Human-Robot Planetary Exploration Teams

Purpose of Human-Robot Teams

- JSC projects

Field Testing

- Locations
- Functionalities

Agent Communication & Safety

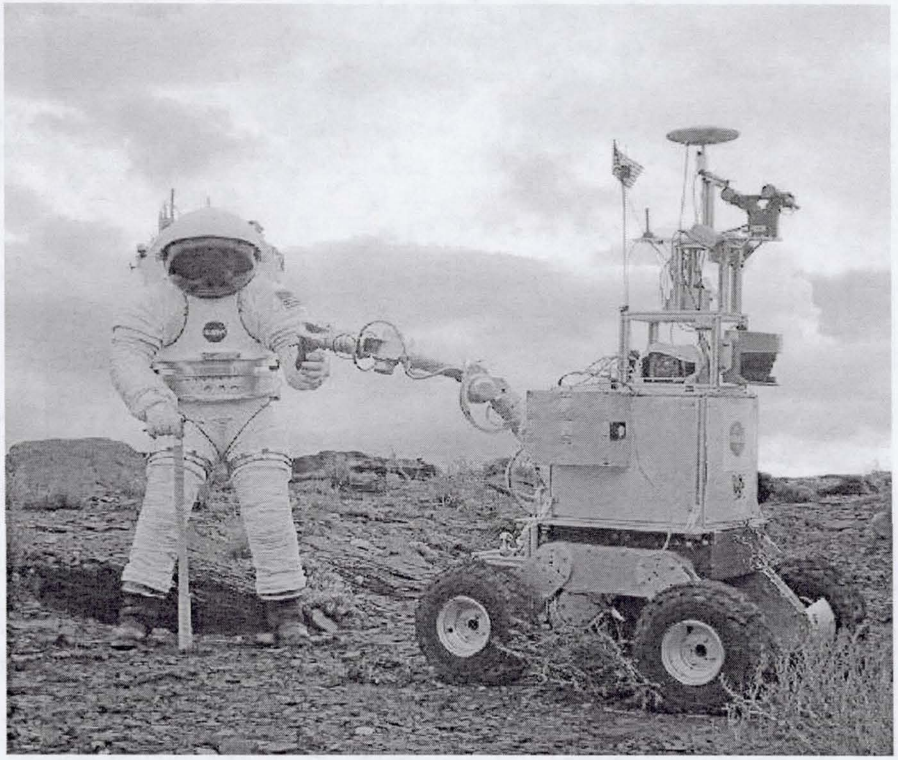
Human-Robot Teams

Planetary exploration will need both robots and humans

- Humans provide the adaptability for handling new situations
- Robots provide automation for dangerous and/or repetitive jobs
- Robots are tools for extra sensing and computing capabilities

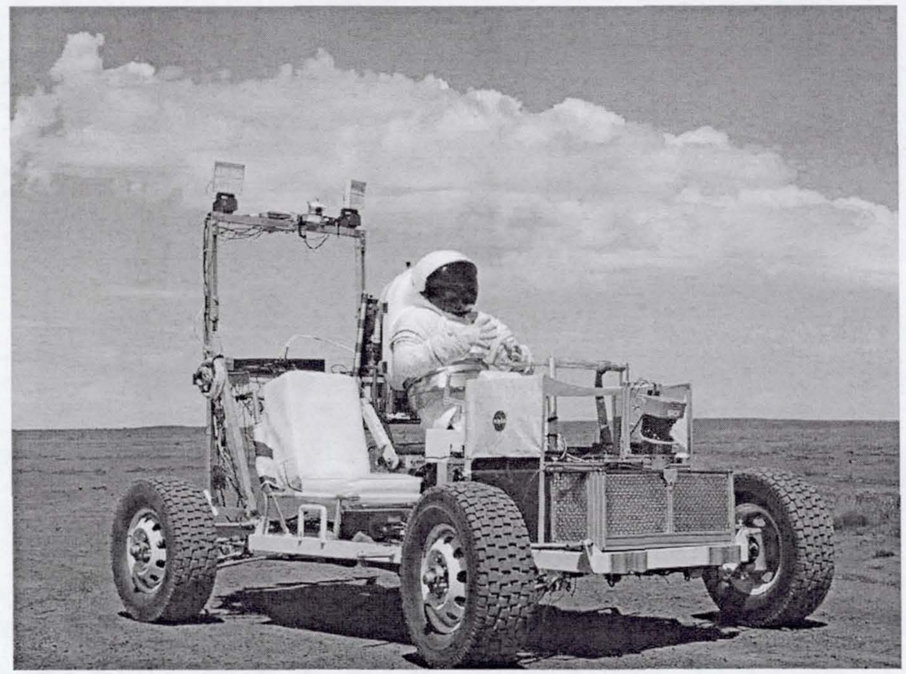
EVA Robotic Assistant

- Goals
  - Testbed for studying human-robot interaction
  - Test platform for multiple research groups
  - Development of modular software architecture
- Hardware
  - GPS, laser rangefinder, dmu, multiple cameras, 7-DOF arm, 3-finger hand, wireless ethernet, laptop computers, rigid suspension



SCOUT

- Goals
  - Develop semi-automated astronaut surface transport
  - Testbed for engineering divisions' hardware
- Hardware
  - First year used original Apollo Lunar Rover trainer
  - Now fabricating a new vehicle
  - Most autonomy systems/hardware from ERA being ported to SCOUT



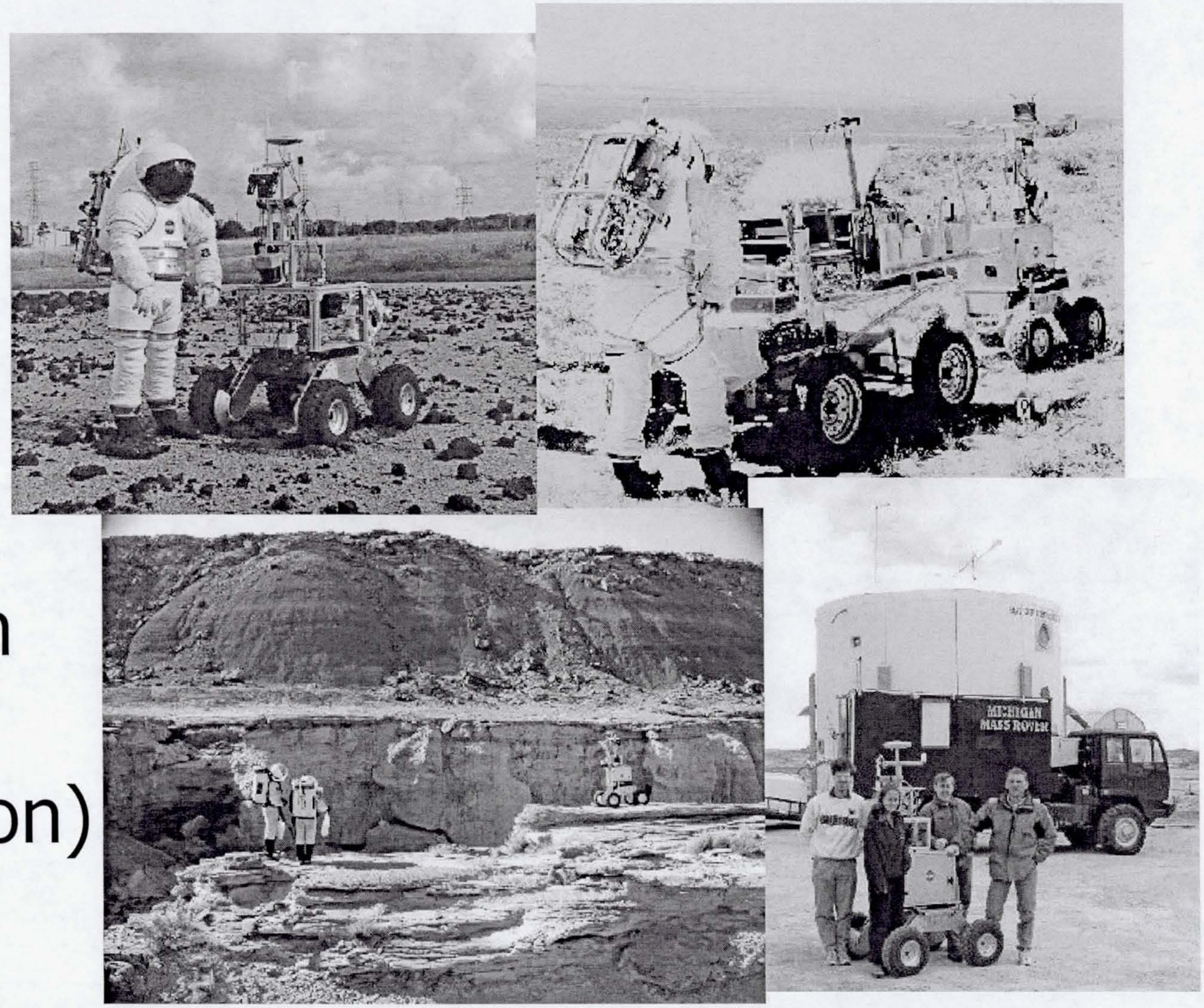
Field Testing - Locations

JSC Rock Yard

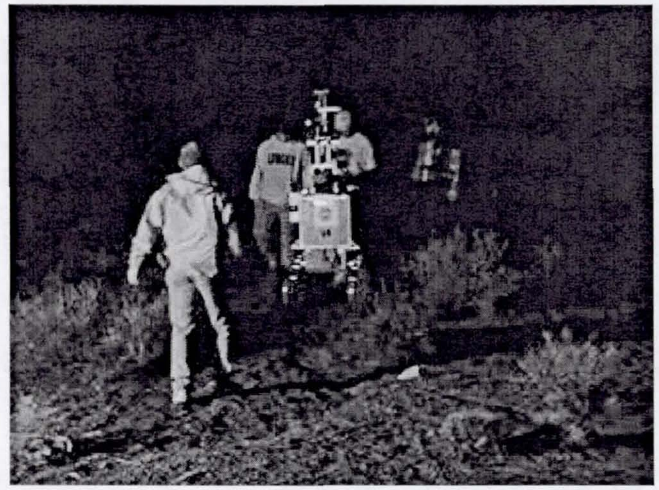
Arizona

- Meteor Crater
- Joseph City
- Others

Hanksville, Utah (Mars Desert Research Station)



Field Test Movies



Geophone deployment

Night time laser tracking run

Field Testing - Functionalities

- Tracking of astronauts
  - Stereo vision
  - Laser rangefinder
  - Differential GPS
- Driving to waypoints
- Coverage patterns
- Deployment
  - Geophones or other science instruments
  - Flexible solar panel
  - Power cable
- Path planning
- Obstacle detection and avoidance
- EVA monitoring
  - Location
  - Mission elapsed time
  - Spacesuit health
- Imagery
  - Snapshots
  - Panoramas
- Data recording

Agent Communication

When humans and robots are working within the same space, safety is a primary concern.

Reliable communication between agents (humans and robots) is one way to improve safety.

Unreliable communication is a reason to have more robotic autonomy:

- Shorter commands are more likely to get through, and require less detail and less bandwidth
- Desired behavior can continue despite temporary comm dropouts (as opposed to teleoperation)

Communication Modes

- Voice – primarily for mode changes, limited behavior alterations (e.g. speed), emergency commands
  - Pros: natural command method, astronaut can control robot while both are in the field, short-range comm
  - Cons: difficult to parse voice when in a spacesuit, limited detail possible
- Gesture – primarily for directional indications, item identification
  - Pros: natural command method, usable in field, provides directions not available otherwise, no comm
  - Cons: may be misinterpreted, difficult to gesture while in a spacesuit, requires considerable processing and vision system calibration, may not be detailed enough for general commands

Communication Modes

- Computer control – Graphical User Interfaces
  - Local, e.g. touchpad, wristpad
    - Pros: detailed commands, visible feedback, short-range comm
    - Cons: hard to press buttons while in a spacesuit, have to carry around or mount a display, keyboard and/or touch screen, limited space on small display
  - Remote, e.g. habitat or mission control computers
    - Pros: more detailed commands, visible feedback
    - Cons: long range comm needed, may be unreliable, unable to see what is happening, or at least limited sensory information

Conclusions

We use a combination of communication modes, and autonomy whenever possible, in order to increase reliability and robustness to comm problems.

Additional safety measures are in place to assure safe behavior when comm is interrupted, such as a remote heartbeat (for loss of comm during computer control) and a remote kill switch (for other control issues and errors).

Contact Info

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Or, see our website at http://www.jsc.nasa.gov/er/era

Human-Robot Planetary Exploration Teams

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The EVA Robotic Assistant (ERA) project at NASA Johnson Space Center studies human-robot interaction and robotic assistance for future human planetary exploration. Over the past four years, the ERA project has been performing field tests with one or more four-wheeled robotic platforms and one or more space-suited humans. These tests have provided experience in how robots can assist humans, how robots and humans can communicate in remote environments, and what combination of humans and robots works best for different scenarios. The most efficient way to understand what tasks human explorers will actually perform, and how robots can best assist them, is to have human explorers and scientists go and explore in an outdoor, planetary-relevant environment, with robots to demonstrate what they are capable of, and roboticists to observe the results. It can be difficult to have a human expert itemize all the needed tasks required for exploration while sitting in a lab: humans do not always remember all the details, and experts in one arena may not even recognize that the lower level tasks they take for granted may be essential for a roboticist to know about. Field tests thus create conditions that more accurately reveal missing components and invalid assumptions, as well as allow tests and comparisons of new approaches and demonstrations of working systems.

We have performed field tests in our local rock yard, in several locations in the Arizona desert, and in the Utah desert. We have tested multiple exploration scenarios, such as geological traverses, cable or solar panel deployments, and science instrument deployments. The configuration of our robot can be changed, based on what equipment is needed for a given scenario, and the sensor mast can even be placed on one of two robot bases, each with different motion capabilities. The software architecture of our robot is also designed to be as modular as possible, to allow for hardware and configuration changes.

Two focus areas of our research are safety and crew time efficiency. For safety, our work involves enabling humans to reliably communicate with a robot while moving in the same workspace, and enabling robots to monitor and advise humans of potential problems. Voice, gesture, remote computer control, and enhanced robot intelligence are methods we are studying. For crew time efficiency, we are investigating the effects of assigning different roles to humans and robots in collaborative exploration scenarios.