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DESERT RATS 2011 MISSION SIMULATION: EFFECTS OF MICROGRAVITY OPERATIONAL MODES ON FIELD GEOLOGY CAPABILITIES. J.E. Bleacher[1], J.M. Hurtado, Jr.[2], J.A. Meyer[2], C.M. Tewksbury-Christle[3]. [1]Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, Jacob.E.Bleacher@nasa.gov, [2]University of Texas at El Paso, Department of Geological Sciences & Center for Space Exploration Technology Research, El Paso, TX, 79968, [3]United States Air Force.

Introduction: Desert Research and Technology Studies (DRATS) is a multi-year series of NASA tests that deploy planetary surface hardware and exercise mission and science operations in difficult conditions to advance human and robotic exploration capabilities. DRATS 2011 (Aug. 30-Sept. 9, 2011) tested strategies for human exploration of microgravity targets such as near-Earth asteroids (NEAs). Here we report the crew perspective on the impact of simulated microgravity operations on our capability to conduct field geology.

Methods: Two significant human exploration concepts were tested: (1) the effect of time-delayed communications; and (2) multiple combinations of hardware and crew assignments. Communication between the crew in Arizona and the Mission Control Center (MCC) and Science Backroom (SB) (both in Houston, TX) was conducted with an artificial 50 s time delay to simulate a NEA mission at a distance of ~0.1 AU from Earth. MCC/SB could speak directly with extravehicular (EV) and intravehicular (IV) crew. Two-way communication via text messaging was available between Houston and the IV crew, as was one-way text messaging from Houston to the EV crew.

We report on 3 test conditions, each involving 3 or 4 human crewmembers and various combinations of hardware, including: (1) shirtsleeve backpacks for simulated extravehicular activities (EVAs) [1]; (2) two Space Exploration Vehicles (SEVs) [2]; and (3) the Deep Space Habitat (DSH), a notional laboratory module [3]. When tested, the DSH was assumed to be orbiting ~1 km from the microgravity target. The crew could leave on exploration sorties directly from the DSH via EVA, or they could use the SEV to approach the target before initiating EVAs.

We simulated two microgravity EVA modes. One assumed the use of a “Super” SAFER (Simplified Aid For EVA Rescue), a notional, self-contained propulsive backpack system. This assumed capability enabled crewmembers to conduct un-tethered EVAs. To simulate the propulsive capability of a SSAFER, crew translation rates were restricted to <~0.3 m/s. Translations were kept (as much as reasonable) to straight lines, and all starts, stops, and direction changes were recorded to provide 1st-order data on propellant usage and impose constraints on propellant loads. SSAFER crewmembers were required to anchor to and de-anchor from the surface before and after sample collection and documentation. This imposed a time penalty (~2 min.), and limited the radius of anchored operations to ~1 m.

The second EVA mode involved a notional Astronaut Positioning System (APS), a passive “robotic” arm mounted to the front of the SEV and attached to the EV crewmember. It was assumed that the EV crewmember would control their position on the APS while the SEV maintained position around the target. The APS constrained the operational radius of EVA crewmembers to ~4 m, and any motion beyond that distance required a translation of the SEV.

Results: We find that delayed voice communications from Houston to the EV crewmembers was disruptive to EVAs and risked loss of information between Houston and the crew because of the high workload EV crewmembers face, especially if communications arrive during an EV crewmember’s science documentation over the voice-loop. Having at least one IV crewmember acting as an intermediary was highly valuable for managing delayed communications with Houston. The IV crewmember dominantly communicated with Houston by two-way text messaging, and information for the EV crewmembers was relayed by the IV crewmember during moments of decreased workload. The IV crewmember was therefore a buffer between Houston and the EV crewmembers which made the time delay transparent to the EV crew. Text messaging was a vital capability as it is inherently asynchronous, and, unlike with voice, the flow of information in a text conversation is not greatly affected by a time delay. When direct voice communication was required, Houston relayed a precursor message indicating an important voice message would follow in 30 s, giving the IV and EV crews time to prepare.

APS and SSAFER had complementary advantages. APS enables crews to avoid anchor/de-anchor time penalties and was most beneficial to EVAs that emphasized sample collection. However, the APS limited contextual perspective because it restricted the distance that crewmembers could move away from the SEV. SSAFER enabled greater mobility and was ideal for making contextual observations. However, SSAFER imposes anchor/de-anchor penalties. Generally, we found that geologic context was best characterized with SSAFER, while sample collection and detailed site characterization was best conducted with APS.

Prior to the 2011 test, we hypothesized that a trained geologist would be best used in an EV position. As a result of the test, we also identified value in having an IV geologist. Sample collection and documentation is costly with respect to time [4], and even more so under the constraints of microgravity operations. While an EV crewmember was documenting samples on EVA, an IV geologist in the SEV could be several steps ahead (e.g. making independent observations, collecting images, choosing the next sample, etc.). An IV geologist, free of the burden of performing the EVA, might also be better suited to synthesize and communicate science to the SB (and/or the DSH), especially since the EV crews were never farther than ~25 m from the SEV, and, therefore, the IV crew had a clear view of those activities.

Our experiences show that optimal crew and asset allocation depends greatly on the details of each station, each requiring different crewmember assignments, utilization of geologist expertise, and hardware configurations to best achieve the science objectives. Therefore, we find great value in preserving the capability for the crew (particularly due to the time delay) to make real-time crewmember assignments for EVAs. This flexibility highlights the advantage of including humans in planetary exploration: their ability to make real-time observations, interpretations, and judgments that factor into each subsequent step of a traverse [1,4,5,6]. While rigidly-scripted and highly-practiced EVAs, such as those on Apollo and ISS, are executed to dependable success, such EVAs reduce the advantage of using a human over a robot and are less scientifically productive [7]. Future exploratory EVAs, particularly at distances that impose time-delayed communication, will require real-time adjustments to EVA plans [6,7] without the luxury of extensive pre-planning and scripting.

Finally, we find that the operational and safety overhead related to EVAs increases the total cost of effectively conducting fieldwork and exercising real-time exploration decisions. Based on the 2011 test compared to previous tests [1,4,5,8,9], we note that this overhead is different (and arguably greater) for microgravity EVAs than it is for planetary surface EVAs (i.e. Moon or Mars). We suggest that, while humans may be more effective science explorers than remotely-operated robots, the operational overhead imposed by EVAs may offset this benefit in the case of microgravity targets. However, we still find a compelling scientific advantage for including humans, as opposed to robots alone, in lunar- or Mars-like gravity environments.

Conclusions & Recommendations: The technologies required to conduct field geology on a microgravity target are in development. As such, we recommend capabilities that should be preserved within this developing exploration architecture. The complementary nature of SSAFER and APS highlights the importance of preserving both mobility, for site characterization, and anchoring capabilities, for sample collection. This may require the continued development of both APS- and SSAFER-like hardware, or dictate the necessary capabilities for new EVA technologies.

The role of an IV crewmember, as a communications intermediary as well as offering geologic expertise when necessary, is highly important. However we do not feel that this role was adequately tested during 2011 with respect to the number of IV crew, their optimal location (DSH and/or SEV), or their specific roles. We recommend future tests focus on how best to use this position. We also note that the workload of precision station-keeping operations around a NEA target may require a dedicated pilot, so an additional IV crewmember may be required.

Future testing might focus on the decision-making process between the crew and MCC/SB for real-time crew assignments at a station. It is clear that crew autonomy becomes increasingly important as communications time delays increase. This requires a high level of training for all crewmembers, and the inclusion of trained specialists (e.g., professional geologists) to lead science activities onsite. All crewmembers should be cross-trained as much as is practical. Furthermore, science team feedback to the crew is extremely important. The crew benefit greatly from inclusion in the science discussion and from a basic evaluation of data quality (observations, images, etc.) as the data is being collected or soon thereafter.

Comparison with previous DRATS tests indicates that the additional operational overhead of exploring an extreme microgravity target such as a NEA reduces the scientific advantage of using a human over a robot compared to operations on a planetary surface such as the Moon or Mars. As such, the true science value of sending a human to a microgravity target must be weighed against the cost of doing so.

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