A Progress Report on Team Northeastern's Avatar Technology

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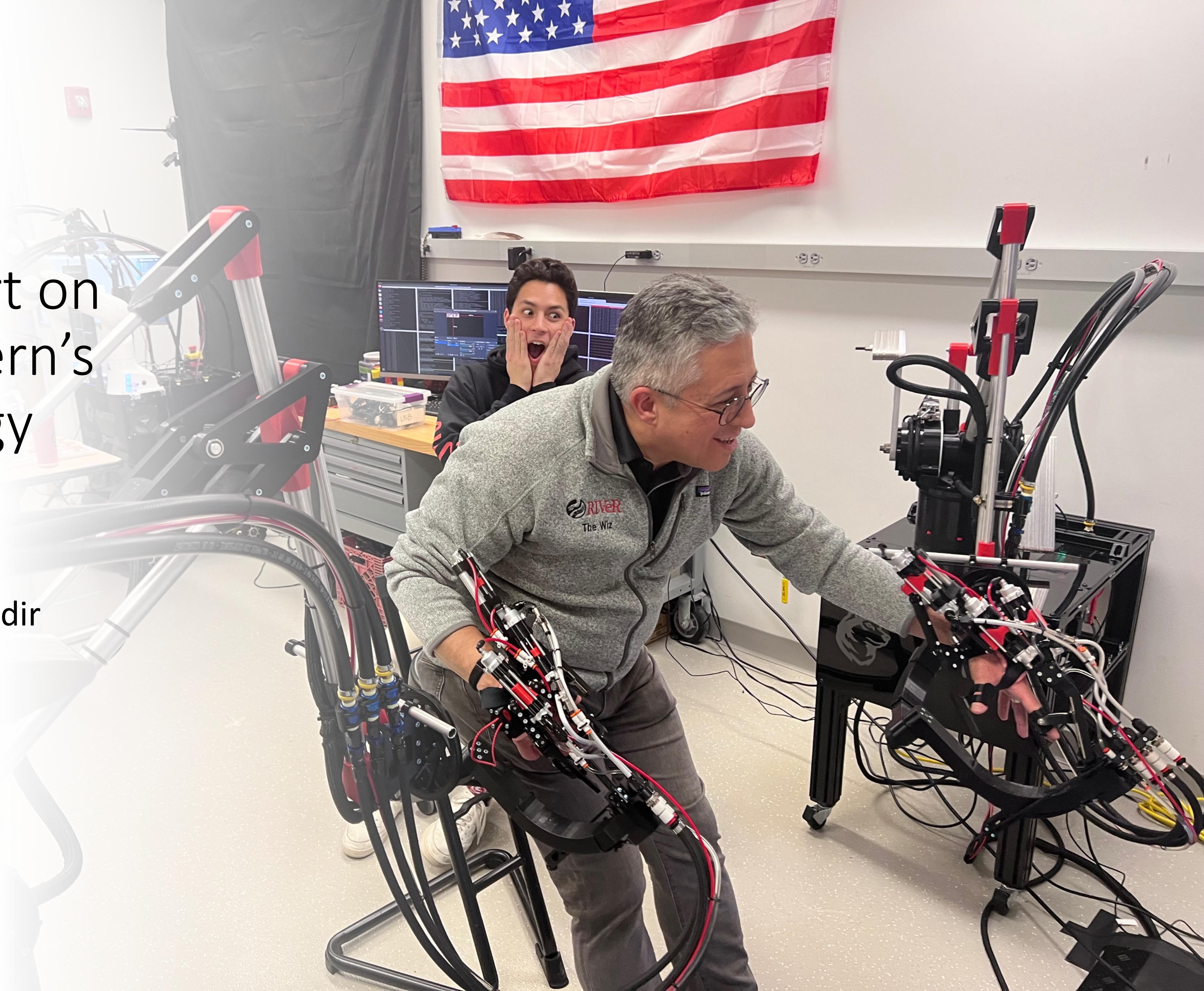
Northeastern University

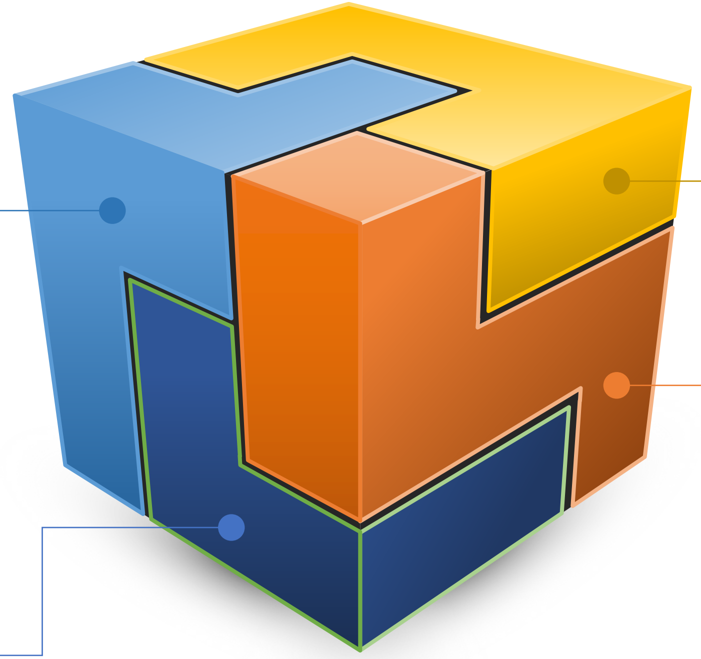


Four Elements of Experiential Robotics

Experiential robotics

ENRICH human experiences

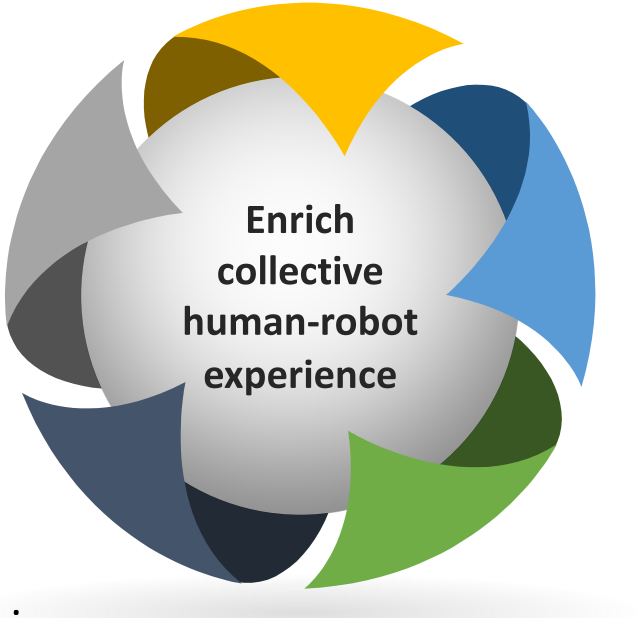
ENABLE personalization and co-adaptation

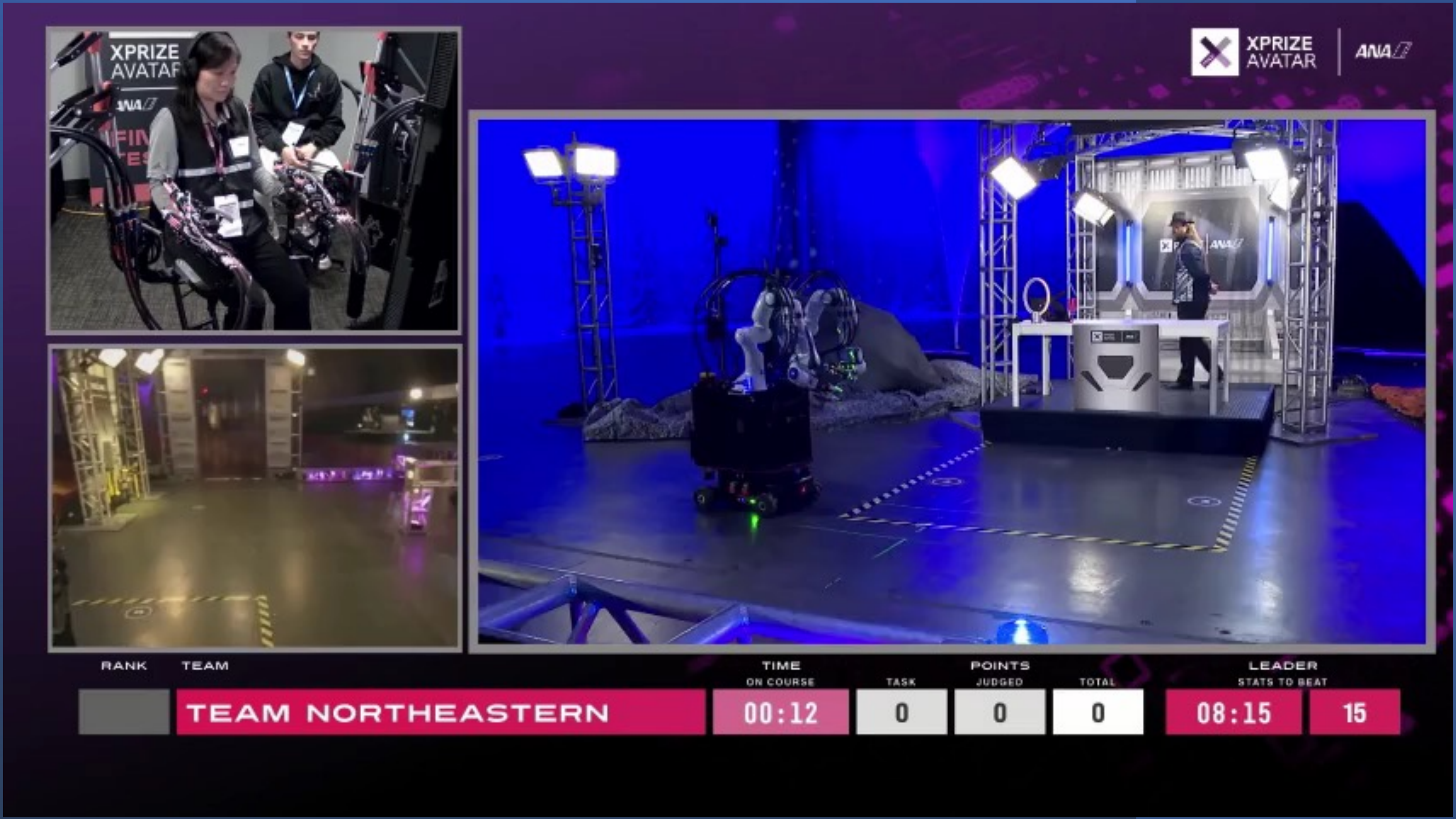


EMBODY artificial intelligence

ENERGIZE experiential discovery and learning

Institute for Experiential Robotics




XPRIZE
AVATAR
RANK
TEAM
TEAM NORTHEASTERN
TIME
ON COURSE
00:12
POINTS
TASK
0
JUDGED
0
TOTAL
0
LEADER
STATS TO BEAT
08:15
15

The Finals

- Long Beach Convention Center, LA
- 17 teams from around the world
- 6-day event, 2 days of testing
- Goal: push telepresence robotics forward for use in exploration, disaster relief, travel, and much more.

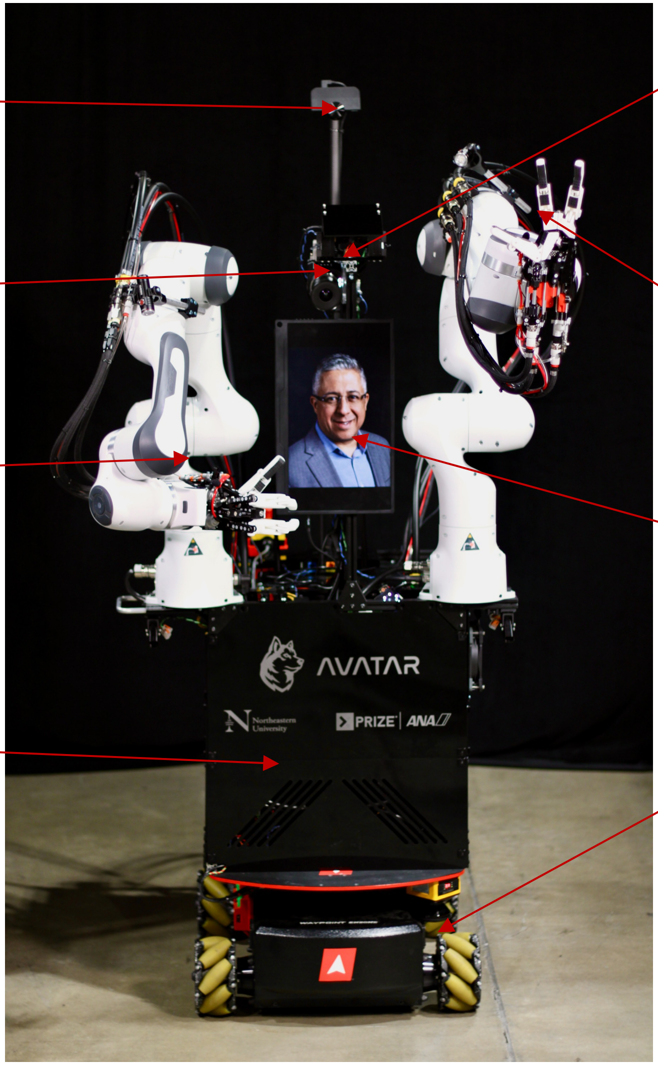
Avatar Robot

Top view peripheral camera

Depth aid lasers

Franka Emika Robot Arm

Frame housing 6 gripper motors

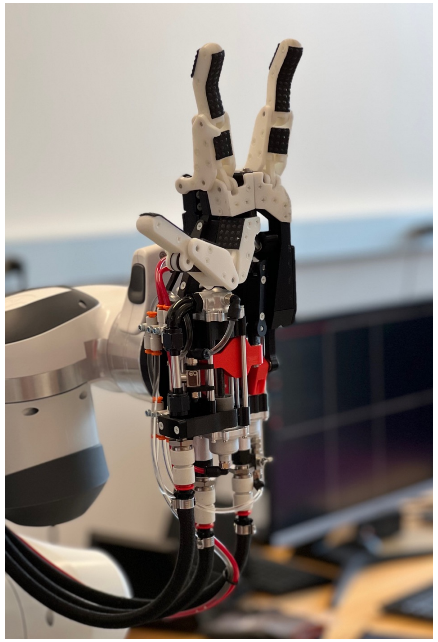


Main manipulation camera

3DOF Gripper

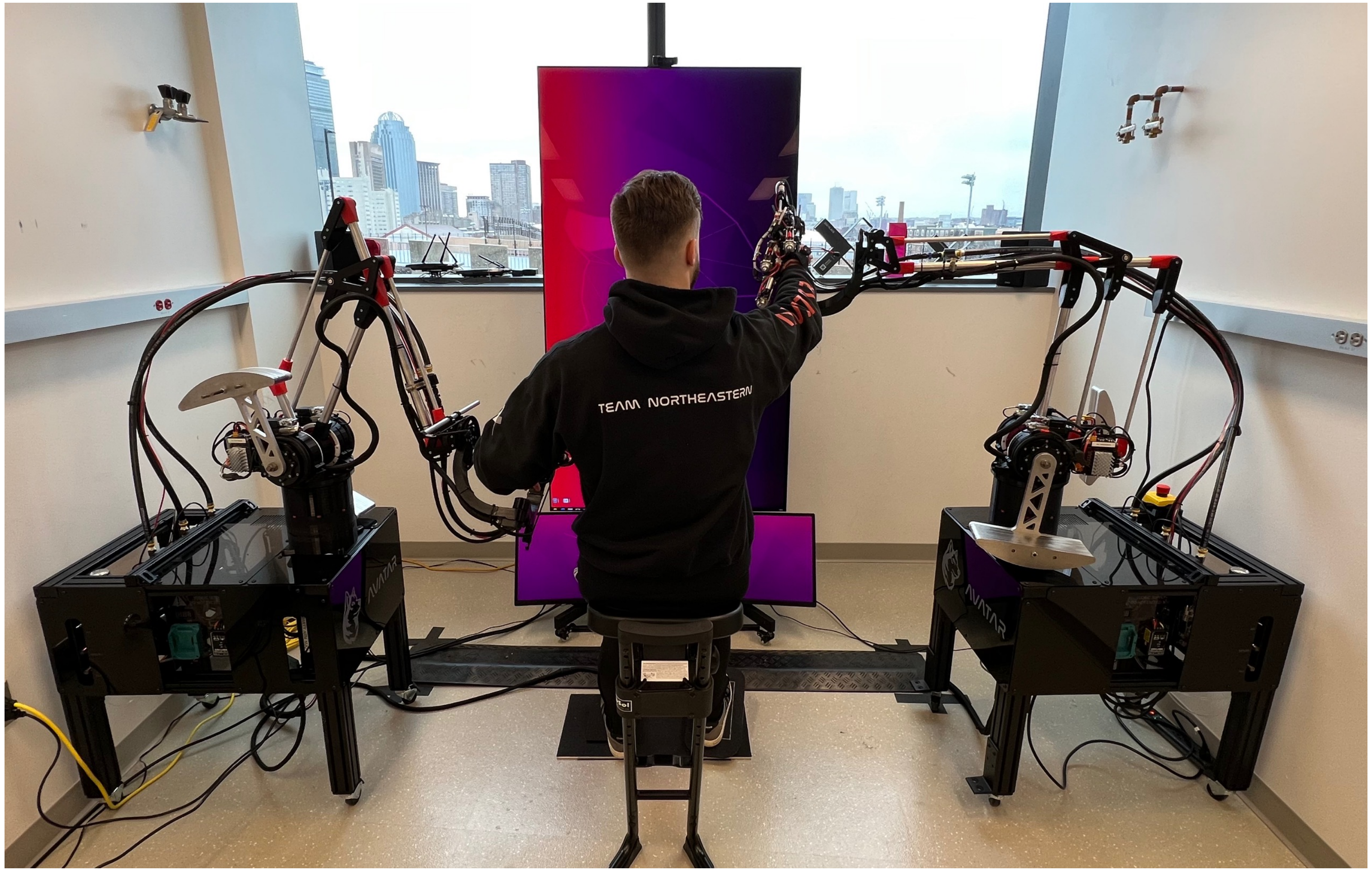
Operator View Screen

Omnidirectional base



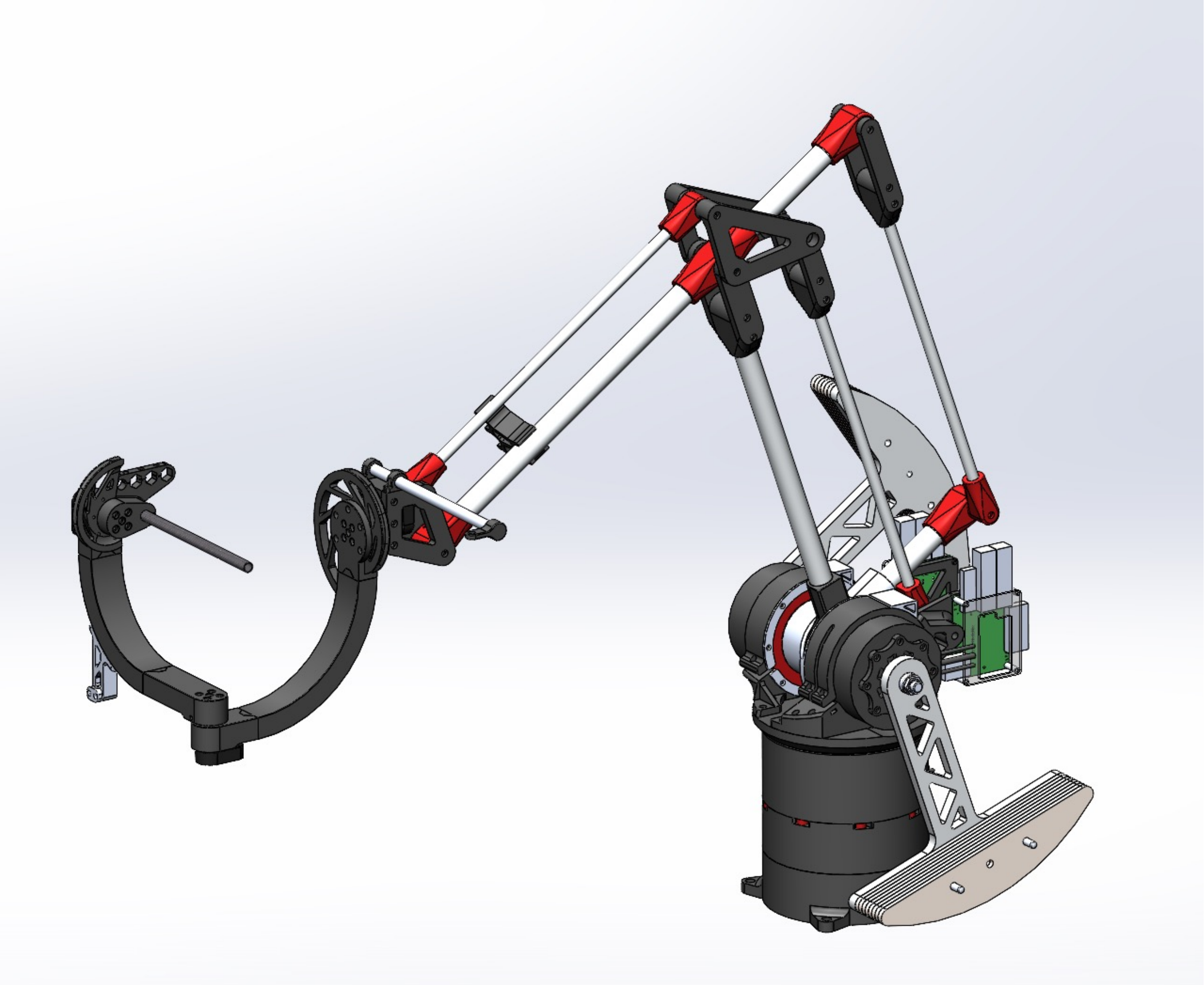
- Custom designed robot
- Over 5 years of research
- 8-month final sprint
- 26 degrees of freedom

Operator Cockpit



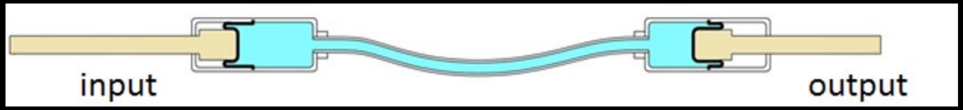
Arm Control

- 3 DOF position tracking and force feedback
- 3 DOF orientation tracking
- Positively counterbalanced arm for reduced fatigue



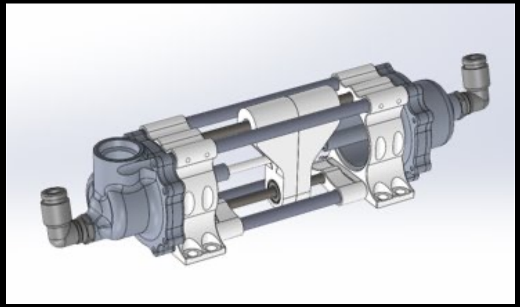
Force Feedback Control

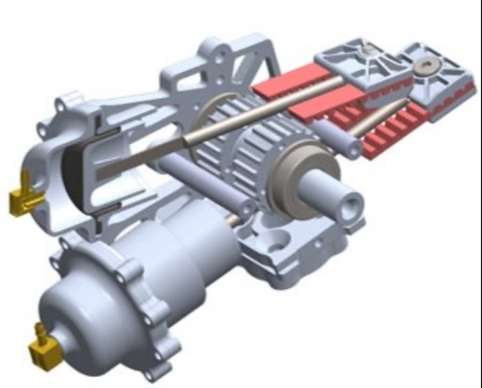
- Hydraulic driven
- Wave variable controls closed loop force feedback over network.
- Gripper and glove motors run local force feedback controller to reduce friction.
- Adaptable to varying network latency by dynamically changing overall stiffness.

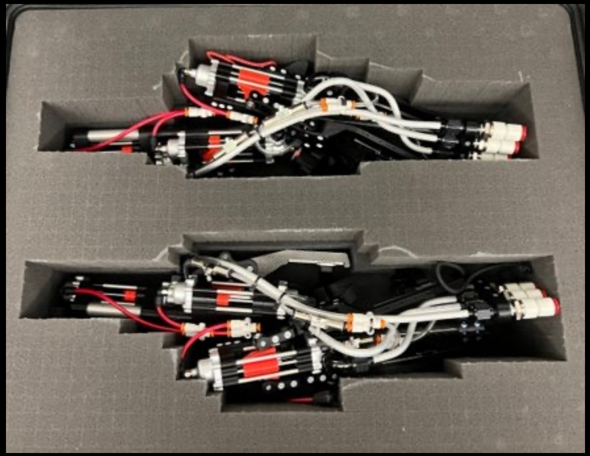


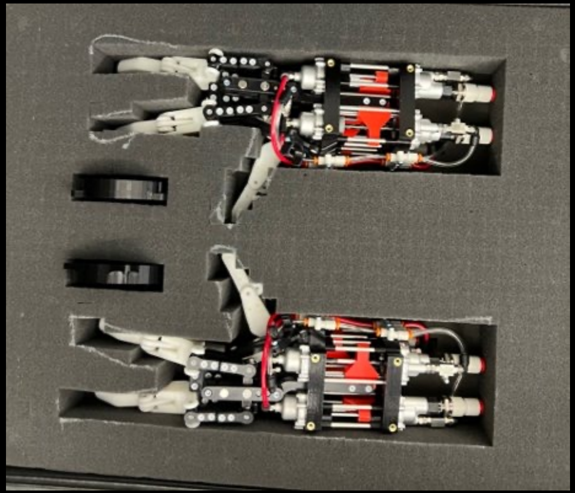
Exo-glove

Gripper









Mobile Base Control

- Single foot control
- 3 DOF for omnidirectional base
- Contact sensors
- Nonlinear velocity control
- IMU based angle measurements

Network

Control network:

- ROSUDP

Video:

- NDI (4K 30 fps, 1080p 60fps, 1080p 30fps, 720p 50fps, 480p 30fps)
- Bandwidth (180Mbit/s - 40Mbit/s)
- NV12 or YUYV encoding to ensure image quality
- Latency : approx. 0.2s over WiFi

Audio:

- NDI + Alsa/Pulseaudio,
- Least buffer
- Video audio sync via hardware
- Stereo mics on robot side
- Acoustic Echo Cancellation is a challenge

Hardware:

Option 1: Control PC + Video PC -> Wireless bridge
Option 2: Control PC -> Wireless bridge, Video PC -> extended antenna (8 dbi)
Option 3: Control PC -> extended antenna, Video PC -> extended antenna

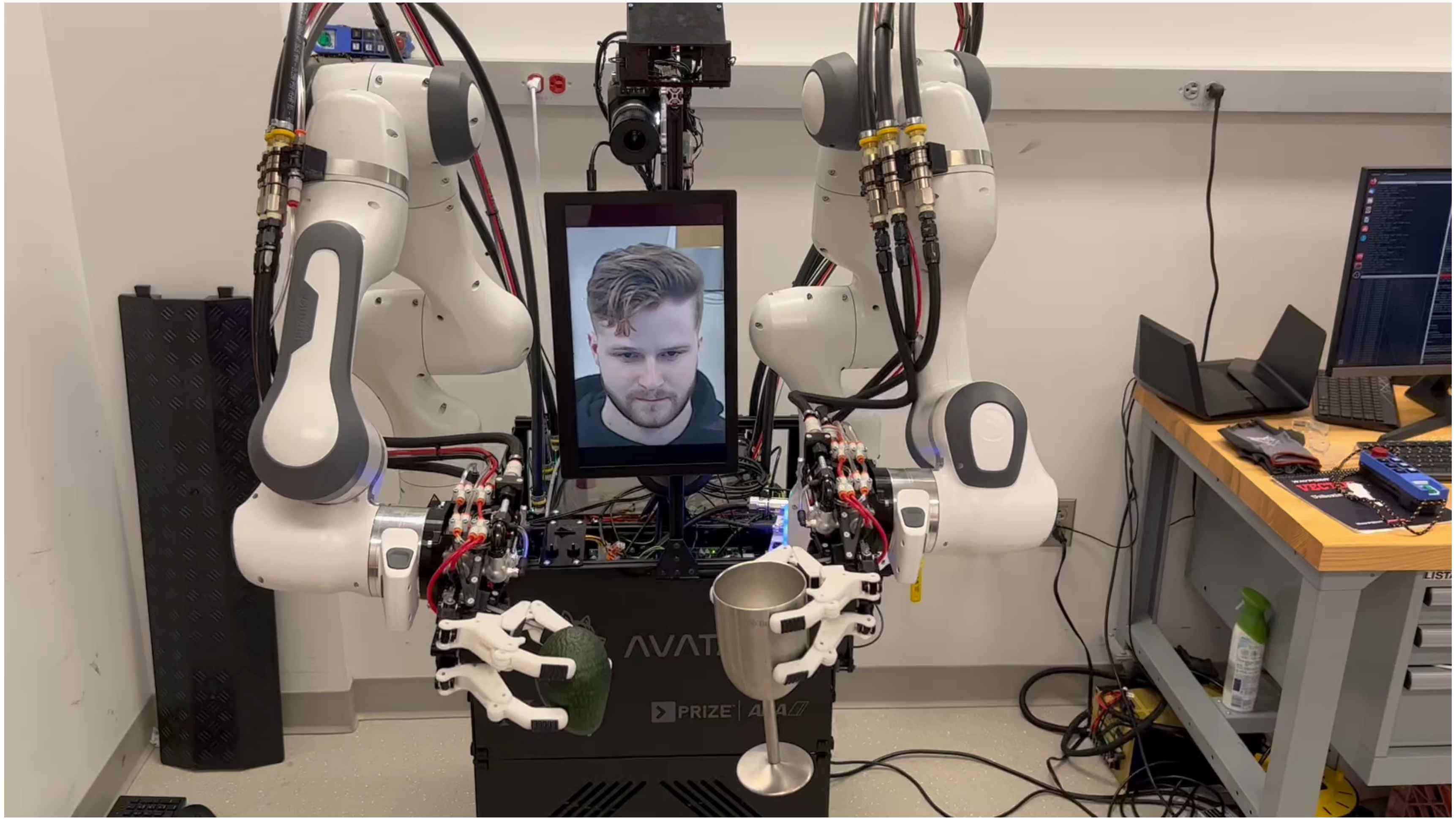
(All network communication run in 5Ghz WiFi)

Result

- Placed 3rd as the highest ranked U.S. team
- Won $1 million prize
- Learned invaluable lessons in engineering, design, and teamwork
- Had fun!

Demo - Operator

Demo - Avatar



LVX
VERITAS
VIRTVS

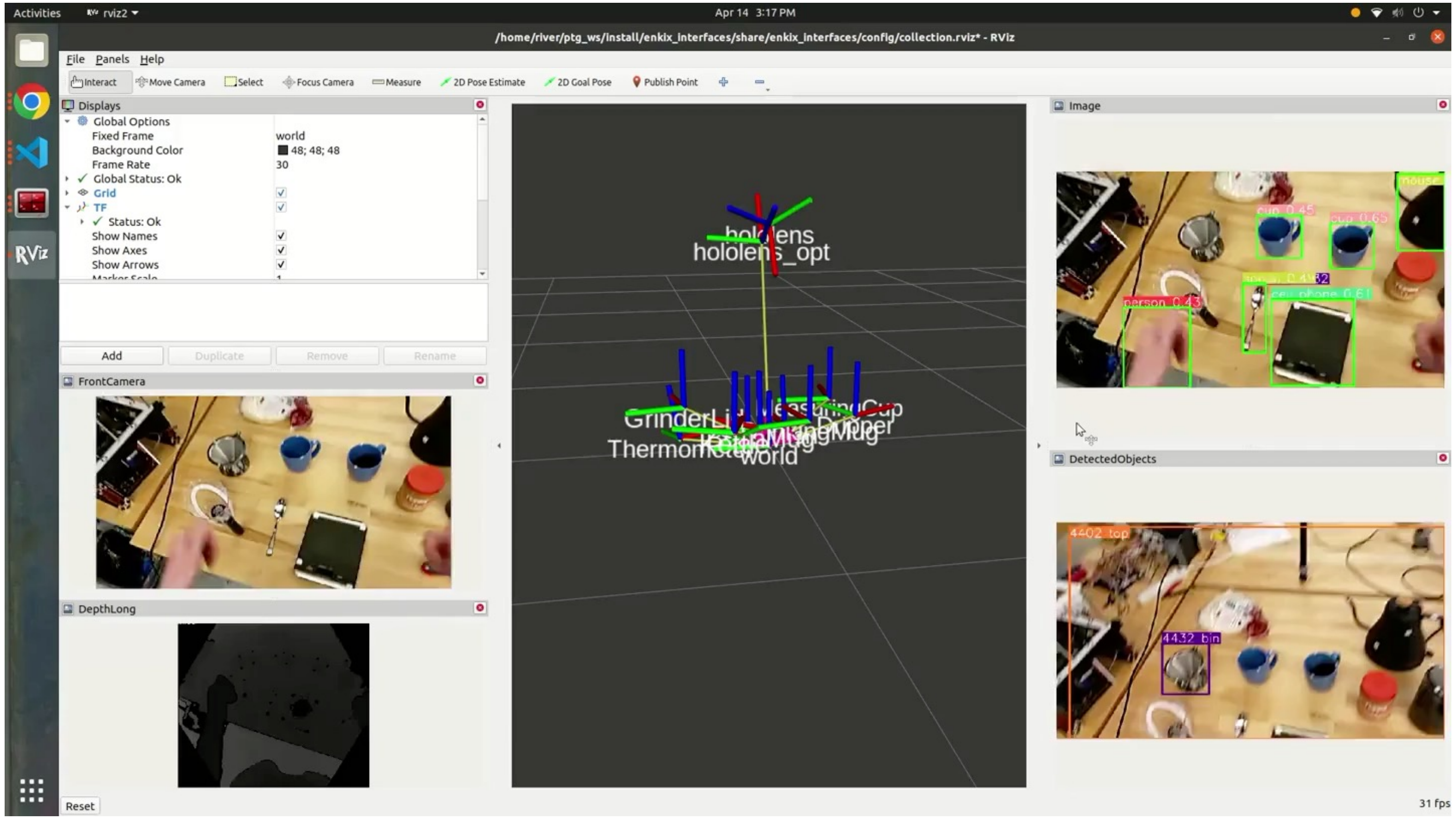
Avatars for Health

Remote health

Rehabilitation

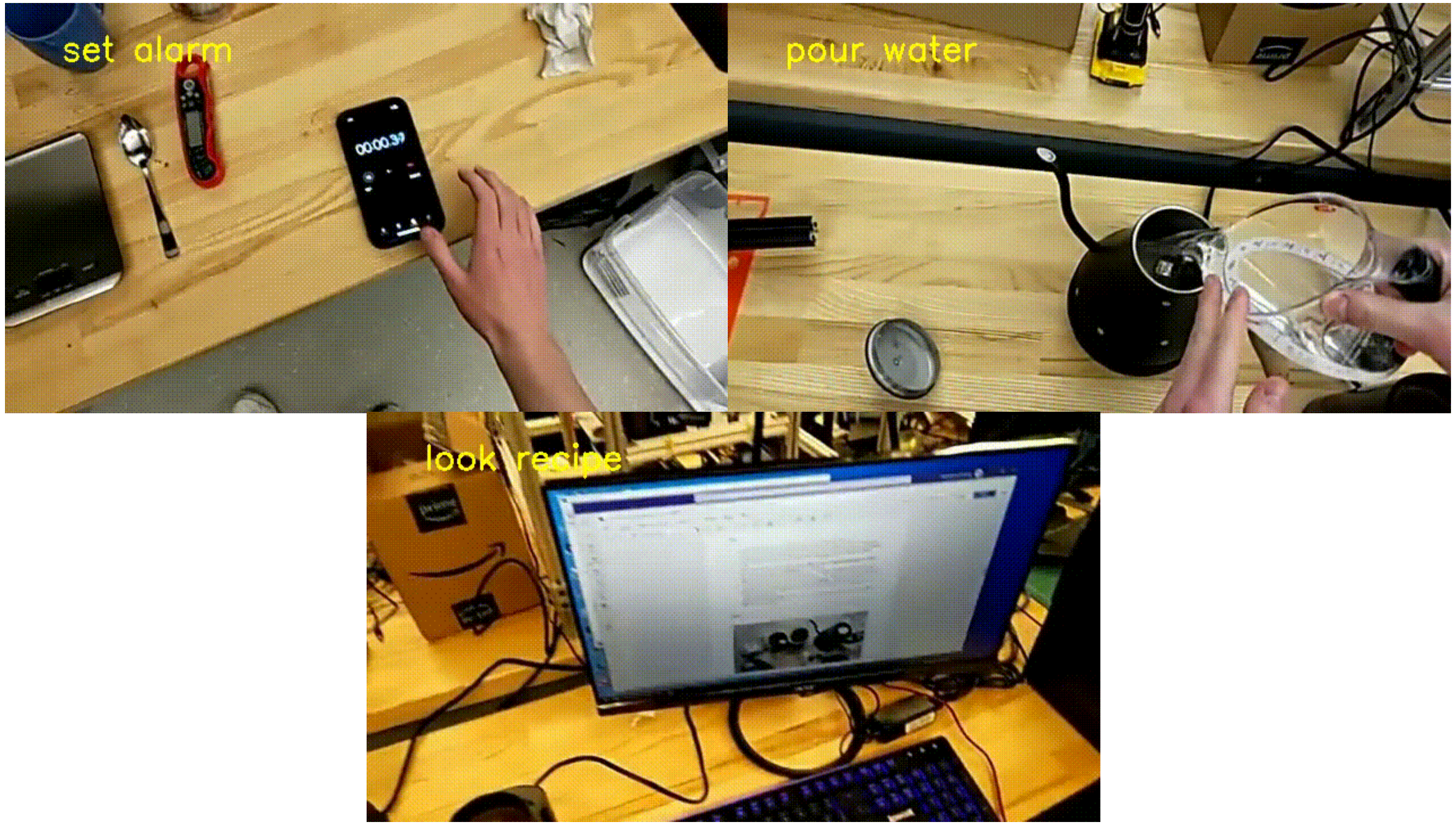
Safety in the Workplace

Understanding Human Worlds



ENKIx: Enabling Knowledgeable Task Guidance In the Extremes

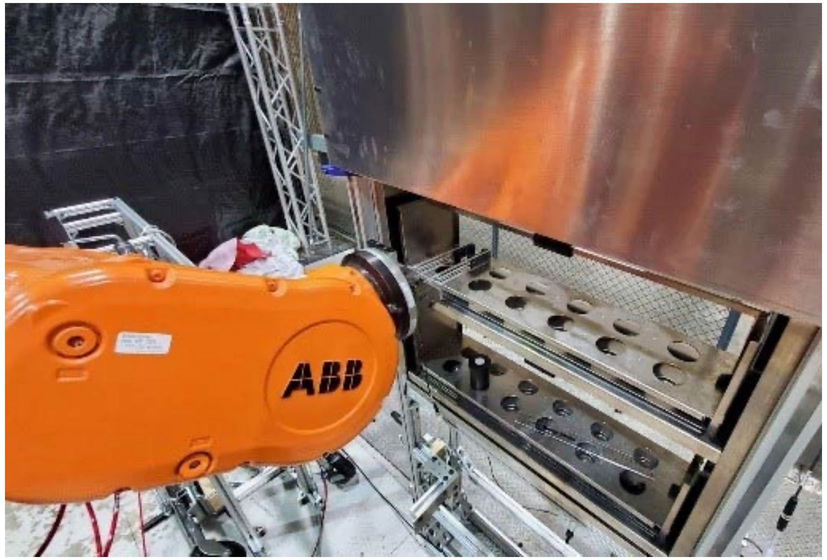
Understanding Human Activity



Safe and Use-driven Manipulation of Energetics with Risk-Metrics (SUMMER)

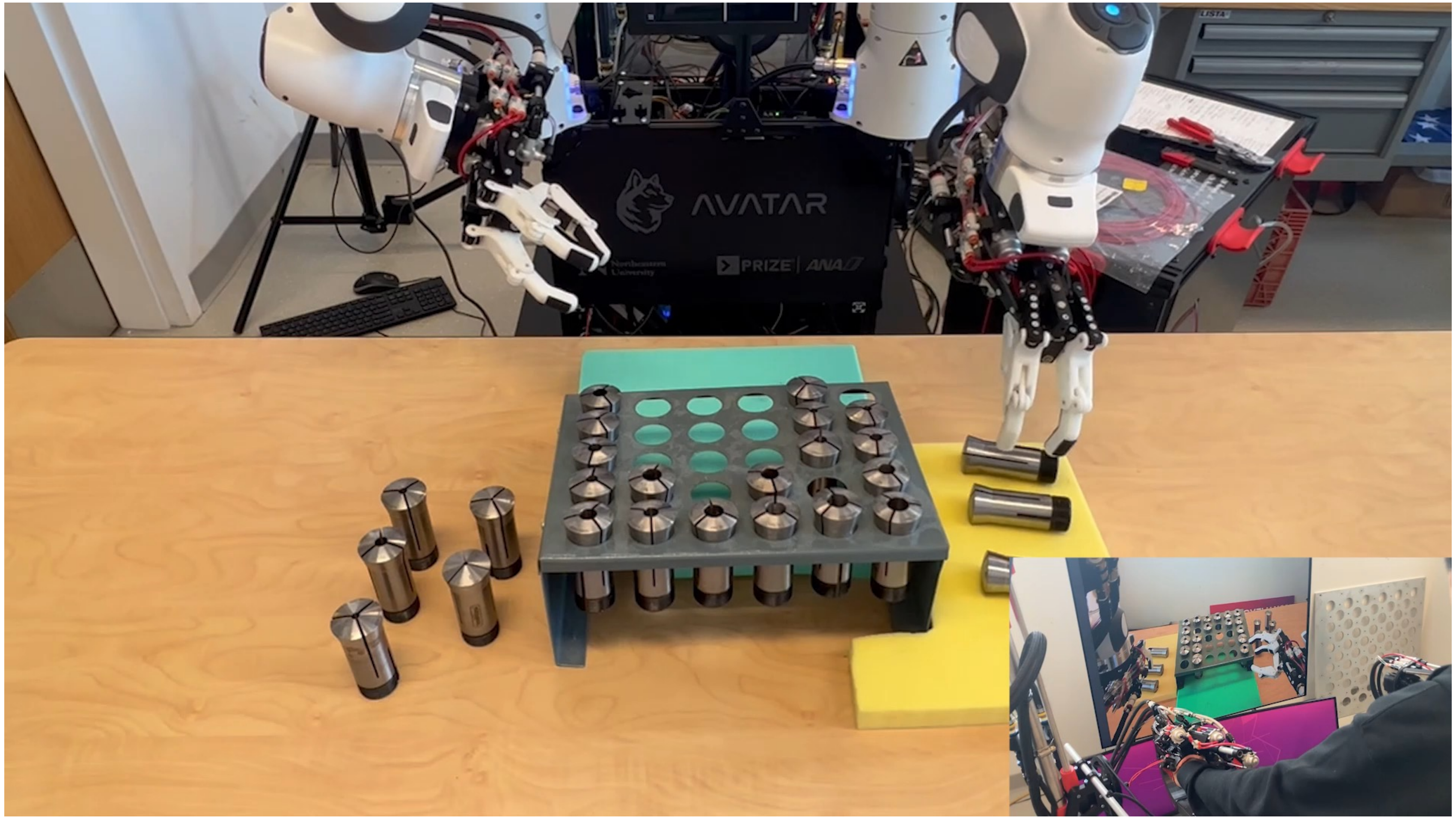
- **Underserved** industry in the U.S.
- DoD imports one third of its energetics materials from foreign sources
- Recent survey found over 300 points of failure in supply chain

Requirements



- Must **remove** sources of **energy stimulus**[4]:
  - Pinching, cutting, grinding, or slicing
  - Friction between surfaces
  - Drilling, hammering, welding
  - Electrostatic discharge, electrically or mechanically produced sparks
- Steady motion and **low vibration** manipulation to reduce accidental hazards or loss of energetic material
- **Smooth transitioning** between process steps, e.g., slow speeds for high-risk steps and faster tempo for low-risk coarse motion

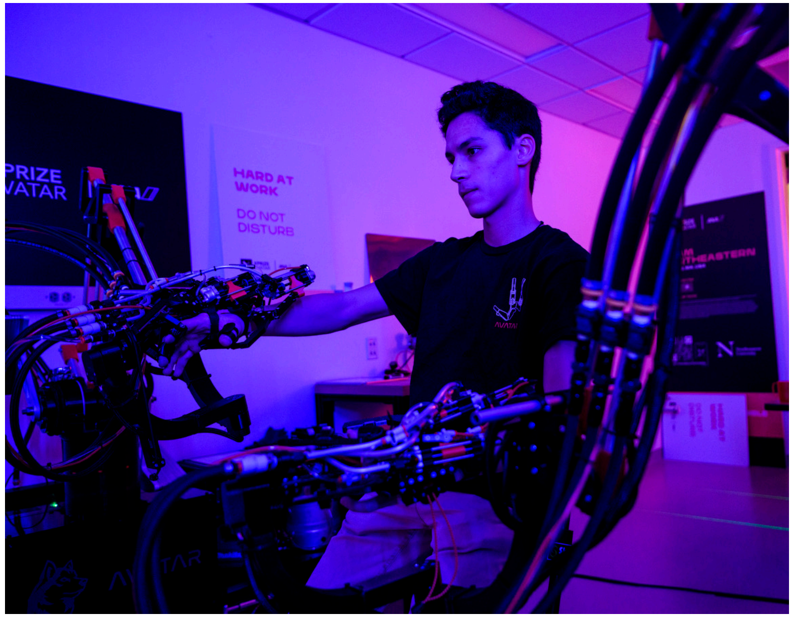
SUMMER Technical Approach



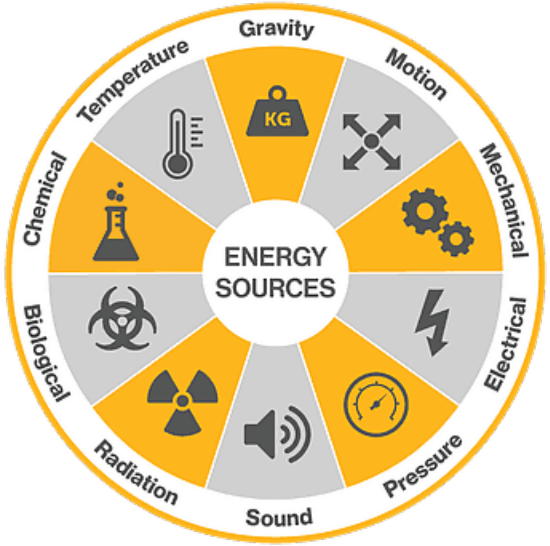
SUMMER Technical Approach

- Develop a **human-supervised** robotics solution for safe energetics material handling that:

Reduces sparks, friction, static, and pinch points by using **soft grippers**



Learns from human teleoperated demonstrations the **correct speed and sensitivity** of manipulation



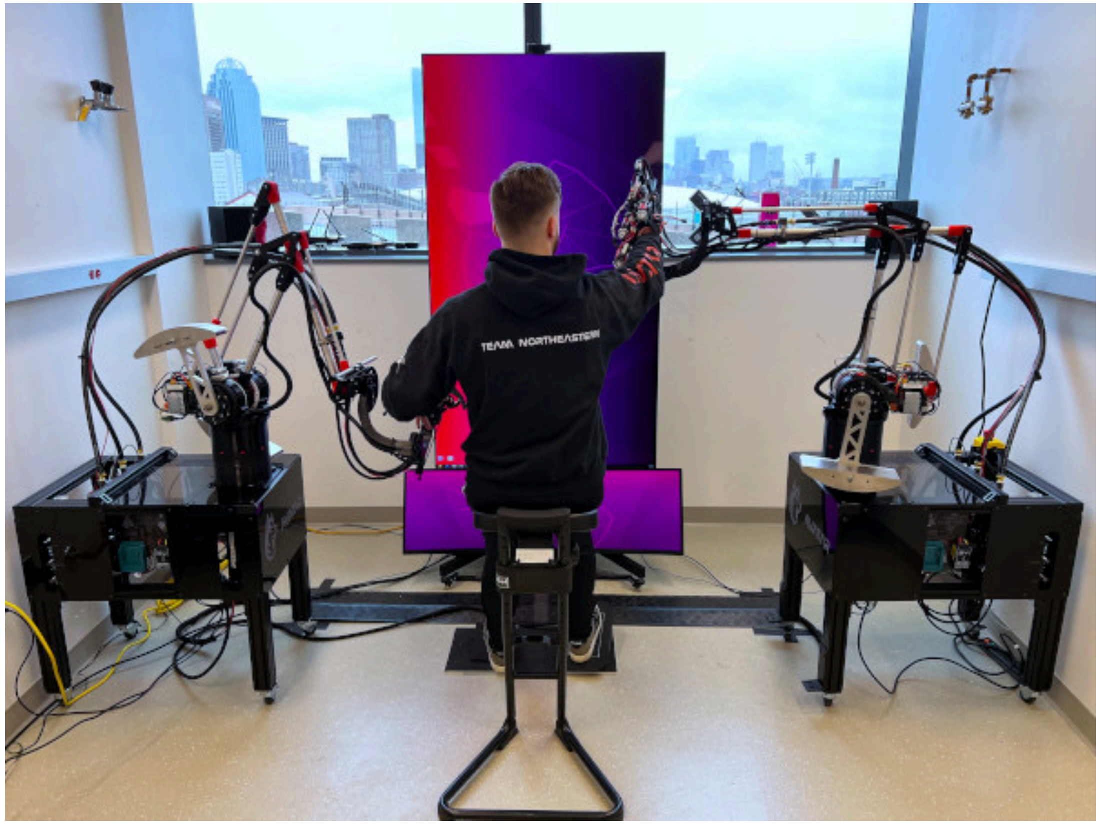
Quantifies the **risks** in energetics manufacturing to inform the robot control

Learning from Demonstration

- Learn mobile manipulation behaviors from expert teleoperation demonstrations of pick-and-place and transferal of containers

- Collect data streams on:
  - Robot joint state
  - Operator joint positions
  - RGB-D images
  - Tactile information

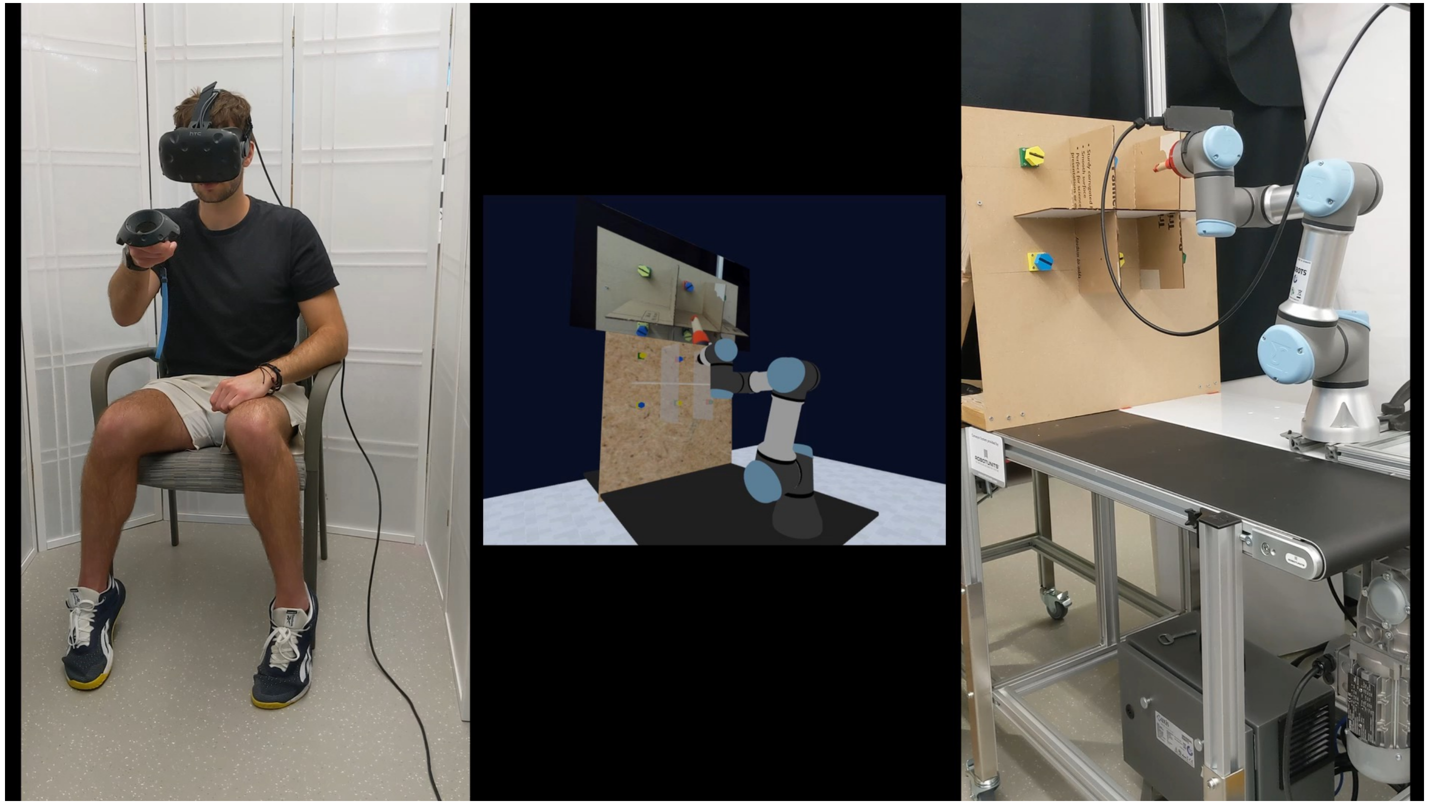
- Train state-of-the-art **latent variable models** on dataset to associate sensor data with an autonomous behavior policy



Risk-informed Control

- Develop risk-informed autonomous control strategies, e.g., stabilize manipulator for low-vibration motion during high-risk events

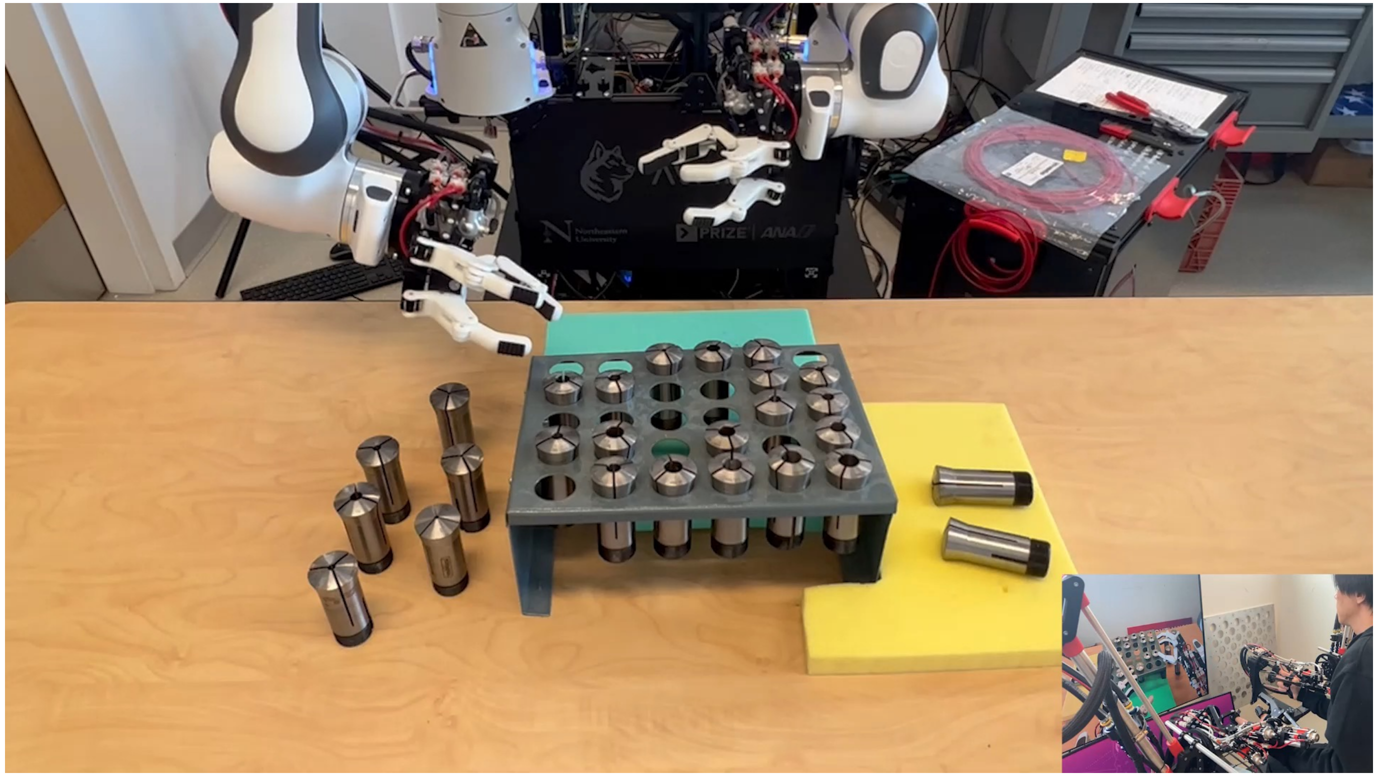
- Monitor % correct risk classifications based on **regulatory** requirements
- Evaluate # risks correctly identified vs **human expert**
- Assess operator-reported **mental workload** when risk-averse control assistance provided



Final Demonstration

- Demonstrate human-operated & fully autonomous dual arm mobile manipulation with the soft gripper at:

1. Tasks to pick, inspect, and insert combustible containers into a tray across 3 different energetics-like materials
2. Loading 10 trays onto mobile trolley
3. Classifying container types and damages



Questions