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THE USE OF VARIABLE AUTONOMY ROBOTICS TO IMPROVE CAPABILITY, UTILIZATION, AND FLEXIBILITY IN DEEP SPACE EXPLORATION MISSIONS FROM CISLUNAR SPACE TO MARS

Abstract

The international space community is exploring methods of strategically building upon International Space Station capabilities and partnerships to address the challenges associated with human exploration initiatives beyond Low Earth Orbit. This paper explores how Canadian heritage robotic technologies can be leveraged in a cost-effective way to reduce risk, improve operational and scientific productivity, and maximize utilization for multiple deep space exploration missions including NASA's Asteroid Redirect Mission, an Exploration Augmentation at the second Earth-Moon libration point, and human exploration of the Martian system. Robotics represent a 'key capability' that is an important part of an International Capability Driven Framework to support an evolving Mars campaign. Robotics have established their value over the last three decades supporting the Shuttle and ISS programs, and technology advancements will further increase mission utility during untended periods and crew productivity during tended phases of missions. Crew self-reliance is imperative as missions move further from Earth, and multi-purpose robotics systems will be a necessary tool in their 'kit'. Crew risk will be reduced by providing external situational awareness, and by minimizing the need to expose crew to the radiation environment during extravehicular activity. The advancement of supervisory autonomy will enable ground control of robotic assets over latent and intermittent communications, serving to alleviate the crew during time-critical periods or permitting operations during untended mission phases. Designing future systems for robotic manipulation (e.g. module berthing) will give mission operators flexibility in system reconfiguration methods, and provide a low mass alternative to automated docking. A Deep Space eXploration Robotics (DSXR) concept design, funded by the Canadian Space Agency (CSA), is presented which is an evolution of the state-of-the-art Next-Generation Canadarm prototype designs developed and built by MDA for the CSA. The nine degree of freedom manipulator includes extendable booms to support compact stowage on the Orion MPCV and other volume constrained spacecraft. DSXR contains an end-effector that interfaces with a variety of specialized tools to support mission specific operations. The tool suite includes contact tools for scientific surface exploration operations (sample collection, visual inspection, mass spectrometry, and in-situ resource utilization), and dexterous tools for automated vehicle inspection, repair, and logistics management. The ability of the DSXR system to meet the needs of an evolving Mars mission will be discussed through operational scenarios, the presentation of system concepts and architectures, and a review of available technologies to achieve the mission goals of an affordable, adaptable, and sustainable exploration roadmap.