

Humans and Humanoids



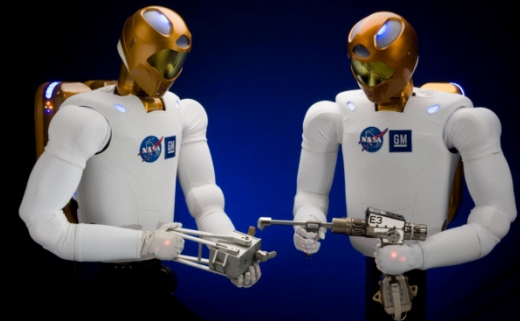
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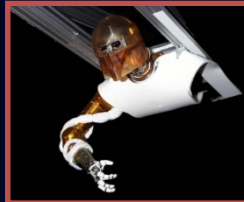
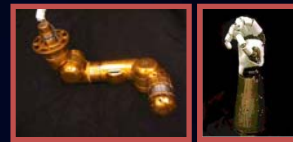
Robonaut Vision:

*Build a Robotic Assistant that
Can Safely Assist Astronauts,
Working in EVA Access Corridors
and with EVA Interfaces.*



Robonaut 1 History (Distant Past)

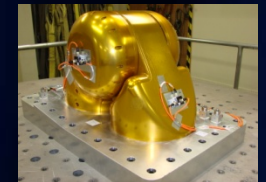
- **1998**
 - Subsystem Development
 - Testing of hand mechanism
- **1999**
 - Single Arm Integration
 - Testing with teleoperator
- **2000**
 - Dual Arm Integration
 - Testing with dual arm control
- **2001**
 - Waist and Vision Integration
 - Testing under autonomous control
- **2002**
 - R1A Testing of Autonomous Learning
 - R1B Integration
- **2003**
 - R1A Testing Multi Agent EVA Team
 - R1B Segway Integration
- **2004**
 - R1A Autonomous Manipulation
 - R1B 0g Airbearing Development
- **2005**
 - Development of R1C Joints
 - Supervision Across Time Delay
- **2006**
 - Integrate R1B with Centaur Base
 - Thermal, vacuum and vibe testing of R1C



R1A



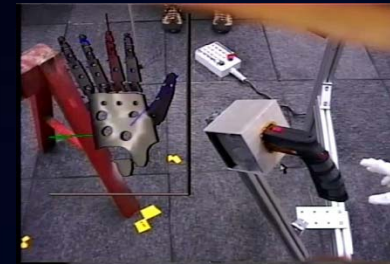
R1B



R1C

Robonaut 1 (R1) Challenges

- **Dexterity**
- **Autonomy**
- **Human Robot Interaction**
- **Mobile Manipulation**



Robonaut 2 History (Recent Past)

- **2007**
 - SAA for GM & NASA
 - R2 concepts
 - Prototype joints
- **2008**
 - R2 Single Limb Integration
 - R2A Integrated
- **2009**
 - R2A completes first assembly task
 - R2B Integrated
- **2010**
 - January ISS decision made
 - February Public Release
 - July R2B Certification
 - August R2B Packed in MPP
- **2011**
 - February STS-133 Launch



R2A

R2B

Robonaut 2 ISS Update

- R2 Launched February 2011
 - STS 133
- R2 Unpacked March 2011
 - Punk'd by Crew
- R2 Power Up August 2011
 - Thermal model validation
- R2 Safety Checkout Sept 2011



ISS026E034292



ISS026E034304



Robonaut 2 (R2) ISS Flight Demo

Brief History

- GM Industrial partnership
- NASA ESMD demonstration
- NASA SOMD ISS payload
- Launched on STS-133

Experimental Objectives

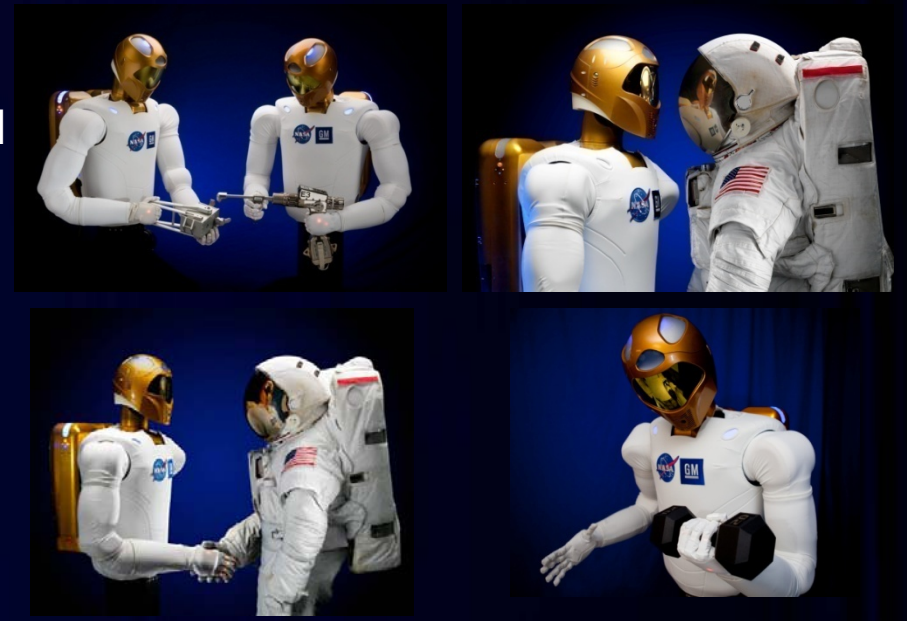
- Test dexterous manipulation in 0g
- Test robot-crew safety in 0g
- Refine control based on tests

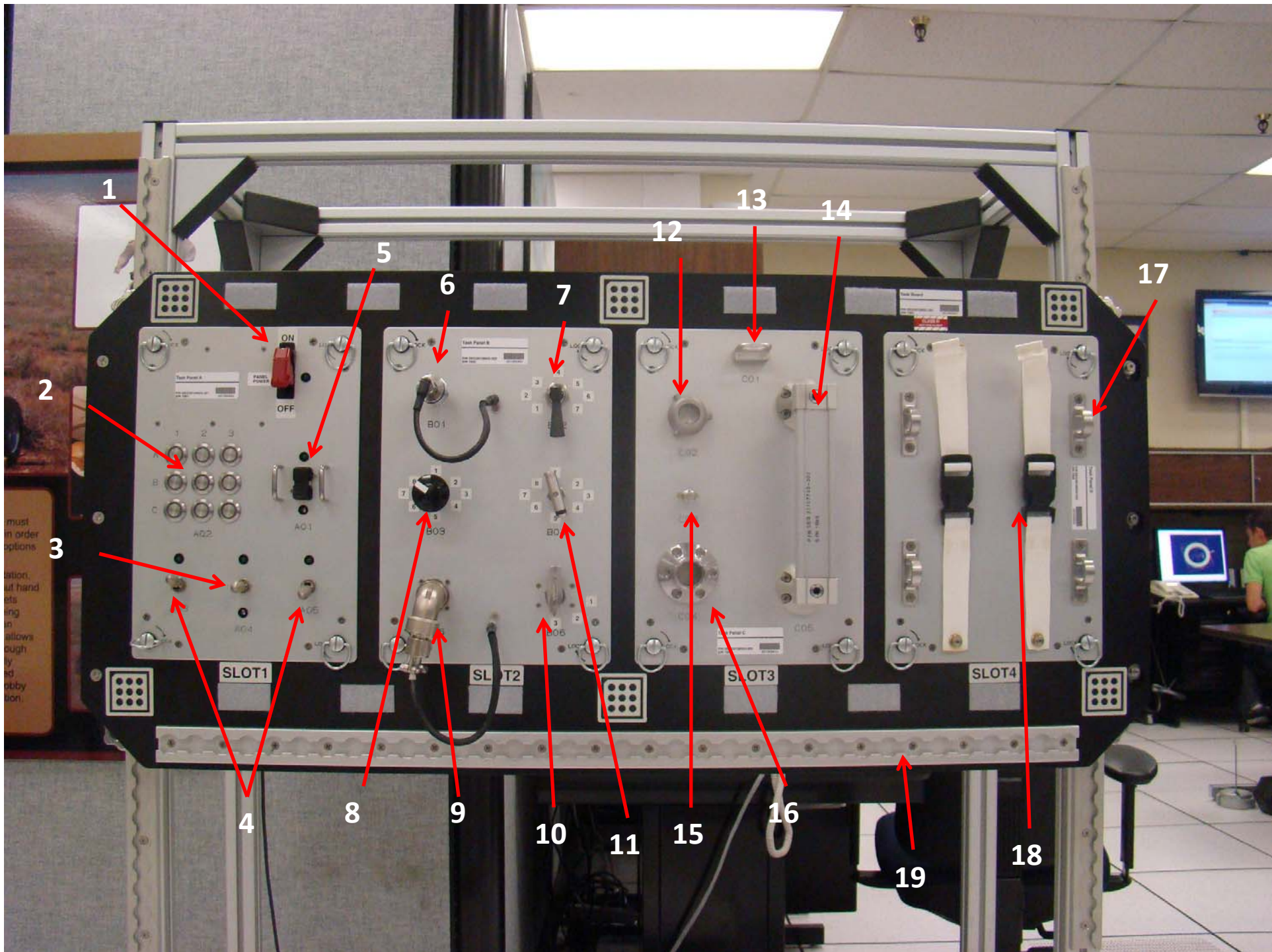
Experiment Phases

- IVA on fixed stanchion & taskboard
- IVA mobile
- EVA mobile

Future Utility

- Transition to ISS EVA asset
- Future robots for beyond LEO
- Terrestrial applications & partners





Task Board Key (See Previous Slide)

- **Powered Panel Assy**

1. Non-locking 2-way switch with switch guard
2. Push button switch array (blue and green)
3. Locking 3-way switch
4. Locking 2-way switch
5. 2-way rocker switch with finger guards

- **IVA Panel Assy**

6. Fluid Quick Disconnect (QD) Valve
 - Used for fluid connections on station
7. Toggle Valve
8. Metering Valve
9. Circular connector
 - Used for powered connections on station
10. Ball Valve
11. Needle Valve

- **EVA Panel Assy**

12. Microconical Fitting
 - Interfaces with the Round Scoop EVA handling tool
13. Tether Ring Assembly
14. EVA Handrail Assembly
15. 7/16" EVA Bolt
16. EVA Change-Out Mechanism (ECOM) Socket
 - Interfaces with the Body Restraint Tether (BRT) and Multi-Use Tether (MUT)

- **Stowage Panel Assy**

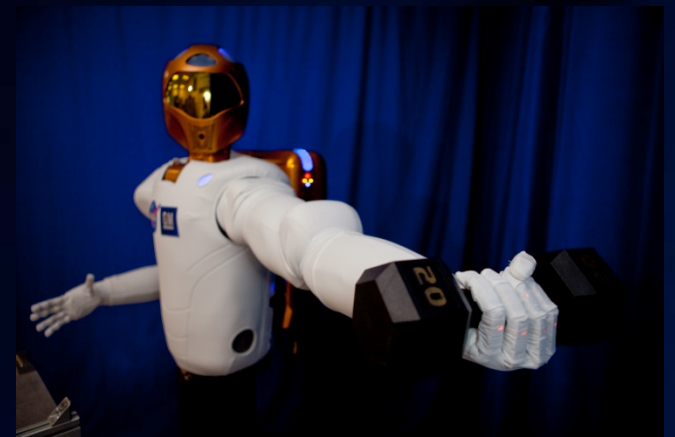
17. Tether loops (x4)
18. Strap Assembly

- **Task Board Face**

19. Seat Track

Robonaut 2 (R2) Challenges

- **Safety**
- **Autonomous Grasping**
- **Zero Gravity Dexterous Manipulation**
- **Mobile Manipulation**



Robonaut 2 Safety

- **ISS Certification**

- Approved for work with crew
- No “E-Stop” needed

- **Includes 3-layer safety software**

- Joint force control
- Wrist force control
- Shoulder force control

- **Force Thresholds**

- Pause magnitude threshold
- Stop magnitude threshold
- Stop frequency threshold



Robonaut 2 Autonomous Grasping

- **Tactile SLAM (Platt)**

- Raster Scan Object
- Make Contact
- Localize
- Go To Desired Location

- **Object identification (Platt & Pfeiffer)**

- Sample Population
- Interrogate Objects
- Sort Objects

Automated
Haptic
Learning



Robonaut 2 Zero Gravity

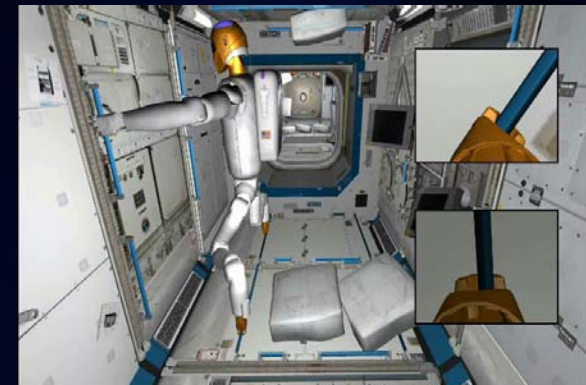
- **Task Board Automation (Hart et al)**

- Vision to coarse alignment
- Tactile and haptic sensing
- Learning
- Vision to confirm task execution



- **Zero Gravity Climbing (Radford et al)**

- Hand rail grasping
- Object carrying
- Tunnel navigation



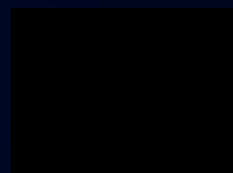
Robonaut 2 and Centaur 2

- **Mobile Manipulation (Diftler, Bluethmann, et al)**

- Mobile Rover Base
 - Crab Drive
 - Active Suspension
- Manipulators
 - Robonaut 2 Torso
 - Digger Tool

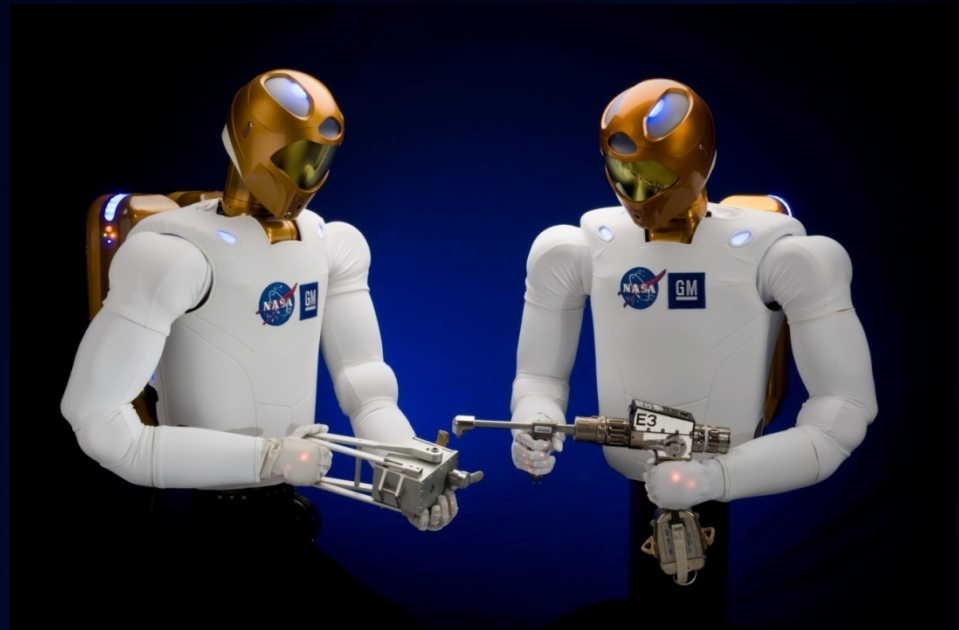
- **Supervised Autonomy (Hambuchen)**

- Operated Across 50 s time 'delay
- Supervisor Designates Rock
- Robot Drive and Grasps
- Tell Robot "Wrong Rock"



Robonaut Future R&D

- **Powerful Limbs**
- **Dexterous Hands**
- **Safe Sensing**
- **Agile Mobility**
- **Smart Control**



Questions ?

