NASA Extreme Environment Mission Operations: Science Operations Development for Human Exploration

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The purpose of NASA Extreme Environment Mission Operations (NEEMO) mission 16 in 2012 was to evaluate and compare the performance of a defined series of representative near-Earth asteroid (NEA) extravehicular activity (EVA) tasks under different conditions and combinations of work systems, constraints, and assumptions considered for future human NEA exploration missions. NEEMO 16 followed NASA's 2011 Desert Research and Technology Studies (D-RATS), the primary focus of which was understanding the implications of communication latency, crew size, and work system combinations with respect to scientific data quality, data management, crew workload, and crew/mission control interactions. The 1-g environment precluded meaningful evaluation of NEA EVA translation, worksite stabilization, sampling, or instrument deployment techniques. Thus, NEEMO missions were designed to provide an opportunity to perform a preliminary evaluation of these important factors for each of the conditions being considered. NEEMO 15 also took place in 2011 and provided a first look at many of the factors, but the mission was cut short due to a hurricane threat before all objectives were completed. ARES Directorate (KX) personnel consulted with JSC engineers to ensure that high-fidelity planetary science protocols were incorporated into NEEMO mission architectures. ARES has been collaborating with NEEMO mission planners since NEEMO 9 in 2006, successively building upon previous developments to refine science operations concepts within engineering constraints; it is expected to continue the collaboration as NASA's human exploration mission plans evolve.

The Importance of Planetary Sample Returns

Planetary science has seen a tremendous growth in new knowledge as a result of recent NASA robotic missions that have detected deposits of water ice at the Moon's poles and potential conditions under which life could have flourished on Mars.

While some sophisticated data can be derived from "in-situ" measurements taken by rovers and satellites, returned planetary samples allow scientists on Earth to use the latest technologies available to maximize the scientific return. The science community has recently seen compelling sample returns, including solar wind particles (NASA's Genesis), comet particles (NASA's Stardust), asteroid particles (Japan Aerospace Exploration Agency's Hayabusa), and Antarctic meteorites, which scientists collect each Austral summer.

The National Research Council Decadal Study of 2011 recommended that NASA's chief scientific goal should be to return samples from Mars by 2023. Measurements taken by the Mars Exploration Rovers Spirit and Opportunity indicate that Mars' climate was warmer and wetter early in Mars' history – conditions in which scientists believe life could have formed. But chemical evidence of life in materials like the rocky regolith of Mars can be quite small and difficult for robotic geologists to detect and measure.

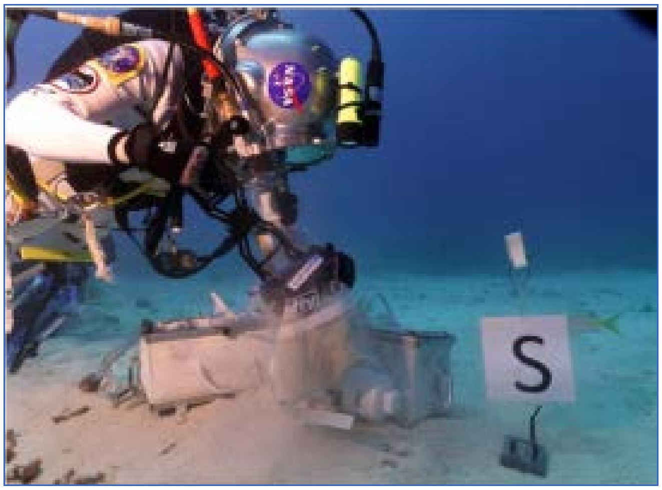

Figure 1.– Clamshell sample collection device in use during NEEMO 16.

Figure 2.– NEEMO aquanauts collect and document samples.

The ARES Directorate at JSC curates all of NASA's extraterrestrial samples. ARES' mission is to protect, preserve, and distribute samples from the Moon, Mars, and interplanetary space for scientific study. These sample collections include lunar rocks and regolith returned by the Apollo missions.

Samples from Mars will require special handling protocols from the time the sample collection site is chosen through documentation, encapsulation, and transport to Earth and to NASA's curation facility for allocation to scientists for analysis and study. Because scientists do not yet know how to differentiate an Earth-derived sample of life from a Mars-derived sample of life, scientists are eager to develop protocols that will protect Mars samples from Earth contamination. Landers, collection tools, and sample containers could all carry trace amounts of Earth biology, so they must be equipped with decontamination materials and procedures to protect the precious samples.

How do NASA's analog missions, like NEEMO, help scientists develop special sample-handling techniques for exploration programs?

Planetary environments are considered extreme for both robotic and human exploration. Apollo astronauts experienced lower gravity on the Moon and a very thin atmosphere that required them to wear a space suit with life protection and support systems. When they collected Moon rocks, the astronauts did not know if they were exposing themselves to health hazards, so they wore large bulky gloves and used special sample collection tools and containers. These protective materials and special sample devices were developed in laboratories at JSC and tested in the field by geologists. After the sampling tools and techniques were sufficiently refined, Apollo astronauts were trained to use the techniques developed by the scientists.

Figure 3.– A NEEMO 15 Aquanaut tests sample collection tools.

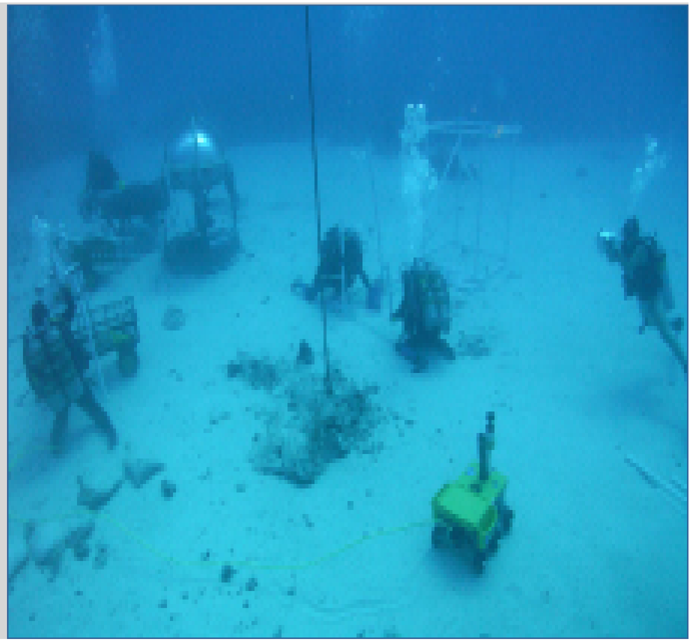

Figure 4.– Aquanauts test and develop surface operations in the reduced-gravity underwater environment.

Today, ARES scientists are developing tools and techniques for use on planets that have the same life-support requirements and gravity conditions as the Moon or Mars as well as for lower gravity environments, such as near-Earth asteroids. Low-gravity environments present special obstacles for collecting and containing geologic materials because loose material can drift away, and an astronaut can be propelled away from a planetary surface just by hitting a rock with a hammer. NEEMO is an undersea research facility that allows humans to experience reduced gravity due to the buoyancy provided by water in an environment requiring life support. During NEEMO 16, NASA refined sample collection techniques in an extreme environment and trained astronauts to use tools and procedures developed for those unique conditions.

NASA develops tools and techniques during analog missions to ensure the scientific integrity of samples returned from a variety of planetary surfaces by robots and human explorers. NASA's returned samples will help scientists understand the formation and evolution of the solar system and determine if life or the conditions for life existed on other planets. These samples will be curated for future generations, who may be able to employ advanced techniques not yet available to researchers.

How does this analog activity fit with NASA's current mission plans?
NASA is actively planning to expand the horizons of human space exploration, and with the Space Launch System and the Orion crew vehicle, humans will soon have the ability to travel beyond low Earth orbit, opening a solar system of possibilities. NASA's goal is to send humans to explore an asteroid by 2025. Other destinations may include the Moon or Mars and its moons.

Regardless of the destination, the work must start now. NASA is developing the technologies and systems to transport explorers to multiple destinations, each with its own unique – and extreme – space environment. Because sample return requirements are mission specific, the handling protocols are designed specifically for the types of questions the scientific community hopes to answer using samples from a particular planetary destination. ARES curation scientists are collaborating with mission architecture engineers to develop mission goals that are aligned with science goals. ARES scientists participate in analog missions to develop protocol and scientific operations – from mission conception to execution and sample return – to ensure that the requirements of the scientific community will be met and the scientific return to the public will be maximized.

The 2012 Moon and Mars Analog Mission

Lee Graham

The 2012 Moon and Mars Analog Mission Activities (MMAMA) scientific investigations were completed on Mauna Kea volcano in Hawaii in July 2012. The investigations were conducted on the southeast flank of the Mauna Kea volcano at an elevation of ~11,500 ft. This area is known as "Apollo Valley" and is in an adjacent valley to the Very Large Baseline Array dish antenna.

Two of the four MMAMA investigations selected were led by scientists within the ARES Directorate at JSC. These included the Increasing Robotic Science proposal, the miniature Mössbauer spectrometer (MIMOS II), and the MIMOS II combined with an X-ray fluorescence (XRF) spectrometer (MIMOS IIA). The original robotic investigation proposal called for a comparative study of human field work versus the JSC C2 rover (and potentially the C2 rover with a Robonaut torso mounted on it, often called a "Centaur"). Robonaut is a dexterous humanoid robot that was designed and built at JSC, but last-minute travel restrictions eliminated it from the field test. Working with the NASA Regolith and Environment Science and Oxygen and Lunar Volatile Extraction (RESOLVE) project, a NASA Advanced Exploration System Program project hosted at the Kennedy Space Center (KSC), the MMAMA team was able to identify a replacement rover, the JUNO II (shown in figure 1), which was provided by the Canadian Space Agency. In addition, as planning progressed for the 2012 tests on Mauna Kea, an opportunity presented itself to move the MMAMA test site to a more geologically challenging location. This did, however, also reduce the test time from the original 2 weeks to only 3 days. The primary focus of the investigation was to determine the valley formation processes.

The instruments used in the test were selected based on several considerations. The major criteria included 1) applicability to the scientific investigation of the valley, 2) mobility, 3) availability, 4) remote control capability, and 5) weatherproofing capability. The MMAMA robotic investigation involved the use of six instruments, including a ground penetrating radar (GPR), a second-generation