Analog Research & Habitats: Value & Future Directions

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With the advent of the National Aeronautics and Space Administration (NASA)'s Artemis missions and the rise of commercial space, including space tourism, space exploration goals which once seemed at best a far distant possibility now feel within reach. The excitement stemming from the progress being made by NASA and its partners, as well as the successes of commercial companies, has fueled public interest in space exploration. People from all walks of life are engaged and looking for ways to contribute to, and be involved in, mankind's progress towards establishing a significant off-world presence.

However, while considerable progress has been made in the realm of space exploration, more research is required to develop and test the materials, technologies, processes, and innovations needed to safely support a sustained human presence in space environments, including the Moon and Mars. The space environment is generally non-supportive of life; mitigations are needed for living organisms, including humans, to function properly. This testing has traditionally been performed by NASA and its partners in government funded facilities and at research universities.

Analog facilities both provide a

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means for public participation in space exploration and an accessible testing ground for space technologies and protocols. An analog facility is a terrestrial habitat or environment which mimics aspects of the space environment. While terrestrial analogs cannot effectively replicate some characteristics, such as microgravity, for example, they can approximate the experience of living in an isolated, confined environment very well. They also provide an affordable testing ground for projects which do not require a fully authentic space environment.

Analog facilities also provide the means to perform testing with a wider range of participants, including both a higher number of participants and a greater variety of ages, backgrounds, cultures, and physical abilities. For example, to date, there have been only 12 people who have walked on the moon and a total of 273 individuals who have visited the ISS (NASA Station Visitors, 2023). In contrast, over 1,000 people have served as analog astronaut crew members at the Mars Deseret Research Station run by The Mars Society (MDRS, 2023) since it opened in 2001; this is only one analog facility out of hundreds worldwide. The majority of these participants are everyday people, and, for most, an analog mission represents their only opportunity to experience an astronaut lifestyle. The opportunity for public participation afforded by analog facilities and the large number of participants they support provides greater flexibility in research design and more comprehensive analysis of a wider range of variables in studies relating to human performance, psychology, and crew composition, function, and dynamics.

Studies at analog facilities can be accomplished at much lower cost and on a much faster timeframe than studies in actual space environments. Testing at terrestrial analog facilities is also considerably more affordable than on the ISS, where space and cargo weight are limited; they are also more accessible. This allows a greater number of research projects to be tested and also enables more comprehensive testing over a wider range of variables, which improves the robustness of the results and allows for increased creativity in testing and design. Analog facilities thus represent a valuable contribution to mankind's progress toward crewed space exploration and future off-world settlements.

There are many analog facilities worldwide; some are government funded, while others are privately maintained. Some are established habitats, while others are expeditions or experiences. These analogs offer a wide range of opportunities for testing as well as different levels of fidelity. The highest fidelity analogs currently include Antarctic Stations, the Human Exploration Research Analog (HERA), operated by NASA, and the Scientific International Research in a Unique Terrestrial Station (Sirius)/Nezemnyy Eksperimental'nyy Kompleks (NEK) analog in Russia. These provide a high degree of isolation and confinement, providing an authentic analog experience very similar to space exploration, and are ideal for studies of the psychological effects of space environments.

NASA Analog Research Testing and Simulations

NASA uses a variety of analog habitats to study the effects of isolation, microgravity, hyper gravity, day-night cycle variations, reduced gravity, and space radiation. Two of these, reduced gravity and space radiation, are primarily tested on the International Space Station, but the other categories can be easily tested in terrestrial analog facilities.

Analog facilities range from high to low fidelity and can include a wide range of testing environments, including centrifuges, water immersion facilities, enclosures, and habitats. Terrestrial habitats, in particular, are valuable for testing crew interaction, psycho-social interaction/performance, work schedules, fatigue, and equipment performance.

NASA has been using training facilities and analogs for a long period of time, especially the water immersion facility, which is now called the Neutral Buoyancy Laboratory, located in the Sonny Carter Training Facility in Houston, TX. At this facility, astronauts can practice extravehicular activities, remote manipulators, and different tasks that they'll be doing on orbit. Water emergency and rescue capabilities and protocols, used for ocean landings during the Apollo Era and onward, require extensive training which can be effectively accomplished at the Laboratory as well.

The NASA Mars analog mission, which is currently underway at the Crew Health and Performance Exploration Analog (CHAPEA) located at the NASA Johnson Space Center in Houston Texas. This analog is a year-long analog mission. The crew includes a biologist, an engineer, a physician, and a microbiologist and will study human factors, robotic operations, crop growth, and performed simulated spacewalks.

The Hawai'i Space Exploration Analog and Simulation (HI-SEAS) is another well-known analog facility in the U.S.; it is located on the sides of the Mauna Loa volcano on Hawai'i Island. This facility has been used by NASA for five long-duration analogs, ranging from 4 to 12 months in duration, primarily as a Mars laboratory.

There are many international analog facilities as well, including the Institute of Biomedical Problems, located in Moscow, Russia and run by the Russian Academy of Science. At this facility, culturally diverse, multinational crews representing the United Kingdom, Russia, China, and Japan perform 500-day simulations under conditions of communication delays. This facility focuses mainly on isolation and human factors studies which might be encountered during a Mars mission.

Overall, NASA and its international counterparts recognized the considerable benefits of using analog simulation and testing facilities. Analog mission simulations have resolved problems in hardware, performance, and scheduling, and have contributed to human factors research.

The FMARS Expedition

One very high-fidelity analog is the Flashline Mars (FMARS) habitat on Devon Island in the Canadian Arctic. The FMARS 15 crew recently performed a multi-week mission to the habitat; this was the first FMARS mission in six years. The primary goal was to repair and restore the facility; secondary goals focused on exploring Devon Island, which bears a striking resemblance to Mars, to understand how humans perform in isolated, extreme environments (ICE). Terry Trevino, the executive officer for the FMARS 15 crew, gave a first-hand account of the analog expedition, which was undertaken as part of The Mars Society, under the guidance of Dr. Robert Zubrin, who was central to the mission's success. The team consisted of five members: Andrew (commanding officer from Australia), Olivia (science lead from London, UK), Andy and Caleb (engineers from a space company in Seattle), and Terry (executive officer from San Francisco). They joined the ranks of a select few who have been to this Arctic analog facility, which was established over two decades ago.

Terry described the planning and execution of the analog mission, which, combined, spanned more than 18 months, as thorough and safety-oriented, including precautions like flyovers to check for polar bears. Each member of the team contributed unique strengths essential to the success of the mission. Terry brought expertise in mountain climbing and logistics to the mission, which was vital in dealing with the harsh environment, including strong winds and extreme weather, coupled with roof leaks at the research station. The team's work to restore the analog habitat was hands-on and intensive, involving repairing a failed antenna and dealing with large amounts of mold.

The challenges the mission faced extended beyond the station repairs, however, as the crew also had to adapt to continuous daylight conditions and the psychological effects of extreme isolation. The crew's perseverance was a testament to their adaptability and resilience. During their stay, the crew encountered minimal signs of life in the Arctic desert, such as the resilient Arctic Poppy and lemmings feeding on cushion plants. These observations contributed to the study of survival and adaptation in extreme conditions. In spite of the isolation, the experience of being in a place with no human-centric design was awe-inspiring. Terry compared the landscape to Mars, highlighting the unique geological features, such as the crater caused by a meteorite impact 23 million years ago.

In summary, the mission provided valuable insights into human research and performance, a key metric being actively studied by Terry per the Science Mission Directorate from NASA, and included studying behavior and mental acuity in extreme, isolated conditions, analogous to what might be experienced in extraterrestrial environments. The mission combined the practical challenges of survival in an extreme environment with the intellectual challenges of scientific investigation of life in arid conditions, both of which contribute to our understanding of human capabilities in space exploration.

The American Public University System (APUS) Analog Research Group (AARG)

As the boundaries of human exploration extend back to space, the critical need for understanding and addressing the challenges of space travel becomes more apparent. AARG is a pioneering initiative at the forefront of human spaceflight studies. This presentation describes the mission, research endeavors, target audience, collaborative partnerships, and structural backbone that propels its success.

Mission and Purpose: At its core, AARG stands as a testament to the commitment of APUS towards advancing mankind's understanding of the complexities inherent in human spaceflight. AARG's mission is to provide a unique platform for APUS students, both current and alumni, to actively participate in cutting-edge research related to sustained human space exploration. AARG operates as a crucible for hands-on experience, bridging the gap between theoretical knowledge and practical application.

Scope of Studies: AARG specializes in human spaceflight studies conducted in various analog habitats—meticulously designed environments that simulate conditions encountered during space missions. These habitats serve as Earth-bound laboratories where researchers can scrutinize the intricacies of life support systems, habitat design, and human factors in preparation for extended space missions. The diversity of students ranges from senior leader professionals in the United States Armed forces, to NASA ISS flight controller veterans and human spaceflight industry leaders. AARG's studies range from reliability assessments of Starlink in remote locations, to observing plant biometrics in different Martian and lunar regolith-based soil solutions.

AARG draws upon the diverse community of APUS students, fostering a culture of curiosity and scientific exploration. The program is not confined to the present; it extends a welcoming hand to alumni, creating a continuum of learning and engagement. This inclusive approach ensures that individuals from different backgrounds, disciplines, and stages in their academic or professional journey can contribute to and benefit from AARG's initiatives.

The collaborative spirit is a defining feature of AARG. The program engages in research for multiple stakeholders, creating a dynamic ecosystem that amplifies its impact. From conducting communications testing for industry partner Persistent Systems at the University of North Dakota (UND)'s Integrated Lunar-Mars Analog Habitat (ILMAH) to securing NASA grants for pivotal research, AARG's reach spans academia and industry. Noteworthy is the coordination with the United States Space Force (USSF) and UND for habitat missions, showcasing AARG's pivotal role in real-world space mission coordination.

Structured Leadership Opportunities: AARG is not merely a research program—it is a leadership incubator. The program is structured to offer leadership opportunities for those eager to take charge in the realm of space exploration. For APUS students, this translates to a chance to steer research projects, collaborate with industry partners, and contribute to academic discourse. AARG's leadership team plays a crucial role in guiding the program's trajectory, providing mentorship and ensuring a seamless integration of research initiatives.

The leadership structure of AARG is designed for efficiency and mentorship. At the helm are the Lead Faculty Advisor and Program Manager, who oversee the strategic direction of the group. Under this pivotal role are coordinators responsible for specific facets, such as research, communications, and partnerships. This hierarchical arrangement not only ensures the smooth functioning of the program but also provides a clear pathway for individuals to ascend into leadership roles, fostering a culture of growth and development.

Impacts and Future Trajectory: As AARG navigates the vast expanse of space research, its impacts are manifold. The program contributes not only to the academic realm but also to the practicalities of space exploration. From advancing the reliability of remote location research tools to studying plant growth in simulated Martian conditions, AARG's footprint is indelible.

In the grand tapestry of space exploration, AARG emerges as a vibrant thread, weaving together education, research, and practical experience. Its multifaceted approach not only empowers students and alumni but also forges invaluable partnerships with industry and government entities. AARG is not just a program; it is a launchpad for dreams, a crucible of knowledge, and a beacon guiding humanity into the cosmos. As the celestial journey continues, AARG stands tall, a testament to the boundless possibilities that await those who dare to explore the frontiers of space.

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