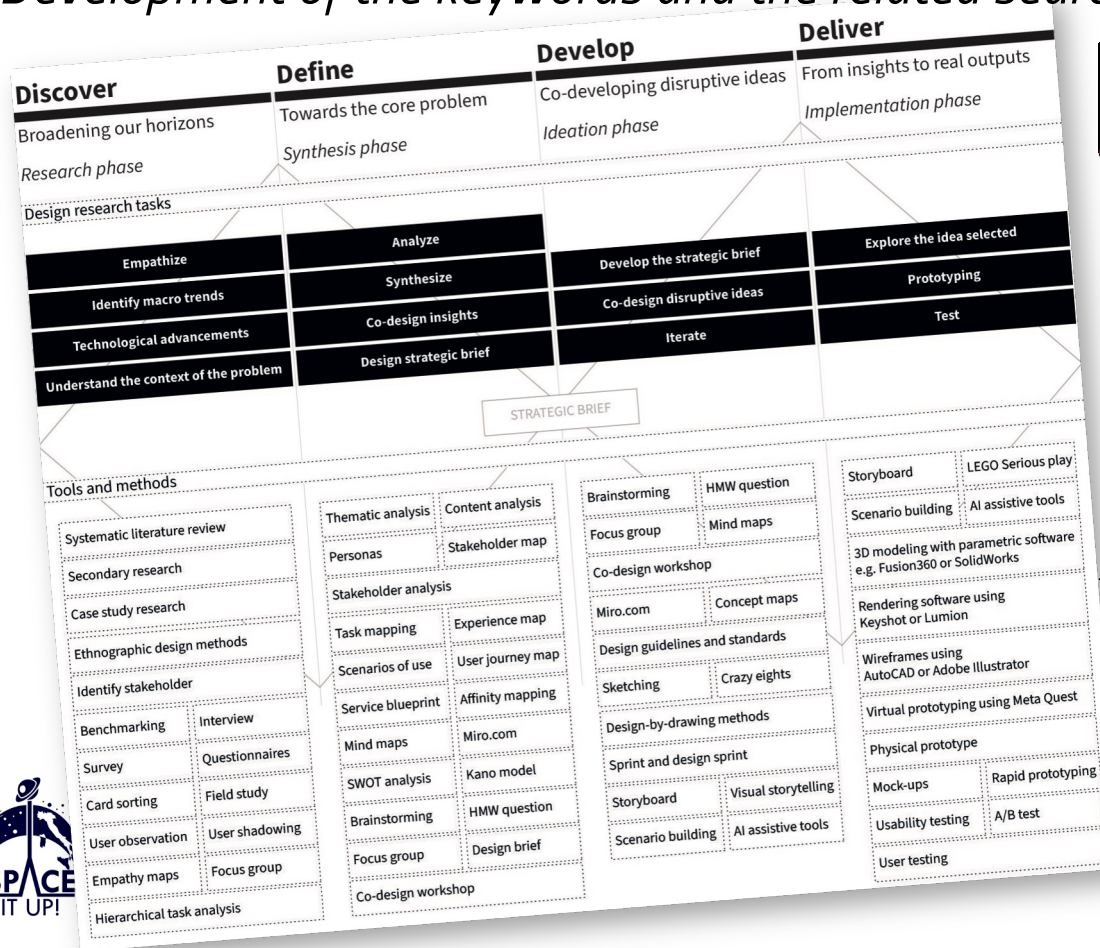
Preparation	<i>Development of the keywords and the related search string</i> ("space design" OR "space architecture*" OR "habitable space*" OR "habitation mean*" OR "habitable crew station*" OR "logistic module*" OR "space infrastructure*") AND ("space exploration" OR "moon exploration*" OR "moon village*" OR "mars exploration*")	
Identification	Identification of peer-reviewed sources - 331	Elimination of the duplicates - 69
Screening	Screening of the sources identified - 262	Exclusion of the papers outside the scope - 163
Eligibility	Eligibility assessment of full-text papers - 99	
Analysis	Thematic analysis of the content, extrapolation and clusterisation - 4	
HMW	Qualitative re-elaboration of the clusters identified - 6	





Methodology | Set up

Development of the keywords and the related search string



Double Diamond Design Thinking Model research task

Search string

Macrotrends

Space design

Space architectures*

Habitable space*

Habitation mean*

Habitable crew station*

Logistic module*

Space Infrastructure*

Context of the problem

Space exploration*

Moon exploration*

Moon village

Mars exploration*

Agencies for human space exploration: a systematic literature review

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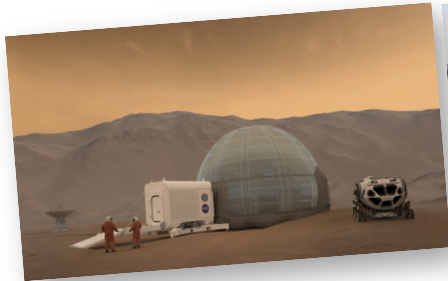


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Methodology | Analysis

Thematic analysis of the content, extrapolation and clusterisation



Cluster #1



Cluster #2



Cluster #3



Cluster #4

Cluster #1

Architectural best practices

This cluster focuses on habitat modules and infrastructures designed for long-term human permanence on the Moon so far.

Cluster #2

Digital design toolkit

The second cluster includes the suite of digital tools and platforms employed throughout the design process which enable the development, visualisation, and optimisation of space architectural solutions.

Cluster #3

Human factors and wellbeing

The third cluster addresses the integration of human-centred design principles, emphasising aspects such as physical and mental health, nutrition, circadian rhythm regulation, social interaction, and motivation to support astronaut health, safety, and overall wellbeing.

Cluster #4

Technological advancements

This cluster explores the technological innovations that enable or enhance space habitation, including ISRU, ISMU, AM, 3D printing with regolith, or FIS to increase autonomy, resilience, and sustainability.



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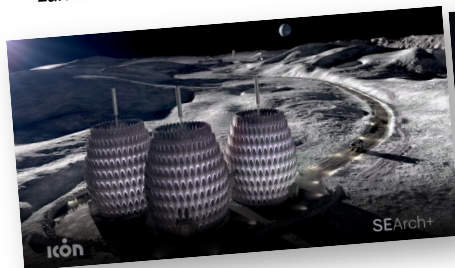
Methodology | Analysis

Thematic analysis of the content, extrapolation and first results



Lunar Habitation - Foster + Partners

MaMBA Project



Lunar Lantern - Project Olympus



One Moon - SOM + MIT + ESA

Habitable module and infrastructure solutions

Numerous (>20) concepts by significant architectural studies, developed in collaboration with space agencies, research institutions, and private industry

Infrastructure and habitat systems framework

Strategy of **open design** and **architecture**
Transportability, modularity, expandability, flexibility, and multifunctionality

International and **multidisciplinary** cooperation

Sustainability (for humans and economics)

Technological advancements

A combination between **pressurized inflatable structure** and a protective **shell** against radiation and micrometeorites in **3D printed regolith**

TRL

2 - 3 (technology concept / experimental proof of concept)

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Methodology | HMW idea generation

Qualitative re-elaboration of the clusters identified



Tiny House – Designed by Leonardo Di Chiara



*INTELLIGENT MOBILITY DESIGN CENTER –
Design by Maxime Gauthier*



Autohome – Land Rover

Research question #5

HMW extend fundamental knowledge and develop **innovative design scenarios** for habitable modules and infrastructure, from an **open architecture** and **design perspective**, to make long-term human permanence on the moon sustainable and to support and foster future Moon exploration activities?

Research question #6

HMW develop innovative ideas and **disruptive solutions** that respond to the many **technological** and **logistical challenges** associated with long-term human residence on Moon, **and increase the capabilities and radius of exploration?**

Research question #7

HMW design a system of nomadic habitable modules and **widespread service stations**, to **strengthen exploration possibilities**, increasing the area for sustainable Moon exploration activities, away from Shackleton?



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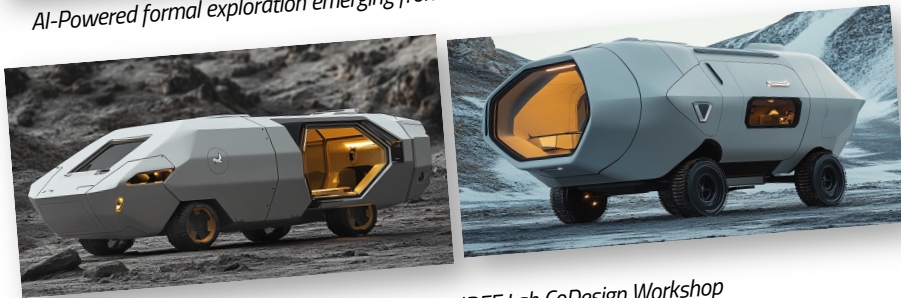
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Discussion on design opportunities



AI-Powered formal exploration emerging from IDEE Lab CoDesign Workshop



AI-Powered formal exploration emerging from IDEE Lab CoDesign Workshop

Increase TRL 4-5 of advance knowledge o infrastructure and habitat systems framework developed so far (inflatable + regolith 3D printed)

Expanding **human exploration** radius on the Moon missions **beyond Shackleton area**

Focus on a **nomadic housing**: small, nomadic habitation modules (towed by a rover), ranging from 10 to 20 square meters, designed for 2 people, and intended **for short-term missions** (3–7 days) with both **habitat and laboratory** functions.

Create a **widespread service infrastructures**: the nomadic modules are supported by a network of widespread **shelters** and/or **service stations**, spaced at yet-to-be-defined intervals, and constructed using inflatable and 3D-printed regolith shells.



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Future research directions

Research question #8

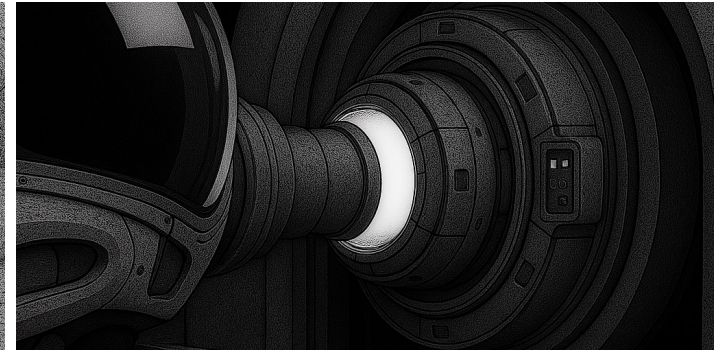
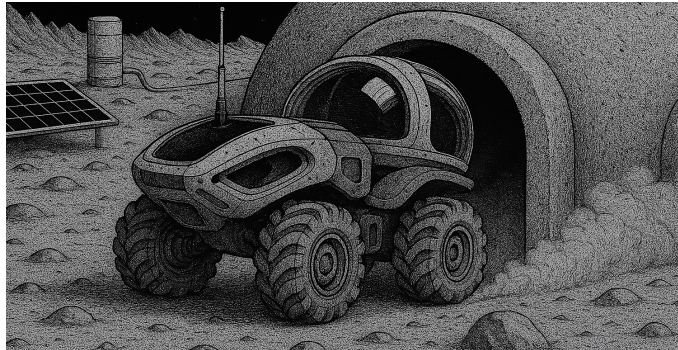
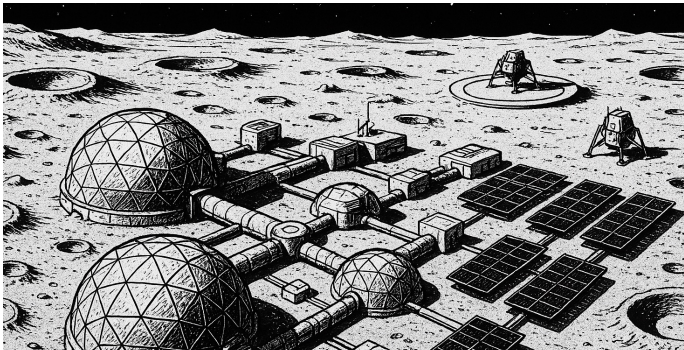
HMW design a **nomadic module** for habitat that can be **like an accessory space** integrated with the habitat modules and infrastructure **of a Moon Village**?

Research question #9

HMW develop a **nomadic module** for habitat inspired by the concepts of **tiny houses, campers, or autohomes**, to serve as a temporary habitat supporting human exploration on the lunar surface?

Research question #10

HMW envision **infrastructure** for nomadic habitat models, based on the concept of **shelters and/or service stations**, where crews can find refuge and resources during explorations far from the Moon Village? What functions must these facilities fulfil?



Design vision elaborated within the codesign workshop “CODESIGNING FUTURE SPACE EXPLORATION” held at IDEE Lab



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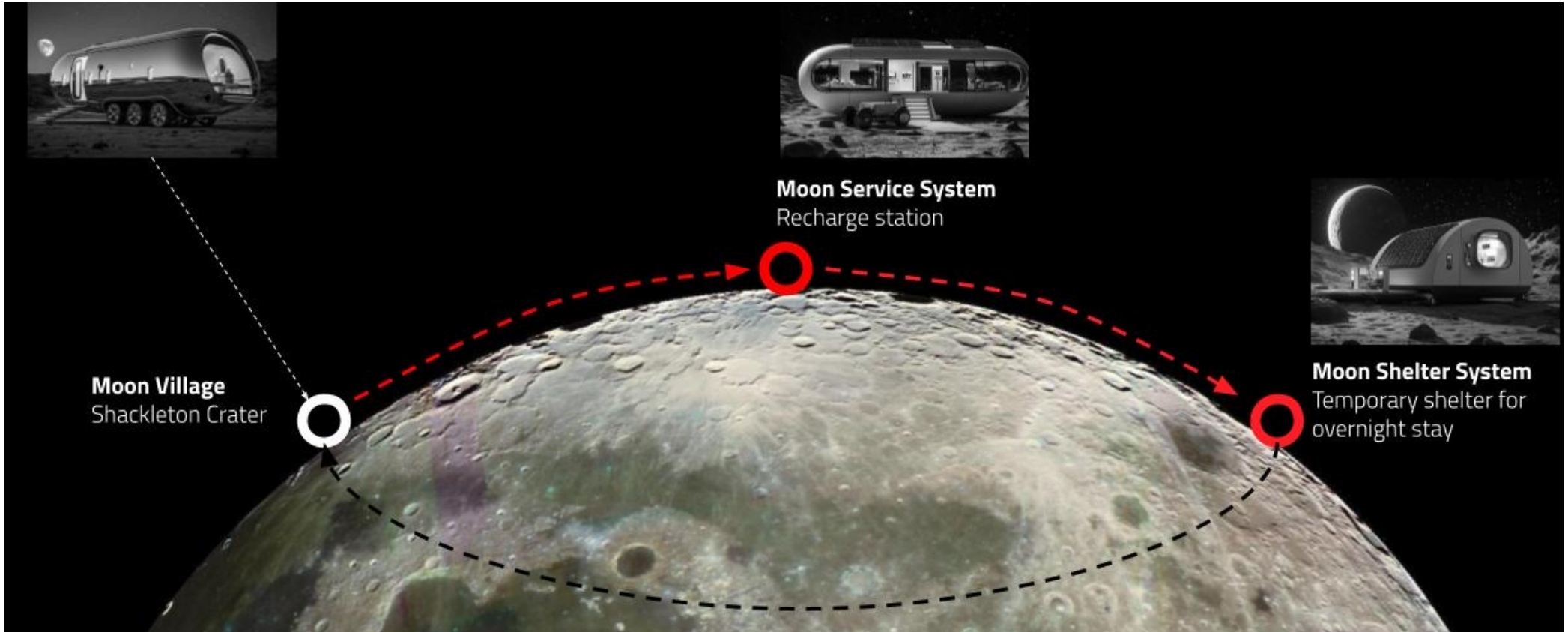
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Future research



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Thank you!

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