Robotic Habitat Technologies for Minimizing Crew Maintenance Requirements

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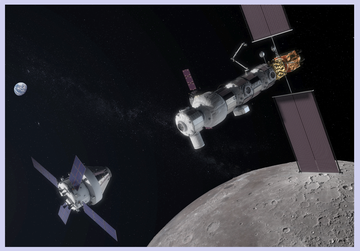
Research Problem Statement

- International Space Station (ISS) astronauts spend over 21% of work time keeping the station running limiting time for science [1]
- NASA will launch the Deep Space Lunar Gateway in 2024 [2]
- Gateway will be uncrewed eleven months out of the year [2]
- Dexterous robotic system(s) are required to maintain and operate the outpost, and when crewed, to allow for astronauts to focus their limited time on scientific experimentation and research
- System must safely operate with or without human presence



Artist concept of the NASA Lunar Gateway [3]

Research Question

How can robotic systems be utilized to perform operational and maintenance tasks on the Lunar Gateway to allow astronauts to focus on science and mission objectives?

Hypothesis

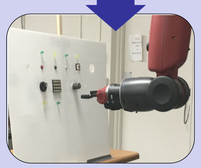
Robotic systems can complete a multitude of tasks, such as pressing buttons, flipping switches, turning knobs, attaching and detaching electrical connectors, and manipulating cargo transfer bags, when equipped with the appropriate end effector.

Methodology

Define Desired Abilities

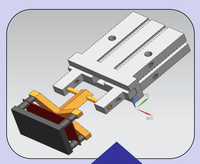
First generation taskboard with mounted buttons keypads, switches, and electrical connectors

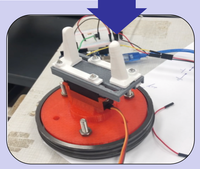
Create Task Database



Baxter interacting with the Taskboard, attempting different tasks

Increase Capabilities





Nicadrone end effector (top) Gripper Modifications (bottom)

Improve Fidelity

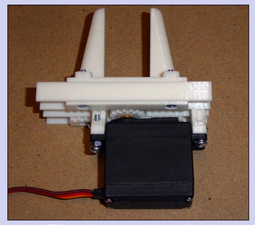
ISS Payload Rack Mockup (top) Robot interaction with rack (bottom)

Hardware

7-DOF Baxter Robot [4]

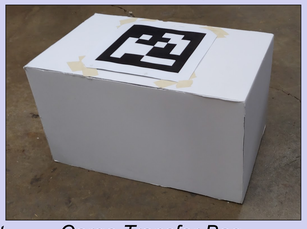
7-DOF SSL RANGER NBV Robot

Taskboard (buttons, switches, knobs, etc.)



Electromechanical gripper end effector

NicaDrone electromagnet end effector

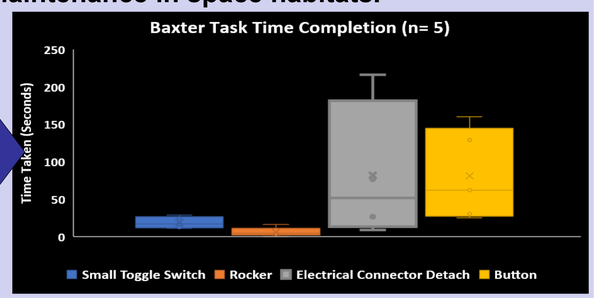


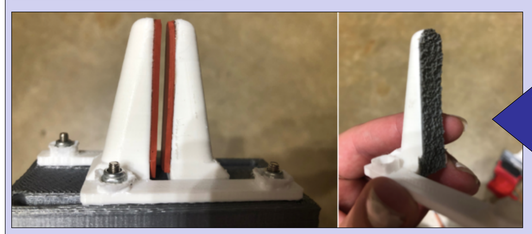
Cargo Transfer Bag (CTB) Mock-Up

Initial Experimental Results

Proved feasibility of utilizing robotic systems for maintenance in space habitats.

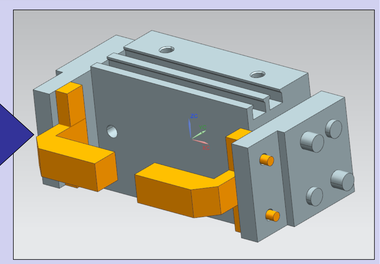
More complex tasks take longer to operate with robot. Wider variety of end effectors required.





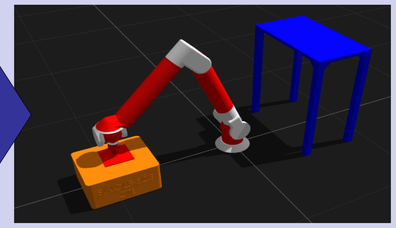
Gripper end effector slipping during testing, so rubber/ sandpaper-like modifications added to gripper surface.

Electromechanical end effector fails to supply enough force for certain tasks. Pneumatic system required to supply more force to the robot.

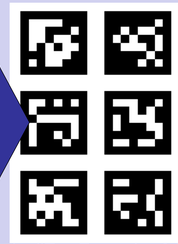


Simulations

Gazebo simulations are developed to autonomously enable a robot to locate and move a randomly placed CTB to a specified location



AprilTags (providing positional data) placed on a mock CTB to enable autonomous bag management with Baxter via NicaDrone end effector



AprilTag Examples [5]

Future Research Goals

Primary Goals:

- Construct International Standard Payload Rack for testing
- Demonstrate complex CTB logistics management by maneuvering a CTB mock-up between various shelves on the rack mock-up
- Automate AprilTag identification system to demonstrate full-scale identification and sorting of multiple CTBs
- Demonstrate more complex robotic movements, such as pulling out a drawer in the rack mock-up

Robots interacting with ISS Life Support System

Secondary Goals:

- Automation of robot interaction with taskboard
- Migration of the Ranger NBV manipulator onto a wheeled base for test operations/mobility in SSL habitat mockups
- Implementation of obstacle detection and avoidance system

Acknowledgements & Sources

Space Systems Lab, Robotics Realization Lab, Gemstone Honors College, NASA X-Hab, NASA RASC-AL