A Rigid-Soft End-Effector Mechanism for Microgravity Free-Flying Manipulation

Jordan Kam[1*], Andres Mora Vargas[2], Stephanie Woodman[3], Brian Coltin[4]

University of California, Berkeley[1], NASA Ames (Astrion)[2], Yale University[3], NASA Ames (KBR Inc.)[4]

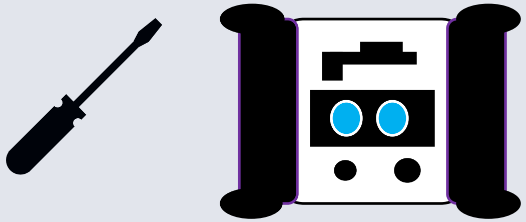
Point of Contact: *jordan.k.kam@nasa.gov* *

Opportunities in Microgravity Free-Flying Manipulation

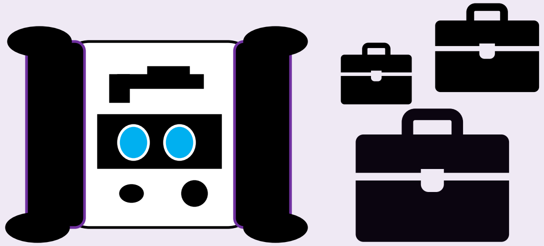
Logistics Management[1,2]

Complex Geometries

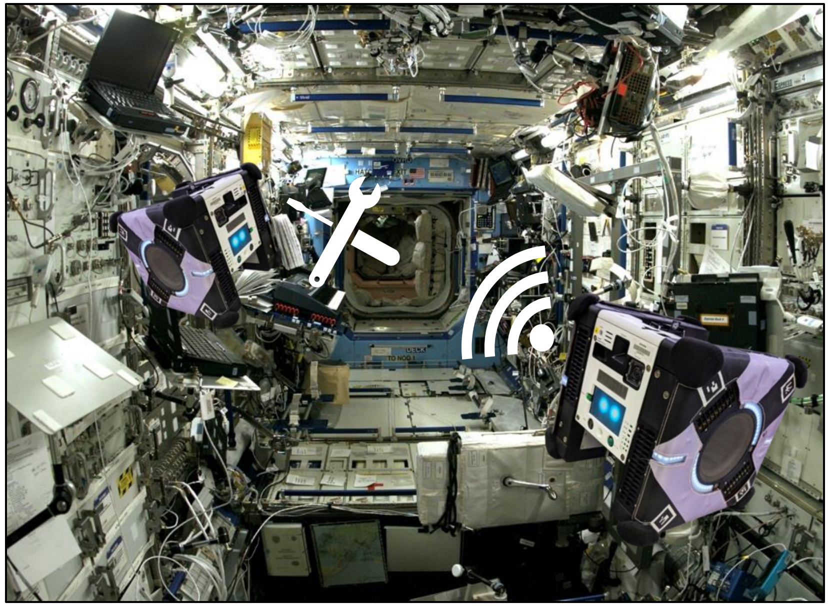
Maintenance Equipment



ISS CTBs

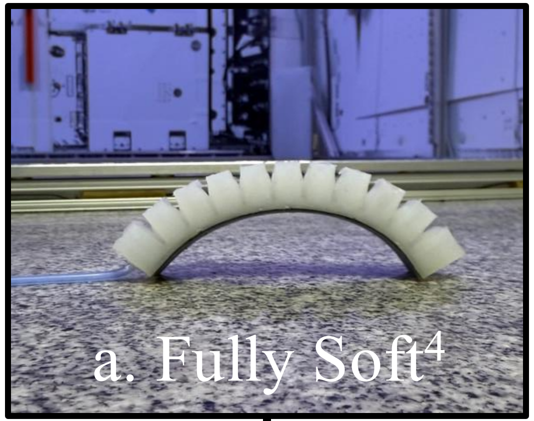


Maintenance Tasks[3]



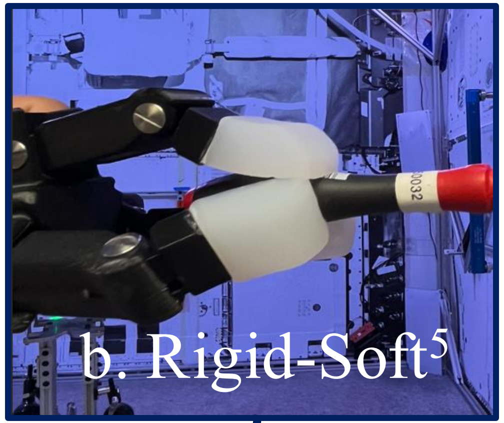
[1] Moreira, Marina et al. "Cooperative Real-Time Inertial Parameter Estimation."
[2] Morton, Daniel, et al. "Deformable Cargo Transport in Microgravity with Astrobee."
[3] Smith, Trey, et al. "ISAAC: An integrated system for autonomous and adaptive caretaking."

Manipulation Related Works



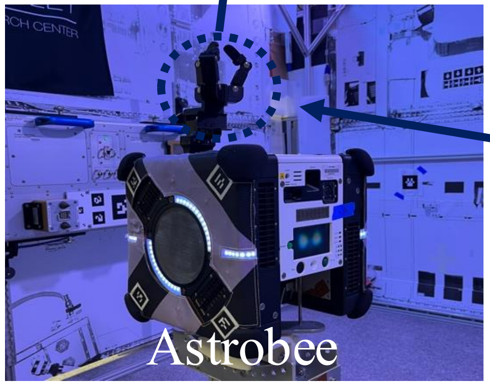
Pros
- Safe manipulation
- Secure grasp on uncertain objects

Cons
- Lower grip force
- Lower precision



Pros
- Higher force grasp
- Increased precision

Cons
- Poor performance when grasping complex objects
- Lacks modularity



Perching Arm Payload

[4] Hao, Yufei, et al. "Universal soft pneumatic robotic gripper with variable effective length."
[5] Gerez, Lucas, et al. "A hybrid, encompassing, three-fingered robotic gripper combining pneumatic telescopic mechanisms and rigid claws."
[6] Park, In-Won, et al. "Developing a 3-DOF compliant perching arm for a free-flying robot on the International Space Station."

Hybrid Rigid-Soft Gripper

- Three-finger rigid *“claws”*
- Tendon-driven
- Underactuated *(1-DOF)*
- Soft pneumatically inflatable padding
- Soft distal joints
- Closed-loop

(no feedback)

Computer Aided Design *Fabricated Prototype*

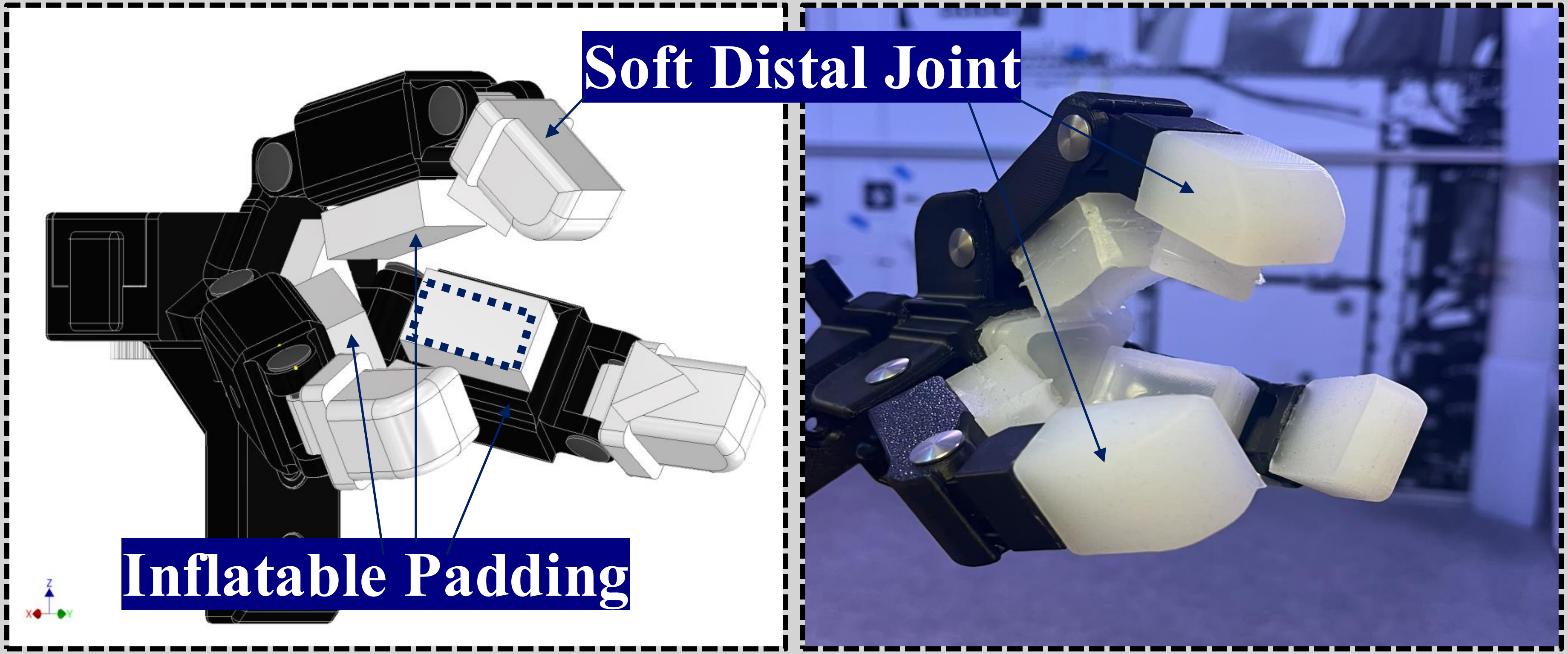


Figure: Computer Aided Design (CAD) rendering of the rigid-soft gripper next to the fabricated prototyping highlight rigid vs. soft components in the prototype.

Rigid-Soft Manipulation Mechanism

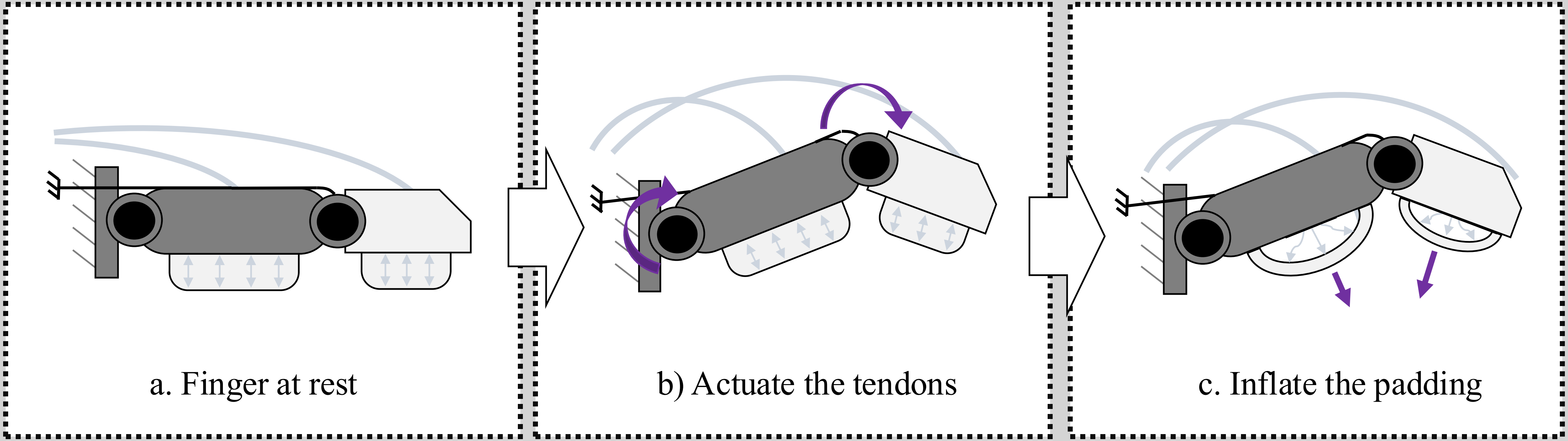


Figure: Three states highlighting the manipulation mechanism.

a) The fingers are at rest, no actuation

b) Actuate the motor at the gripper's base pulling the tendons

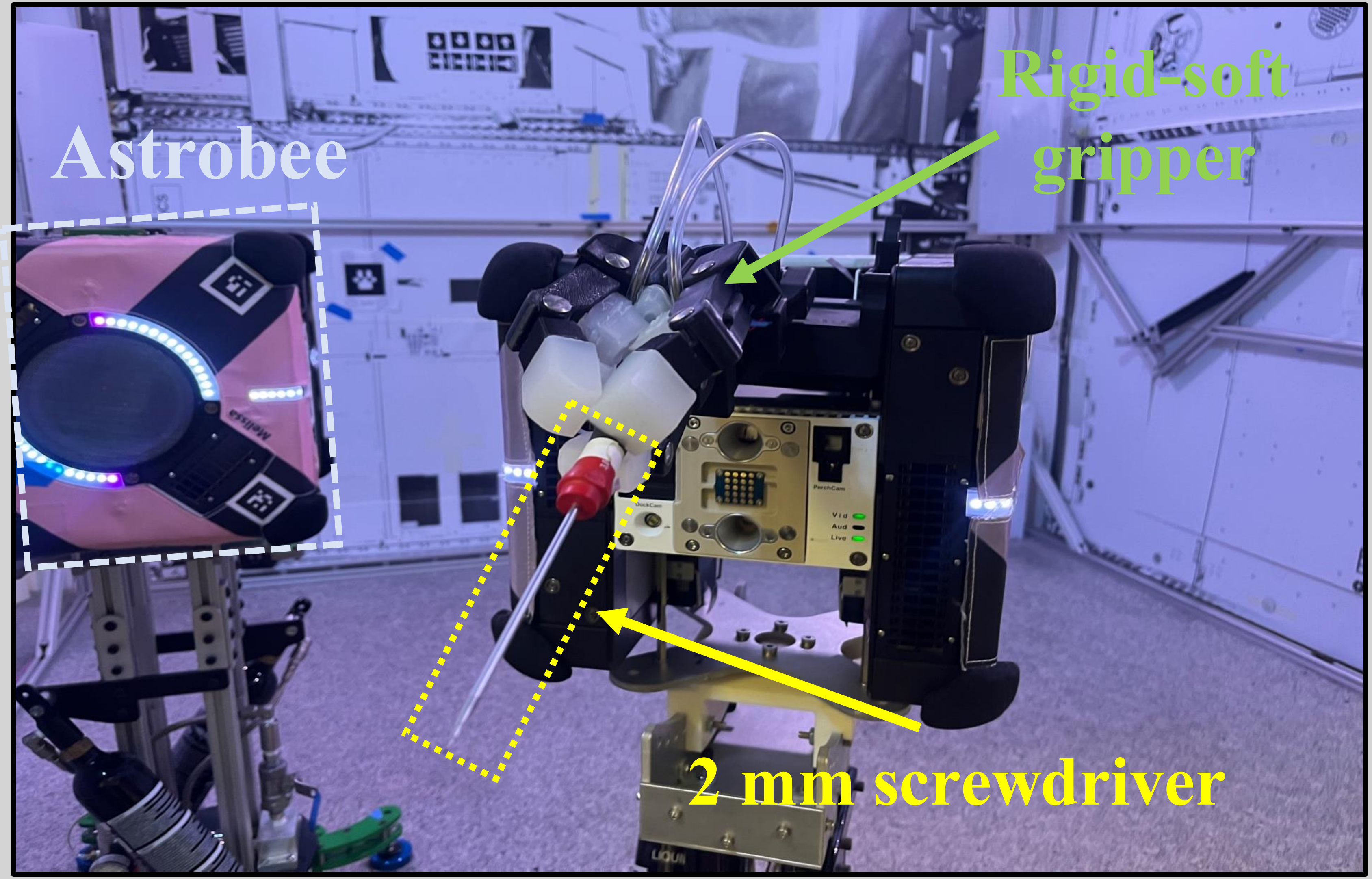
c) Pneumatically actuate and inflate the compliant padding to conform around the grasped objects

Granite Lab Testing

- Astrobee Testing Facility or the Granite Lab
- Attached gripper to Astrobee's perching arm payload
- Grasped a 2 mm screwdriver

(~2 inches in diameter)

- Had Astrobee "fly" while grasping the screwdriver



General Applications

Structurally rigid objects that are fragile or sensitive to high forces:

- Grasping delicate fruits *(on a general-purpose multi-agriculture farm)*
- Handling glassware
- Industrial applications where consumer goods are in a variety of shapes, but require a general-purpose manipulation *(supply chain)*

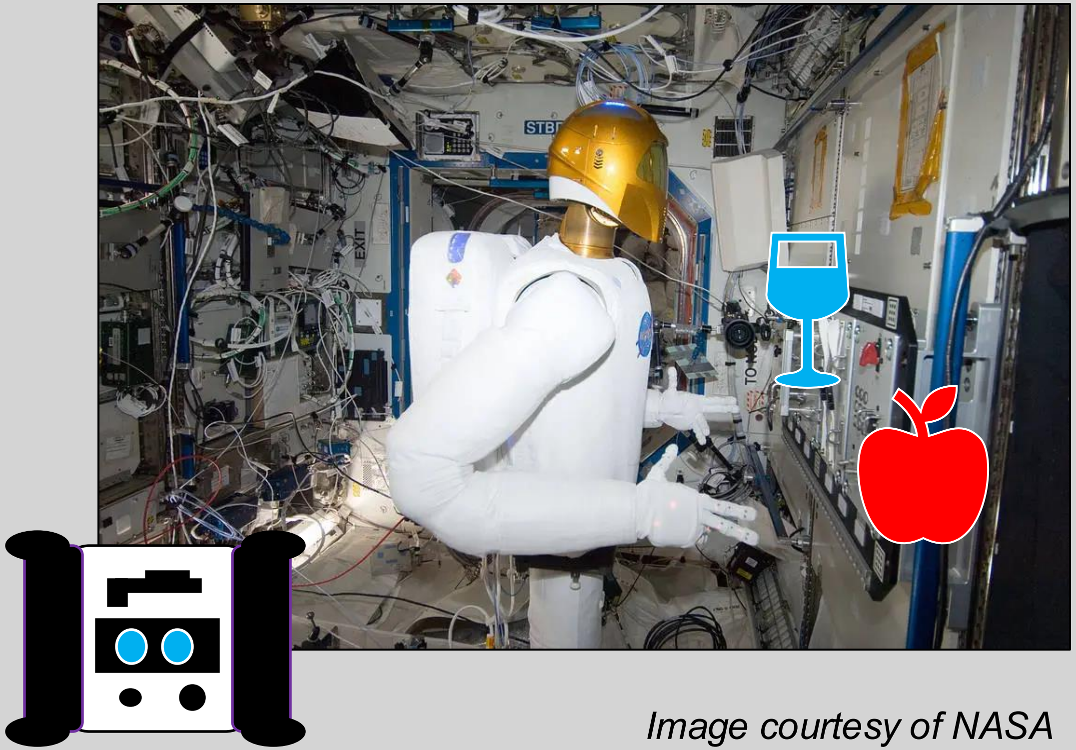
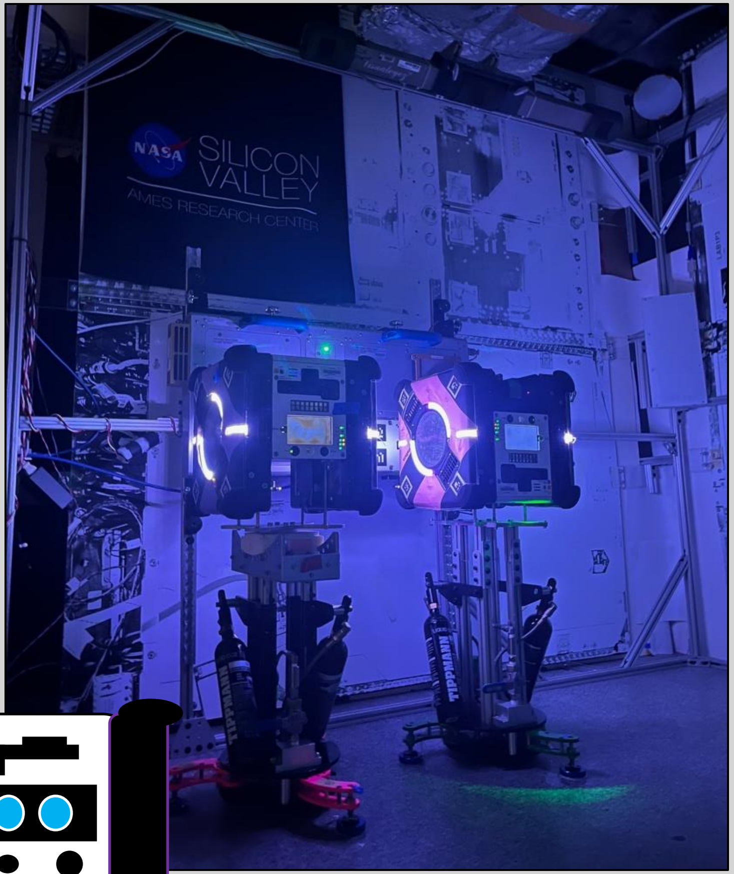
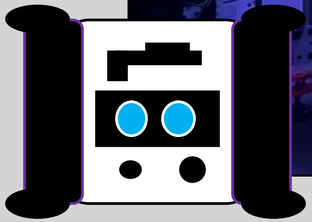


Image courtesy of NASA

Future Work

- Incorporate feedback into the prototype via force sensors
- Do a wider range of testing of different objects
- Do a comparative study of grasping handrails compared to the perching gripper and of different objects to show baseline comparison and modular advantages with the hybrid gripper





QUESTIONS?

jordan.k.kam@nasa.gov