PRACTICING CREW AUTONOMY. K. Holden[1], [1]Leidos, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX, kritina.l.holden@nasa.gov

Introduction: Future deep space missions will present significant challenges for astronauts. Stressors such as extended microgravity with gravity transitions, increased space radiation, isolation, distance from Earth, and the hostile space environment will negatively impact crew performance and threaten mission success. Researchers, developers, and planners must also prepare for a mission unlike anything ever before attempted. NASA's training paradigms have been designed to support relatively short space missions, with crew training preflight for virtually all tasks. Mission Control Center (MCC) is available around the clock to assist with tasks, troubleshoot and solve problems, and monitor for errors. Future deep space missions will require a much different approach. Onboard training, refresher training, and Just-in-Time (JIT) training will have to be designed and tested so that crews can train during the mission itself. The tools and support services provided by MCC will have to be replicated onboard so that crew can work independently during time delays and communication blackouts. We must be prepared for the worst case scenario – total crew autonomy.

Preparedness for Autonomy: A group of experts representing the crew office, flight/mission control, mission planning, medicine, behavioral health, and training were brought together as part of a focus group to discuss the challenges of autonomous operations. After a half day of discussion, they concluded that we are inadequately prepared for crew to operate autonomously today, as the majority of unexpected situations and problems have always been handled by experts at MCC. They also stated that intelligent systems will be critical to support astronauts when they do not have communication with MCC. They noted that these systems are long-lead items and will need to be developed and extensively tested with crew to ensure that they are well-designed, provide the needed support, and have crew trust [1].

Critical Proving Ground: Lunar surface missions will serve as critical proving grounds for future deep space missions. These missions satisfy most of the anticipated stressors of deep space flight, to include extended microgravity and gravitational transitions, space radiation, isolation, and hostile environment. Distance from Earth resulting in potential for crew autonomy is the primary exception. For that reason, it is critical that we practice and assess our readiness for autonomous crew operations in an environment where MCC is still available as a safety net – lunar missions. This can be accomplished safely using a scientific approach, and integrating with the planetary science already planned.

Practicing Autonomy: The approach to this investigation would involve multiple phases: 1) Collection of baseline autonomy measures under nominal planned operations, 2) Monitored autonomy with human performance measurement, and 3) Autonomy technology demonstration with human performance measurement.

Baseline Measures. An important first step will involve characterization of the amount and type of crew interaction with MCC to determine crew dependence during lunar tasks. This will involve unobtrusive data collection of data such as number of calls to MCC for assistance, information, sanity checking, direction, etc.

Monitored Autonomy. During the pre-defined monitored autonomy phase, astronauts will perform their normal planned tasks, but will be instructed to contact MCC only in an emergency or if a significant milestone will be missed after they have exhausted all of their resources to solve the problem. They will be briefed on the importance of practicing autonomy and told that they should depend solely on their crewmates and the resources available to them in their vehicle/habitat. After the period of monitored autonomy is over, crew will be asked to respond to a post autonomy survey, identifying what information, resources or capabilities they had needed for task accomplishment, but did not have. Errors and incomplete tasks and objectives will be recorded. Data from this phase will indicate the types of tools and information autonomous crews may need that was not been anticipated or provided.

Autonomy Technology Demonstration. Several autonomy-enabling technologies will be provided for use/evaluation to support key tasks. Performance data on those tasks, and surveys for crew feedback on the technologies will be collected. The success of these select technologies in a real mission environment will be critical for planning their use in the future, as well as for identifying modifications or enhancements needed. Example technologies include Just-in-Time (JIT) training tools, decision support systems, and medical diagnostic software.

Resources for the Investigation. This investigation would require the following estimated resources:

- Crew time across entire mission: two crew, 12 hours per person for technology demonstration and surveys

- Upmass: tablet computer, laptop computer, possibly a small medical instrument

Conclusion: Astronauts will face increased physical, cognitive, and environmental challenges as they embark on deep space journeys to destinations such as Mars. On these missions, crews will need to be prepared to operate autonomously due to distance from Earth. NASA has no experience conducting missions in which astronaut crews are operating completely autonomously, and we do not currently have the intelligent systems and tools needed to adequately support these autonomous crews. It is critically important that we take advantage of lunar missions as a testbed for these future deep space missions. These missions offer the unique opportunity for crews to practice autonomy, and this experience is crucial for identifying needs and improvements for future deep space missions.

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References: [1] Holden, K., Munson, B., Russi-Vigoya, M.N., Dempsey, D., and Adelstein, B.D. (2020) *Human Capabilities Assessment for Autonomous Missions (HCAAM) Phase II: Development and Validation of an Autonomous Operations Task List Final Report* (Internal Report: Human Factors and Behavioral Performance (HFBP), NASA Johnson Space Center.