JSC Robotics: iMETRO

The Integrated Mobile Evaluation Testbed for Robotics Operations (iMETRO) Facility

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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 Recurring Tenets

- RT-4: Maximize crew time available for science, research, and technology development activities within planned mission duration.
  - Use of tele-robotics, robotic assistance, and autonomous systems to increase crew time and effectiveness for science and utilization. For example, uncrewed operations like pre-positioning an asset can reduce the crew task burden before they arrive.
- RT-5: When practical, design systems for maintainability, reuse, and/or recycling to support the long-term sustainability of operations and increase Earth independence.
  - Reduce crew time by automating or having robotics perform maintenance tasks where possible

[] Moon to Mars Architecture

Crew Time Estimates

NASA's 2023 Moon to Mars Architecture estimates for a crew of 2 members on a 28-day lunar surface mission:

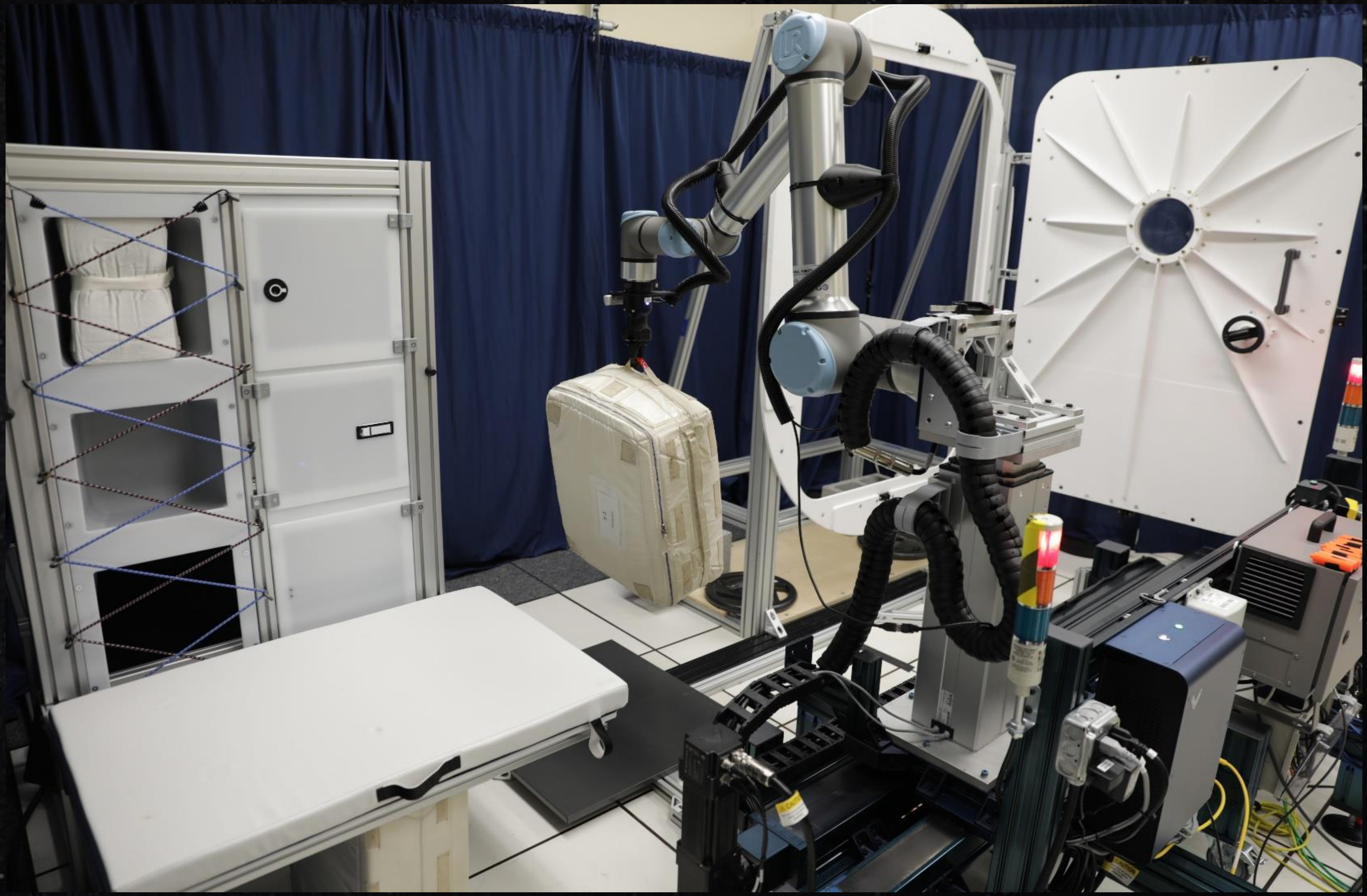
- 24.7 hours of crew time for maintenance
- 1500 kg of logistics required

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

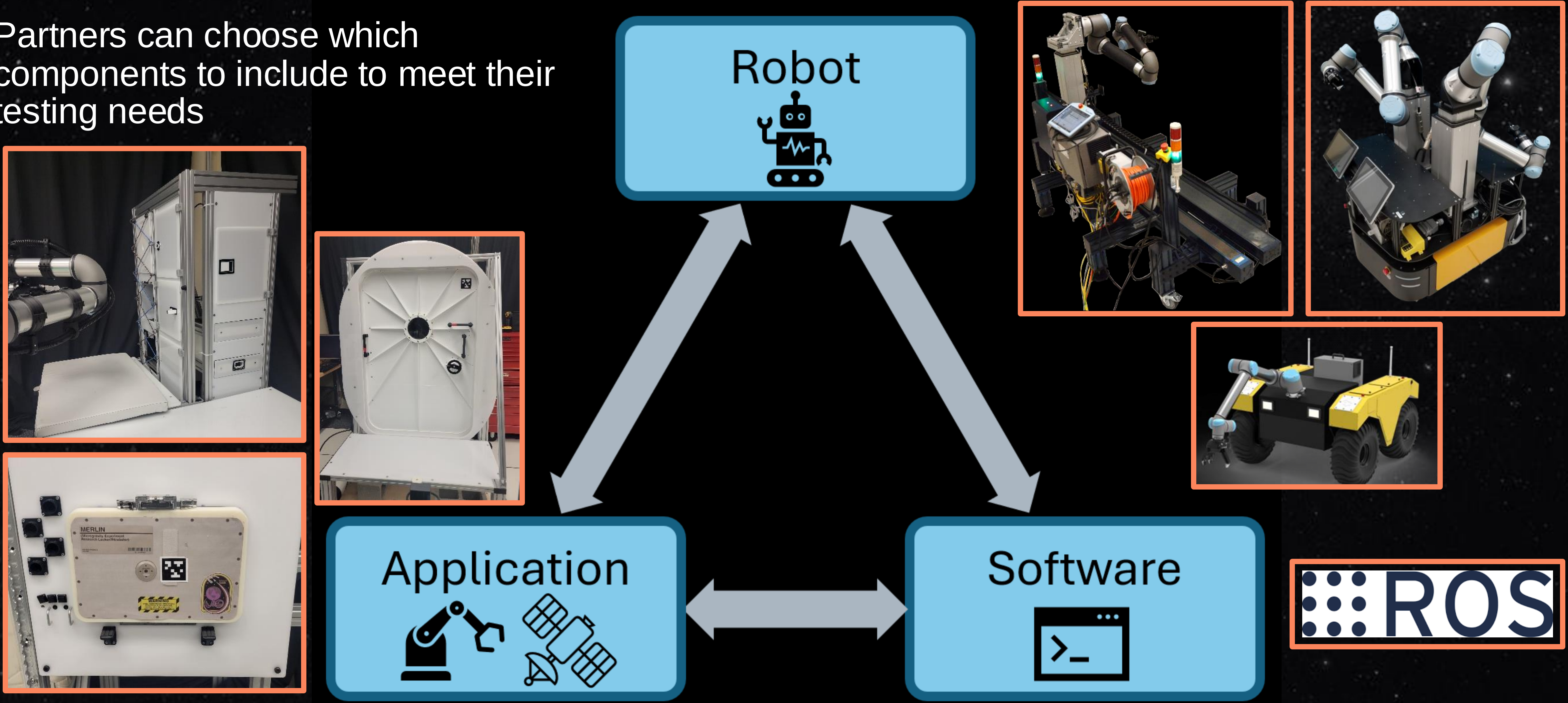
Integrated Mobile Evaluation Testbed for Robotic Operations (iMETRO)

- For Space Robotics to be successful – 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, Industry, and Academia to develop these technologies
- iMETRO provides:
  - COTS robots
  - Space Applications
  - Core open source software for all
  - Remote operator consoles (test like you fly)



Components of iMETRO Facility

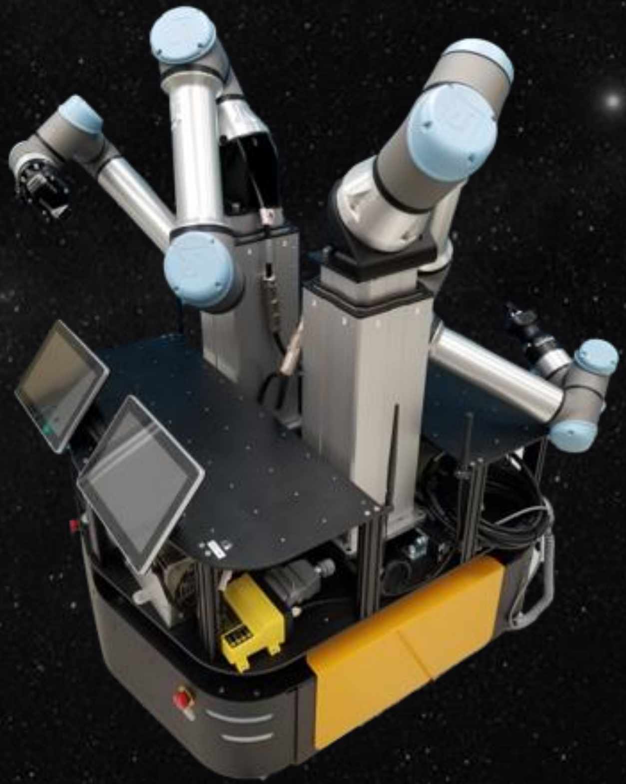
Partners can choose which components to include to meet their testing needs



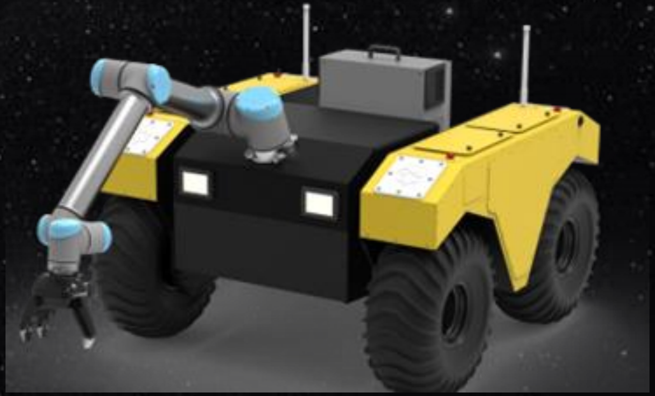
iMETRO Robots

- Single Arm on a Rail

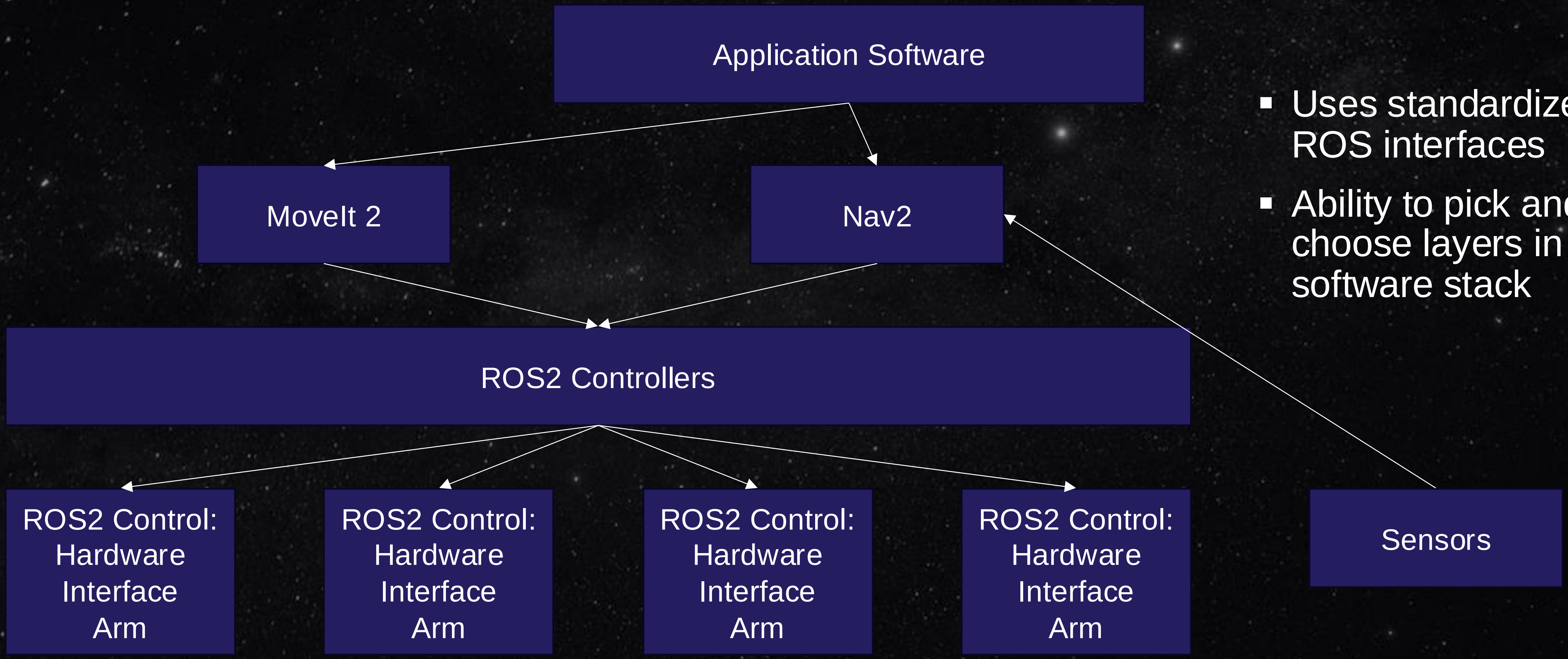
- IVR Mobile Dual Arm System



- EVR Mobile Single Arm System



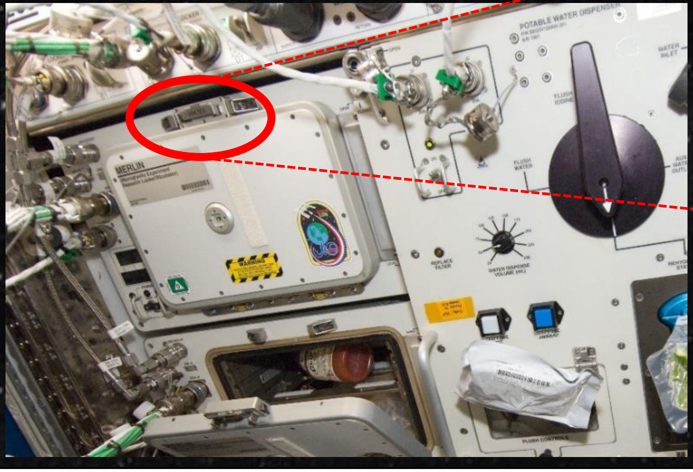
ROS2 Software Stack



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

iMETRO Applications: ISS MERLIN Freezer Example

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

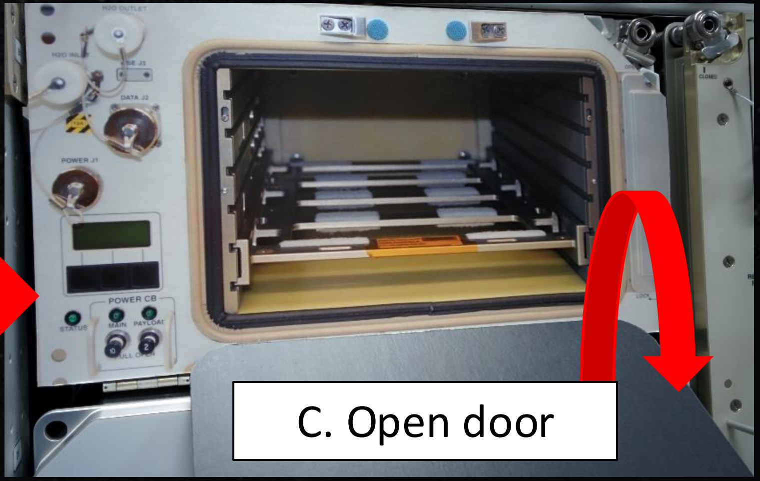


Actual freezer on ISS

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

A. Unlatch door 1

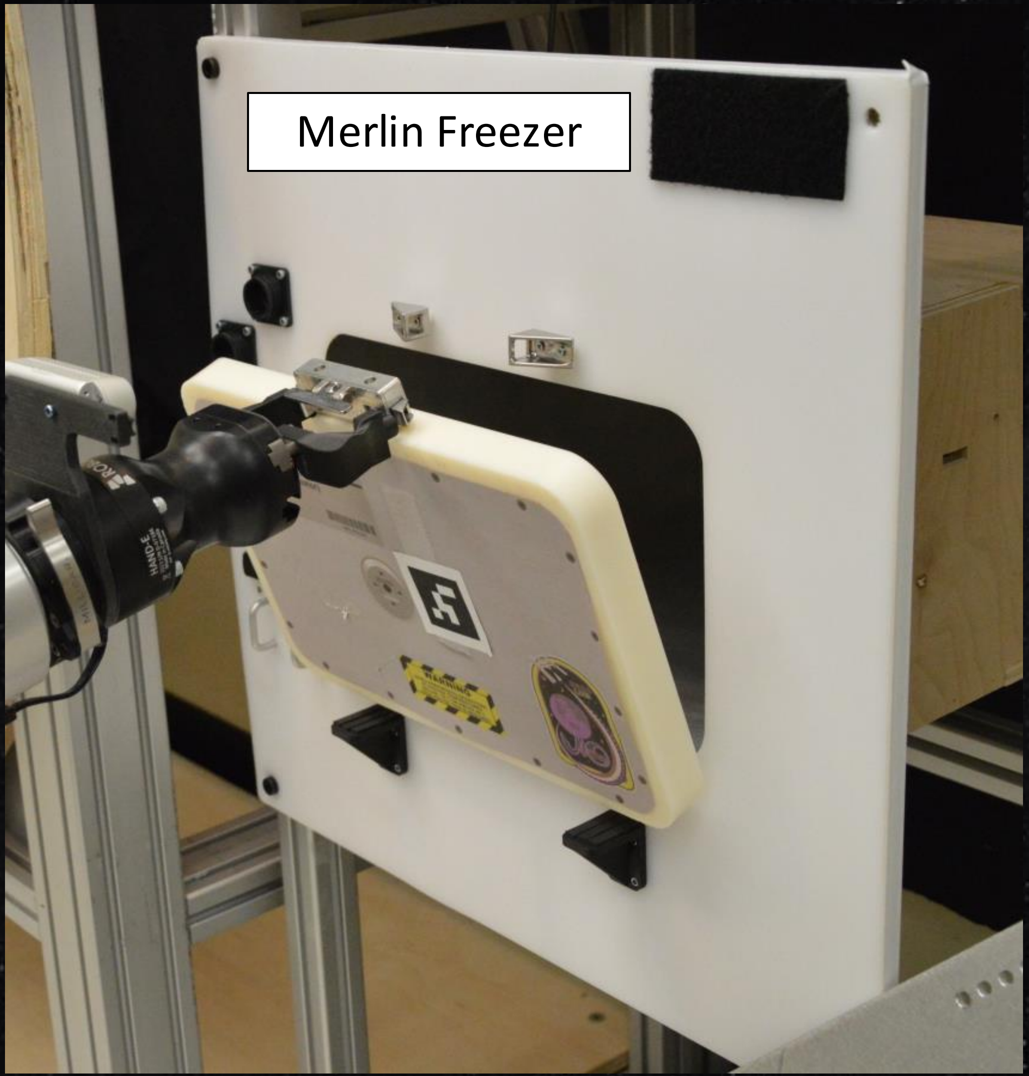
B. Unlatch door 2



C. Open door

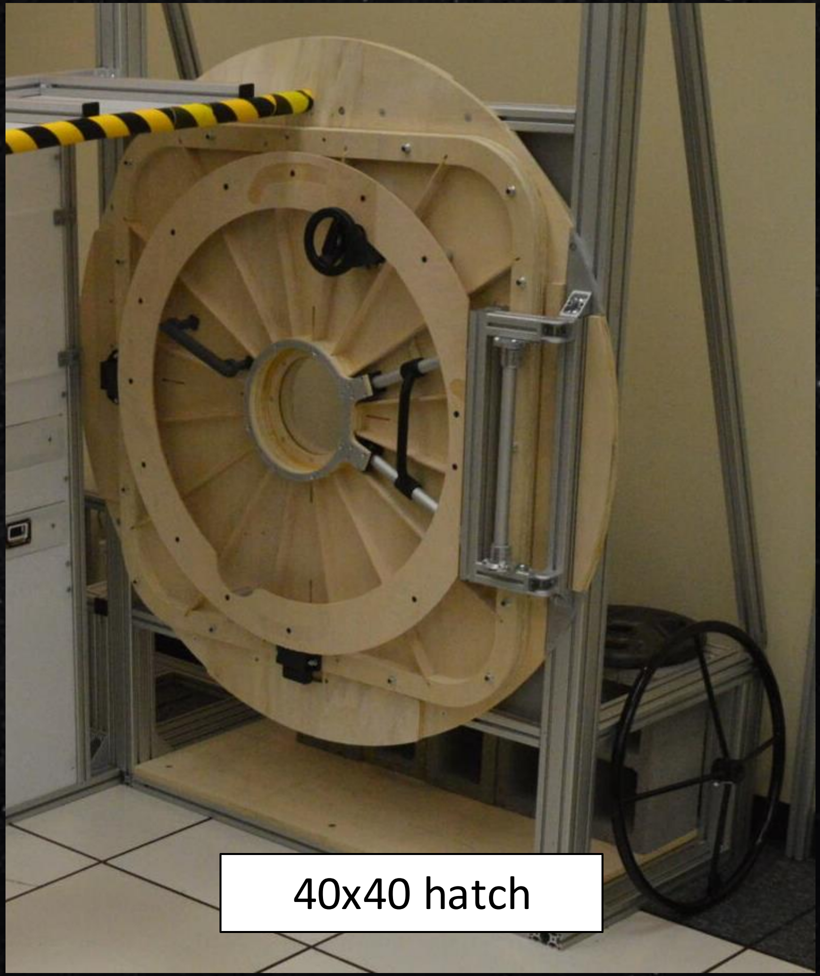
D. Stow sample

iMETRO Applications



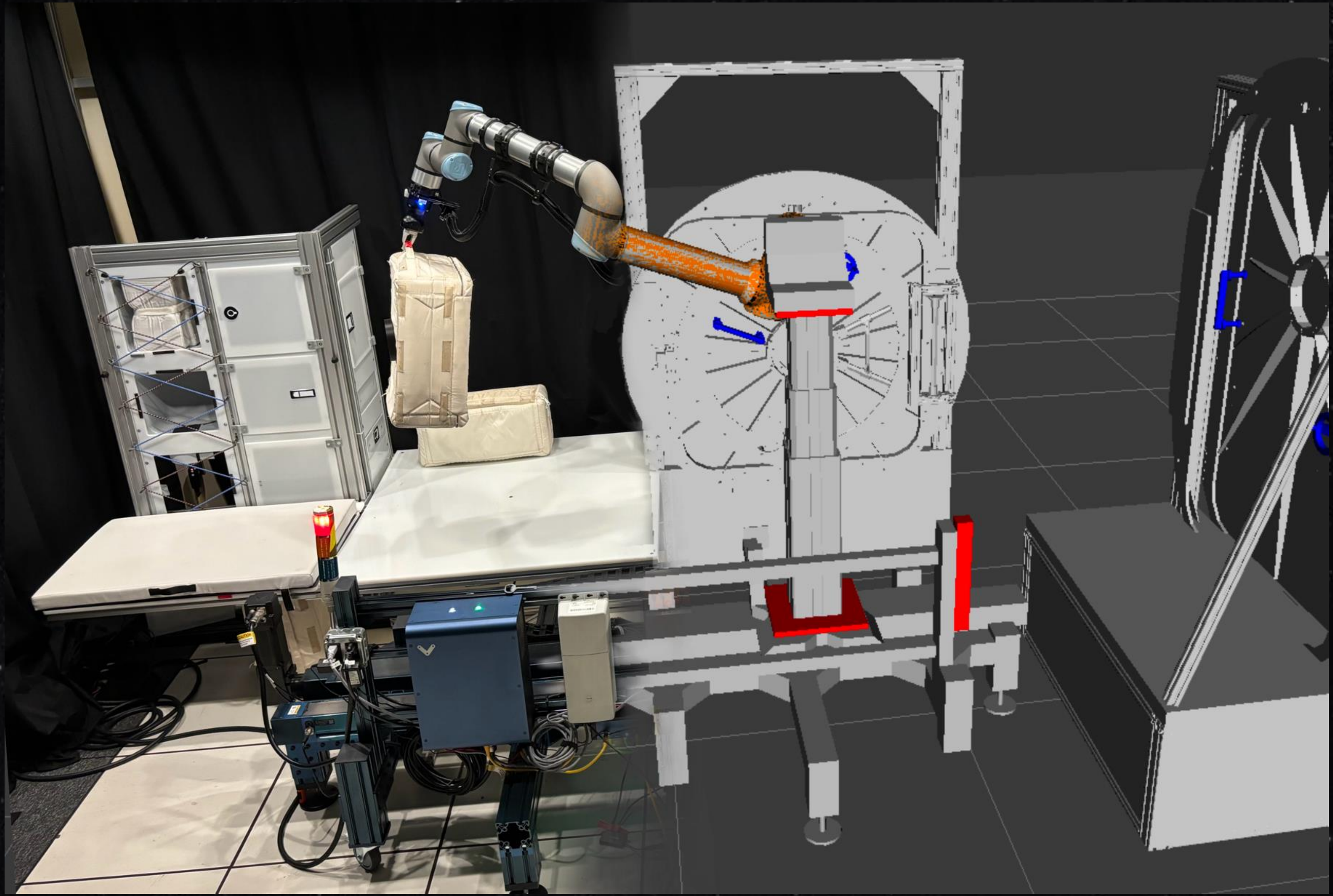
iMETRO Applications: Surface Vehicle Hatch Mockups

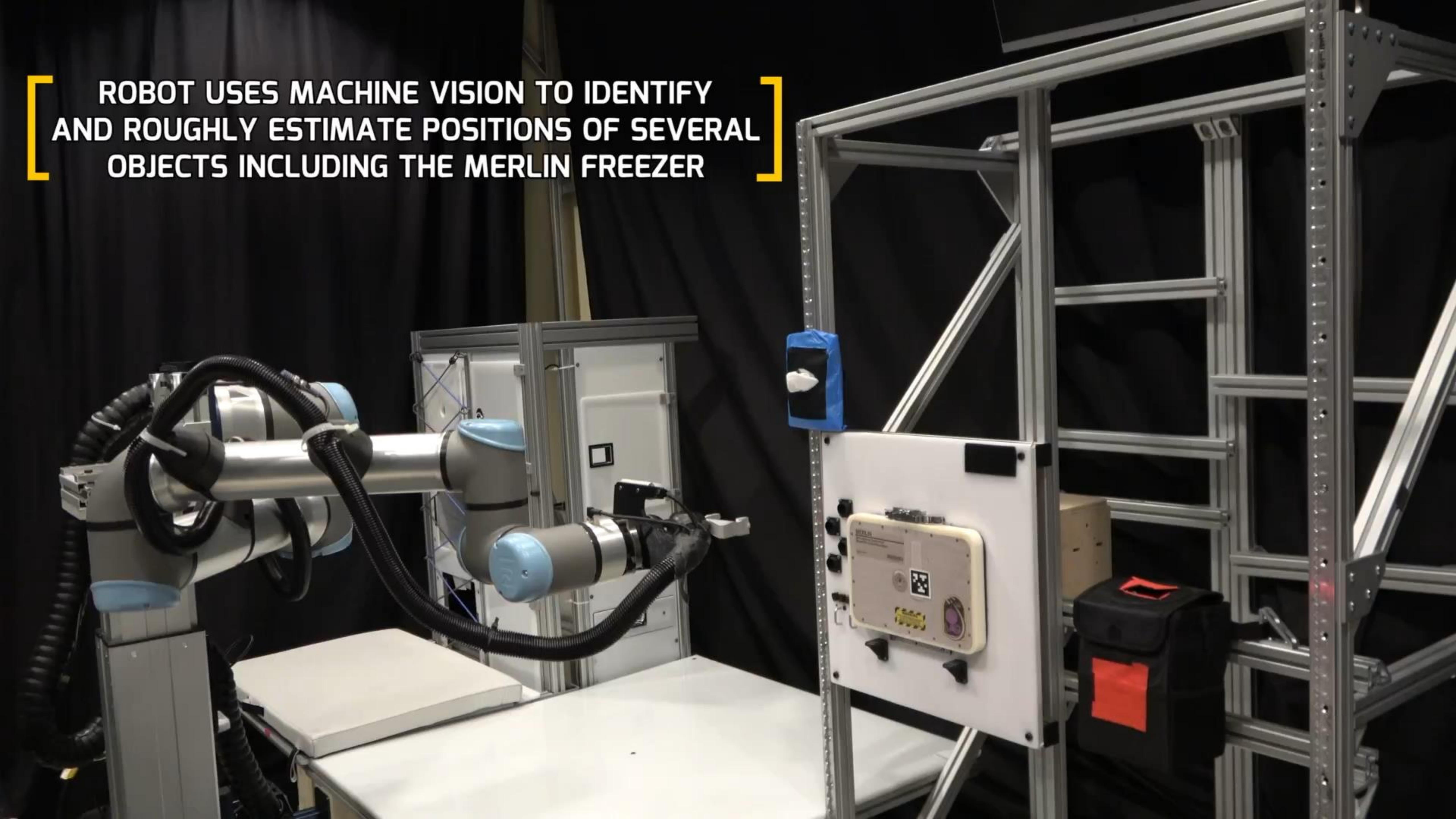
40x60 hatch



40x40 hatch

True Digital Twin: Simulation + Hardware in the Loop




ROBOT USES MACHINE VISION TO IDENTIFY
AND ROUGHLY ESTIMATE POSITIONS OF SEVERAL
OBJECTS INCLUDING THE MERLIN FREEZER

Open Source Software

- All NASA-developed iMETRO software is being released as open source
  - Approved for open source – all mockup URDFs and supporting data
  - Imminent approval expected (May 2025) – robot on rails, dual arm mobile IVR robot
    - Hardware
    - Kinematic Simulation
- Releases will be containerized via docker
- All source code will be available on NASA GitHub and listed in the NASA Software Catalog

Configuration Management and Distribution

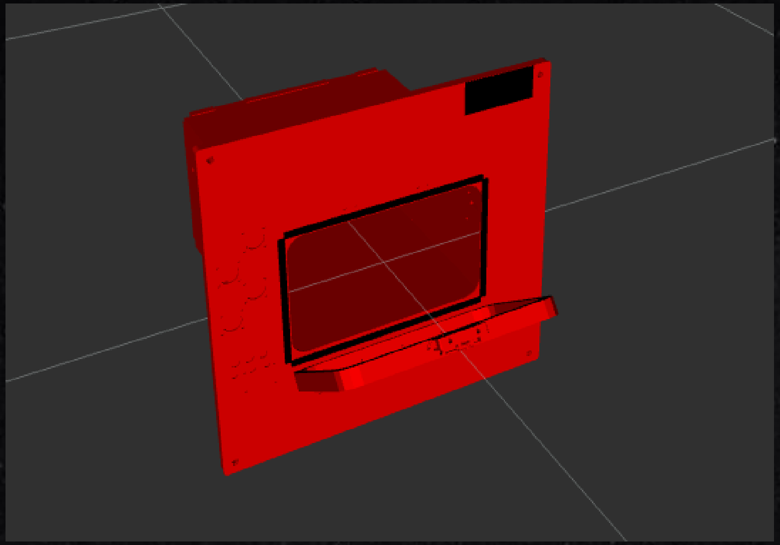
- Robot docker container

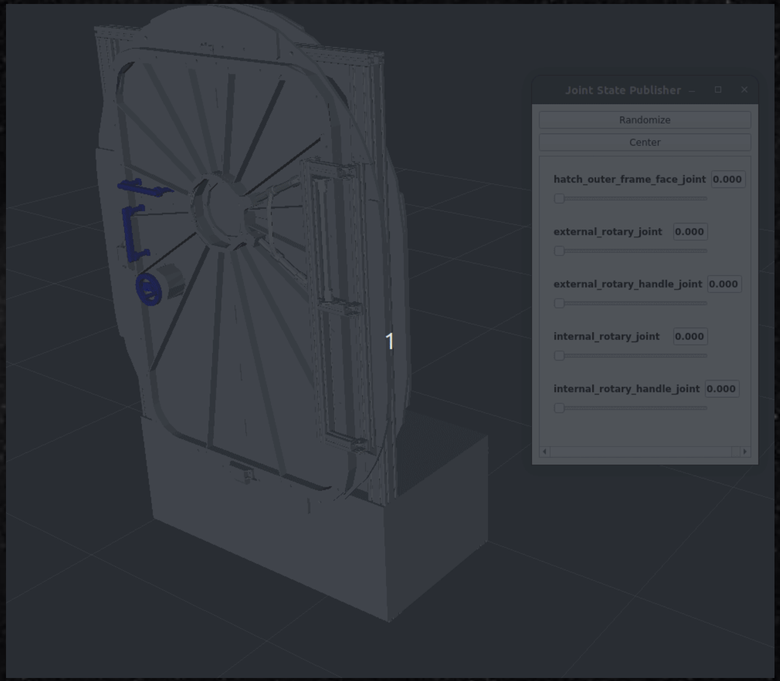
Name	Last commit
.ccache	Add placeholders for compiler artifacts
build	Add placeholders for compiler artifacts
config	Remove the release build
install	Add placeholders for compiler artifacts
log	Add placeholders for compiler artifacts
scripts	Add pre-commit configuration
src	Set submodules back to humble-devel ...
.dockerignore	Switch to using pre-built ROS images, c...
.env	Remove remaining references to binary ...
.gitignore	Use folders instead of volumes
.gitlab-ci.yml	Add pre-commit configuration
.gitmodules	Add new submodule
.pre-commit-config.yaml	Use pip installable shellcheck
Dockerfile	Update default gid and update a few co...
README.md	Use folders instead of volumes
docker-compose.yml	Remove service name for dev container

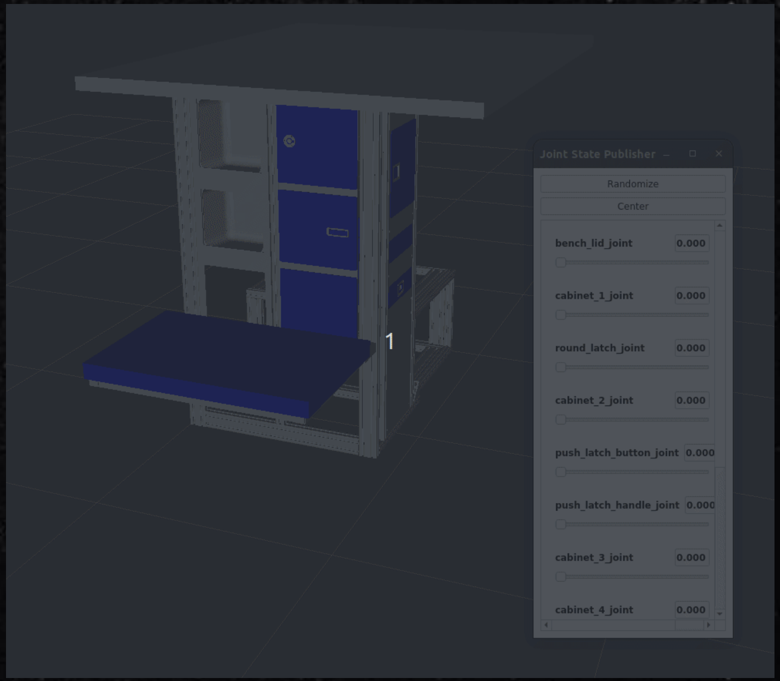
- Use submodules for workspace management

Name	Last commit
..	
chonkur @ 39375bb3	Set submodules back to humble-devel after merges
chonkur_l_raile @ 3e2b4e8c	bumping submodules for gripper changes
dextivr_hande @ db62b459	bumping submodules for gripper changes
drt_ros2_control_tools @ da0e2c8a	Bum chonkur, clr, ros2 control tools, and ur control for custom
drt_ros2_launch_common @ 87e90723	Bumping submodules for non-functional pre-commit changes
drt_ros2_ur_tools @ 9ea9aefd	Set submodules back to humble-devel after merges
ewellix_lift_kit @ 38b84e31	bumped ewellix after merge
ros2_robotiq_gripper @ 592cc1b3	bumping submodules for gripper changes
serial @ d8d16067	Convert to submodules
trac_ik @ 210f767d	Convert to submodules
vention_rail @ efdc26bd	Bump chonkur, clr, ros2 control tools, lift, and vential submod
.gitkeep	Add src directory to base repo for workspace clones

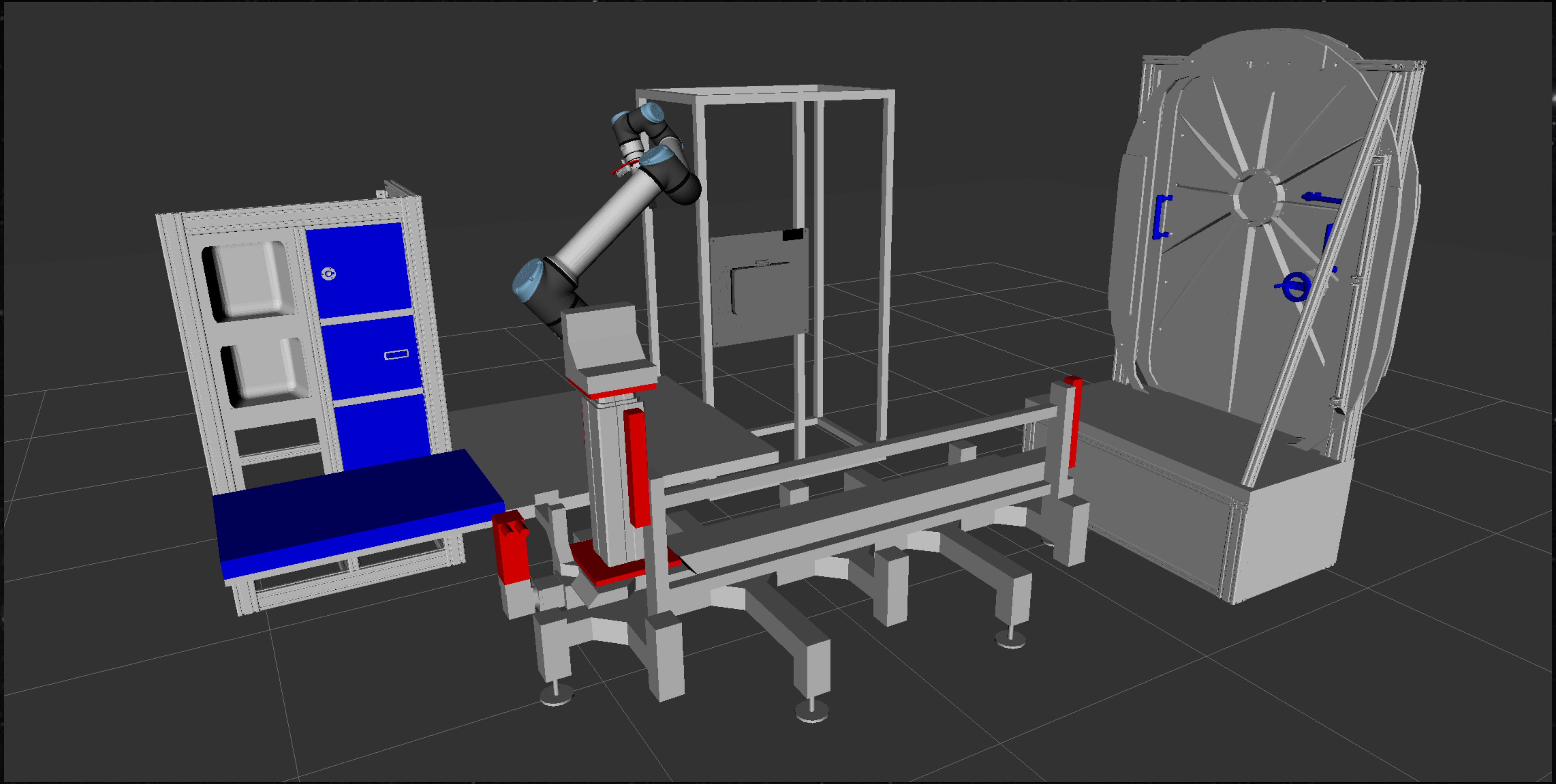
Mockups described via URDF







Kinematic Simulation



Next Steps: Dynamic Simulation Support

- Focusing on the single arm on rail to start and the hatch mockup as initial assets
- Exploring support for the three most common dynamic simulation environments:

MuJoCo

NVIDIA ISAAC

GAZEBO

iMETRO Contact Information

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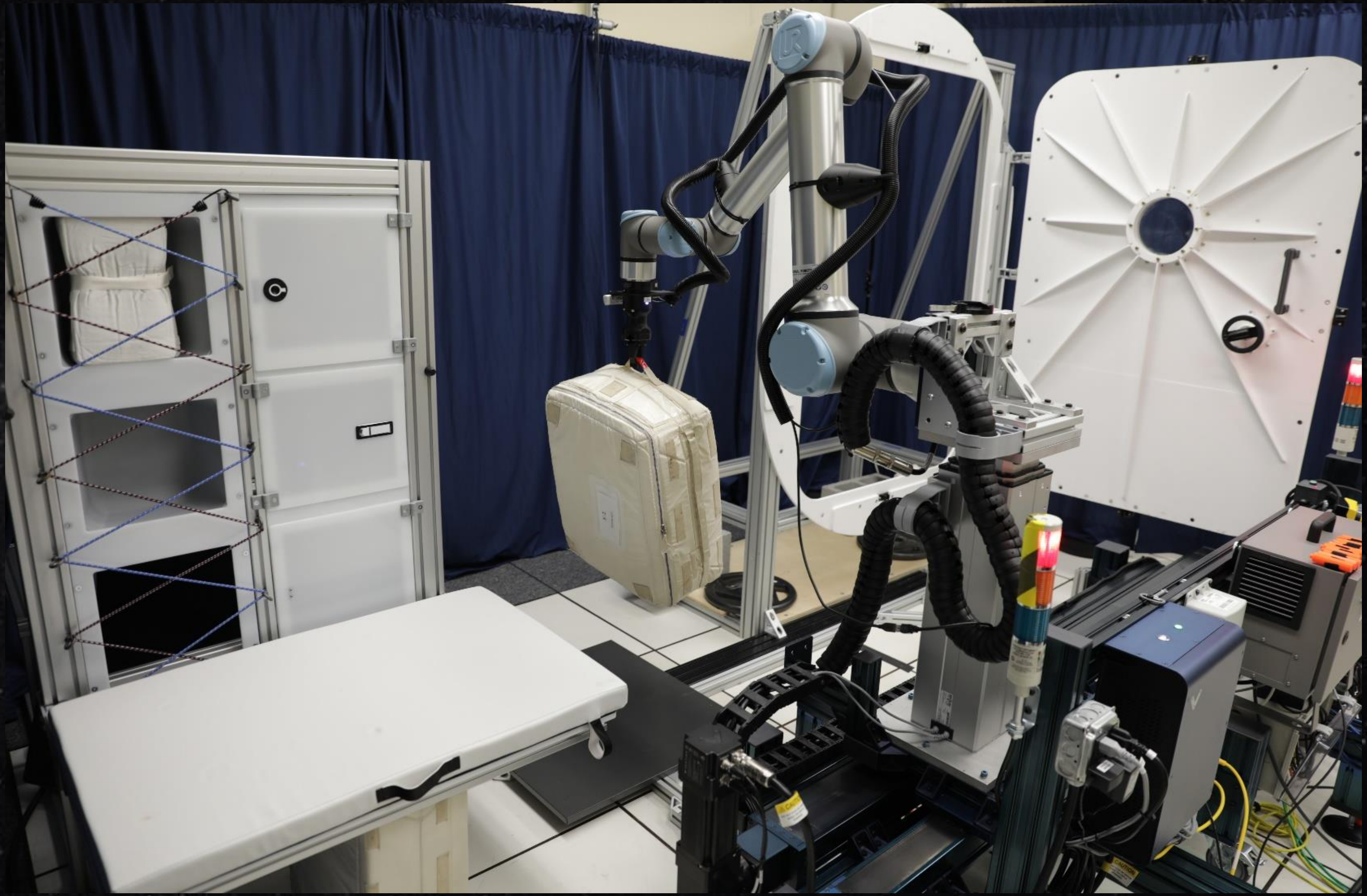
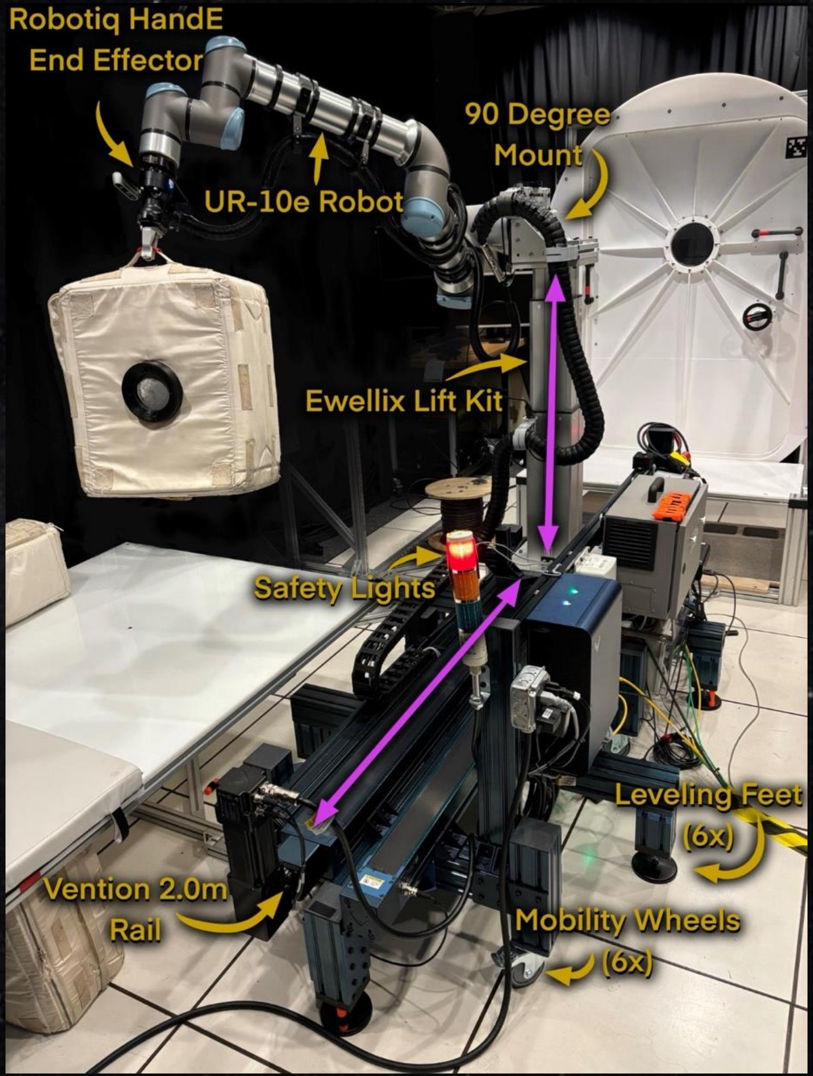


Backup Slides

Single Arm on a Rail



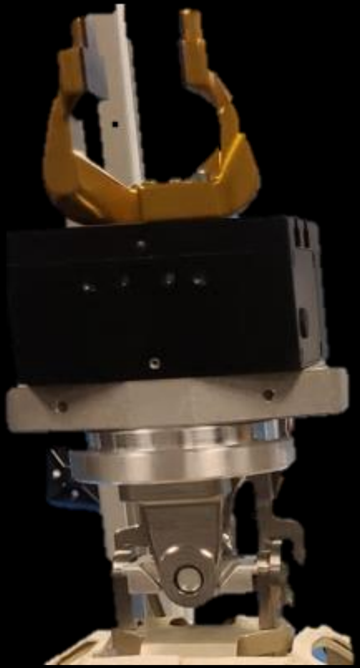
IVR Mobile Dual Arm System

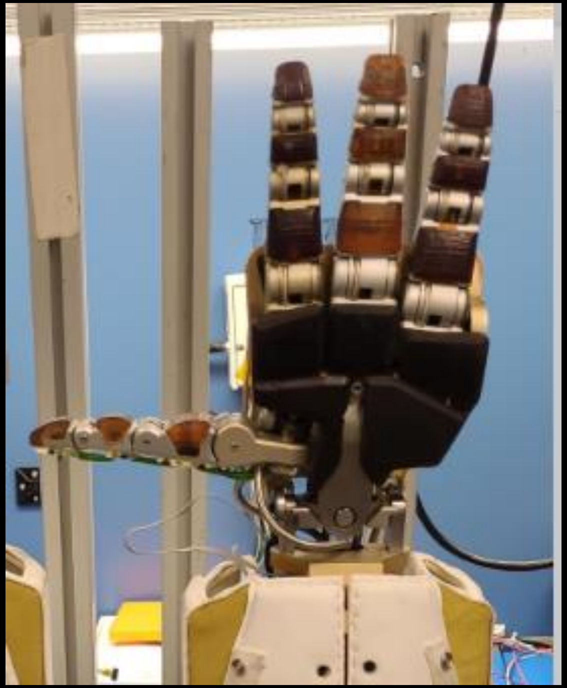
- Clearpath ridgeback
- X2 Ewellix Liftkit 500mm stroke
- X2 UR5e
- X2 Robotiq Hand-E

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