# NASA Telerobotic Operations

## From Earth orbit to deep space




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# NASA Space Telerobotics

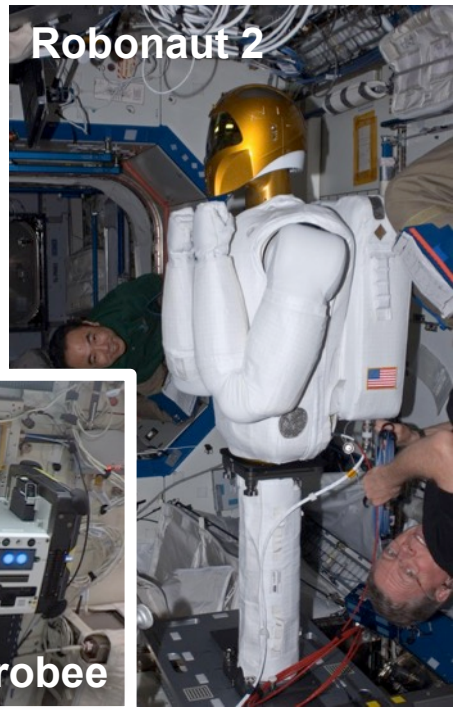
## Uses

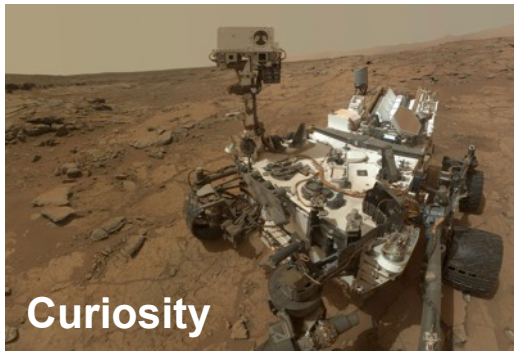
- Exploration (assembly, maintenance, crew/payload positioning, ISRU)
- Science (instrument deployment, measurements, sampling, analysis)
- Technology development and research (NASA and non-NASA)







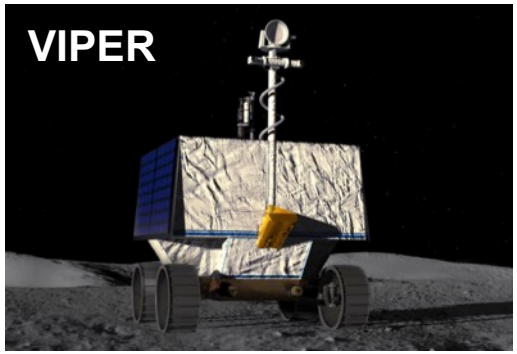









Fong, Zumbado, Currie, Mishkin, & Akin (2013). **Space telerobotics: unique challenges to human-robot collaboration in space**. Reviews of Human Factors & Ergonomics Society 9(1).

# Telerobotic Operations




**Robot in Earth orbit**
**Ground control**



**Robot on surface**
**Ground control**



**Astronaut in space**
**Robot on surface**

# ISS Mobile Servicing System (MSS)



**Space Station Remote Manipulator System (Canadarm2)**

# ISS Mobile Servicing System (MSS)



**Special Purpose Dexterous Manipulator (“Dextre”)**

# MSS Operations at JSC




Flight Control Room (FCR)



Multi-Purpose Support Room (MPSR)

## Flight controller roles

- **ROBO** (FCR) – Manages ops, interacts with other controllers
- **MSS Systems** (MPSR) – Primary commanding, health monitoring
- **MSS Task** (MPSR) – Monitors procedure, real-time replanning, etc.

*Note: the Canadian Space Agency also performs MSS operations from CSA Headquarters*

# MSS Operations

## Tasks

- Crew and payload external positioning
- EVA servicing tasks
- Grappling and berthing visiting vehicles (Cygnus, Dragon, etc)

## Planning

- A typical 8 hour robot ops shift requires at least 40 hours of planning
- Software used for automated trajectory planning and command scripting

## Ground control

- Step-by-step command script execution for nominal operations
- Discrete commands (joint angles and end effector pose)
- Software for script monitoring, pre/post condition checks, and simple computer vision (target alignment)
- Primarily text-based user interfaces

# Space Station Robotic Workstation



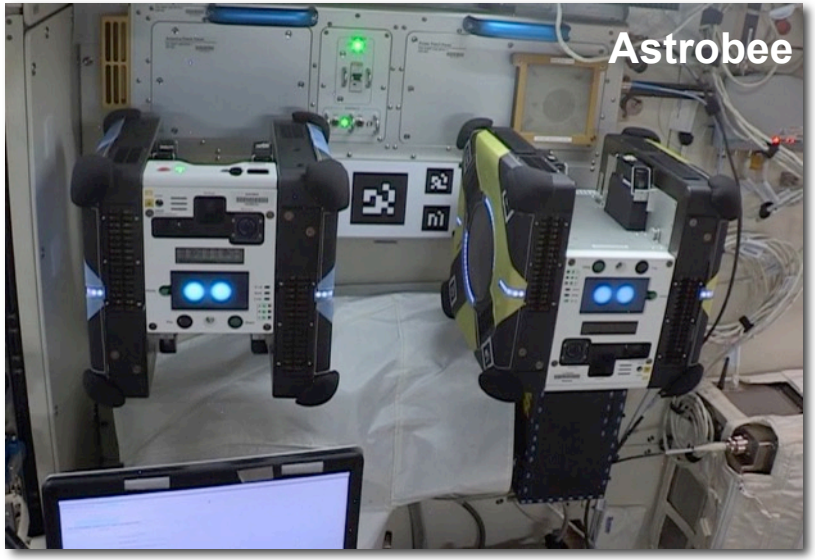
**Koichi Wakata, Expedition 39 commander remotely operating the Canadarm2**

# Space Station IVA Robots





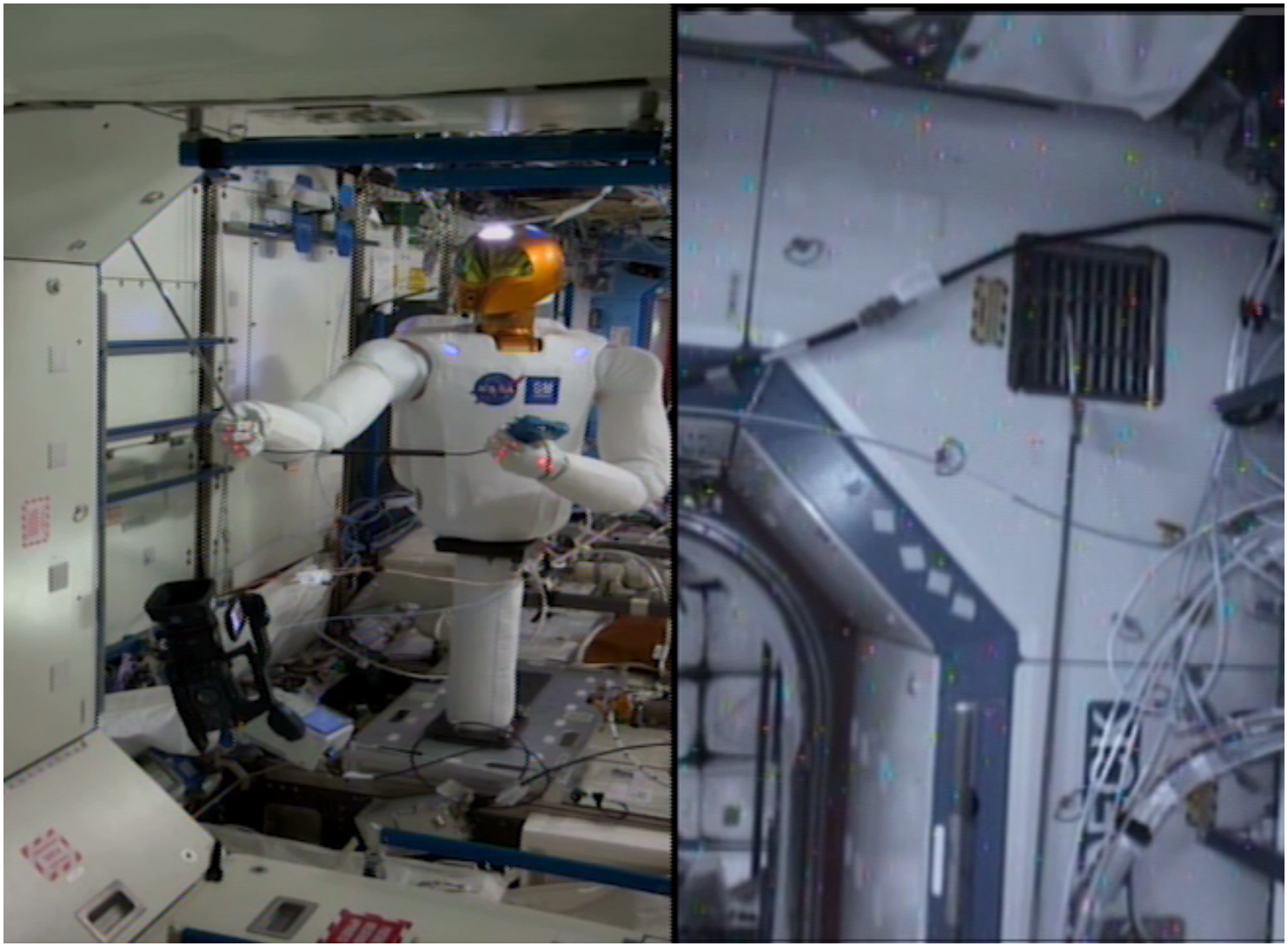




# IVA Free-Flyer Operations

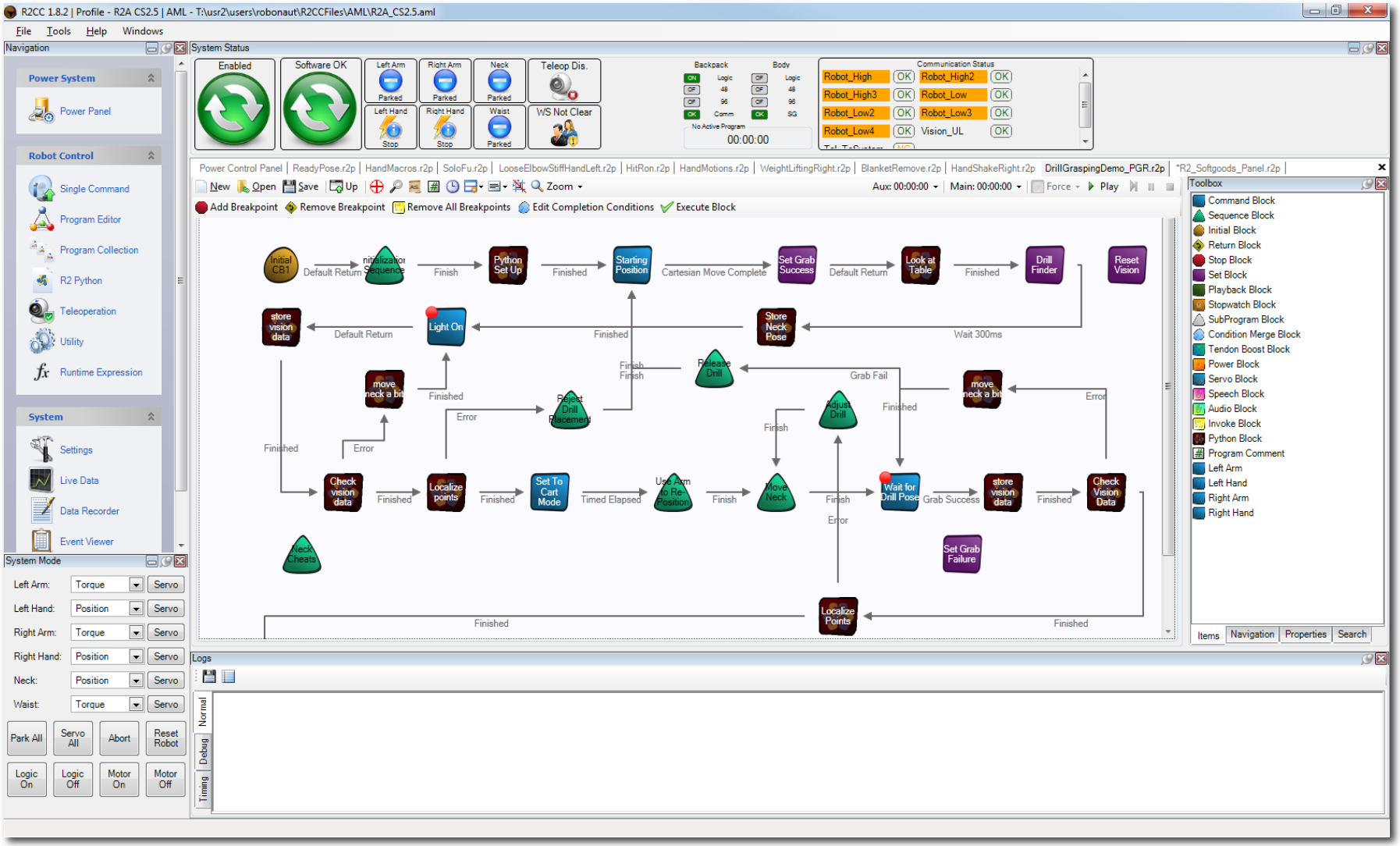


# Robonaut 2 Operations



***Robonaut 2 with VelociCalc on ISS (June 2013)***

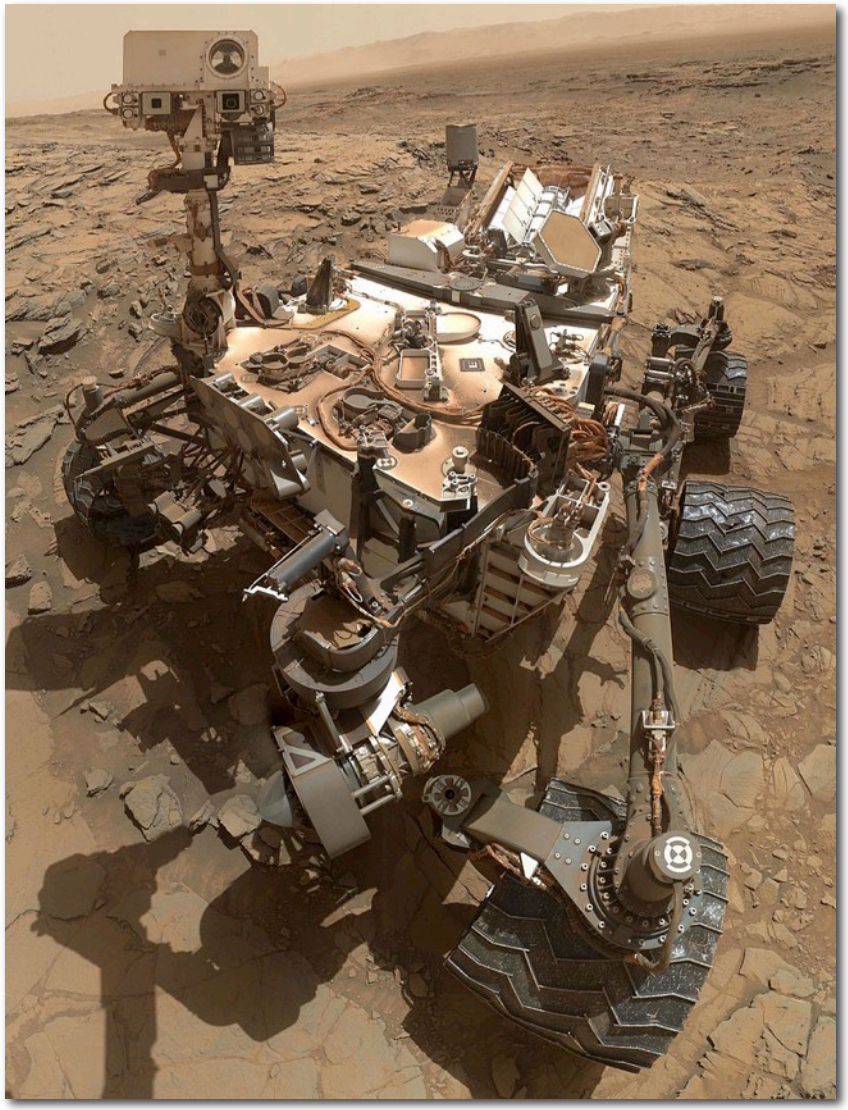
# Robonaut 2 Control Interface



# Mars Rovers



**Mars Exploration Rover on Mars (artist concept)**



**Curiosity at “Big Sky” on Mars (2015)**

# Mars 2020



**Perseverance rover**



**Ingenuity helicopter**

# Mars Rover Communications

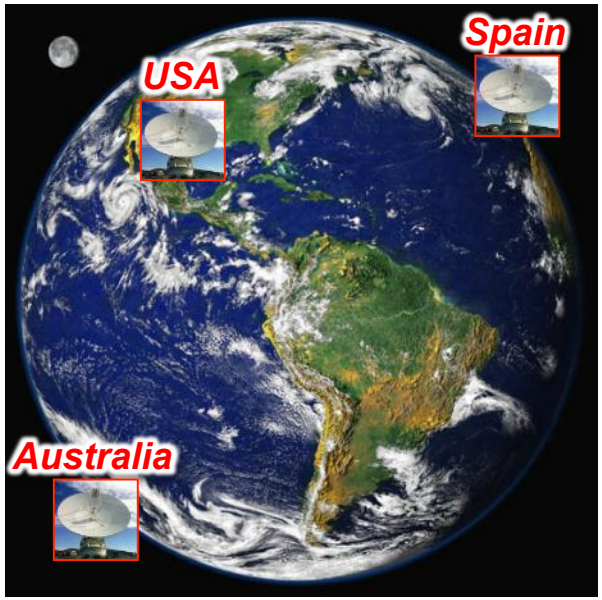


MRO,
Mars Odyssey,
Mars Express

Up to 6 Mbps
Up to 24 min delay

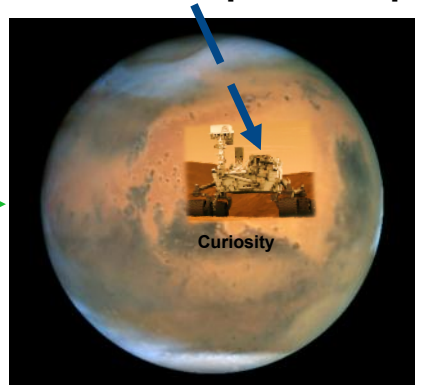
Up to 2 Mbps

*Deep Space Network*
*(70 m antennas)*




Earth's Rotation: 24 hour day

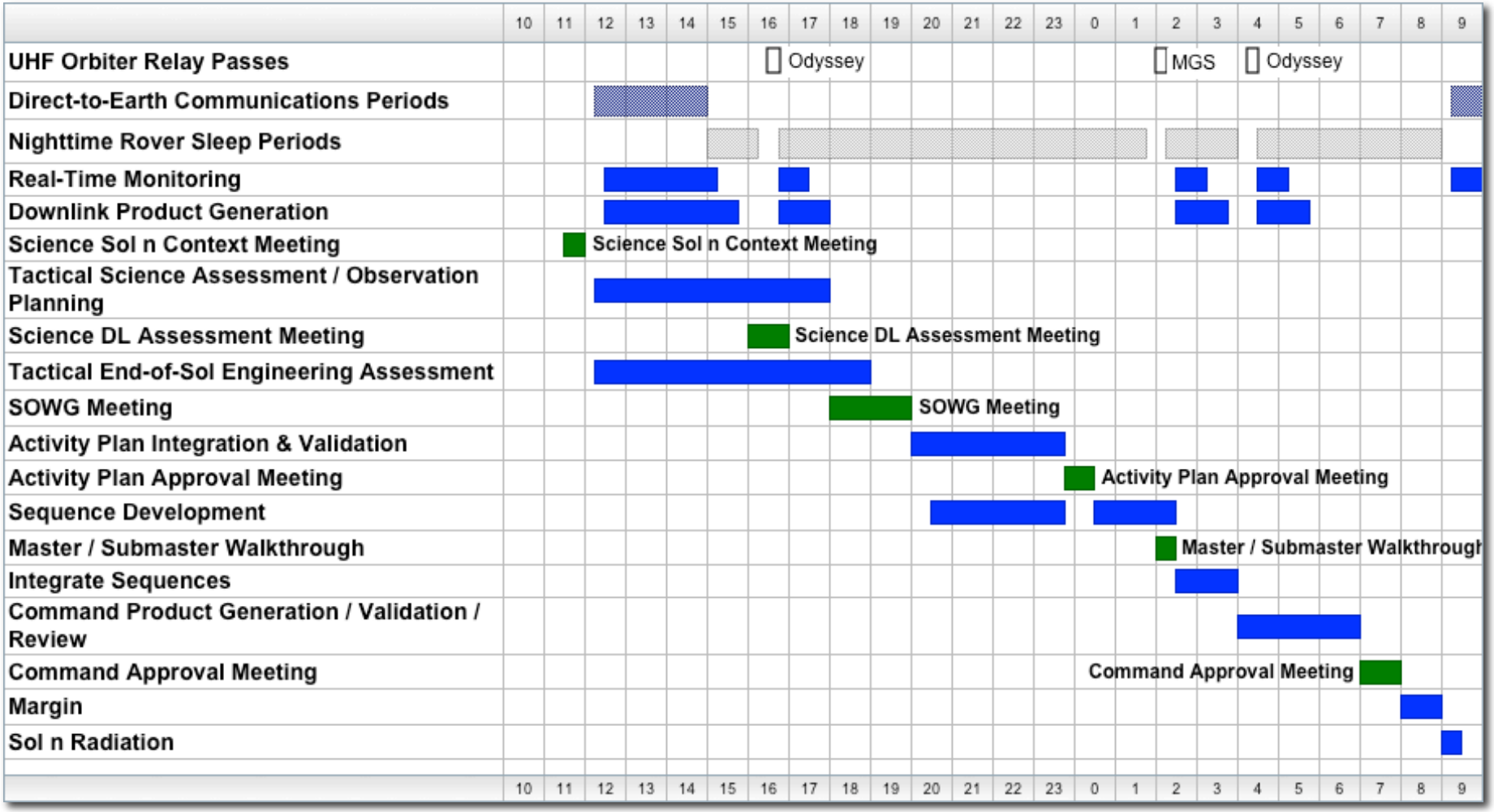
Up to 32 kbps
Up to 24 minute delay



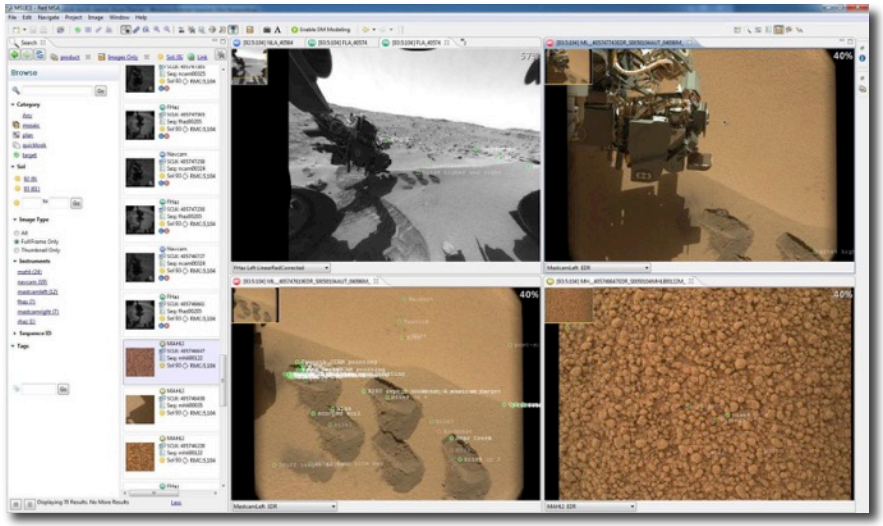

Mars' Rotation: 24.65 hour Sol

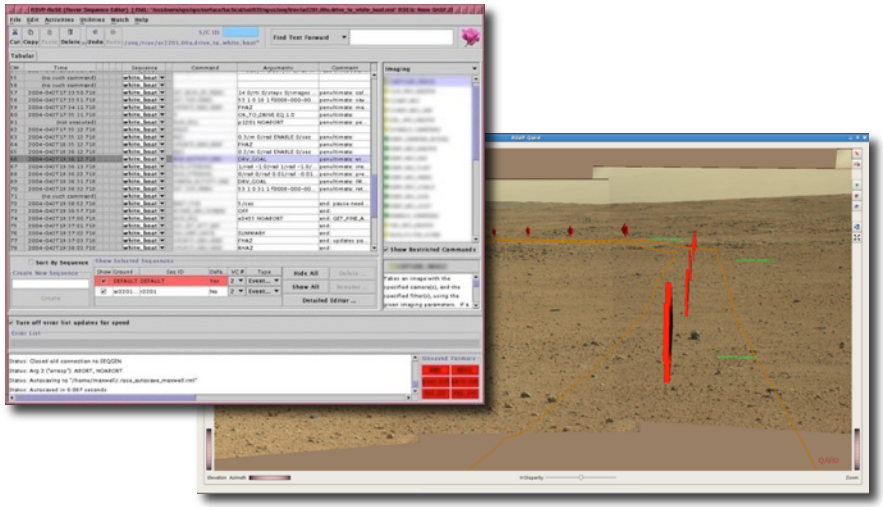
*Courtesy V. Verma (JPL)*

# Mars Rovers Tactical Ops Process (2004)

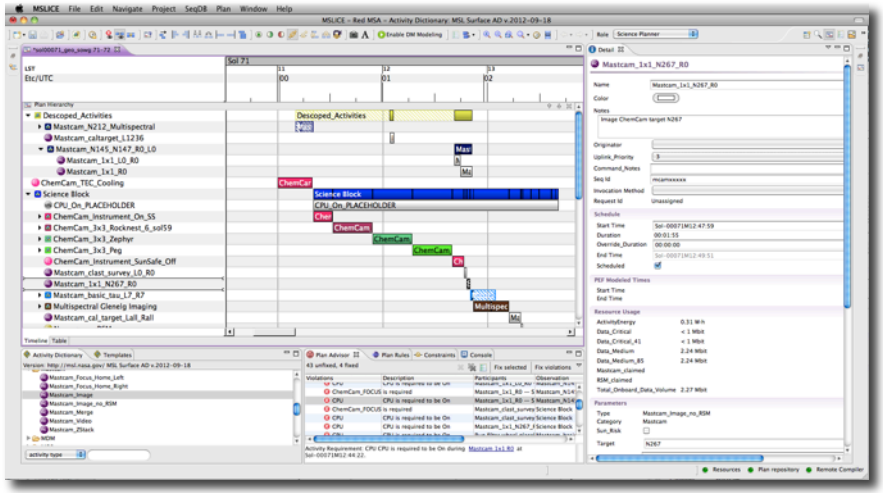


# Curiosity Rover Ops Tools

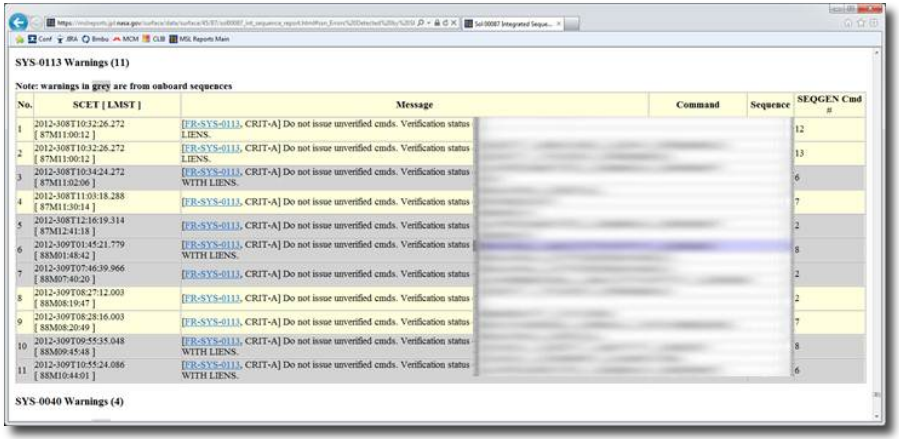




Sequencing



Planning



SYS-0113 Warnings (11)

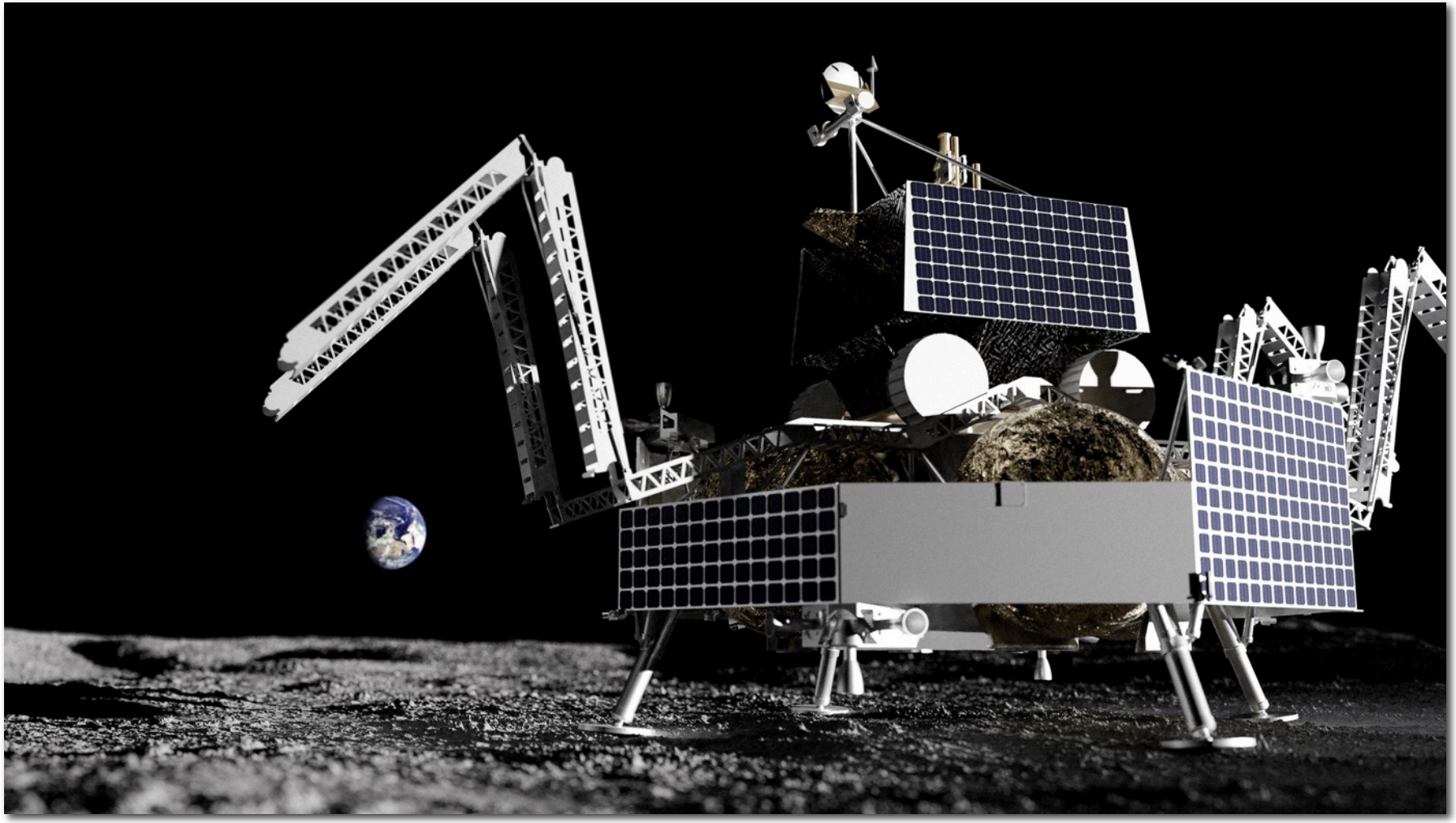
Note: warnings in grey are from onboard sequences

| No. | SCET [ LMST ] | Message | Command | Sequence | SEQGEN Cmd # |
|---|---|---|---|---|---|
| 1 | 2012-308T10:32:26.272 [ 87M11:00:12 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status LIENS. | | | 12 |
| 2 | 2012-308T10:32:26.272 [ 87M11:00:12 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status LIENS. | | | 13 |
| 3 | 2012-308T10:34:24.272 [ 87M11:02:06 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS. | | | 6 |
| 4 | 2012-308T11:03:18.288 [ 87M11:30:14 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status | | | 7 |
| 5 | 2012-308T12:16:19.314 [ 87M12:41:18 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status | | | 2 |
| 6 | 2012-309T01:45:21.779 [ 88M01:48:42 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS. | | | 8 |
| 7 | 2012-309T07:46:39.966 [ 88M07:40:20 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status | | | 2 |
| 8 | 2012-309T08:27:12.003 [ 88M08:19:47 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status | | | 2 |
| 9 | 2012-309T08:28:16.003 [ 88M08:20:49 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status | | | 7 |
| 10 | 2012-309T09:55:35.048 [ 88M09:45:48 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS. | | | 8 |
| 11 | 2012-309T10:55:24.086 [ 88M10:44:01 ] | [FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS. | | | 6 |

SYS-0040 Warnings (4)

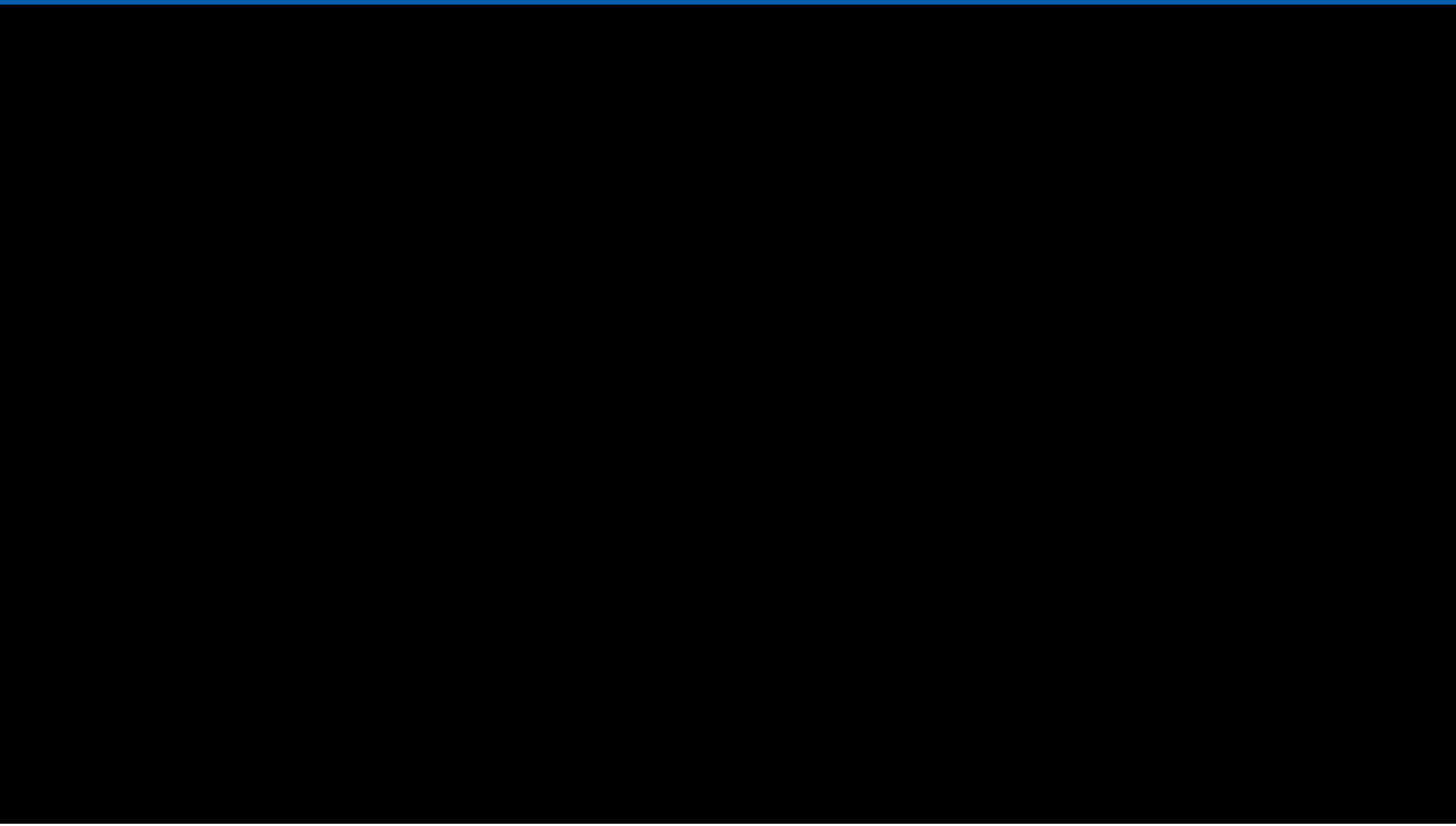
Validation

# Volatiles Investigating Polar Exploration Rover (VIPER)



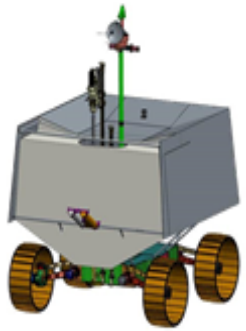
**VIPER Rover on Astrobotic Griffin Lander (artist concept)**

# VIPER Mission Simulation



# VIPER vs. ISS vs. Mars Rovers





MARS ROVERS

Non-interactive

High latency
(20-40 min
round-trip)

Good orbital
maps

Natural terrain

Real-time
science

Interactive

Med latency
(6-15 s round-trip)

"Poor" orbital
maps

Short
mission

VIPER

Command
sequence

Intermittent comms

Low-tempo ops

Long mission

Continuous comms

Extreme lighting

High-tempo ops

Low latency
(<2s round-trip)

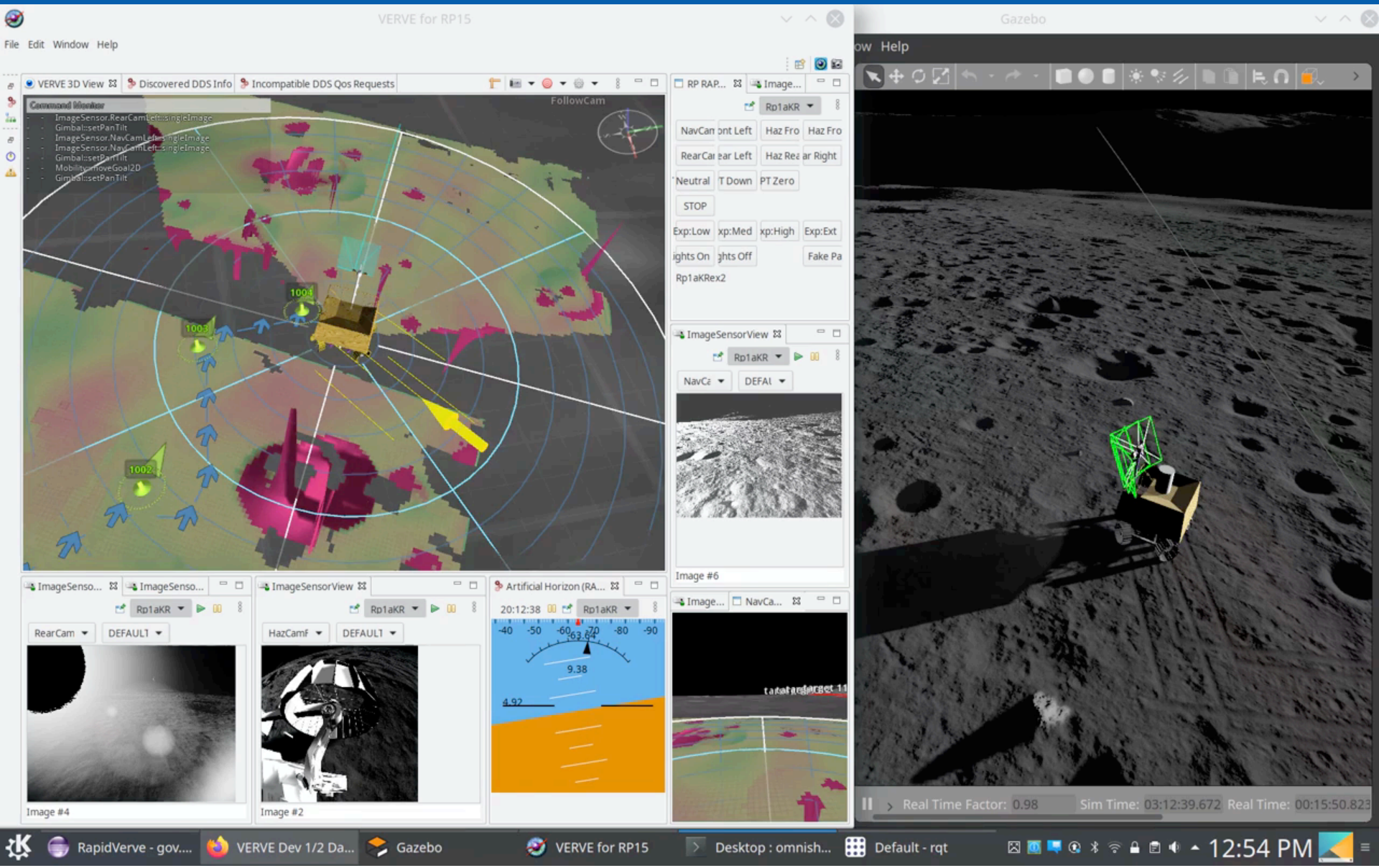
Crew and payload
positioning

Structured environment

ISS EVA ROBOTICS



# VIPER Operations



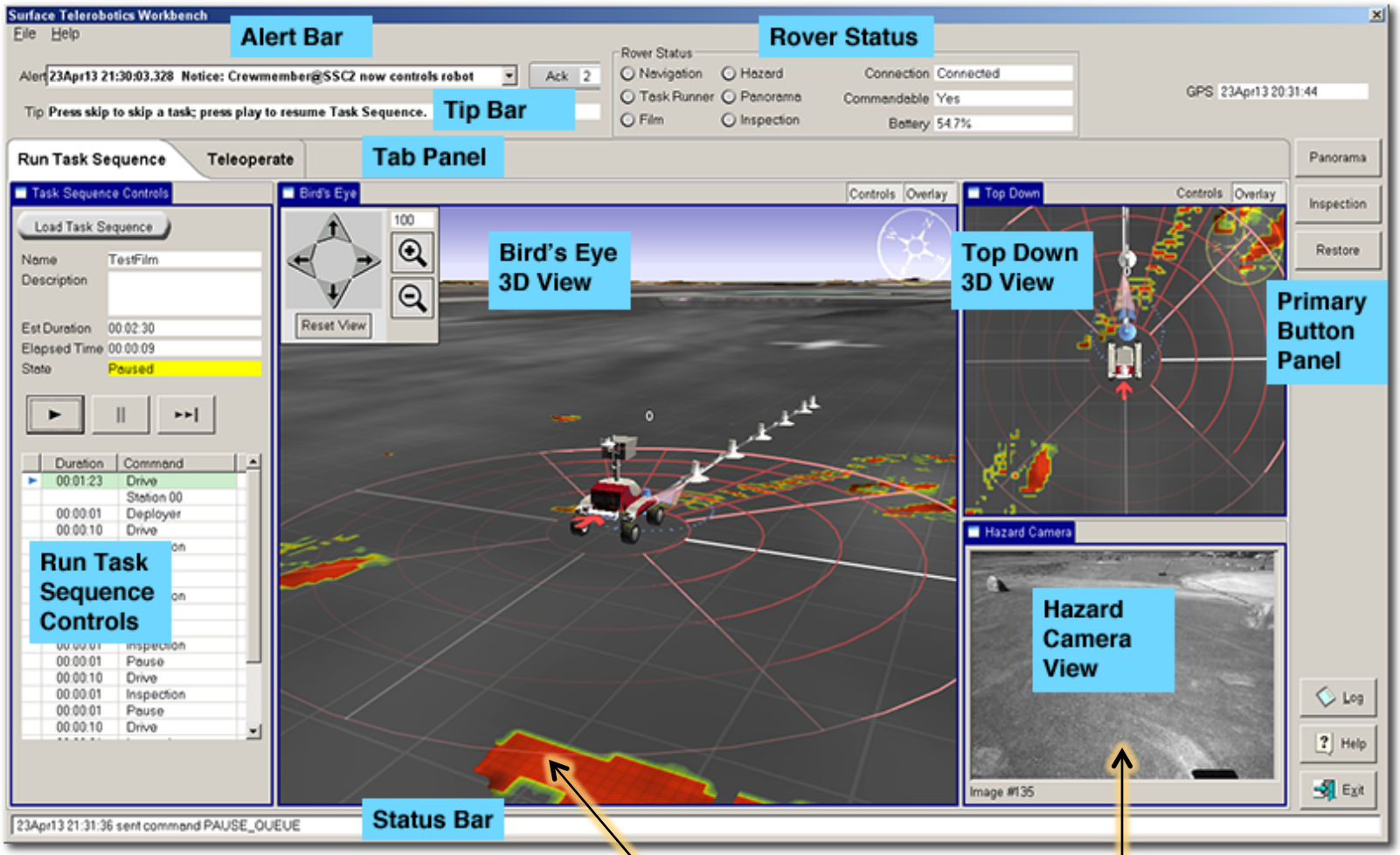
# NASA Surface Telerobotics (2013)



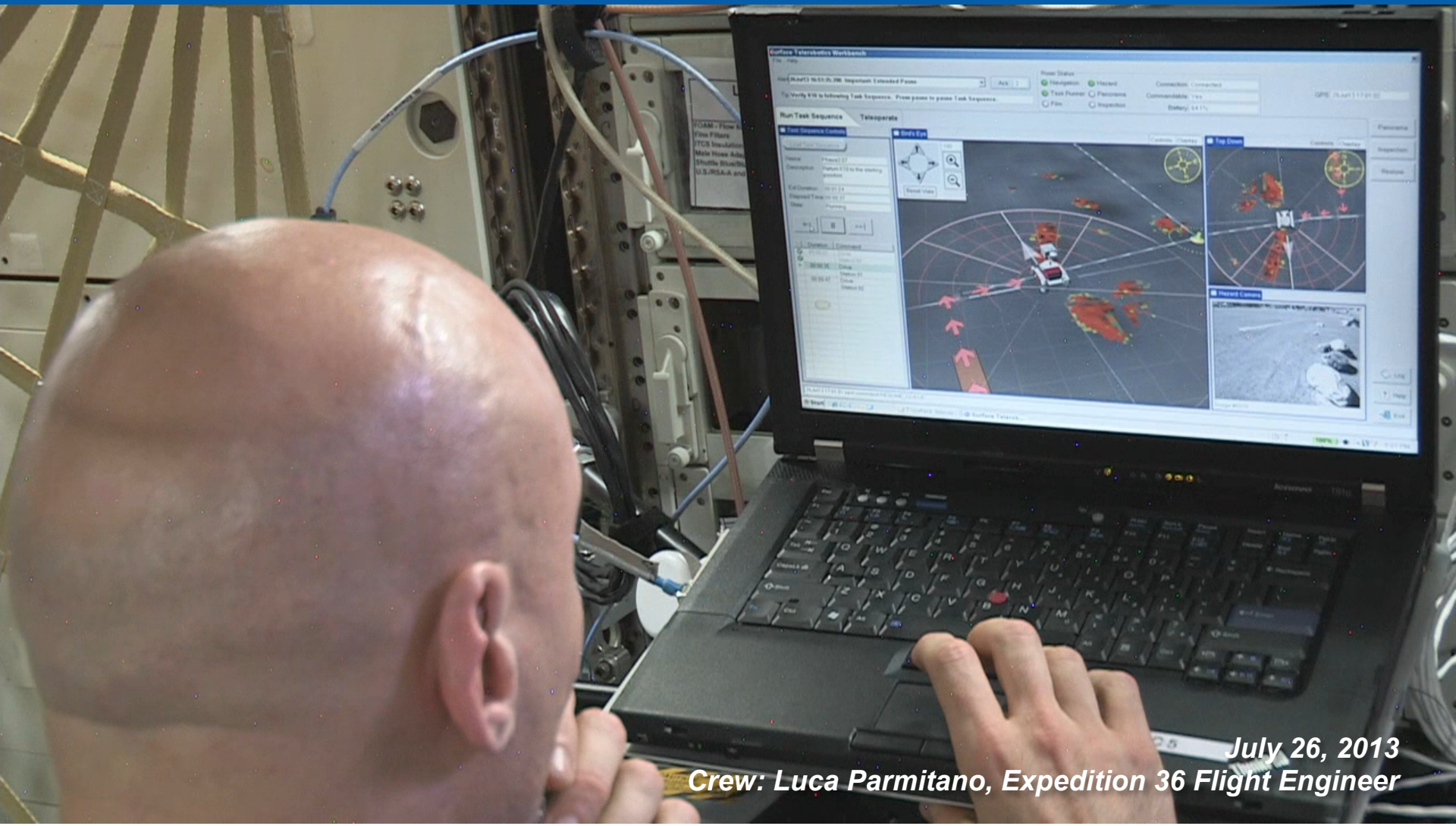
# Astronaut in space / Robot on Earth



# Supervisory Control Interface



# Astronaut in space / Robot on Earth



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

# Questions?



