

TOWARDS AUTONOMOUS OPERATIONS OF THE ROBONAUT 2 HUMANOID ROBOTIC TESTBED

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Robonaut 2 (R2)

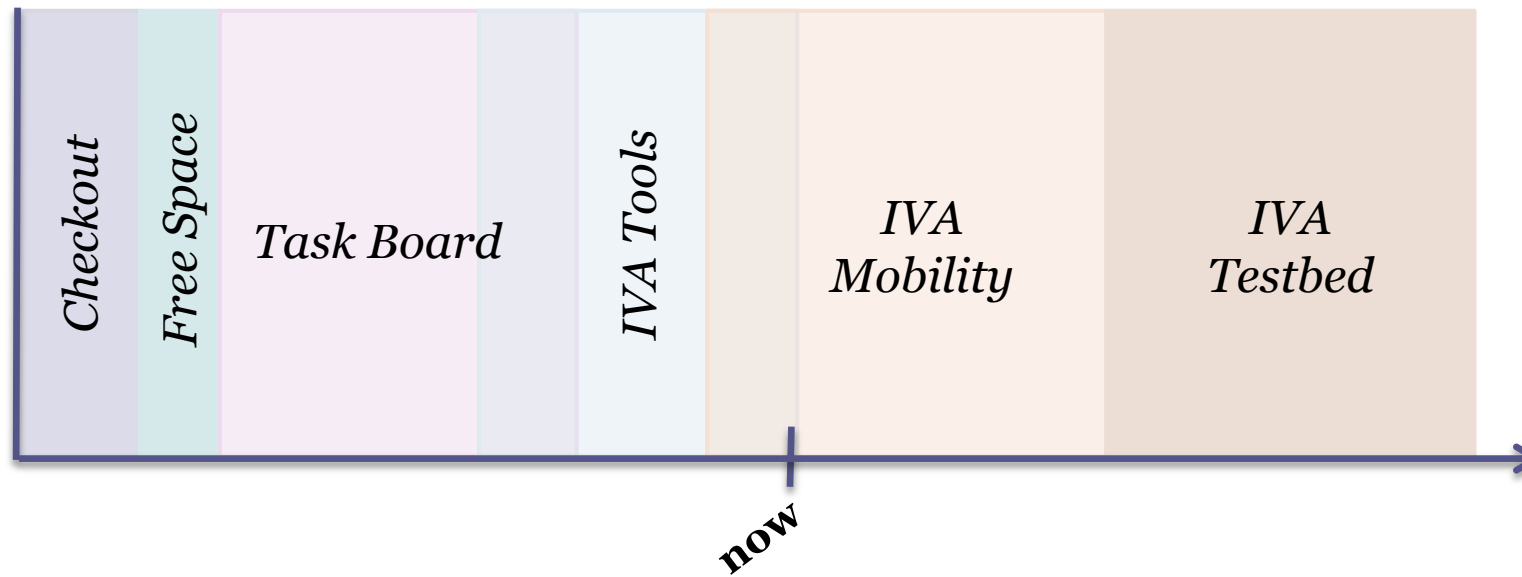
- Started in 2007 with GM
 - Leveraged Robonaut 1 technology (1998-2006)
- Common goals
 - Use humans' tools
 - Safely share humans' workspace
 - Do real (useful) work
- Launched on STS-133 in Feb 2011



Robonaut 1, Units A & B

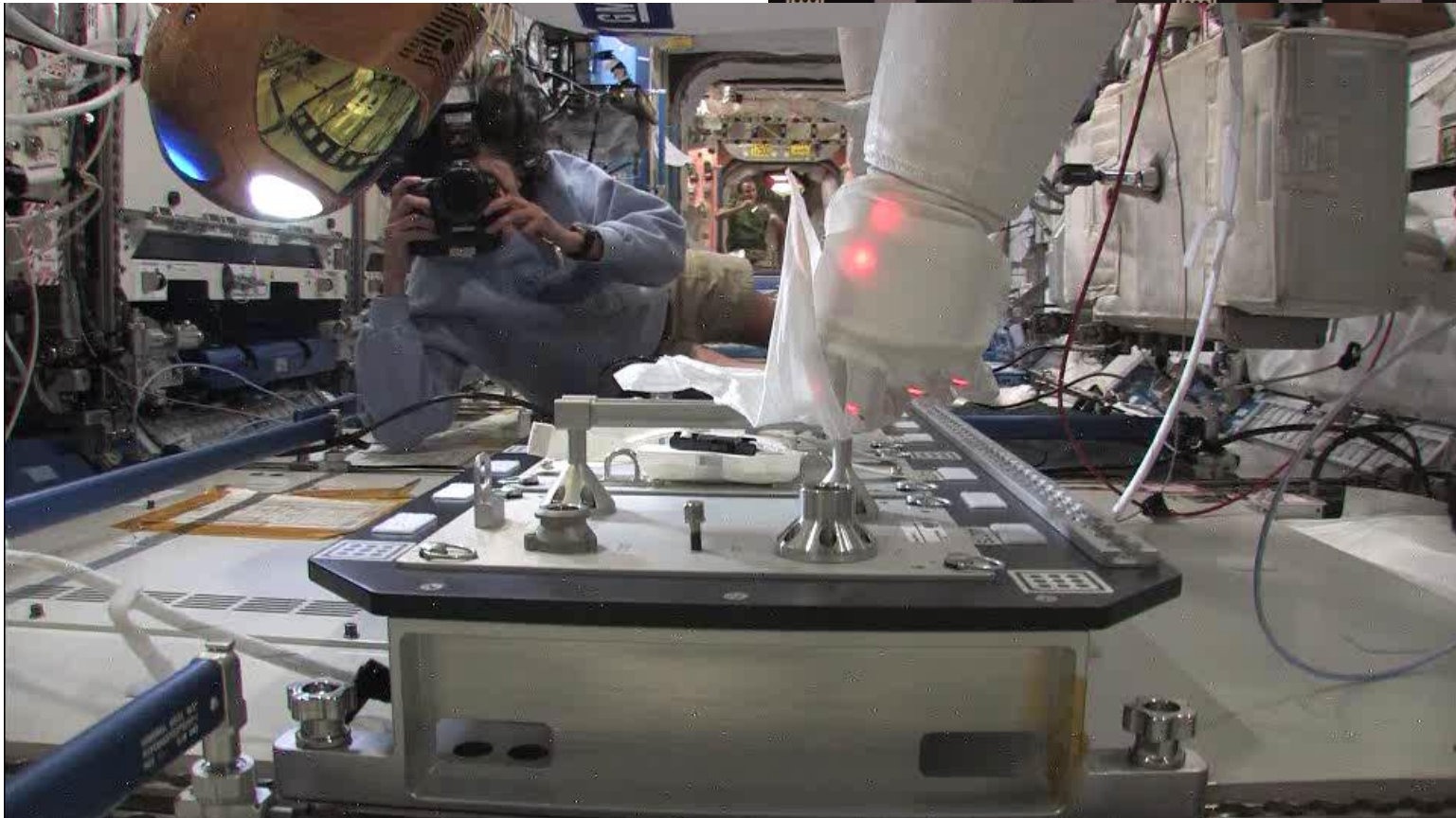
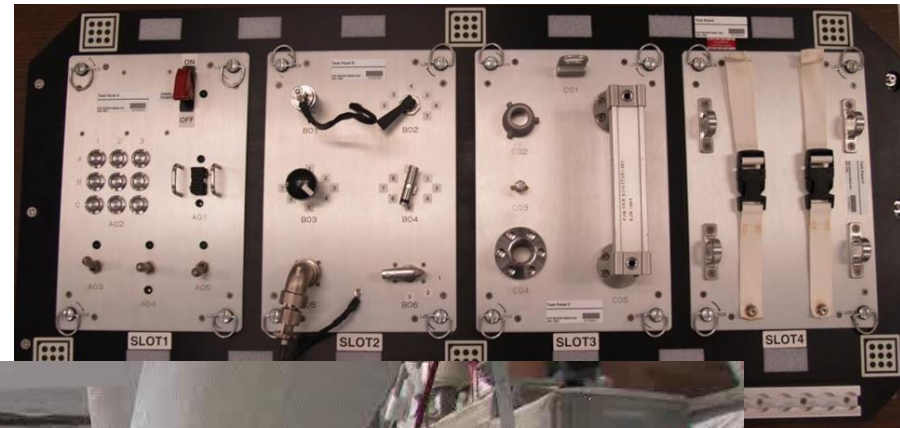


R2 ISS Task-Level Timeline



Tasks: Taskboard

Edited version of R2's wipe
manipulation and handrail cleaning



Tasks: IVA Tools



R2 using the VelociCalc tool to measure air flow from a vent

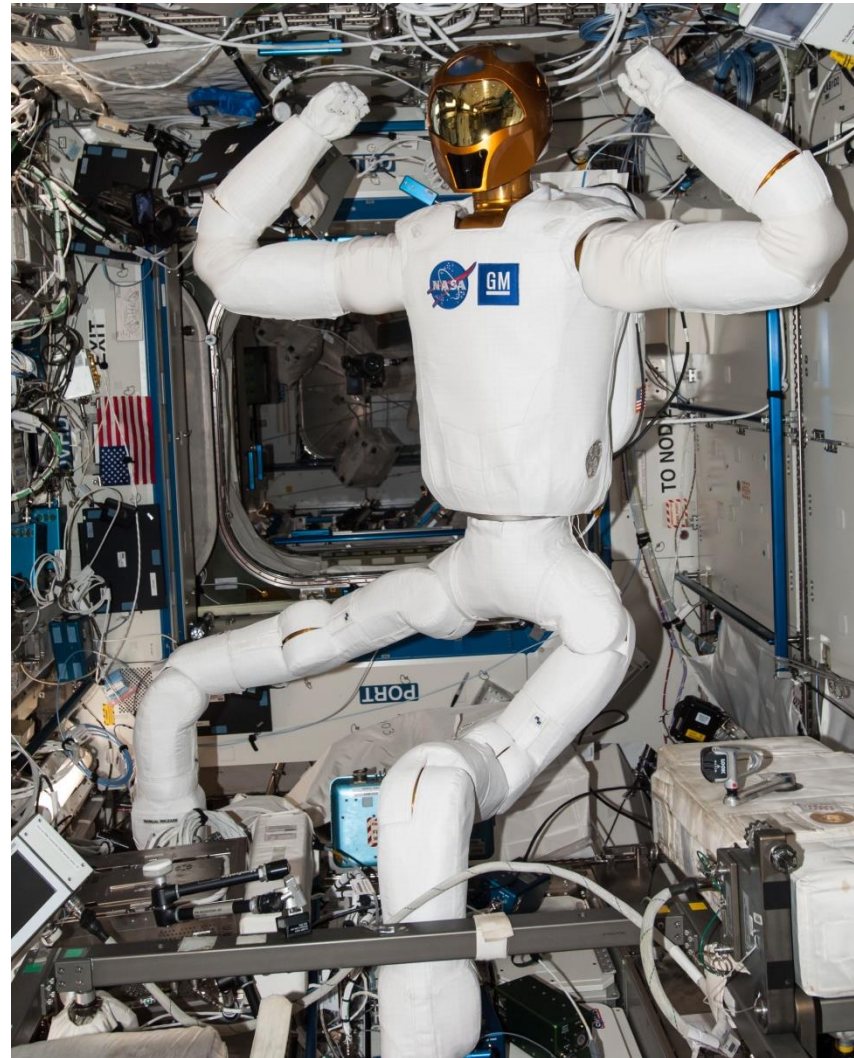


R2 using the an RFID reader to take inventory of items in a cargo bag

IVA Mobility Upgrade

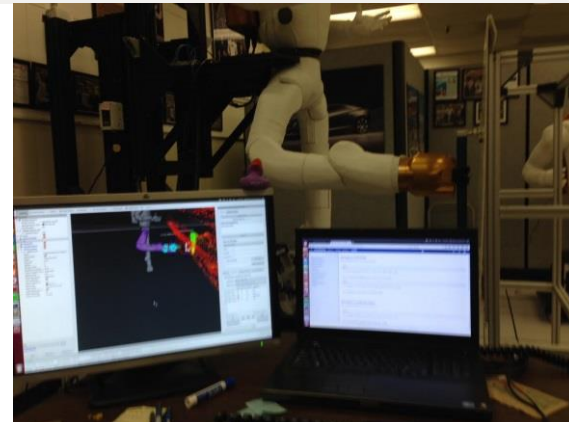
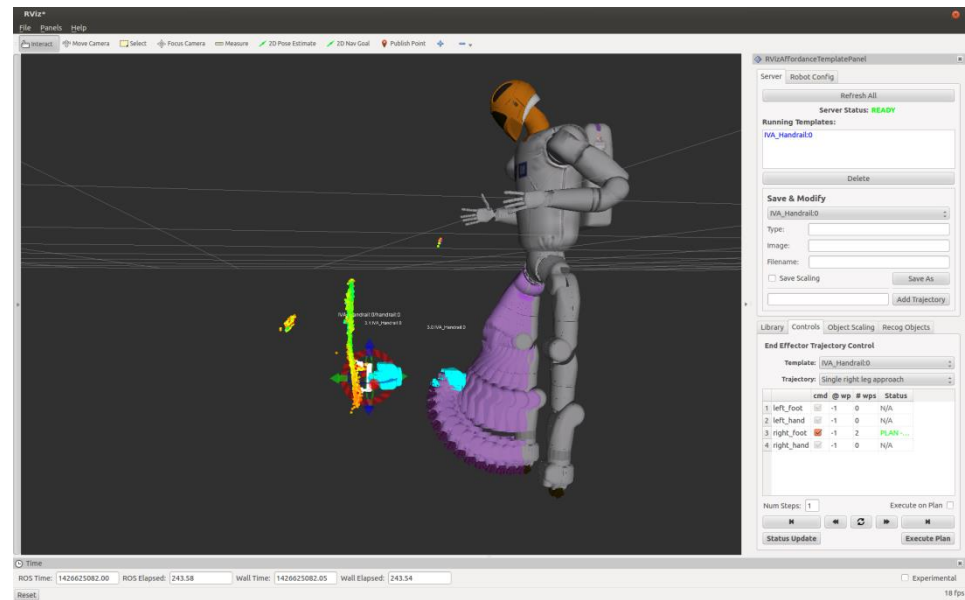
Upgrades included:

- Robotic “legs”
 - 7 DOF each + gripping end effector
 - Vision package (camera + TOF sensor) in each end effector
- New helmet for increased vision capabilities
- 3 Core i7 Processors for control and safety system



Affordance Templates

- Adopted this approach to move from supervised control to autonomous robotic behaviors
- Adapted from concept attempted during first DARPA Robotics Challenge
- Several upgrades and semi-autonomous functionalities introduced for successful IVA task demonstration



Grasp Planning Library

Grasp & Arm Motion Planning

RVizAffordanceTemplatePanel

Server: Robot Config

Refresh All

Server Status: **READY**

Running Templates:

RFID_reader:0

Delete

Save & Modify

RFID_reader:0

Type:

Image:

Filename:

☐ Save Scaling

Save As

Add Trajectory

Library Pose Compliance Controls Object Scaling

End Effector Trajectory Control

Template: RFID_reader:0

Trajectory: Right Hand Grasp

	cmd	@ wp	# wps	Status
1 left_foot	<input checked="" type="checkbox"/>	-1	-1	N/A
2 left_hand	<input checked="" type="checkbox"/>	-1	-1	N/A
3 right_foot	<input checked="" type="checkbox"/>	-1	-1	N/A
4 right_hand	<input checked="" type="checkbox"/>	6	8	SUCCESS

Waypoint to reset to: 1

Execute on Plan ☒

Status Update Reset Waypoint Execute Plan

Time

ROS Time: 1436208912.86 ROS Elapsed: 2794.72 Wall Time: 1436208912.89 Wall Elapsed: 2794.72

Reset | Left-Click: Move X/Y. Right-Click: Move Z. Mouse Wheel: Zoom.

29 fps



Supervised Template Placement

Stereo vision-assisted template placement

ObjectLocalization

Settings

Camera Topic: `/r2/head/prosilica/left/image_re`

Camera Info: `/r2/head/prosilica/left/camera_i`

Select Object: `rfid_reader_top`

RVIZAffordanceTemplatePanel

Server: Robot Config

Refresh All

Server Status: **READY**

Running Templates:

Delete

Save & Modify

Type:

Image:

Filename:

☐ Save Scaling

Library Poses Compliance Controls **Object Scaling**

End Effector Trajectory Control

Template:

Trajectory:

	cmd	@ wp	# wps	Status
1 left_foot	<input checked="" type="checkbox"/>	-1	-1	NO PLAN
2 left_hand	<input checked="" type="checkbox"/>	-1	-1	NO PLAN
3 right_foot	<input checked="" type="checkbox"/>	-1	-1	NO PLAN
4 right_hand	<input checked="" type="checkbox"/>	-1	-1	NO PLAN

Waypoint to reset to: Execute on Plan ☐

ObjectLocalization Views Displays

Time

ROS Time: 1436199125.89 ROS Elapsed: 1074.31 Wall Time: 1436199125.92 Wall Elapsed: 1074.29

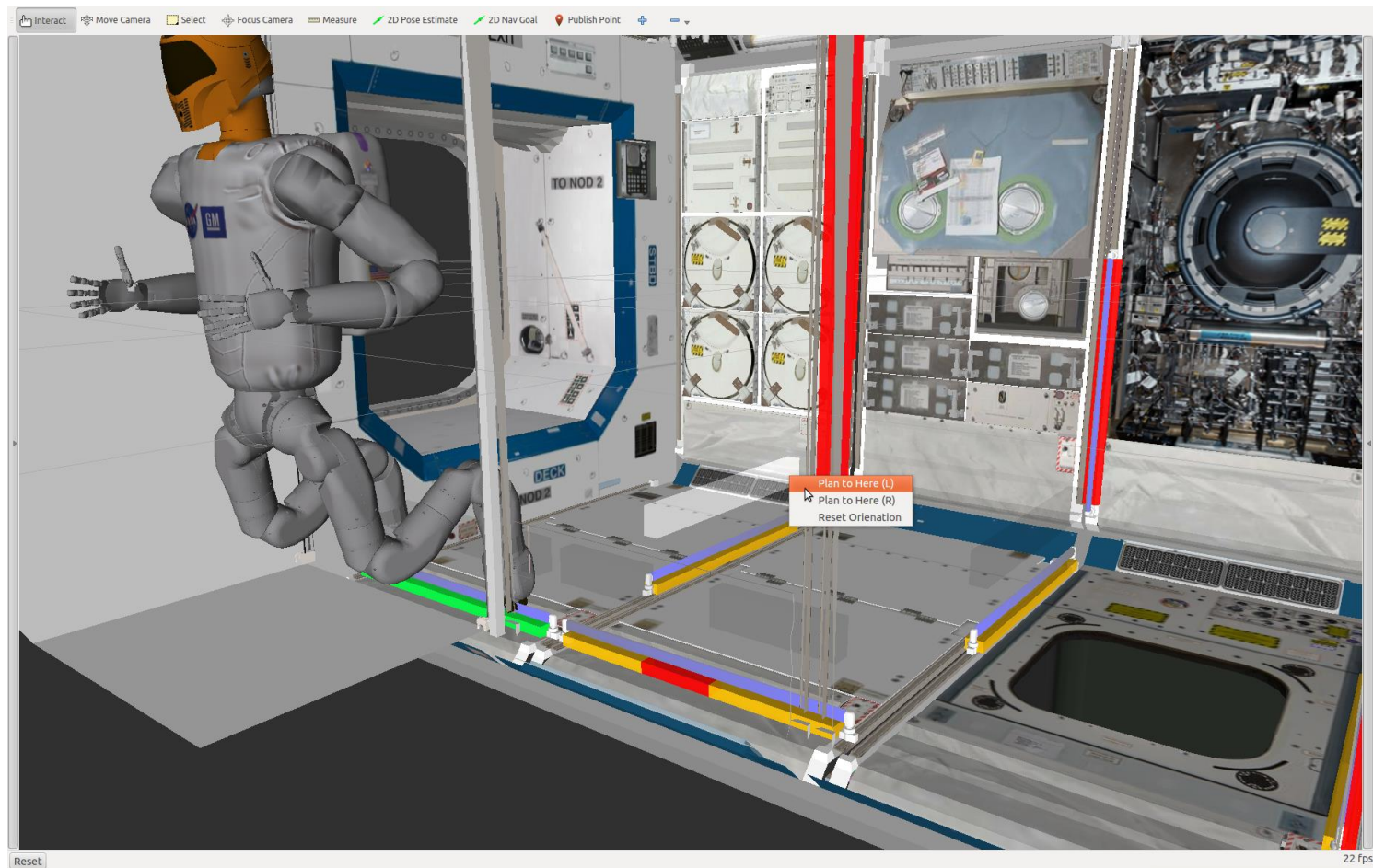
Reset Left-Click: Move X/Y. Right-Click: Move Z. Mouse Wheel: Zoom.

Experimental ☐

28 fps

NASA JSC GM ROBOT

Path Planning Integration



IVA Task Demonstration



Affordance Templates 2.0

Framework upgrades and improvements:

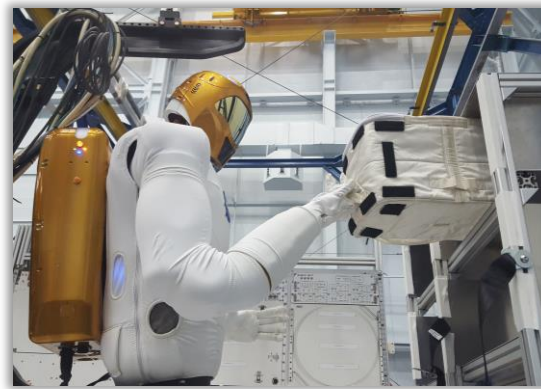
- Embedded collision data & checking
 - Allowable Collision Matrix
 - Obstacle Avoidance
- Planner Plugins
 - Customizable planners and trajectory generators
- Active supervisors
 - QR Code Detection
 - Automatic Object Recognition
 - Handle-Like Shape Detection¹

[1] Andreas ten Pas and Robert Platt. **Localizing Handle-Like Grasp Affordances in 3-D Points Clouds Using Taubin Quadric Fitting**. International Symposium on Experimental Robotics (ISER), Morocco, June 2014.



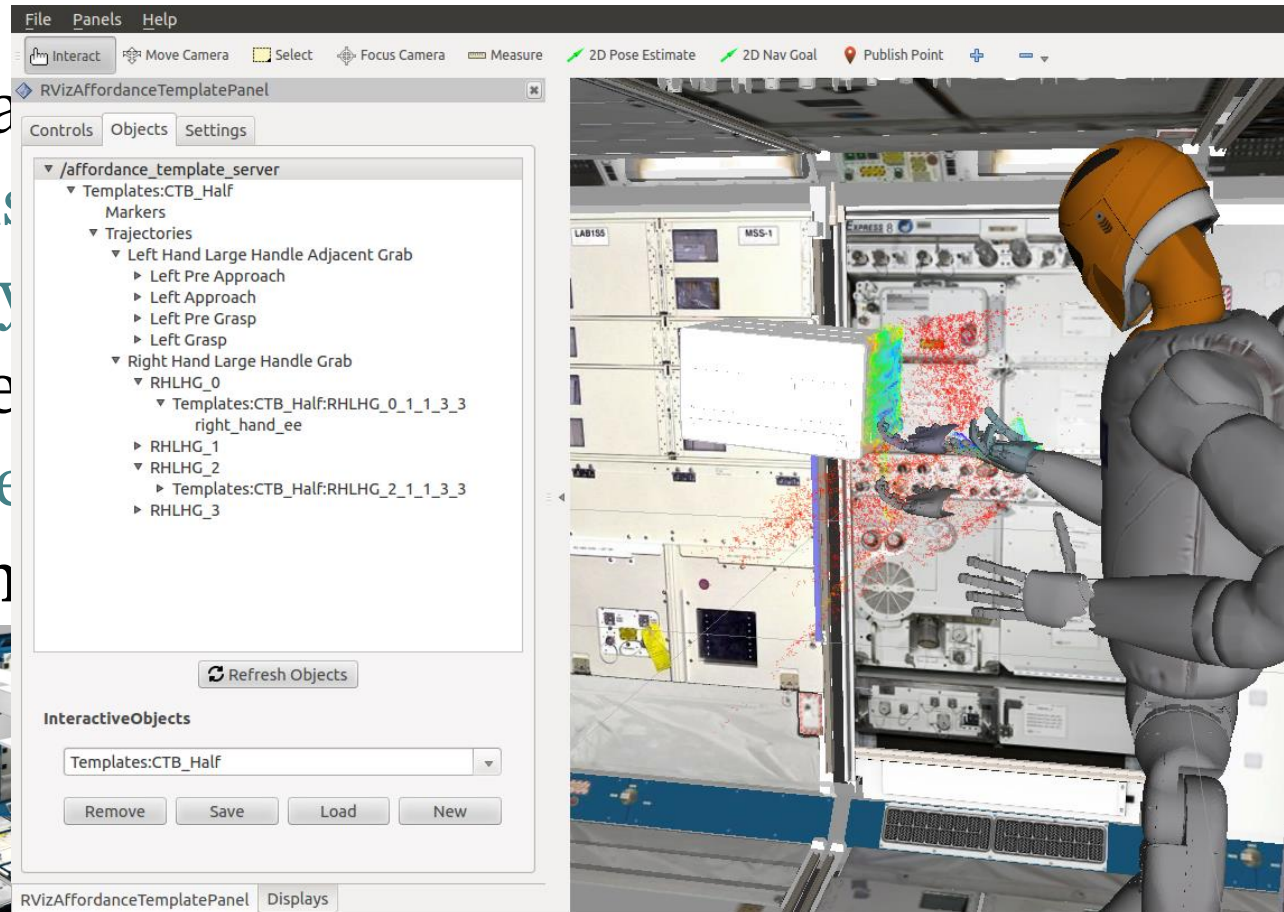
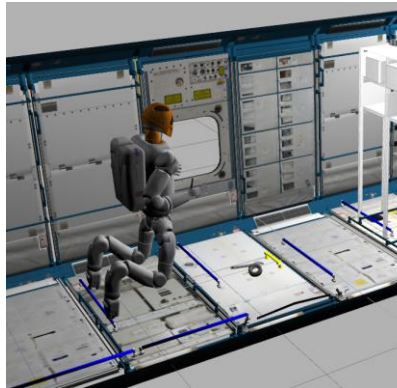
Autonomous Resupply Demonstration

- Resupply manipulation
 - Cargo Transfer Bag
 - Restraint System
- Automatic template placement
 - Template servoing
- Task-state monitoring



Autonomous Resupply Demonstration

- Resupply manipulation
 - Cargo Transfer
 - Restraint System
- Automatic template selection
 - Template selection
- Task-state monitoring



Conclusions and Future Work

- Efforts continue to develop the R2 on ISS into a semi-autonomous robotic testbed
 - Sophisticated manipulation strategies
 - Integrated path planning features
- Future work includes both on orbit and ground testing
 - Further development of several IVA tasks
 - Advanced path planning
 - Autonomous manipulation
 - EVA tasks and tools

