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# POTENTIAL LIFE CYCLE BENEFITS OF INTELLIGENT TOOLS FOR GROUND CONTROL OF SPACE ROBOTICS

**Abstract**

Recent advances in automation and simulation tools have the potential to reduce the complexity of planning, analysis, and execution of robotic servicing systems. Traditionally, space manipulators have been operated from the ground using a real-time, human-in-the-loop paradigm. Individual commands are manually uplinked while a team of experts monitors telemetry to maintain constant situation awareness. Procedures are also largely planned, written, and validated manually. This approach has been used for over 30 years and has proven to be very safe, but does require a large commitment of human effort.

Future space missions beyond low Earth orbit, such as the Lunar Orbital Platform – Gateway are envisioned to operate under much stricter communications constraints. Operationally they will be more akin to Mars rover missions than the ISS, with limited windows of communications followed by week-long blackouts. Since the traditional paradigm is predicated on continuous communications, it cannot be applied in these circumstances; at least, not without drastically reducing the availability of the robotic system. Clearly, a new approach is needed in order to meet the Mars-forward objective of Gateway.

Automated planning techniques from the field of artificial intelligence have the potential to greatly speed up the tempo of robotic operations planning. By modelling the logical states of the Gateway components, robotic elements, and payloads, and how these states get transitioned as actions are performed, the automated planner can suggest an initial plan based on a goal specified by the human user. As the user modifies the plan, the model can be used to perform automated validation. This allows the humans to focus their attention on the hard problems, while the machine intelligence takes care of routine operations and bookkeeping.

New approaches to human-machine interfaces have the potential to decrease monitoring efforts. Alphanumeric displays can be replaced by mixed- or augmented-reality displays to provide the same level of situational awareness with less (cumulative) cognitive load. This awareness applies equally to real-time monitoring, playback of stored telemetry (logged during blackout periods), and rehearsal of upcoming plans. The interfaces can also be used as an intuitive means of inputting goals for the automated planning system to act upon.