USING EARTH-BASED OPERATIONAL FIELD TESTS AS HIGH-FIDELITY ANALOGS FOR PLANETARY SURFACE EXPLORATION.

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Introduction: NASA is preparing to land the first woman and first person of color on the Moon within the next decade and establish a permanent sustainable human presence before sending humans onto Mars. To ensure the success of these missions, NASA has performed operational testing in terrestrial, aquatic, and laboratory analog environments that simulate Lunar and Martian environmental characteristics to evaluate exploration concepts of operations (ConOps), engineering design requirements, science support needs, mission operations techniques, and crew training. Terrestrial analogs include Desert Research and Technology Studies (D-RATS), Biologic Analog Science Associated with Lava Terrains (BASALT), and Next Space Technologies for Exploration Partnerships (NextSTEP) Habitat Ground Testing. Aquatic analogs include NASA Extreme Environment Mission Operations (NEEMO) and Pavilion Lake Research Project (PLRP). Laboratory analogs include the Neutral Buoyancy Laboratory (NBL), Active Response Gravity Offload System (ARGOS), rock yards, and virtual and hybrid reality simulation environments. While no single Earth-based analog environment is perfect for simulating all characteristics of other planetary surfaces, testing across multiple locations leverages the strengths of each to provide an integrated understanding of how to best conduct real spaceflight surface exploration missions.

Discussion: Analog testing supports operationally-driven design of systems and architectures. It provides an early understanding of the nuts and bolts of how we will execute exploration operations in environments that are orders of magnitude easier and cheaper than spaceflight, and how those operations drive hardware requirements and key architectural decisions. These analog operations are an integral part of a lean development system focused on reaching the point where we know with a high degree of confidence what we want to build, how we are going to build it, and how we are going to operate it.

The “Operationally-Driven Design” philosophy requires frequent and rigorous testing of prototype hardware, software, and ConOps to continually inform the ongoing development of exploration technologies, systems, and architectures through formalized testing, data collection, analysis, and validation. Analog field tests, combined with analysis and simulations, provide a cost-effective means of systematically evaluating architectural assumptions, prototype hardware, and operations concepts with participation from end-users (e.g. crew, scientists, mission operators, etc.) early in the development process. They provide substantial cost-saving benefits by uncovering technical and operational deficiencies in a terrestrial environment before flight.

Since 2008, the Exploration Analog and Mission Development (EAMD) team, now identified as the Human Exploration and Operations Mission Directorate (HEOMD) Systems Engineering and Integration (SE&I) Strategic Analysis (SA) Human-in-the-Loop (HITL) Test Team, has successfully conducted multiple evaluations of spaceflight analog missions using a consistent set of operational products, tools, methods, and metrics to enable the iterative development, testing, analysis, and validation of evolving exploration architectures, operations concepts, and vehicle designs. This has been achieved by ensuring that the required level of rigor and consistency is applied before, during, and after the operational tests so that the data collected remains highly relevant to NASA’s strategic architecture and technology development goals and provides data-driven, actionable recommendations.

Conclusion: Earth-based operational field tests in multiple environments serve as high-fidelity analogs to enable operationally-driven design of systems and architectures. The HEOMD SE&I SA HITL Test Team has led the study design and protocols for many of these analogs.

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Figure 1. *Example terrestrial, aquatic, and laboratory analog environments. (A) D-RATS; (B) BASALT; (C) NextSTEP Habitat; (D) NEEMO; (E) PLRP; (F) ARGOS.*