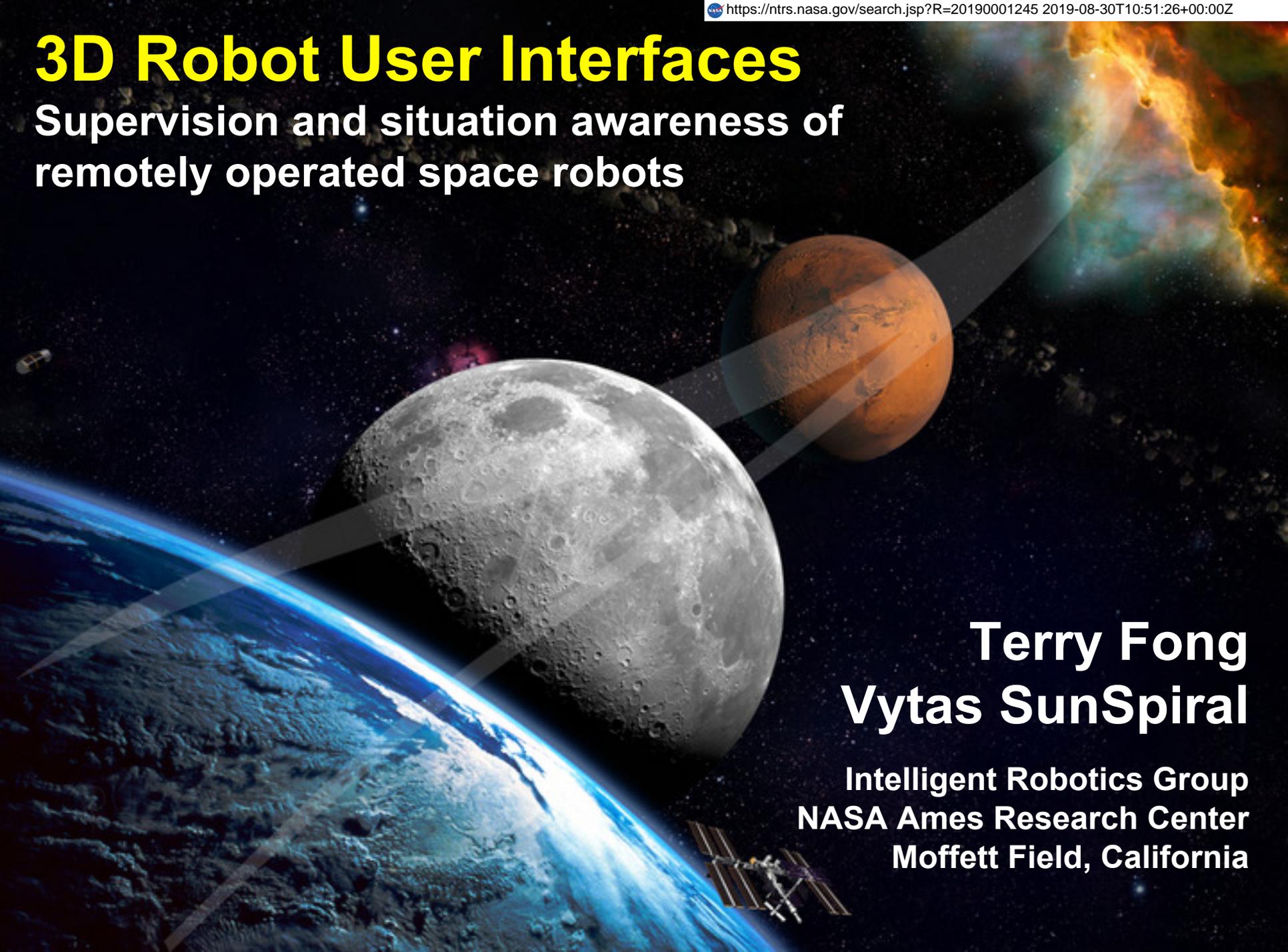


# 3D Robot User Interfaces

Supervision and situation awareness of  
remotely operated space robots

**Terry Fong**  
**Vytas SunSpiral**

Intelligent Robotics Group  
NASA Ames Research Center  
Moffett Field, California



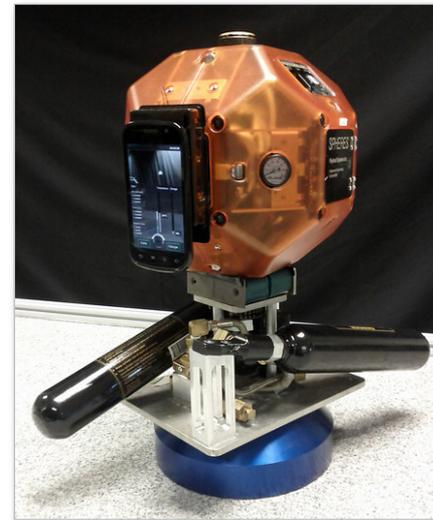
# NASA Ames Intelligent Robotics Group

## 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

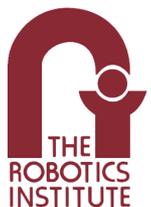


[irg.arc.nasa.gov](http://irg.arc.nasa.gov)



# IRG Collaborations (2015-2016)

## Academic



Cornell University



3D Robot User Interfaces

## Commercial



Otherlab



ProtoInnovations



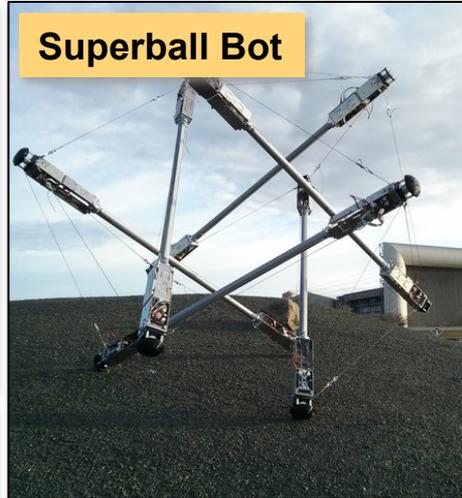
## Government



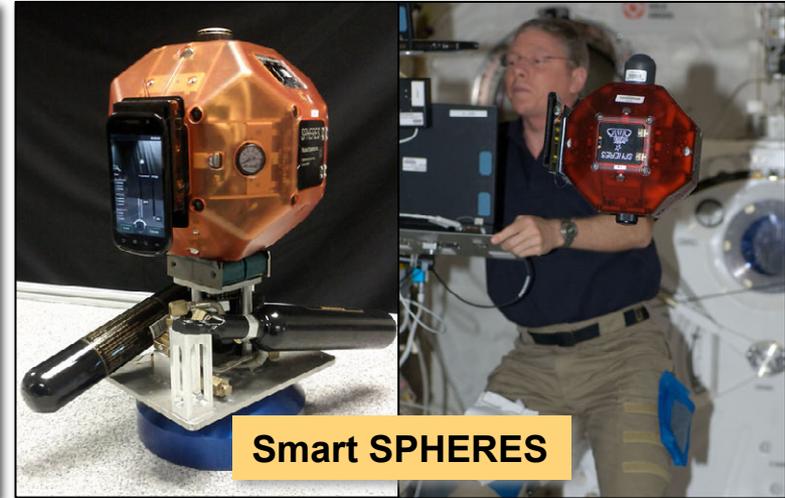
# Robots



**K10**



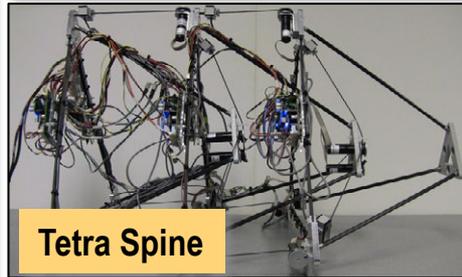
**Superball Bot**



**Smart SPHERES**



**KREX**



**Tetra Spine**



**K10 mini**



**GigaPan Voyage**



**Lake Lander**



## Interactive 3D UI

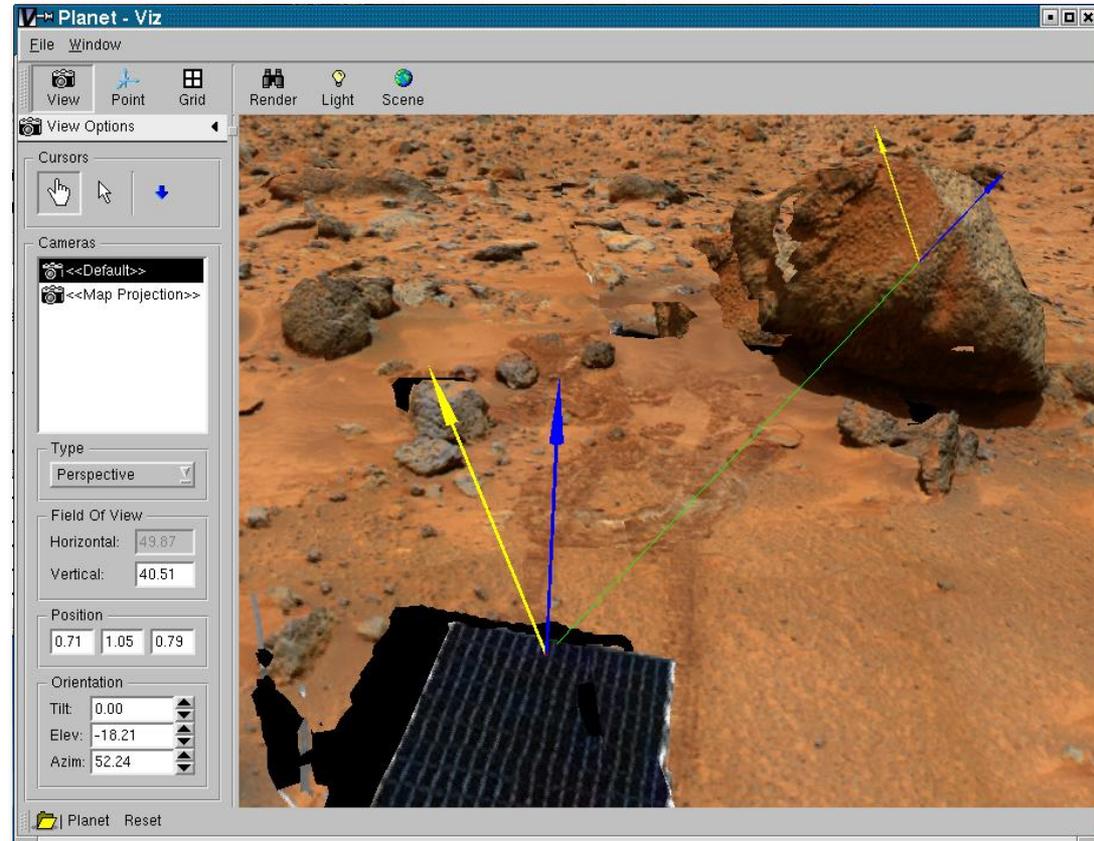
- Stereo viewing
- Background image

## 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

The screenshot displays the Centaur robot control interface, which is a multi-view application. The main window is titled "Centaur" and contains several sub-windows:

- Centaur - Follow Mode View:** Shows a 3D model of the Centaur robot on a blue grid floor. A blue arrow points to the right, and another blue arrow points to the left. The text  $x = 19.2$ ,  $y = 21.3$ , and  $z = 0.0$  is visible on the grid.
- Centaur - Robot Eye View:** Shows a first-person view from the robot's perspective, looking down at its two robotic arms and hands, which are positioned over a white tray containing several small objects.
- Centaur - Top Down View:** Shows a top-down view of the robot on the blue grid floor. A blue arrow points to the right, and another blue arrow points to the left. The text  $x = 19.2$ ,  $y = 21.3$ , and  $z = 0.0$  is visible on the grid.
- DCI Event Log Viewer:** A log window showing a list of events with timestamps and descriptions. The log entries are:
  - (1:35:31 PM) Motion Stopped in LJ2 -1.4699
  - (1:35:31 PM) Motion Stopped in LJ7 0.153
  - (1:35:31 PM) Motion Stopped in RJ4 -0.7218
  - (1:35:31 PM) Motion Stopped in RJ7 -0.1715
  - (1:35:31 PM) Motion Stopped in right arm
  - (1:35:32 PM) Motion Stopped in LJ4 -0.6722
  - (1:35:32 PM) Motion Stopped in left arm
  - (1:35:34 PM) Motion Started in RJ2 -1.4597
  - (1:35:34 PM) Motion Started in right arm
  - (1:35:35 PM) Motion Started in RJ6 0.2687
  - (1:35:35 PM) Motion Started in LJ2 -1.5614
  - (1:35:35 PM) Motion Started in left arm
  - (1:35:35 PM) Motion Started in LJ4 -0.5881
  - (1:35:36 PM) Motion Started in LJ6 0.3093
  - (1:35:36 PM) Motion Started in RJ4 -0.6663
  - (1:35:36 PM) Motion Started in RJ3 0.5723
  - (1:35:37 PM) Motion Stopped in LJ4 -0.5644
  - (1:35:37 PM) Motion Started in LJ5 0.7375
  - (1:35:37 PM) Motion Started in LJ7 0.115
  - (1:35:37 PM) Motion Stopped in RJ3 0.5469
  - (1:35:38 PM) Motion Stopped in LJ2 -1.6962
  - (1:35:38 PM) Motion Stopped in RJ6 0.3733
  - (1:35:39 PM) Motion Stopped in LJ7 0.0875
  - (1:35:39 PM) Motion Started in LJ2 -1.6085
  - (1:35:39 PM) Motion Started in LJ4 -0.6567
  - (1:35:39 PM) Motion Stopped in LJ5 0.6892
  - (1:35:39 PM) Motion Stopped in LJ6 0.4838
  - (1:35:42 PM) Motion Stopped in RJ2 -1.5381
  - (1:35:42 PM) Motion Stopped in RJ4 -0.6768
  - (1:35:42 PM) Motion Stopped in right arm
  - (1:35:42 PM) Motion Stopped in LJ2 -1.5873
  - (1:35:42 PM) Motion Stopped in LJ4 -0.674
  - (1:35:42 PM) Motion Stopped in left arm
- Observer:image0\_2.jpg:** A small window showing a photograph of the Centaur robot in a field.
- EgoSphere Status, Corba Status, Viz Status, Console:** A row of status windows. The Console window shows a list of image capture events:
  - (1:34:37 PM) new LeftEye image: GryL\_0.jpg\_time\_2993823.0000\_stamp.jpg
  - (1:34:42 PM) new Observer image: image0\_3.jpg\_time\_2993839.4680\_stamp.jpg
  - (1:34:50 PM) new LeftEye image: GryL\_2.jpg\_time\_2993859.0460\_stamp.jpg
  - (1:34:55 PM) new Observer image: image0\_2.jpg\_time\_2993875.7030\_stamp.jpg
  - (1:35:00 PM) new LeftEye image: GryL\_2.jpg\_time\_2993892.3590\_stamp.jpg
  - (1:35:06 PM) new Observer image: image0\_3.jpg\_time\_2993909.2810\_stamp.jpg
  - (1:35:11 PM) new LeftEye image: GryL\_0.jpg\_time\_2993925.7960\_stamp.jpg
  - (1:35:17 PM) new Observer image: image0\_0.jpg\_time\_2993942.7180\_stamp.jpg
  - (1:35:22 PM) new LeftEye image: GryL\_0.jpg\_time\_2993958.3120\_stamp.jpg
  - (1:35:30 PM) new Observer image: image0\_2.jpg\_time\_2993980.7030\_stamp.jpg
  - (1:35:35 PM) new LeftEye image: GryL\_3.jpg\_time\_2993997.6090\_stamp.jpg
  - (1:35:42 PM) new Observer image: image0\_2.jpg\_time\_2994019.5000\_stamp.jpg
- LeftEye:GryL\_3.jpg, CamImageView:** A window showing a close-up image of the robot's left eye, which is a camera lens.



# Centaur (Robonaut): Hardware Faults

The screenshot displays the Centaur robot control interface, which is a multi-view application. The main window is titled "Centaur" and contains several sub-windows:

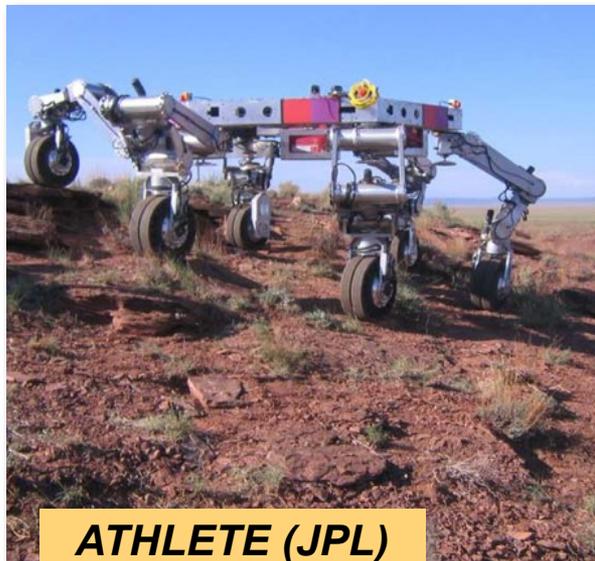
- Centaur - Follow Mode View:** Shows a 3D model of the Centaur robot on a virtual terrain with a grid and blue arrows indicating movement directions.
- Centaur - Robot Eye View:** Shows a first-person view from the robot's perspective, looking down at the ground.
- Centaur - Top Down View:** Shows a top-down view of the robot on the terrain.
- DCI Event Log Viewer:** A log window displaying a list of events and alerts. The log includes timestamps and descriptions of motion events and joint status alerts.
- Observer: image0\_0.jpg:** A window showing a real-time video feed of the Centaur robot in a physical environment.
- EgoSphere Status, Corba Status, Viz Status, Console:** A row of status and console windows.
- LeftEye: GryL\_1.jpg:** A window showing a real-time video feed from the robot's left eye.
- CamImageView:** A window showing a real-time video feed from a camera.

The DCI Event Log Viewer displays the following log entries:

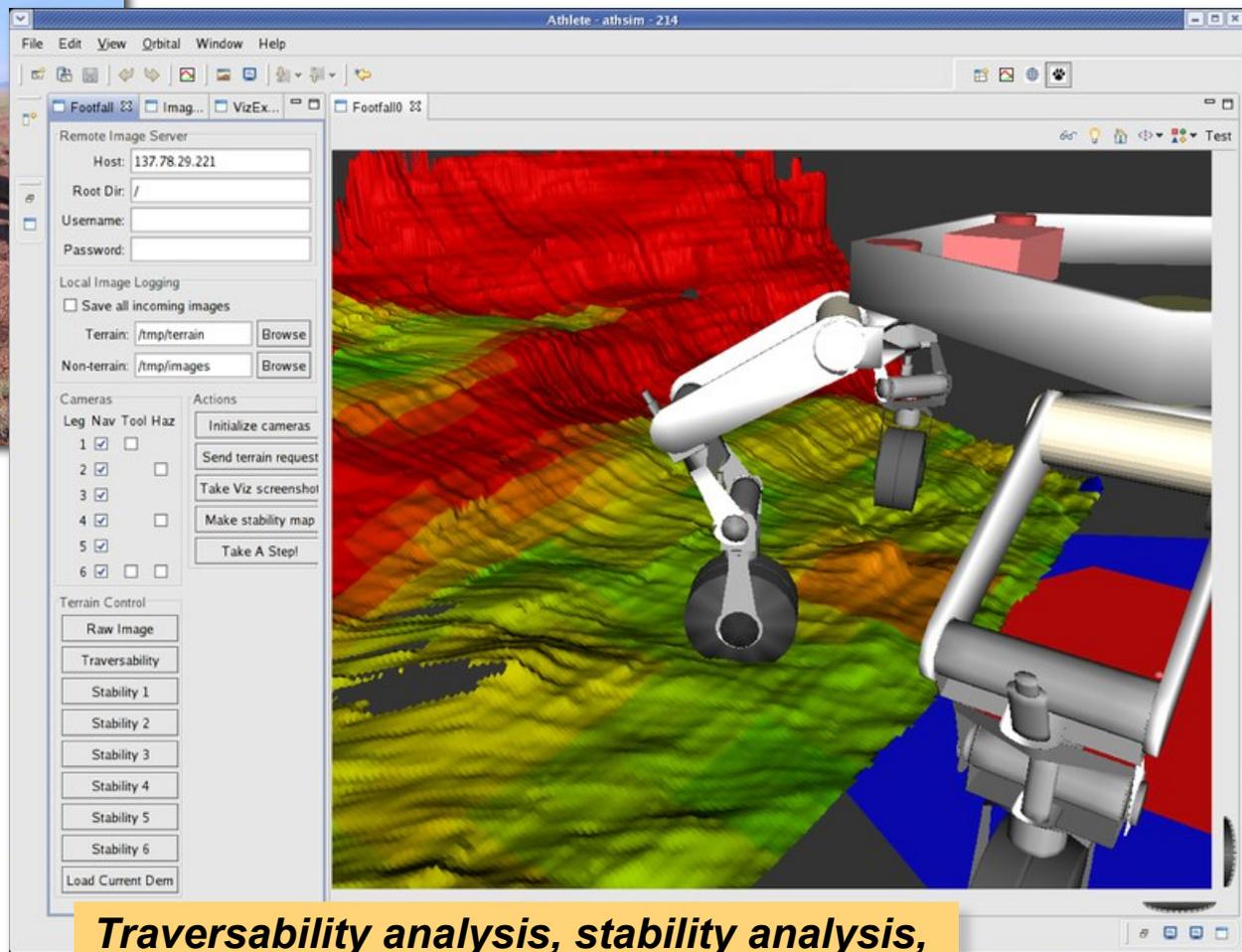
```
(1:36:26 PM) Motion Started in LJ5 1.0925
(1:36:26 PM) Motion Started in LJ6 0.5251
(1:36:26 PM) Motion Started in left arm
(1:36:26 PM) Alert Loss of joint in RJ1 0.2575
(1:36:26 PM) Alert Possible Loss of joint in RJ:
(1:36:26 PM) Motion not observable in RJ4 -2.2558
(1:36:26 PM) Alert Possible Loss of joint in RJ:
(1:36:26 PM) Motion not observable in RJ6 0.6589
(1:36:26 PM) Alert Possible Loss of joint in RJ:
(1:36:26 PM) Motion not observable in RJ7 0.3282
(1:36:26 PM) Motion Started in LJ3 -1.3056
(1:36:26 PM) Motion Started in LJ4 -2.2791
(1:36:26 PM) Motion Started in LJ7 -0.2339
(1:36:26 PM) Alert Loss of joint in RJ2 -0.752
(1:36:26 PM) Alert Possible Loss of joint in RJ:
(1:36:26 PM) Alert Loss of joint in RJ5 -0.936
(1:36:27 PM) Motion Stopped in RJ7 0.3282
(1:36:27 PM) Alert Possible Sticky joint in RJ7
(1:36:27 PM) Alert Loss of joint in RJ6 0.659
(1:36:28 PM) Alert Loss of joint in RJ3 1.2115
(1:36:28 PM) Alert Sticky joint in RJ6 0.659
(1:36:28 PM) Motion Stopped in RJ6 0.659
(1:36:29 PM) Alert Possible Loss of joint in RJ:
(1:36:29 PM) Alert Loss of joint in RJ6 0.659
(1:36:29 PM) Motion not observable in RJ6 0.659
(1:36:29 PM) Alert Loss of joint in RJ7 0.3284
(1:36:29 PM) Motion Stopped in LJ4 -2.3553
(1:36:29 PM) Motion Stopped in LJ1 1.0378
(1:36:29 PM) Motion Stopped in LJ3 -1.5685
(1:36:29 PM) Motion Stopped in LJ5 1.5606
(1:36:29 PM) Motion Stopped in LJ6 0.0149
(1:36:29 PM) Motion Stopped in LJ7 -0.014
(1:36:30 PM) Motion Stopped in LJ2 -1.6504
(1:36:30 PM) Motion Stopped in left arm
```



# ATHLETE Footfall Planning



**ATHLETE (JPL)  
at Meteor Crater**



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



# ATHLETE Footfall Planning

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

Preview Button shows "Ghost" of commanded motion.

Terrain, colored for reachability and stability

Planned Command Sequence.

Command	Joint Move
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
------------------	--------------------------------------

Replan Hide Ghost Done

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 over the terrain. The scene includes a grid and various control elements like heading, elevation, distance, zoom, and viewpoint location.
- RAC (Rover Activity Catalog):** Located in the top right, it displays a grid of images and provides Azimuth (Az) and Elevation (El) coordinates. The current view shows Az: 47.5 and El: -73.49.
- SSI (Site Specific Information):** Located in the bottom right, it displays a 3D model of the lander's workspace and provides Azimuth (Az) and Elevation (El) coordinates. The current view shows Az: -90.3 and El: -90.58.
- Info:** Located in 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 in the bottom center, it displays the log of the application, including the loading of resources and the picking of the selected model.



# VERVE

## 3D robot user interface

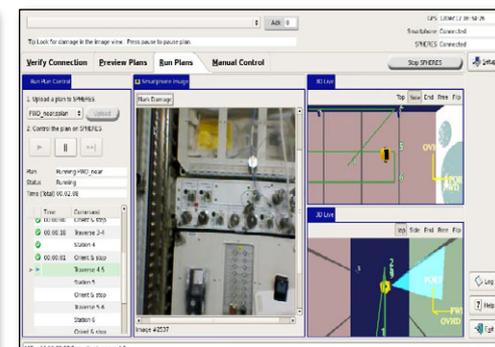
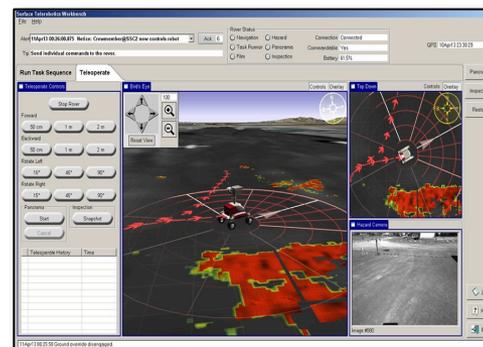
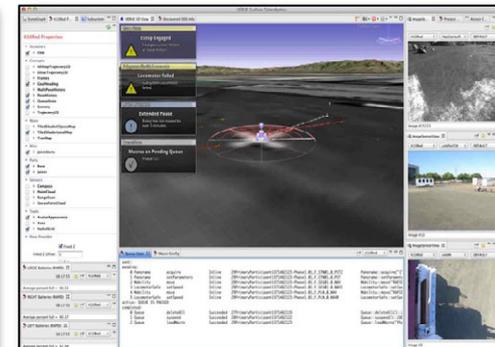
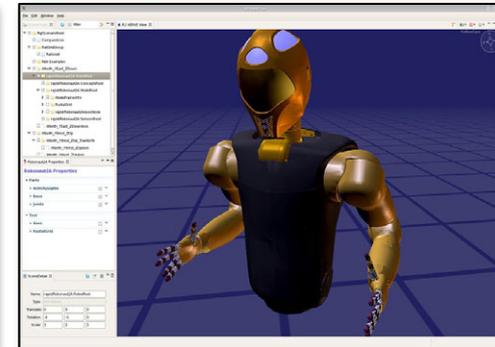
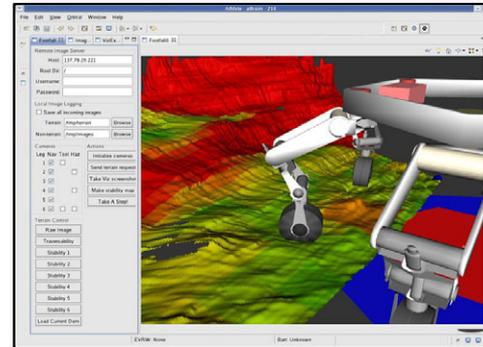
- Interactive planning and monitoring of space robots
- Facilitates situation awareness
- Multiple control modes

## Technologies

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

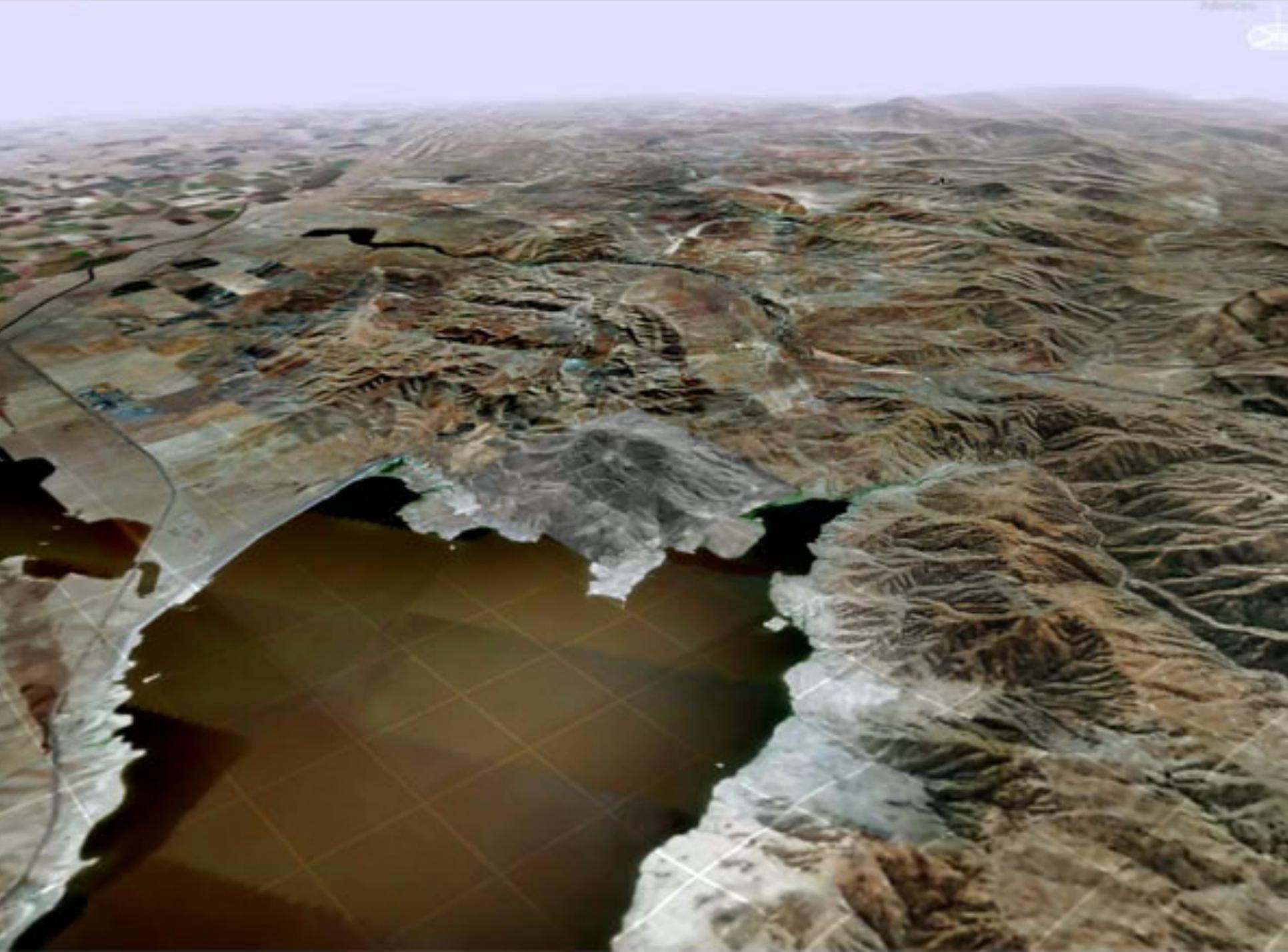
## Applications

- 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

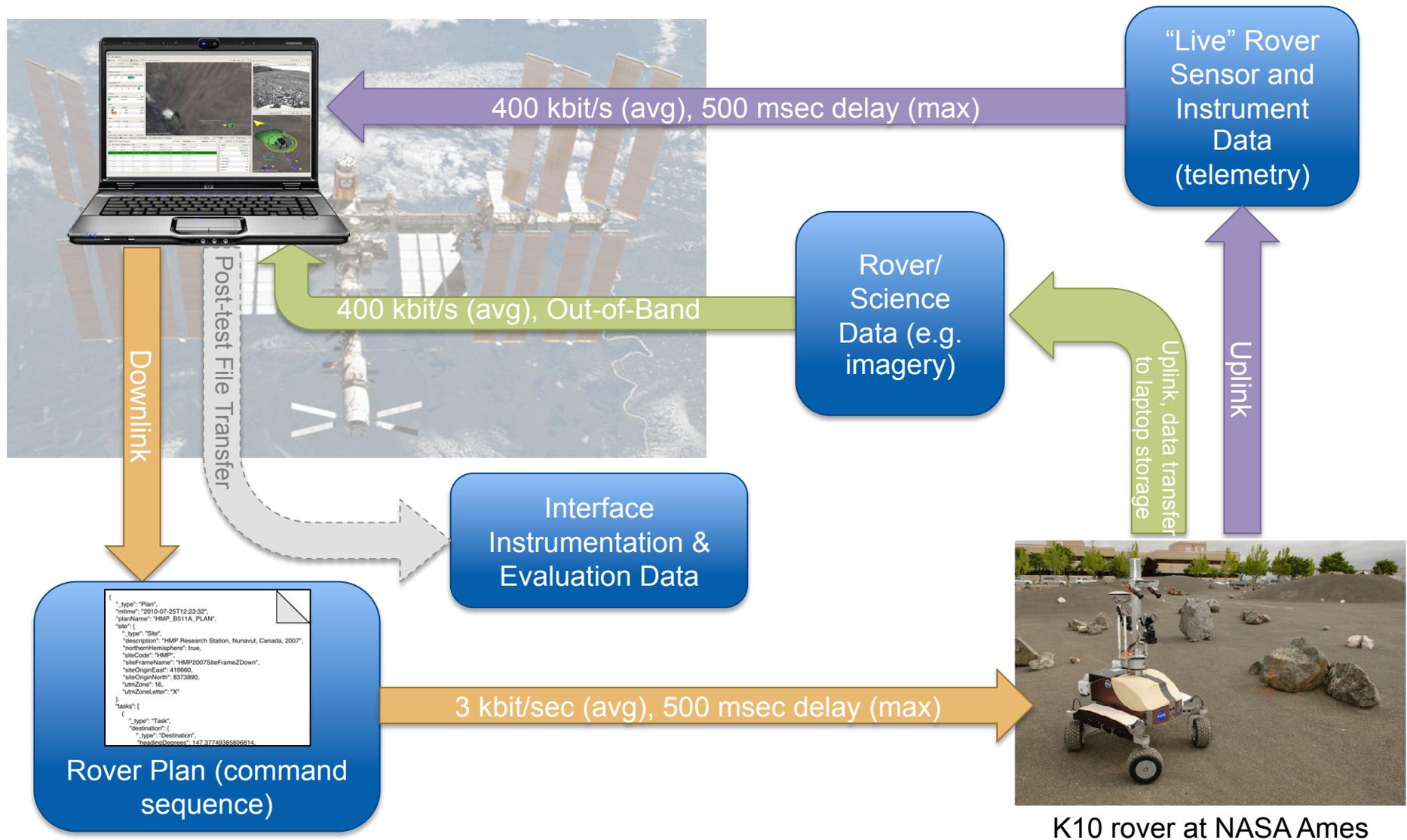


INSPECT

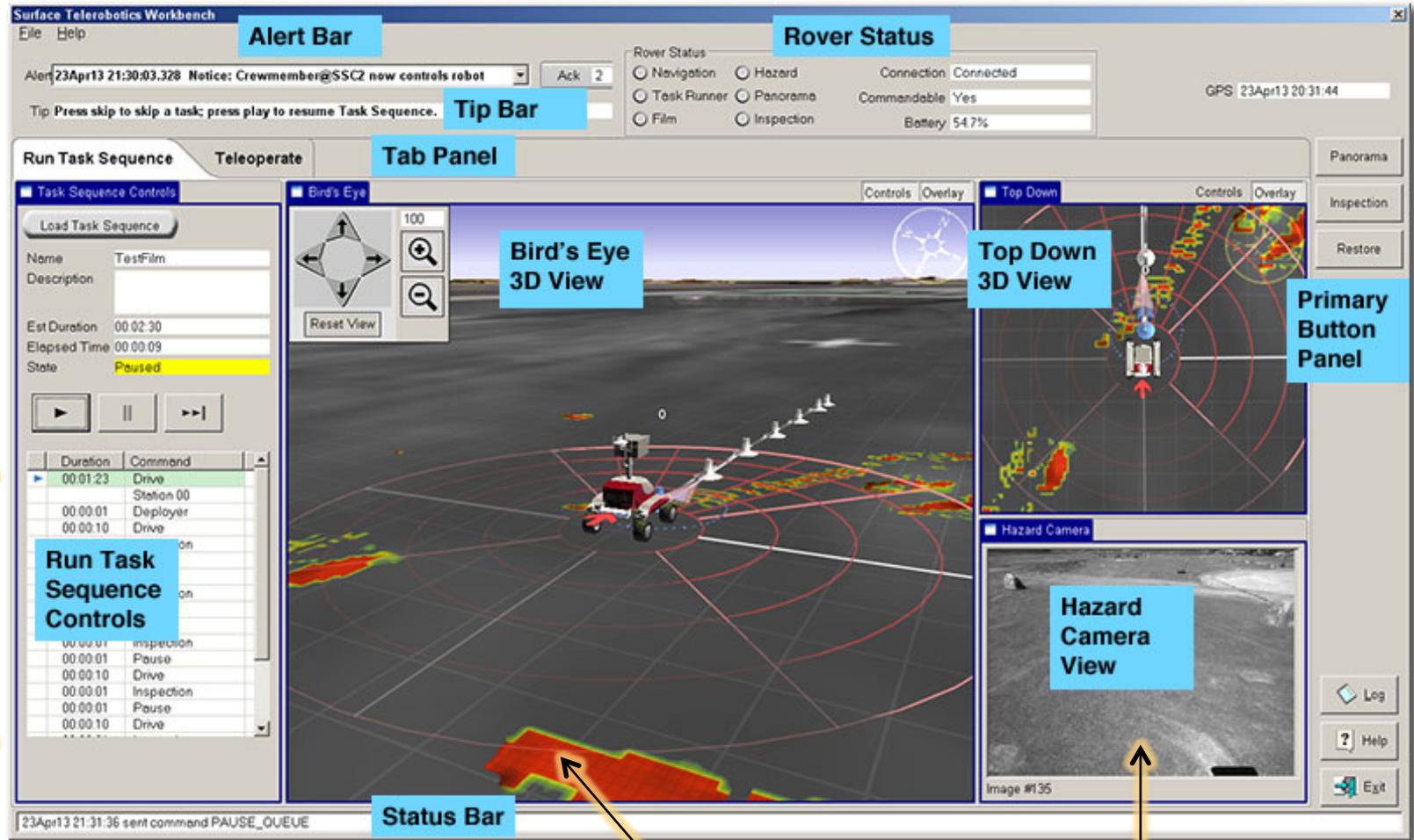
- **Human-robot mission sim:** site survey, telescope deployment, and inspection
- **Telescope proxy:** Kapton polyimide film roll (no antenna traces, electronics, or receiver)
- **3.5 hr per crew session** (“just in time” training, system checkout, ops, & debrief)
- **Robot ops:** manual control (discrete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



# ISS Test Setup



# Robot Interface (Supervisory Control)



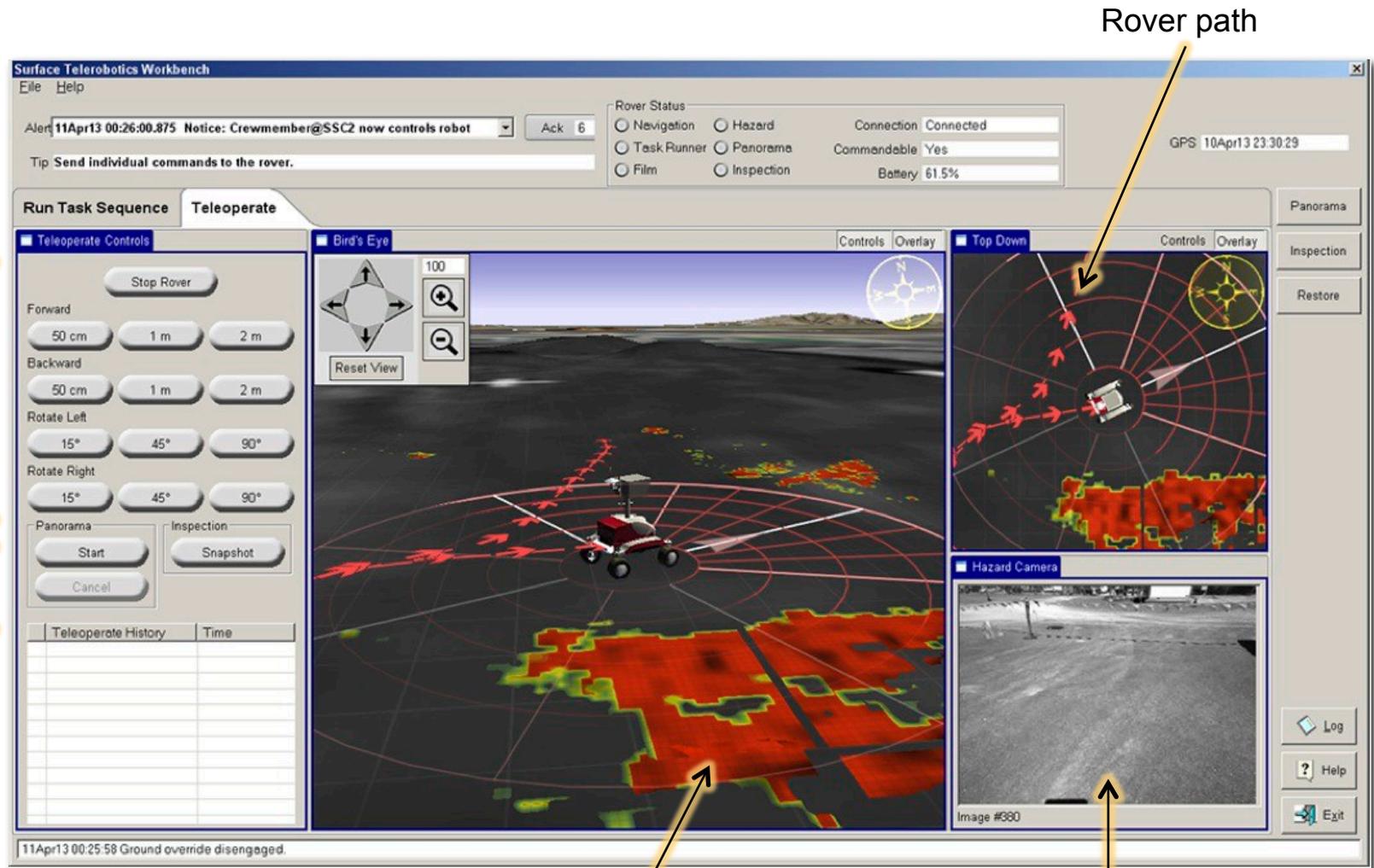
Task Sequence

Terrain hazards

Rover camera display



# Robot Interface (Manual Control)



Motion controls

Camera controls

Rover path

Terrain hazards

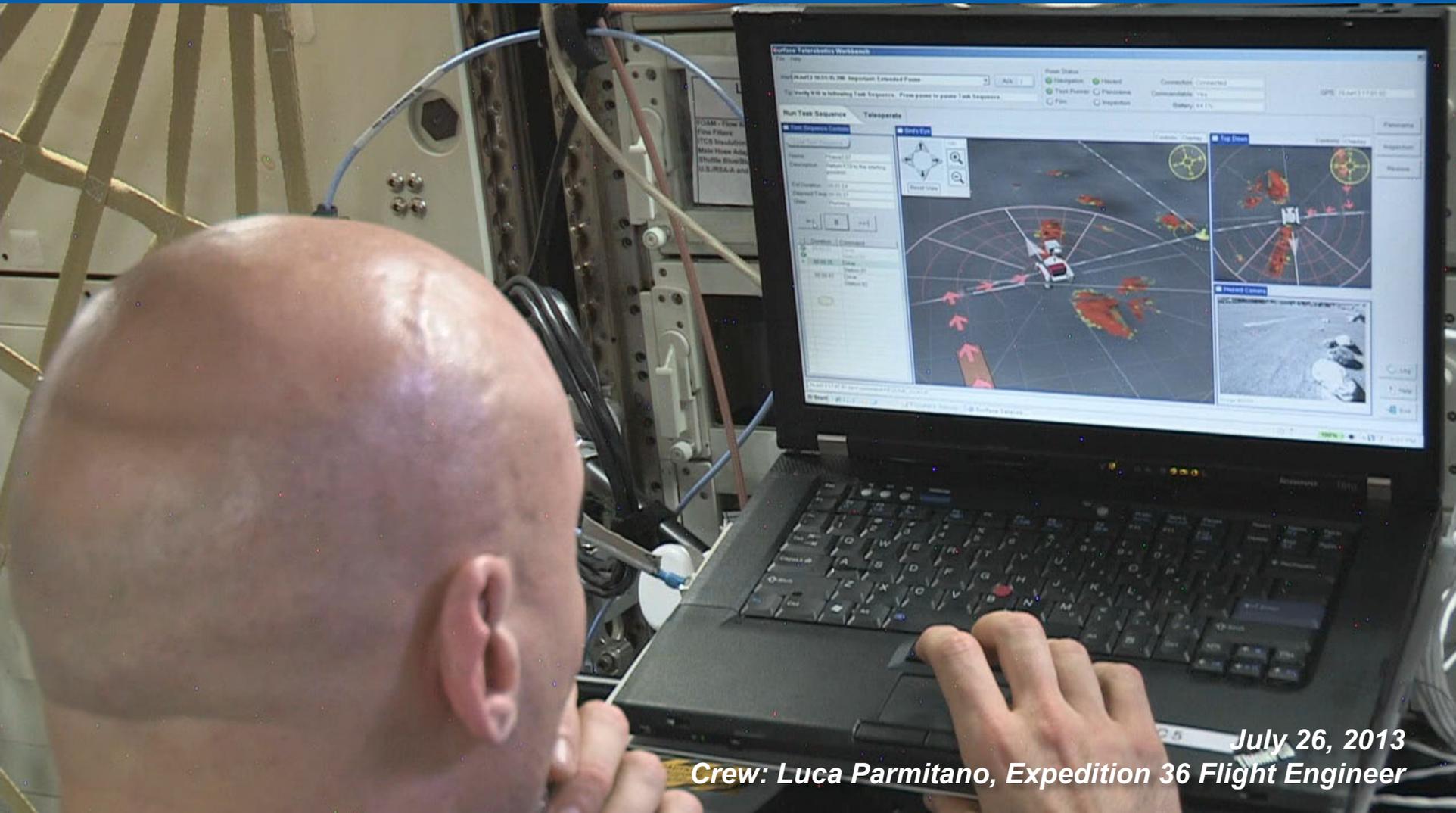
Rover camera display



# Surface Telerobotics



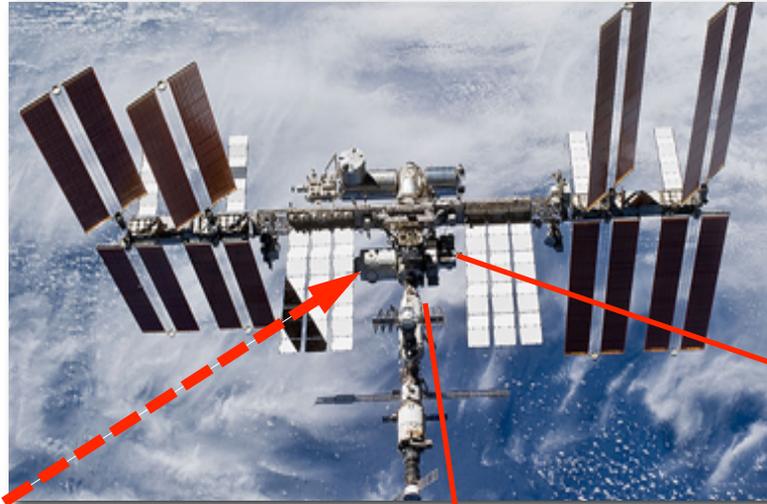
# Surface Telerobotics



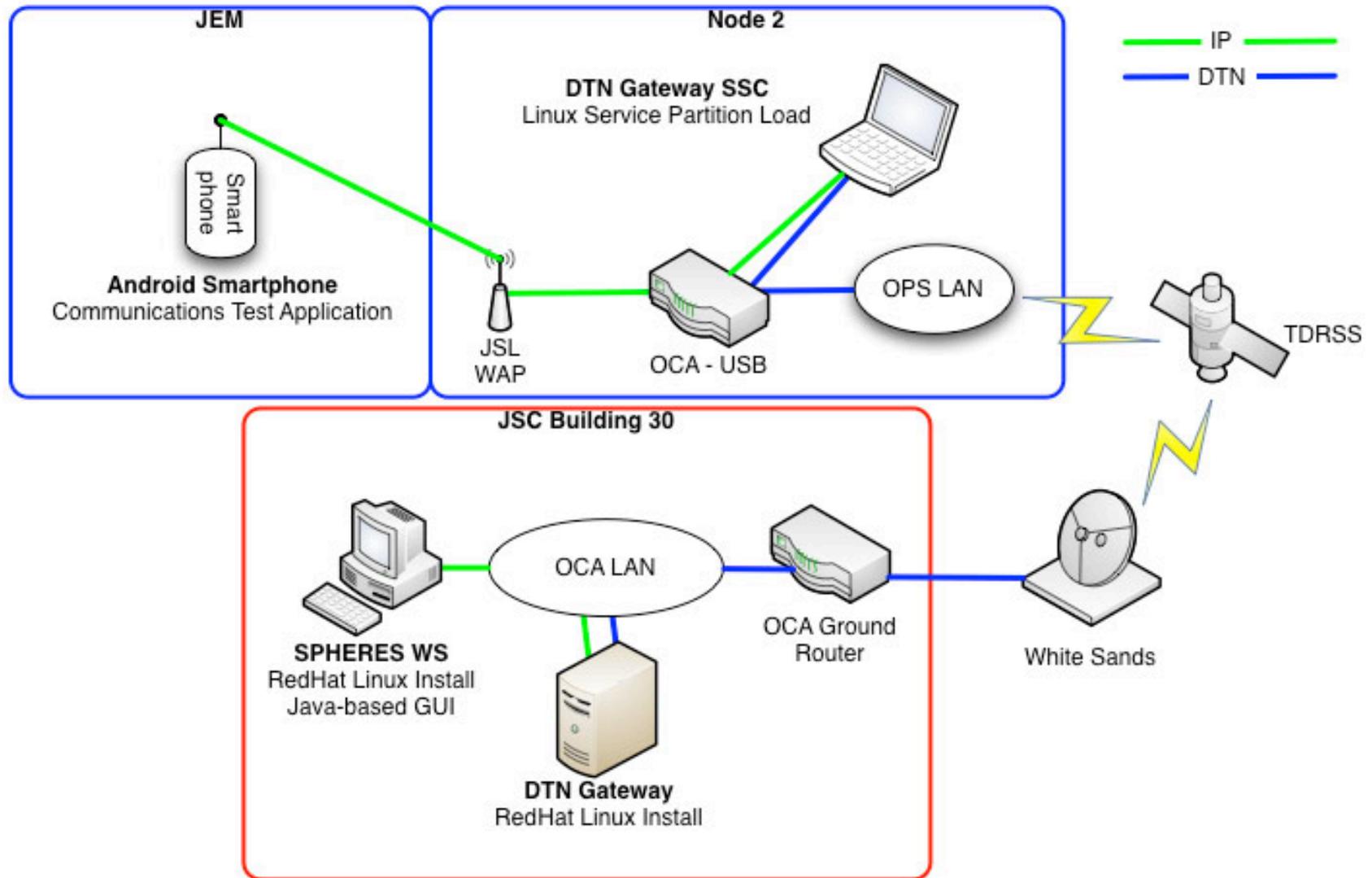
July 26, 2013  
Crew: Luca Parmitano, Expedition 36 Flight Engineer



# Smart SPHERES



# Smart SPHERES Network Setup



# ISS Interior Survey with SmartSPHERES



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

*2x speed*



# Questions?



Intelligent Robotics Group  
[irg.arc.nasa.gov](http://irg.arc.nasa.gov)