ED41C-0935: Long-Duration, Multi-Stage Mars Analog for Testing Human Resilience in Space

H.E.L.I.X.

Human Exploration Long-Duration Interplanetary Xpedition Analog

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Video Presentation

PREVIOUS ANALOG PROGRAMS

HERA:

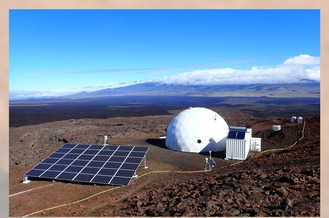
HERA is a NASA analog program based out of the Johnson Space Center that primarily works to understand psychological effects of humans living in confined spaces for long periods of time. HERA is designed for four crew members to live in for 45 days. The main goal of this program is to study human responses to things like lack of natural sunlight and light-dark cycles of areas far from Earth. HERA has had a wide range of other tests and investigations run on board during its lifetime, and the current iteration has 16 experiments running on board covering a variety of important topics.

CHAPEA:

CHAPEA is a long-term analog based at the Johnson Space Center that aims to simulate challenges of a human mission to Mars, including limited resources, possible equipment failure simulations, communication delay implementation, and various environmental stressors. The goal of CHAPEA is to help NASA prepare for the effects that a mission to Mars could have on the human body. CHAPEA is unique in that it is housed in a 3D printed habitat designed to emulate what habitats may look like on Mars and using similar materials to those available on the red planet. CHAPEA is designed for a crew size of four, with all participants required to have a Master's Degree or better, STEM experience, and be a citizen or resident of the United States. Participants of the CHAPEA program live in the habitat for around one year.

HI-SEAS:

HI-SEAS is an analog based in Hawaii 8,200 feet above sea level on the Mauna Loa Volcano. HI-SEAS is one of the longest analogs that NASA runs and aims to address problems with living long-term on other planets. HI-SEAS was designed to run for one year with a crew size of six. All crew members must have at least an undergraduate degree, pass multiple physical exams, and be fluent in English. The first mission focused on solving the issue of adequate food supply. The next three focused on team performance and cooperation. The most recent two missions focused on the impacts of having improper team cooperation and communication. HI-SEAS research is still being analyzed, but it's main purpose is to improve NASA emergency protocols and understanding of human interactions. However, this Analog failed due to its remote location causing dangers. The program was ended in 2018 following a medical emergency that nearly killed a crew member.



NEEMO:

NEEMO is an underwater analog designed for a group of 4 astronauts to live in isolation for up to 3 weeks on the ocean floor in the Florida Keys. Being underwater is a great way to simulate space missions, and affords the crew the ability to go on "space walks" with increased range of motion to further understand movement in environments with gravity different from our own. NEEMO also records psychological data on its crew and their response to the isolation, confined spaces, and dangerous environment.

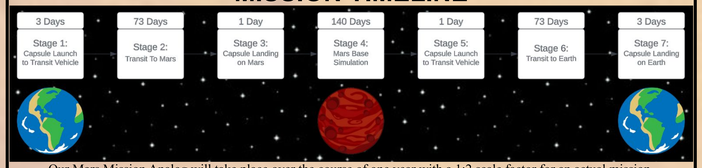
PURPOSE OF H.E.L.I.X.

In the context of this analogy, we aim to fulfill many primary objectives that cover a variety of important dimensions. Firstly, emphasis is placed on fortifying resilience against off-nominal events, such as Cascadia failures, escalating temperatures with consequential ramifications, and tangible threats such as tank explosions. Secondly, we aim to analyze the psychological and physiological impacts of prolonged isolation within unfamiliar environments and enclosed spaces. The third goal involves the assessment and analysis of teamwork capabilities through collaborative efforts in task completion. The fourth objective is the emulation of a self-sustaining habitat reflective of Mars conditions with realistic resource constraints. Lastly, we aim to foster robust interactions among human participants, robots, and human-AI interfaces through scenarios like conversing with an AI simulated family, utilizing robots to complete tasks, and more.

PLANNED LOCATION FOR H.E.L.I.X.

Our chosen analog site is Devon Island, Canada, situated in Baffin Bay. Devon Island's resemblance to Mars is marked by explosive craters, volcanic formations, and the barren and rocky terrain. This remote location enforces a sense of isolation on crew members while maintaining easy access to assistance just across the water. The temperature variations on Devon Island, with winters dropping to -60˚F and shorter summers averaging 50˚F, closely resemble the temperature extremes on Mars (ranging from -200˚F to 70˚F). This location selection ensures an authentic replication of the environmental challenges inherent in a Martian mission.

MISSION TIMELINE



Our Mars Mission Analog will take place over the course of one year with a 1:2 scale factor for an actual mission.
Times were calculated based on the NASA Ames Research Center Trajectory Browser.

CREW REQUIREMENTS

Crew Size: 8 Members
- Must Pass a Class-2 Flight Physical Examination
- Must be Scuba Certified
- Must be a U.S. Citizen
- Must be between 30 - 60 years of age

- Bachelor's degree in any STEM Field and 2 years experience
  OR
- Master's degree or PhD in any STEM Field

- 1 Crew member should have a Doctorate in Medicine
- 1 Crew member should have 4+ years Psychiatry Experience

Military experience, advanced STEM experience, experience with extreme environments, and teamwork experience are deemed valuable help strengthen applications.

MEDICAL / FAMILY CONSIDERATIONS

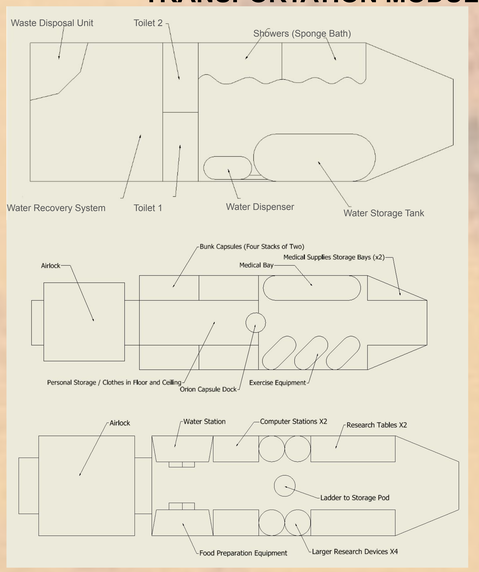
Long-term travel to Mars presents significant communication challenges, primarily due to the substantial time delay in radio signals, ranging from 5 to 20 minutes depending on the planets' positions. In response, Helix will facilitate family contact for crew members, implementing a one-way 20-minute communication delay during such interactions to simulate potential worst-case scenarios in astronaut training.

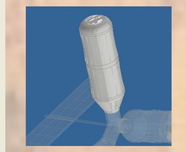
Given the limited bandwidth access, conferences related to medical and family matters will be available but time constrained. Helix will also explore the integration of robotics and virtual reality technology. This approach aims to enable crew members to engage with their families asynchronously, using a virtual reality world that replicates a physical setting. NASA scientists will closely monitor the psychological effects and effectiveness of utilizing virtual reality for family and medical communication throughout the mission.

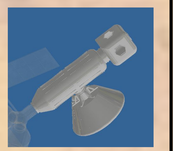
In order to keep our astronauts healthy, we will also have regular medical checkups with the onboard doctor, and require a strict exercise regime to simulate requirements on Mars due to its lower gravity. Mental health is also critical to functioning astronauts, so we will also require regular psychiatric reviews and therapy appointments.

HELIX ANALOG DESIGN

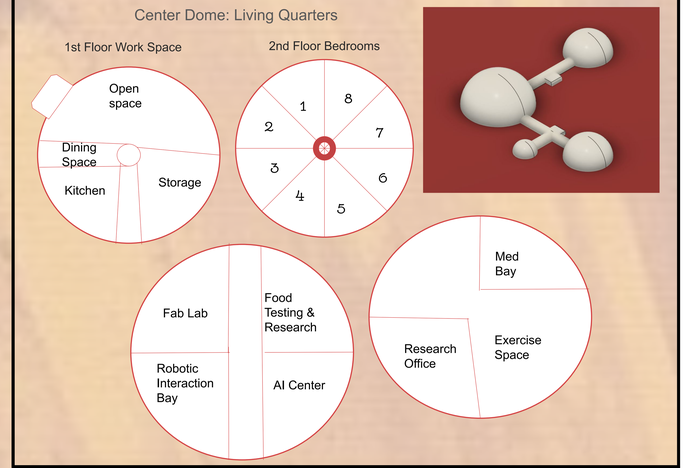
TRANSPORTATION MODULE







SURFACE HABITAT



ANALOG MATERIAL COMPOSITION

For Transit Vehicle: Our neutral buoyancy pool will be both saline and chlorinated. These chemicals ensure astronaut buoyancy and pool cleanliness but result in corrosive conditions. Due to this, the Transit Vehicle must exhibit exceptional resilience, making stainless steel the ideal material. A protective coating would further enhance durability. Windows will be constructed from polycarbonate, as it is translucent, half the weight of glass and 250 times stronger. The only drawback is that it can scratch relatively easily.

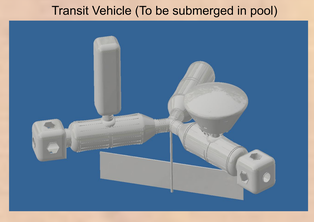
For Mars Habitat: The solid domes in our habitat will be constructed using lavacrete, similar to CHAPEA. To minimize heat loss and ensure soundproofing, closed-cell insulation will be incorporated into the walls. Our transparent dome will feature an aluminum and polycarbonate lattice. Aluminum, chosen for its lightweight properties compared to steel or titanium, offers the additional benefit of corrosion resistance. Furthermore, the polycarbonate material in the lattice blocks UV rays, providing protection against radiation.

Neutral Buoyancy Pool

Neutral buoyancy is the state when an object has neither positive nor negative buoyancy. This condition enables the manipulation of heavy objects in a neutrally buoyant environment, simulating microgravity and allowing Extra-Vehicular Activities (EVAs) for the Helix crew. EVAs are crucial for potential hardware component replacements during extended missions like the Mission to Mars.

The Neutral Buoyancy Pool, housed in an enclosed building with access through a tube connected to the capsule. The pool's water temperature, regulated at 82 to 88 degrees Fahrenheit, prevents hypothermia for divers. Water will be cycled out every 19.6 hours to ensure cleanliness.

Transit Vehicle (To be submerged in pool)



Safety precautions include two divers per person on standby, with crew members required to be scuba certified. Neutral buoyancy procedures occur in the airlock, and not all crew members participate in EVAs simultaneously. A medical team is present for emergencies, and in case of decompression sickness, a hyperbaric chamber is available. The airlock also serves as a decompression chamber to prevent sickness.

ANALOG EXPERIMENTS

A primary objective of our analog mission is to develop self-sustainability methods for the crew, both during transit and on Mars. This goal will be carried out through a variety of methods, including diverse hydroponic systems, enabling the cultivation of various foods and fresh plants to enhance crew morale. We will also be experimenting with the cryopreservation of fish eggs to provide food for astronauts upon landing on Mars. The crew will explore growing different crops in simulated Martian soil on Devon Island, broadening the range of nutritious foods available in astronaut diets.

Given the water-intensive nature of hydroponics, we will incorporate a water recycling and purification system akin to the one operational on the ISS. This system aims to recycle up to 98 percent of the initially brought water, ensuring efficient water resource utilization. Diversification of the diet will include experimenting with cryo-preserved fish eggs, providing additional variety for the crew's nutritional needs.

To further minimize ecological impact, local resources on Mars, such as surface ice, will supplement the water supply. Additionally, a zero-waste policy will be implemented, incorporating compostable materials to mitigate pollution and space debris generation.

We will also place a heavy focus on monitoring the psychological effects of many facets of Mars life, including the rationing of resources such as food, water, and electricity. We will also be exploring the impacts of communication delay as the mission proceeds, and research the effects of isolation and sensory deprivation that comes with these types of missions.

Self-Sustainability Experiments:
- Development of hydroponic systems
- Growing crops on Mars
- Water recycling + purification
- Cryopreservation of fish eggs
- Use of Mars surface ice for water supply
- Zero-waste efforts on Mars

Planned Off-Nominal Experiments:
- Equipment Failures
- EVA repairs
- Underwater leaks (To simulate Air Leak)
- Airlock Failure

Psychological Effects Monitoring
- Food Rationing
- Water Rationing
- Electricity Rationing
- Psych Surveys
- Psychiatrist Conferences
- Sensory Deprivation
- Comms Delay
- Isolation