AMO EXPRESS: A Command and Control Experiment for Crew Autonomy Onboard the International Space Station

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NASA is investigating a range of future human spaceflight missions, including both Mars-distance and Near Earth Object (NEO) targets. Of significant importance for these missions is the balance between crew autonomy and vehicle automation. As distance from Earth results in increasing communication delays, future crews need both the capability and authority to independently make decisions. However, small crews cannot take on all functions performed by ground today, and so vehicles must be more automated to reduce the crew workload for such missions.

NASA's Advanced Exploration Systems Program funded Autonomous Mission Operations (AMO) project conducted an autonomous command and control experiment on-board the International Space Station that demonstrated single action intelligent procedures for crew command and control. The target problem was to enable crew initialization of a facility class rack with power and thermal interfaces, and involving core and payload command and telemetry processing, without support from ground controllers. This autonomous operations capability is enabling in scenarios such as initialization of a medical facility to respond to a crew medical emergency, and representative of other spacecraft autonomy challenges. The experiment was conducted using the Expedite the Processing of Experiments for Space Station (EXPRESS) rack 7, which was located in the Port 2 location within the U.S Laboratory onboard the International Space Station (ISS). Activation and deactivation of this facility is time consuming and operationally intensive, requiring coordination of three flight control positions, 47 nominal steps, 57 commands, 276 telemetry checks, and coordination of multiple ISS systems (both core and payload). Utilization of Draper Laboratory's Timeliner software, deployed on-board the ISS within the Command and Control (C&C) computers and the Payload computers, allowed development of the automated procedures specific to ISS without having to certify and employ novel software for procedure development and execution. The procedures contained the ground procedure logic and actions as possible to include fault detection and recovery capabilities.

The autonomous operations concept includes a reduction of the amount of data a crew operator is required to verify during activation or de-activation, as well as integration of procedure execution status and relevant data in a single integrated display. During execution, the auto-procedures (via Timerliner) provide a step-by-step messaging paradigm and a high level status upon termination. This messaging and high level status is the only data generated for operator display. To enhance situational awareness of the operator, the Web-based Procedure Display (WebPD) provides a novel approach to the issues of procedure display and execution tracking. WebPD is a web based application that serves as the user interface for electronic procedure execution. It incorporates several aspects of the HTML5 standard. Procedures are written in a dialect of XML called Procedure Representation Language (PRL). WebPD tracks execution status in the procedure or procedures being displayed. WebPD aggregates and simplifies the auto-sequence execution status information, and formatted to be easily followed and understood by an operator who is not dedicated to actively monitoring the task. WebPD also provides an integrated data and control interface to pause or halt the execution in order to provide a check point of operation and to examine progress before starting the next sequence of activities. For this demonstration, the procedure was initiated and monitored from the ground. As the Timeliner sequences executed, their high level execution status was written to PLMDM memory. This memory is read and downlinked via Ku-Band at a 1 Hz rate. The data containing the high level execution status is de-commutated on the ground, and rebroadcast for WebPD consumption. A future demonstration will be performed onboard, with ISS astronauts initiating the operations instead of ground controllers.

The AMO EXPRESS experiment demonstrated activation and de-activation of EXPRESS rack 7, providing the capability of future single button activations and deactivations of facility class racks. The experiment achieved numerous technical and operations 'firsts' for the ISS, including:

- Integration of core and payload automation onboard ISS (Payload bundles communicating to core and payload avionics).
- Embedding of vehicle command and telemetry into an auto-procedure.
- Integration of nominal and off-nominal operations (embedded fault detection and recovery) in single procedure.
- Combined three console position procedures into two "Single Button" autonomous operations.
- Combined core and payload operations in a single autonomous procedure.
- Autonomous command response to a detected failure (two configuration files did not load; this was detected and file contents loaded autonomously).

This paper will describe the development, test and execution results of the autonomous operations that have been performed on-board the ISS with the AMO EXPRESS team and will also outline the future planned development and operational efforts of the team as it continues to probe the issues with deep space manned mission operations.