



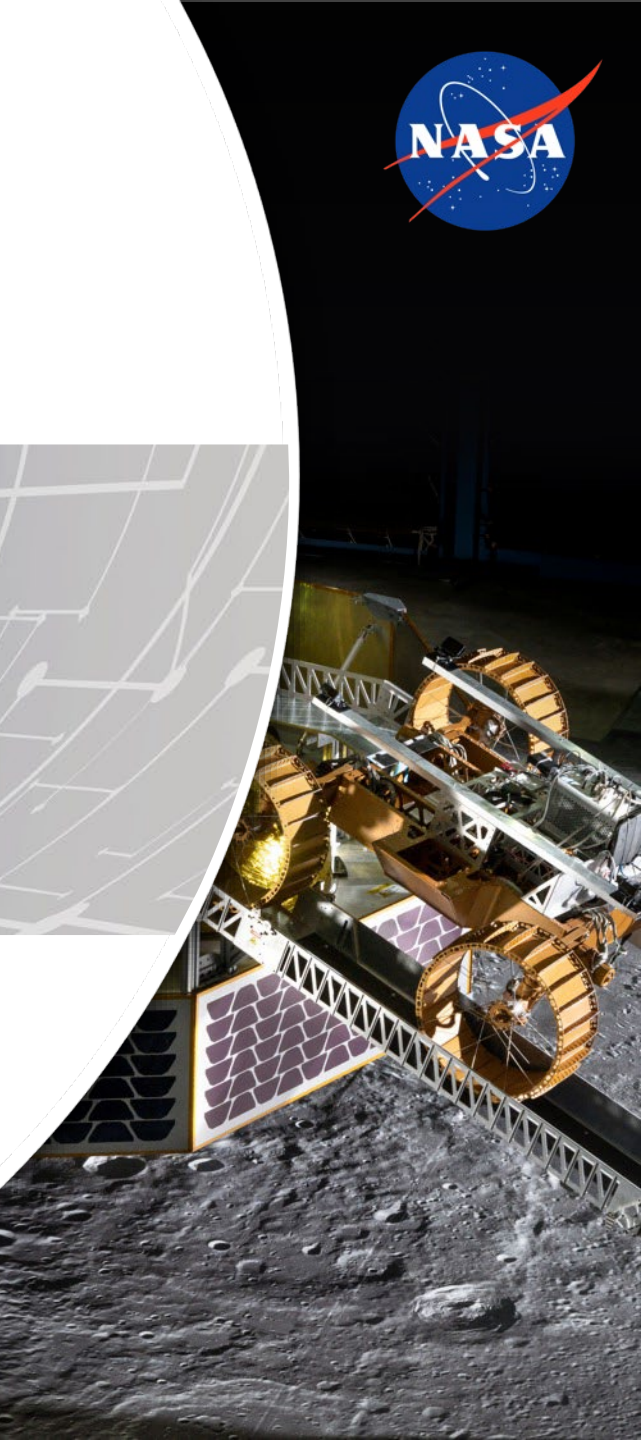
Design of the iMETRO Facility: A Platform for Intravehicular Space Robotics Research

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Dexterous Robotics Team

NASA Johnson Space Center¹, CACI², Amentum³

Approved for Public Release DAA #





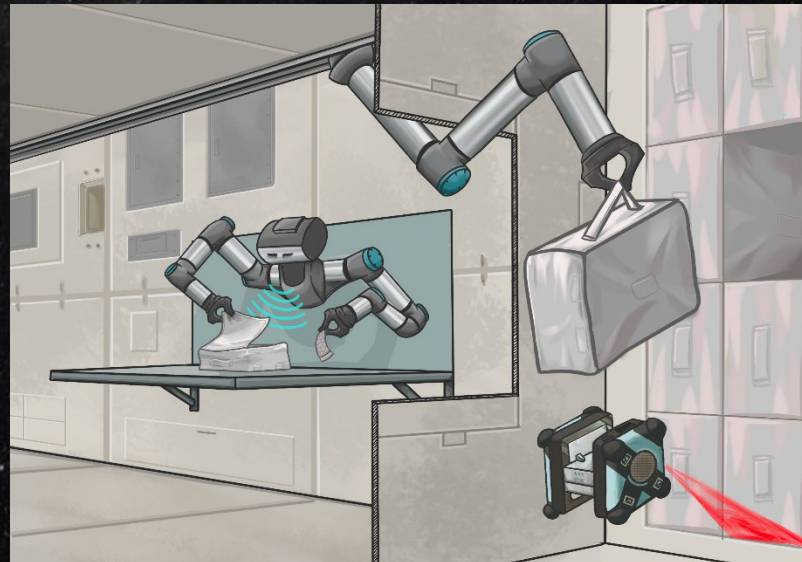
NASA Moon to Mars Architecture

- NASA's Moon to Mars Architecture currently comprises four segments:
 - Human Lunar Return
 - Foundational Exploration
 - Sustained Lunar Evolution
 - Humans to Mars



Moon to Mars Architecture Reoccurring Tenants

- Maximize crew time available for **science, research, and technology**
- When practical, design systems for maintainability, reuse, and/or recycling to support the long-term sustainability of operations and increase Earth independence
- Robotics can help us accomplish these goals by offloading tasks that would use astronaut time



Crew estimates



NASA's 2023 Moon to Mars Architecture estimates for a crew of 2 members and a 28 day mission:

- 24.7 hours of crew time for maintenance
- 1500 kg of logistics required

Robots are necessary and we have a massive challenge ahead of us.

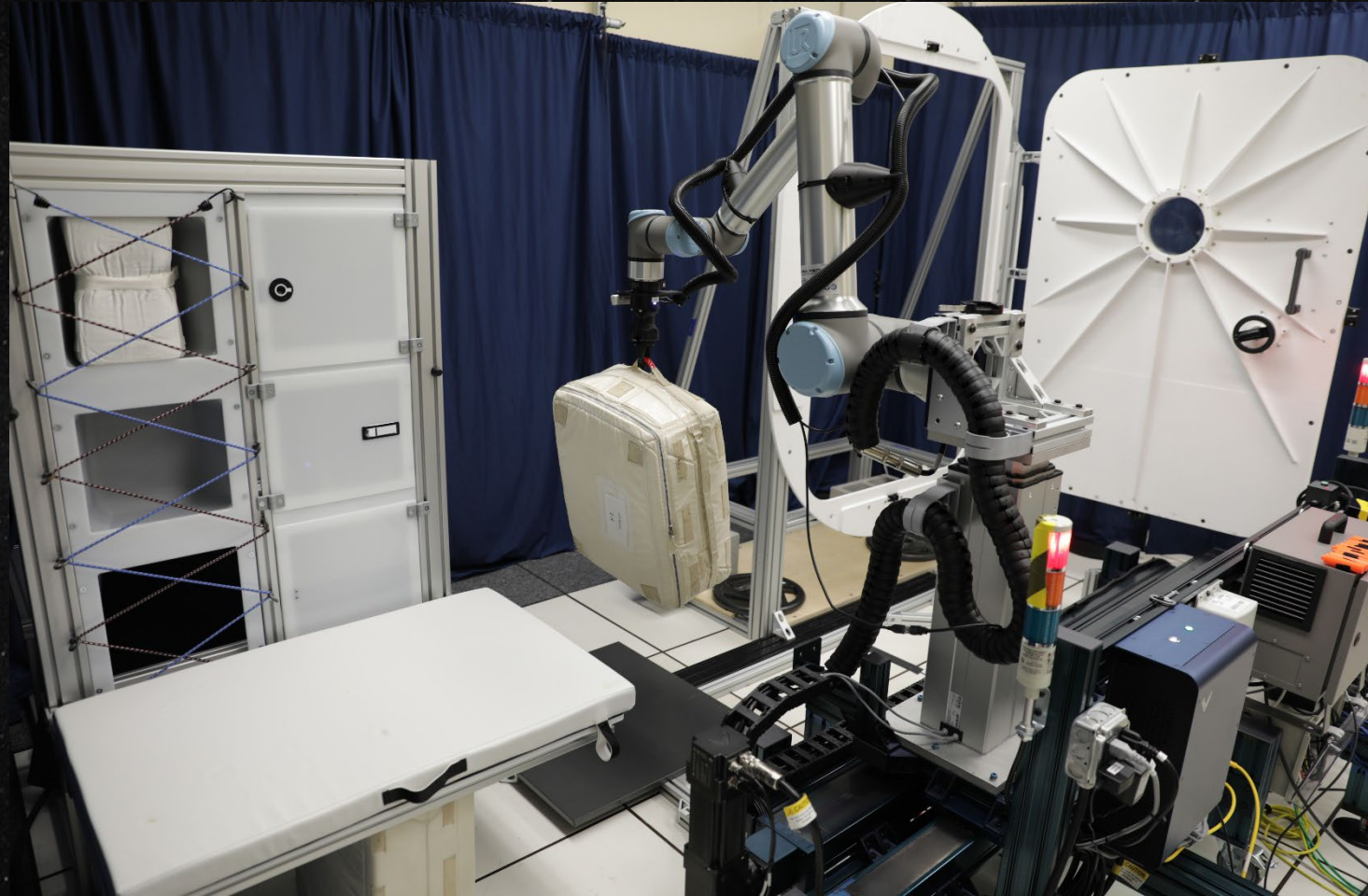


- Pressurized Rover Resupply Evaluation:
 - ~38 CTBE (2 crew 14 days)
 - Bags block the hatch for crew to re-enter
 - Lengthy process (possibly multi-EVA)
 - Dust mitigation challenge

Integrated Mobile Evaluation Testbed for Robotic Operations (iMETRO)



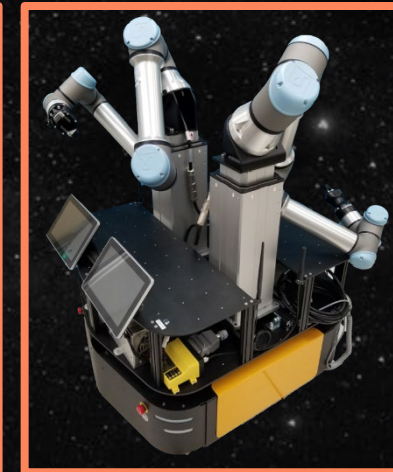
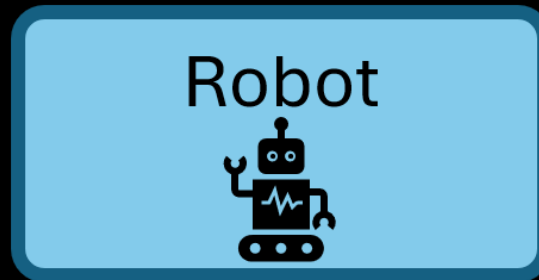
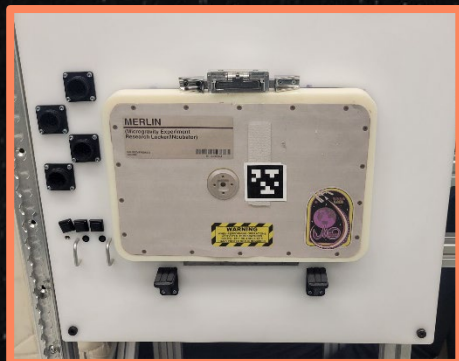
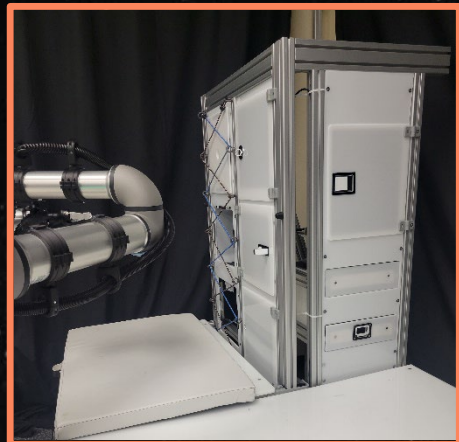
- We must advance the Technology Readiness Levels (TRL) of integrated technologies for missions requiring remote space robotics operations.
- iMETRO is a test facility at JSC for NASA, Academia, and Industry to develop these technologies
- iMETRO provides:
 - COTS robots
 - Space Applications
 - Core open source software
 - Remote operation tools (test like you fly)



Components of iMETRO Facility

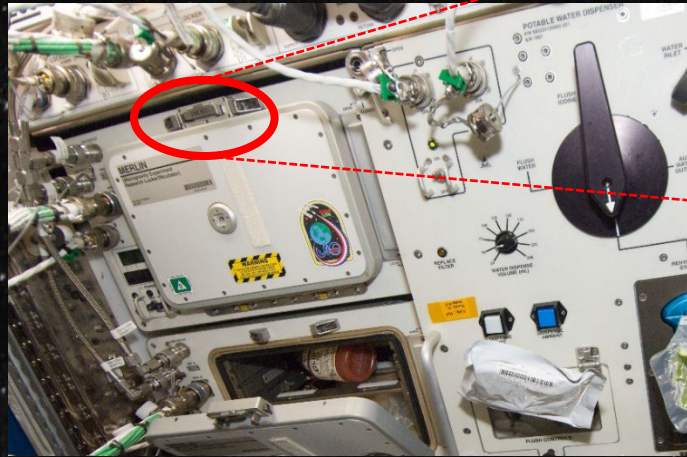


- Pick and choose which components you want to include in your test



iMETRO Mockups

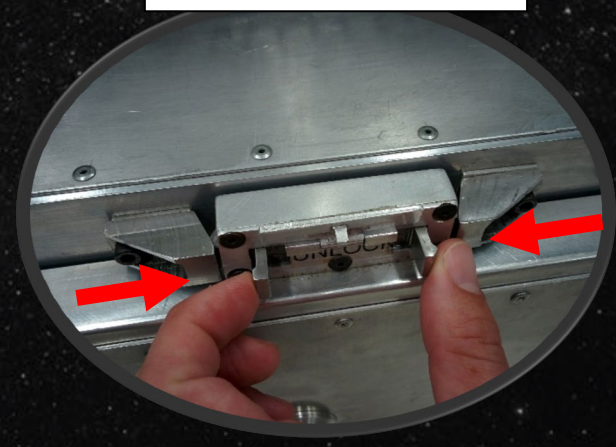
- Goal: Provide non-proprietary, realistic, and current space use cases
- Focus on:
 - High fidelity manipulation interfaces
 - Low fidelity body/secondary interfaces



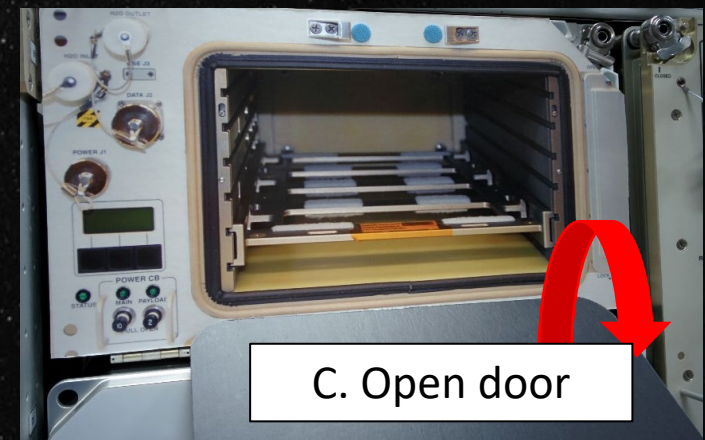
A. Unlatch door 1



B. Unlatch door 2

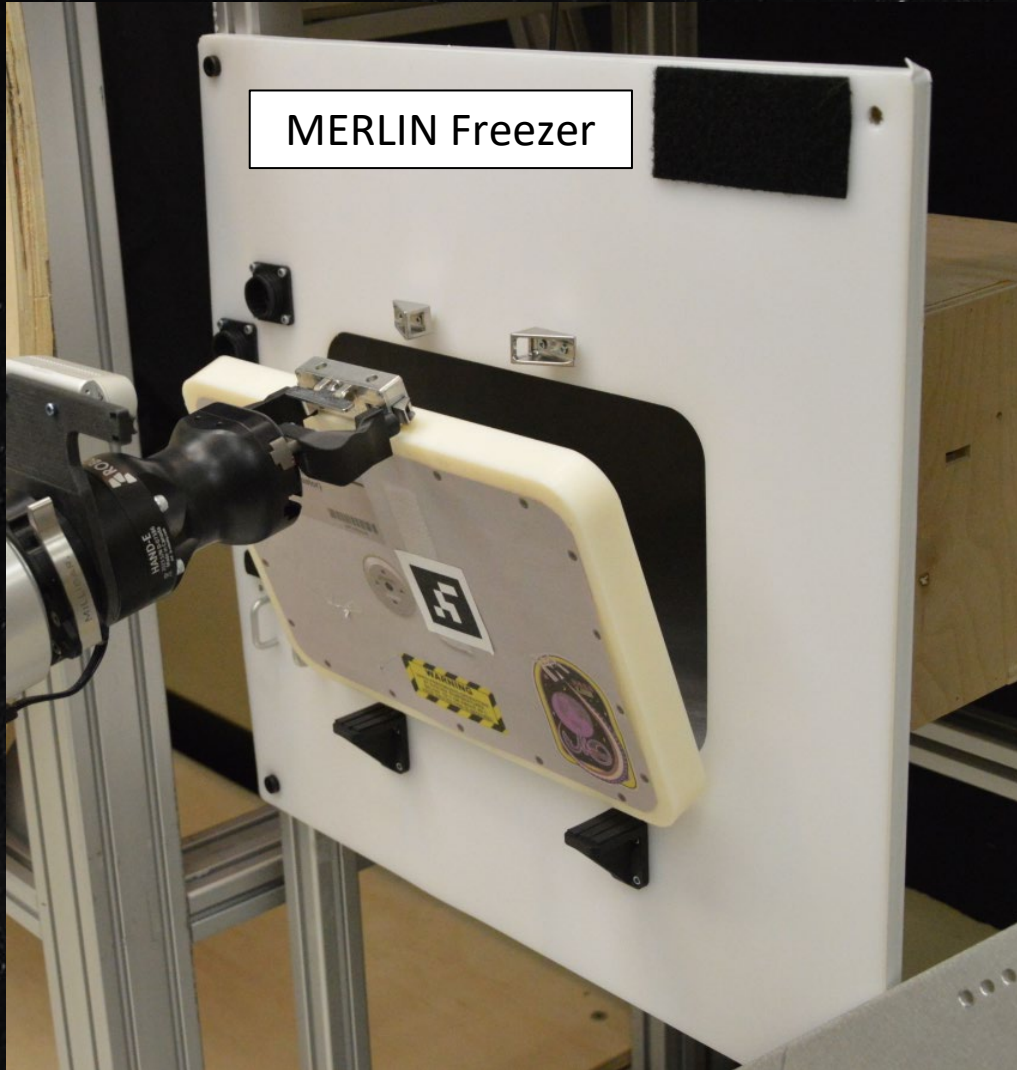


Actual freezer on ISS
(Current lab demo uses mockup hardware with relevant components built-to-drawing from active ISS payload design)



C. Open door

iMETRO Mockups

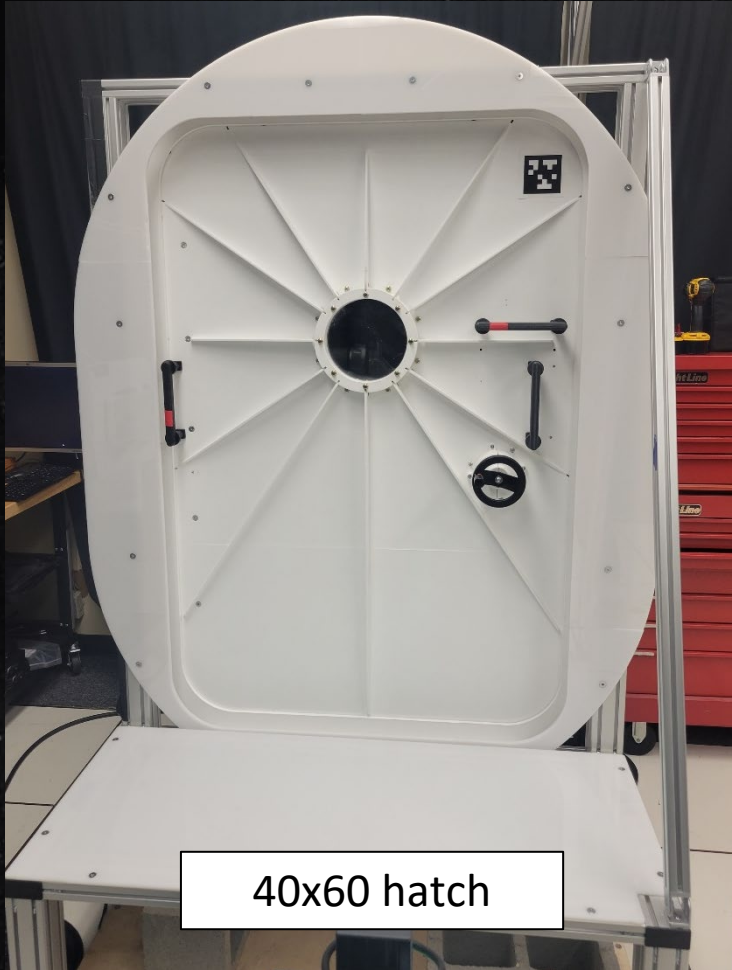


Task Trainer:

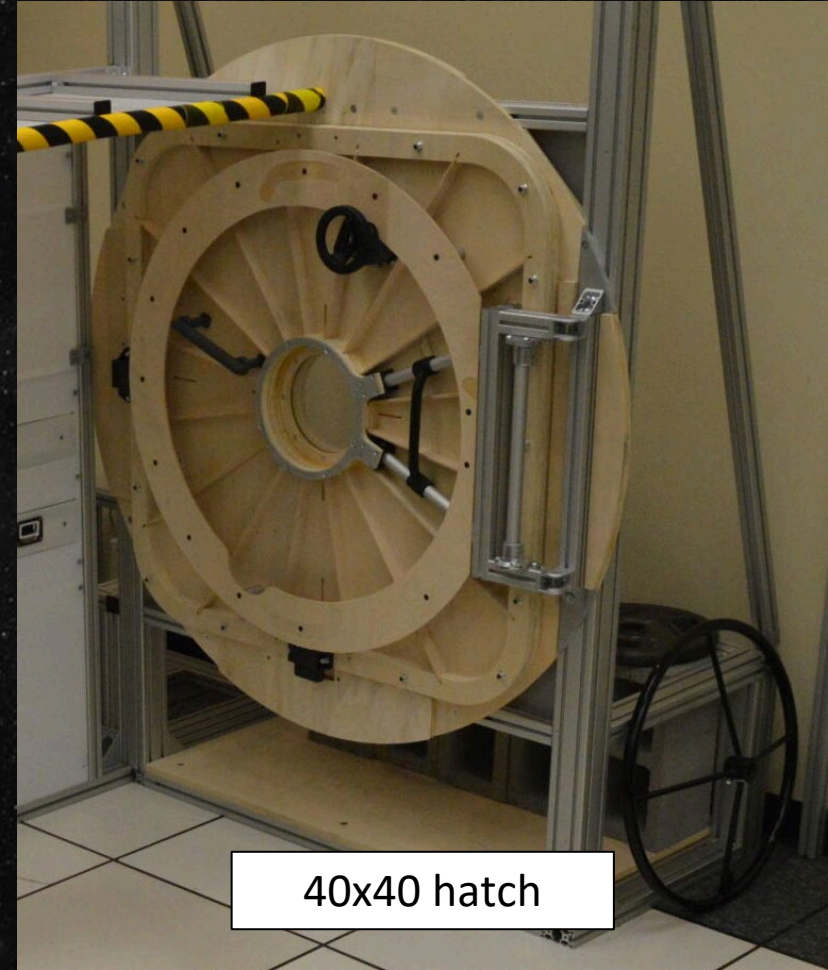
- Storage bench seat
- Cabinets
- Drawers



iMETRO Mockups



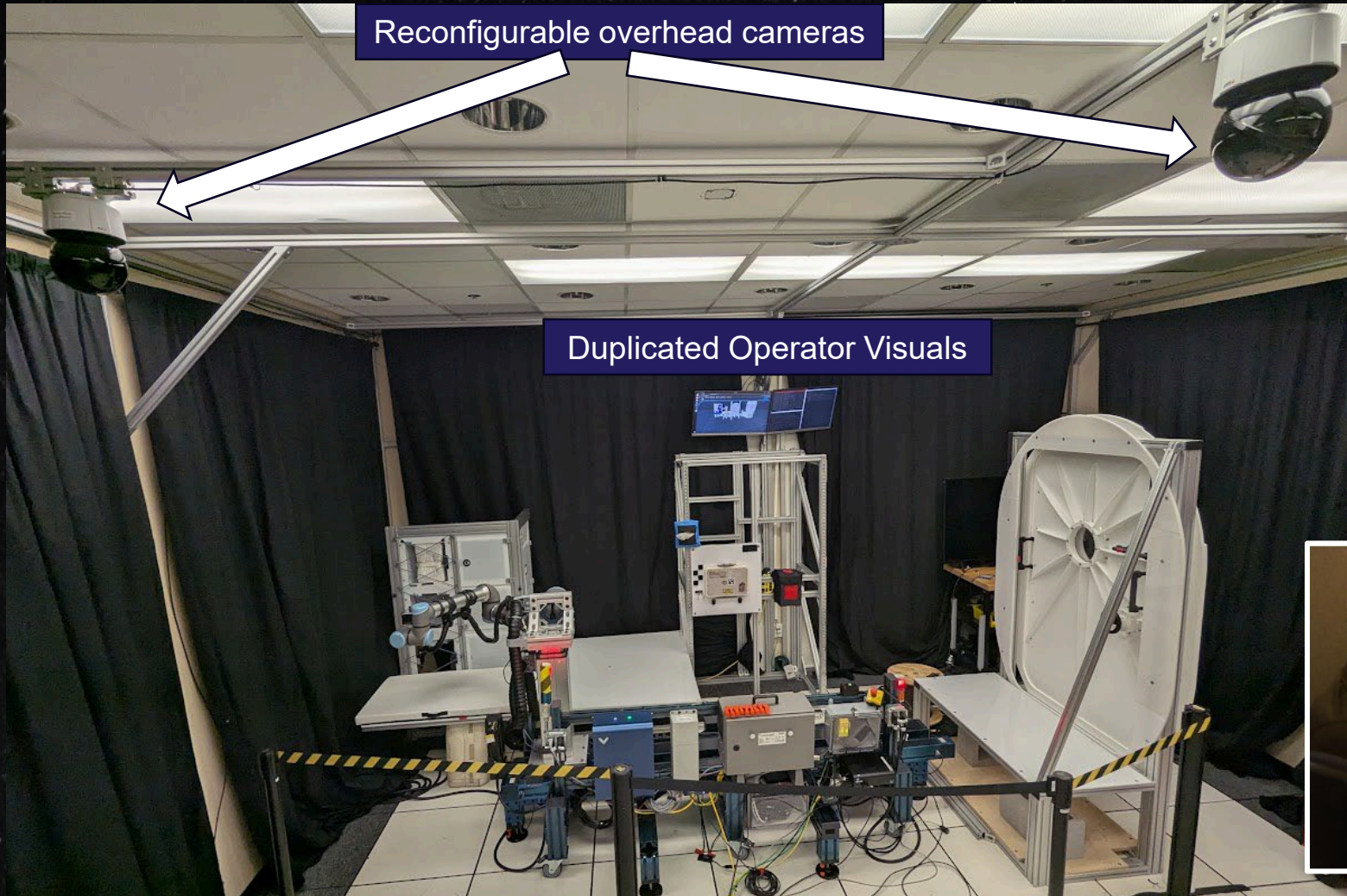
40x60 hatch



40x40 hatch

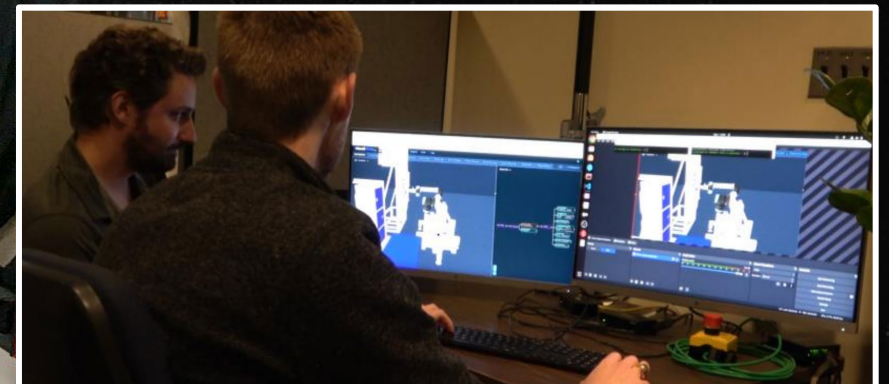


iMETRO Facility Infrastructure



- 5 emergency stops distributed throughout workspace

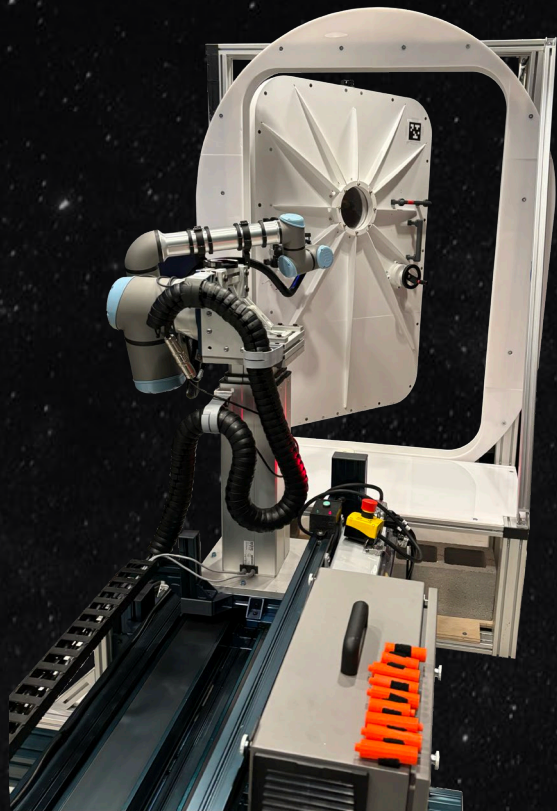
In separate room - remote operator station for remote ops testing



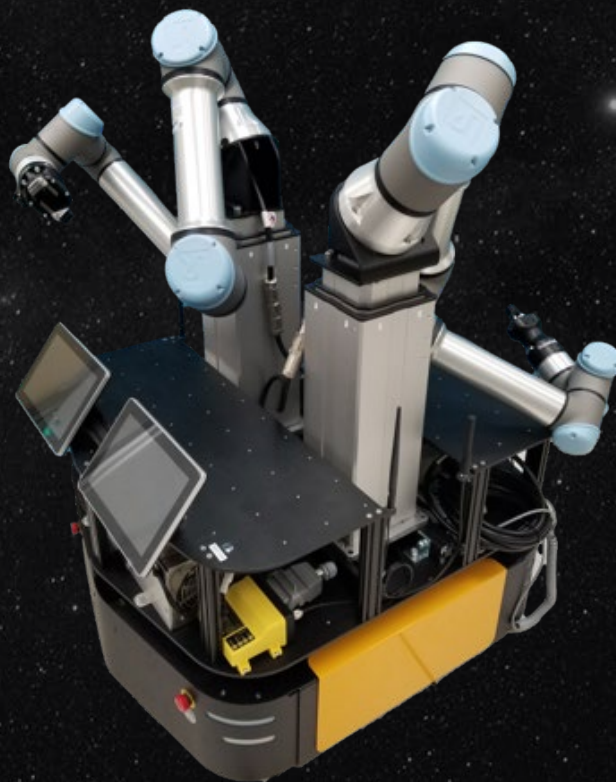
iMETRO Robots



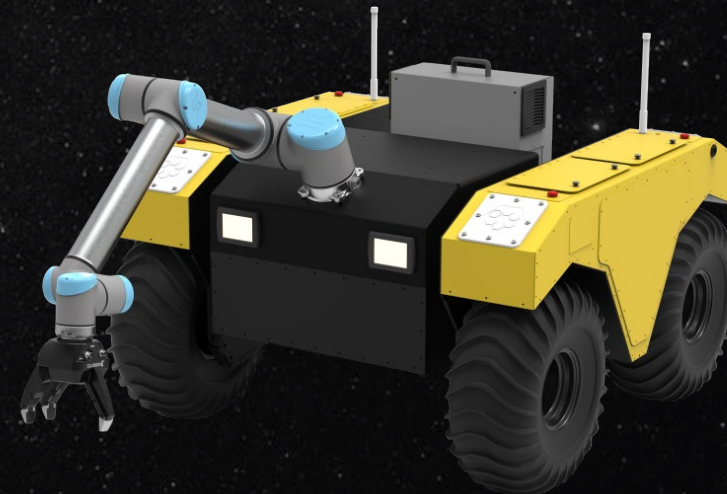
- Single Arm on a Rail



- IVR Mobile Dual Arm System



- EVR Mobile Single Arm System

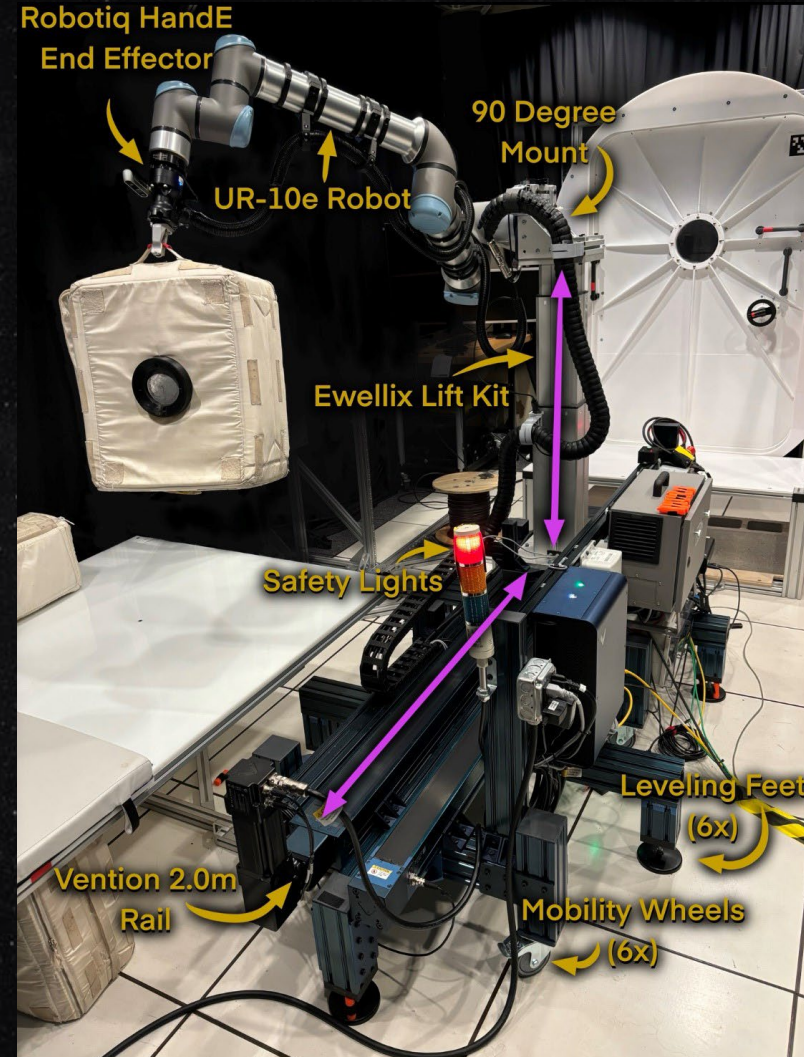


*In progress



Single Arm on Rail

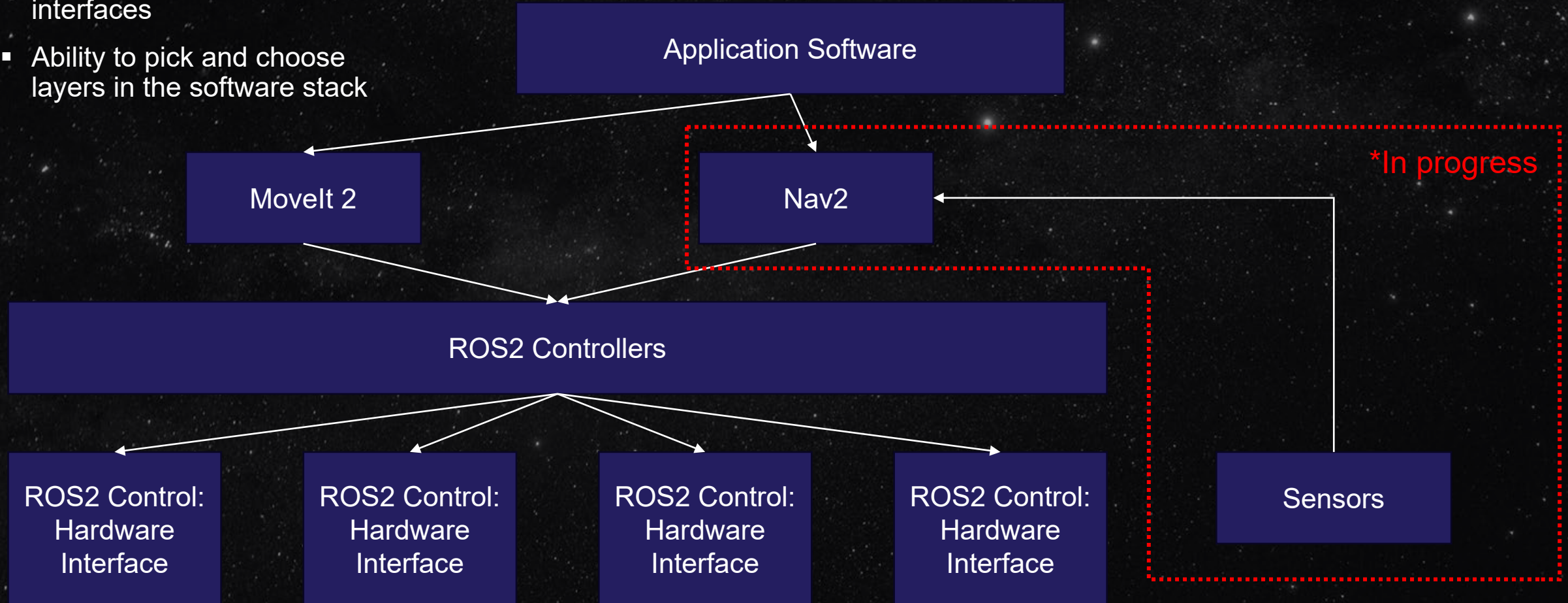
- 8 dexterous DOFs
 - Two linear DOFs
 - 6 DOF integrated UR10e
- Parallel jaw gripper with custom fingers
- Sensors
 - Force torque sensor
 - Wrist-mounted Realsense RGBD camera



ROS2 Software Stack



- Uses standardized ROS interfaces
- Ability to pick and choose layers in the software stack



Open Source Software

- All iMETRO Software is being open sourced
 - Approved for open source – all mockups
 - Imminent approval (May 2025) – robot on rails, dual arm mobile IVR robot
 - Hardware
 - Kinematic Simulation
- Containerized via docker
- All source code will be available on NASA GitHub and listed in the [NASA Software Catalog](#)

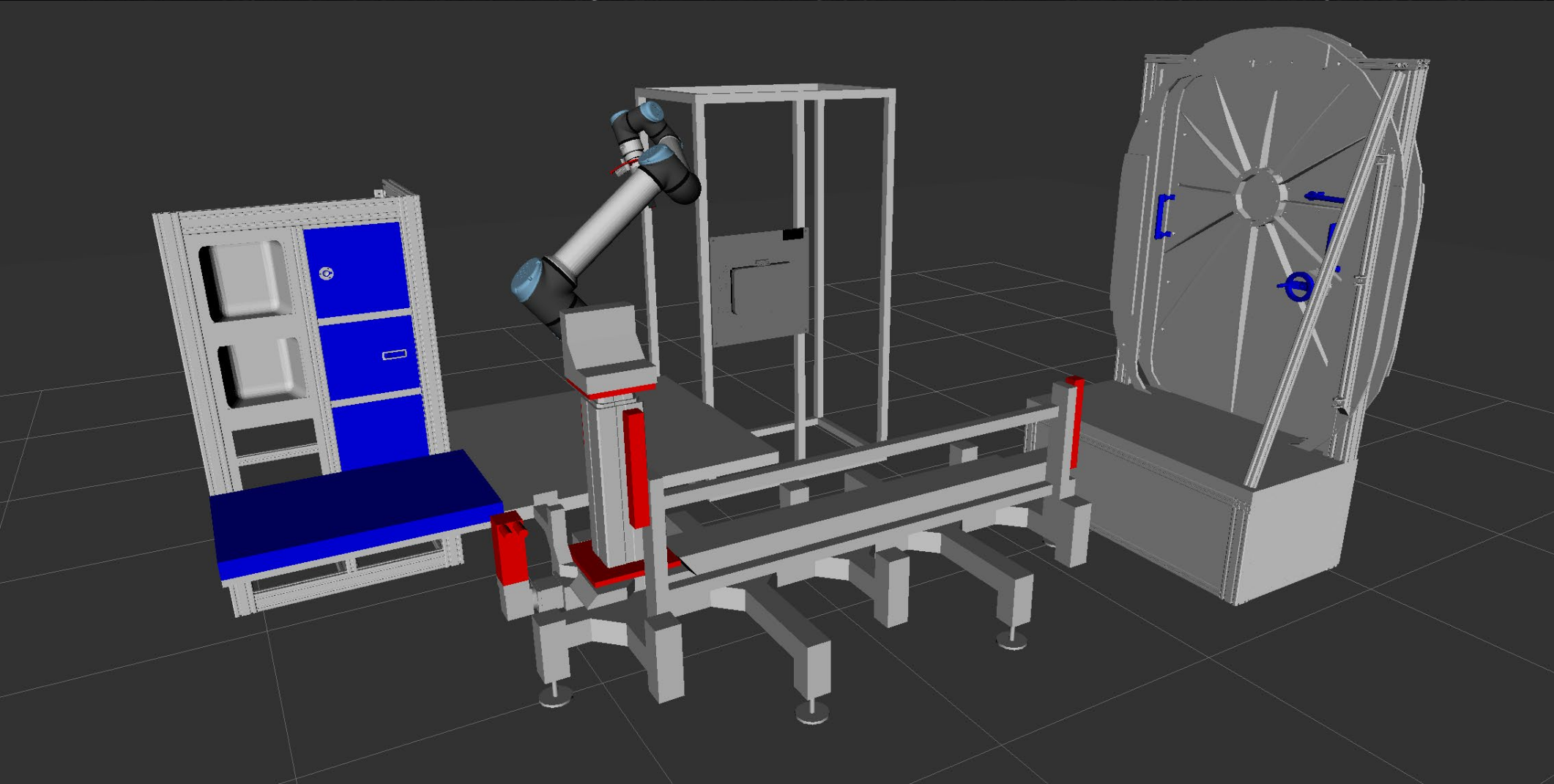
The ROS 2 logo features a 3x3 grid of black dots on the left, followed by the text "ROS 2" in a large, bold, black sans-serif font. A small "TM" trademark symbol is positioned to the upper right of the number "2".

ROS 2™

The Docker logo consists of a blue icon of a ship's hull with a white arrow pointing to the right, followed by the word "docker" in a lowercase, blue, sans-serif font.

docker

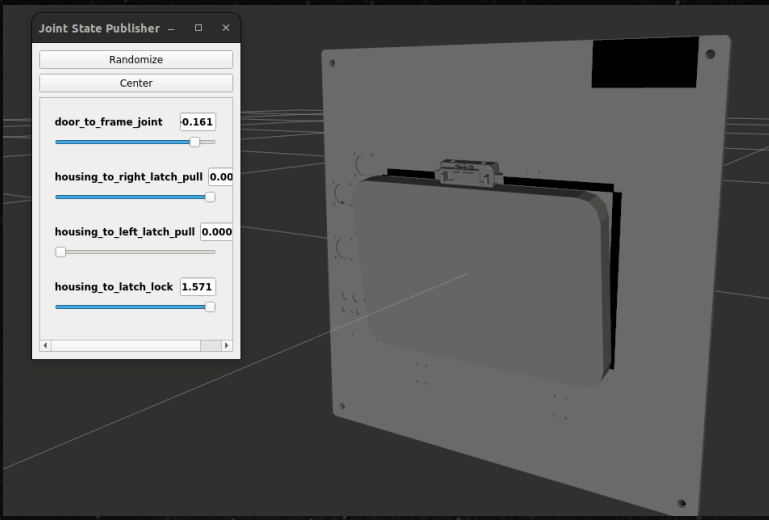
Kinematic Simulation



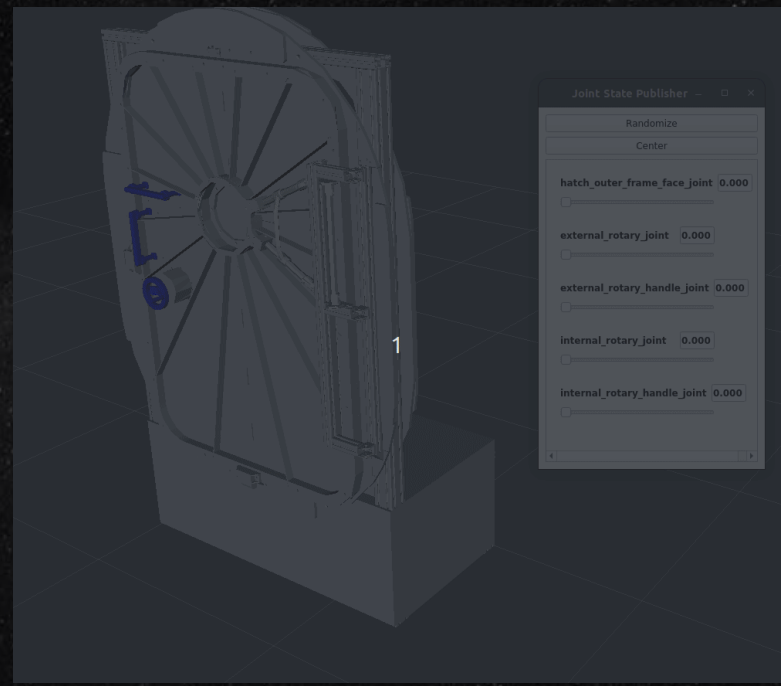


Mockups described via URDF

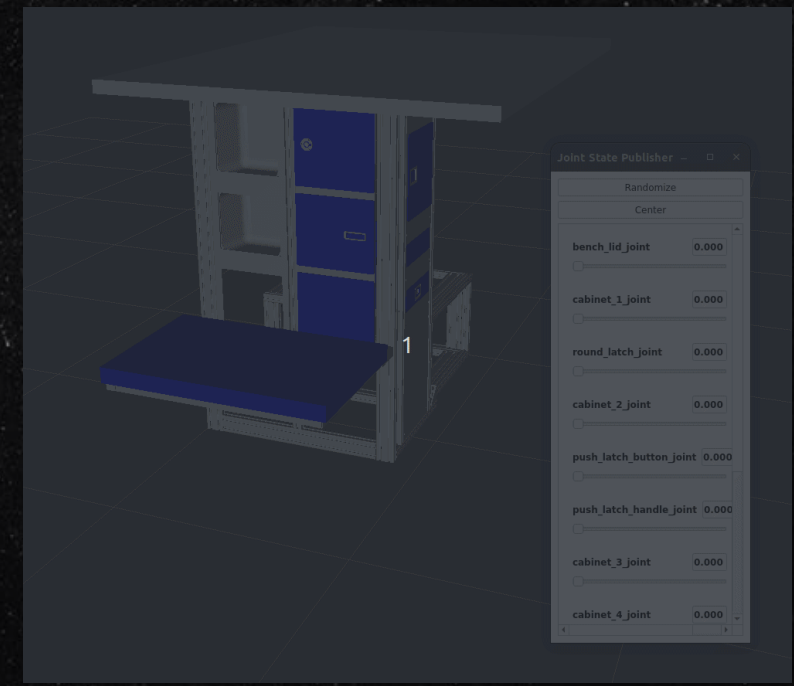
Merlin Freezer



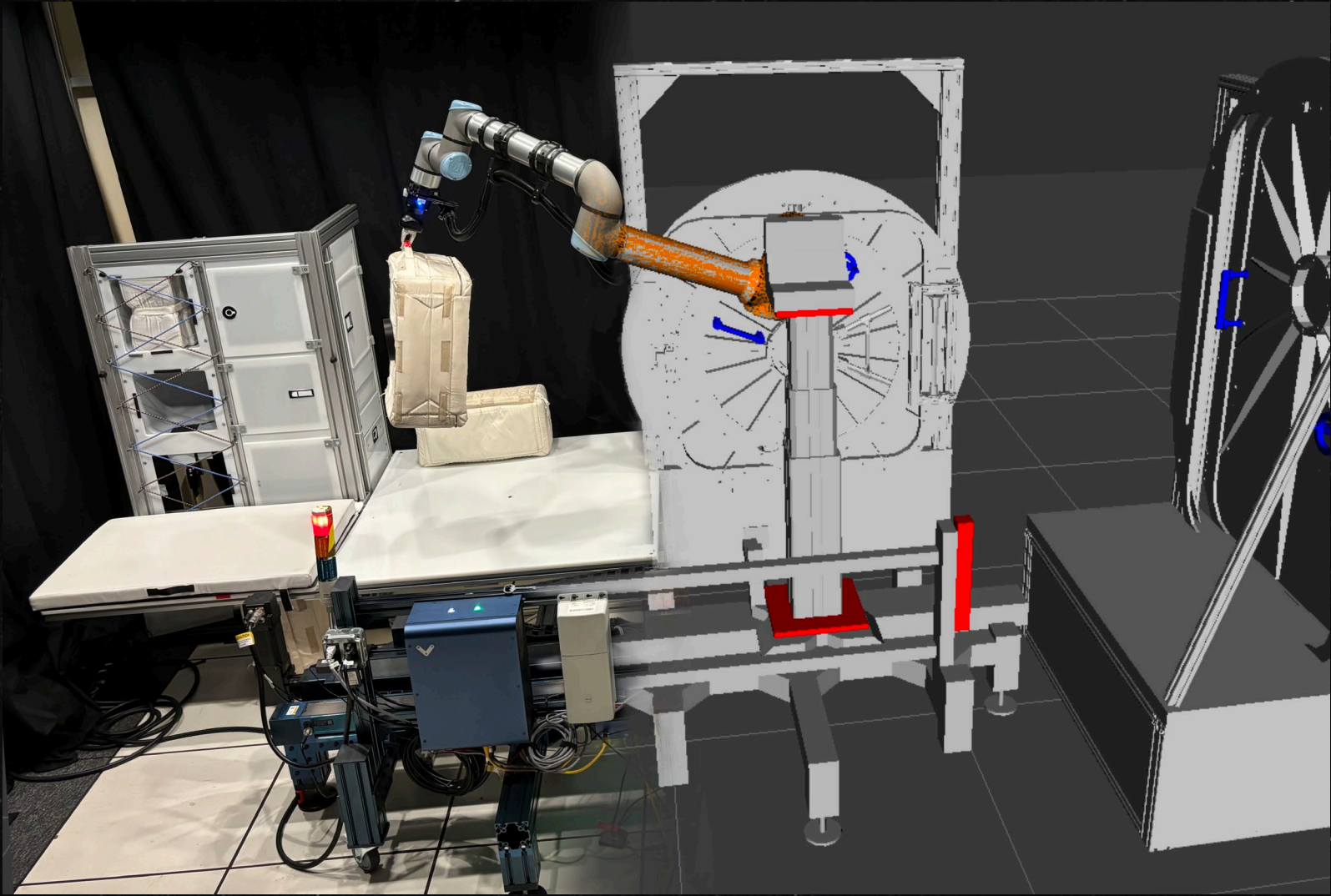
40x60 Hatch



Bench Seat and Cabinets

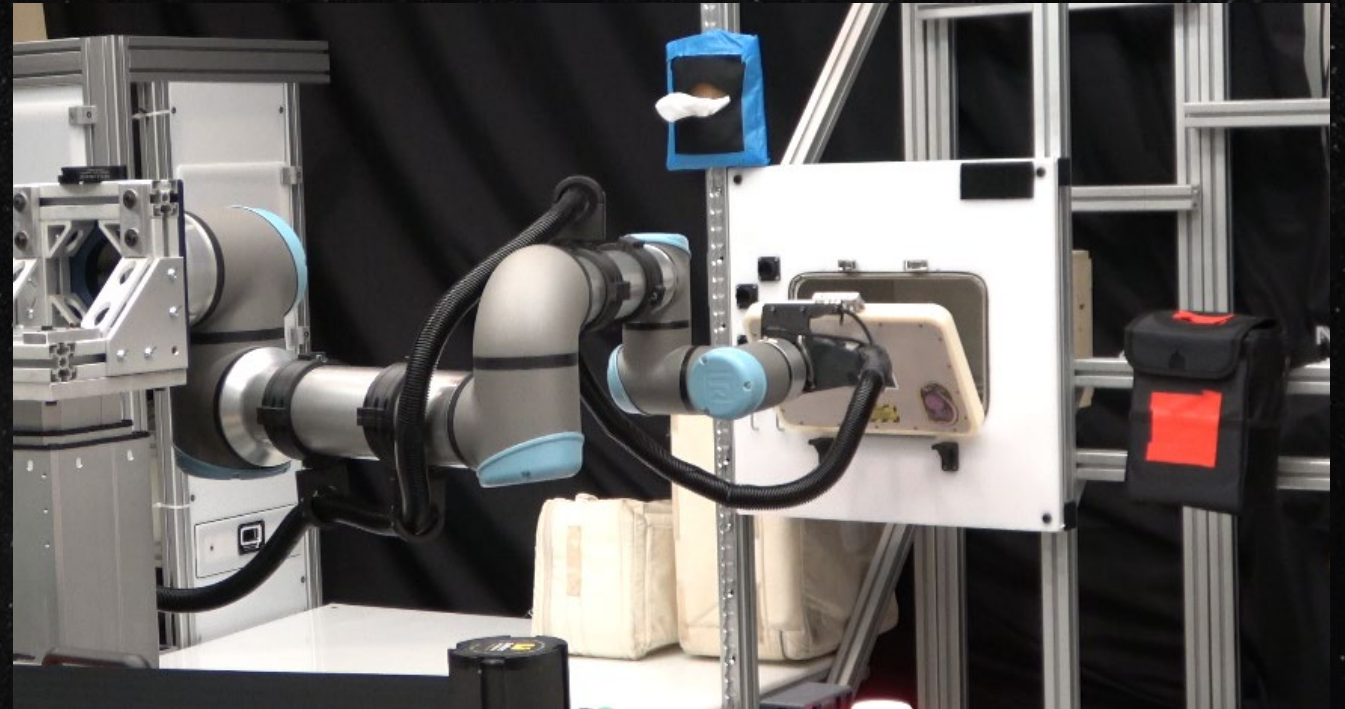


Dual Facility: Simulation + Hardware in the Loop



Example Application: Clean MERLIN freezer seal

- Goal
 - Open the freezer
 - Pick up a wipe and wipe the seal
 - Dispose of wipe
 - Close the freezer
- Application layer implementation
 - BehaviorTree.CPP
 - MoveIt C++ API
- Perception
 - Custom machine vision to
 - Localize front face of the freezer
 - Pick the wipe from the holder
 - Put the trash in the bin
- Application was developed first in kinematic simulation, then refined on hardware



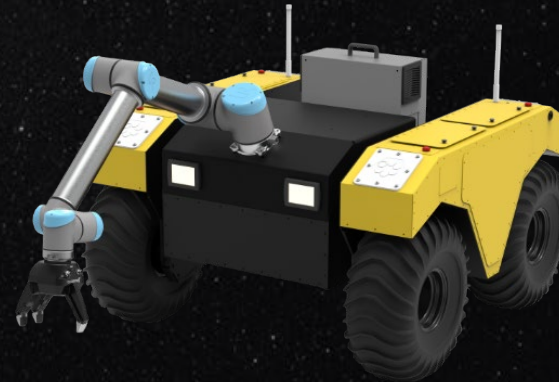
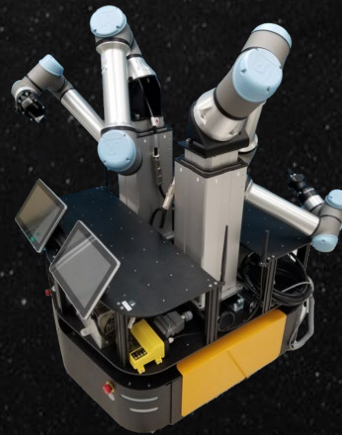


Future work

- Provide dynamic simulation capabilities through MuJoCo
 - Simulate perception
 - Simulate object interaction

MuJoCo

- Continue integrating more robots into the facility
 - Providing more robot architectures for exploration



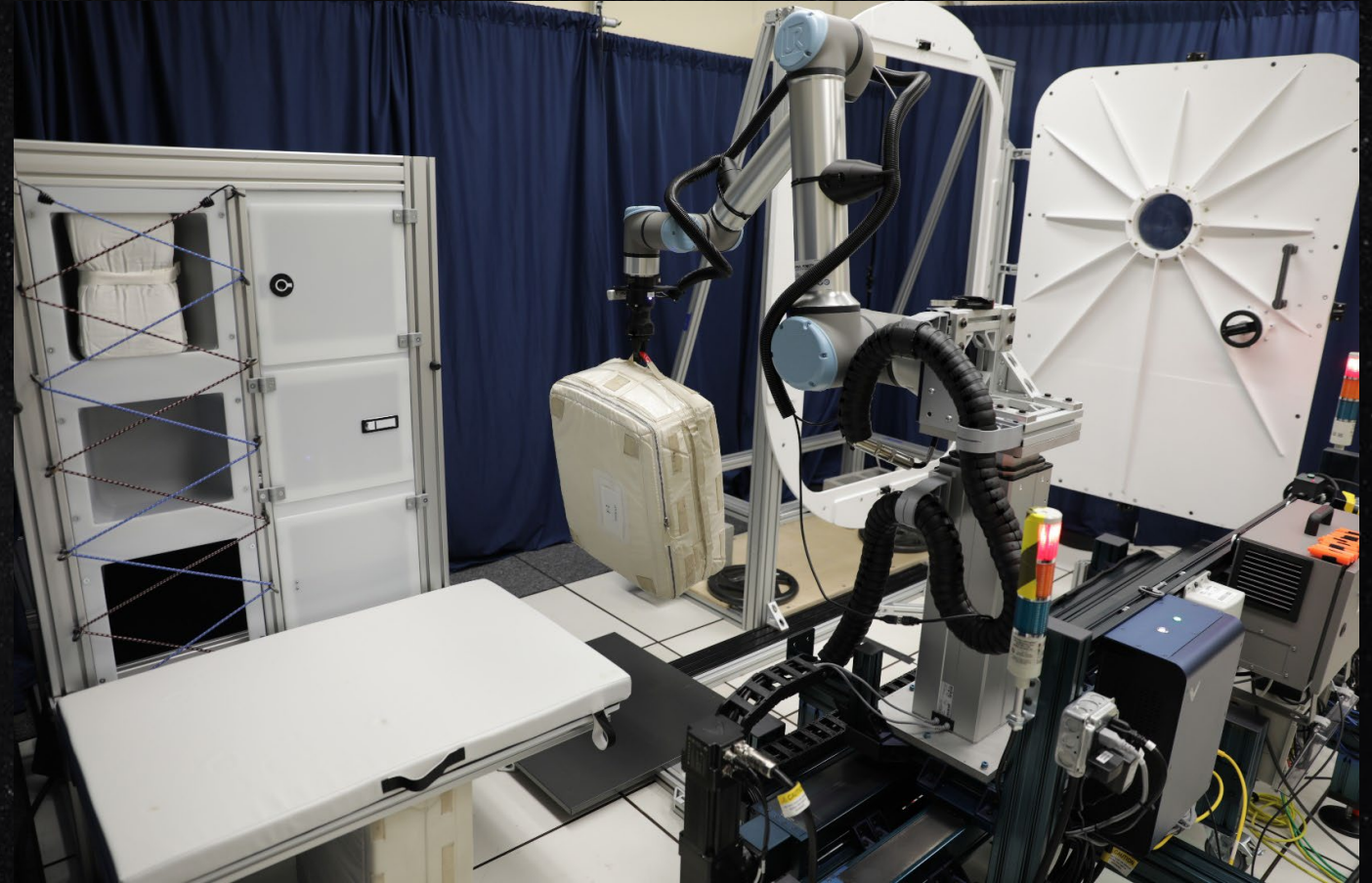
- Collaborate with partners!

iMETRO Contact Information

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- Emma Zemler
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- Shaun Azimi
 - iMETRO Project Manager
 - shaun.m.azimi@nasa.gov



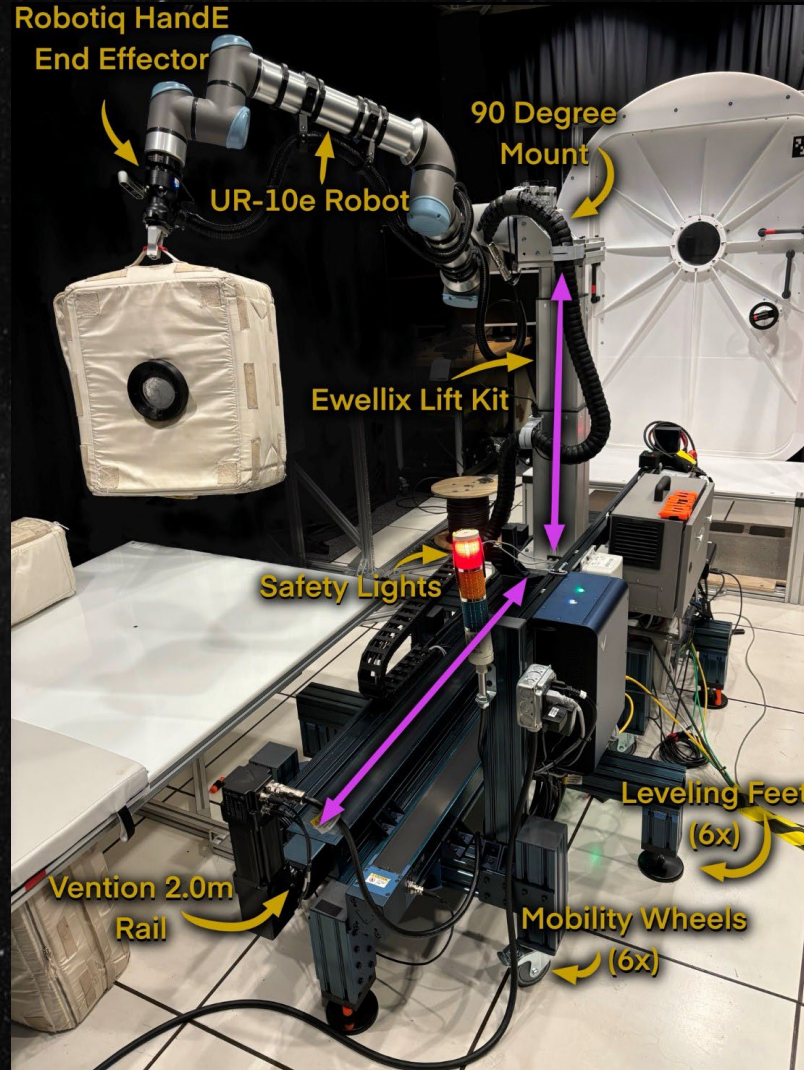
- Open-source software is available at <https://github.com/nasa-jsc-robotics/iMETRO>



Backup Slides



Single Arm on a Rail

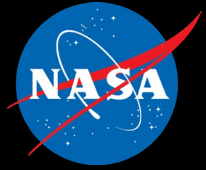


IVR Mobile Dual Arm System



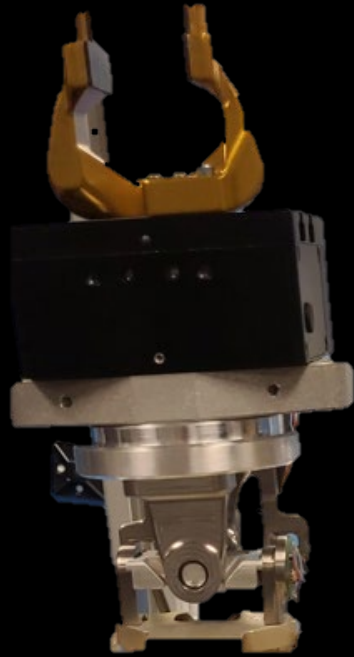
- Clearpath ridgeback
- X2 Ewellix Liftkit 500mm stroke
- X2 UR5e
- X2 Robotiq Hand-E

Modular End Effectors



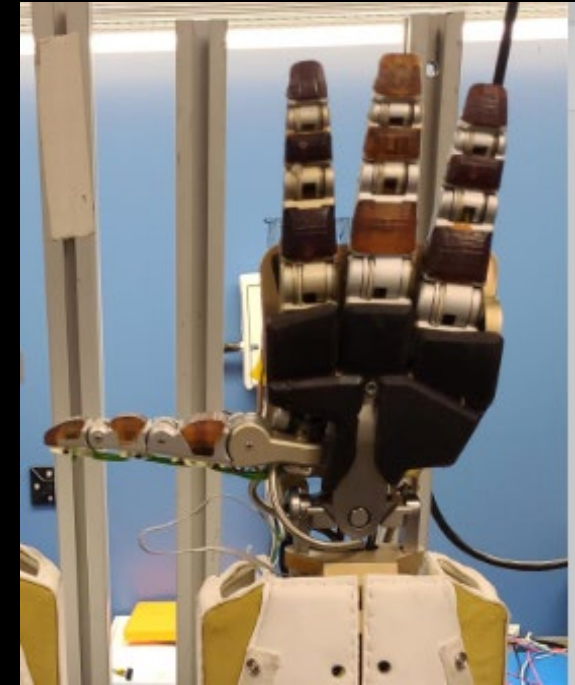
Parallel Jaw Grippers

- Non-backdrivable
- More common for iMETRO applications
- Higher pinch force maximum
- Custom fingers



Dexterous Hands

- Backdrivable and underactuated
- More compliant
- Force Controlled
- Lower pinch force capability



More Robust

Less Robust