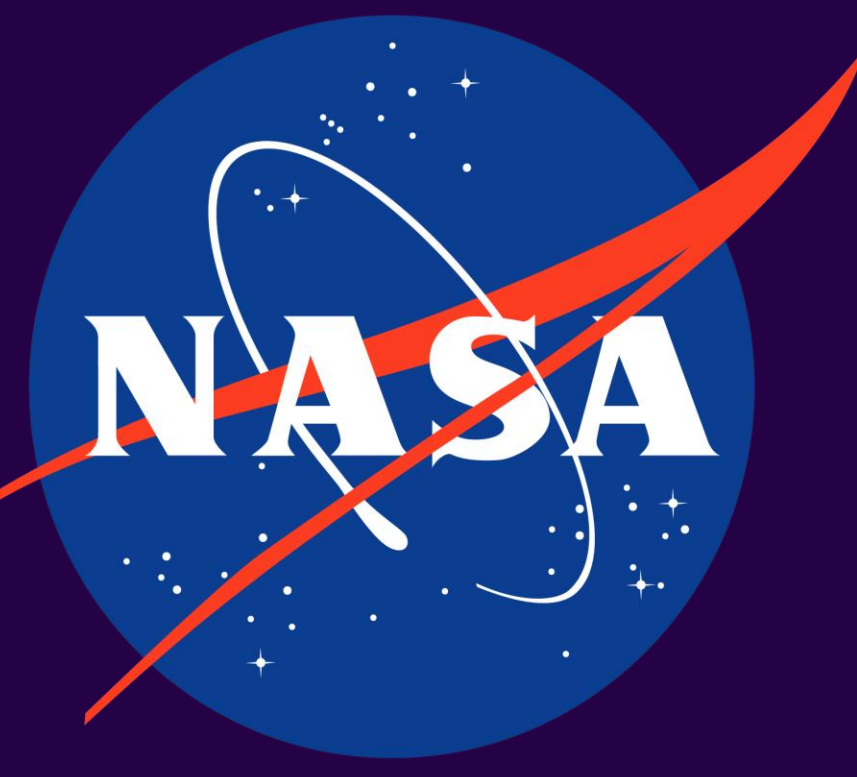




A Three-Finger Gripper Prototype for Autonomous Free-Flying Manipulation of On-Orbit Logistics



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Abstract

Astrobee is a free-flying robot aboard the International Space Station (ISS) that performs autonomous microgravity manipulation tasks such as anchoring onto smooth surfaces and perching onto ISS handrails [1-3]. Autonomous free-flying intra-vehicular robots that transport cargo could help manage on-orbit logistics for future crewed and uncrewed space stations [4,5]. However, cargo transport in microgravity presents novel challenges in ensuring contact-rich free-flying manipulation. The authors propose a novel prototype of a three-finger underactuated tendon-driven gripper for Astrobee to manipulate cargo logistics in microgravity. By leveraging Astrobee's reconfigurable perching arm payload, this prototype is capable of contact-rich grasping and transport of a single-size ISS cargo transfer bag (CTB). This article presents the hardware design, gripper prototype, and payload testing at Astrobee's Granite Lab testing facility.

Cargo Transfer Bags

ISS Cargo transfer bags (CTB) store on-orbit:

- Crew provisions
- Hardware spares
- Crew clothing
- Scientific experiments
- Spaceflight hardware



CTBs have soft-body and handles made of fabric. On ISS today, crew transport these cargo bags by hand between modules [4,5].

State-of-the-art

Astrobee's guest scientists have developed gripper payloads for microgravity manipulation such as [1]:

1. Gecko gripper: bio-inspired gecko-like adhesion gripper payload to anchor onto flat surfaces [2]
2. Perching gripper: perch onto ISS handrails [3]
3. REACCH gripper: active orbital debris removal

Manipulating the deformable CTB handles [5], using a rigid surface area contact-rich gripper would allow for robust grasp in microgravity. A gripper with more distal joint surface coverage and increased fingers would give the robust manipulation needed for deforming objects.

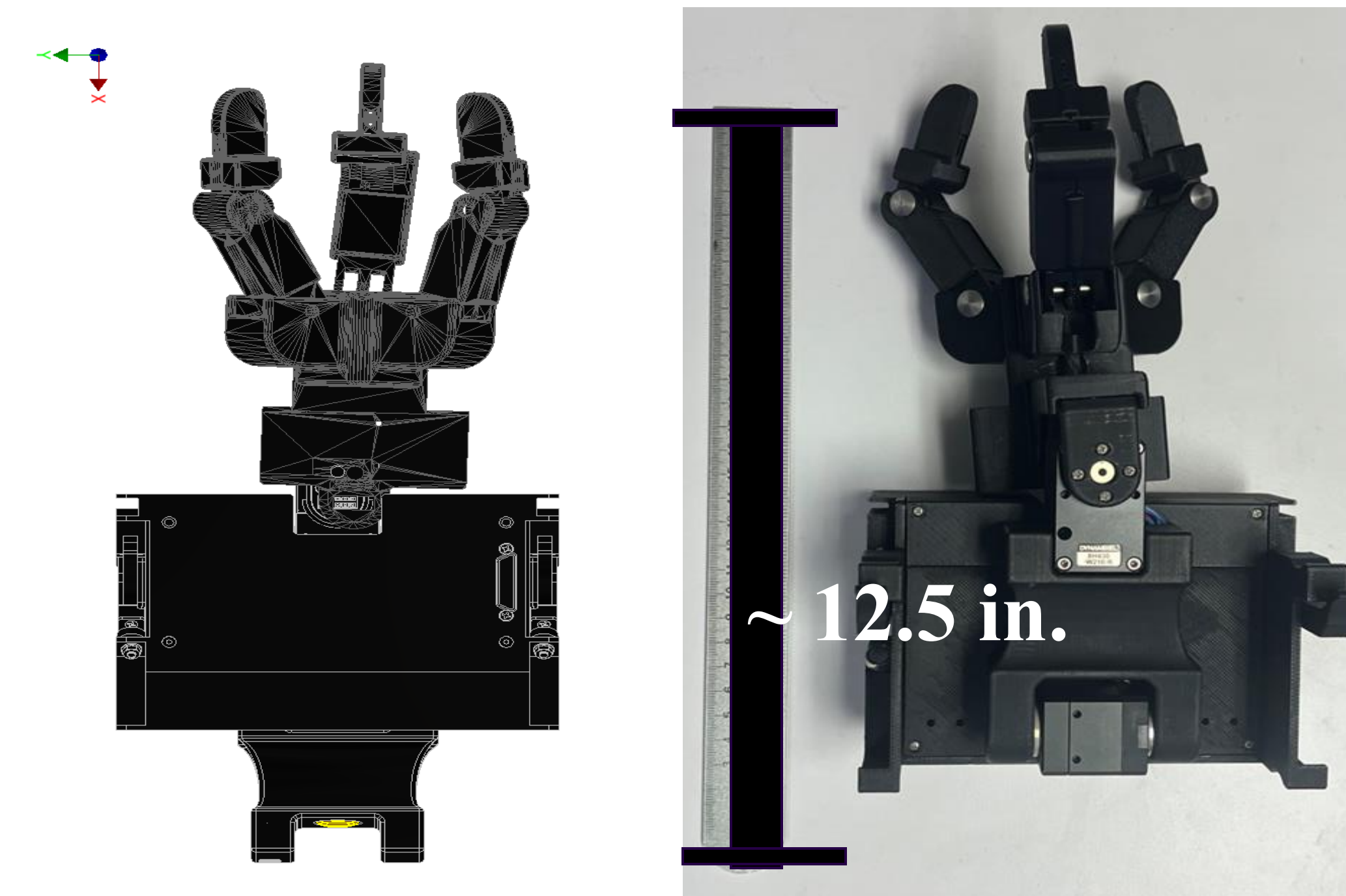
Three-Finger Gripper Prototype

This gripper prototype is a rigid three-finger underactuated tendon-driven gripper designed for grasping ISS CTBs.

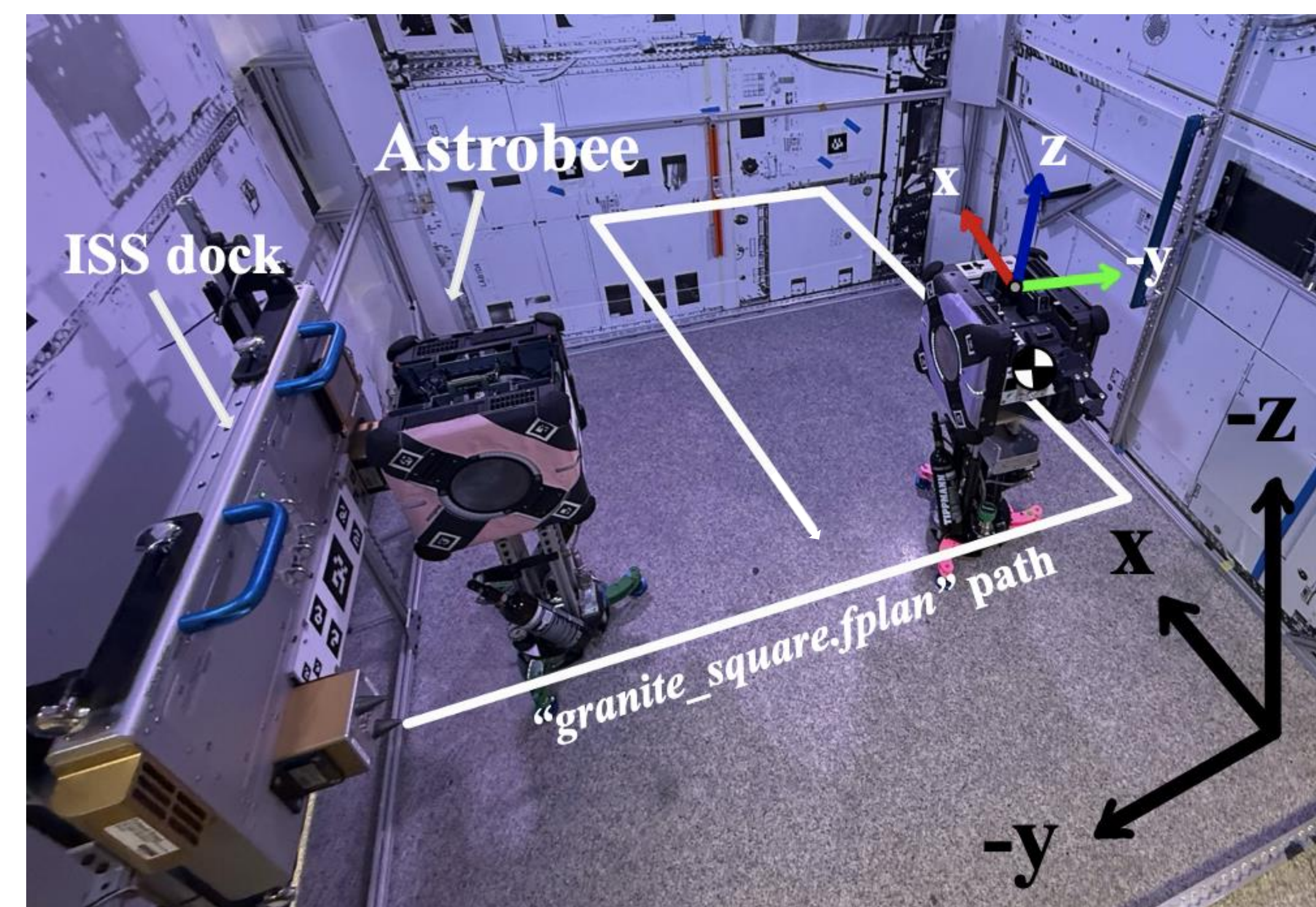
Some of the hardware design considerations include:

- Ease of integration in Astrobee's perching arm
- Constraint to Astrobee's 4.85 × 6.0 × 4.0 in. payload bay volume
- Contact-rich surface area coverage for the gripper's distal joints
- Claw-like grasp onto a single surface (CTB handle)

The gripper was designed using computer aided design (CAD) software and then 3-D printed using PLA filament. The manufactured prototype next to the CAD model is shown on the right figure.



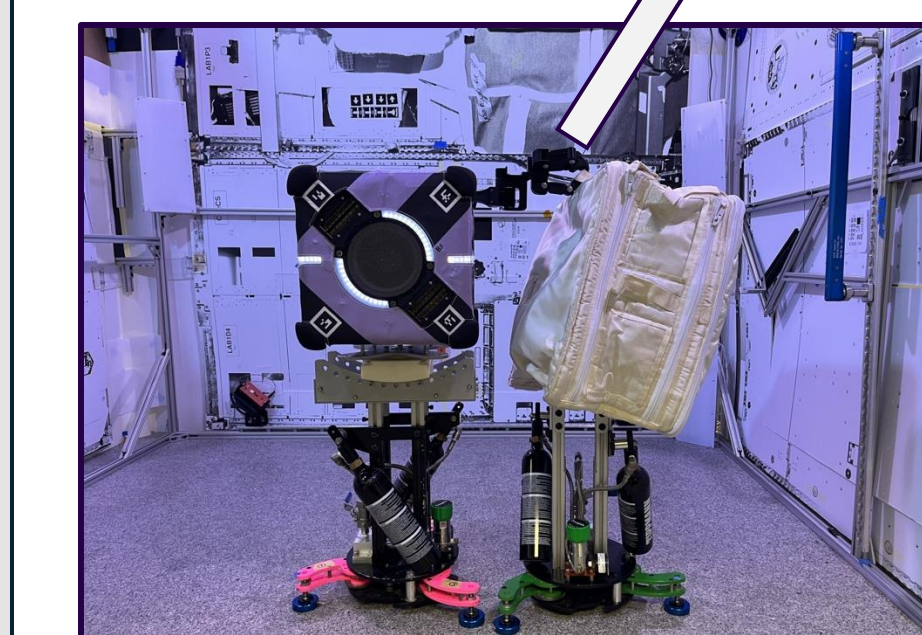
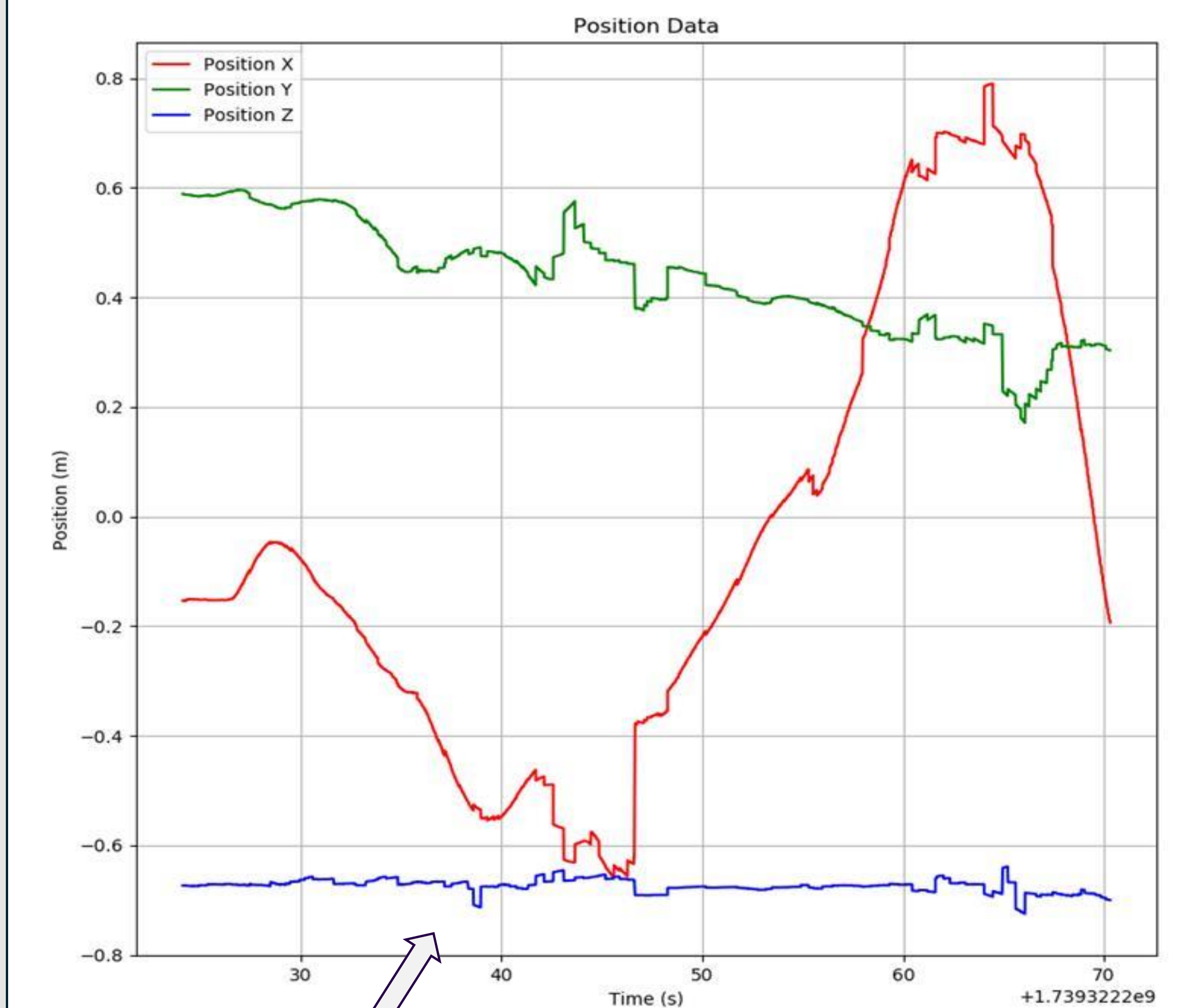
Granite Lab Testing Setup



For the gripper testing in the Granite Lab:

1. Attached the prototype onto Astrobee's perching arm at the wrist joint.
2. Mounted and secured a single-size ISS CTB on separate air carriage.
3. Controlled Astrobee to grasp the CTB with the gripper.
4. Ran the *granite_square.fplan* to free fly around the granite table along the set path while holding the CTB.
5. Observed position changes and torque values at the wrist joint during 3-Degree-of-Freedom free-flight.

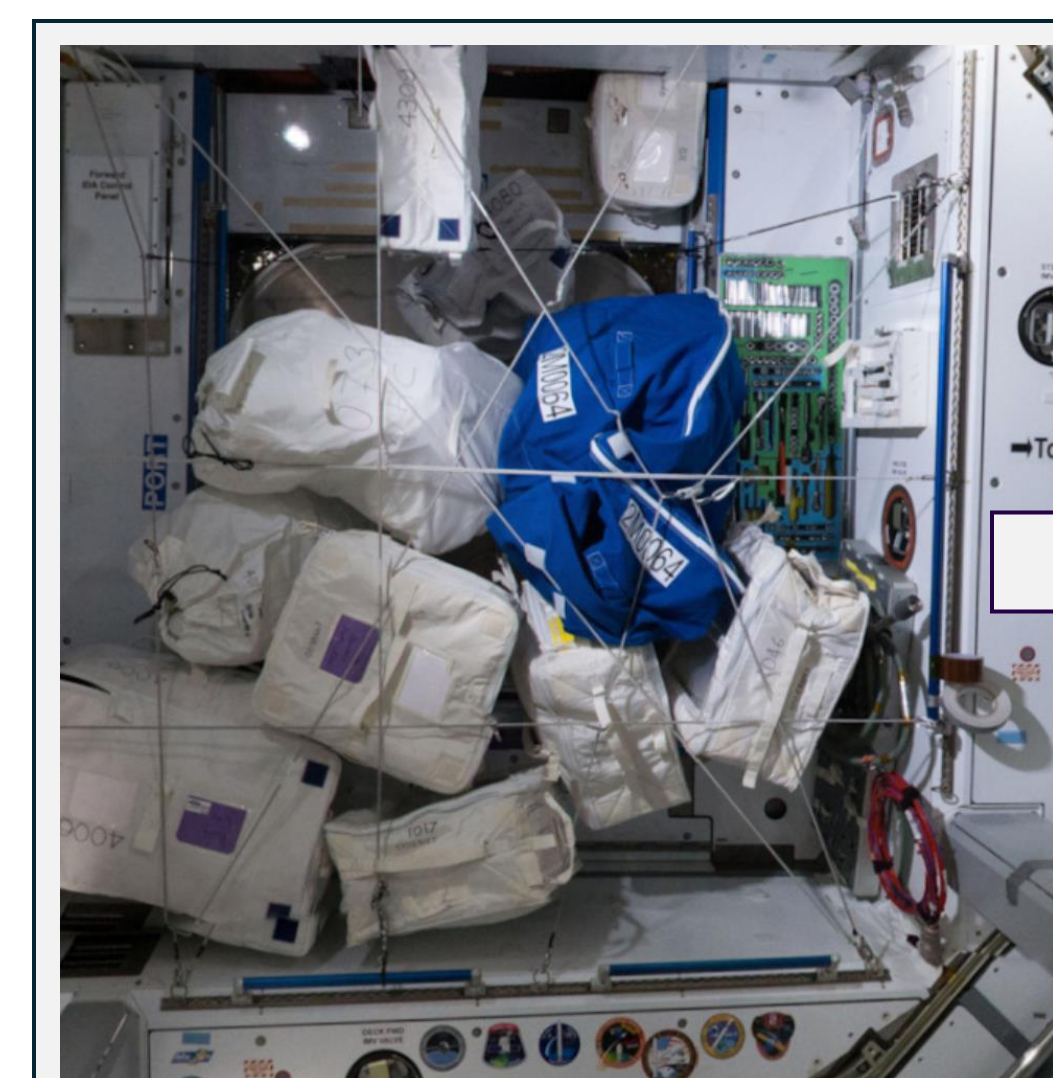
Testing Results



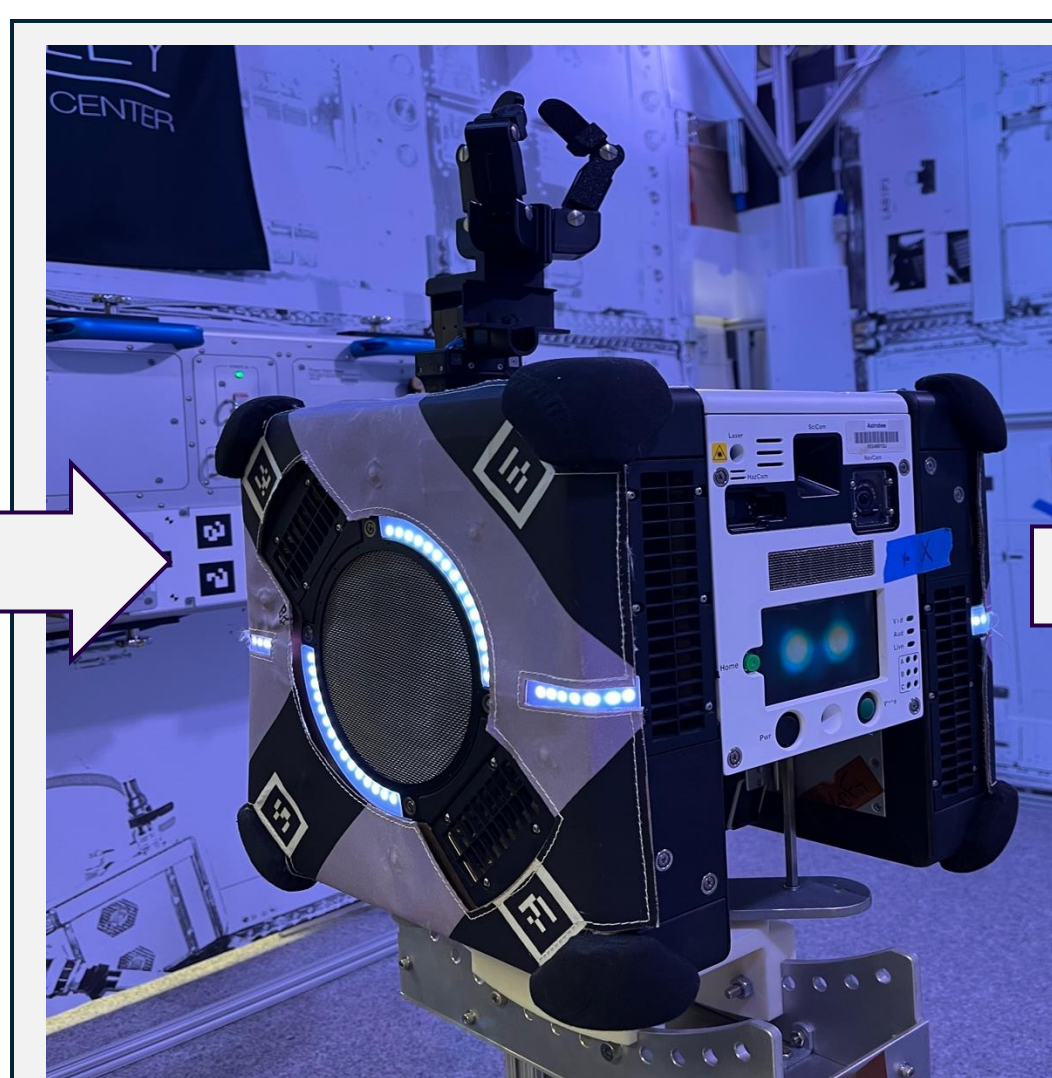
- Position on the granite
 - Nominal position with carriage attached
- Gripper does not significantly affect Astrobee's ability to fly

Astrobee Concept of Operations

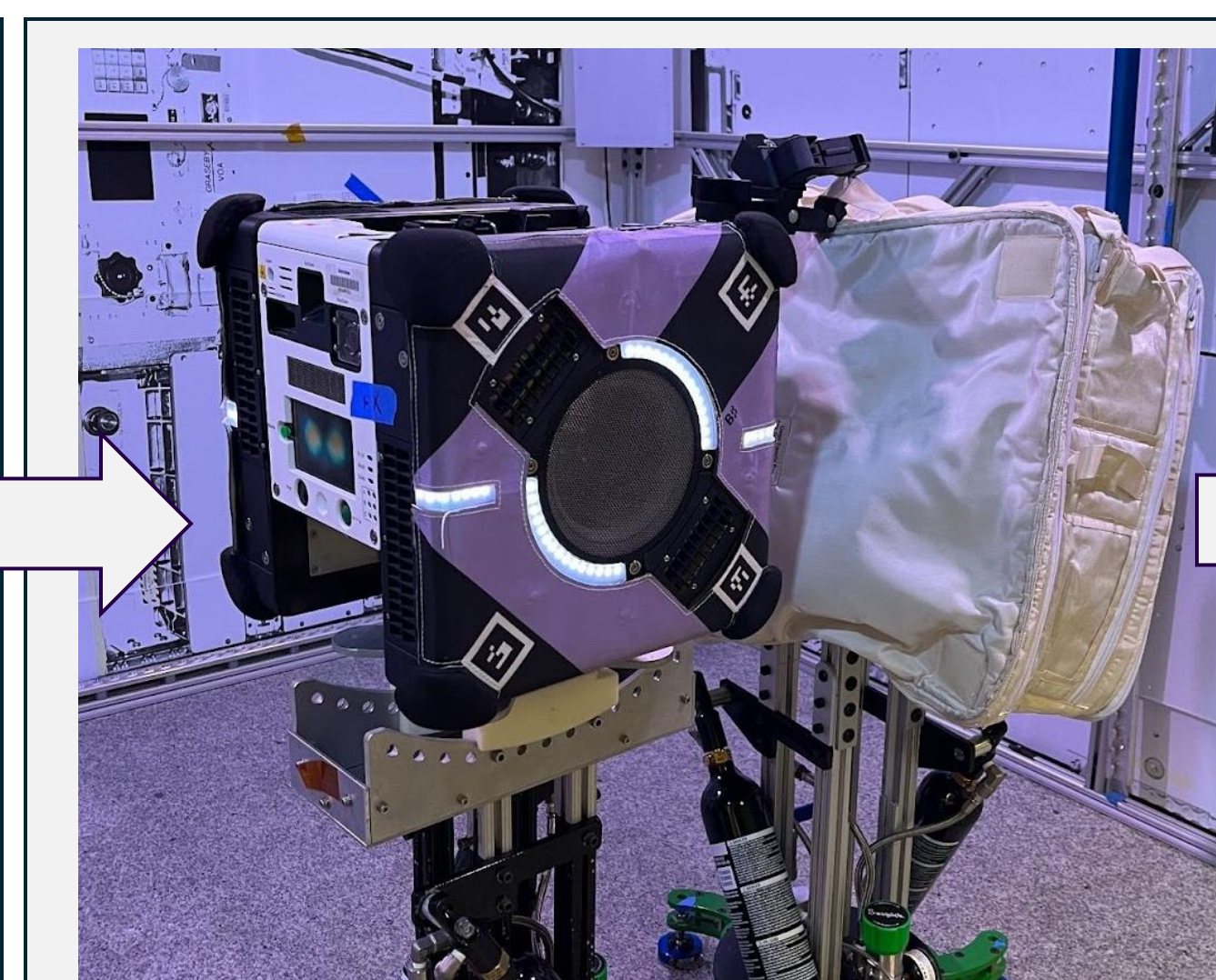
Un-managed logistics stored on different modules of the space station



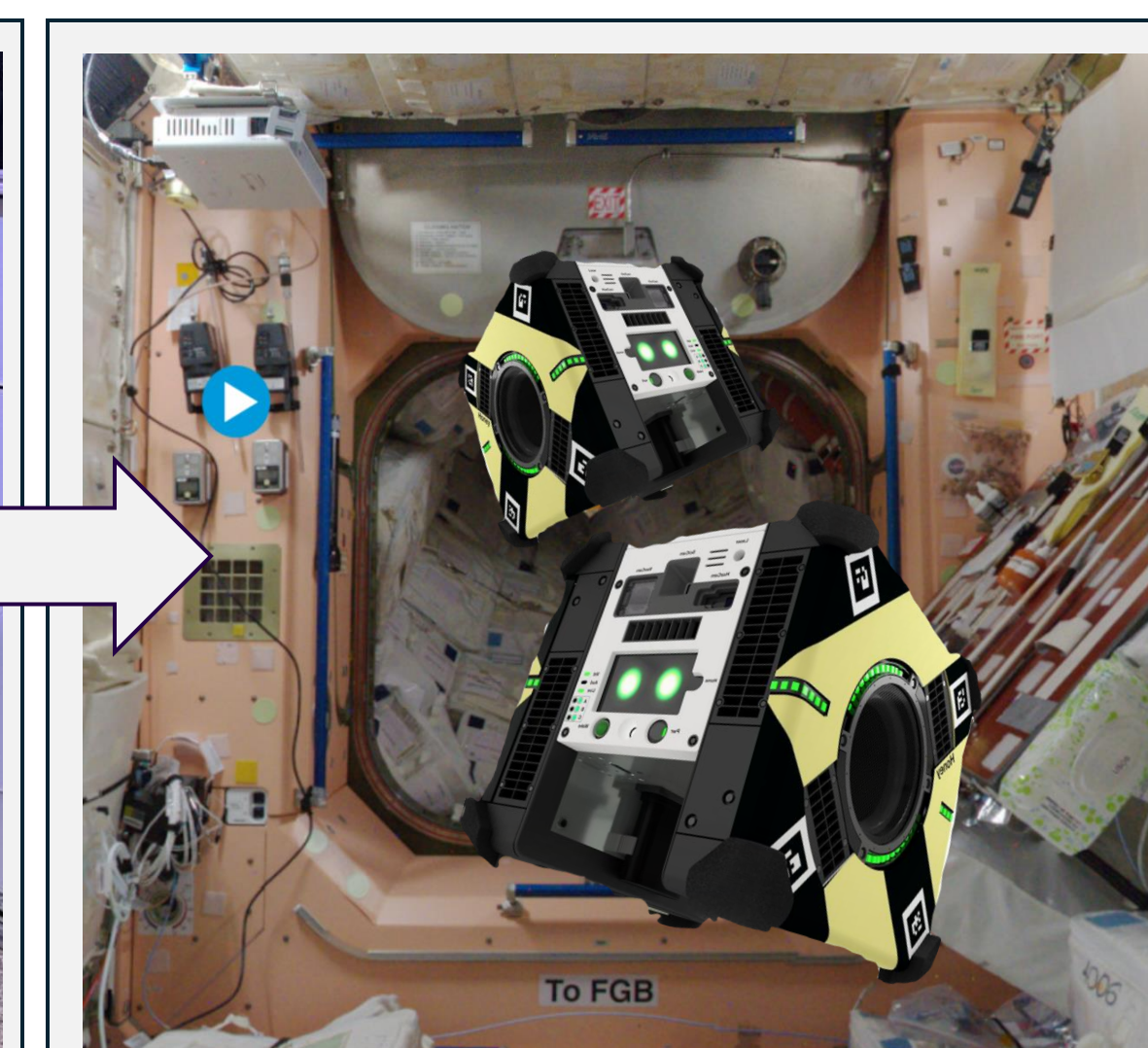
Astrobee with three-finger gripper payload prototyped attached into the arm



Astrobee autonomously grasps, manipulates, and transports the cargo [5].



Astrobee autonomously organizes the cargo logistics on station



References

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