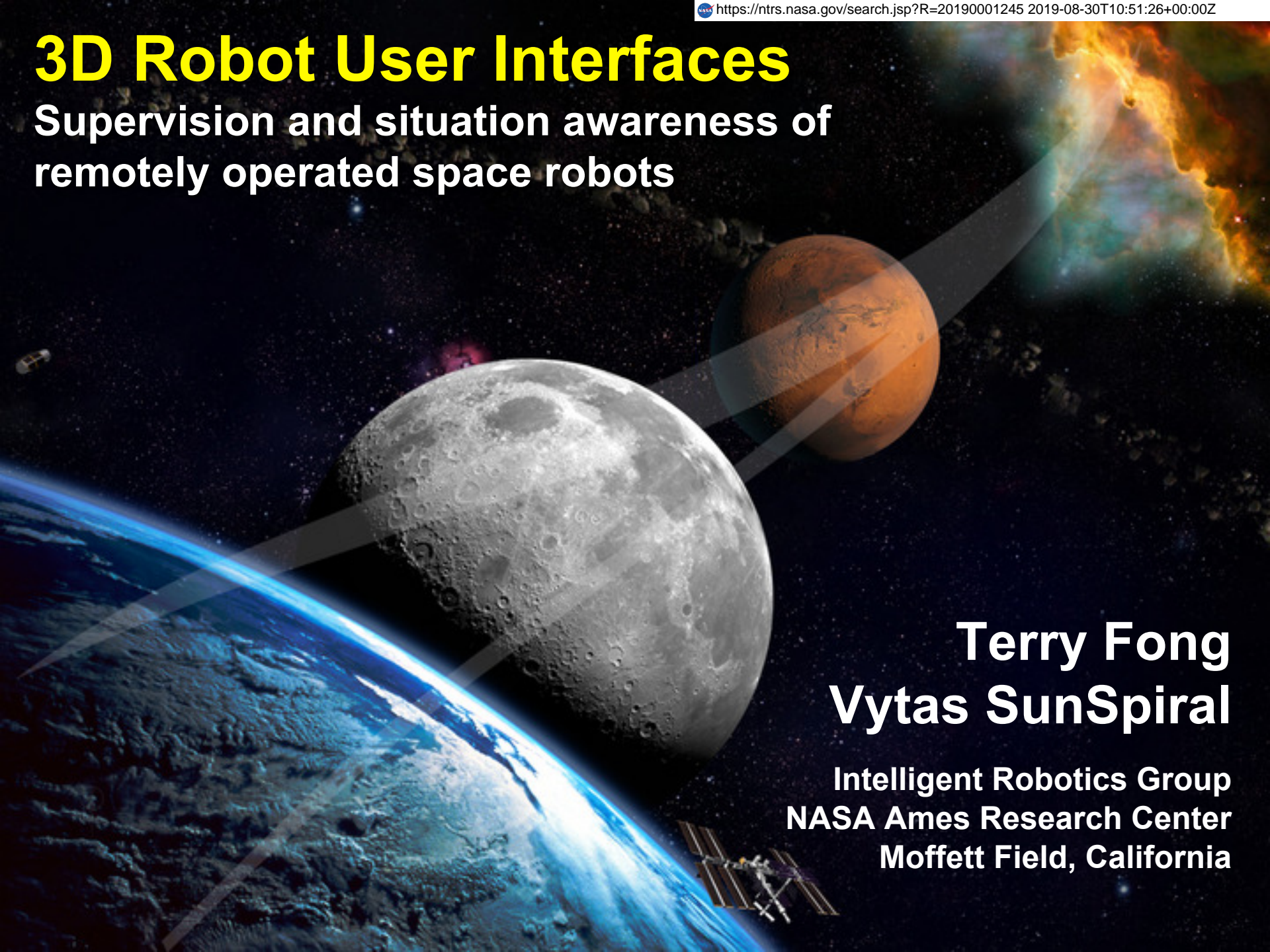


# 3D Robot User Interfaces

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

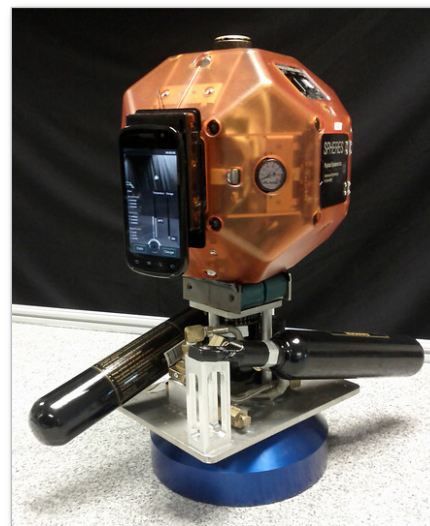
## Overview

- 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



## Commercial



Otherlab



ProtoInnovations



## Government

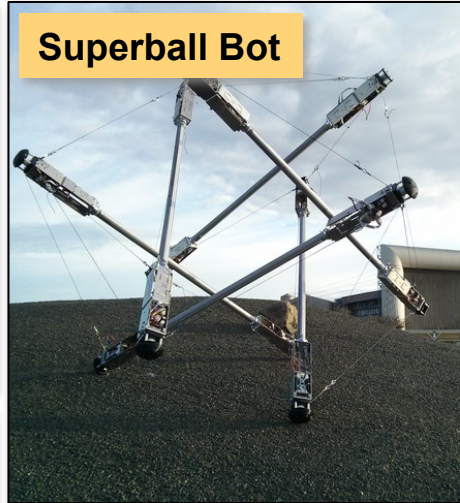


3D Robot User Interfaces

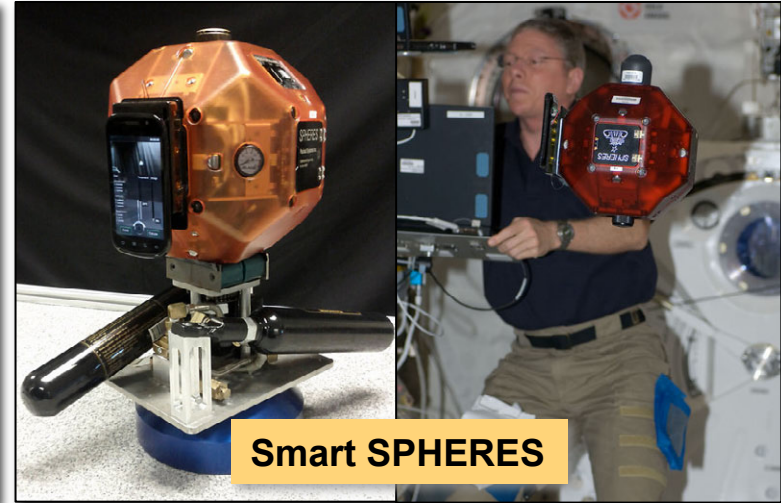
# Robots



**K10**



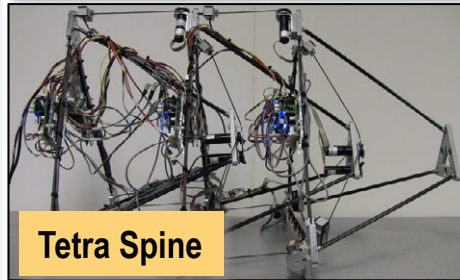
**Superball Bot**



**Smart SPHERES**



**KREX**



**Tetra Spine**



**K10 mini**



**GigaPan Voyage**



**Lake Lander**

## Interactive 3D UI

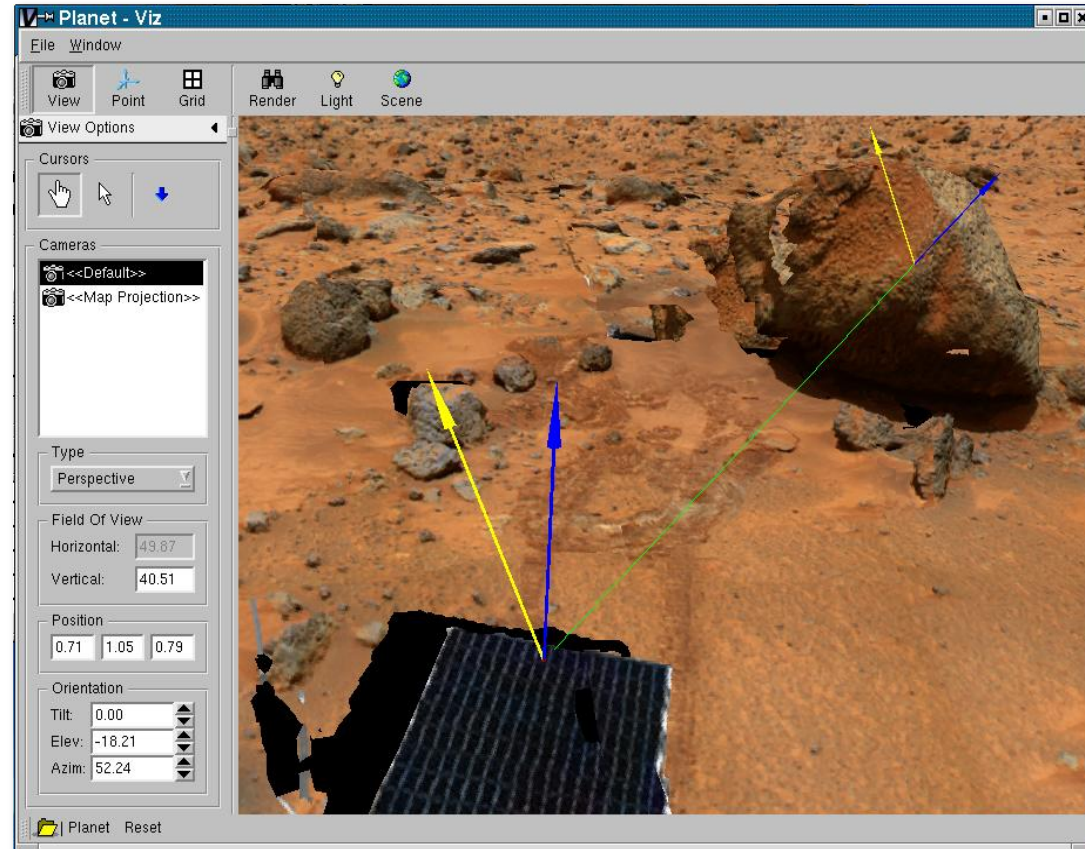
- Stereo viewing
- Background image

## 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. The robot is a white, four-wheeled rover with a yellow antenna and a white robotic arm. Blue arrows on the floor indicate movement directions. Mathematical coordinates are visible:  $x = 19.2$ ,  $y = 21.3$ ,  $z = 0.0$ .
- Centaur - Robot Eye View:** Shows a first-person view from the robot's perspective, looking down at its two white robotic arms and hands, which are positioned over a white tray containing several small, rectangular objects.
- Centaur - Top Down View:** Shows a top-down view of the robot on the blue grid floor, with blue arrows indicating movement directions.
- DCI Event Log Viewer:** A log window showing a list of events with timestamps and descriptions. The log includes entries such as "Motion Stopped in LJ2 -1.4699", "Motion Started in RJ2 -1.4597", and "Motion Stopped in left arm".
- Observer:image0\_2.jpg:** A small window showing a real-world photograph of the Centaur robot in a field.
- EgoSphere Status, Corba Status, Viz Status, Console:** A row of status and console windows. The console window shows a list of image capture events, such as "new LeftEye image: GryL\_0.jpg\_time\_2993823.0000\_stamp.jpg" and "new Observer image: image0\_3.jpg\_time\_2993839.4680\_stamp.jpg".
- LeftEye:GryL\_3.jpg, CamImageView:** A window showing a real-time video feed from the robot's left eye, showing the robotic arms and hands over the tray.



# Centaur (Robonaut): Hardware Faults

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

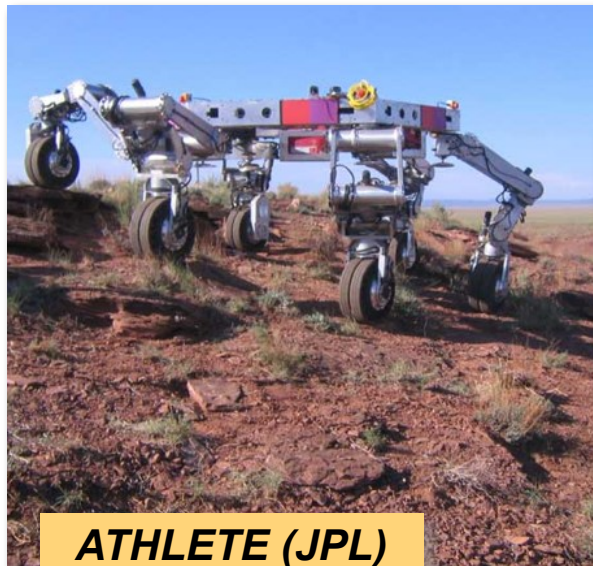
- Centaur - Follow Mode View:** A 3D rendering of the Centaur robot on a virtual terrain with a grid and blue arrows indicating movement directions.
- Centaur - Robot Eye View:** A first-person view from the robot's perspective, showing a dark, textured environment.
- Centaur - Top Down View:** A top-down 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 list of events and alerts, including motion status and joint loss warnings.
- Observer: image0\_0.jpg:** 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 log windows.
- LeftEye: GryL\_1.jpg:** A real-time video feed from the robot's left eye.
- CamImageView:** A real-time video feed from a camera mounted on the robot.

The DCI Event Log Viewer displays the following log entries:

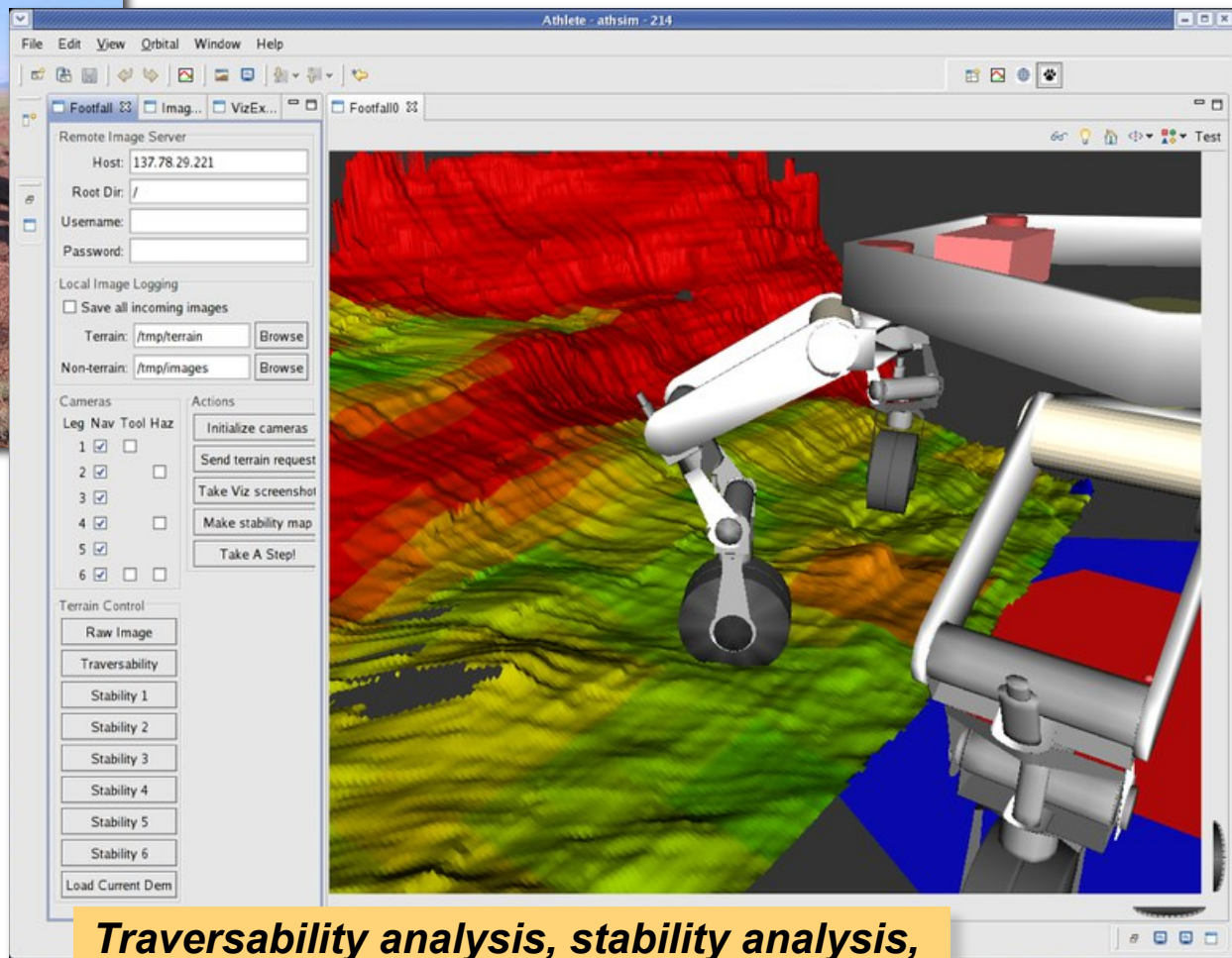
- (1:36:26 PM) Motion Started in LJ5 1.0925
- (1:36:26 PM) Motion Started in LJ6 0.5251
- (1:36:26 PM) Motion Started in left arm
- (1:36:26 PM) Alarm Loss of joint in RJ1 0.2575**
- (1:36:26 PM) Alert Possible Loss of joint in RJ:**
- (1:36:26 PM) Motion not observable in RJ4 -2.2558
- (1:36:26 PM) 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) Alarm Loss of joint in RJ2 -0.752**
- (1:36:26 PM) Alert Possible Loss of joint in RJ:**
- (1:36:26 PM) Alarm 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) Alarm Loss of joint in RJ6 0.659**
- (1:36:28 PM) Alarm Loss of joint in RJ3 1.2115**
- (1:36:28 PM) Alarm 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) Alarm Loss of joint in RJ6 0.659**
- (1:36:29 PM) Motion not observable in RJ6 0.659
- (1:36:29 PM) Alarm 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

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
---------	----------	--------------------------------------

Replan Hide Ghost Done

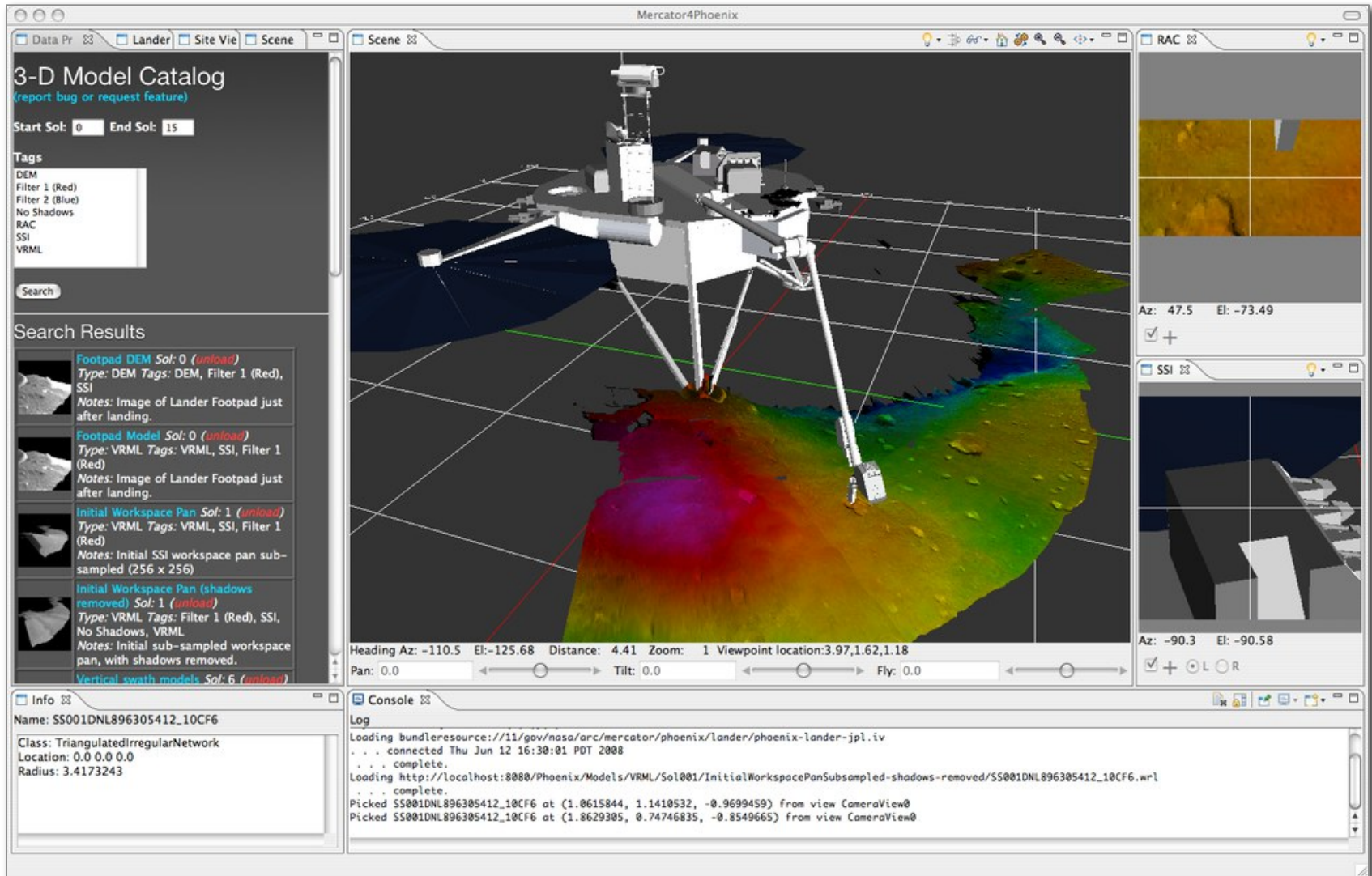
Planned Command Sequence.

STOP

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



# Phoenix Lander: Manipulator Monitoring



# VERVE

## 3D robot user interface

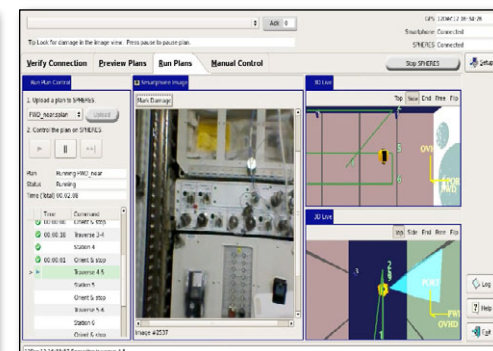
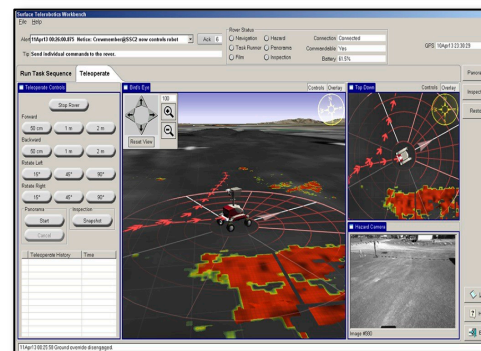
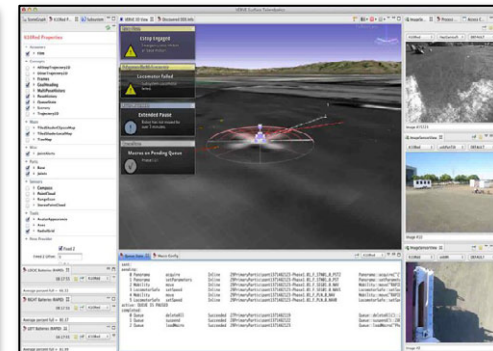
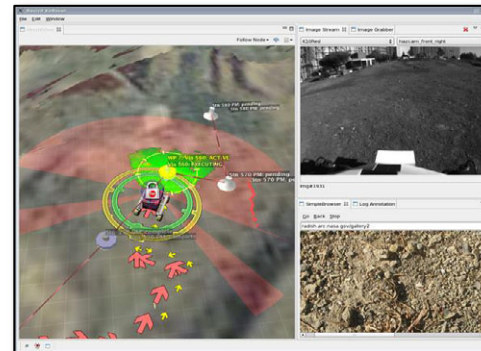
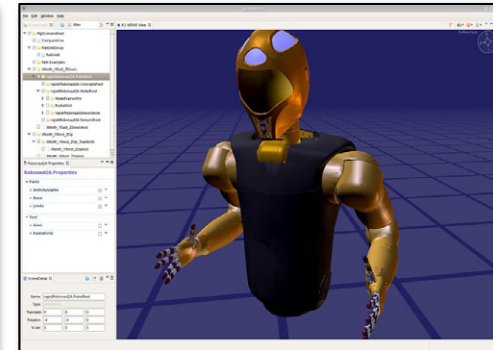
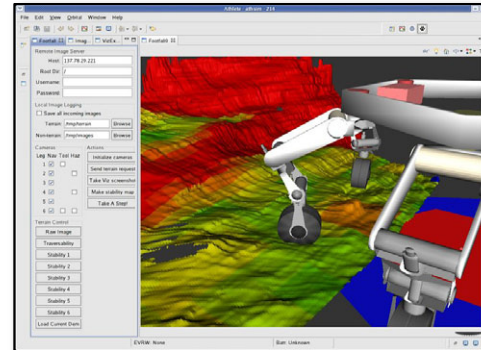
- Interactive planning and monitoring of space robots
- Facilitates situation awareness
- Multiple control modes

## Technologies

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

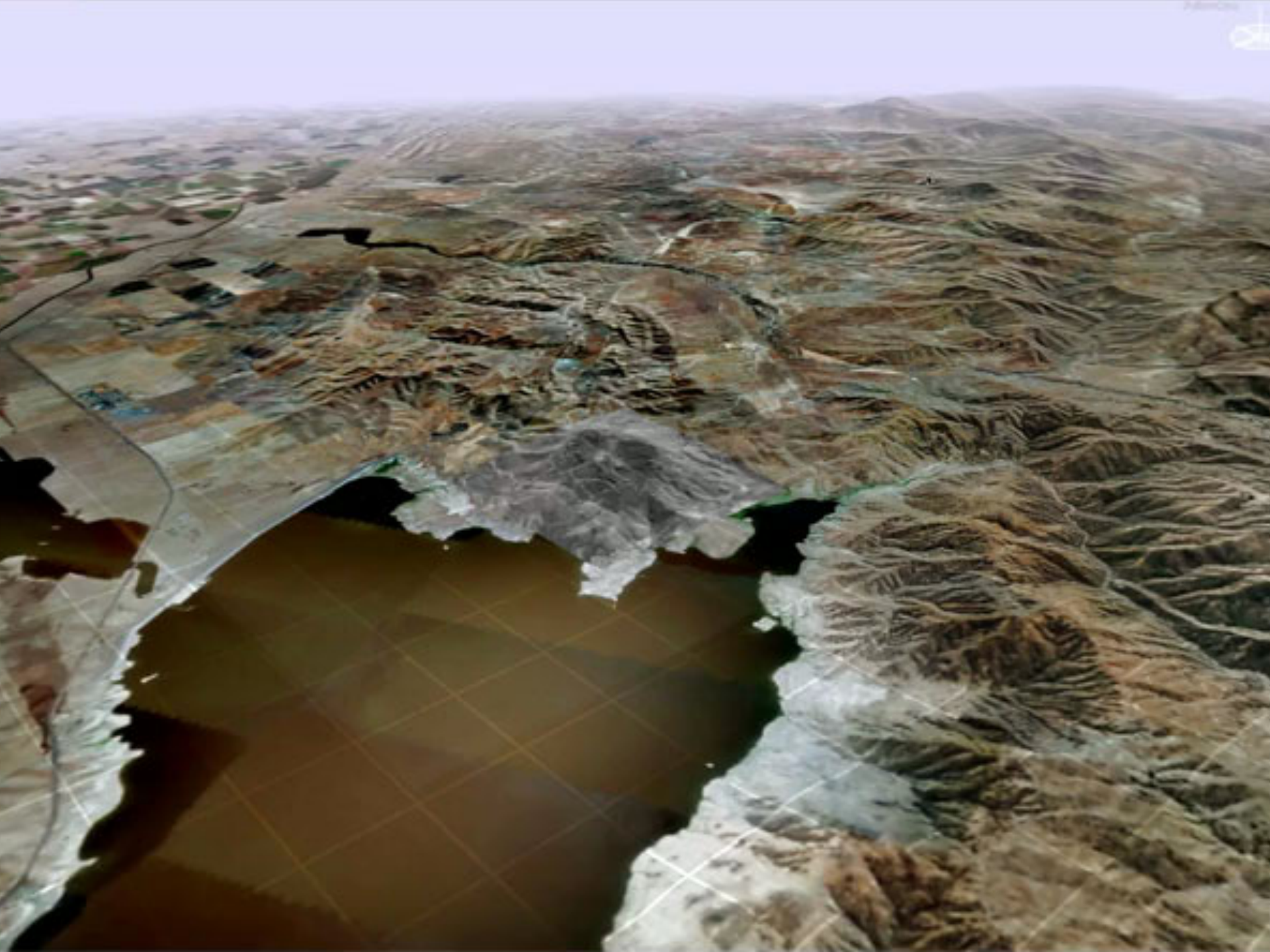
## Applications

- 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

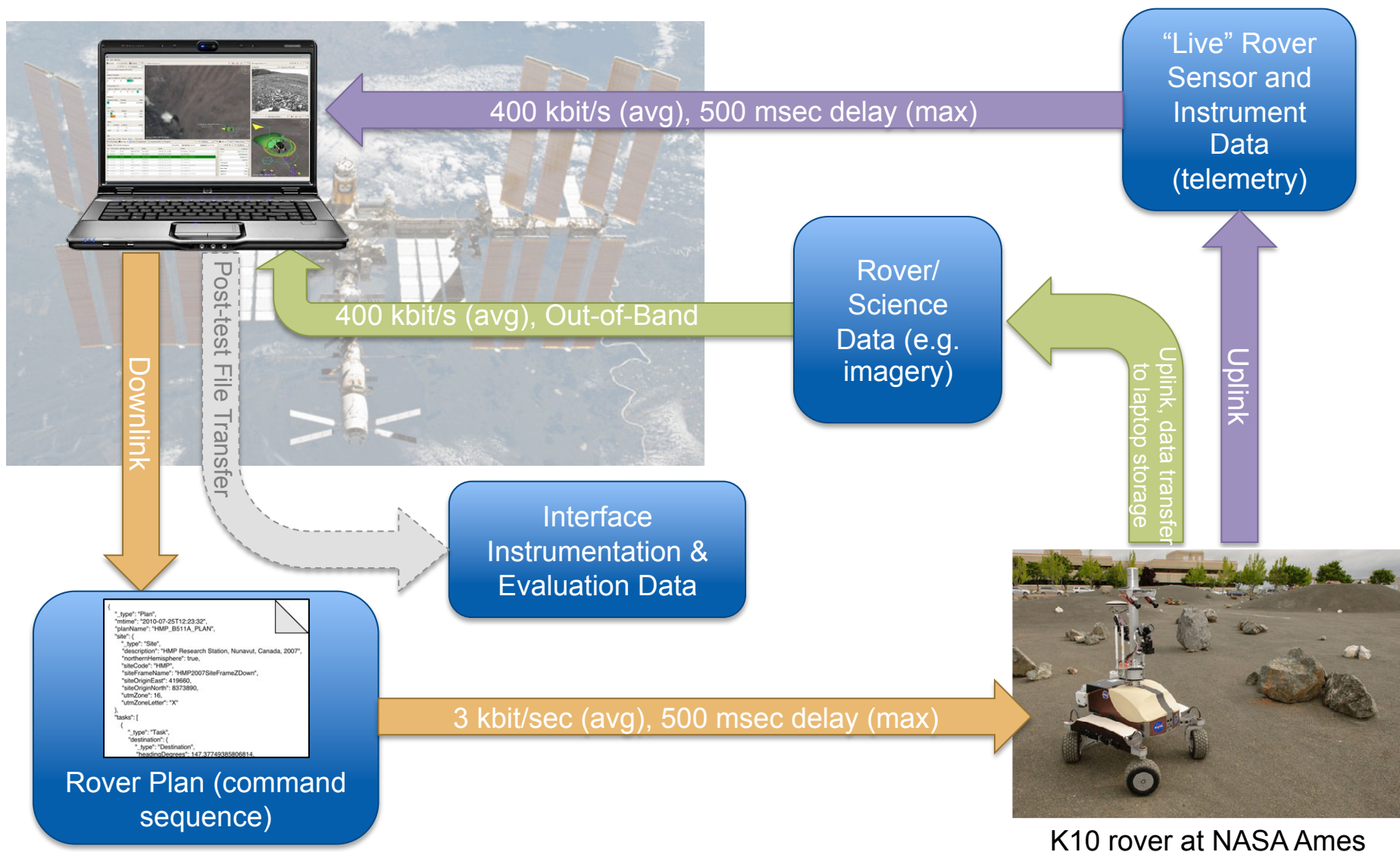


INSPECT

- **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)



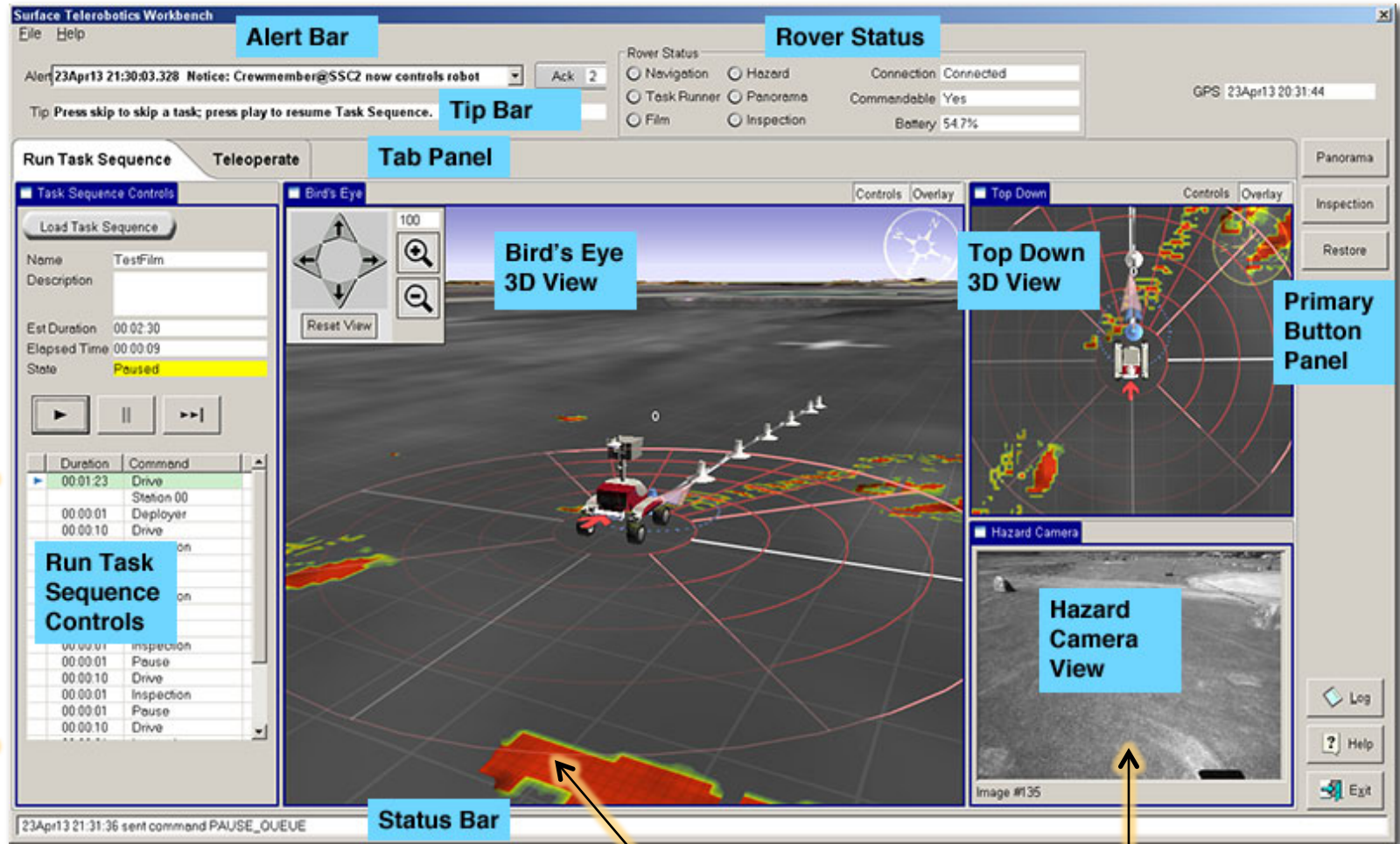
# ISS Test Setup



K10 rover at NASA Ames



# Robot Interface (Supervisory Control)



Task Sequence

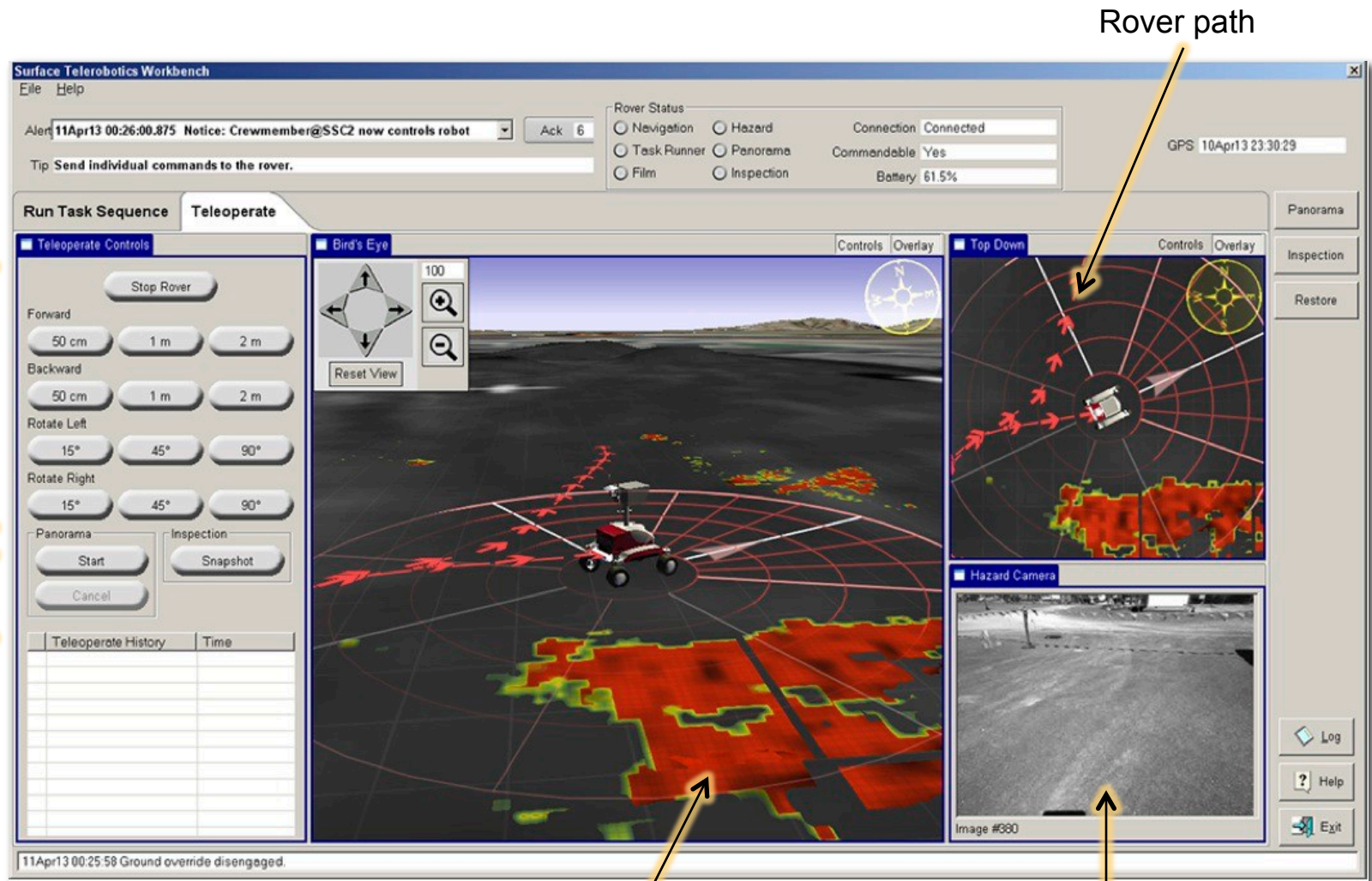
Terrain hazards

Rover camera display





# Robot Interface (Manual Control)



Motion controls

Camera controls

Rover path

Terrain hazards

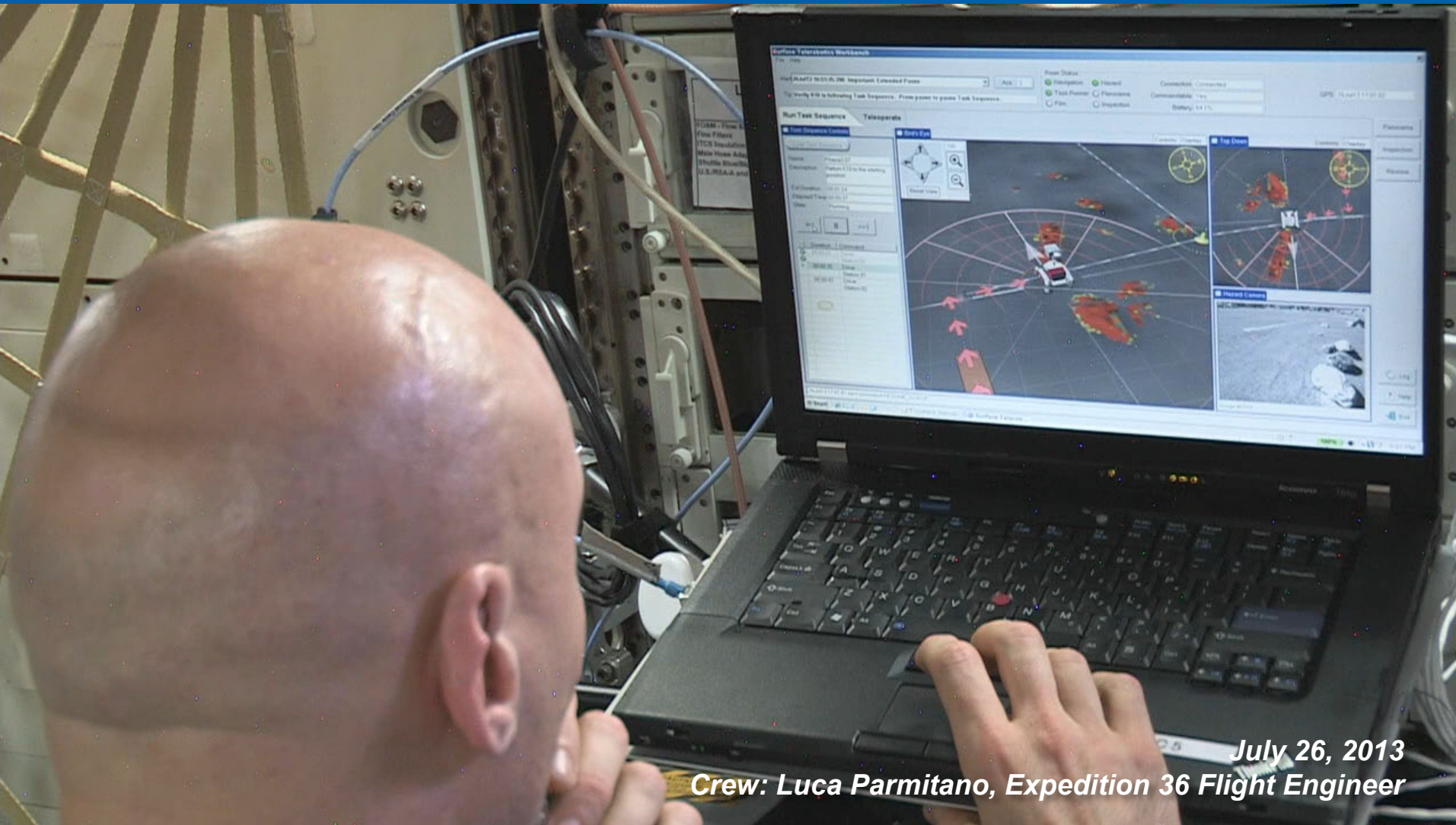
Rover camera display



# Surface Telerobotics

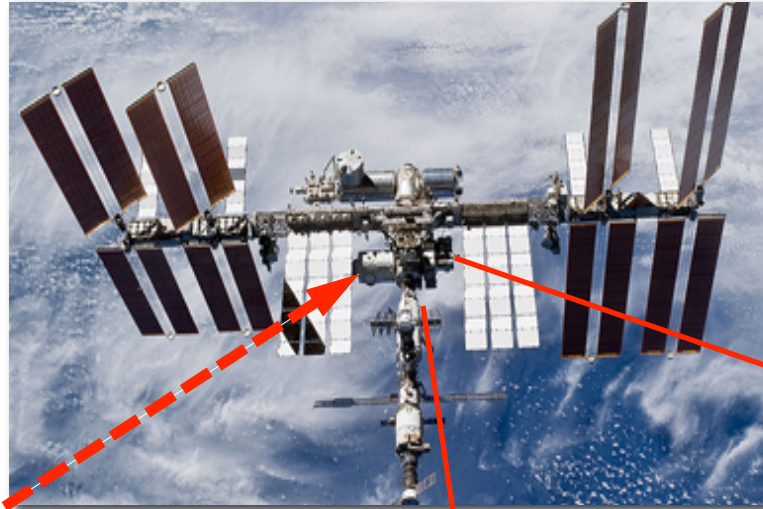


# Surface Telerobotics

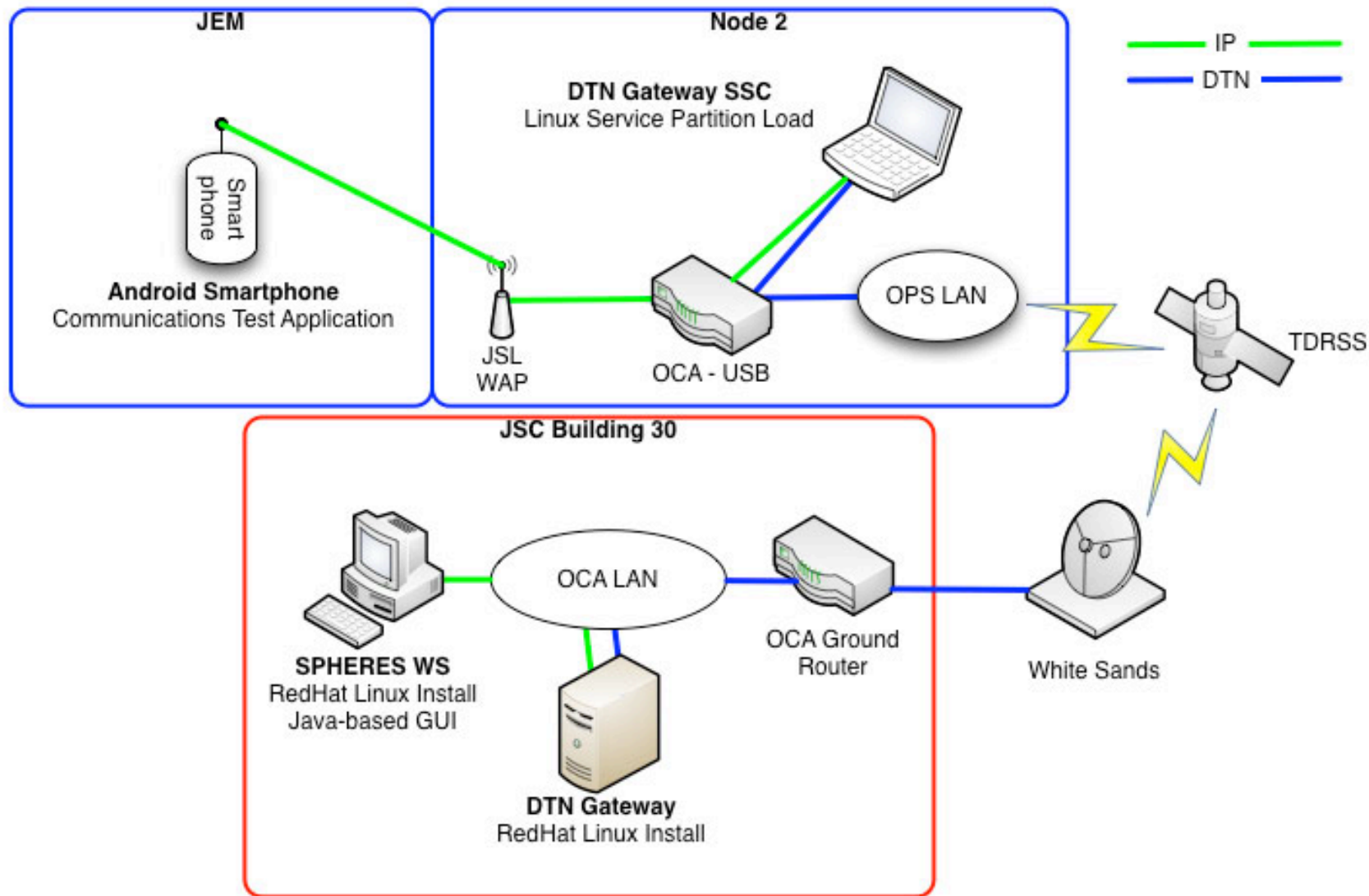


July 26, 2013  
Crew: Luca Parmitano, Expedition 36 Flight Engineer

# 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)