Lunar Rover Driving Tools

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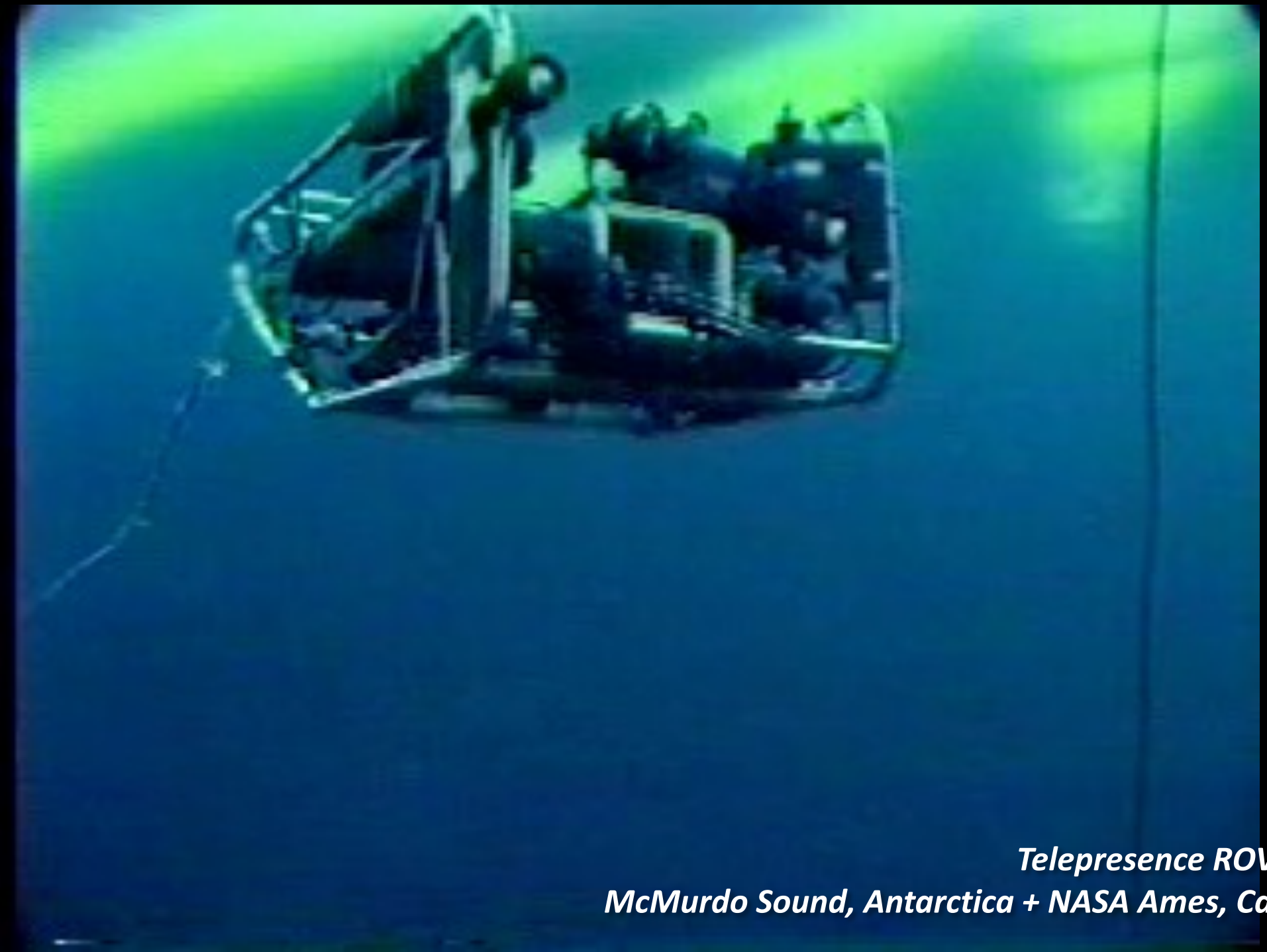
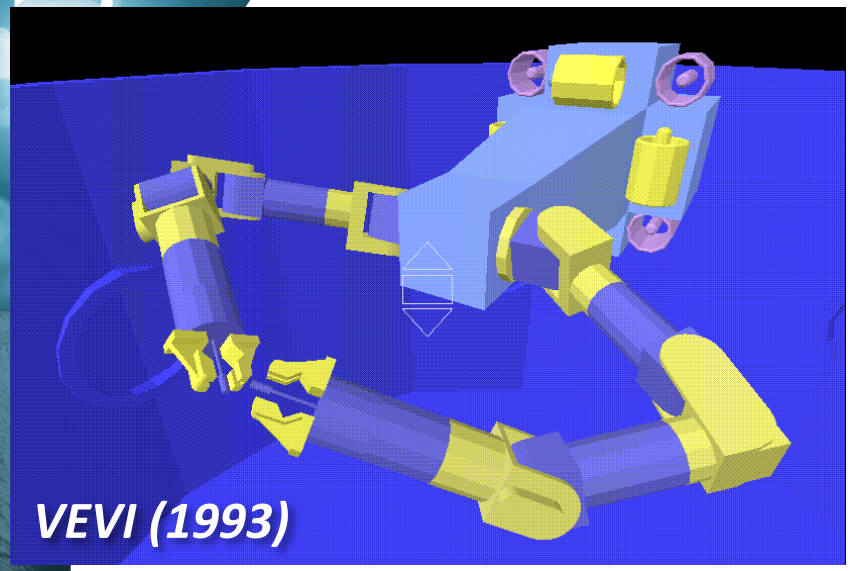
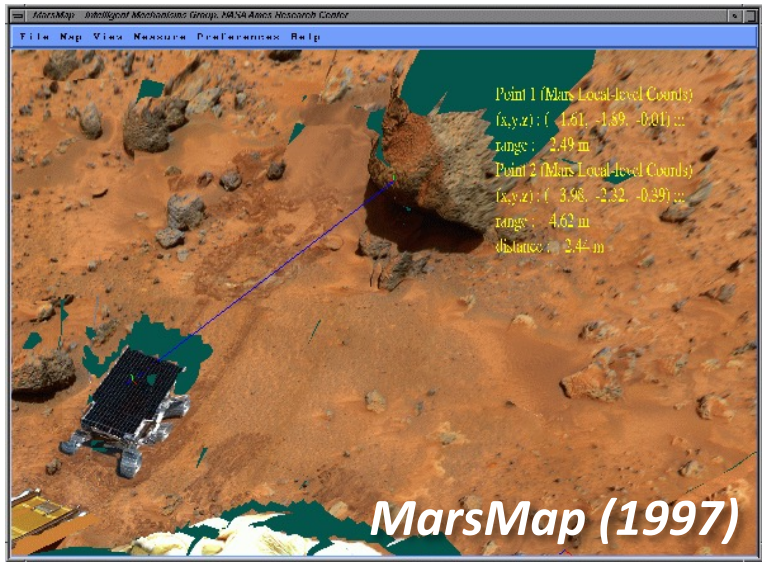
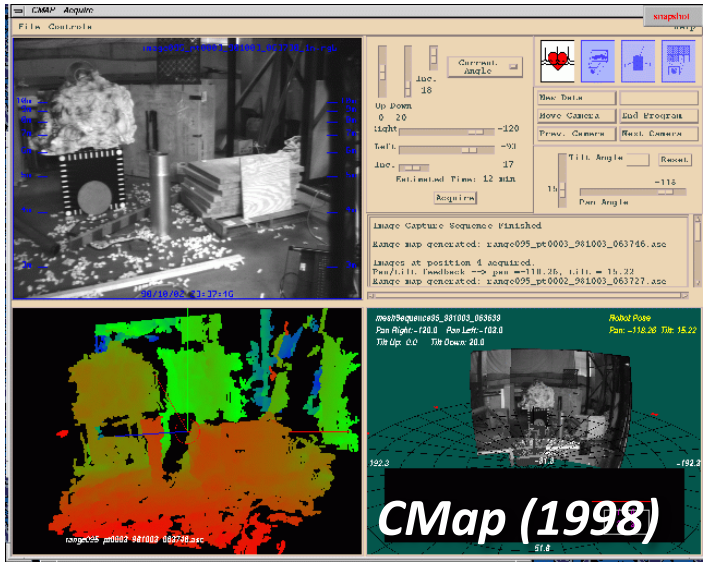


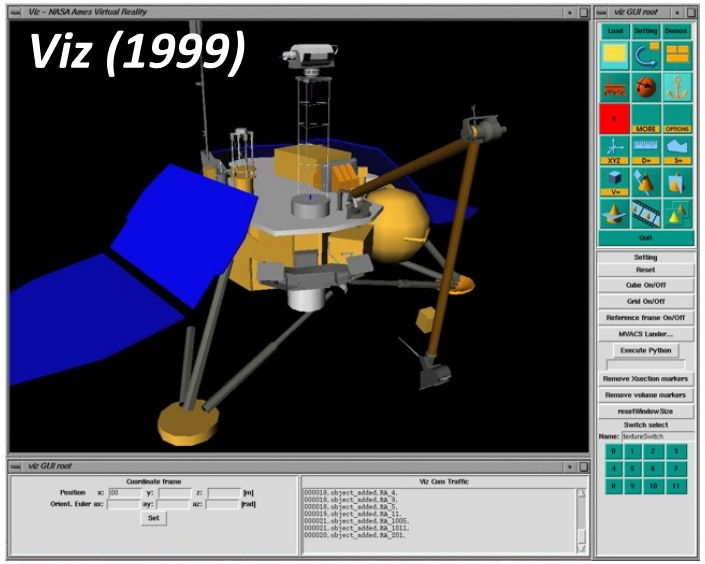
Telepresence ROV (1993)
McMurdo Sound, Antarctica + NASA Ames, California

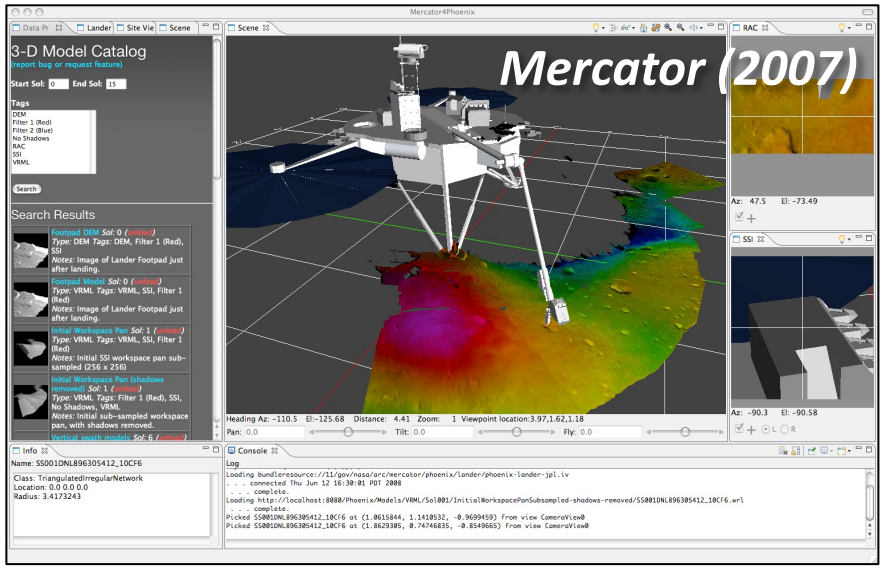
NASA Ames Telerobotic Interfaces









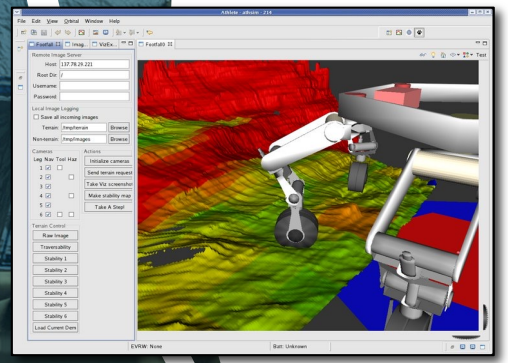
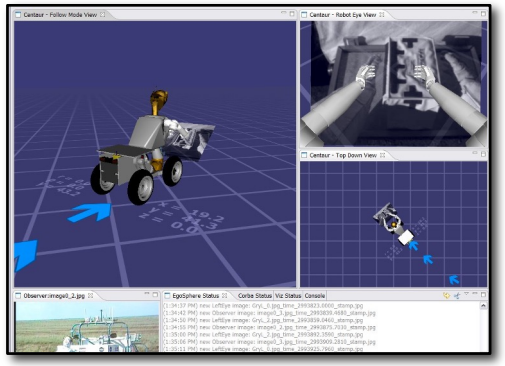
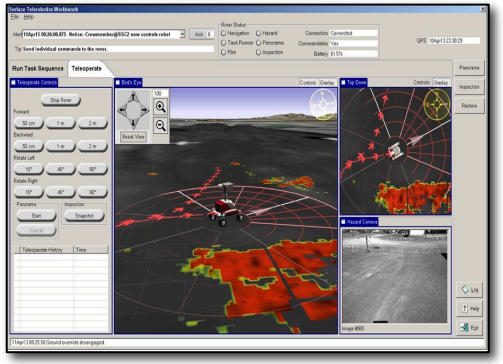
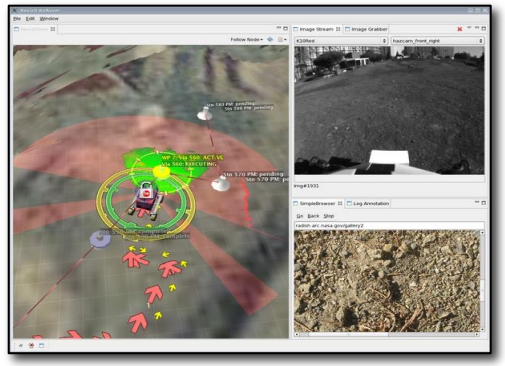
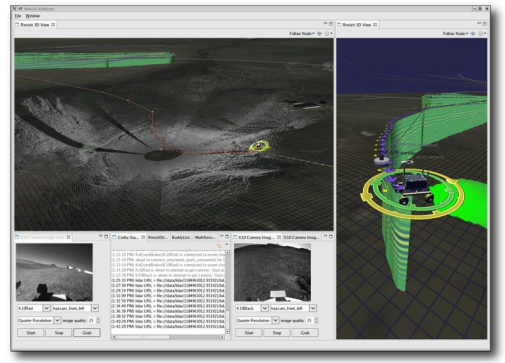


VERVE (2008-present)

Modular user interface with interactive 3D views for robot commanding and situational awareness

Key Features

- Real-time display of robot state, location, sensor data, motion, etc.
- Visualization of maps, topography, traverse plan, derived data
- Commanding, collaborative map annotation, multiple operator roles

Lunar mission study

“Surface Telerobotics” Project (2013)

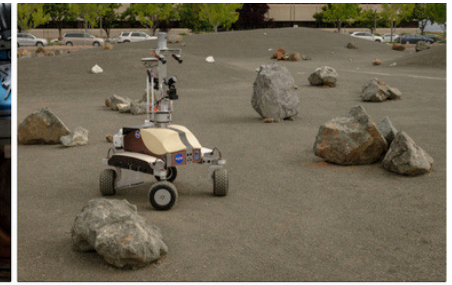
- Simulation of the “Orion at Earth-Moon L2 Lagrange” concept
- Astronauts in the International Space Station (ISS)
- K10 planetary rover at NASA Ames
- Data comm via satellite relay with short delay (**750 msec round-trip**)
- Asynchronous bandwidth (**3 Kbps downlink, 800 Kbps uplink**)

ISS Expedition 36 testing

June 17, 2013 – **C. Cassidy**, survey

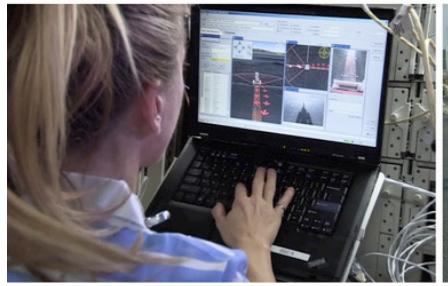
July 26, 2013 – **L. Parmitano**, deploy

Aug 20, 2013 – **K. Nyberg**, inspect



SURVEY

DEPLOY



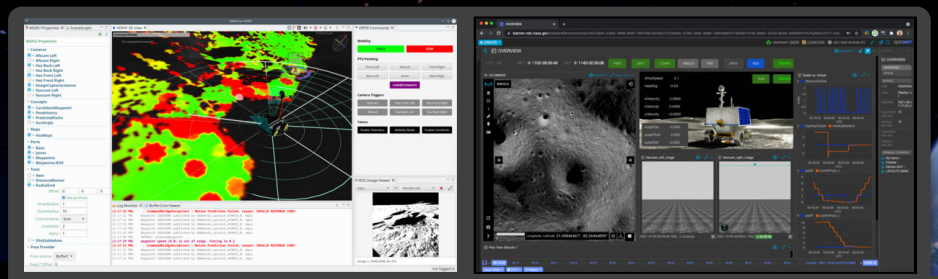
INSPECT

Astronaut in space / Robot on Earth

VERVE on ISS

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

VIPER Mission Operations



Rover Driving

Mission Monitoring

KSC
MSOLO

JSC
Rover Systems & Thermal

ARC
Systems & Execution

Comms round trip ~6 - 10 sec

Science Station

Lander

Waypoints
~ 5 m

Traverse Points
~ 50 m

Drill A

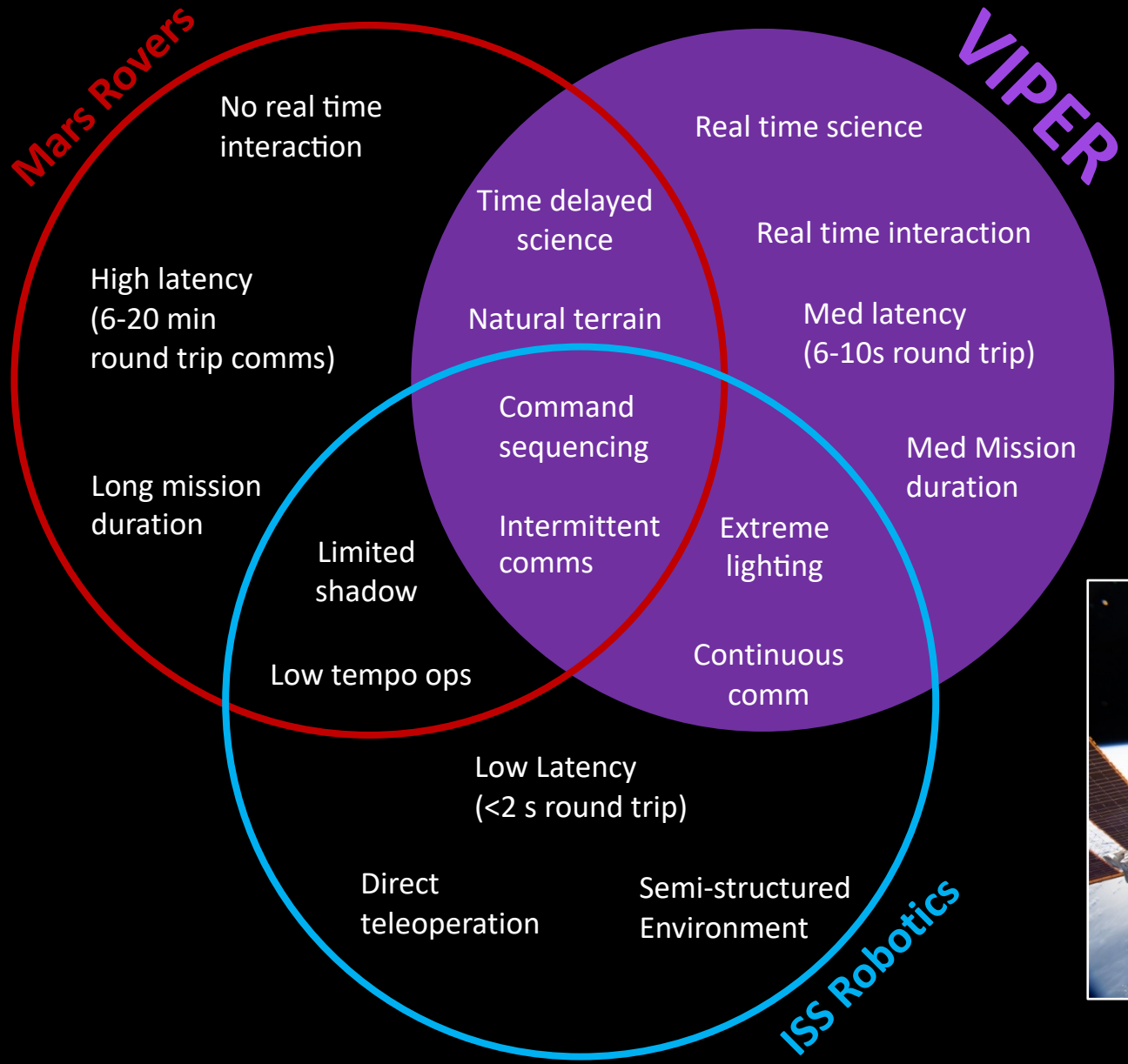
Drill B

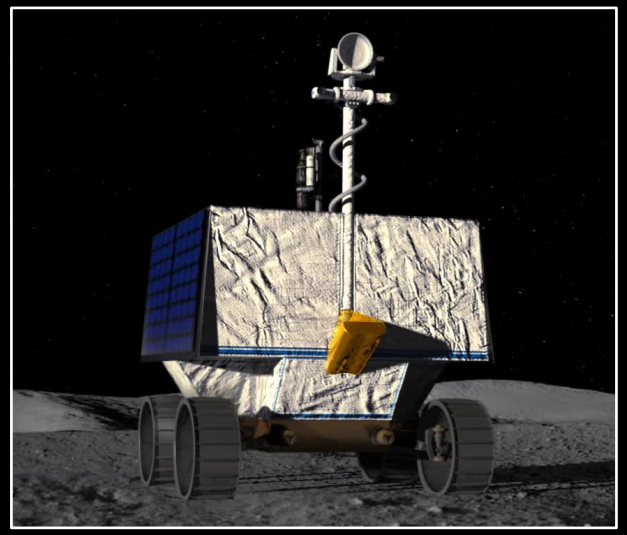
Drill C

Science Station

Mons Mouton (84.6°S, 31.0°W)
near Nobile Crater

VIPER vs ISS vs Mars Rovers





Mission Control Center

“Drive Team”

VIPER Interactive Rover Driving (2023)

“Drive Team” Ops Structure

- Driver – command rover mobility and imaging
- Co-Driver – supports decision making, mobility monitoring, voice loops
- Navigator – monitors pose (absolute/relative) and nav sensor health
- Real-time Science – supports real-time science ops, liaison to science team

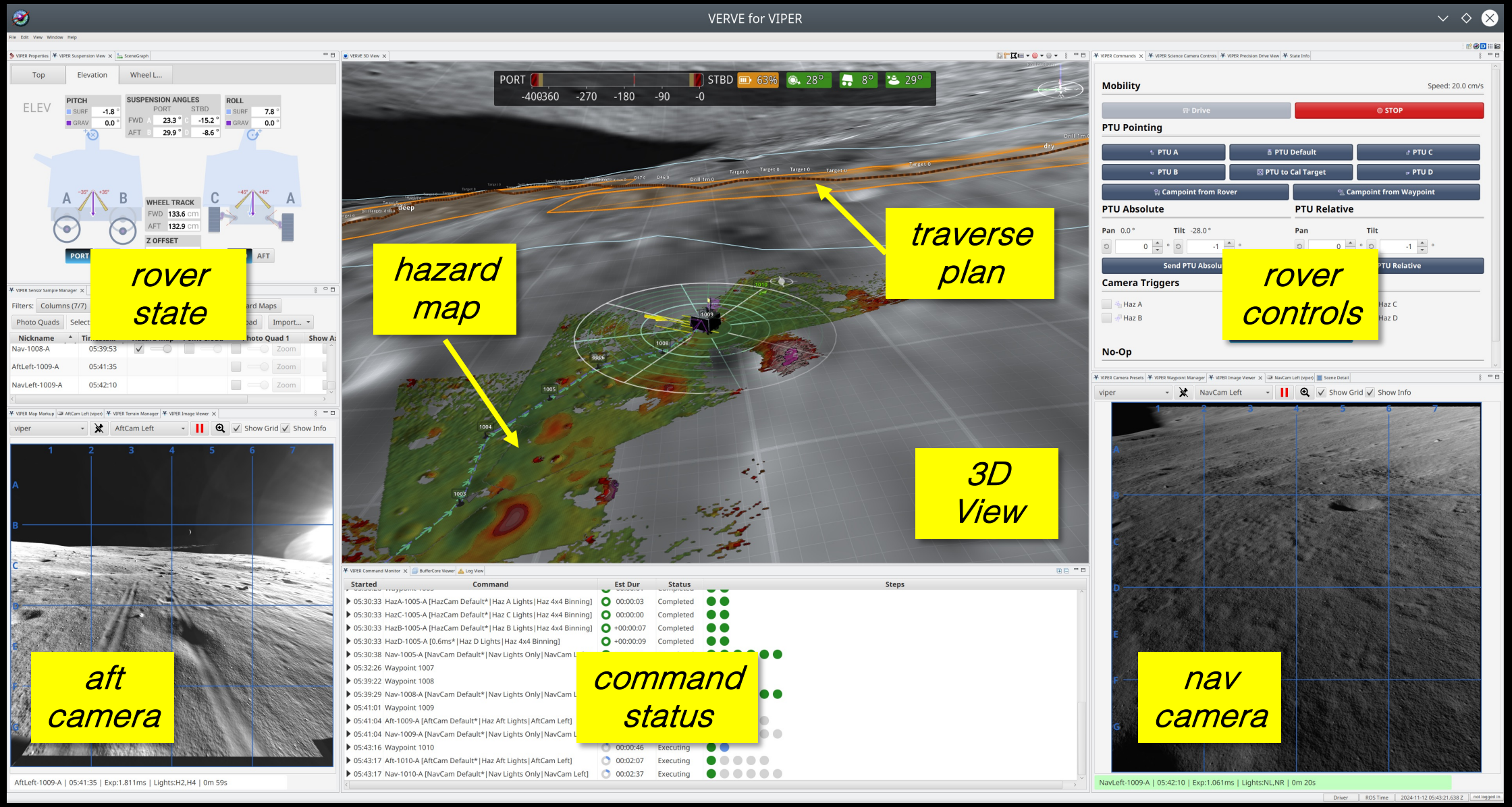
Command Cycle (4-5 min duration)

- Terrain hazard assessment, tactical motion planning, image capture planning, interactive science, and waypoint driving
- Highly interdependent teamwork using decision support tools

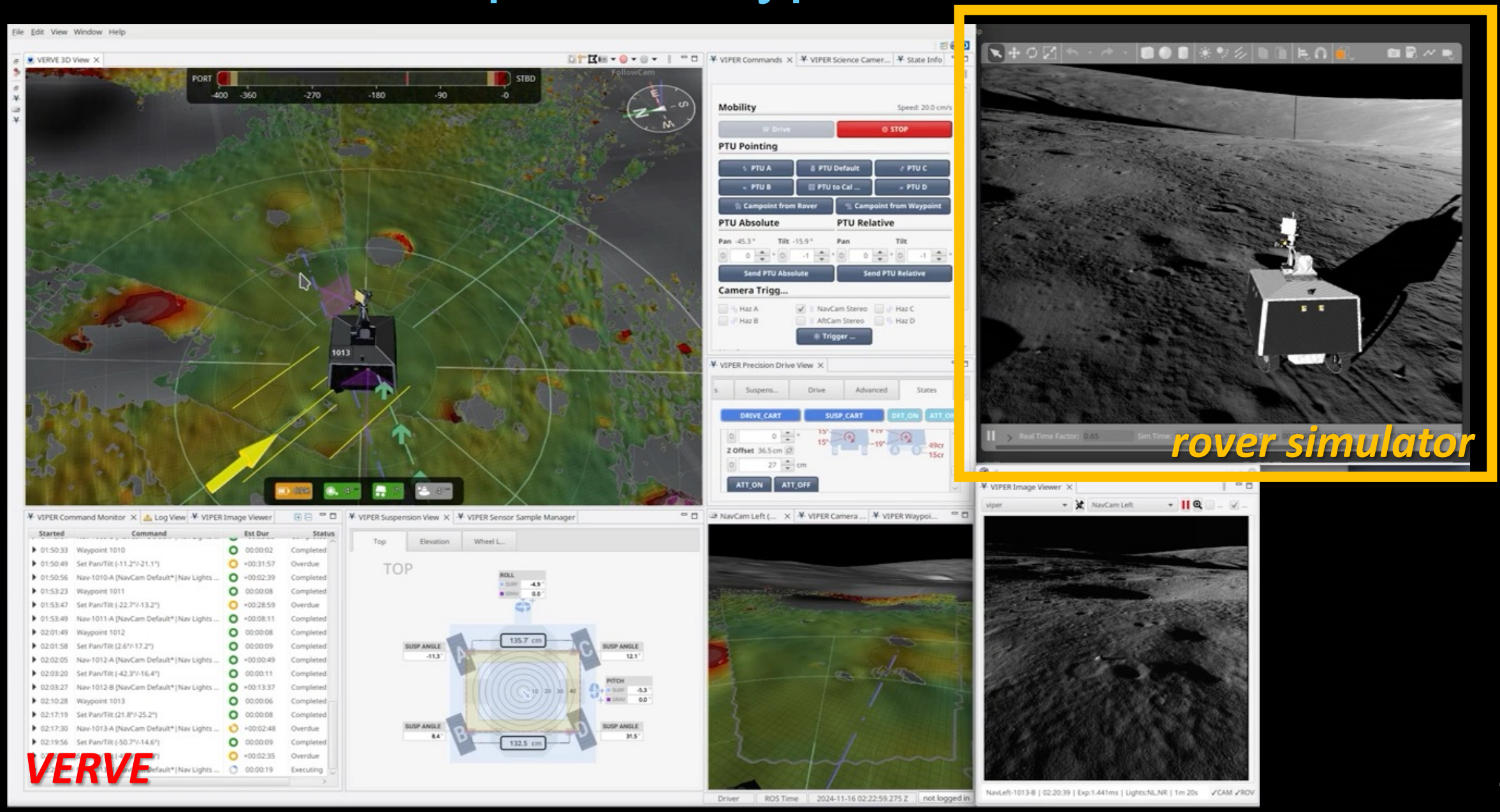
Waypoint Driving

- Interactively command rover to drive to a waypoint 4-8m away
- Rover on-board control achieves the waypoint
- Employ a variety of tactical driving techniques to handle different surface conditions and environments (slopes, craters, hazard traversal, PSRs, etc)

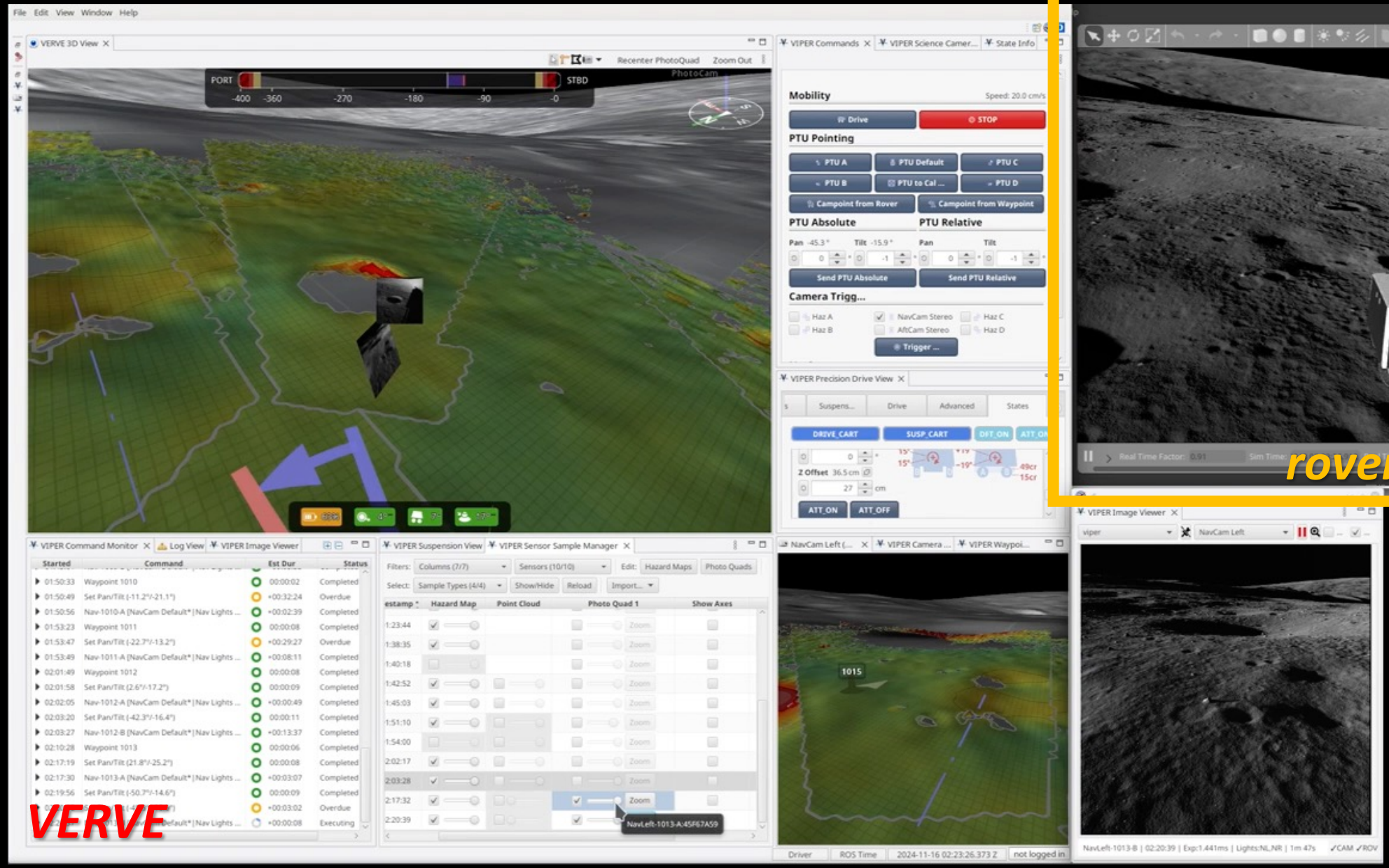
VERVE for VIPER



Assess terrain + place waypoint



Refine waypoint + command motion



Lessons Learned (since 1993)

Latency

- Latency is **only one factor** for telerobotics: type of science, instruments & data, cost, risk, staffing, robot capabilities, etc.
- **Data collection** (with instruments), **analysis**, and **decision making** (strategic + tactical planning) are usual more important.

Spatial displays

- 3D visualizations is essential for rover operations
- **Head-mounted** and **stereo video** displays are **pseudo 3D**, not true 3D, which leads to many issues (accommodation errors, etc)
- High levels of **presence** can be achieved even with limited data.

Interactive telerobotics

- Telepresence (immersive real-time presence) is **not a panacea**
- **Manual control** is highly coupled to human performance (skills, experience, training), **supervisory control** is more consistent.
- **Minimizing risk** is often (far more) important that efficiency.

For additional information:

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