Paper ID: 26282
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SPACE SYSTEMS SYMPOSIUM (D1)
Enabling Technologies for Space Systems (2)

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FURTHER DEVELOPMENT OF ROBOTIC TOOLS AND TECHNIQUES FOR TELE-OPERATED AND AUTONOMOUS ENGAGEMENT INITIATIVES

Abstract

Robotic Refueling Mission (RRM) is an ISS-hosted (International Space Station) payload that was developed by NASA Goddard Space Flight Center (GSFC). Its original mission objectives were accomplished in 2012 and 2013 by demonstrating the tasks required to perform an on-orbit robotic refueling of an uncooperative client.

With the experience and lessons of RRM Phase 1 operations to build upon, the Phase 2 Resupply hardware was designed to further mature the tools and techniques required for autonomous and tele-operated robotic tasks. The challenges of manipulating intricate interfaces such as safety wires, safety caps, fill/drain valves, SMA (Shape Memory Alloy) connectors, torque screw-heads and MLI (Multi-Layer Insulation), were met successfully by rigorous ground-based testing. Though the ground-based testing was done mostly with a non-flight-like robot arm and end effector; (and of course, gravity) pre-engagement coarse alignment maneuvers were executed onorbit very much as scripted by ground operators in the robot development lab.

Grasping or otherwise engaging the specific interfaces required precise alignment tweaks–with more of a free-hand fine adjustment approach using smaller tele-operated steps, more precise visual clues and compliance management. On-orbit robot arm stiffness and play affected the execution of tasks differently. Sometimes it helped, sometimes it hindered–underscoring the need to simulate the flight-like characteristics on the ground.

These lessons and experience will be applied to future RRM work, and will contribute to the on-going development of autonomous rendezvous, capture and berthing capabilities. The current development effort for the Restore project includes development of autonomous operations that rely on ground-based and flight software-based decision making. Tele-operations require human decisions based on visual clues and engineering telemetry. The challenge is to develop an operations approach that combines the best of all available options. We must consider requirements for Situational Awareness for both operator and machine; round-trip command/ sensor delay–engineering telemetry (slow) and video (slower) feed-back. A rendezvous and docking scenario for an LEO (Low Earth Orbit) servicer can be semi-autonomous and tele-operated with minimal delay.

The continuing development of these tools and techniques get us closer to a robot that can perform mission-extending and cost-saving services–refueling, relocation, remote inspection and ORU replacement. To date, the Restore concept has been focused on rendezvous and capture of spacecraft whose physical features and geometry are well characterized. The addition of (or a transition to) a more generic grasping mechanism for orbital debris redirection or removal will be discussed.