A Robot Supervision Architecture for Safe and Efficient Space Exploration and Operation

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Carnegie Mellon

THE ROBOTICS INSTITUTE

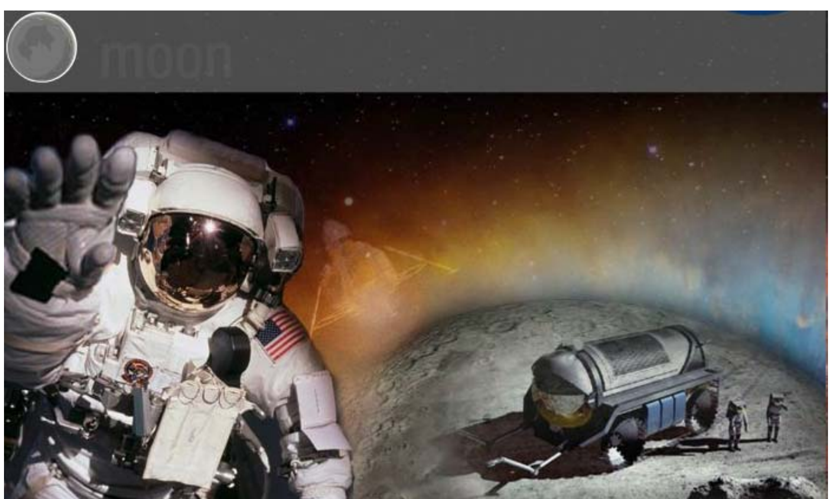
Outline

- Motivation
- State of the Art – Current and Desired
- Robot Supervision Architecture Overview
- Current System Implementation
- Conclusions and Future Work

Motivation

Motivation

- Jan. 2004 Vision for Space Exploration
  - Extend human presence across the solar system and beyond
  - “NASA will increase the use of robotic exploration to maximize our understanding of the solar system and pave the way for more ambitious manned missions.“



Motivation

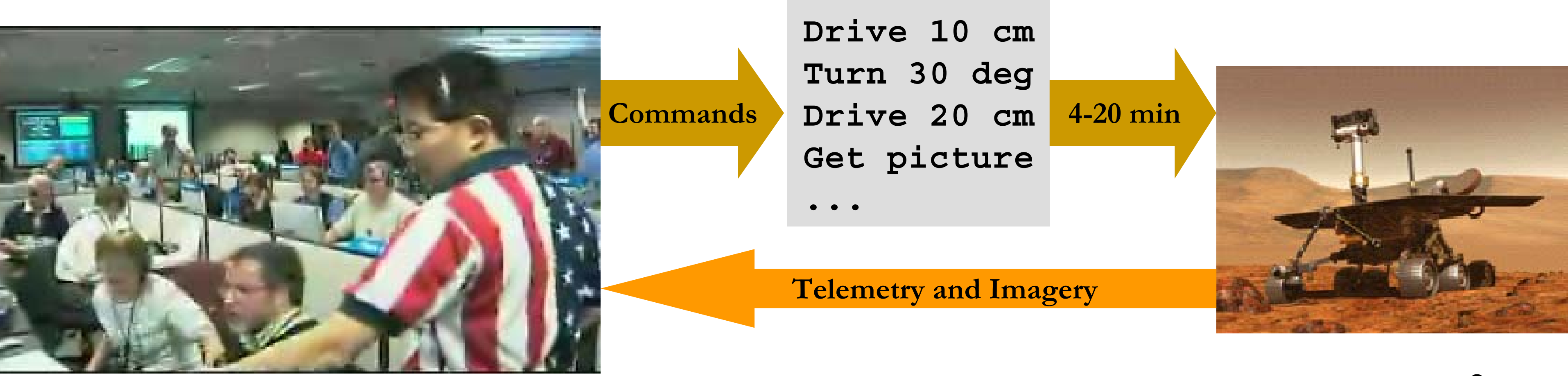
- Robotic missions will be used for:
  - Identification and preparation of a safe landing site
  - Placement of communications, power, and other infrastructure
  - Searching for resources (oxygen, hydrogen, water ice, minerals, etc.)
- These robotic missions will provide the means for a safe and successful human mission back to the Moon and beyond

State of the Art

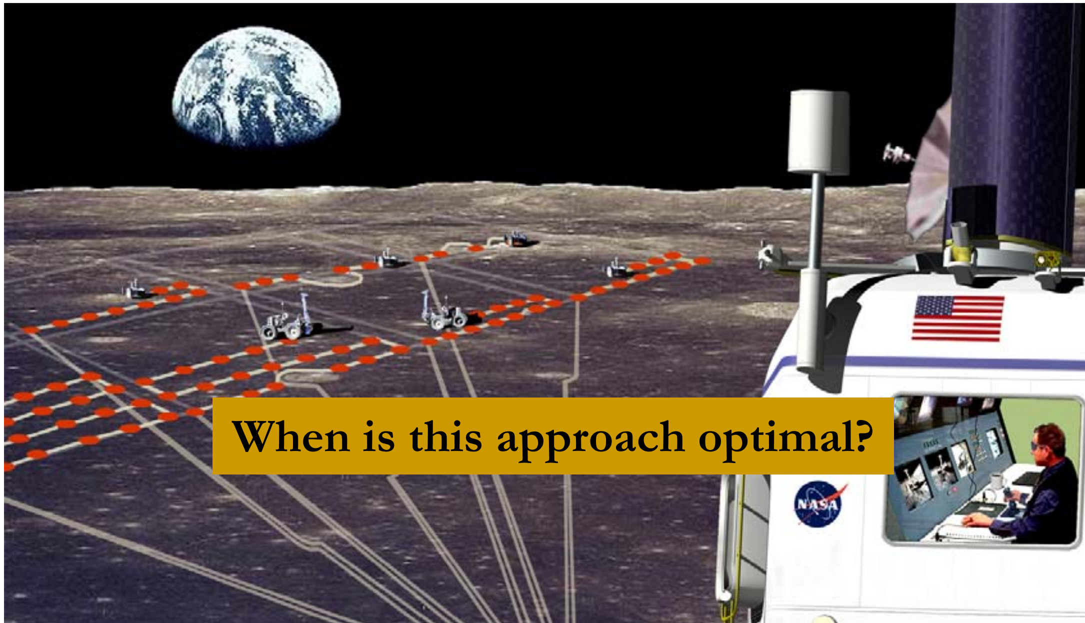
Robotic Space Exploration: State of the Art

- **Mars Exploration Rover** mission is currently the most successful robotic space exploration
- Rovers logged over 12 km in 1,100 sols

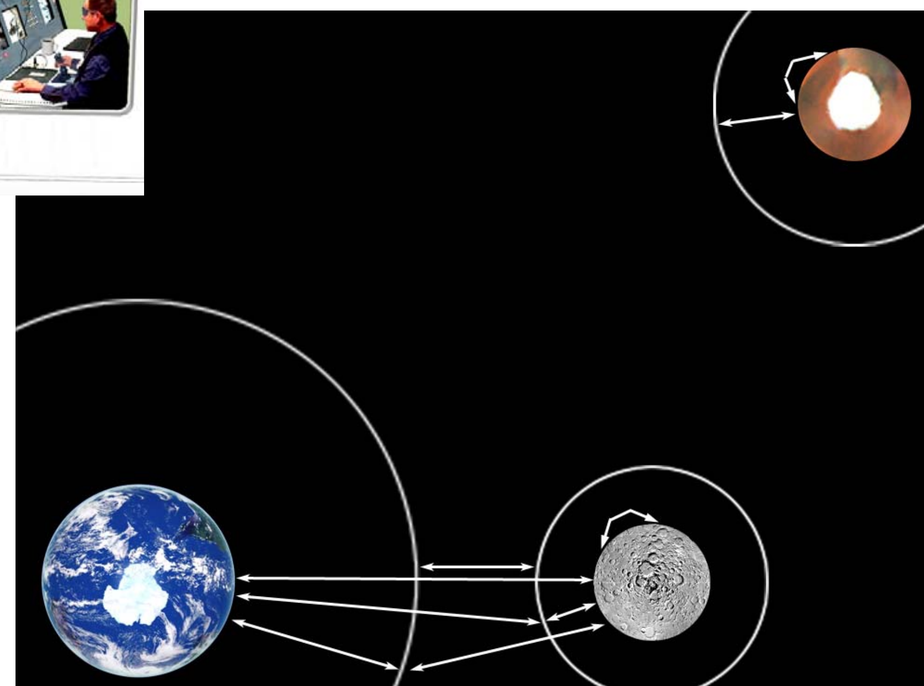
- Each rover relies on a team of 20+ highly skilled professionals
- Communication delays only allow for operating a rover by issuing a daily sequence of control commands
- "It's like trying to drive a car by writing a computer program…" Dr. Ashley Stroupe



Desired State of the Art



Robots operate as autonomously as possible, requesting assistance when necessary; the telesupervisor can teleoperate any robot with high-fidelity telepresence



Humans and robots are "near" (within ¼ light-seconds)

Goals

- **Develop a robot supervision architecture** for human supervision of a fleet of autonomous robots
- **Demonstrate the architecture's feasibility and usefulness in a complete working system**
- **Measure the performance improvement the architecture provides**

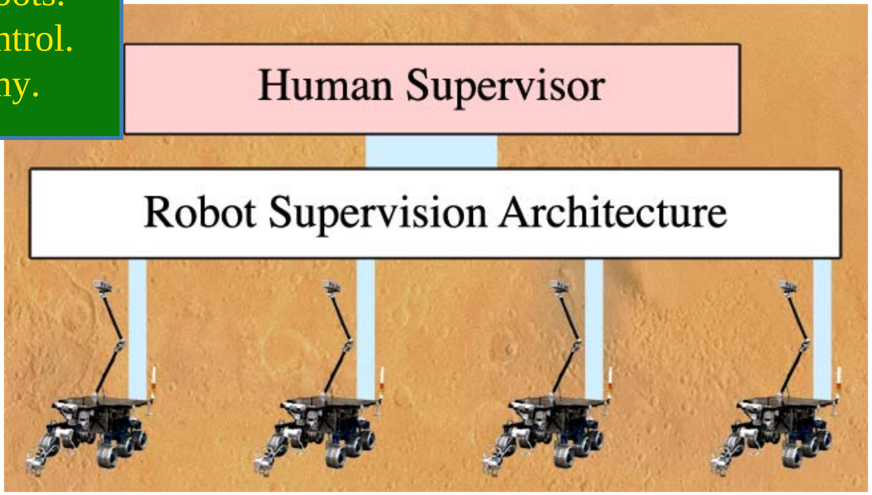
Robot Supervision Architecture (RSA)

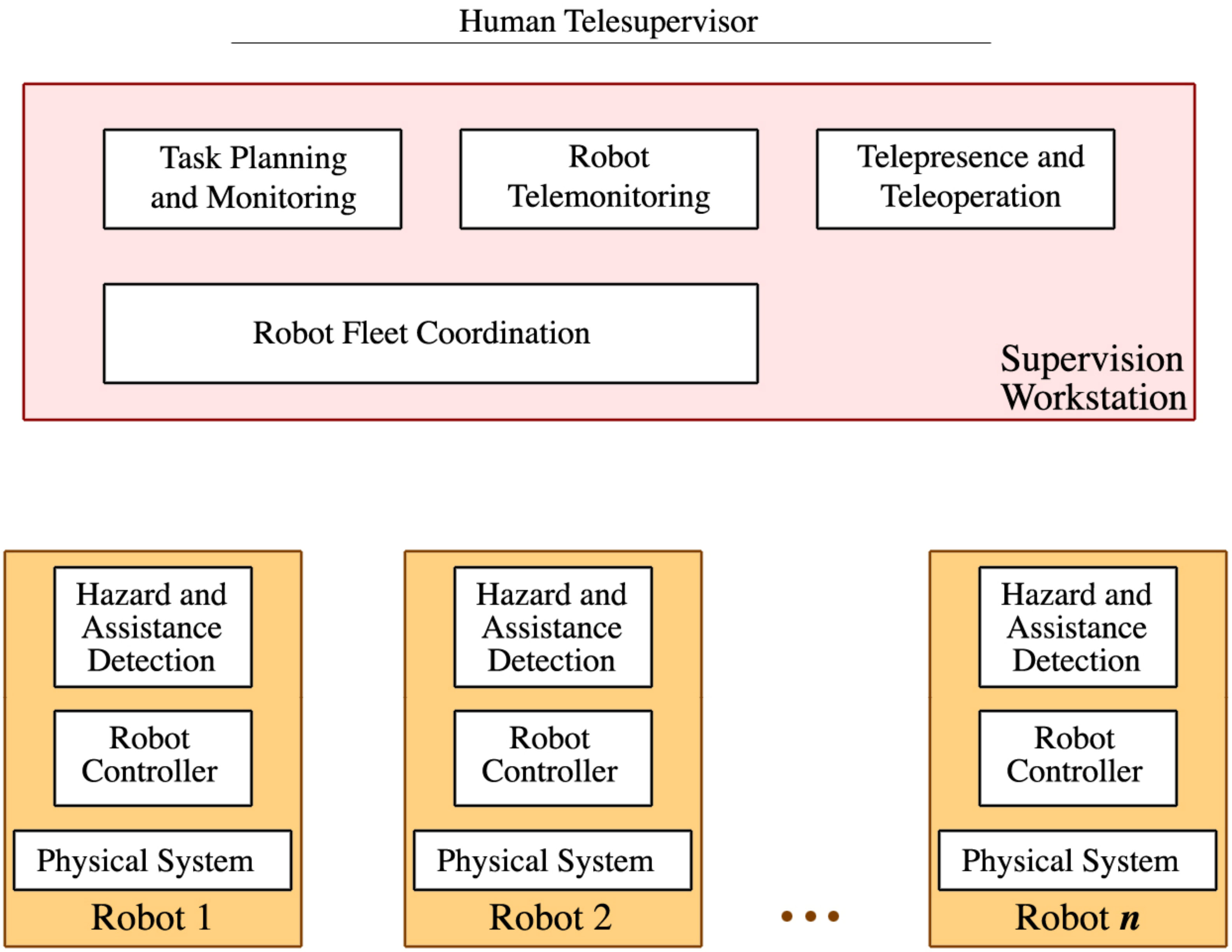
RSA Paradigm

Robot Autonomy

Human Control

	NO	YES
NO		**Full Autonomy** (1980s-2000s) • No human. • Autonomous robot control.
YES	**Telerobotics** (1950s-1980s) • One human, one robot. • Low-level human control.	**Supervised Autonomy** • One human, many robots. • High-level human control. • *Partial* robot autonomy.




Human Telesupervisor
Task Planning and Monitoring
Robot Telemonitoring
Telepresence and Teleoperation
Robot Fleet Coordination
Supervision Workstation
Hazard and Assistance Detection
Robot Controller
Physical System
Robot 1
Hazard and Assistance Detection
Robot Controller
Physical System
Robot 2
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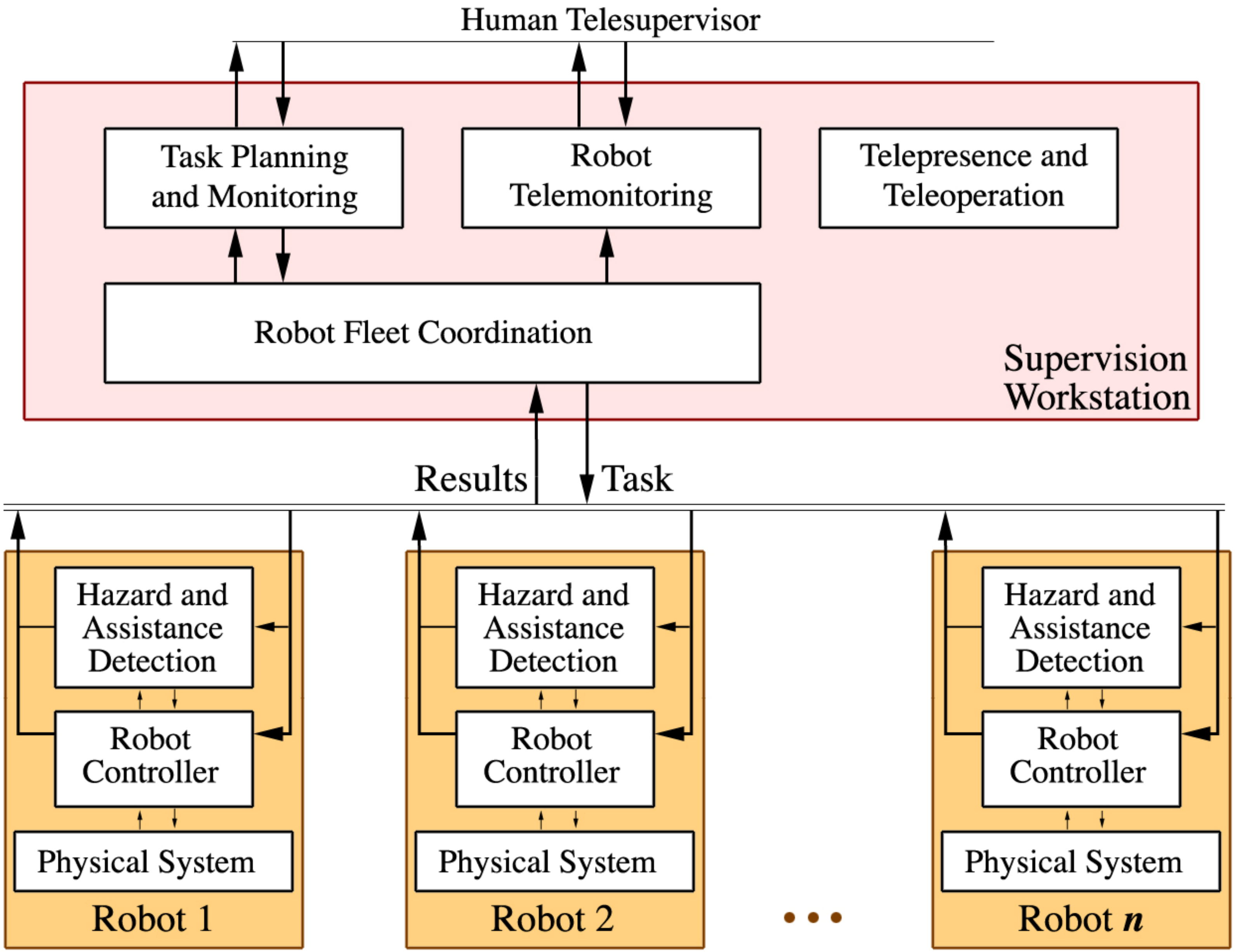
Hazard and Assistance Detection
Robot Controller
Physical System
Robot *n*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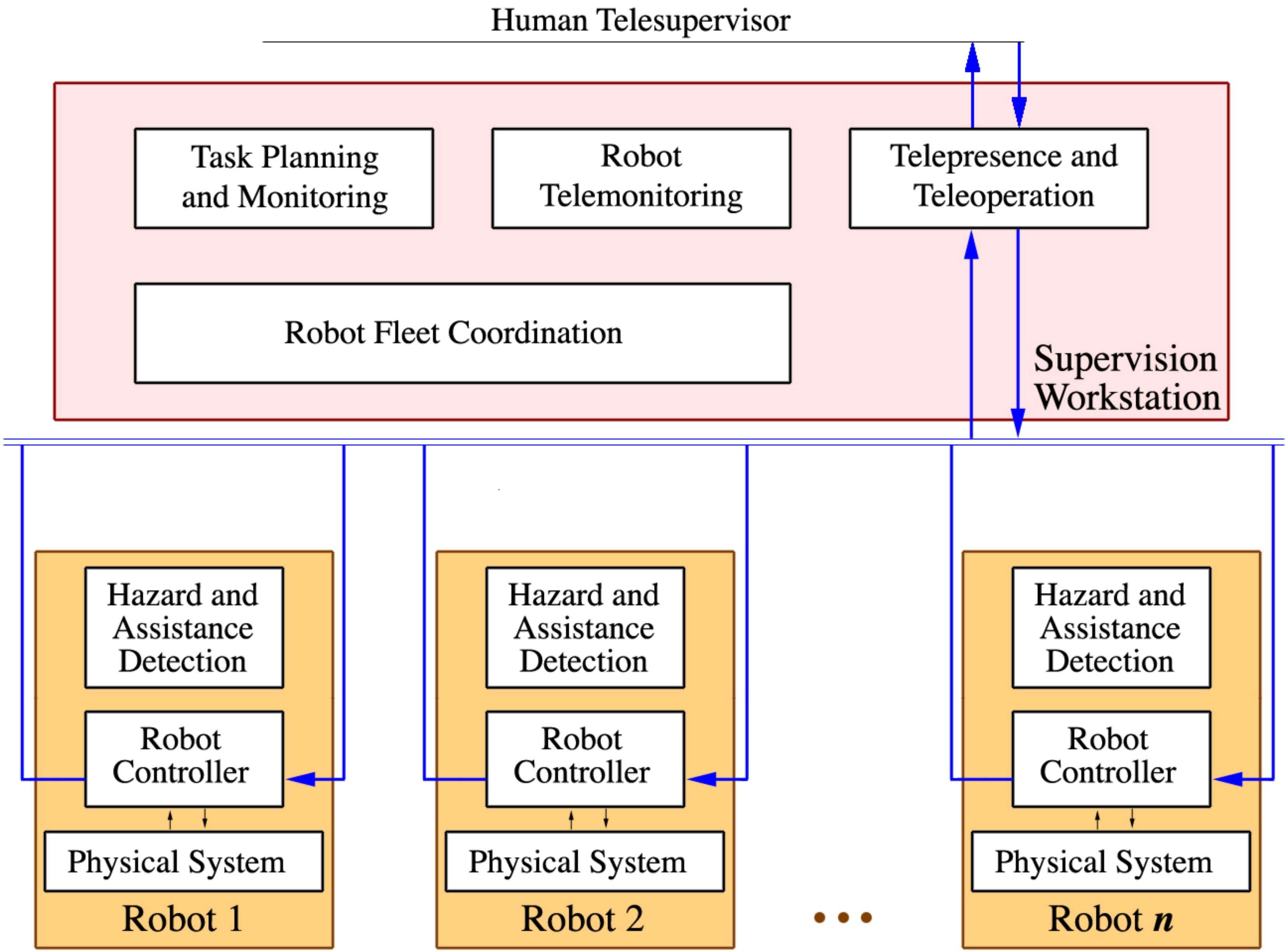

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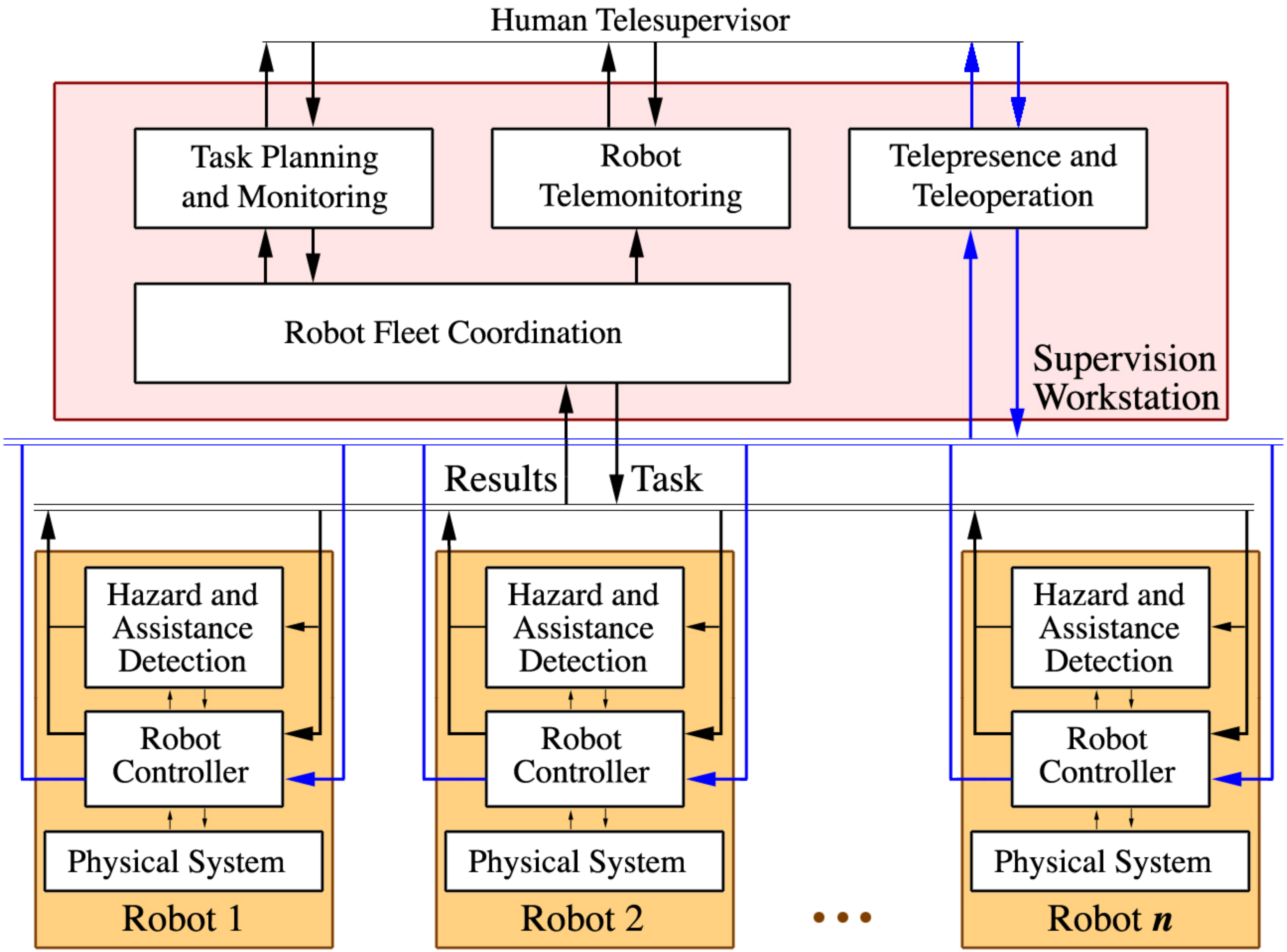
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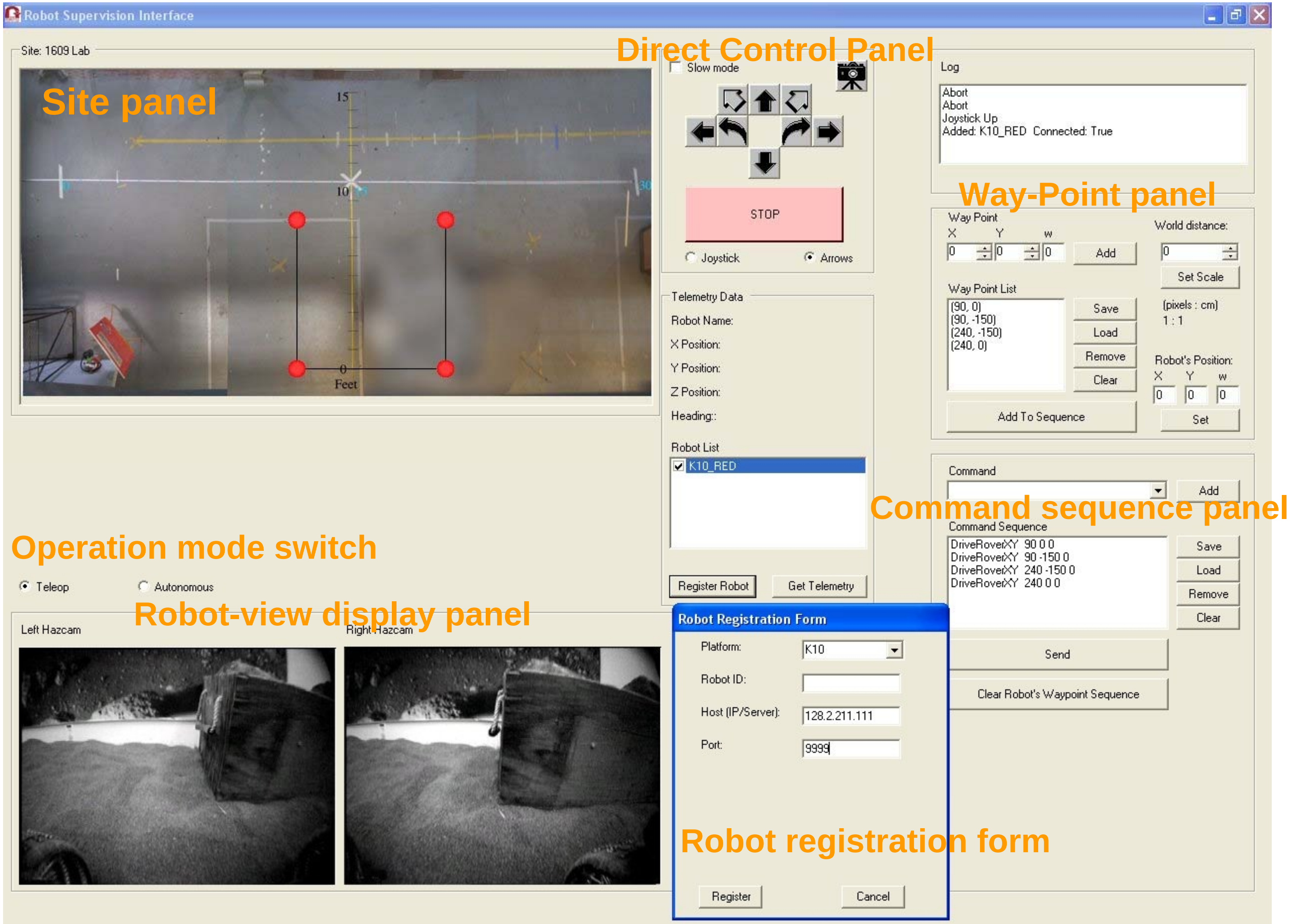
Current System Implementation

Telesupervisor Workstation

• Design goal: Provide an easy-to-use user interface for task planning and monitoring, and robot fleet teleoperation

Task Planning and Monitoring Tool

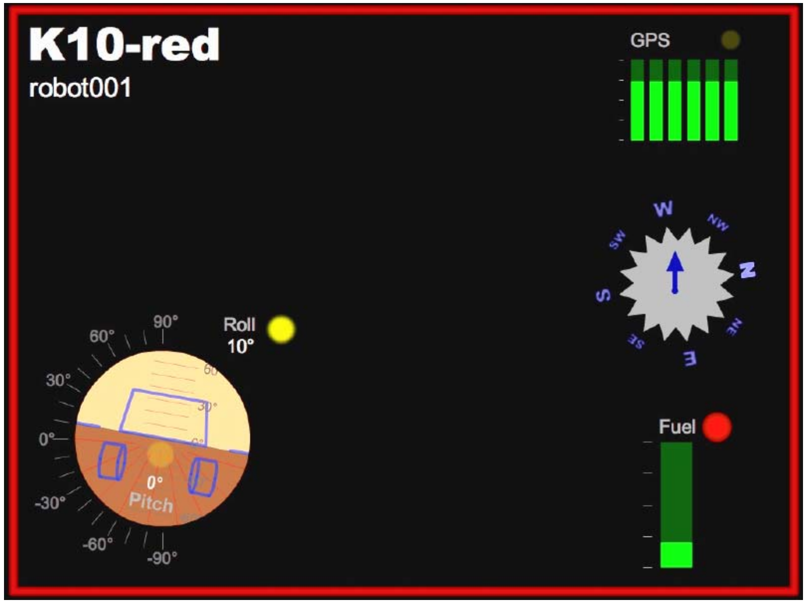


Telepresence

- Provide telepresence capability by faithfully reproducing a view analogous to that viewed by the uninstrumented eyes

Robot Telemonitoring

- Dashboard client provides a real-time graphical representation of robot state information
- Robot state information is stored in XML format
- Information files are accessible to any client in the local network



Robotic Platforms

SRR

K10

Experimental Results

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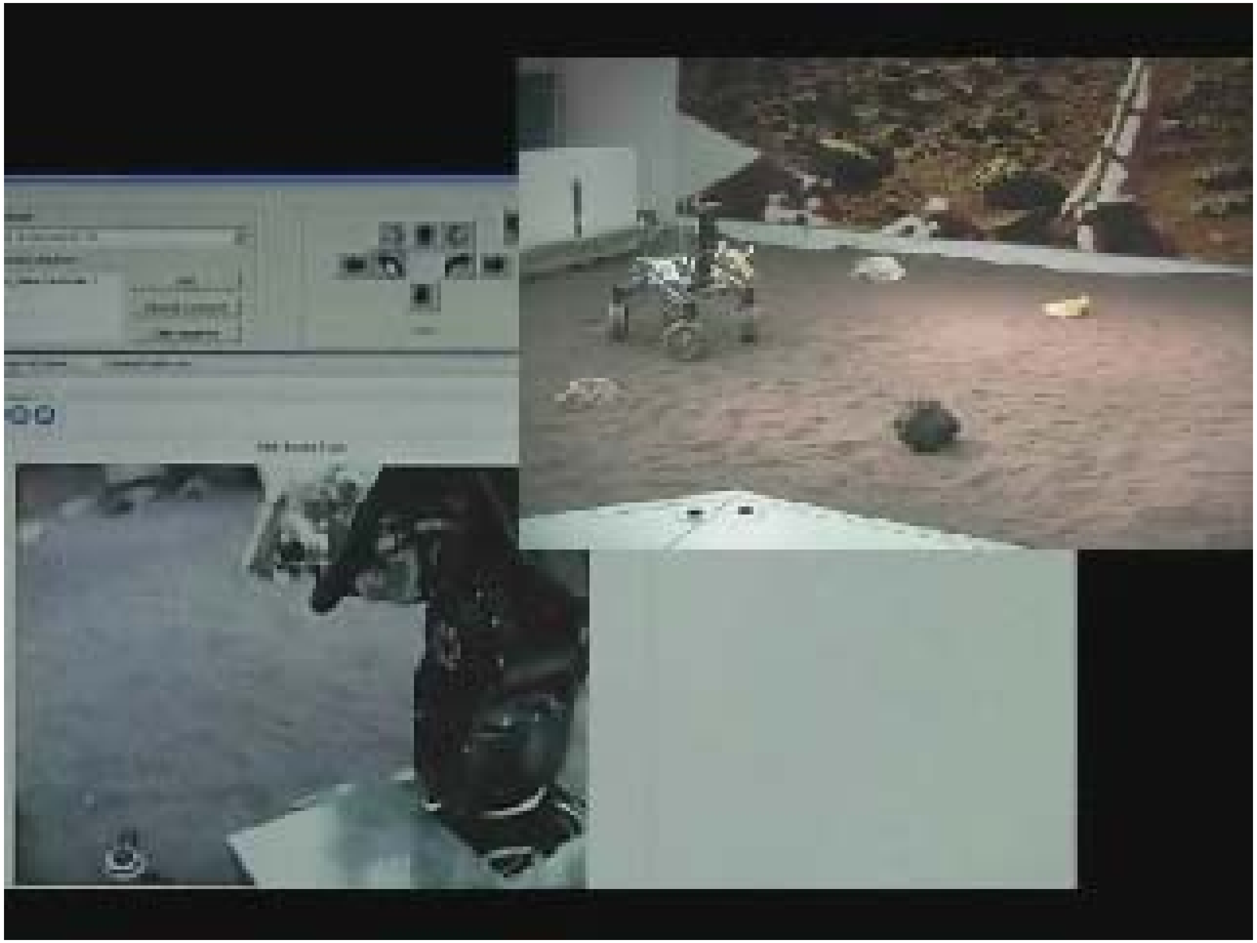
Objectives

1. Build expertise in aspects of telepresence / teleoperations

2. Establish end-to-end web-based teleoperation to drive development of RSA modules

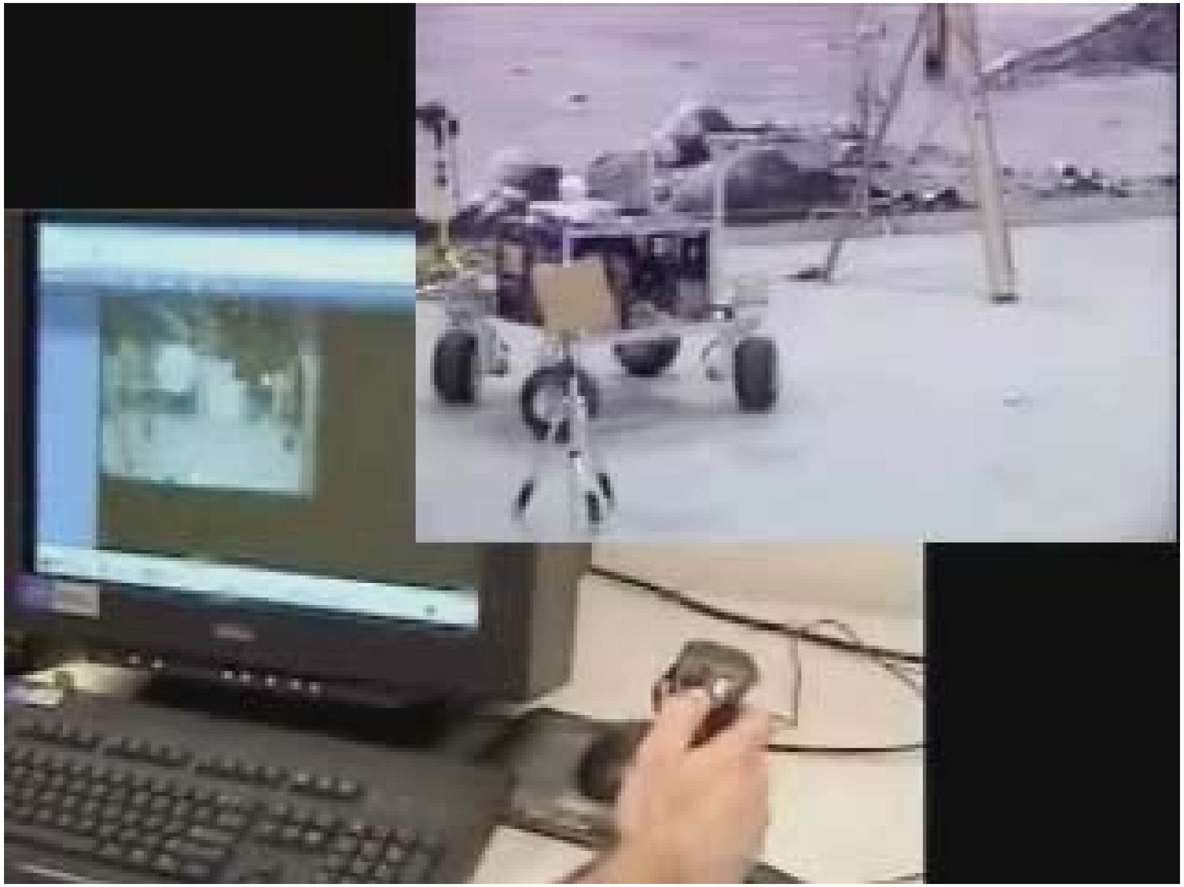
Teleoperation of SRR at NASA JPL

- Using a control GUI at CMU we guided an SRR to three target rocks in JPL’s sandbox
- Real-time coast-to-coast teleoperation experiment



Teleoperation of K10 at NASA ARC

- Using a joystick at CMU we guided a K10 rover to three targets at ARC's Moonscape
- Excellent system responsiveness despite varying latency and relatively low bandwidth



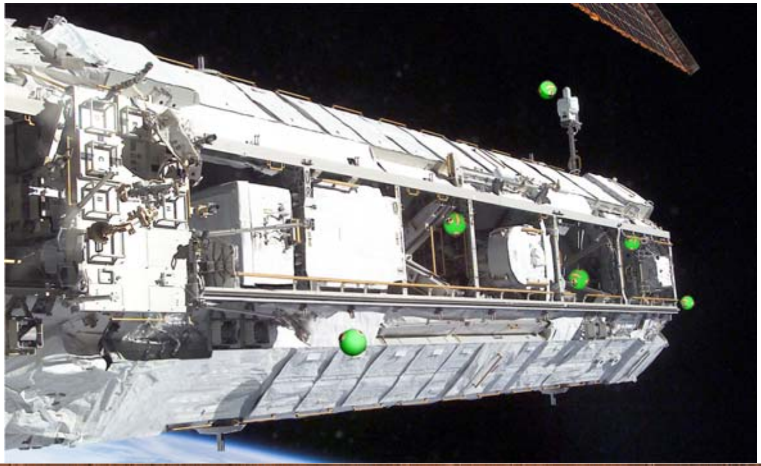
Conclusions and Future Work

Conclusions

- Initial implementation of RSA modules successfully supports remote operation of heterogeneous robot platforms.
- Provides a solid infrastructure upon which we can continue our ongoing effort to deliver the means to perform significant science and space exploration.

Future Work

- Complete year 1 demonstration with 4 robots deployed in the field
- Assess the increase in efficiency and safety provided by the architecture
- Extend concept to other applications (e.g., space inspection and maintenance, robotic search and rescue)



Thank you.