From Analog Missions to Lunar Settlement: Optimising Logistics, Teamwork and Training

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Abstract

Terrestrial analogue moonbases provide controlled yet realistic environments to study training and operational processes relevant to future lunar settlers and astronauts. This research examines how analogue simulations can optimise logistics coordination, team communication, and organisational workflows in constrained, resource-limited settings. Using facilities such as the ExoSpaceHab - Xpress Moon Outpost in Leiden as case studies, the project analyses how analogue crews plan missions, manage limited supplies, and coordinate across technical, scientific, and organisational roles. By comparing practices across different analogue habitats, the study aims to identify scalable approaches for effective training, adaptation, and decision-making under uncertainty. The expected outcome is a conceptual framework that links technical performance with human resilience and organisational robustness, offering generalisable recommendations for both future analogue campaigns and real missions aimed at sustainable, long-term space settlement on the Moon and beyond.

Keywords: analogue missions; space habitats; lunar settlement; logistics awareness; teamwork; training; student education; ExoSpaceHab-X; ICEE.Space.

1. Introduction

Future lunar settlement is often discussed through its most visible technical dimensions: launch systems, habitat architecture, energy supply, life support, radiation protection, mobility and in-situ resource utilisation. These elements are essential. However, a sustainable lunar habitat will not only be a technical object. It will also be a working and living environment where people must understand spaces, use equipment, follow procedures, share responsibilities and communicate under constraints.

This paper approaches the topic of space habitats from this human-operational and educational perspective. Its central argument is that analogue missions are important not only because they simulate future habitats, but because they create practical learning situations. They allow participants to experience, on Earth, some of the organisational and behavioural conditions that may become relevant for future lunar settlement.

The research question is:

How can terrestrial analogue missions contribute to training future lunar settlers by developing practical skills in logistics awareness, teamwork and communication?

This question does not imply that analogue missions can fully reproduce lunar conditions. They cannot recreate lunar gravity, radiation levels, regolith properties or the real distance from Earth. However, they can reproduce selected operational constraints: limited space, shared resources, procedural work, communication with a support team and the need to adapt to uncertainty.

NASA describes analogue missions as Earth-based activities used to test systems, protocols and scenarios before crews are sent to space. NASA also identifies isolation and confinement, distance from Earth, altered gravity, radiation and closed or hostile environments as major hazards of human spaceflight. ESA training programmes such as CAVES and PANGAEA further show that preparing for exploration involves not only technology, but also teamwork, field skills, communication and scientific procedures. These examples support the idea that future habitat development should include training in how habitats are actually used.

This paper focuses especially on students and early-career participants. Students are not merely passive learners; they represent the first stage in preparing the next generation of space professionals. Before becoming engineers, researchers, operators, mission support specialists or educators, they need environments where they can move from theoretical knowledge to practical mission-oriented experience.

2. Method and case material

This paper is based on qualitative case material collected during an internship connected with space education and analogue habitat activities. The material is not presented as a complete operational study of lunar logistics. Rather, it is used as an exploratory basis for identifying training lessons from small-scale analogue environments.

Three case contexts are considered:

1. **Inholland Space Lab**, understood as a practice-oriented educational environment where students and partners work on applied space technology projects, such as small satellites, ground support systems and experimental platforms.
2. **ExoSpaceHab-X**, a portable lunar base simulator used for education, analogue missions and outreach. The case material focuses on the habitat's internal layout, functional zones, inventory and storage organisation.
3. **An ICEE.Space 24-hour analogue mission**, involving three analogue astronauts inside a habitat and a support team outside. The case material focuses on communication testing, including a remote collaborative assembly task using LEGO components, and on lessons from the post-mission debriefing.

The analysis is organised around three dimensions: spatial and logistical awareness, team communication and reflective adaptation.

3. Analogue habitats as educational environments

Analogue habitats can serve as a bridge between present-day education and future settlement scenarios. They transform space exploration from an abstract subject into practical experience. Participants can enter a habitat, observe its spatial organisation, work with equipment, follow procedures, communicate with others and reflect on operational difficulties.

This role is particularly important for the formation of a broader space workforce. Future space activities will not involve astronauts alone. They will require engineers, technicians, mission operators, researchers, educators, communication specialists and support teams. Analogue environments provide an early training layer for this ecosystem.

Inholland Space Lab illustrates this connection between education and practical engineering. As a practice-oriented environment, it allows students to encounter hardware, laboratory spaces, development processes and external collaborations. This context shows that analogue habitats should not be isolated from education. They can become part of a broader pathway through which students learn how space systems are designed, tested and operated.

4. Case example 1: ExoSpaceHab-X and logistics awareness

ExoSpaceHab-X is a useful case because it shows a habitat at a concrete operational level: not as a concept drawing, but as a limited working environment. Its interior is organised into functional zones, including a living and life-support area, a work area with desks and electronics, and storage areas for scientific, technical and safety equipment.

This spatial organisation has training value. Before participants can perform a mission scenario, they must understand the habitat itself. They need to know what equipment is available, where it is stored, what is fragile, what is linked to safety and what is required for daily life.

The inventory walkthrough identified several categories of equipment: personal and astronaut-related gear, experimental materials, life-support and household items, cleaning tools, electronic equipment, power and communication devices, safety items and basic maintenance tools. Some items were especially relevant for operations, such as walkie-talkies, medical devices, an air quality monitor, drones, rover-related equipment, toolboxes and a soldering iron.

At first glance, such inventory work may appear simple. However, in a constrained habitat, logistics begins with knowing the environment. It is not only about large-scale supply chains from Earth to the Moon. It also begins at the local level: understanding what resources are present, where they are located, whether they are functional and whether users can access them efficiently.

For future lunar habitats, this type of spatial and logistical awareness will be essential. A crew member must be able to orient themselves quickly, identify the right item, understand its function and use it without creating confusion for others. Inventory, storage and habitat orientation should therefore be treated as part of operational readiness.

5. Shared responsibility in a confined environment

A second lesson from analogue habitats concerns shared responsibility. A habitat remains useful only if it is maintained as a functional, safe and understandable environment. This includes organising equipment, keeping work areas usable, respecting common procedures and preparing the space for subsequent activities.

In an educational setting, these tasks may seem ordinary. However, in the context of space habitats, they have training value. They show that mission performance does not depend only on experiments or advanced technologies. It also depends on the everyday conditions that make work possible.

For students, this represents an important shift. A habitat is not only something to observe from the outside. It is a shared working environment that requires discipline, attention and responsibility. This lesson is relevant to lunar settlement because limited space and limited resources will make shared responsibility even more important.

6. Case example 2: ICEE.Space and communication training

The second main example is the ICEE.Space 24-hour analogue mission. The mission involved three analogue astronauts inside a habitat for a continuous period of 24 hours, with a support team outside. Its purpose was to evaluate systems, procedures and human factors under realistic constraints.

One communication exercise used during the mission was a remote collaborative assembly task with LEGO components. The principle was simple: one person had the printed instructions, while the other person had the physical pieces. The task could only be completed through verbal communication.

Although the object was simple, the exercise revealed a key issue for habitat operations: successful work depends on clear instructions, shared vocabulary, spatial reference frames, confirmation and correction. When one participant cannot see the same information as the other, misunderstandings can arise quickly. The task then requires reformulation, feedback and mutual adjustment.

This is directly relevant to future lunar habitats. Crew members may need to assemble equipment, follow procedures, report anomalies, repair systems or coordinate with a support team. In all these situations, communication affects safety, efficiency and teamwork.

Communication in a mission environment is therefore not only a social skill. It is an operational tool. If instructions are ambiguous, the task becomes slower. If two participants do not share the same spatial reference, errors become more likely. If feedback is not clear, correction becomes difficult.

Analogue missions can train these skills in a practical way. Participants learn how to give precise instructions, ask for clarification, confirm actions and adapt explanations when misunderstanding appears.

7. Debriefing and reflective adaptation

The post-mission debriefing is another important element of analogue training. After the 24-hour ICEE.Space mission, practical issues related to comfort, usability, medical supplies, water management and missing or difficult-to-locate items were discussed.

This illustrates one of the main strengths of analogue missions: they transform individual observations into operational knowledge. Even a short mission can reveal sources of friction that might not be visible in a purely theoretical plan. Sleeping arrangements, medical kit organisation, water access or missing checklist items may seem minor in isolation. Yet, in a longer mission, such issues can affect workload, well-being and crew performance.

Debriefing therefore supports reflective adaptation. It creates a cycle of preparation, action, observation, reflection and improvement. This cycle is essential for training because it teaches participants not only to complete tasks, but also to evaluate how procedures and environments can be improved.

8. Proposed framework: analogue missions as training ecosystems

Based on these case examples, analogue missions can be understood as training ecosystems for future space habitats. They develop at least three learning dimensions.

The first dimension is spatial and logistical awareness. Participants learn to understand the habitat, its zones, equipment categories, storage logic and constraints. This dimension connects physical habitat design with practical use.

The second dimension is team communication. Participants learn to give instructions, ask for clarification, confirm actions, correct errors and coordinate with others. This dimension is central because habitat work often depends on shared understanding.

The third dimension is reflective adaptation. Participants use observations and debriefings to identify problems and improve future procedures. This dimension links short analogue missions with longer-term organisational learning.

This framework is modest, but it helps connect student training with the broader challenge of lunar settlement. It does not replace engineering, architectural or life-support studies. Rather, it complements them by focusing on how habitats are inhabited, maintained and learned through practice.

9. Conclusion

Analogue missions are relevant to space habitats because they show what happens when a habitat becomes used, inhabited and tested in practice. They reveal that a habitat is not only a structure, but a system of spaces, tools, procedures and human interactions.

The case examples discussed in this paper suggest that analogue environments can help prepare the next generation of space professionals. ExoSpaceHab-X demonstrates the importance of spatial and logistical awareness inside a habitat. The ICEE.Space 24-hour mission illustrates how communication and teamwork can be trained through simple but operationally meaningful exercises. Debriefing shows how practical difficulties can be transformed into improvements.

Future lunar settlement will require technical systems, but it will also require people who can understand their environment, communicate clearly, share responsibilities and adapt to constraints. Before future professionals can contribute to sustainable lunar habitats, they need places on Earth where these skills can be practised.

Analogue missions provide such places. They are not perfect reproductions of the Moon, but they are valuable training ecosystems for learning how to work, communicate and organise life inside future space habitats.

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