

3D Robot User Interfaces

Supervision and situation awareness of
remotely operated space robots

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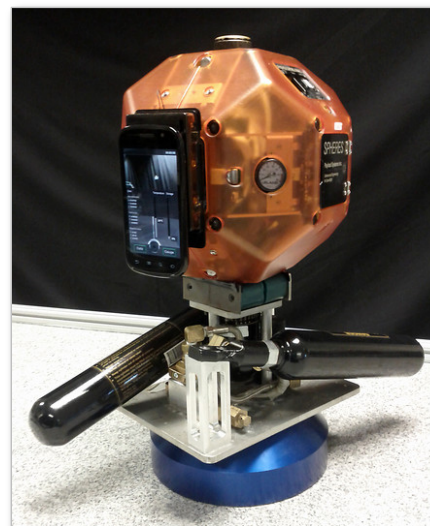
Overview

- 35 researchers (17 Ph.D.'s)
- 25+ student interns yearly
- 80% NASA work
- 20% non-NASA work
- SBIR-STTR (Phase 1, 2, 2E, & 3)



Research themes

- **Automated planetary mapping**
 - Base maps & terrain models
 - Geospatial data systems
- **Exploration user interfaces**
 - Robot & science operations
 - Accessible science data
- **Robots for human explorers**
 - Improve efficiency & productivity
 - Free-flyers, lake lander, & rovers



irg.arc.nasa.gov



IRG Collaborations (2015-2016)

Academic



Cornell University



3D Robot User Interfaces

Commercial



Otherlab



ProtoInnovations



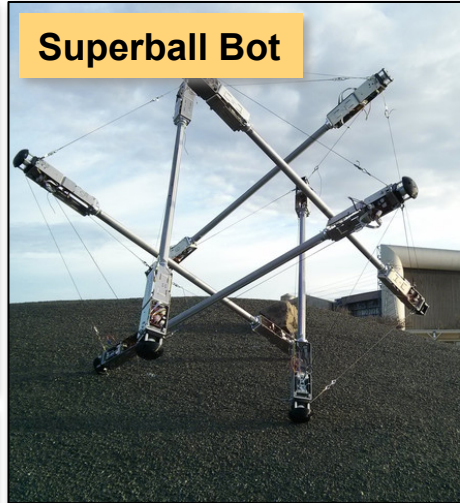
Government



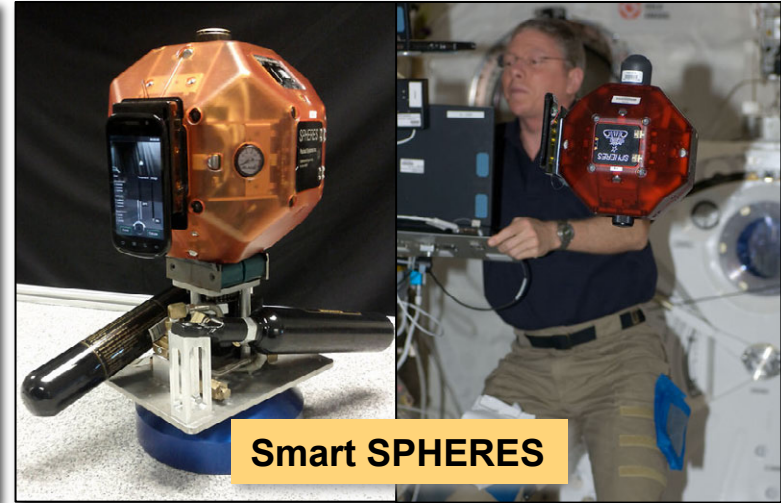
Robots



K10



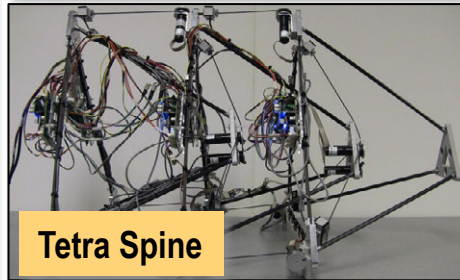
Superball Bot



Smart SPHERES



KREX



Tetra Spine



K10 mini



GigaPan Voyage



Lake Lander



Interactive 3D UI

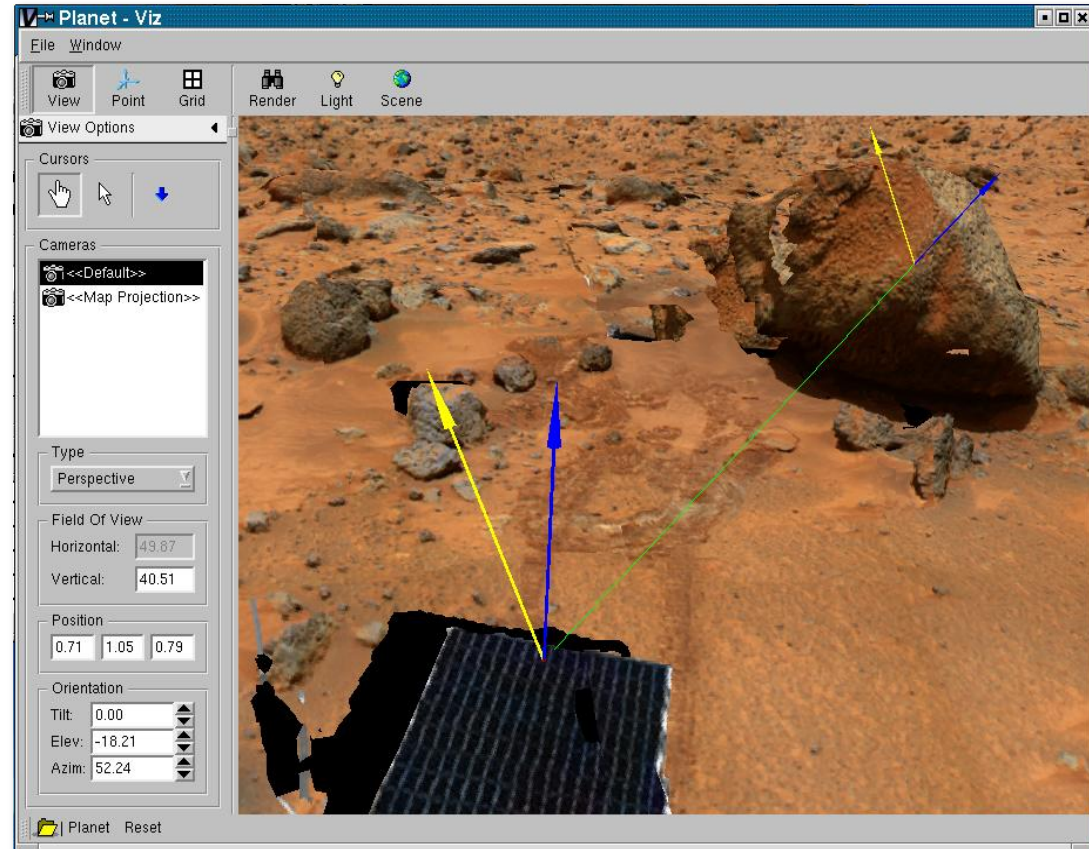
- Stereo viewing
- Background image

Simulation

- Time of day lighting
- Viewpoint + pose
- Object kinematics

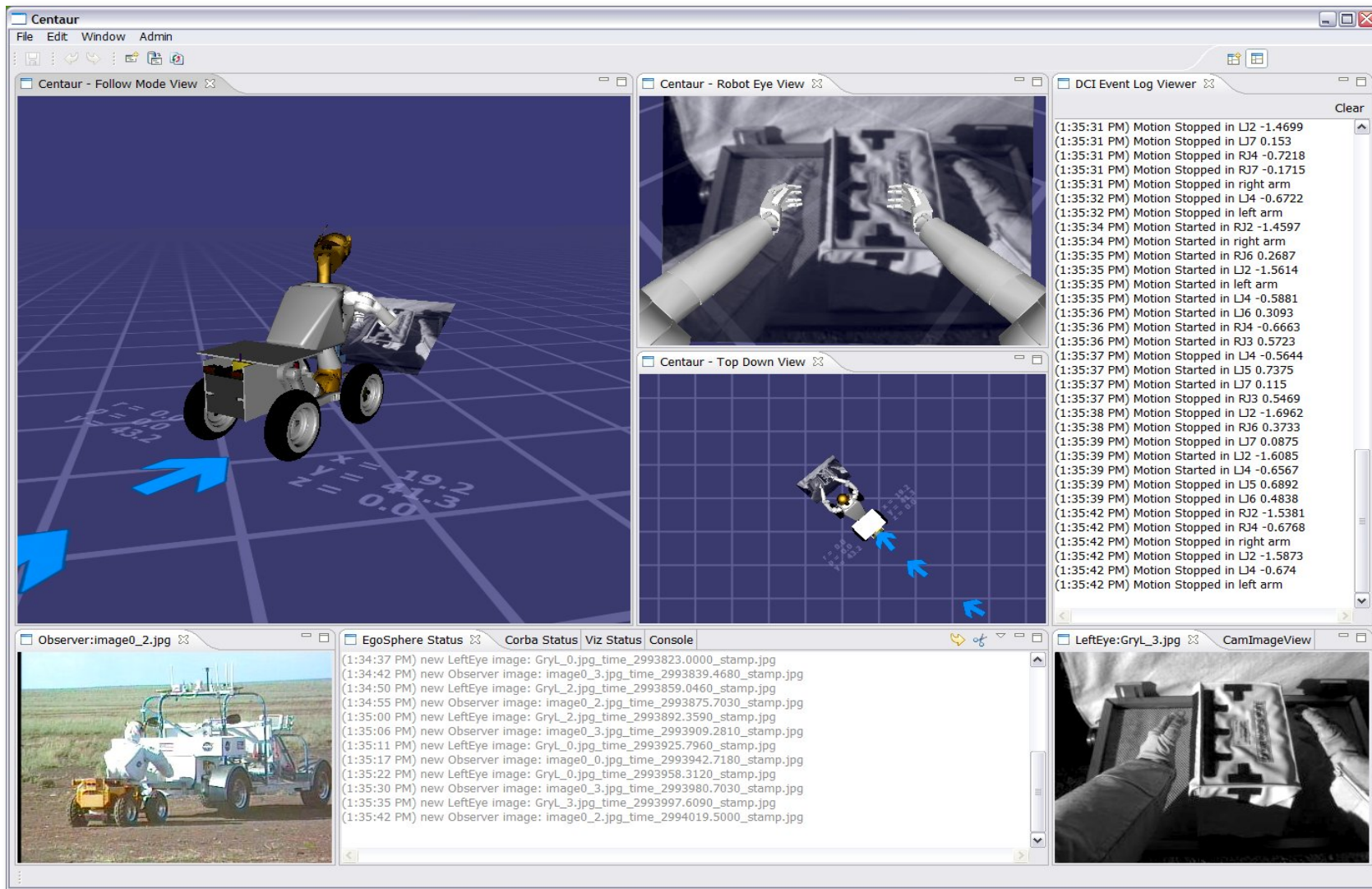
Site understanding tools

- Point, distance, azimuth measure
- Elevation + slope maps
- Sun + planet vectors
- Surface area measure
- Terrain cross-section
- Markers + ancillary data



Missions: MPL, MER, Phoenix, MSL
Field Tests: K9/Mojave, IS Level 1, CDS

Centaur (Robonaut): Grasping Tools



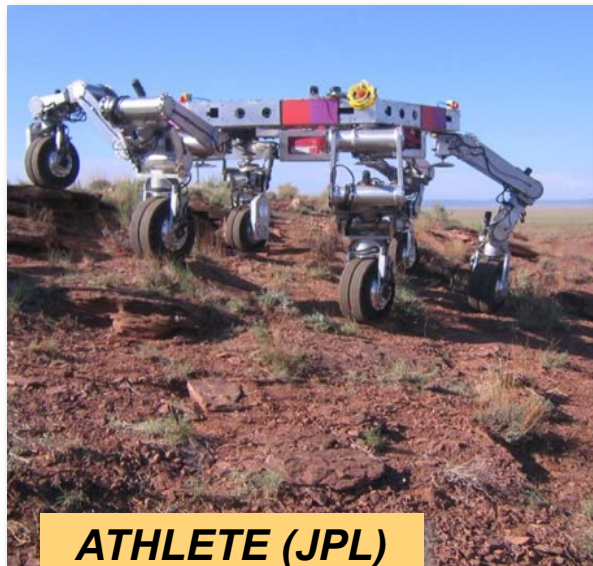
Centaur (Robonaut): Hardware Faults

The screenshot displays the Centaur robot control interface, which includes several windows:

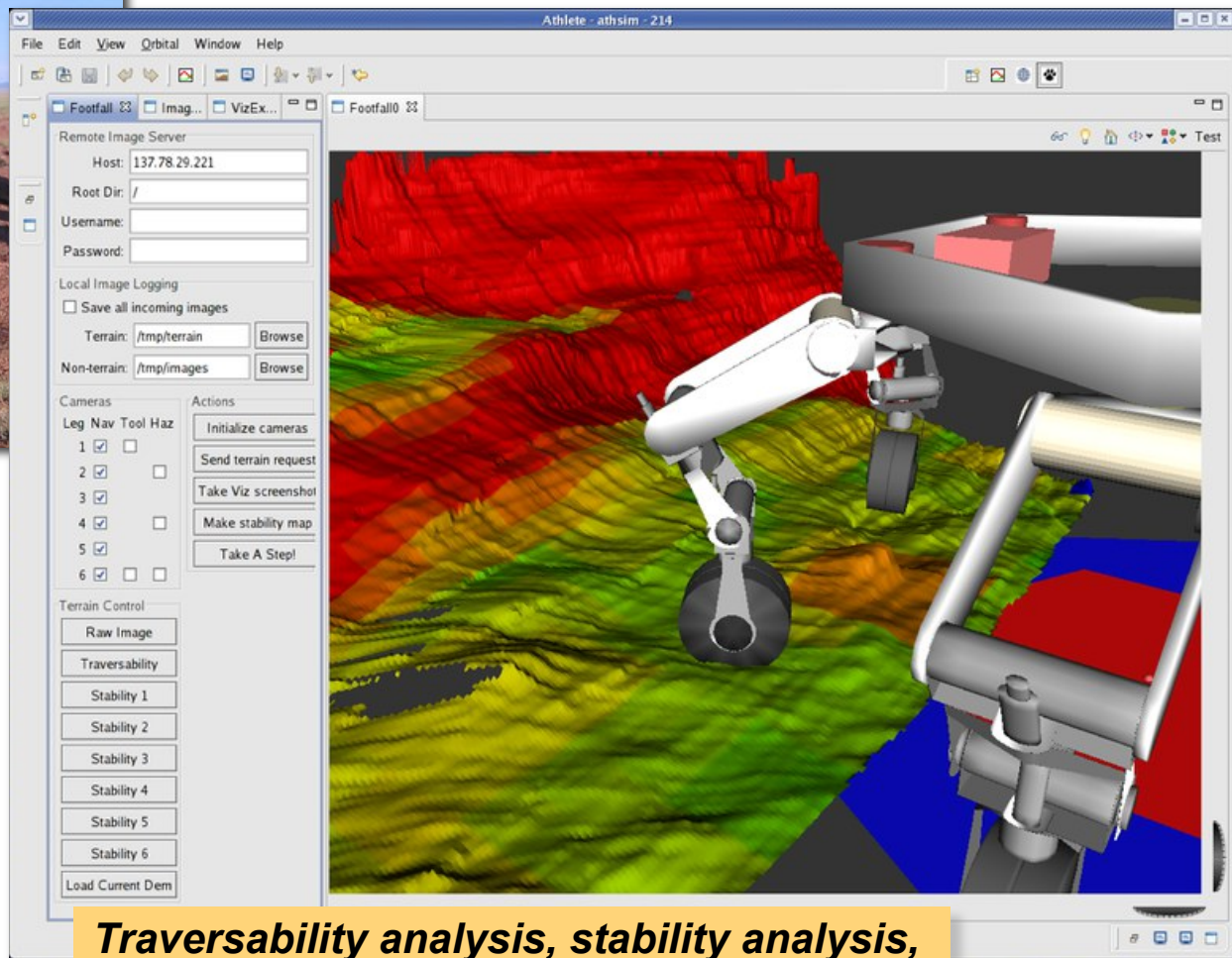
- Centaur - Follow Mode View:** A 3D rendering of the Centaur robot on a virtual terrain with a grid and blue arrows indicating movement directions.
- Centaur - Robot Eye View:** A first-person view from the robot's perspective, showing a dark, textured environment.
- Centaur - Top Down View:** A top-down view of the robot on the virtual terrain, showing its position relative to the grid and arrows.
- DCI Event Log Viewer:** A log window displaying a series of events, including motion starts and stops, and several critical alerts such as "Alert Loss of joint in RJ1 0.2575", "Alert Possible Loss of joint in RJ2 -0.2558", "Alert Loss of joint in RJ5 -0.936", and "Alert Loss of joint in RJ6 0.659".
- Observer: image0_0.jpg:** A real-time video feed showing the physical Centaur robot in a field.
- EgoSphere Status, Corba Status, Viz Status, Console:** A row of status and console windows. The console window shows a log of image captures, such as "new LeftEye image: GryL_0.jpg_time_2993958.3120_stamp.jpg".
- LeftEye: GryL_1.jpg:** A real-time video feed from the robot's left eye, showing a close-up of the robot's head and arm.



ATHLETE Footfall Planning



**ATHLETE (JPL)
at Meteor Crater**



**Traversability analysis, stability analysis,
single/multi-step planning**



ATHLETE Footfall Planning

Remote Image Server
Host:

Local Image Logging
 Save all incoming images
Terrain: /usr/local/irg/localhome/vyt
Non-terrain: /usr/local/irg/localhome/vyt

Cameras
Leg Nav Tool Haz
1
2
3
4
5
6

Actions

Terrain Control

Misc. Control
 use Full Polygon
 Hide CPS
 show Torques

Ground forces shown by arrows, and joint-torques indicated by color.

Preview Button shows "Ghost" of commanded motion.

Terrain, colored for reachability and stability

Motion Plan for Leg 3

preview	Send Cmd	Joint Move 0.7 abs hy3,-0.70856655, hp3,0.014065677, kp3,-1.5306919, kr3,0.07152762, ap3,-0.88354176, ar3,0.43718863
preview	Send Cmd	Joint Move 0.7 abs hy3,-0.66386163, hp3,0.18786772, kp3,-1.3061118, kr3,0.03576381, ap3,-0.8672381, ar3,0.5281727
preview	Send Cmd	Joint Move 0.7 abs hy3,-0.6191567, hp3,0.36166975, kp3,-1.0815316, kr3,0.0, ap3,-0.8509344, ar3,0.6191567
preview	Send Cmd	Joint Move 0.7 abs hy3,-0.6191567, hp3,0.11536662, kp3,-0.95933294, kr3,0.0, ap3,-0.72683007, ar3,0.6191567

Optional command to lower leg further

preview	Send Cmd	tool move z 3 forkzw rvr_rel 0.2 std
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Replan Hide Ghost Done

Planned Command Sequence.

STOP

EVRW: None Batt [20:19:08]: ...ll Current: 128 A

Phoenix Lander: Manipulator Monitoring

The screenshot displays the Mercator4Phoenix software interface, which is used for monitoring the Phoenix Lander's manipulator. The interface is divided into several panels:

- 3-D Model Catalog:** Located on the left, it lists various 3D models with their types and tags. The search results include:
 - Footpad DEM Sol: 0 (unload):** Type: DEM, Tags: DEM, Filter 1 (Red), SSI. Notes: Image of Lander Footpad just after landing.
 - Footpad Model Sol: 0 (unload):** Type: VRML, Tags: VRML, SSI, Filter 1 (Red). Notes: Image of Lander Footpad just after landing.
 - Initial Workspace Pan Sol: 1 (unload):** Type: VRML, Tags: VRML, SSI, Filter 1 (Red). Notes: Initial SSI workspace pan sub-sampled (256 x 256).
 - Initial Workspace Pan (shadows removed) Sol: 1 (unload):** Type: VRML, Tags: Filter 1 (Red), SSI, No Shadows, VRML. Notes: Initial sub-sampled workspace pan, with shadows removed.
 - Vertical swath models Sol: 6 (unload):**
- Scene:** The central 3D view shows the Phoenix Lander on a color-coded terrain map. The terrain colors range from blue (low elevation) to red (high elevation). The lander's manipulator is extended towards the ground. The scene includes a grid and various control elements like heading, elevation, distance, zoom, and viewpoint location.
- RAC (Remote Action Control):** Located on the right, it shows a top-down view of the terrain with a selected area. The selected area is highlighted in orange. The RAC panel displays the azimuth (Az: 47.5) and elevation (El: -73.49) of the selected area.
- SSI (Site Specific Information):** Located below the RAC panel, it shows a 3D model of the lander's workspace. The SSI panel displays the azimuth (Az: -90.3) and elevation (El: -90.58) of the selected area.
- Info:** Located at the bottom left, it displays the name of the selected model: SS001DNL896305412_10CF6. It also shows the class (TriangulatedIrregularNetwork), location (0.0 0.0 0.0), and radius (3.4173243).
- Console:** Located at the bottom right, it displays the log of the application. The log shows the loading of the application and the picking of the selected model from the view.



VERVE

3D robot user interface

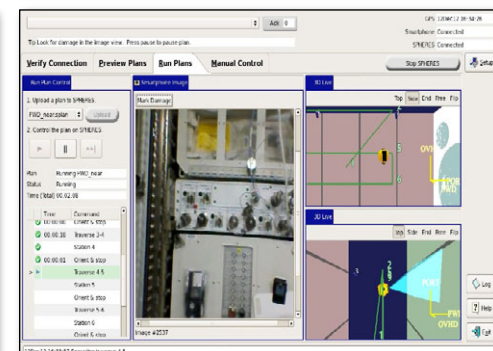
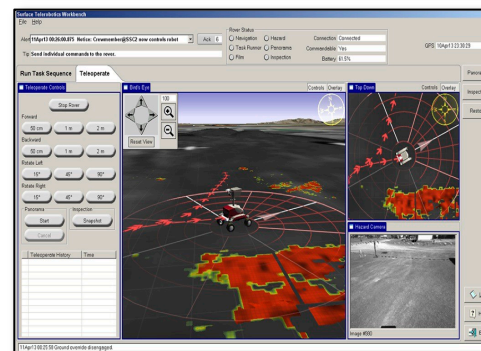
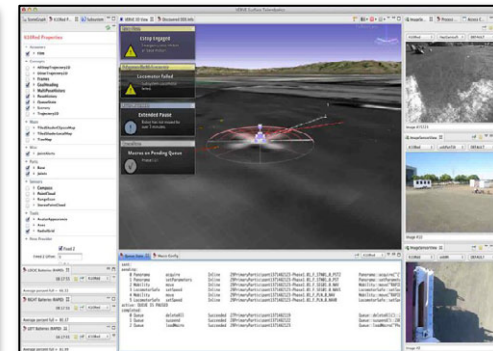
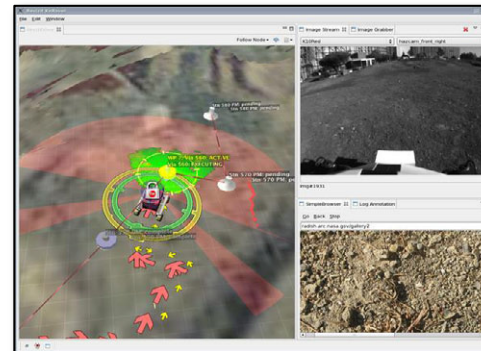
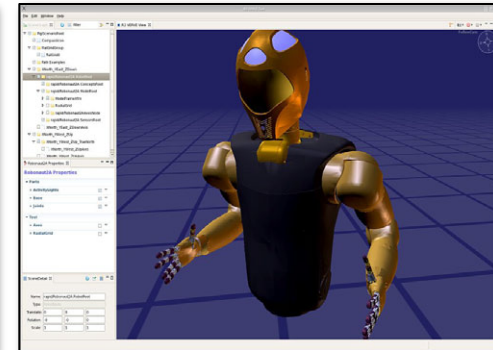
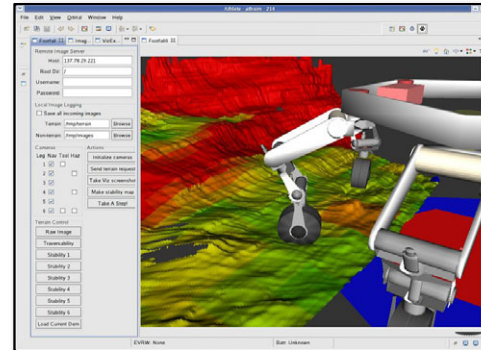
- Interactive planning and monitoring of space robots
- Facilitates situation awareness
- Multiple control modes

Technologies

- Java & Eclipse RCP
- Ardor 3D
- NASA RAPID/DDS messaging

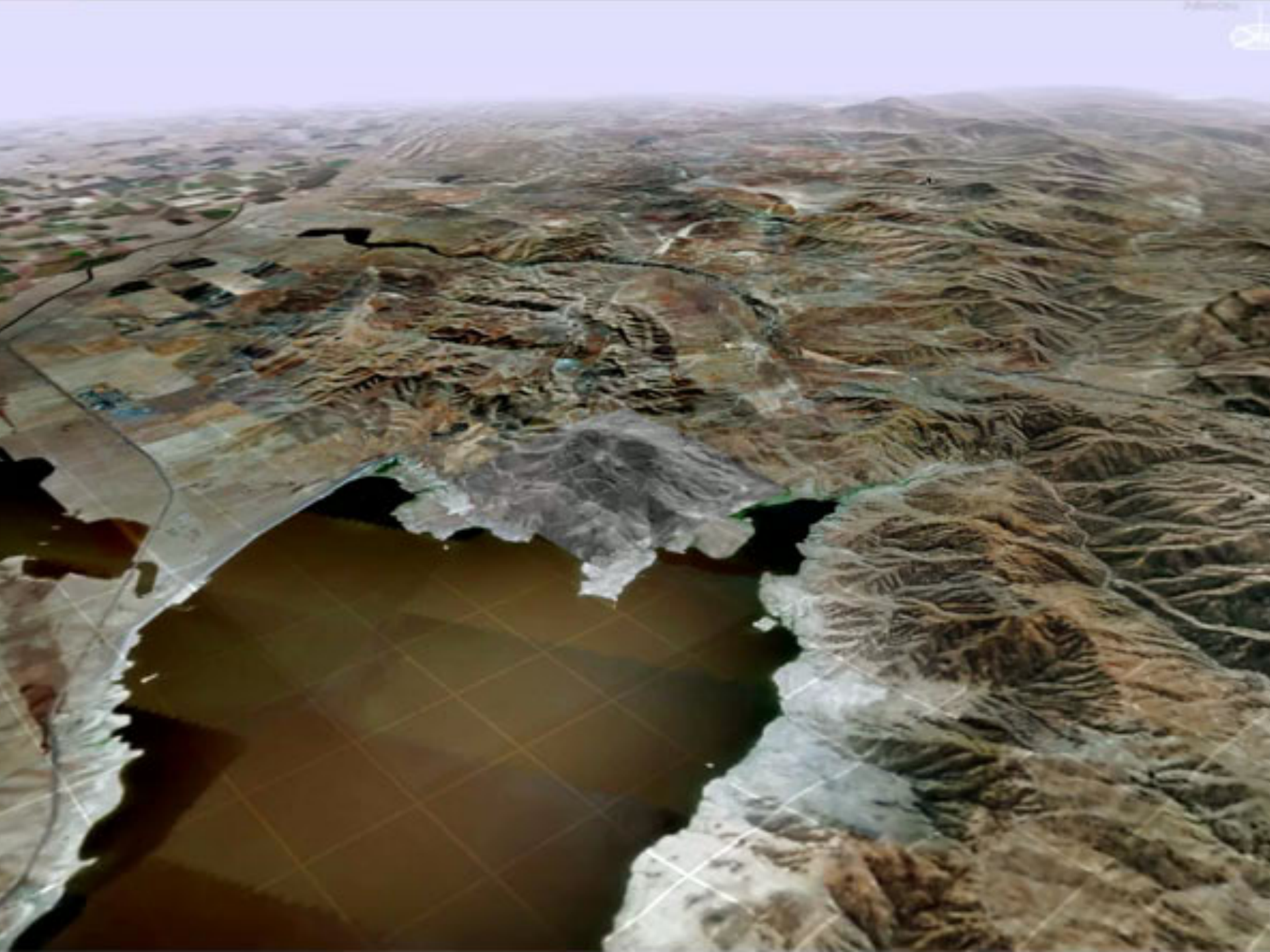
Applications

- ATHLETE, Robonaut, K10, K-REX
- ISS: Smart SPHERES and Surface Telerobotics
- Resource Prospector mission



KREX Robot at Basalt Hills





Surface Telerobotics Project

Summary

- Demo **crew-control** surface telerobotics (planetary rover)
- Test **human-robot conops** for future exploration mission
- Obtain **baseline engineering data** (robot, crew, data comm, task, etc)

Implementation

- Lunar libration mission simulation
- Astronaut on Space Station
- K10 rover in NASA Ames Roverscape

ISS Testing (Expedition 36)

- 17 June 2013 – **C. Cassidy**, survey
- 26 July 2013 – **L. Parmitano**, deploy
- 20 August 2013 – **K. Nyberg**, inspect



SURVEY



DEPLOY

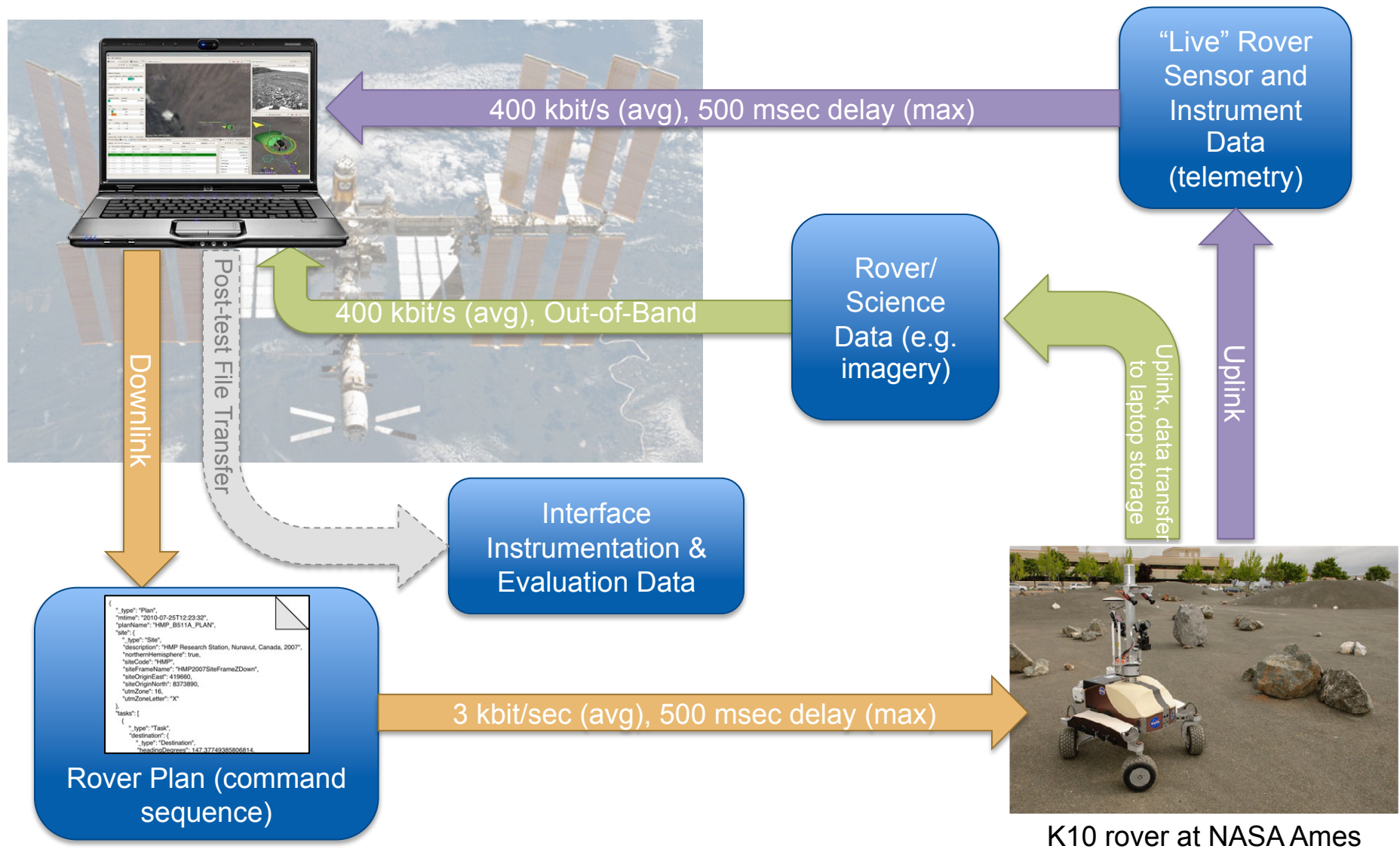


INSPECT

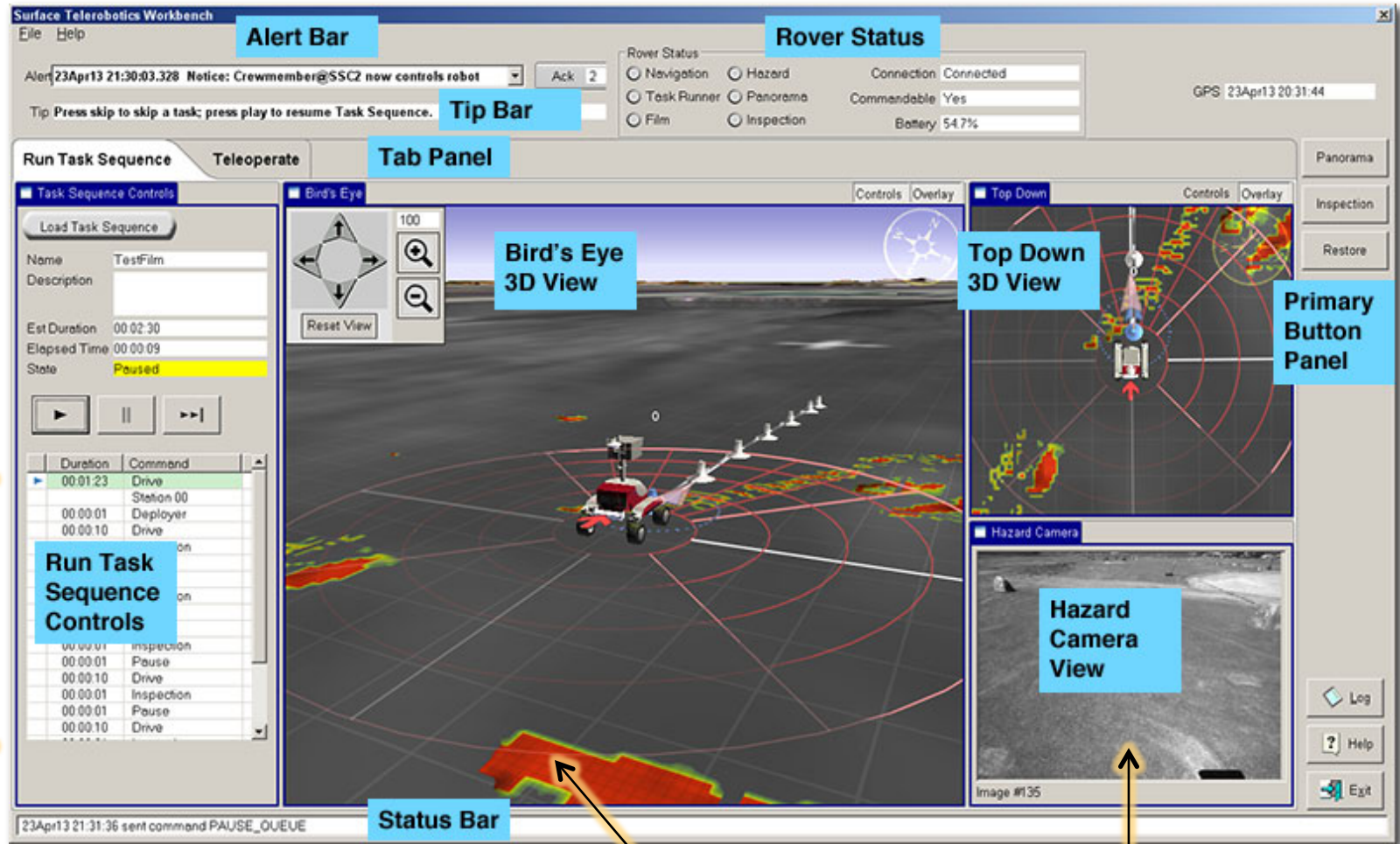
- **Human-robot mission sim:** site survey, telescope deployment, and inspection
- **Telescope proxy:** Kapton polyimide film roll (no antenna traces, electronics, or receiver)
- **3.5 hr per crew session** (“just in time” training, system checkout, ops, & debrief)
- **Robot ops:** manual control (discrete commands) and supervisory control (task sequence)



ISS Test Setup



Robot Interface (Supervisory Control)



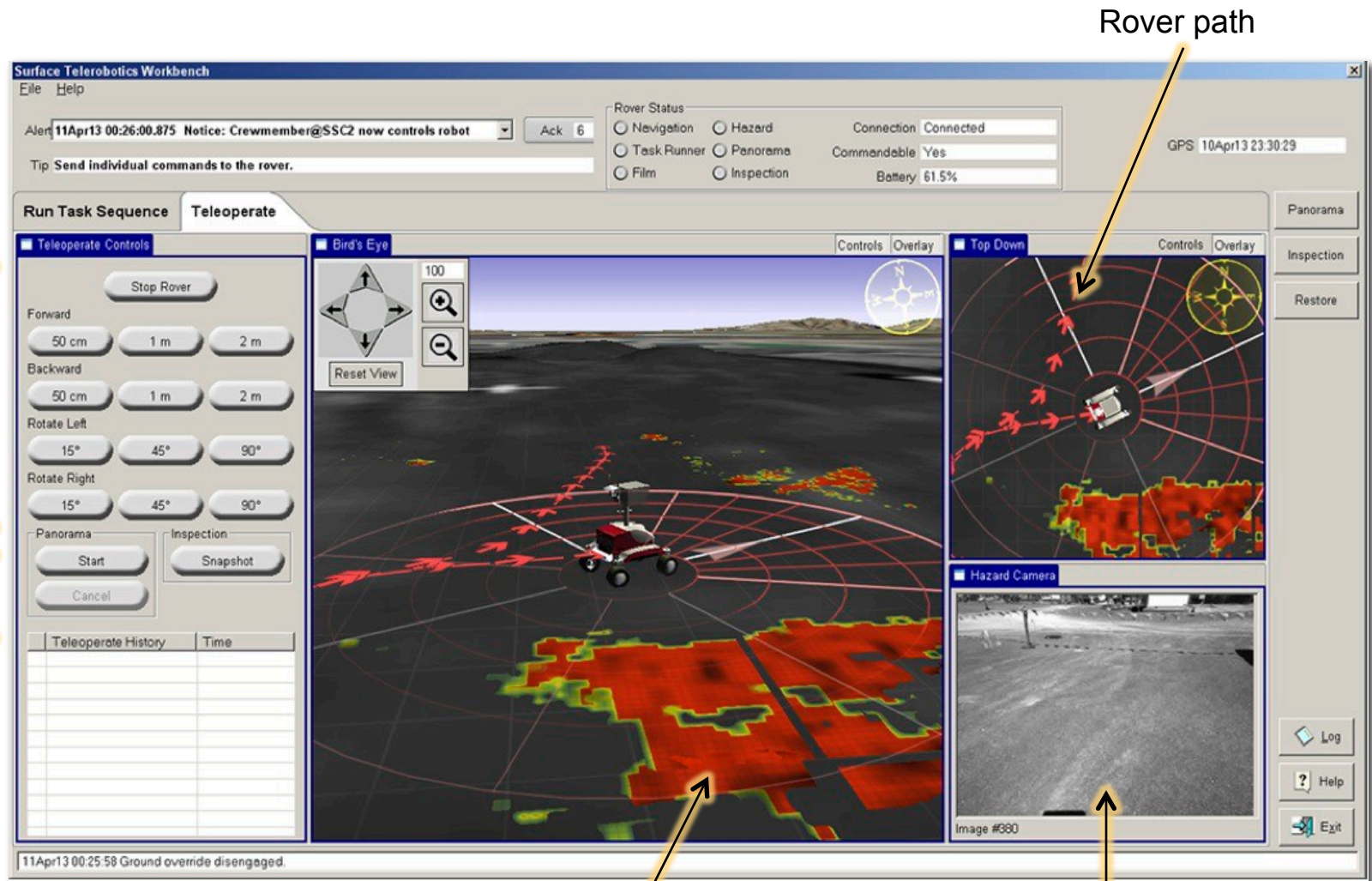
Task Sequence

Terrain hazards

Rover camera display



Robot Interface (Manual Control)



Motion controls

Camera controls

Rover path

Terrain hazards

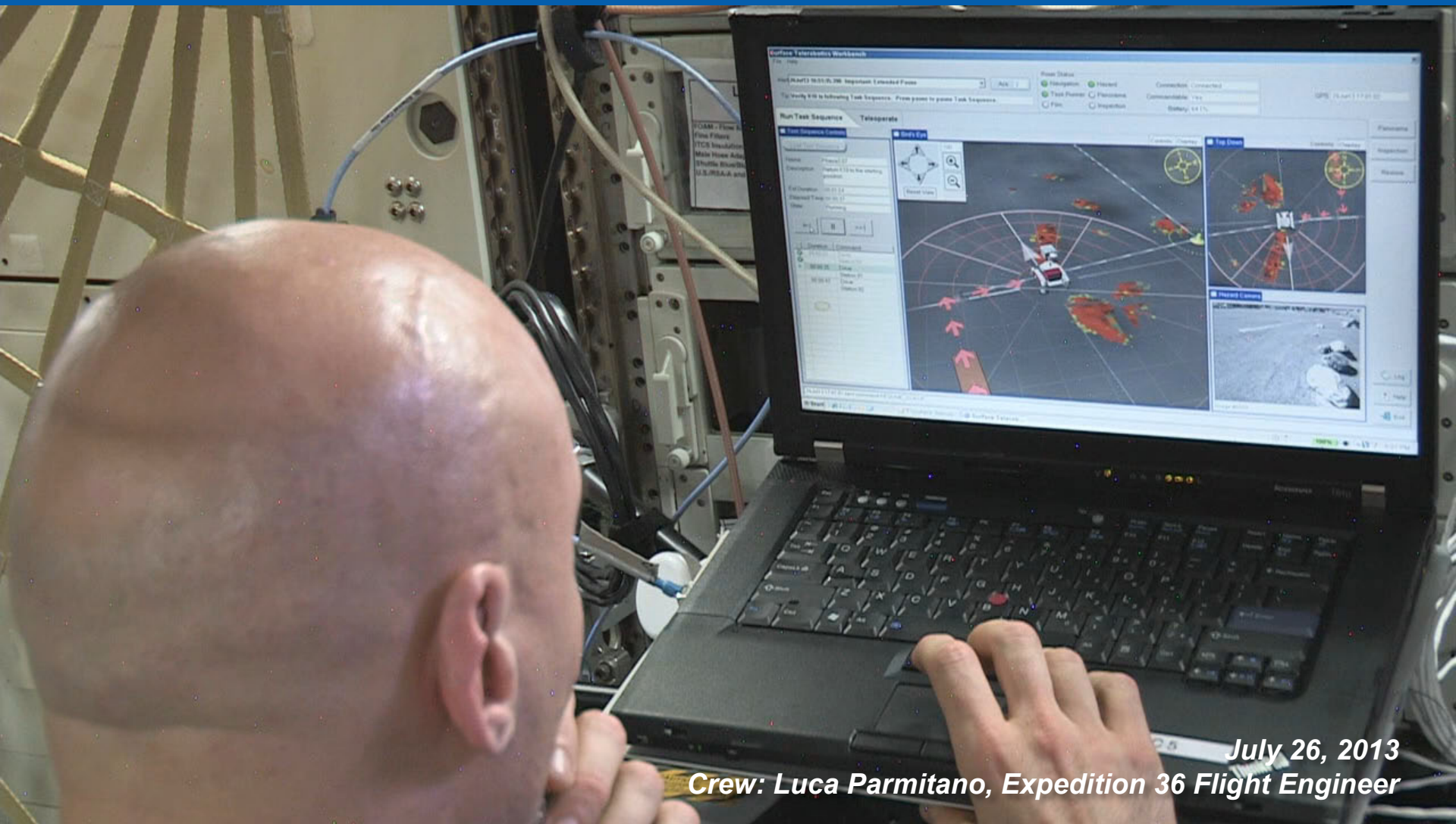
Rover camera display



Surface Telerobotics

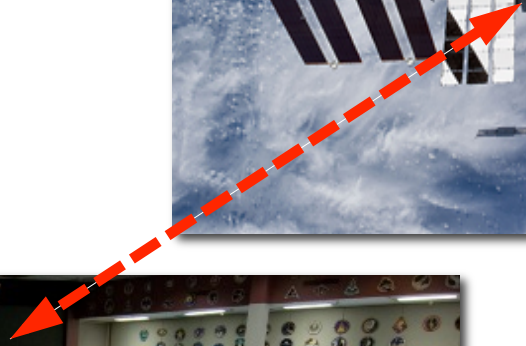
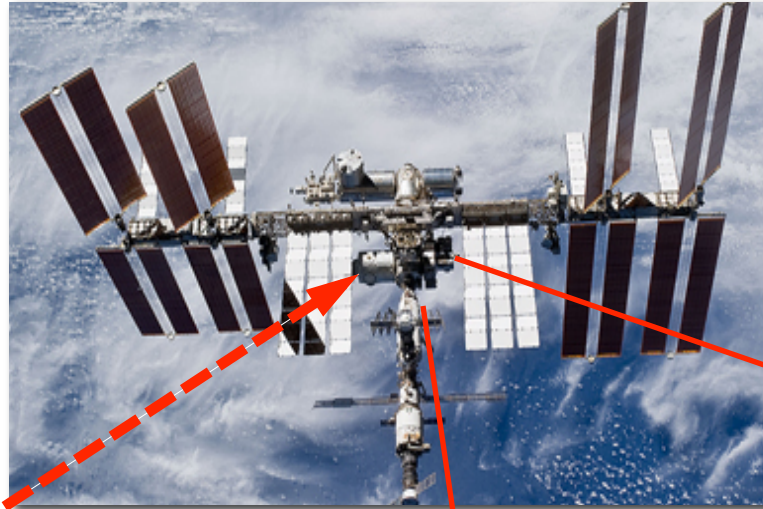


Surface Telerobotics



July 26, 2013
Crew: Luca Parmitano, Expedition 36 Flight Engineer

Smart SPHERES



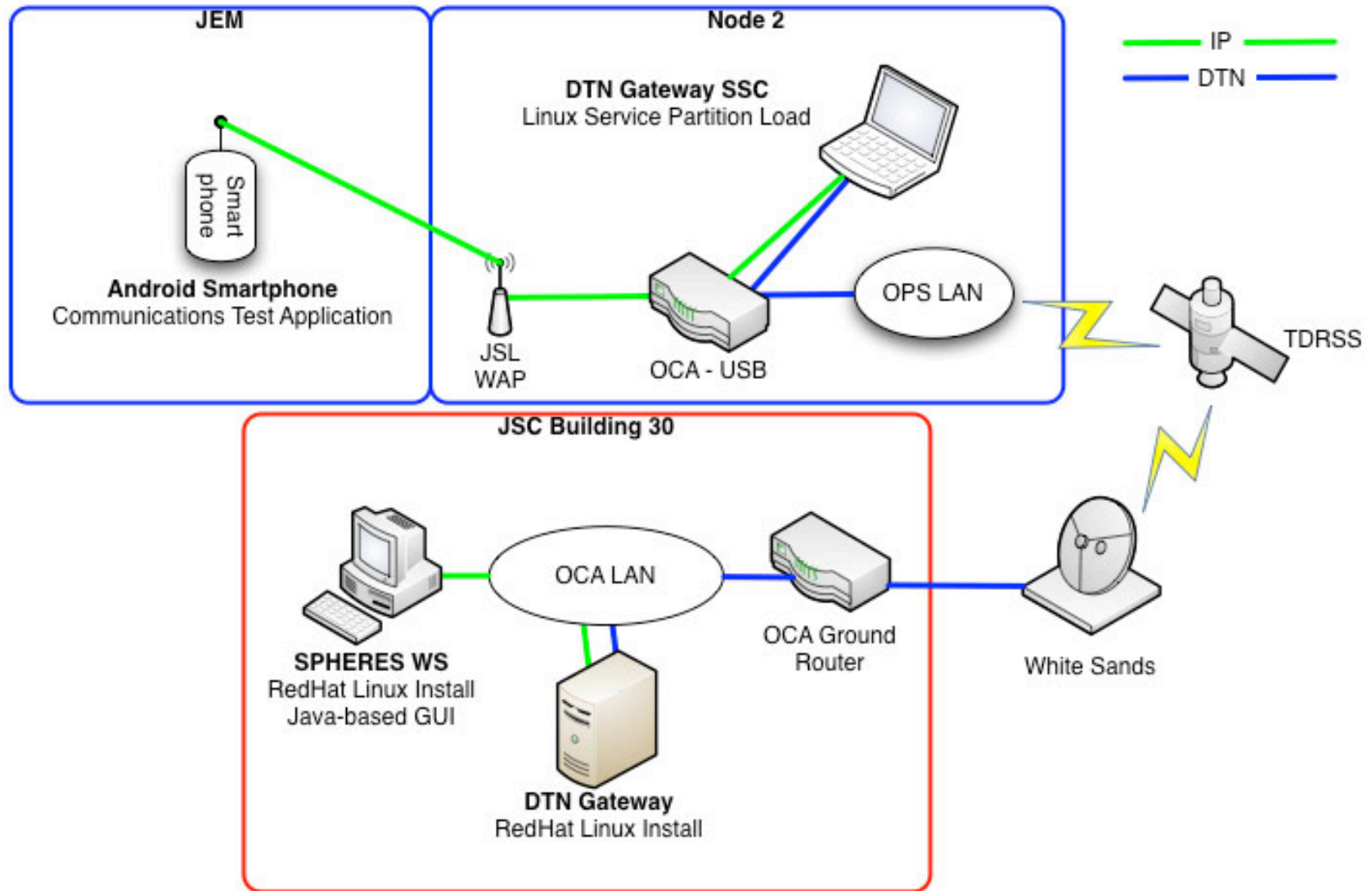
**ISS Mission Control
(Houston)**



**Smart
SPHERES**



Smart SPHERES Network Setup



ISS Interior Survey with SmartSPHERES



December 12, 2012
Crew: Kevin Ford, Expedition 33 Commander

2x speed



Questions?



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