

Making Robonaut An Intelligent Assistant for Humans

Abstract

This presentation is an overview of the Robonaut project. Robonaut is a humanoid robot designed by the Automation, Robotics, and Simulation Division at NASA's Johnson Space Center. The Robonaut project seeks to develop and demonstrate a robotic system that can function as an EVA astronaut equivalent. Robonaut jumps generations ahead by eliminating the robotic scars (e.g., special robotic grapples and targets) and specialized robotic tools of traditional on-orbit robotics. However, it still keeps the human operator in the control loop through its telepresence control system. Robonaut is being designed for "EVA" tasks, i.e., those that were not specifically designed for robots.

Our challenge is to build machines that can help humans work and explore in space. Working side by side with humans, or going where the risks are too great for people, machines like Robonaut will expand our ability for construction and discovery. Central to that effort is a capability we call dexterous manipulation, embodied by an ability to use ones hand to do work, and our challenge is to build machines with dexterity that exceeds that of a suited astronaut.



Making ROBONAUT an Intelligent Assistant for Humans

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Outline

Brief Robonaut Intro & Status Report

Human Robot Teams

 Taxonomy

 Team Models

 Team Examples

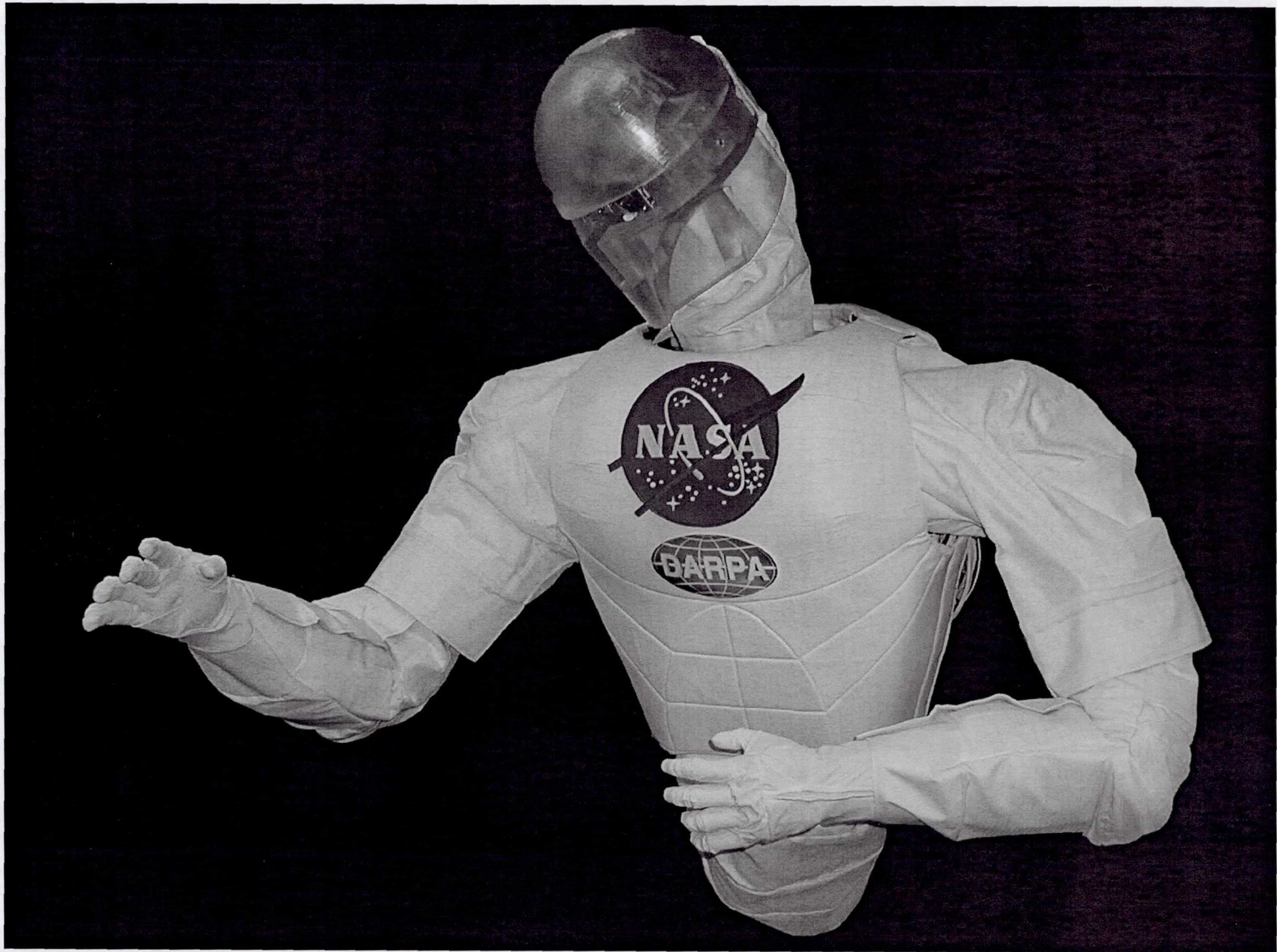
Robonautonomy

 Definition

 Distributed R&D Testbed

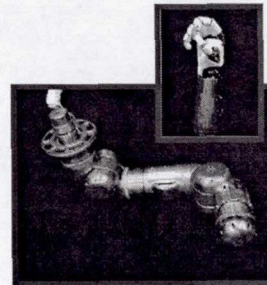
 Recent Vision Work

Collaboration



ROBONAUT Progress

- Thrusts during FY01
 - Autonomy
 - Added vision
 - Added voice
 - Added sequence logic
 - Collaboration
 - Created RoboSim
 - Created RoboAPI
 - 3 Human Factors Studies
 - 2 Human/Robot Team Studies
- Recent Work in FY02
 - Multi tool identification
 - Human Tracking
 - Tool Exchange
 - New Human/Robot Team Study



ROBONAUT
Fall 1998



ROBONAUT
Fall 1999



ROBONAUT
Fall 2000



ROBONAUT Fall 2001

NASA Teams Humans and Robots

- These teams are in orbit today.
- NASA has approaching 20 years of EVA work with robotic systems.
- Mission developers are now calling for expansions of these teams with more robots, new forms of robots, and new capabilities for assisting humans in space.

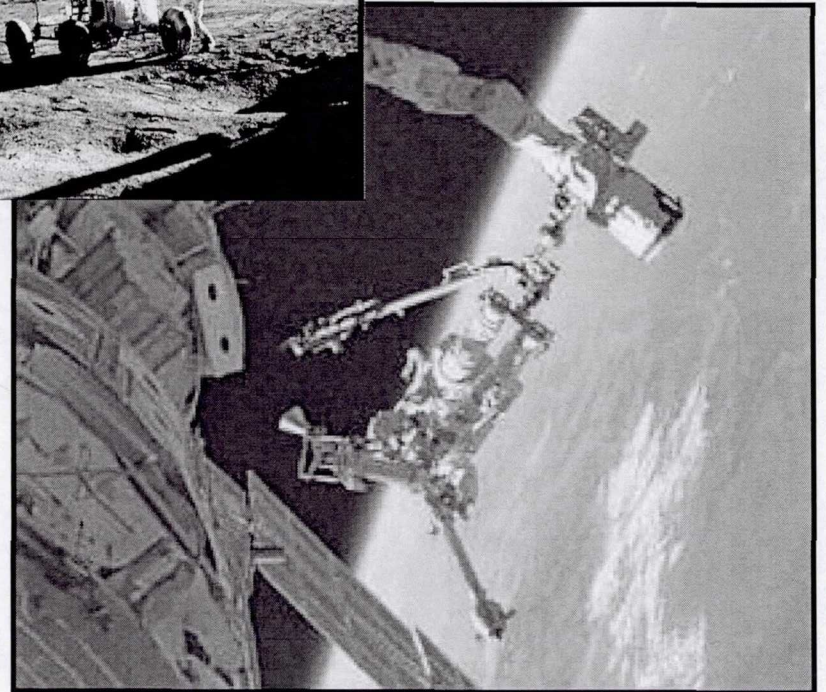
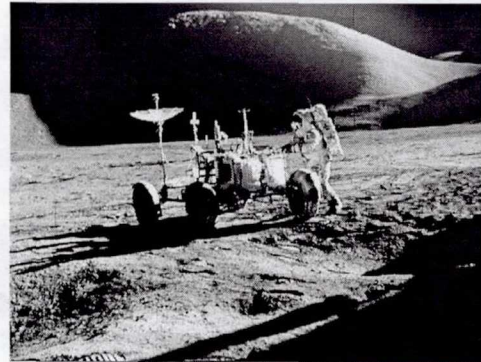


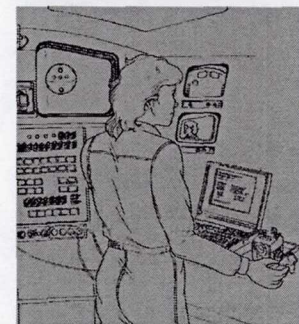
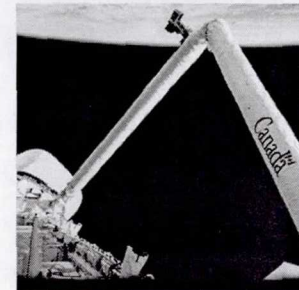
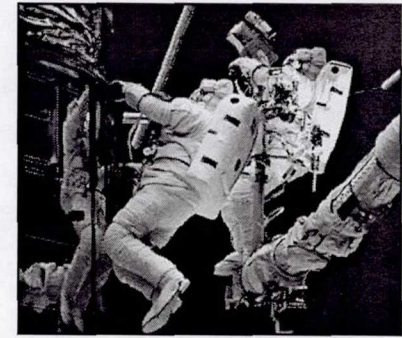
Photo of CanadArm on STS 103 and Lunar Rover

Taxonomy of a Team

- Established Dimensions of a Team
 - Spatial relations (remote operation, shoulder-to-shoulder)
 - Ratios of agents (ratios of subordinates)
 - Relationships of rank (command hierarchies)
- Now being Investigated at JSC
 - Heterogeneous agents (sentries, scouts, transport, shock, artillery)
 - Forms of interactions (data, hand offs, sustained physical contact)

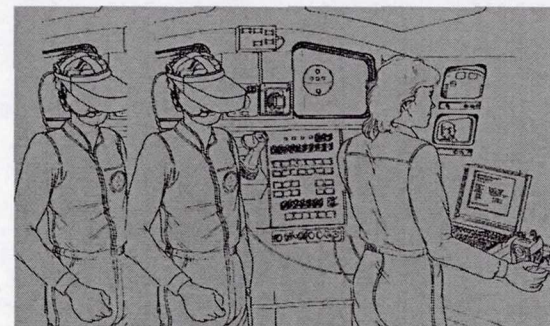
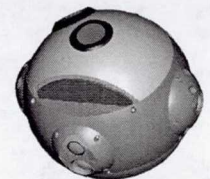
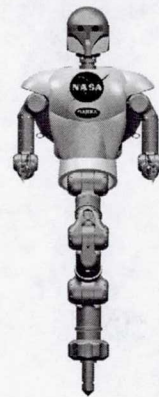
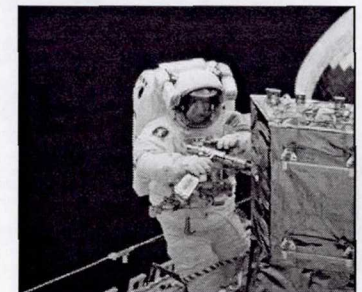
Heterogeneous Teams, Today

- Current EVA Teams
 - 2 EVA Humans
 - 1 RMS
 - 1 IVA RMS Operator
 - 1 IVA “watcher”
 - 10-30 Ground Personnel
- Team limits and strengths
 - > 150 EVA in human history
 - Hugely successful
 - No losses to date
 - Consumes full flight crew
 - 1-3 Hours of prep time
 - 8 Hour EVA time limit
 - 1-3 Hours of cleanup



Heterogeneous Teams, Tomorrow

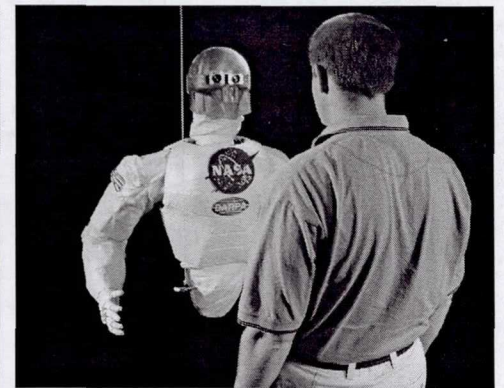
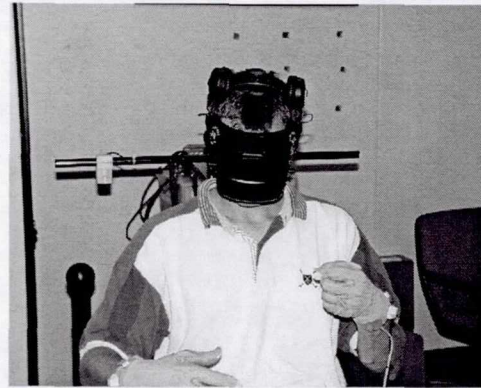
- New EVA practices
 - 2 EVA Humans
 - 1 RMS
 - 1 Robonaut
 - 1 Aercam
 - 1 IVA RMS Operator
 - 1 IVA Robonaut operator
 - 1 IVA Aercam Operator
 - 10-30 Ground Support
- Team limits and strengths
 - Requires more than available crew
 - Allows Humans to “split up”



Forms of Human/Robot Interaction

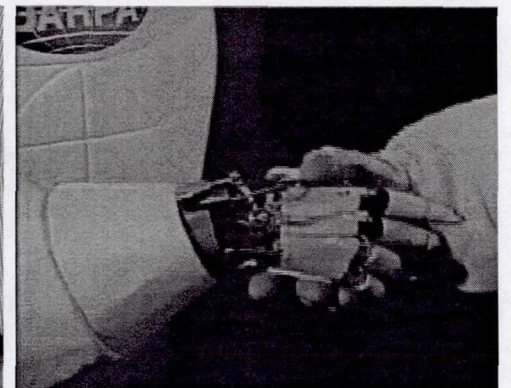
- Information Connections

- Levels of Intervention
 - Autonomous
 - Supervised
 - Teleoperated
- Forms of Communication
 - Voice
 - Natural gestures
 - Input devices
 - Sensor Feedback
 - State & health



- Physical Connections

- Presence (in situ)
- Intermittent contact (hand off)
- Coordinated contact (work)



Agent Interaction: Teleoperation



Video & Sensor
Feedback



Command
Data



Agents are connected by
information alone

Robots and Remote Humans

- Completed 4 human interface experiments
 - MIT: Jen Rochlis working on visual displays
 - NASDA: Sachiko Wakabayashi working on constrained motion
 - Univ. of Houston: Lore Williams working on force feedback
 - RIT: Julie Adams working on qualitative modeling of robot health and state.
- Now upgrading interface

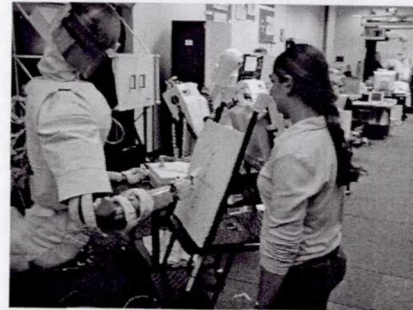


Photo of Jen (June 01)
during her experiment

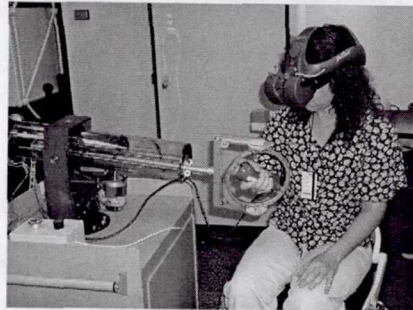


Photo of Lore (July 01)
during her experiment

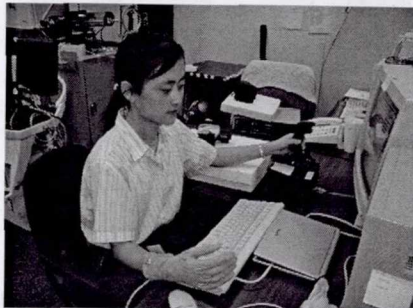


Photo of Sachiko (Nov 01)
during her experiment

Agent Interaction: Autonomous Assistant for Human

Bi-Directional
Data

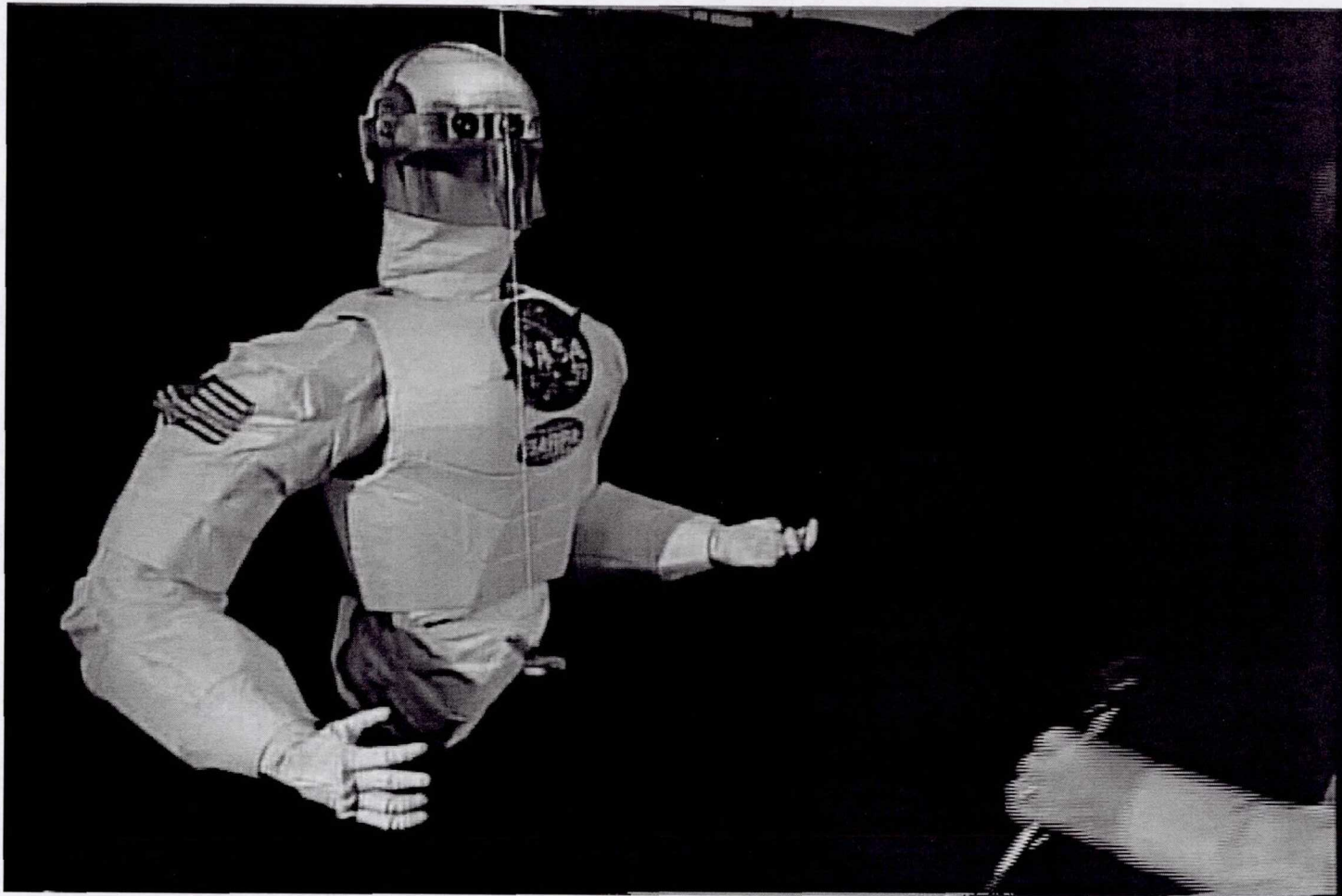


Agents interact physically
and with information flow

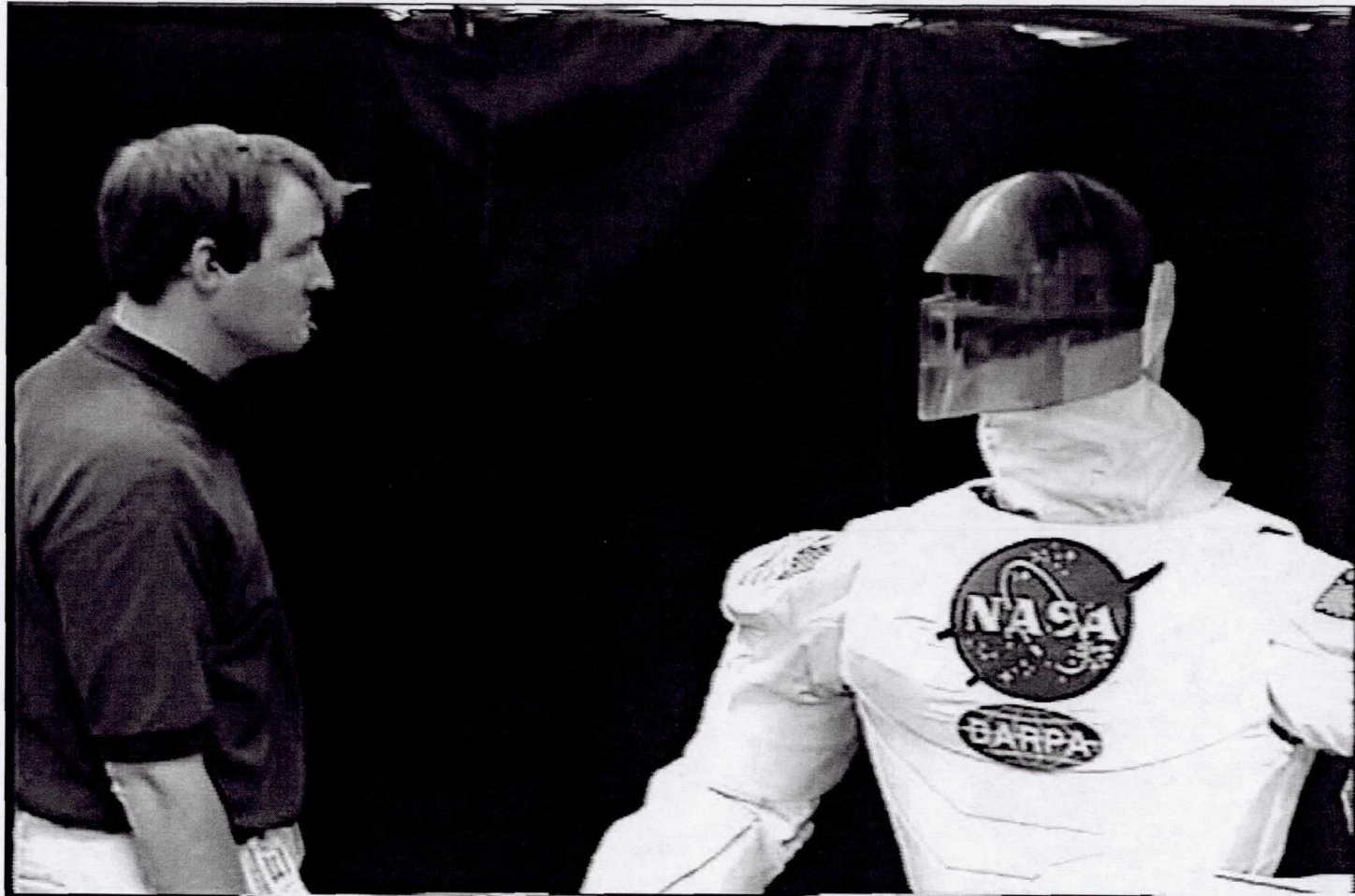


Physical
Interaction

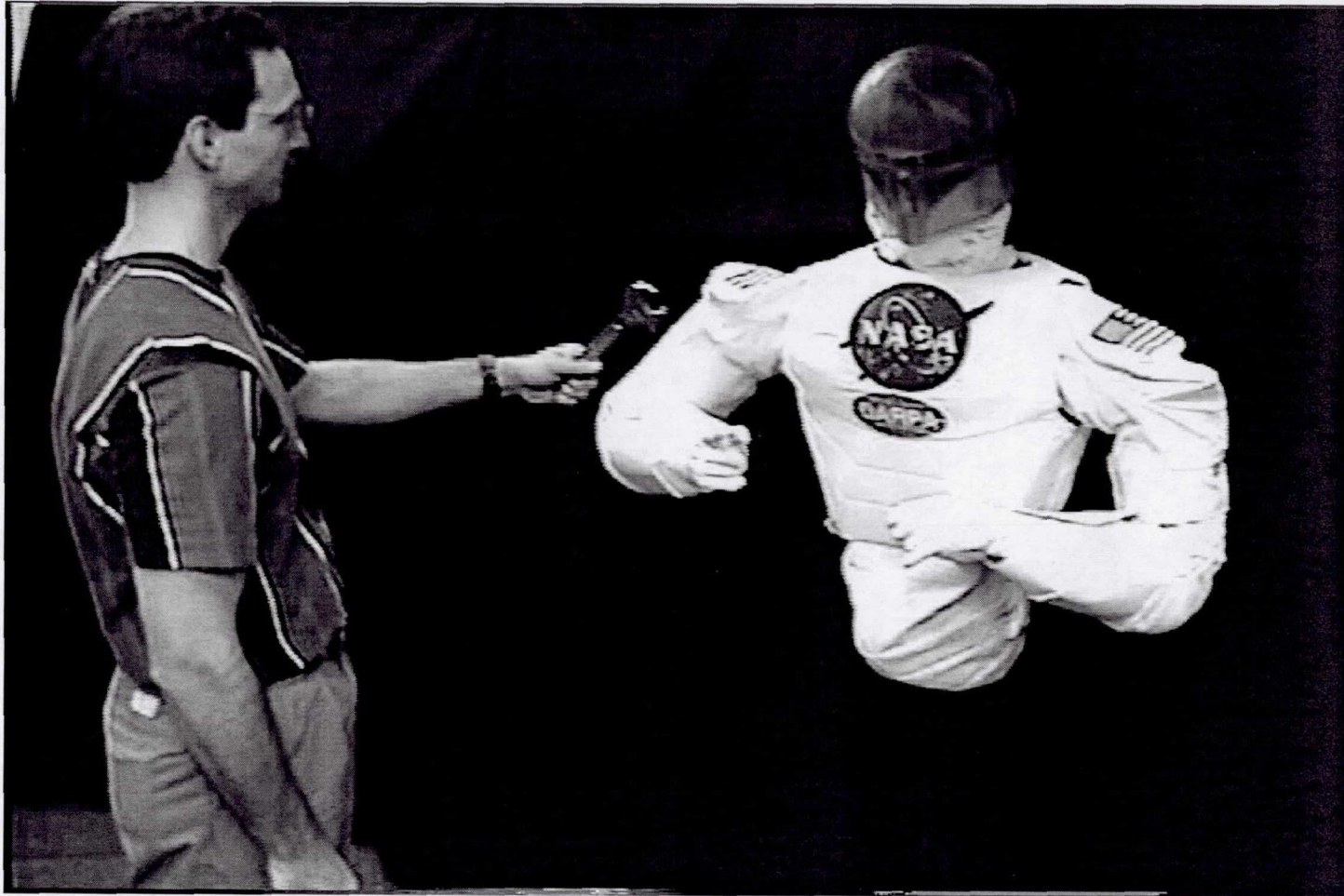
Autonomy: Handing Tool to Human



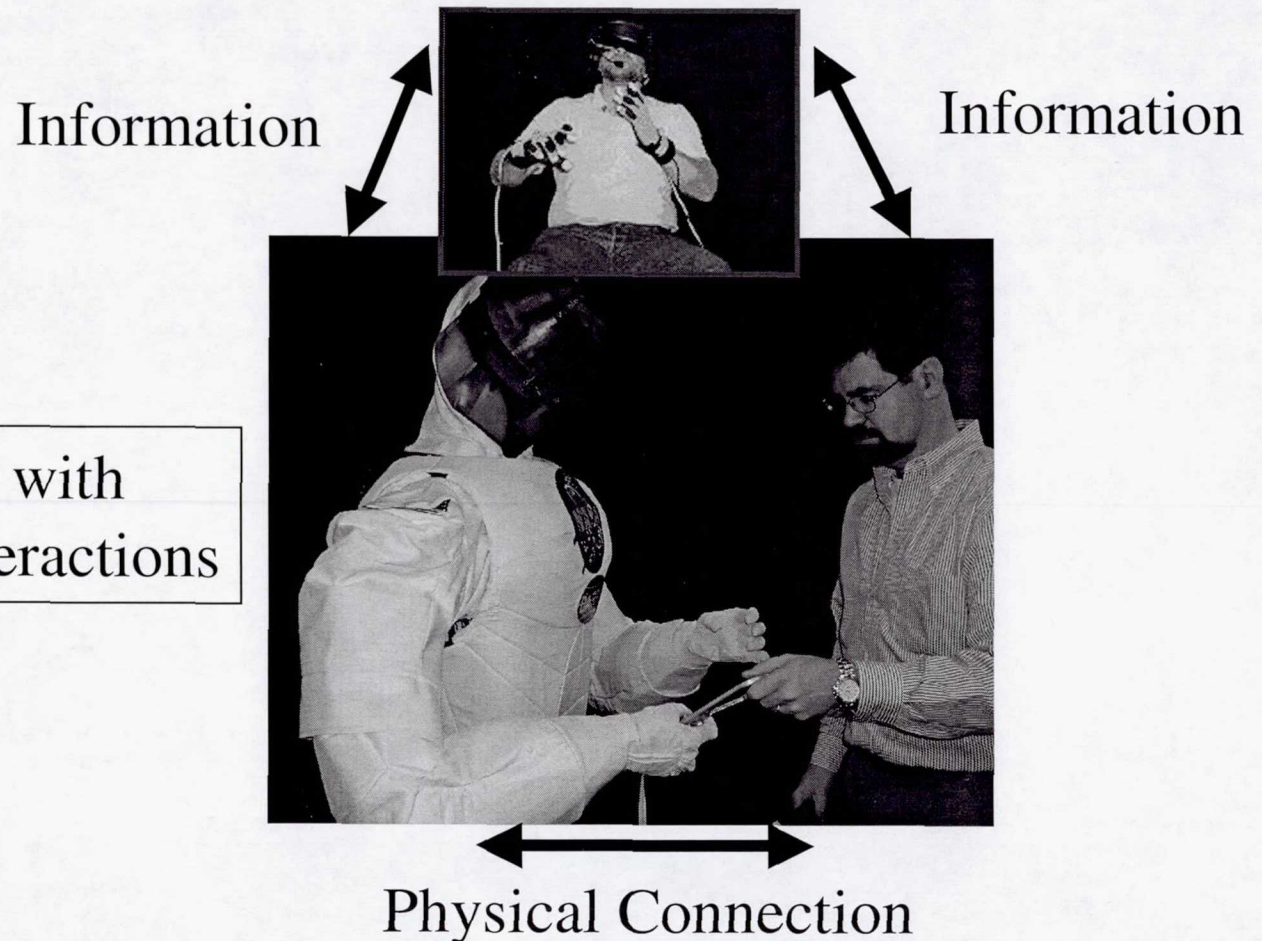
Autonomy: Human Tracking



Autonomy: Tool Tracking



Agent Interaction: Teleoperated Assistant for Human

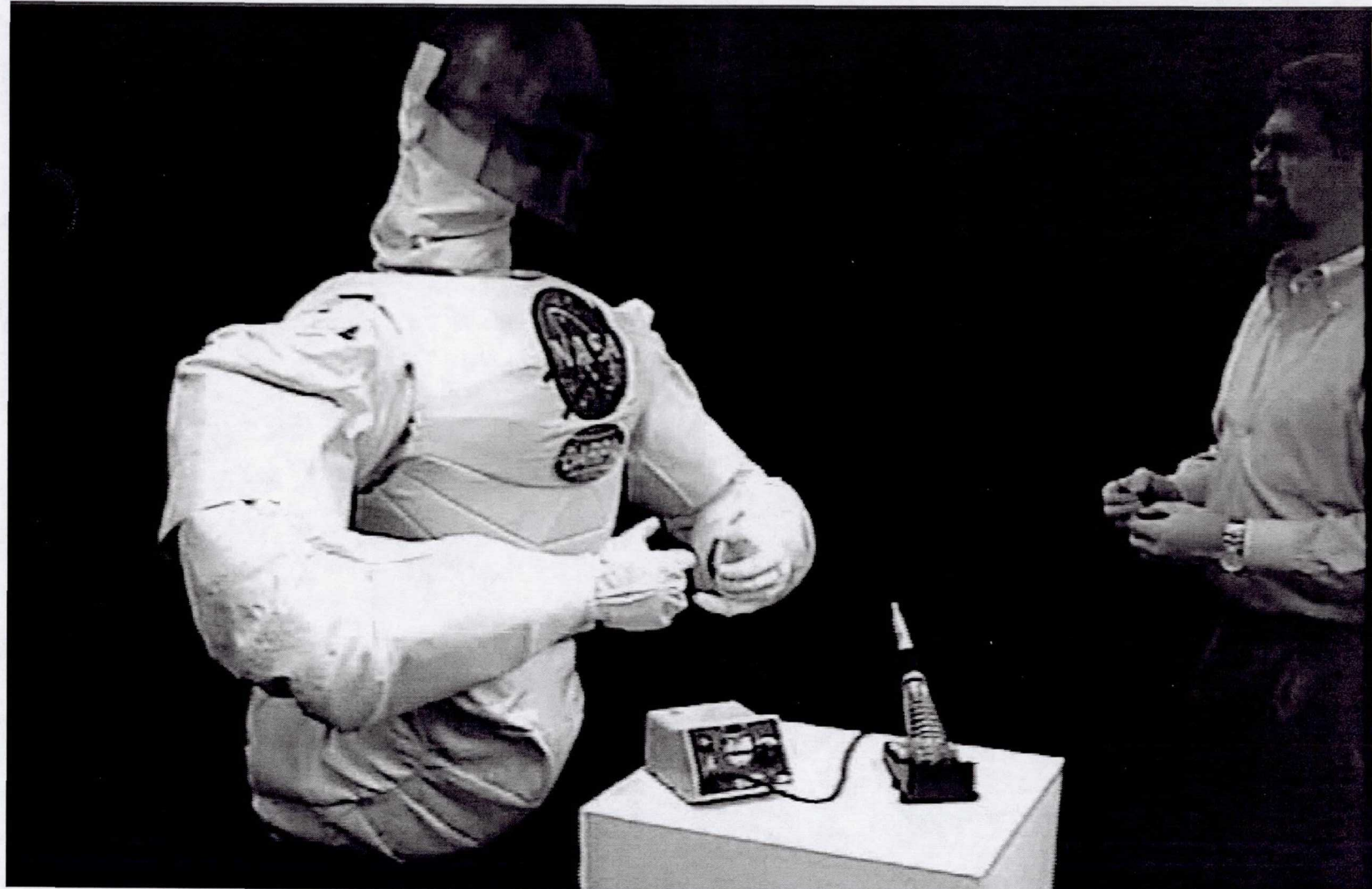


3 Heterogeneous agents with
unique, multi-modal interactions

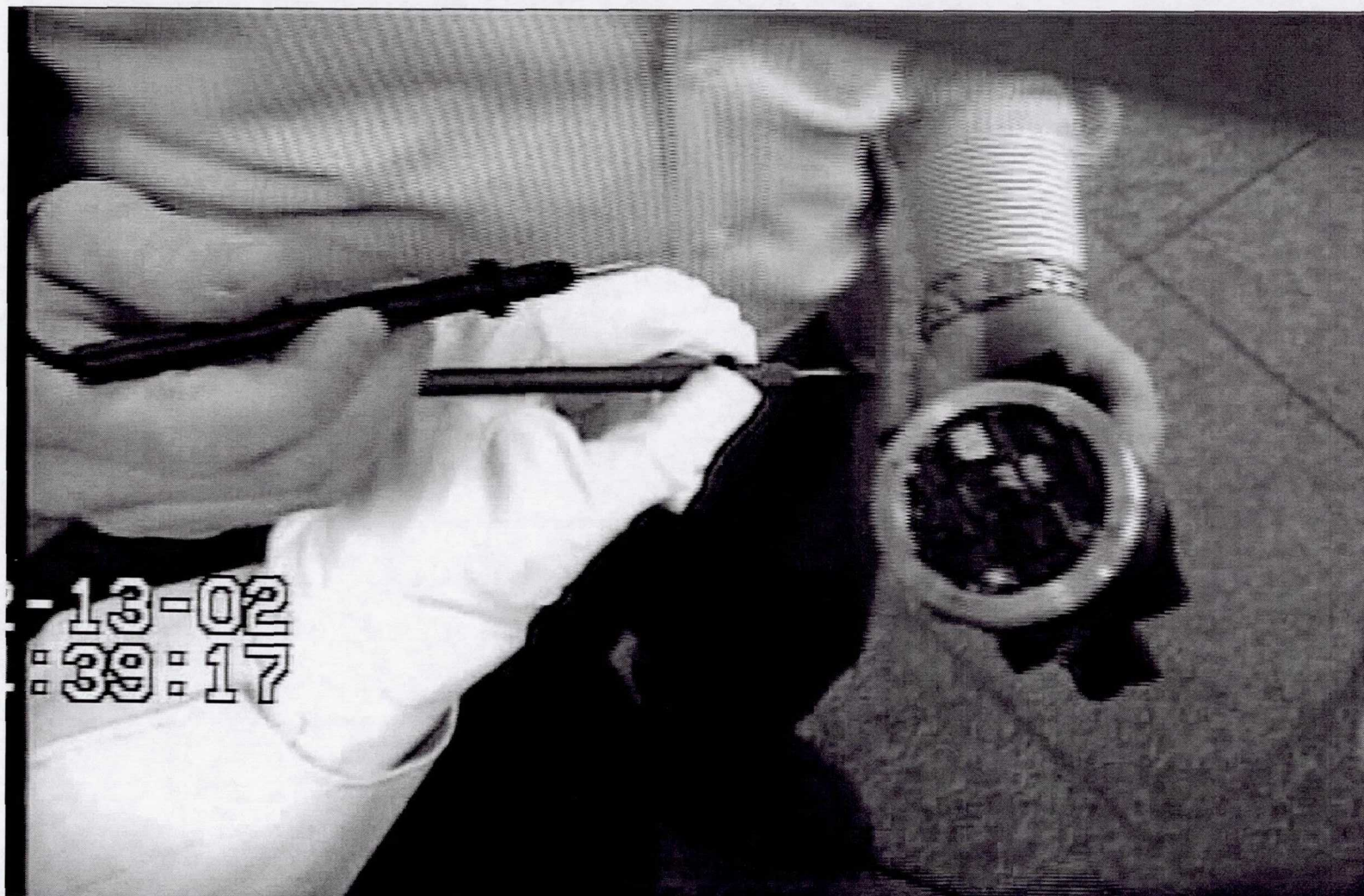
Supervised Assistant: Tether Handling



Supervised Assistant: Soldering



Supervised Assistant: Multimeter



Supervised Assistant: Construction



Agent Interaction: Supervised Assistant for Human



3 Heterogeneous agents with
unique, multi-modal interactions
and intervention levels

Information & Physical Connection

The diagram shows a person in a white protective suit with a clear face shield interacting with a man in a striped shirt. A double-headed arrow is positioned below the two figures, pointing both left and right. The text 'Information & Physical Connection' is written below the arrow.

Robonautomy

Objective:

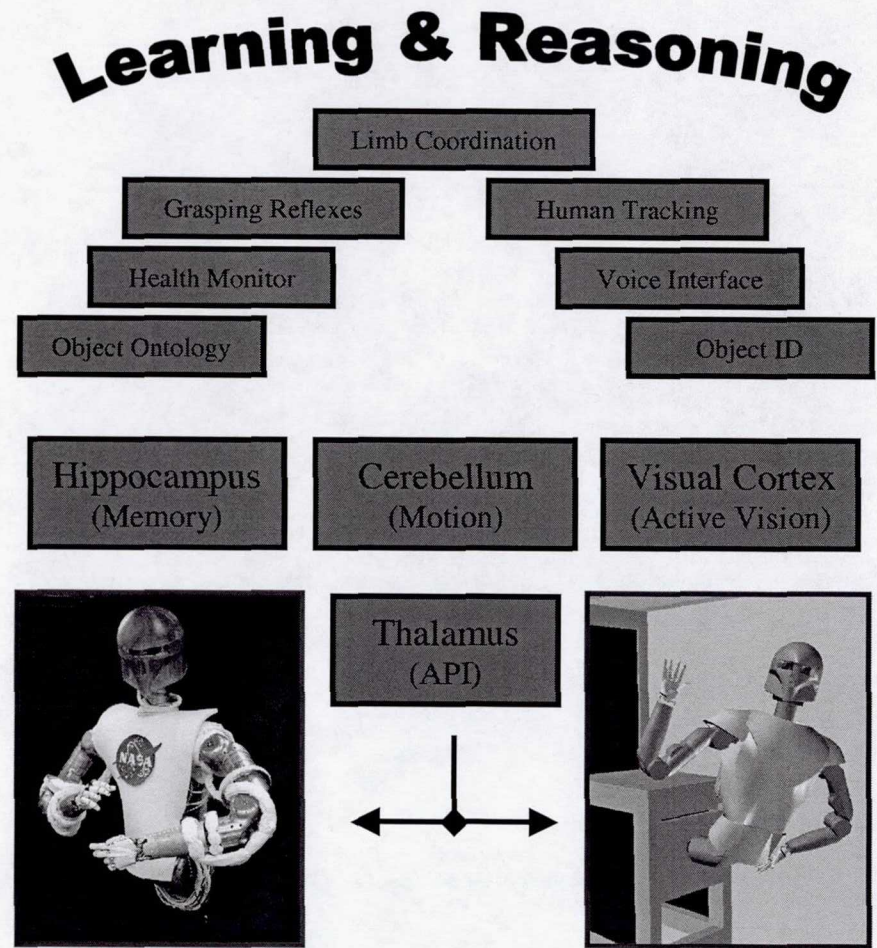
“ The automation of dexterous manipulation for *ROBONAUT* class humanoids, allowing supervisory levels of command from adjacent human team mates.”

Motivation:

- Characteristic distances in space limit information flow needed for interaction.
- Enable more work with a small, in situ workforce

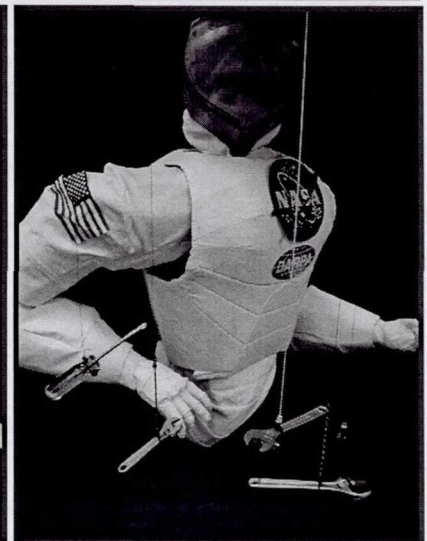
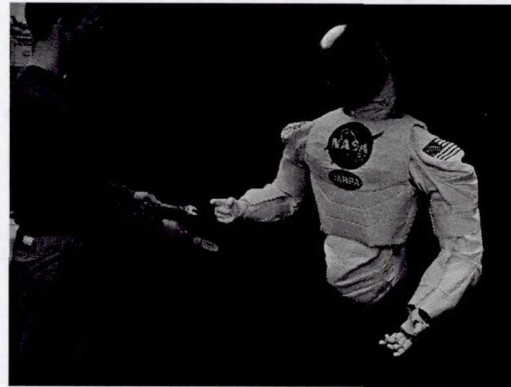
Distributed Approach for R&D

- Avoid R&D constraints
 - Packaging
 - OS incompatibilities
 - Power, Comm, Hardening
- Enable collaboration
 - Open to HW/SW spectrum
 - Provide I/O pathways
- Functional Lobes
 - Vision
 - Grasping
 - Data storage
 - Motion coordination
 - Sensor I/O



Robonautomy: Vision

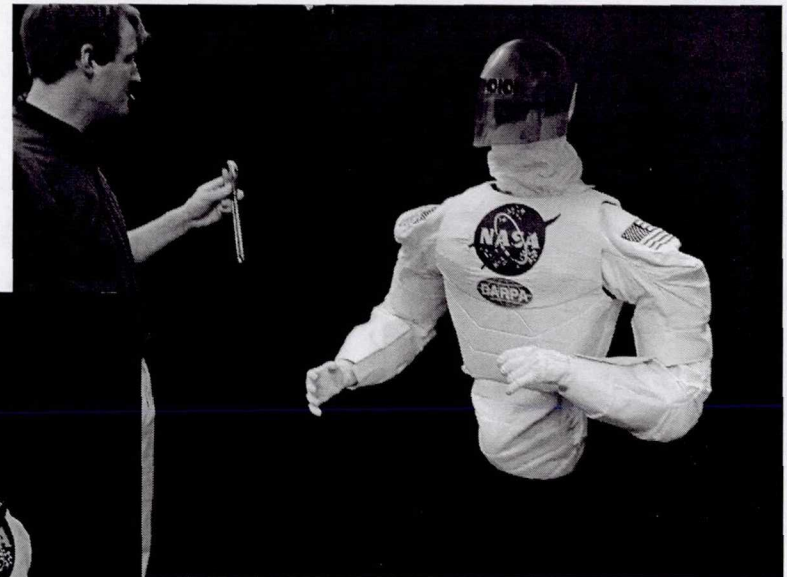
- Human tracking
 - Human identification
 - Limb tracking
- Object Tracking
 - Tool identification
 - Tool pose estimation
 - Tool occlusion
- Integration
 - Integrated with SES
 - Integrated with motion control
 - Integrated with eyes



Recent FY02 Advances



Search for and find a tool,
partially occluded by a hand



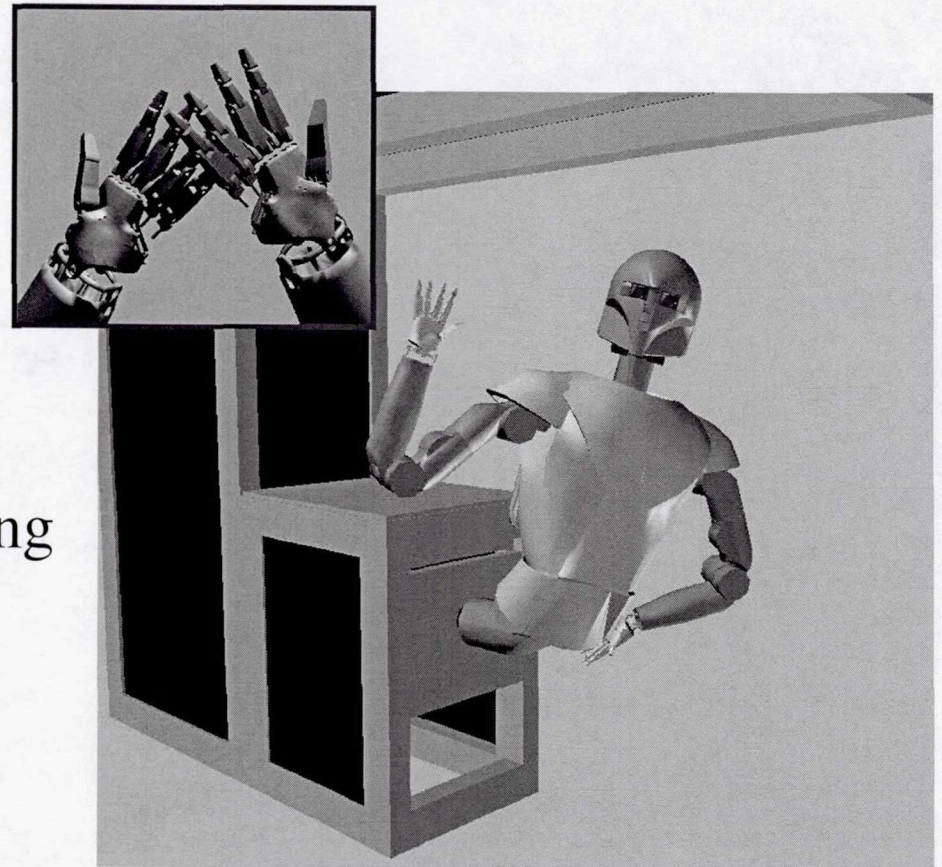
Give and take a tool from a
human commander



Find a tool within a field of
many tools

Collaboration

- RoboSIM & RoboAPI
- DARPA Partners
 - Vanderbilt (SES integrated)
 - UMass (Grasping in progress)
 - Invitations offered
 - USC, MIT, over 20 others
- NASA has avenues for teaming
 - Summer faculty programs
 - Graduate student fellowships
 - Coop and Intern programs



Screen shot of ROBONAUT Simulation running on PC

The *ROBONAUT* Team

