Intra-EVA Space-to-Ground Interactions when Conducting Scientific Fieldwork Under Simulated Mars Mission Constraints

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The Biologic Analog Science Associated with Lava Terrains (BASALT) project is a four-year program dedicated to iteratively designing, implementing, and evaluating concepts of operations (ConOps) and supporting capabilities to enable and enhance scientific exploration for future human Mars missions. The BASALT project has incorporated three field deployments during which real (non-simulated) biological and geochemical field science have been conducted at two high-fidelity Mars analog locations under simulated Mars mission conditions, including communication delays and data transmission limitations. BASALT's primary Science objective has been to extract basaltic samples for the purpose of investigating how microbial communities and habitability correlate with the physical and geochemical characteristics of chemically altered basalt environments. Field sites include the active East Rift Zone on the Big Island of Hawai'i, reminiscent of early Mars when basaltic volcanism and interaction with water were widespread, and the dormant eastern Snake River Plain in Idaho, similar to present-day Mars where basaltic volcanism is rare and most evidence for volcano-driven hydrothermal activity is relict. BASALT's primary Science Operations objective has been to investigate exploration ConOps and capabilities that facilitate scientific return during human-robotic exploration under Mars mission constraints. Each field deployment has consisted of ten extravehicular activities (EVAs) on the volcanic flows in which crews of two extravehicular and two intravehicular crewmembers conducted the field science while communicating across time delay and under bandwidth constraints with an Earth-based Mission Support Center (MSC) comprised of expert scientists and operators. Communication latencies of 5 and 15 min one-way light time and low (0.512 Mb/s uplink, 1.54 Mb/s downlink) and high (5.0 Mb/s uplink, 10.0 Mb/s downlink) bandwidth conditions were evaluated. EVA crewmembers communicated with the MSC via voice and text messaging. They also provided scientific instrument data, still imagery, video streams from chest-mounted cameras, GPS location tracking information. The MSC monitored and reviewed incoming data from the field across delay and provided recommendations for pre-sampling and sampling tasks based on their collective expertise. The scientists used dynamic priority ranking lists, referred to as dynamic leaderboards, to track and rank candidate samples relative to one another and against the science objectives for the current EVA and the overall mission. Updates to the dynamic leaderboards throughout the EVA were relayed regularly to the IV crewmembers. The use of these leaderboards enabled the crew to track the dynamic nature of the MSC recommendations and helped minimize crew idle time (defined as time spent waiting for input from Earth during which no other productive tasks are being performed).

EVA timelines were strategically designed to enable continuous (delayed) feedback from an Earth-based Science Team while simultaneously minimizing crew idle time. Such timelines are operationally advantageous, reducing transport costs by eliminating the need for crews to return to the same locations on multiple EVAs while still providing opportunities for recommendations from science experts on Earth, and scientifically advantageous by minimizing the potential for cross-contamination across sites. This paper will highlight the space-to-ground interaction results from the three BASALT field deployments, including planned versus actual EVA timeline data, ground assimilation times (defined as the amount of time available to the MSC to provide input to the crew), and idle time. Furthermore, we describe how these results vary under the different communication latency and bandwidth conditions. Together, these data will provide a basis for guiding and prioritizing capability development for future human exploration missions.