
MoveIt Pro
by PICKNIK
ROCKETLAB
MOVEIT PRO WORKS HERE
RELIABLE
MOTION CONTROL
& AUTONOMY
FOR SPACE
A WEBINAR WITH ROCKET LAB
AUGUST 6
9:00 AM PT

ROCKET LAB GUESTS

ROCKETLAB

Meet Today's Speakers

Reliable motion control and autonomy for space robotics.

KEVIN FRENCH
Rocket Lab

TOM McCARTHY
Rocket Lab

MoveIt Pro by PICKNIK

ROCKETLAB

PICKNIK TEAM

Meet the PickNik Team

MoveIt Pro by PickNik

DAVE COLEMAN

Founder & CPO

PickNik Robotics

MICHAEL WROCK

Principal Robotics Engineer

PickNik Robotics

MoveIt Pro by PICKNIK | ROCKETLAB

HOUSEKEEPING FOR TODAY

We want to hear from you.

Please interact and submit questions in the Q&A tab during the webinar.

1 Join the conversation

Drop questions in Q&A. We will save time for them at the end.

2 MoveIt Pro by PICKNIK

More information:
picknik.ai

3 ROCKETLAB

More information:
rocketlabusa.com

MoveIt Pro by PICKNIK | ROCKETLAB

NEXT WEBINAR

MoveIt Pro Works Here with Cellular Origins

SEPTEMBER 9

11:00 AM EASTERN

cellularorigins

MoveIt Pro by PICKNIK

ROCKET LAB ROBOTICS

MoveIT Pro Webinar

rocketlabcorp.com

ROCKETLAB

BUILDING UPON A DECADE OF SPACE ROBOTICS

ROCKETLAB

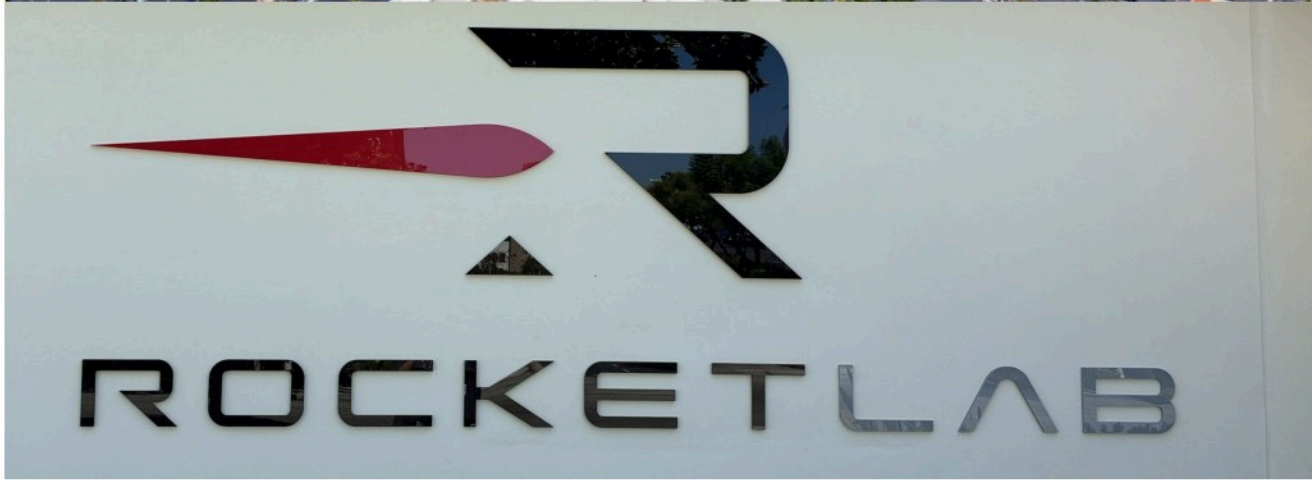
ROCKET LAB

-ROBOTICS AND MOTION CONTROL

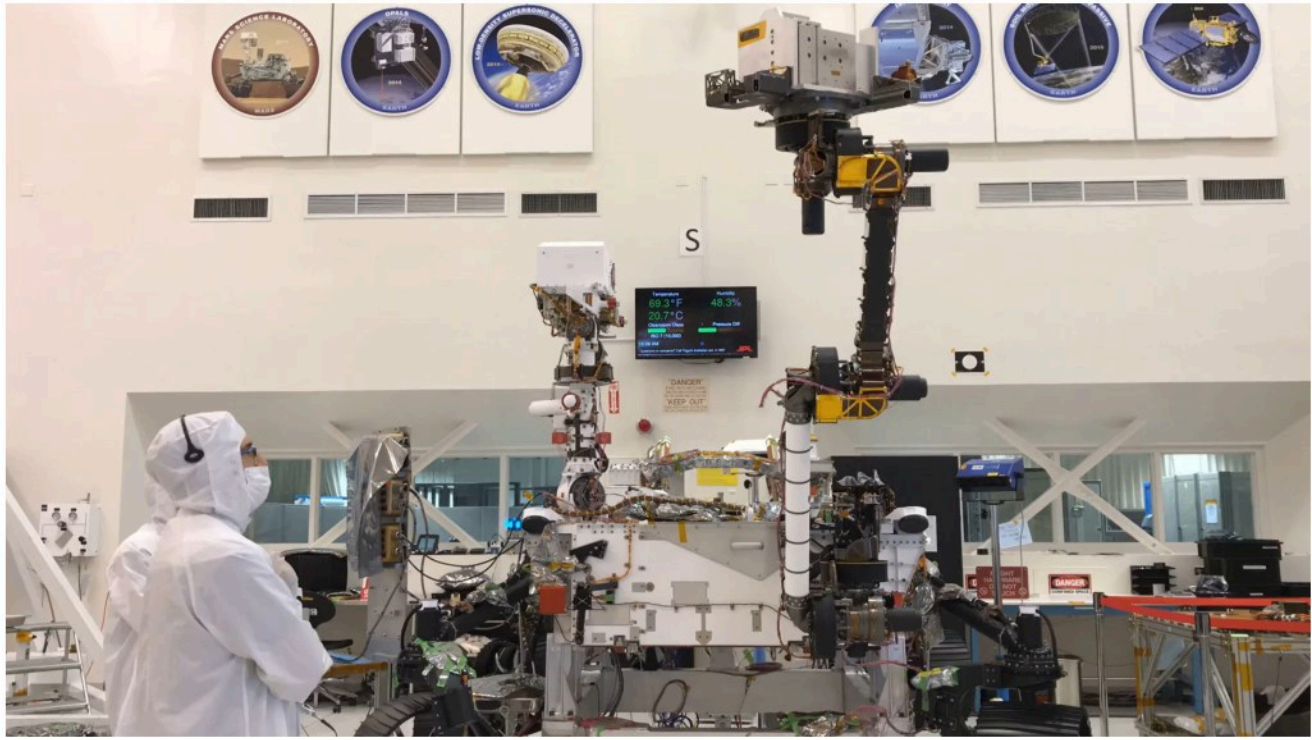
FORMERLY MOTIV SPACE SYSTEMS
- PASADENA, CA

Flight Avionics Facility

Main Building / AI&T

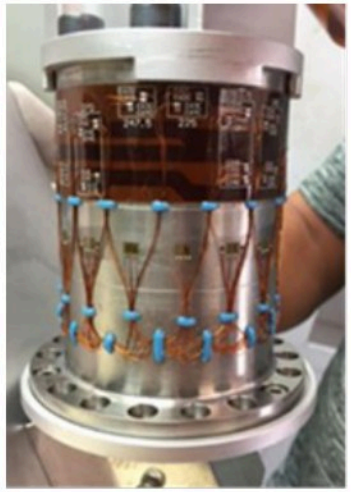


MARS 2020 ROBOTIC ARM



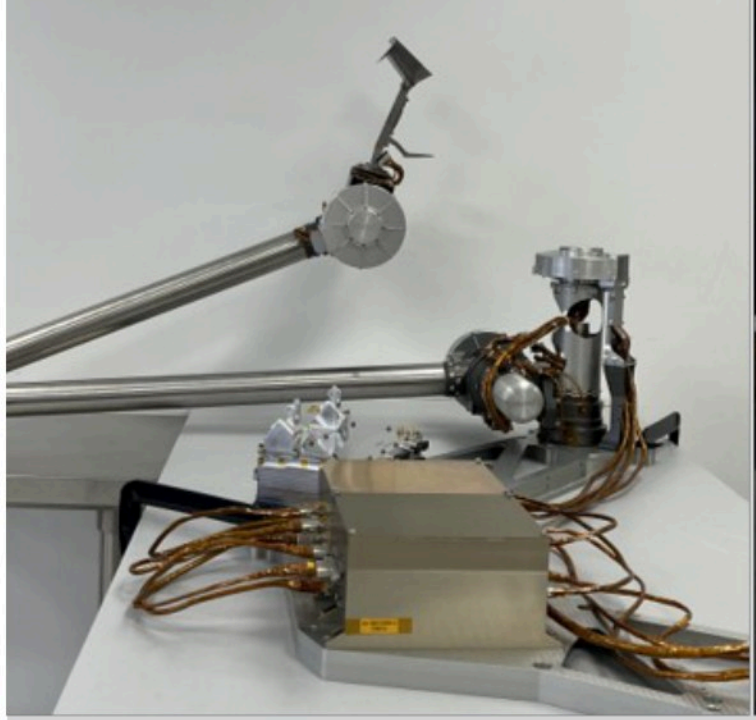
Operating on Mars since February 2021

- Most capable robotic arm ever for Mars!
- 5-DOF arm, 45kg payload
- Custom 6-DOF force-torque sensor



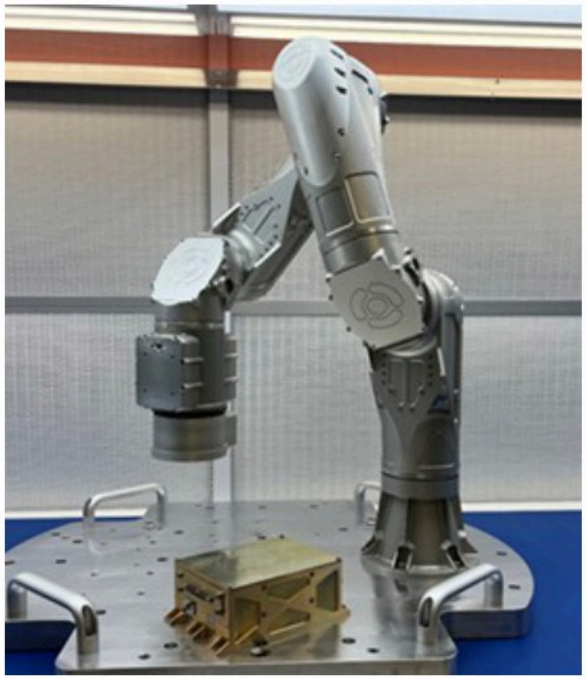
COLDARM
COLD OPERABLE LUNAR DEPLOYABLE ARM

- 4-DOF Robotic Arm System
- ~4kg payload capacity
- 1.7m length to payload interface
- Complete system arm/drive electronics ~20kgs
- Designed for Lunar missions
  - Cryogenic operating for lunar night use



XLINK ROBOTICS






xLink Robotic Arm Testbed

- Modular Manipulator Architecture
- Distributed Control Solution
- Visual Servoing and Compliance Control shown

Flight Qualified - xLink Robotic Arm

- Developed for OSAM-2 Flight demonstration Mission
- 1.3M in Length / 7-DOF
- Core technology of Crosslink for FFR Mission

SECTION

01

ROBOTIC IN SPACE SERVICING ASSEMBLY AND MANUFACTURING (ISAM) AT RLR

WHY SPACE?

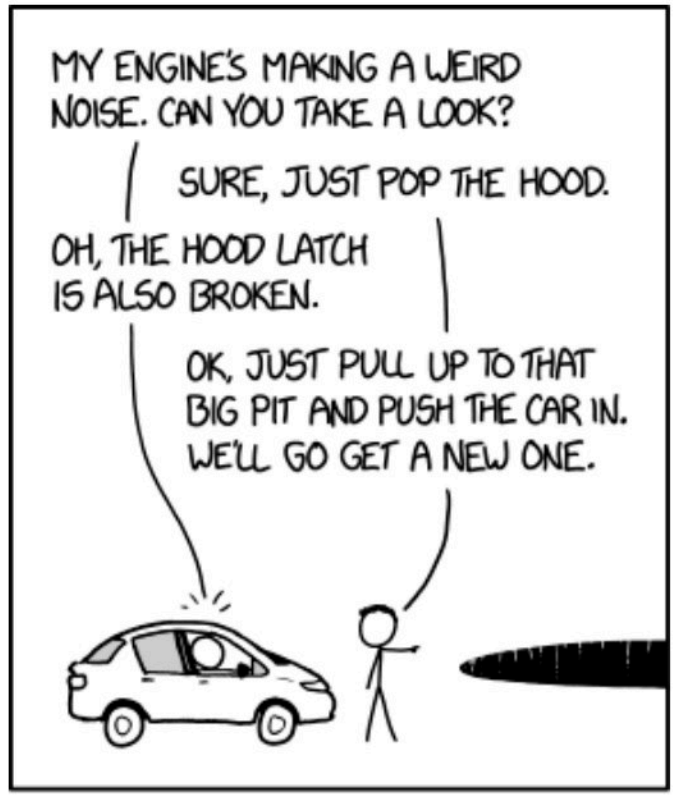
- Science
  - Answering the big questions, how did it all start? Are we alone?
  - Accelerating sciences in the unique environment of space, printing organs, near lossless fiber optics, computers, cosmic rays, etc.
- National Security
  - Advance missile detection, secure communications, intelligence
- Industry
  - Internet for everyone, GPS, cell service, medicine only possible in micro gravity, rare resource collection

Luna (the moon) as depicted in The Expanse TV series

WHY THEN ARE SO FEW PEOPLE UP THERE? SIMPLE, HUMANS ARE PROHIBITIVELY EXPENSIVE

- Human time is precious
  - Working in space is prohibitively expensive
  - Everything is shipped by rocket, water, food, air, fuel, parts, etc. ~$1.5K Kg on Falcon 9
  - Communication bandwidth, and ground support
  - ISS currently requires ~$1.2 billion (see NASA FY26 budget) just to operate
- Can’t afford time on the Dull Dirty and Dangerous
  - Control cost and risk

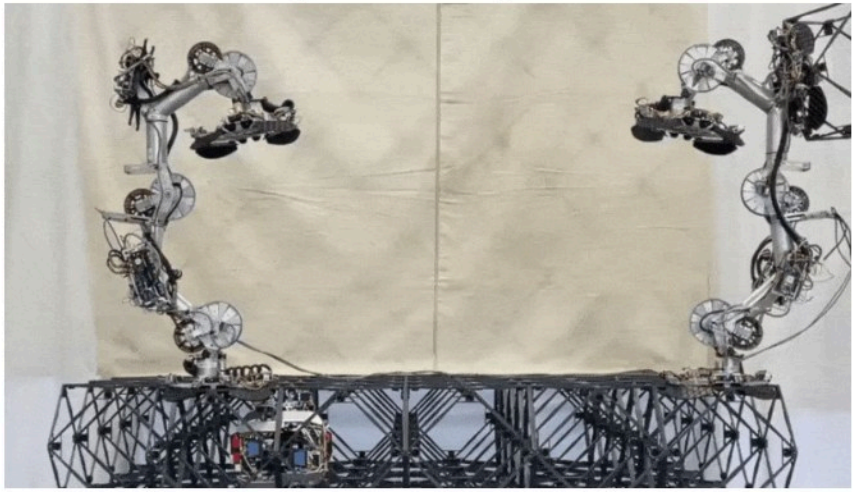
Today’s solution – trash it launch a new one



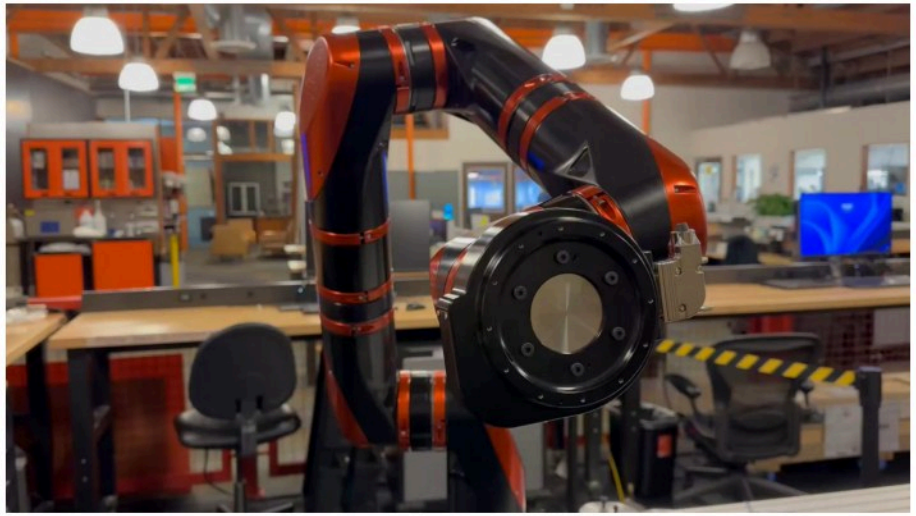
xkcd: Repair or Replace

RLR ROBOTIC IN-SPACE SERVICING AND ASSEMBLY (ISAM) IS A FORCE MULTIPLIER

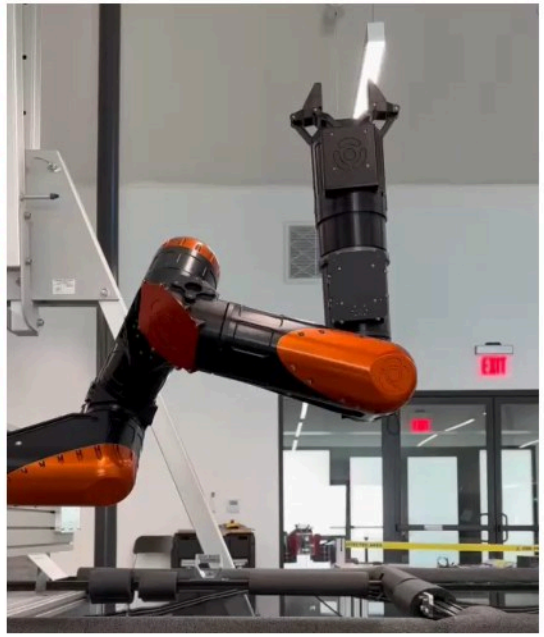
- Robots do the dull dirty and dangerous tasks
- Robots assist humans in collaborative tasks
- Enables previously impossible missions



NASA AMES ARMADAS



Compliance control enables collaborative tasks with any RLR

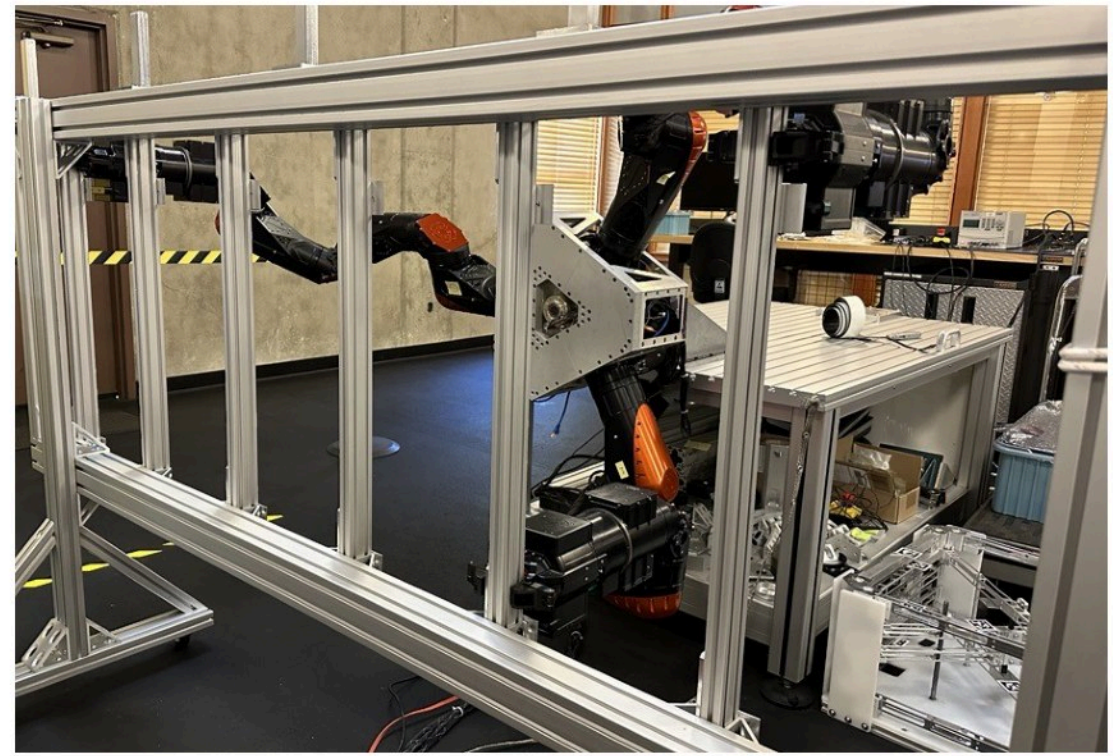


xLink installs an orbital replacement unit (ORU) on a

TODAY WE WILL DISCUSS 2 RLR ISAM PROJECTS BOTH PUSH THE BOUNDARIES OF THE POSSIBLE IN DIFFERENT WAYS

FLY FOUNDATIONAL ROBOTS

XWALKER



SECTION

02

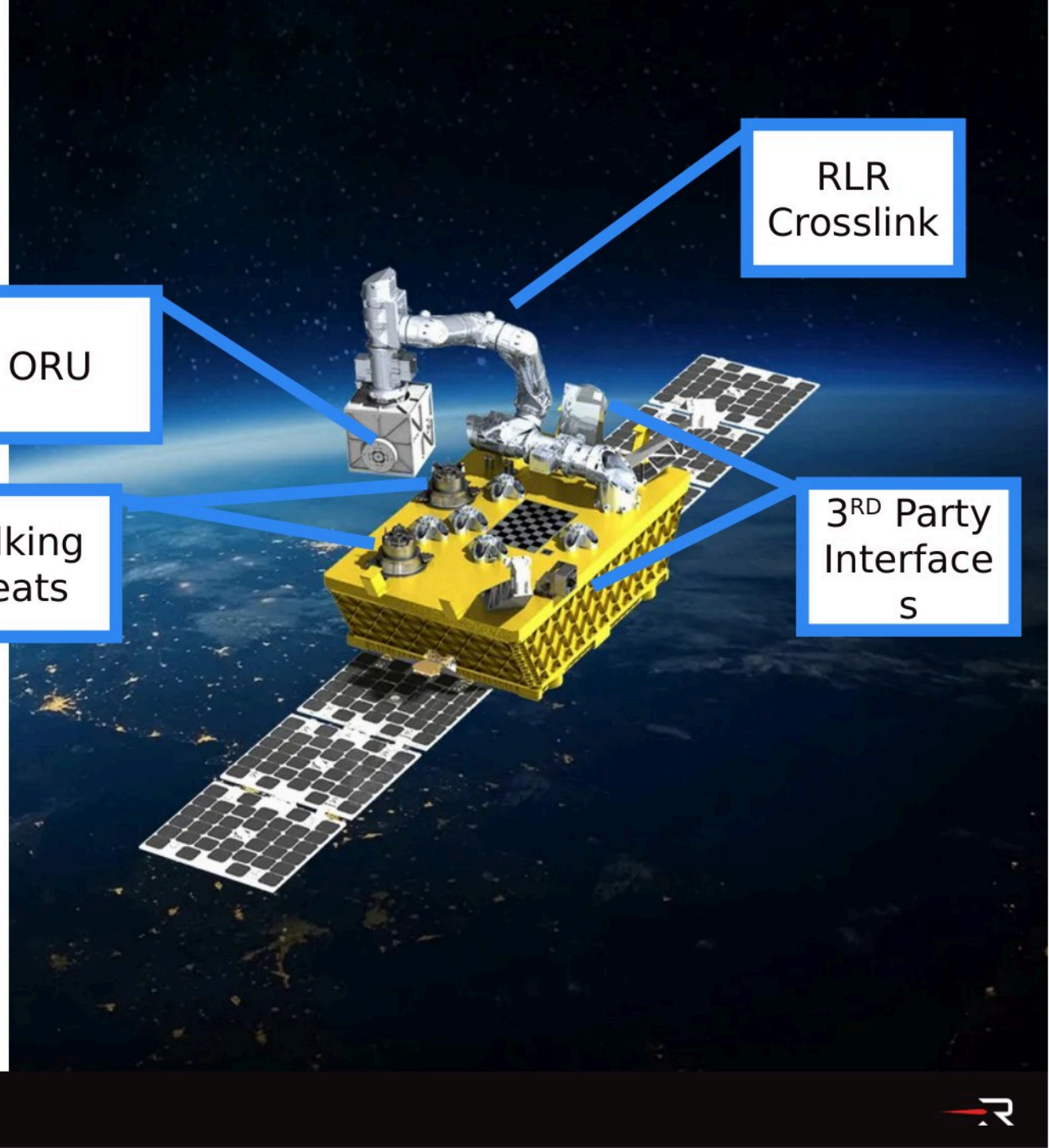
FLY FOUNDATIONAL ROBOTS (FFR)

FLY FOUNDATIONAL ROBOTS (FFR) ROBOT ON ORBIT FASTER, CHEAPER, AND MORE ACCESSIBLE THAN EVER

- Collect and characterize dense engineering telemetry
  - Prove viability of robots in space
- Demonstrate instillation of an orbital replacement unit (ORU)
  - Demonstrate the capabilities
- Provide 3rd party standard interfaces for future mission extensions
  - Extensible and general purpose
- Guest roboticist use the FFR platform
  - Test all our theories on orbit boost TRL

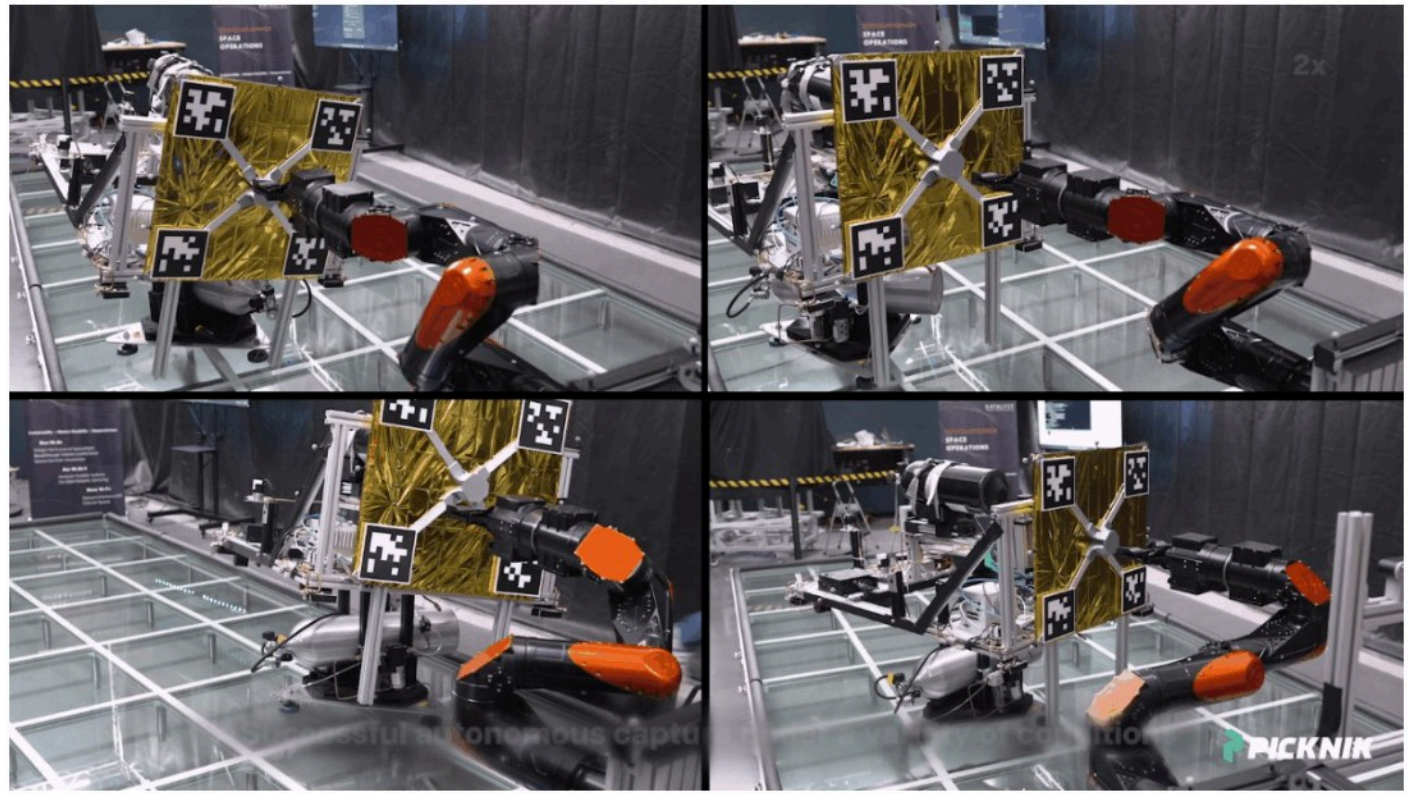
FFR CONCEPT OF OPERATIONS (CONOPS) OVERVIEW

1. Pre-launch checkout
2. Post-launch checkout/commissioning
3. Crosslink walking maneuver
4. ORU installation
5. Guest roboticist and extended operations



COLLECT AND CHARACTERIZE DENSE ENGINEERING TELEMETRY

- There are nearly no datasets from real missions
- Earth bound simulations provide insight but are not perfect
- Dense engineering telemetry is critical:
  - Understand physics
  - Plan future missions
  - Build better simulators and earth bound analogs
- FFR will collect this data
  - 4 HD cameras
  - Standard motor sensors
  - 2 Force Torque Sensors (FTS)
  - Output shaft torque sensors
  - Attitude measurment
- MoveIt Pro collects stores and transmits data as compressed ROS



Satellite capture with xLink demonstration on air bearing table by RLR customer PICKNIK

DEMONSTRATE INSTILLATION OF AN ORBITAL REPLACEMENT UNIT (ORU)

- ORU represents a generic device such as a thruster or sensor
- In the case of FFR we have a particle physics science experiment
- Moving the ORU represents the capability to transfer capability from one system to another
- MoveIt Pro provides scripting, and robot arm controllers that make this operation easy

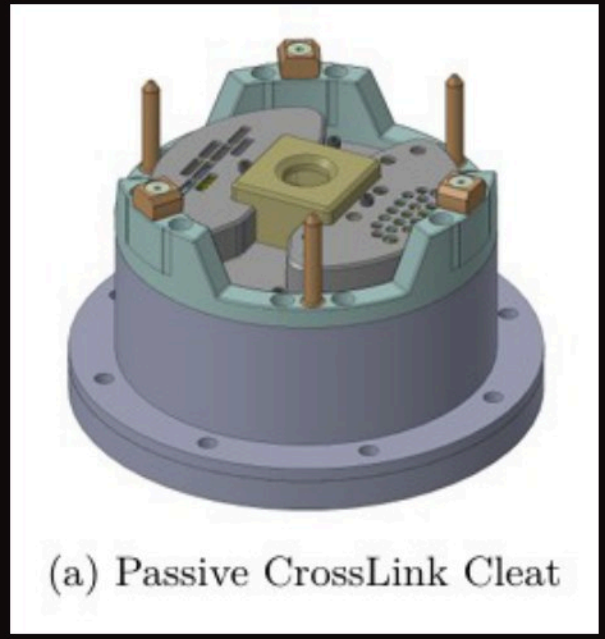
PROVIDE 3RD PARTY STANDARD INTERFACES FOR FUTURE MISSION EXTENSIONS

Future missions are already under consideration

Multiple 3rd party interfaces allow visiting spacecraft to interface with the FFR spacecraft

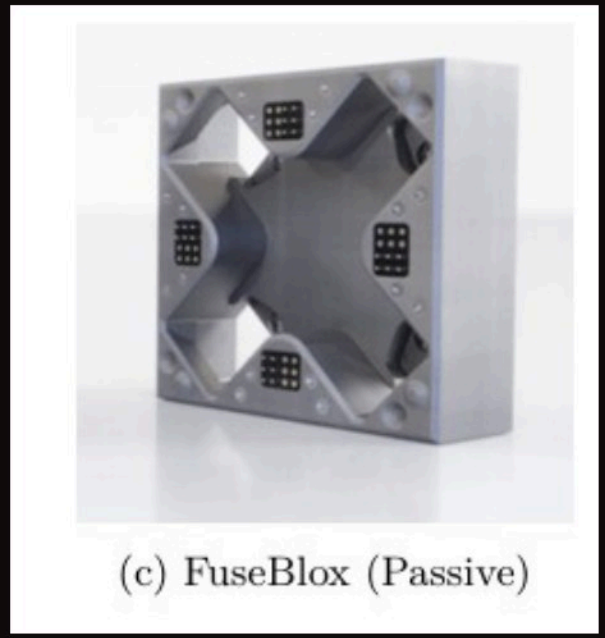
The door is wide open for future missions

MoveIt Pro will allow us to rapidly adapt to changing mission requirements

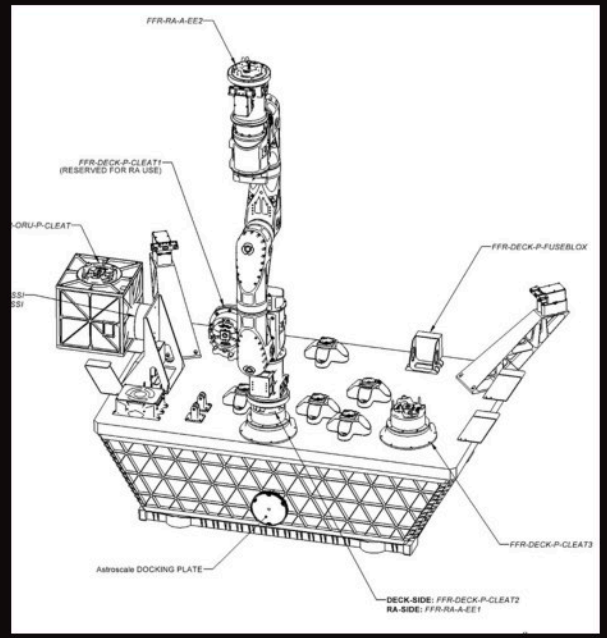


(a) Passive CrossLink Cleat

(b) iSSI (Active)

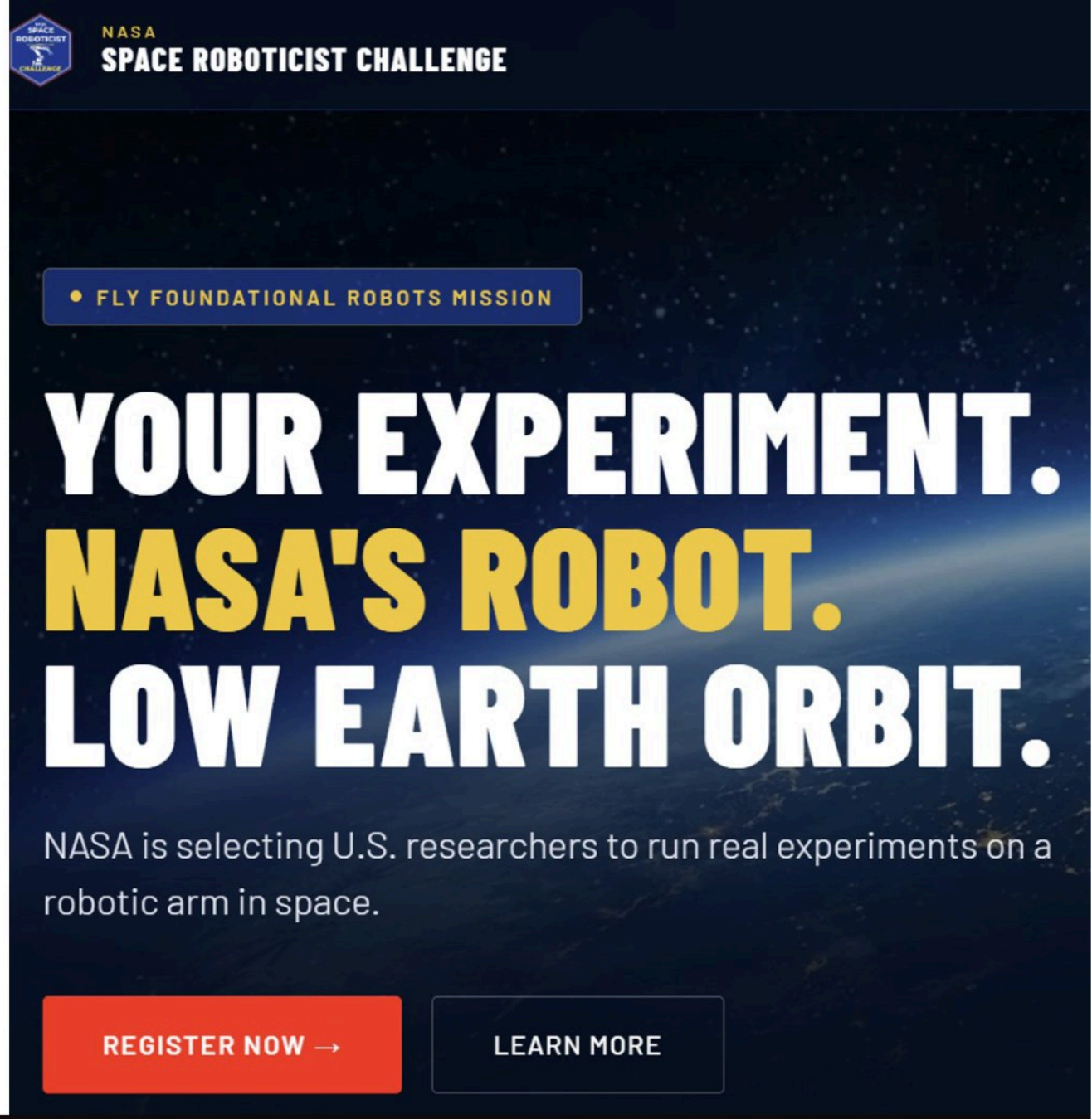


(c) FuseBlox (Passive)

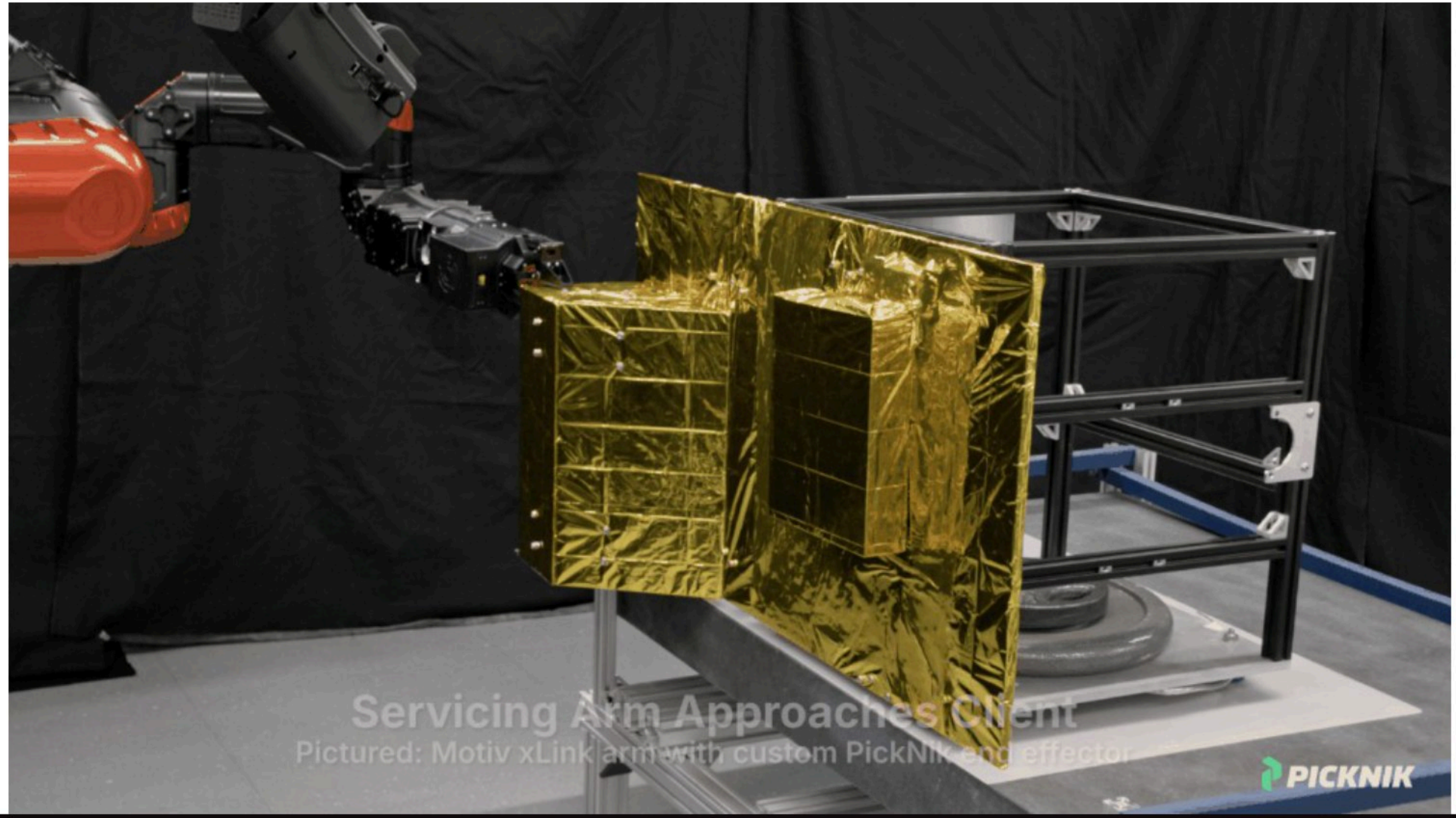


GUEST ROBOTICIST USE THE FFR PLATFORM

- NASA Space Roboticist Challenge
  - We’ve seen massive interest in running robotics experiments on orbit
- MoveIt Pro is built on top of an Open-Source backbone
  - Built on the most popular robotics framework ROS, guests can confidently integrate their ROS work with FFR MoveIt Pro
- No orbital platform for open robot experimentation exists on this scale
- See mission page for fact sheet
  - Fly Foundational Robots - NASA



EXAMPLE OF POTENTIAL FUTURE MISSIONS
PICKNIK DEMONSTRATES MOVEIT PRO TO USE RLR XLINKS TO REFUEL A SATELLITE



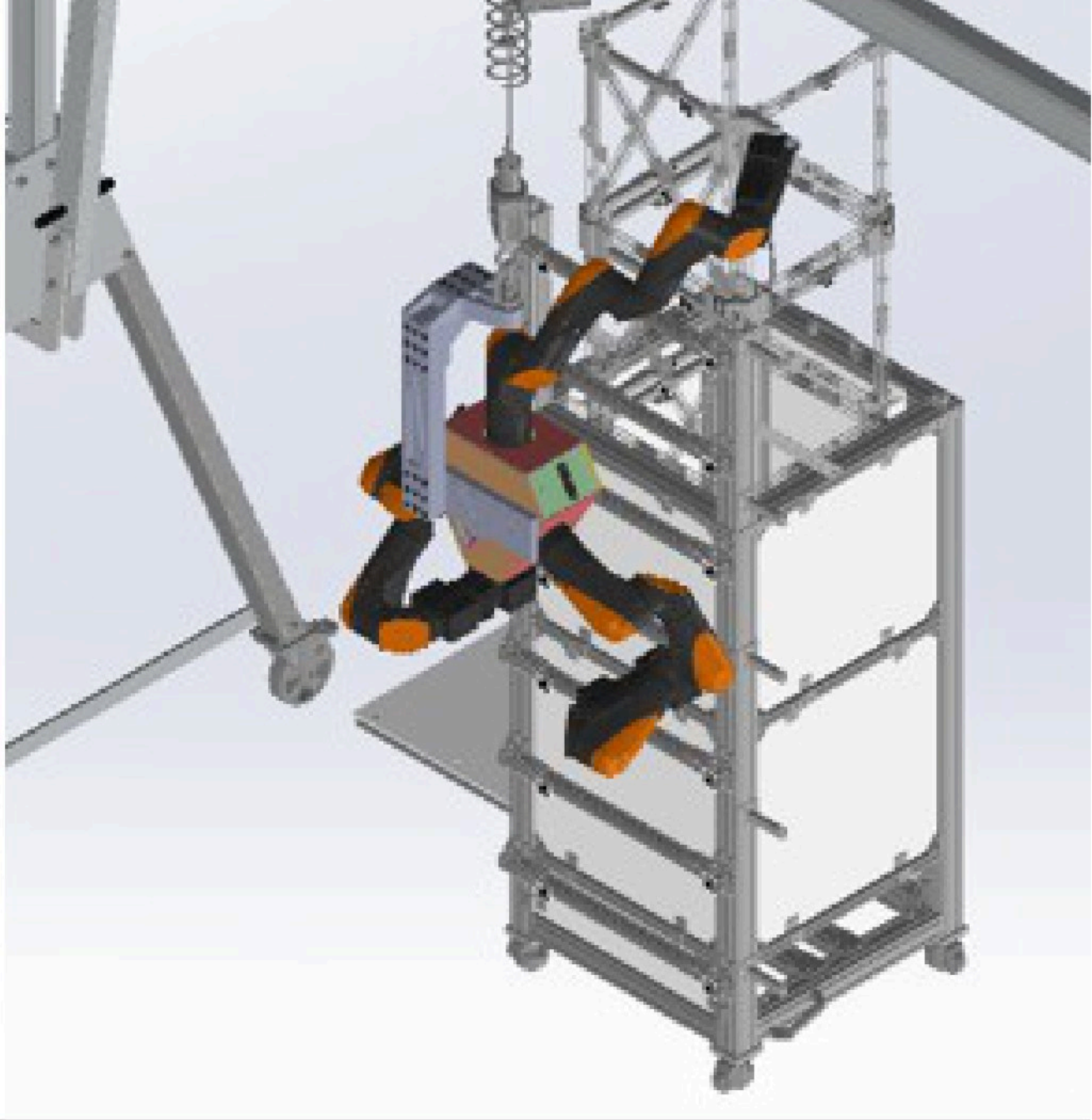
SECTION

03

XWALKER

XWALKER
BUILD, OUTFIT, AND INSPECT TALL LUNAR TOWERS (TLT)

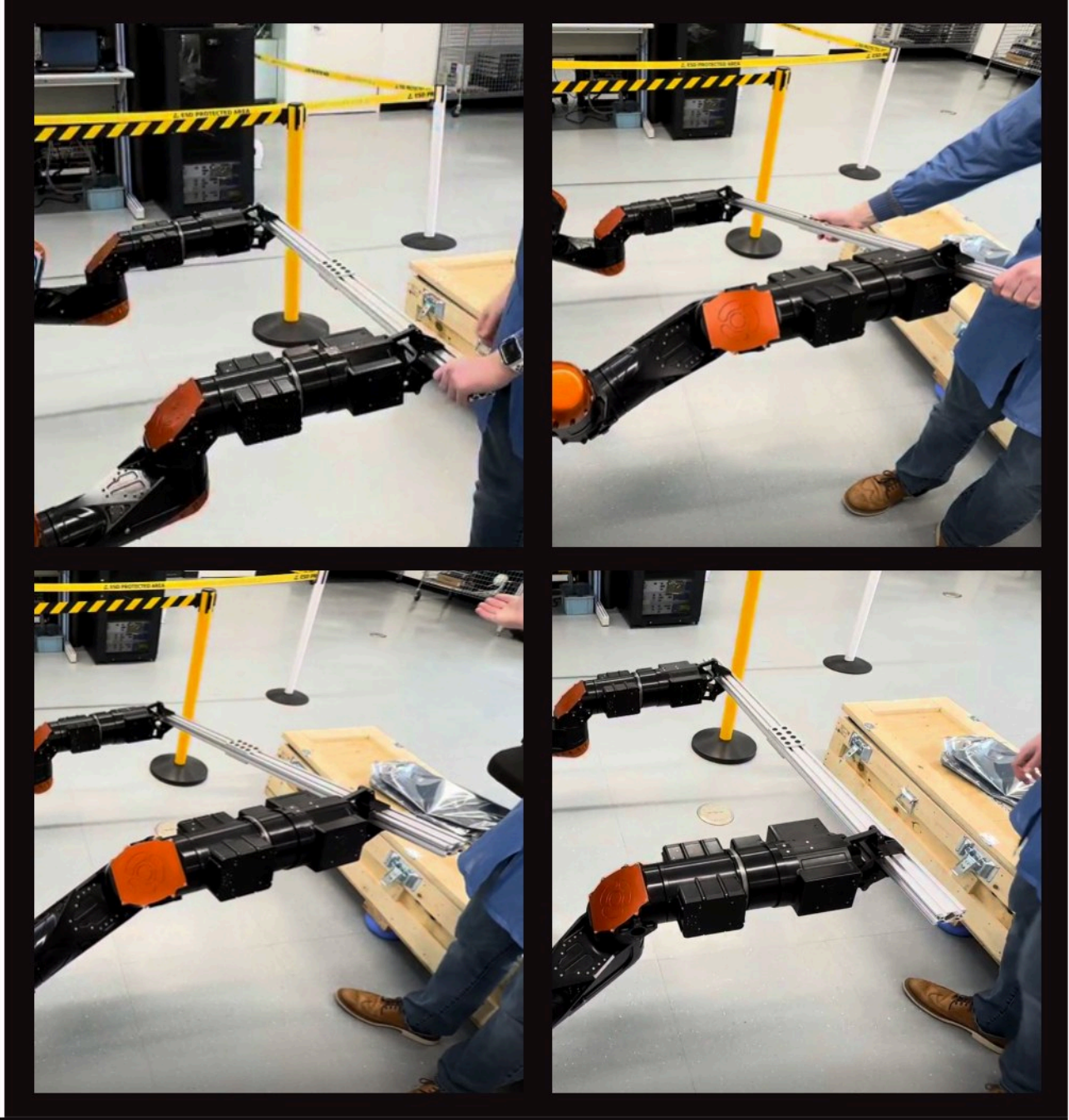
- Demonstrate multi-arm manipulation
- Assemble structural elements of a TLT
- Climb the assembled TLT
  - Showcase new forms of mobility
- Outfit
  - Attach cables, make connections, etc.
- Inspect
  - Prove that it did what was intended



STEP 1 MULTI-ARM MANIPULATION

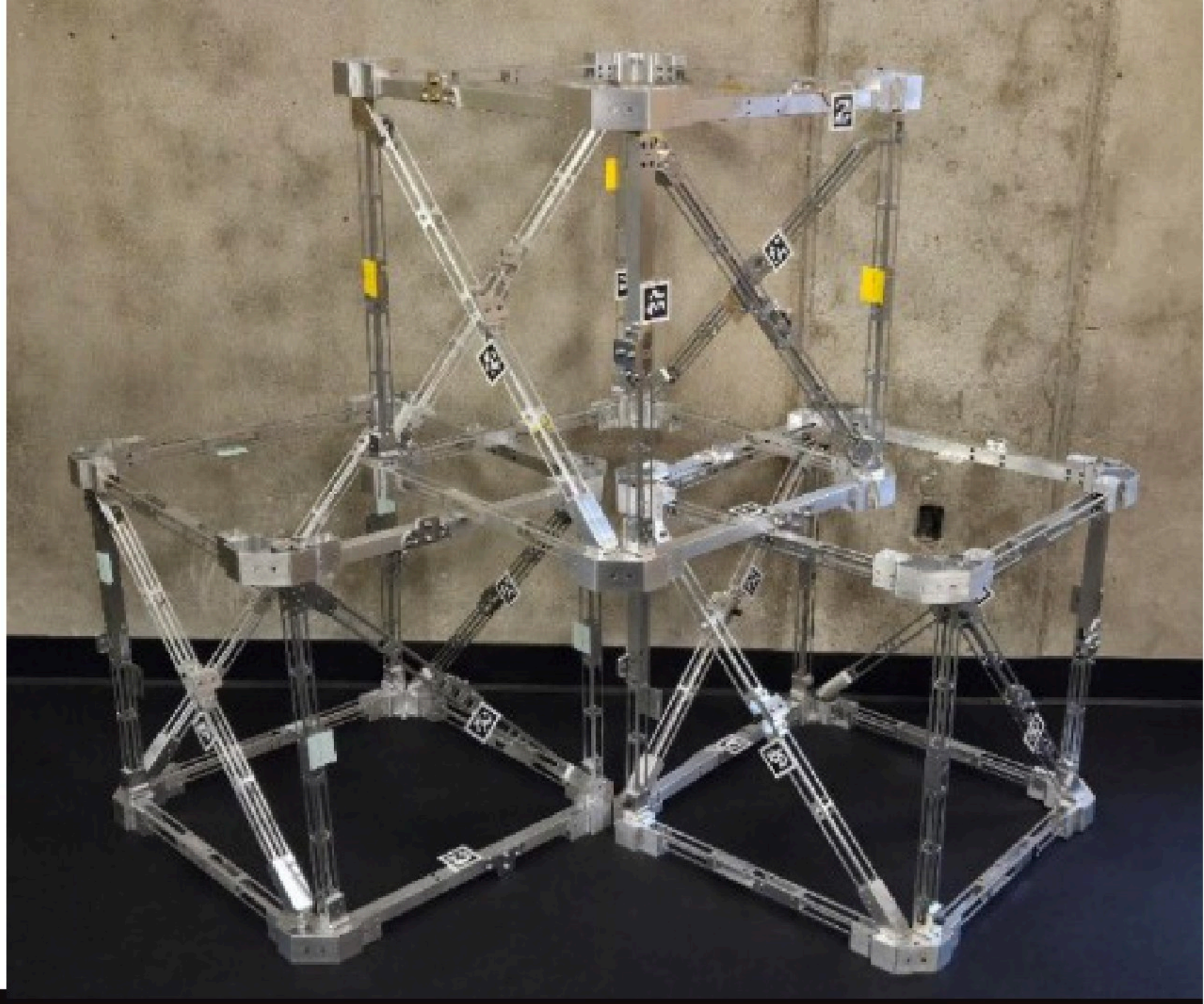
closed_chain_compliance.mov

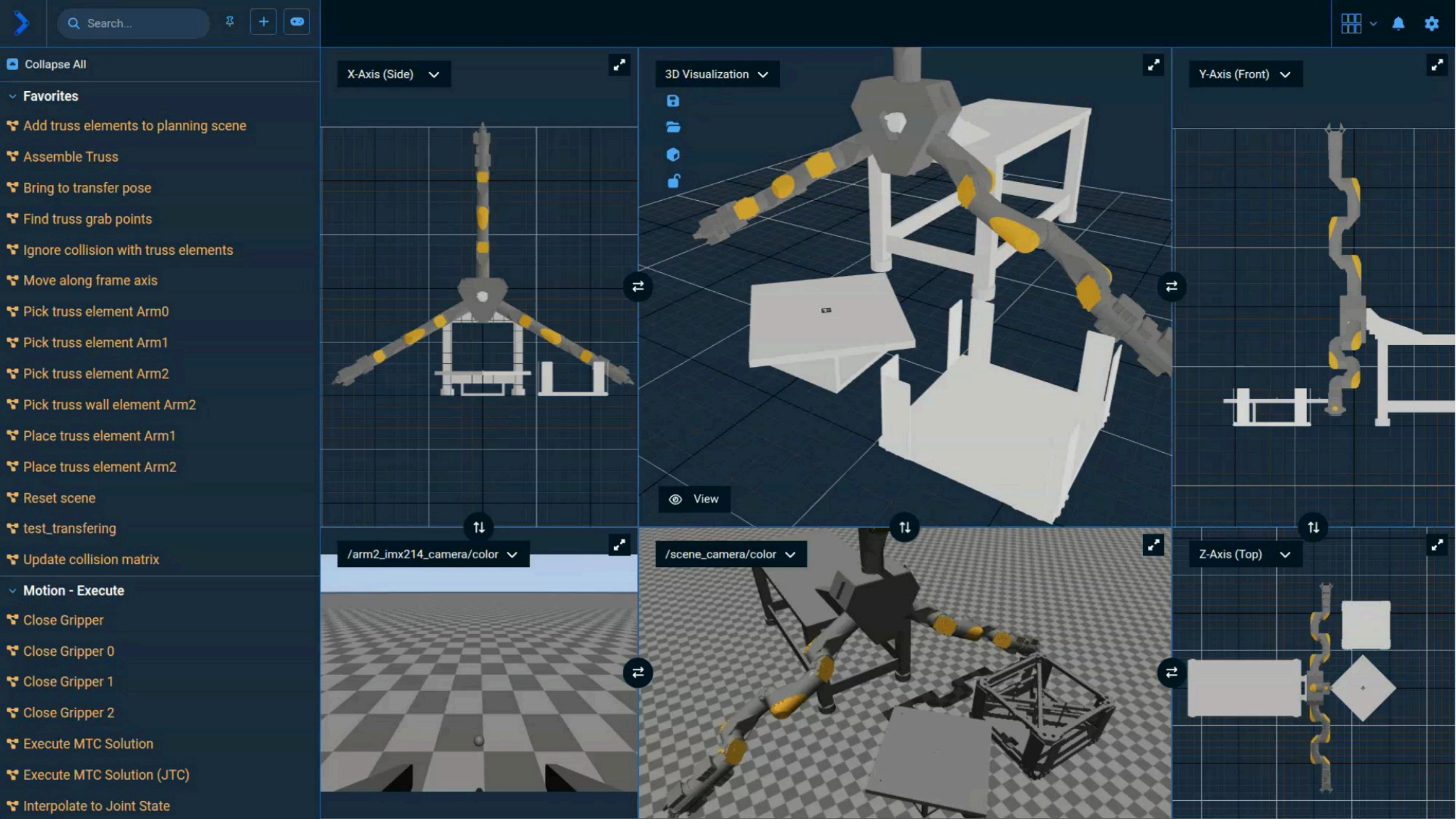
- Implement advanced multi-arm collaborative control algorithms
- Multi-arm assemble
- 3 arm coordinated walks up the tower



STEP 2 TRUSS ASSEMBLY

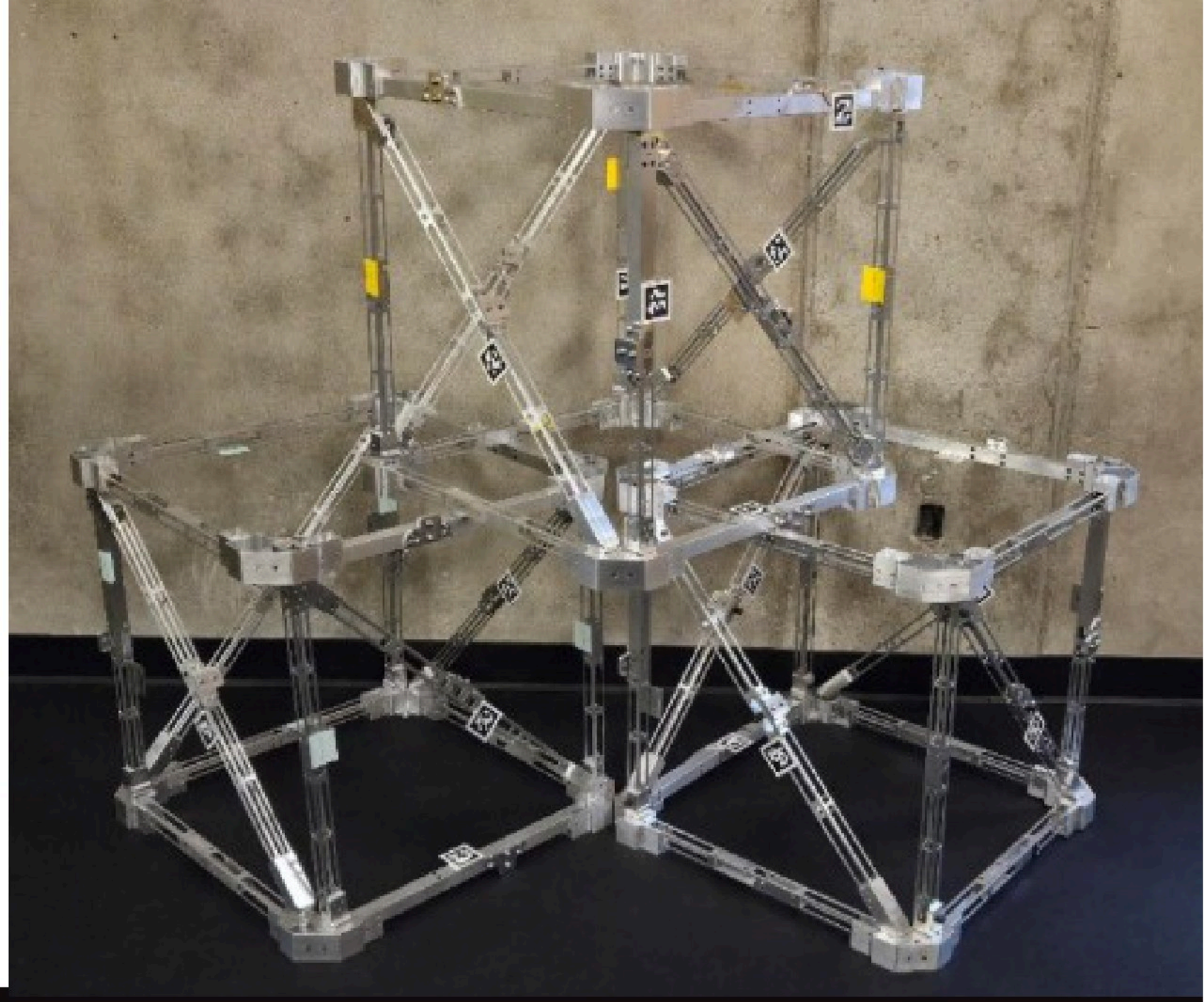
Next slide shows how MoveIt Pro and MuJoCo simulator helped develop the Truss assembly objective




Search...
Collapse All
Favorites
Add truss elements to planning scene
Assemble Truss
Bring to transfer pose
Find truss grab points
Ignore collision with truss elements
Move along frame axis
Pick truss element Arm0
Pick truss element Arm1
Pick truss element Arm2
Pick truss wall element Arm2
Place truss element Arm1
Place truss element Arm2
Reset scene
test_transfering
Update collision matrix
Motion - Execute
Close Gripper
Close Gripper 0
Close Gripper 1
Close Gripper 2
Execute MTC Solution
Execute MTC Solution (JTC)
Interpolate to Joint State
X-Axis (Side)
3D Visualization
Y-Axis (Front)
View
/arm2_imx214_camera/color
/scene_camera/color
Z-Axis (Top)

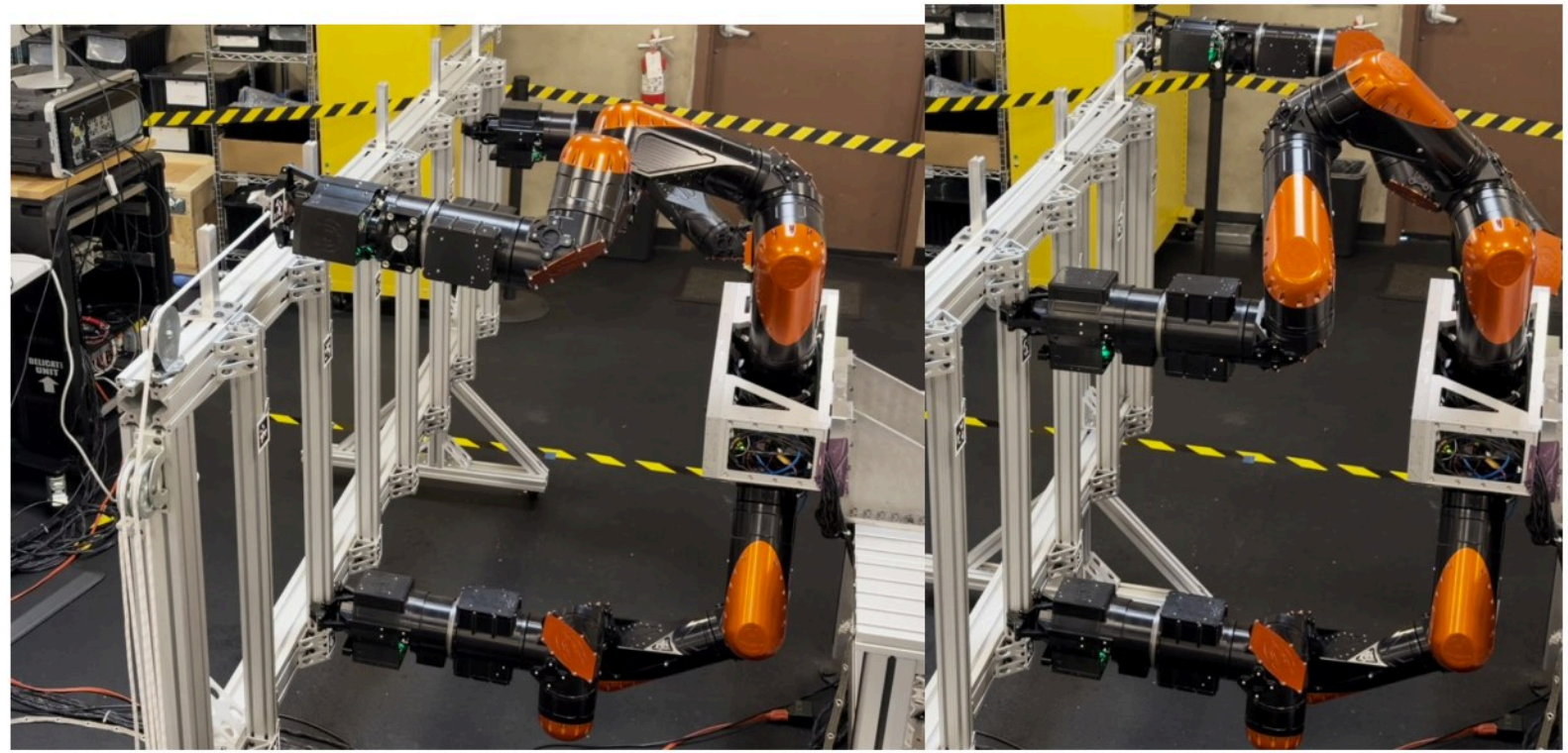
STEP 2 TRUSS ASSEMBLY

- 10xCube.MOV
- Now let's see that in real life



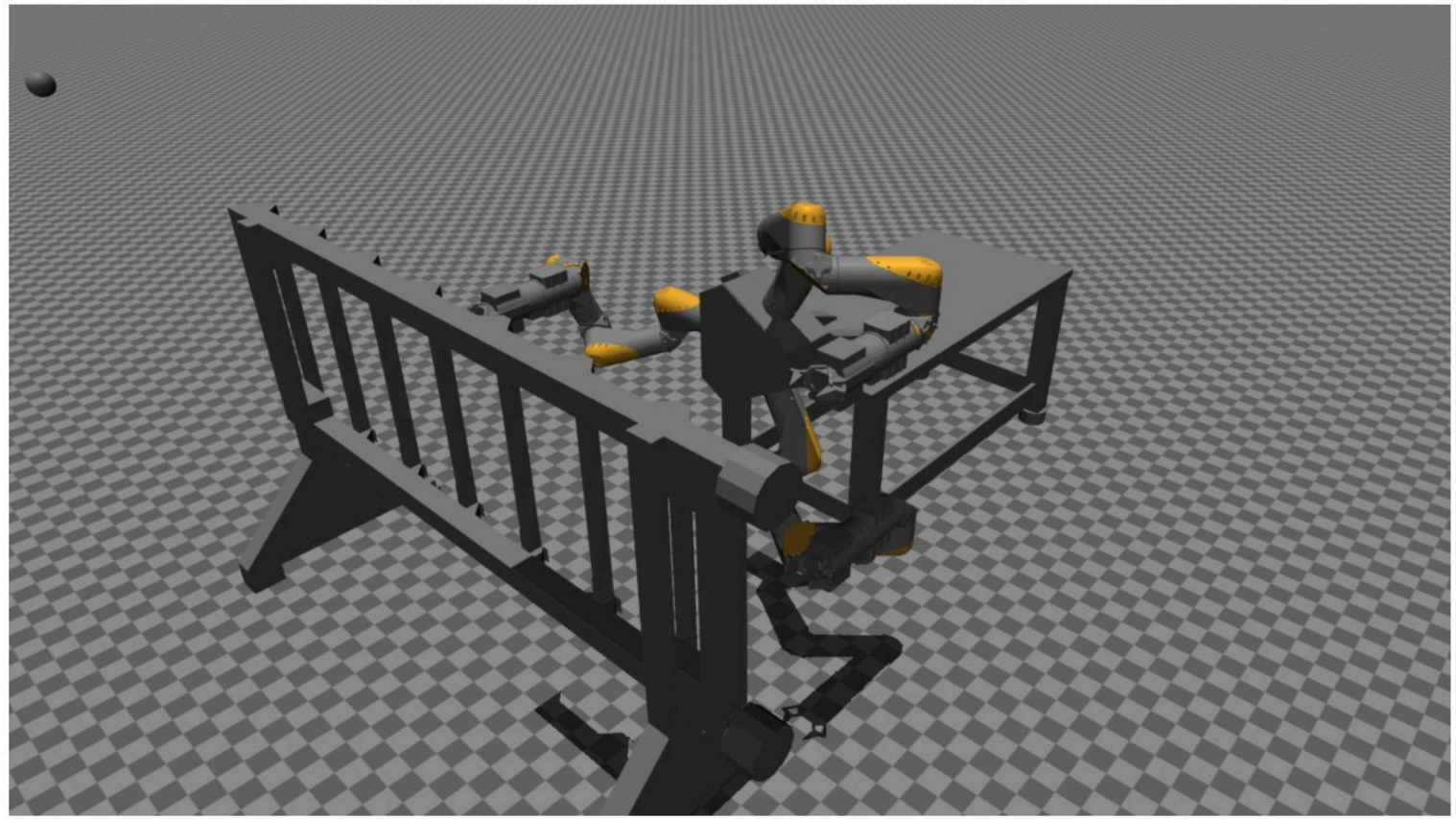
STEP 3 OUTFITTING

- 3xTestOutfitting.MOV
- Here you'll see a cable grasp point moved from one plug to the next



STEP 4 MOBILITY ON TOWER

- 10xLadder.MOV
- All three arms come used in unision to shift xWalker up the tower
- Earth gravity requires the robot to move a tower on wheels instead of moving itself



STEP 5 COMBINE MOBILITY AND OUTFITTING

xWalkerOutfittingTower Full

- xWalker moves up the tower while towing a power/data cable to plug in at the very top

SECTION

04

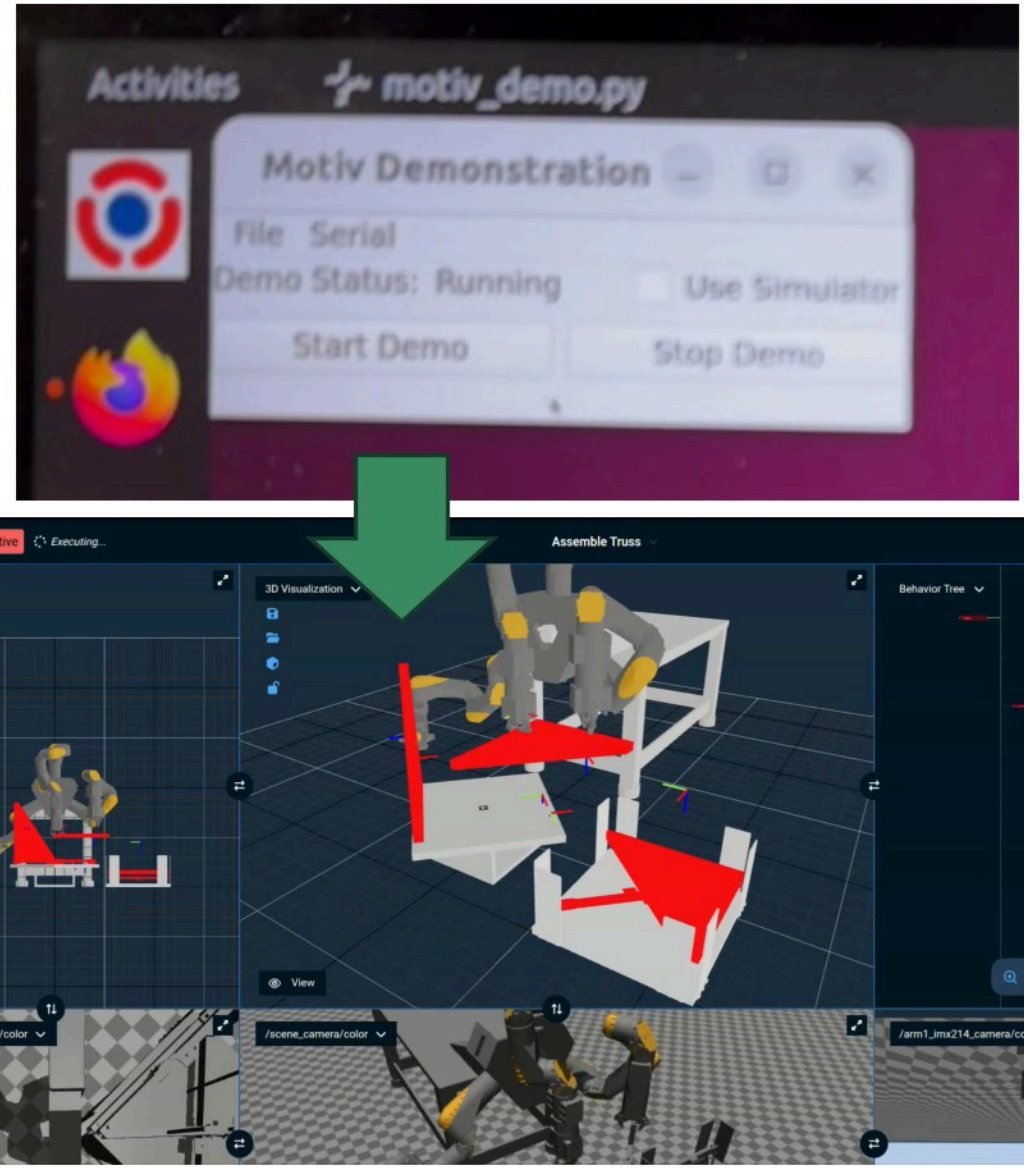
MOVEIT PRO’S ROLE

WHAT WE DID BEFORE MIP

- Custom minimal solution
- Small team
- No time to maintain
- No time for feature requests

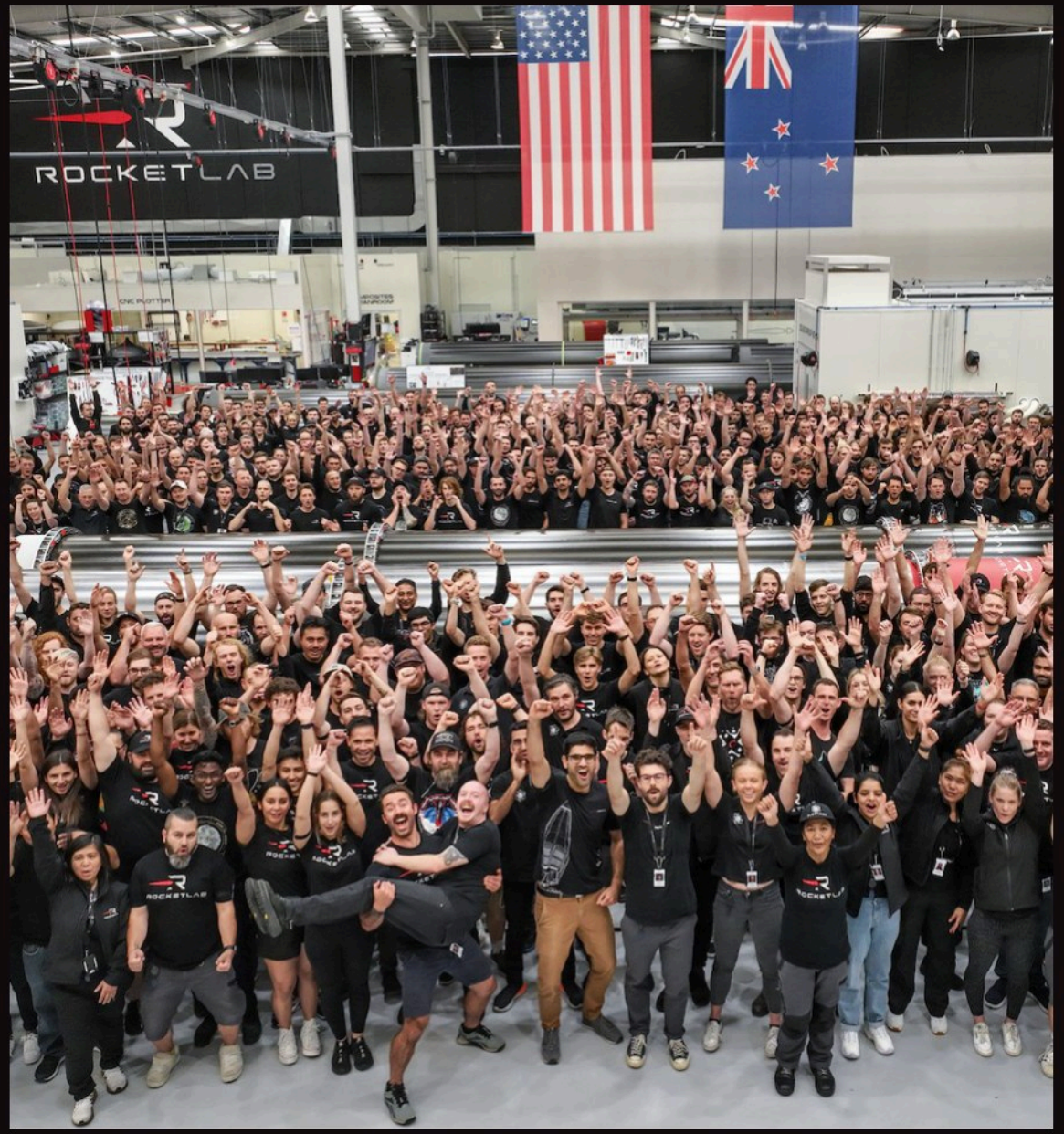
WHAT DOES MIP PROVIDE FOR US WHY DID WE CHOOSE MIP

- Support
- Allows us to focus on robotics not plumbing
- Force multiplier
- Reduced maintenance cost
- Library of common robotics functionality
- Nice to haves that we would never have time for ourselves



IMPACT ON THE SPACE ROBOTICS COMMUNITY

- Guest roboticist
- Space ROS
- Academic involvement
- Cost of entry reduced
- Space cares deeply about TRL so once something flies there is a tendency for everyone to follow
- Show that open-source SW works on orbit



SECTION

05

QUESTIONS?

SECTION

06

BACKUP


WE GO TO SPACE
TO IMPROVE LIFE
ON EARTH

THANK YOU

Kevin French and Tom McCarthy

M.
E.

ROCKETLAB

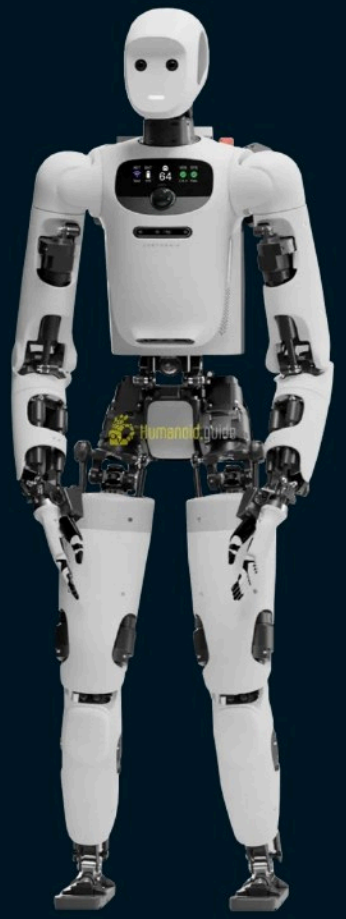
PICKNIK

Designing Reusable Robotic Autonomy Software for Space Missions

Dave Coleman, PhD
Founder, Chief Product Officer
PickNik Robotics
picknik.ai

Building and qualifying space robot arm control software is expensive and slow.

Meanwhile, a worldwide robotics movement has happened since 2009.



Space:
Custom Mission Software

- Bespoke
- Expensive
- Primitive
- Fragmented

Notable exceptions:

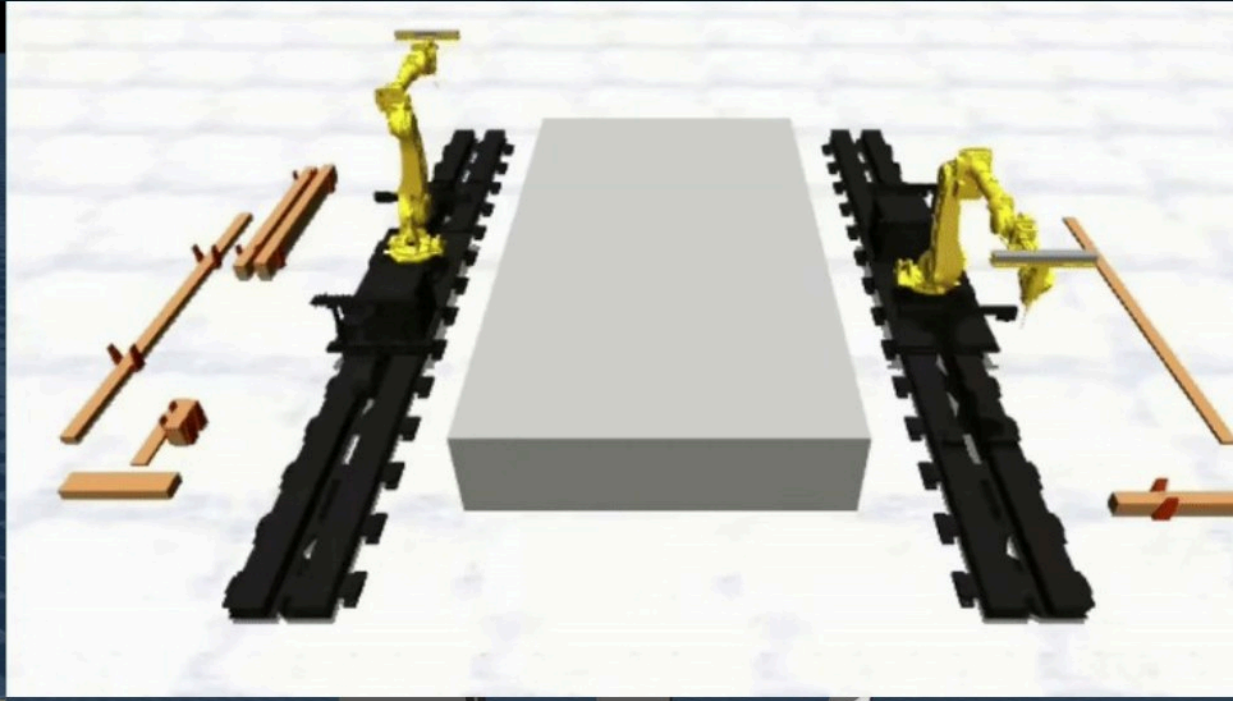
- cFS
- F’Prime

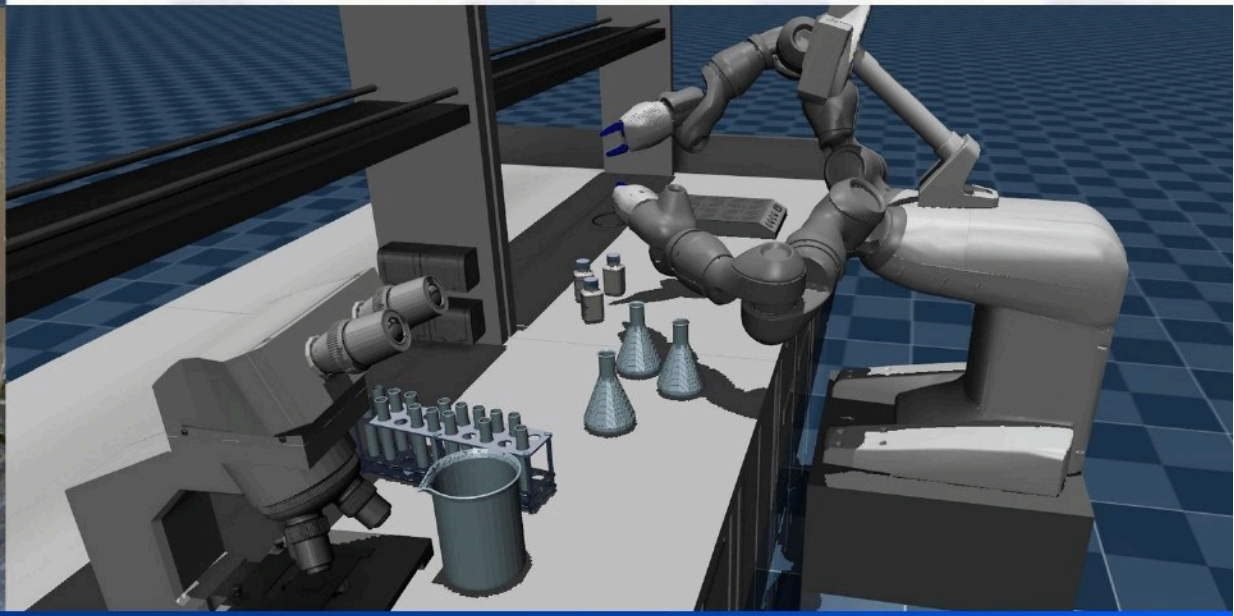
Terrestrial:
Shared Open Standards

- Open Source
- R&D Collaborations
- Modern
- Industrial-grade

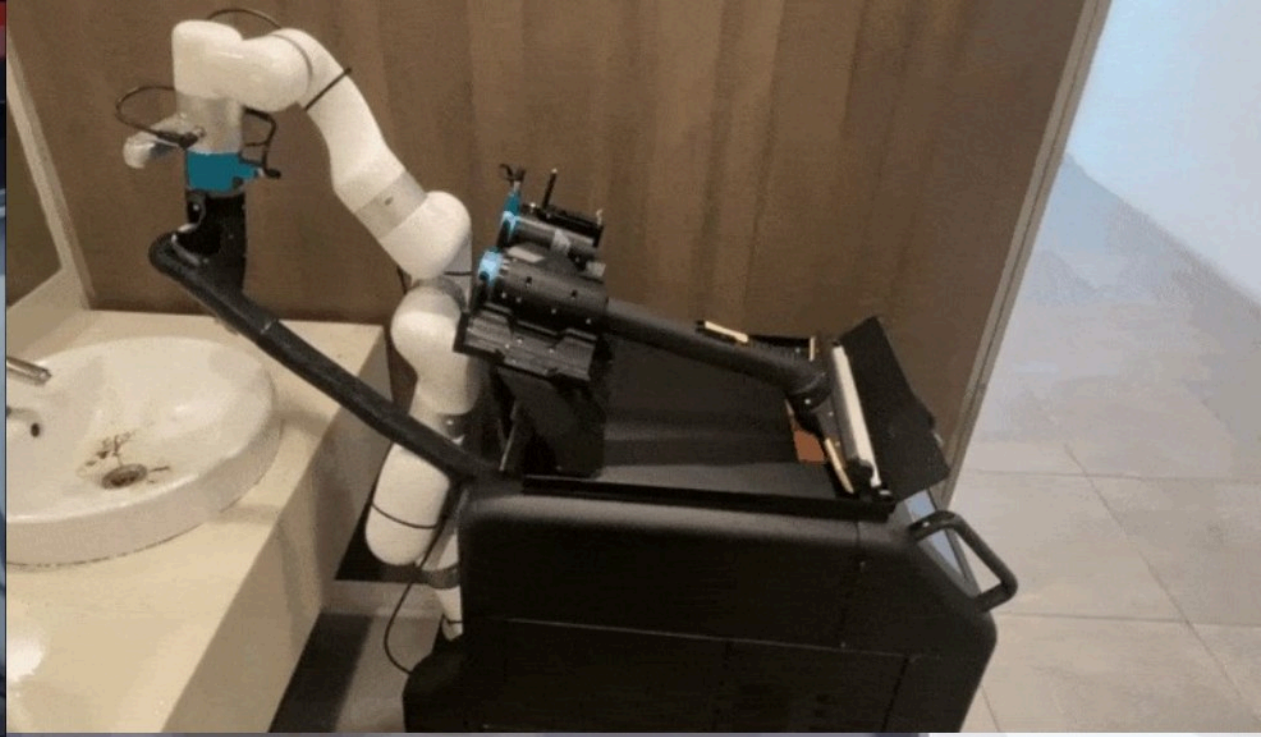
ROS
Robot Operating System

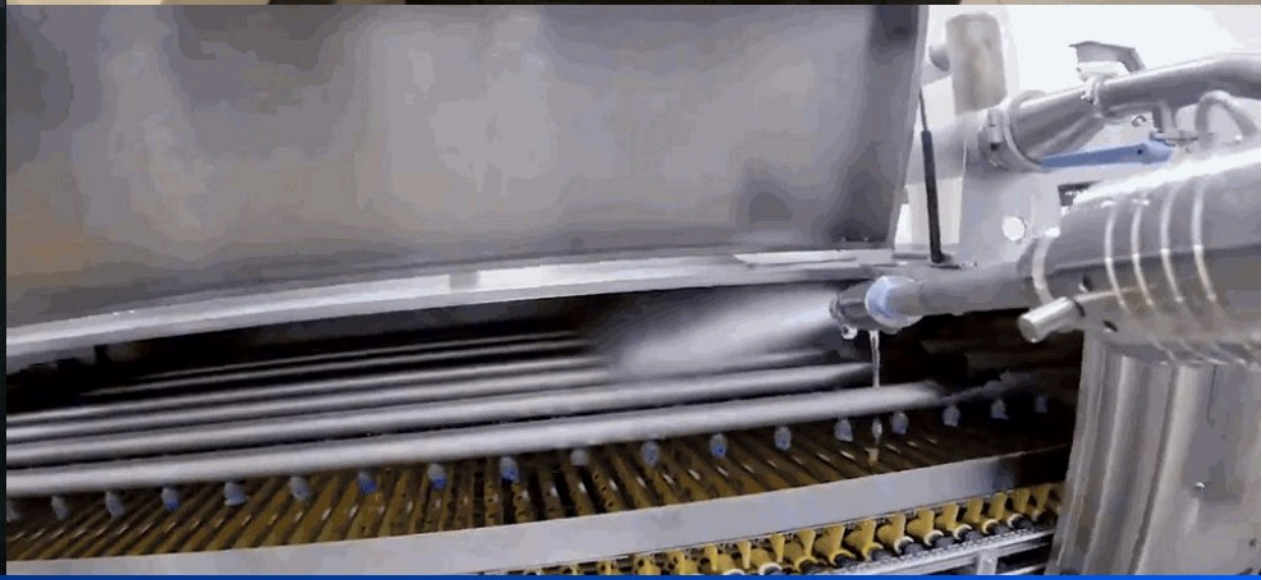
MoveIt Pro





Application Category: Pick and Place





Application Category: Scan and Plan

$15M+ in Space & DOD Funding

NASA

- Advanced planning capabilities for humanoids in microgravity environments
- Advanced planning capabilities for robots in microgravity environments ability
- An Affordance Driven, Human-in-the-Loop Perception Framework
- Improved Manipulation Capabilities for Inter-Vehicle and Lunar Surface Activities
- Improved Capabilities for Dexterous Robot Platforms with MoveIt Studio
- An Affordance-Driven Perception Framework
- Task and Motion Planning for Space Operations, with Human-Assisted Recovery
- Failure Management & Recovery for Remote Autonomous Task Planning & Execution
- Long Range Navigation Capabilities for Autonomous Mobile Manipulation
- Lunar Autonomy Enabled by Simultaneous Localization and Mapping for Space
- Accelerating Space Robot Operating System for a Sustainable Lunar Future
- Dexterous Whole-Body Manipulation for Robotic Lunar Operations
- Tall Lunar Tower Robotics
- Long Range Navigation Capabilities for Autonomous Mobile Manipulation
- Lunar Autonomy Enabled by Simultaneous Localization and Mapping for Space
- Accelerating Space ROS for a Sustainable Lunar Future
- Adaptive Robotic Systems for Orbital Infrastructure

USSF

- Integrated Planning and Control for On-Orbit Capture
- Robotic Arm Satellite Servicing and Decommissioning
- A Platform for Autonomous Robotic Assisted Capture of Resident Space Objects

Navy

- Dual-arm Maritime Manipulation System

Army

- Modernizing Repair and Manufacturing Facilities with Advanced Robotics
- Autonomous System for Decontamination

SOME OF OUR COMMERCIAL SPACE CUSTOMERS

BLUE ORIGIN

LOCKHEED MARTIN

SIERRA SPACE

MAXAR

AXIOM SPACE

HONEYBEE ROBOTICS
A BLUE ORIGIN COMPANY

JAXA

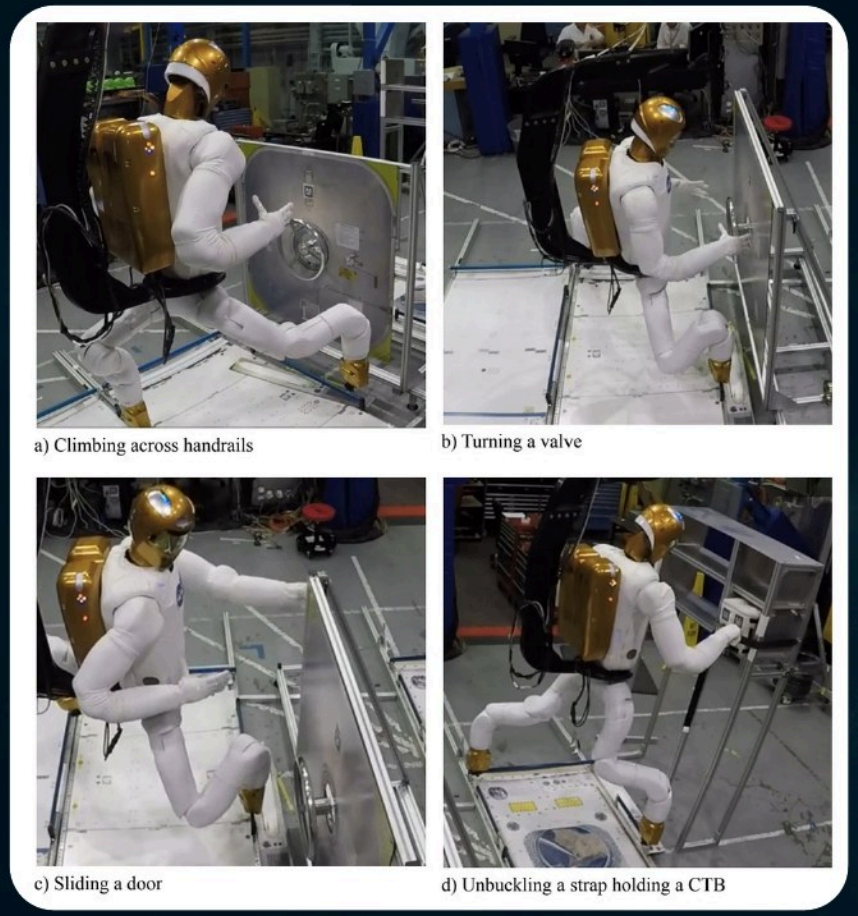
ARKISYS

ARKA

Our MoveIt and ROS software first launched to the ISS on the Robonaut 2 mission in 2011

MoveIt

NASA

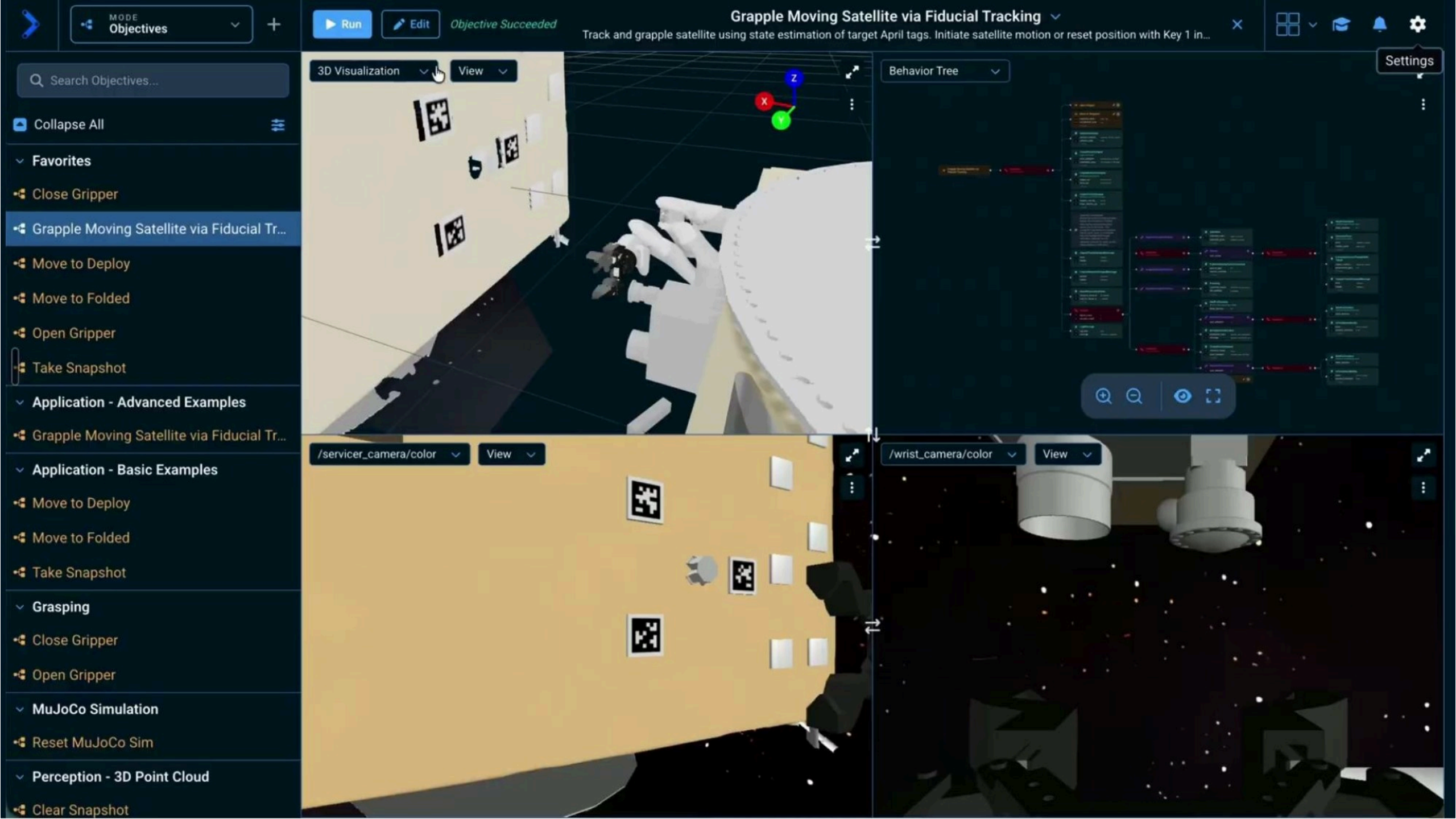


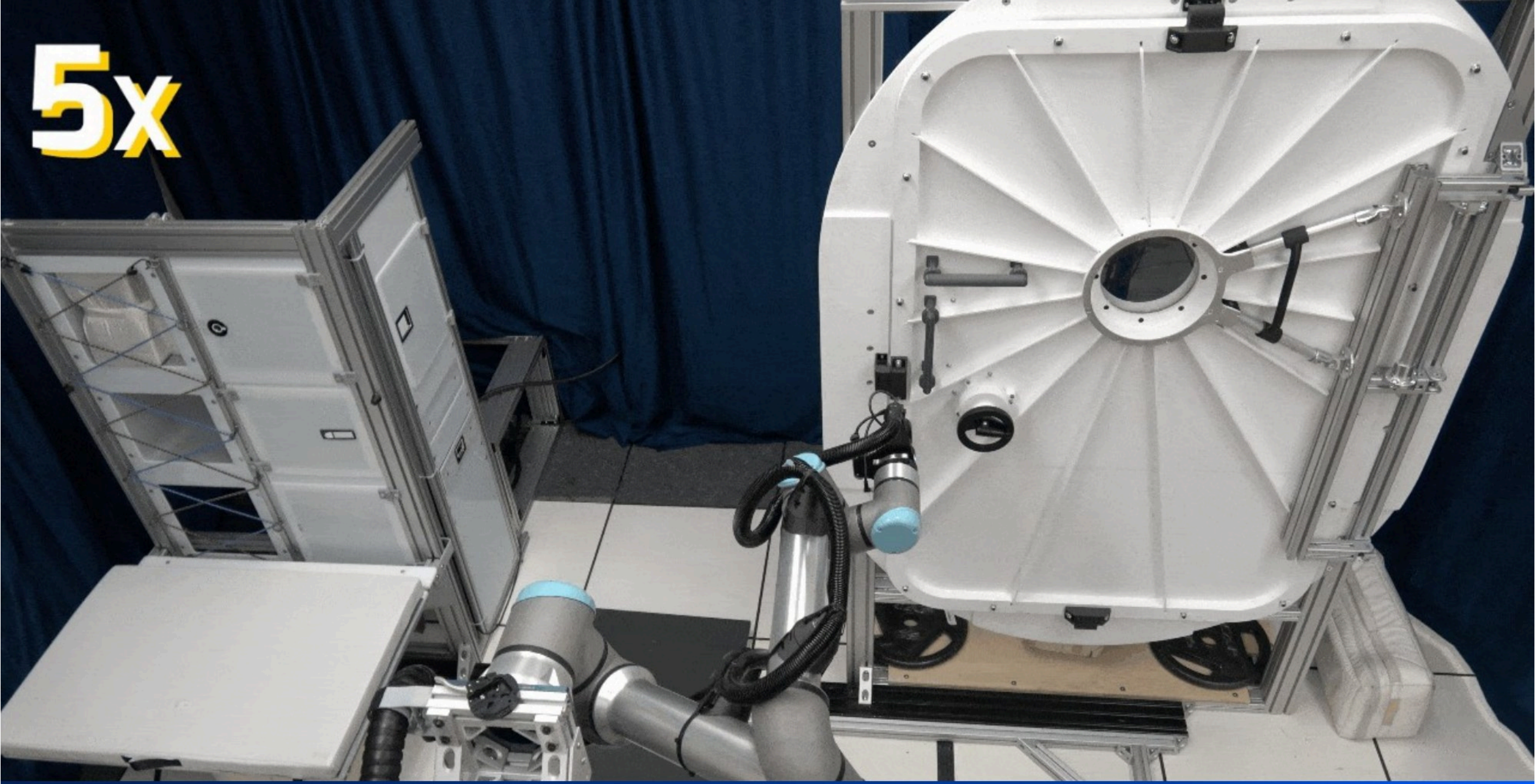
a) Climbing across handrails

b) Turning a valve

c) Sliding a door

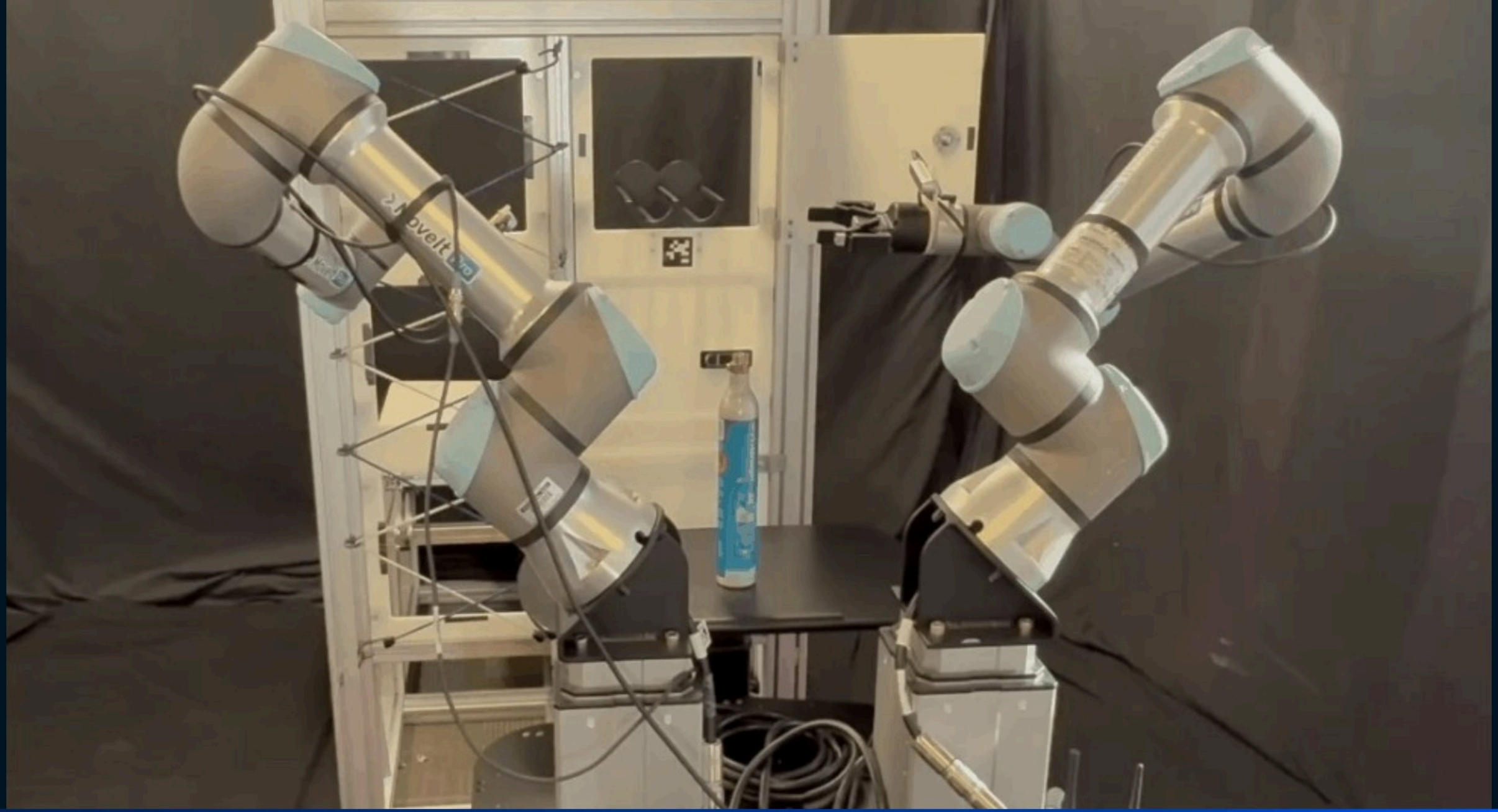
d) Unbuckling a strap holding a CTB


MODE
Objectives
Run
Edit
Objective Succeeded
Grapple Moving Satellite via Fiducial Tracking
Track and grapple satellite using state estimation of target April tags. Initiate satellite motion or reset position with Key 1 in...
Settings
Search Objectives...
Collapse All
Favorites
Close Gripper
Grapple Moving Satellite via Fiducial Tr...
Move to Deploy
Move to Folded
Open Gripper
Take Snapshot
Application - Advanced Examples
Grapple Moving Satellite via Fiducial Tr...
Application - Basic Examples
Move to Deploy
Move to Folded
Take Snapshot
Grasping
Close Gripper
Open Gripper
MuJoCo Simulation
Reset MuJoCo Sim
Perception - 3D Point Cloud
Clear Snapshot
3D Visualization
View
Behavior Tree
/servicer_camera/color
View
/wrist_camera/color
View

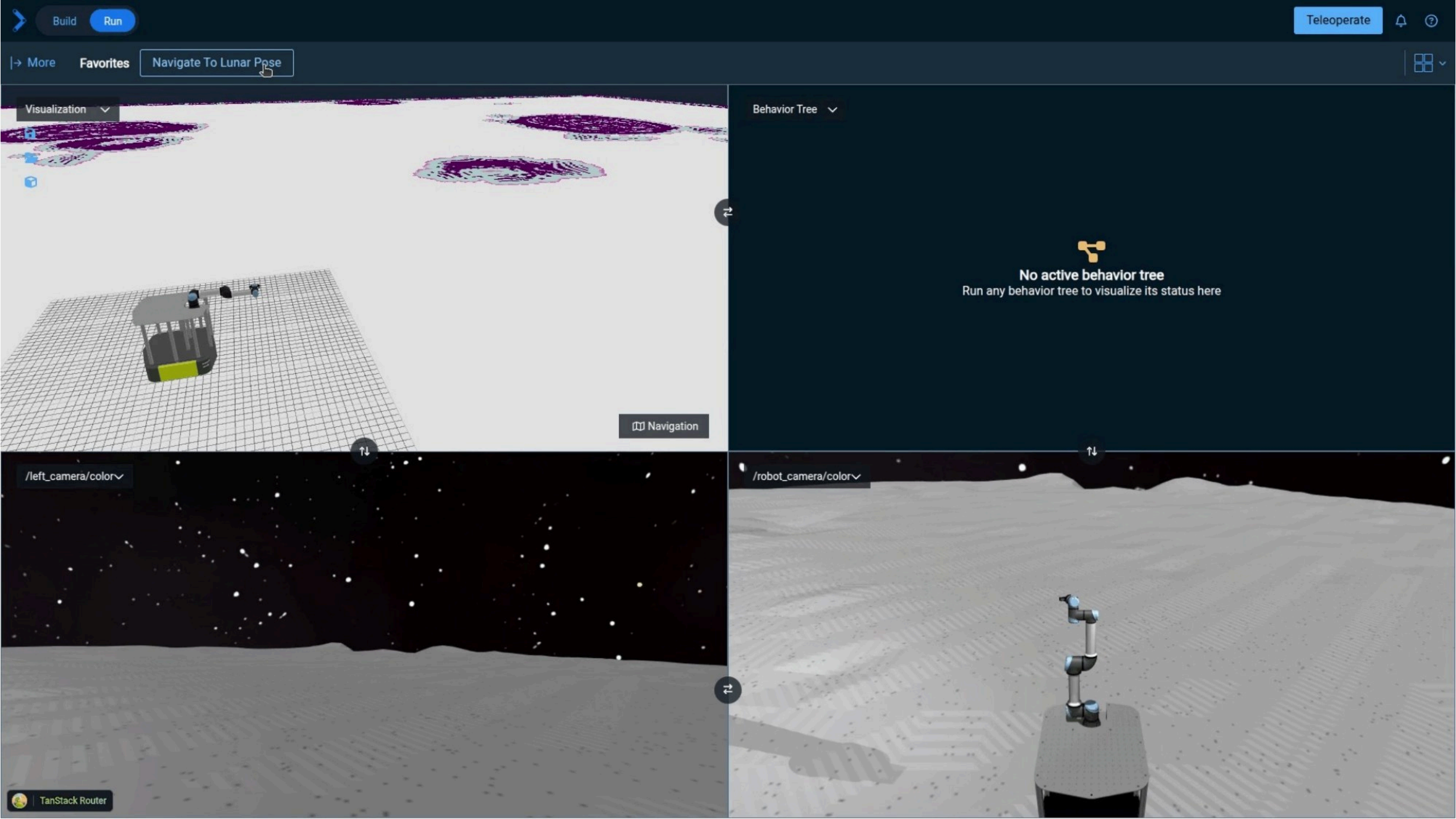


Robotic Movement of Cargo Transfer Bags from a Hatch to a Stowag

See Full Video



Dual Arm Admittance Control - Synchronized Arm Motions


Build
Run
Teleoperate
More
Favorites
Navigate To Lunar Pose
Visualization
Navigation
Behavior Tree
No active behavior tree
Run any behavior tree to visualize its status here
/left_camera/color
/robot_camera/color
TanStack Router

Rapidly retask robots for new missions

Capabilities

MoveIt Pro

All-In-One Developer Platform for Robot Arms and Wheeled Humanoids

RUNTIME AUTONOMY

ML for Perception & Grasping
Off the shelf models for most applications

End-to-End ML
Increase dexterity with generalizable AI

Real-time Planners, Controllers, Solvers
Collision & force aware automatic trajectory generation

Mobile Base Navigation
Integrated for AMRs and humanoids on wheels

USER INTERFACES

Behavior Tree Builder
Low code studio for state machines

Robot Visualizer
Understand robot telemetry and logic

Debugging Toolchain
Insert breakpoint and view parameters at runtime

Teleoperation Suite
Four modes of human in the loop control

SIMULATION

AI Training Sim
Toolchain for synthetic training data generation

Offline Developer Sim
Create apps without or before robot hardware

MoveIt Pro Architecture

MoveIt Pro | MoveIt Pro Core | Custom to Application

MoveIt Pro Developer UI
Visualizer | Simulator | Data Collection
Teleoperation | Behavior Tree Editor |
Debugger

Custom Application UI
Optional

Fleet Management
Optional

MoveIt Pro **Run**

- Behavior Trees
- Robot Configuration
- Logging & Monitoring

Your Application / Objective

- VLA & VLM Models
- AI Perception & Grasping Models
- Motion Planning
- Real-time Control Algorithms
- Inverse Kinematics
- Visual Servoing
- AMR Navigation
- Whole Body Planning
- Collision Detection

Safety Layer
- Collision Monitoring
- Constraint Limits
- Filters
- Verification

Execution Layer

ROS Middleware *MoveIt Pro Managed*

Real-time Control Drivers & Controllers

Physics Simulator

Robot Hardware

MoveIt Pro by PICKNIK

spaceROS

PickNik is helping lead the international effort of ROS for Space

space.ros.org | github.com/space-ros

Why Space ROS?

- Reduce project costs and schedule
- Integrate open source interoperability standards
- Transition technology from desktop to flight
- Tech transfer and training from academia to industry

Technical Working Group meetings every 2 weeks, lead by Ivan Perez Dominguez at Ames.

We’ve built the world’s first modular software platform for space robotic arms.

picknik.ai

"There are few others in the industry of robotics with the capability of PickNik, especially capabilities as expansive as their abilities with dexterous manipulator control.”

NASA Johnson Space Center