

National Aeronautics and
Space Administration



Lunar Rover Driving Tools

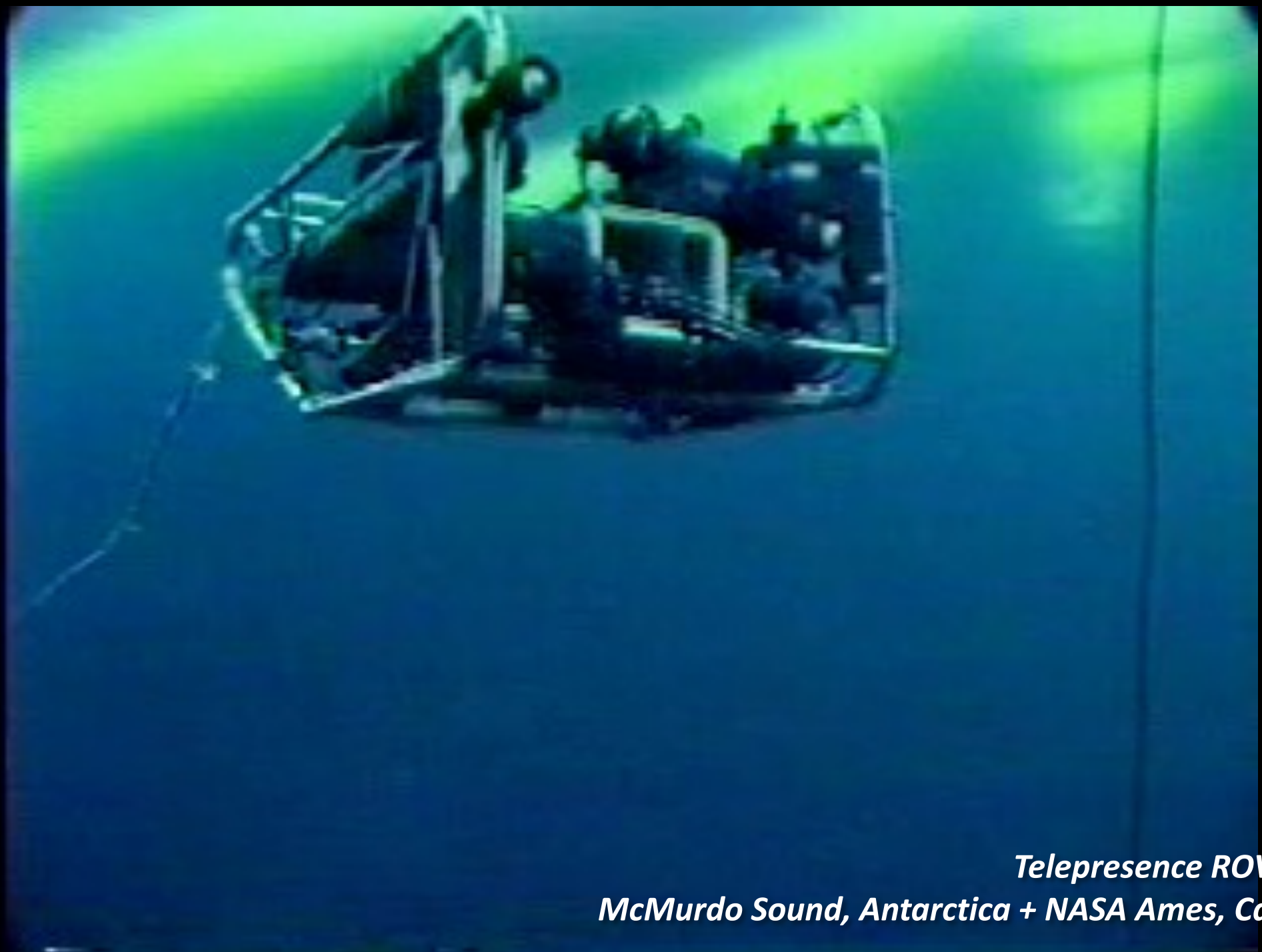
Terry Fong

Chief Roboticist

NASA Ames Research Center

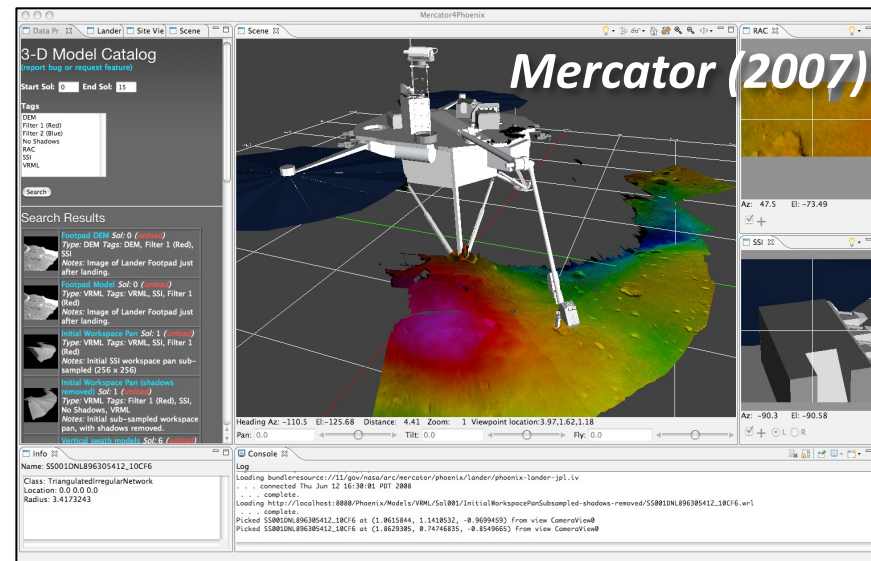
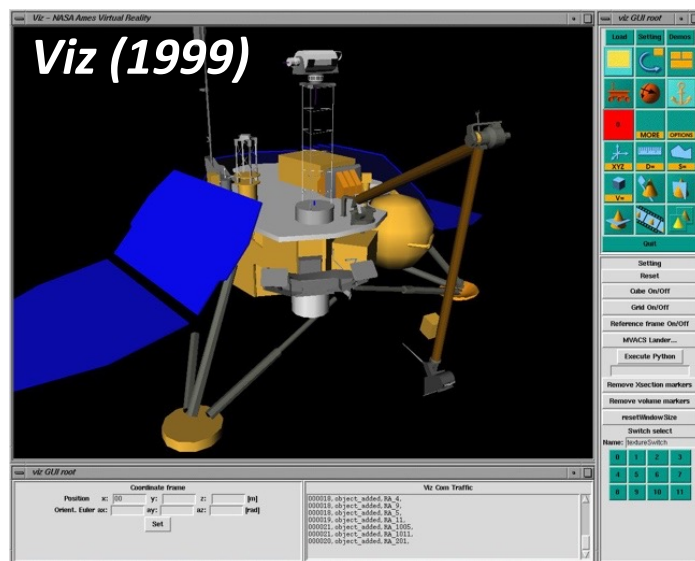
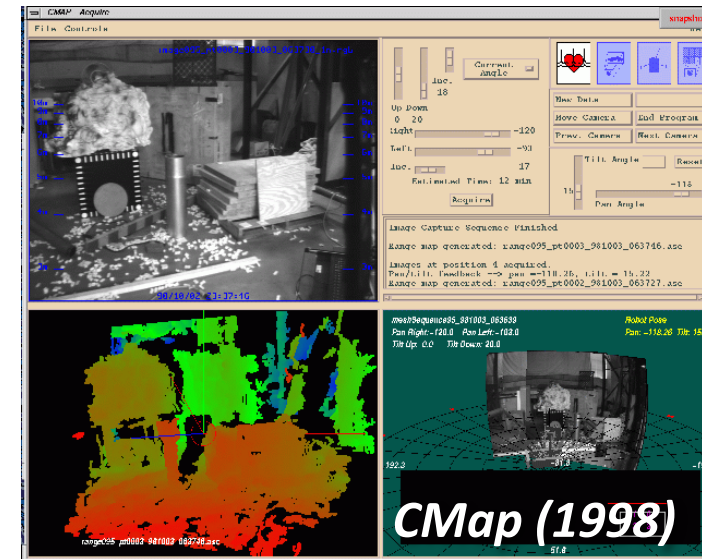
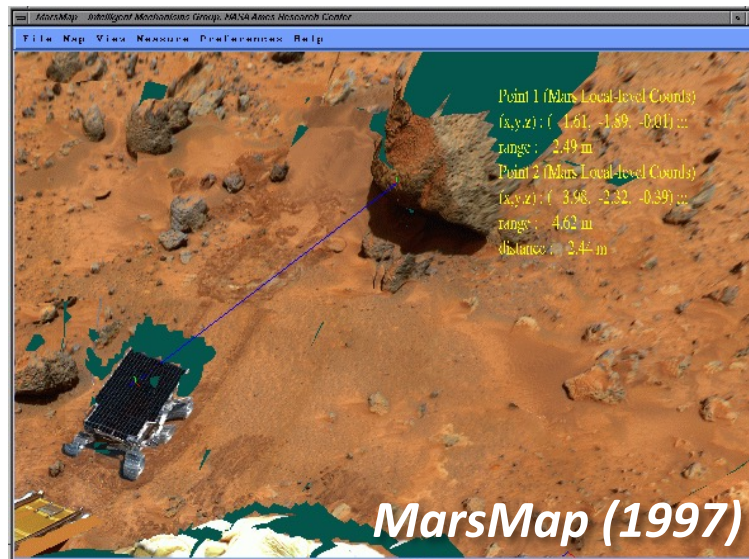
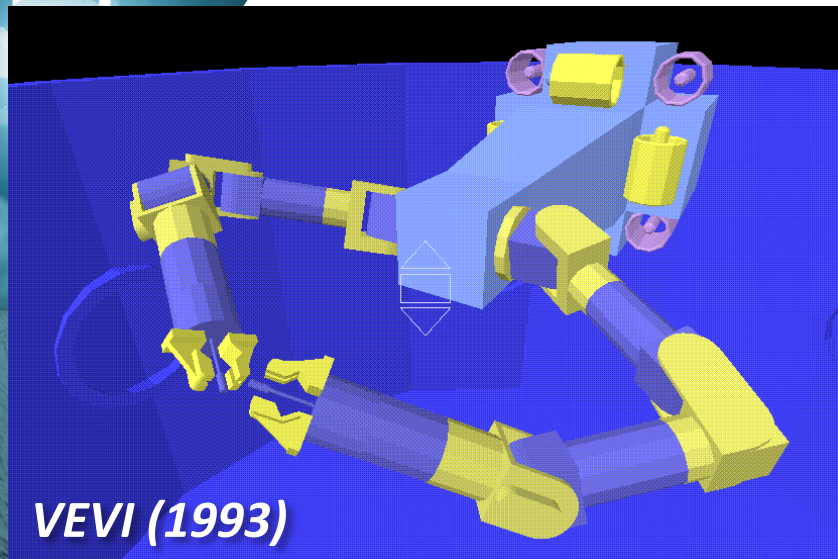
10 February 2025





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

NASA Ames Telerobotic Interfaces

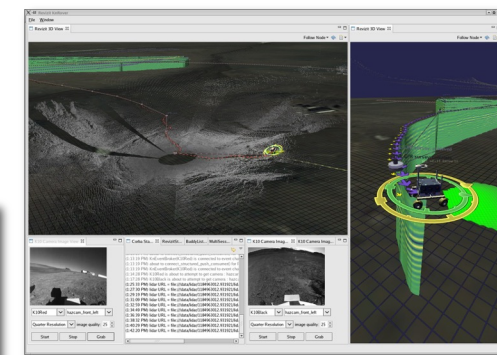
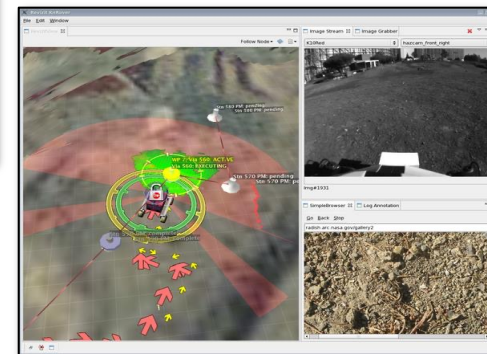
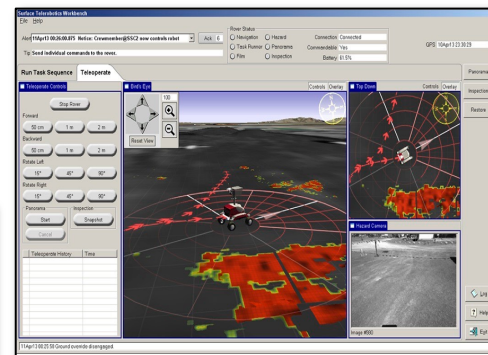
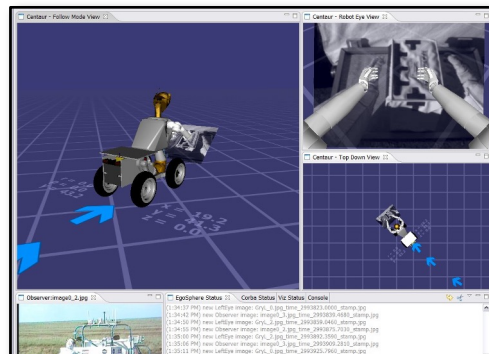
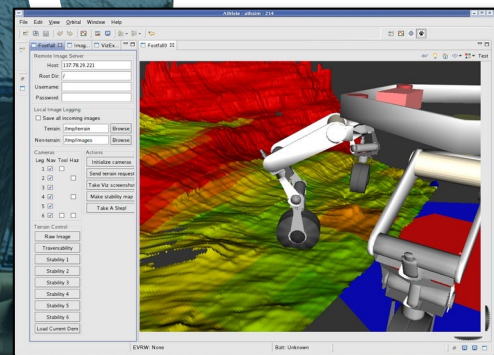


VERVE (2008-present)

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

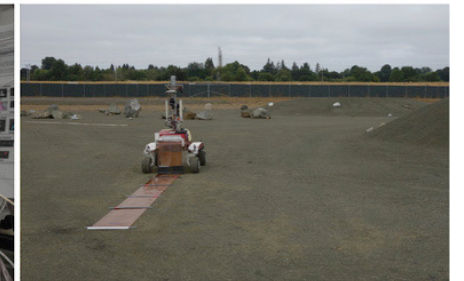
June 17, 2013 – **C. Cassidy**, survey

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

Aug 20, 2013 – **K. Nyberg**, inspect



SURVEY



DEPLOY



INSPECT

Astronaut in space / Robot on Earth

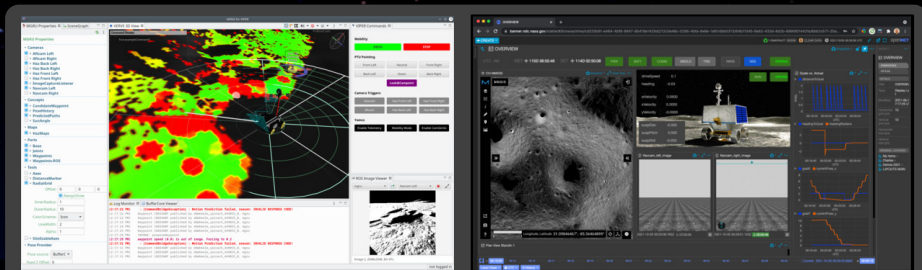


VERVE on ISS



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

VIPER Mission Operations



Rover Driving

Mission Monitoring

ARC

Systems & Execution

KSC
MSOLO

JSC
Rover Systems & Thermal

Comms round trip ~6 - 10 sec



Lander

Science Station

Waypoints
~ 5 m

Traverse Points
~ 50 m

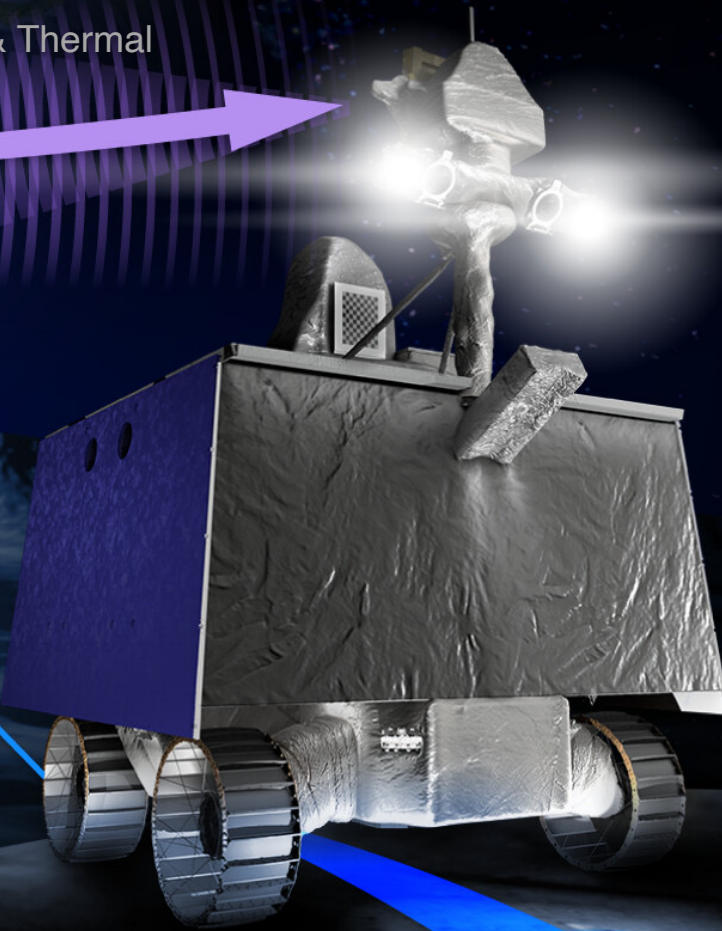
Drill A

Drill B

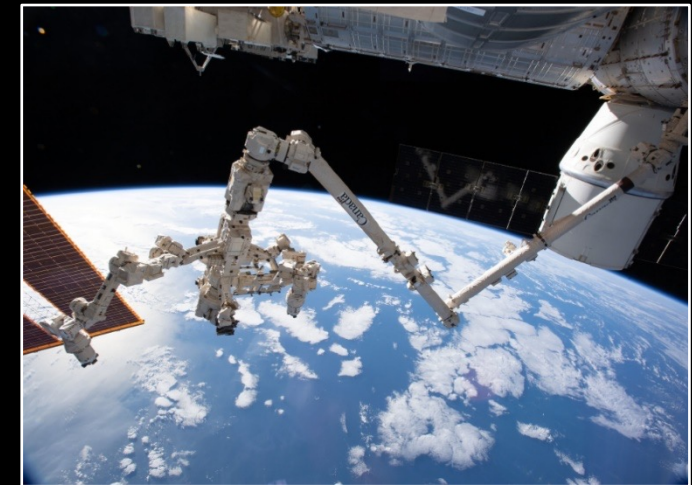
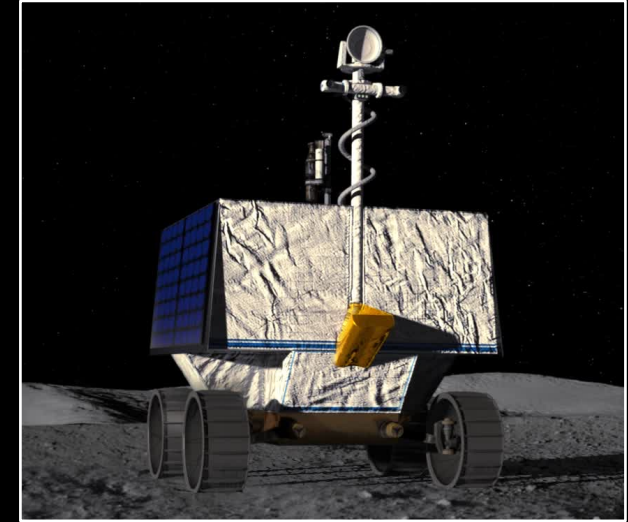
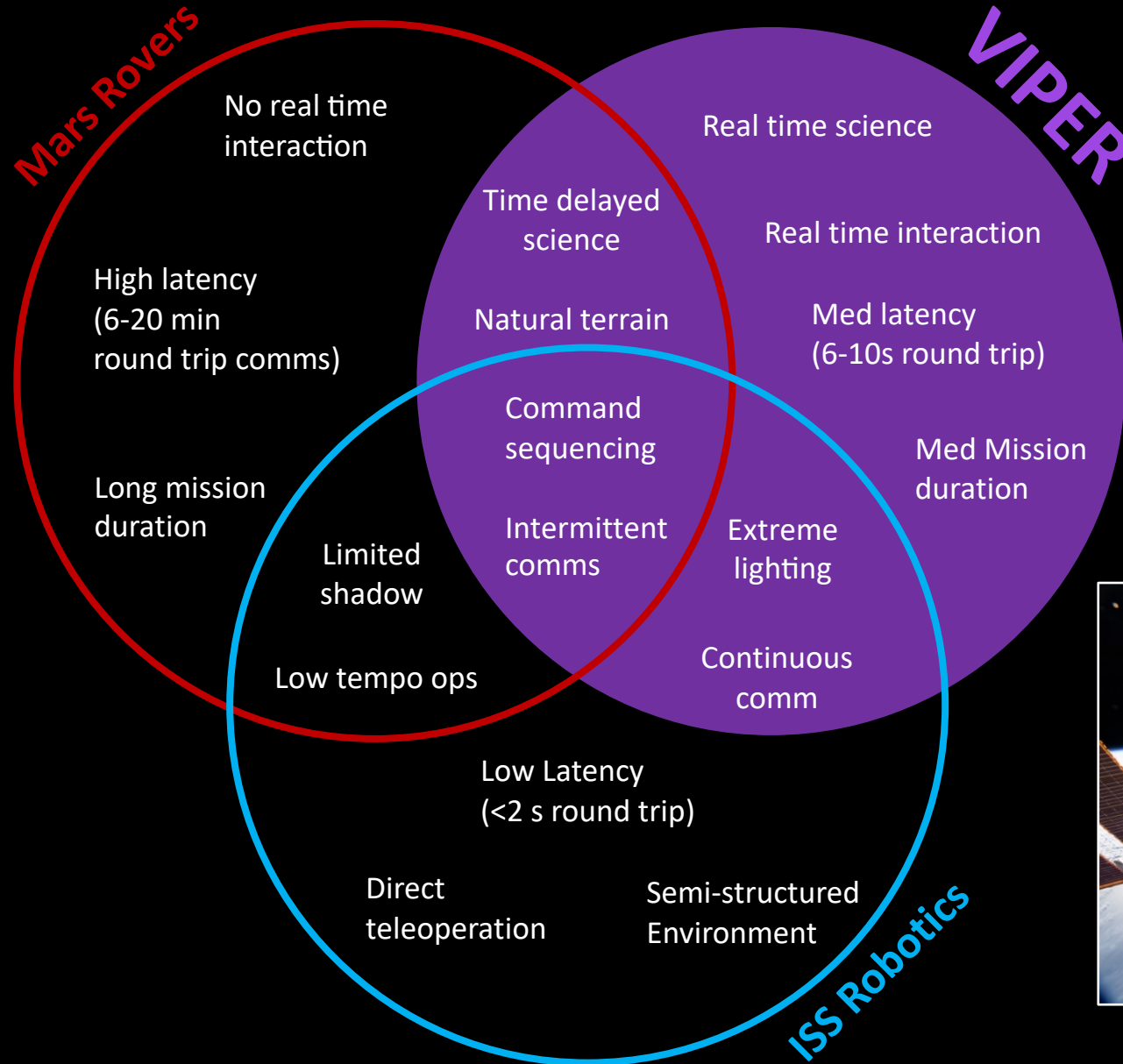
Drill C

Science Station

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



VIPER vs ISS vs Mars Rovers



Mission Control Center



“Drive Team”

Real-Time Science

Driver

Co-Driver

Navigator





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

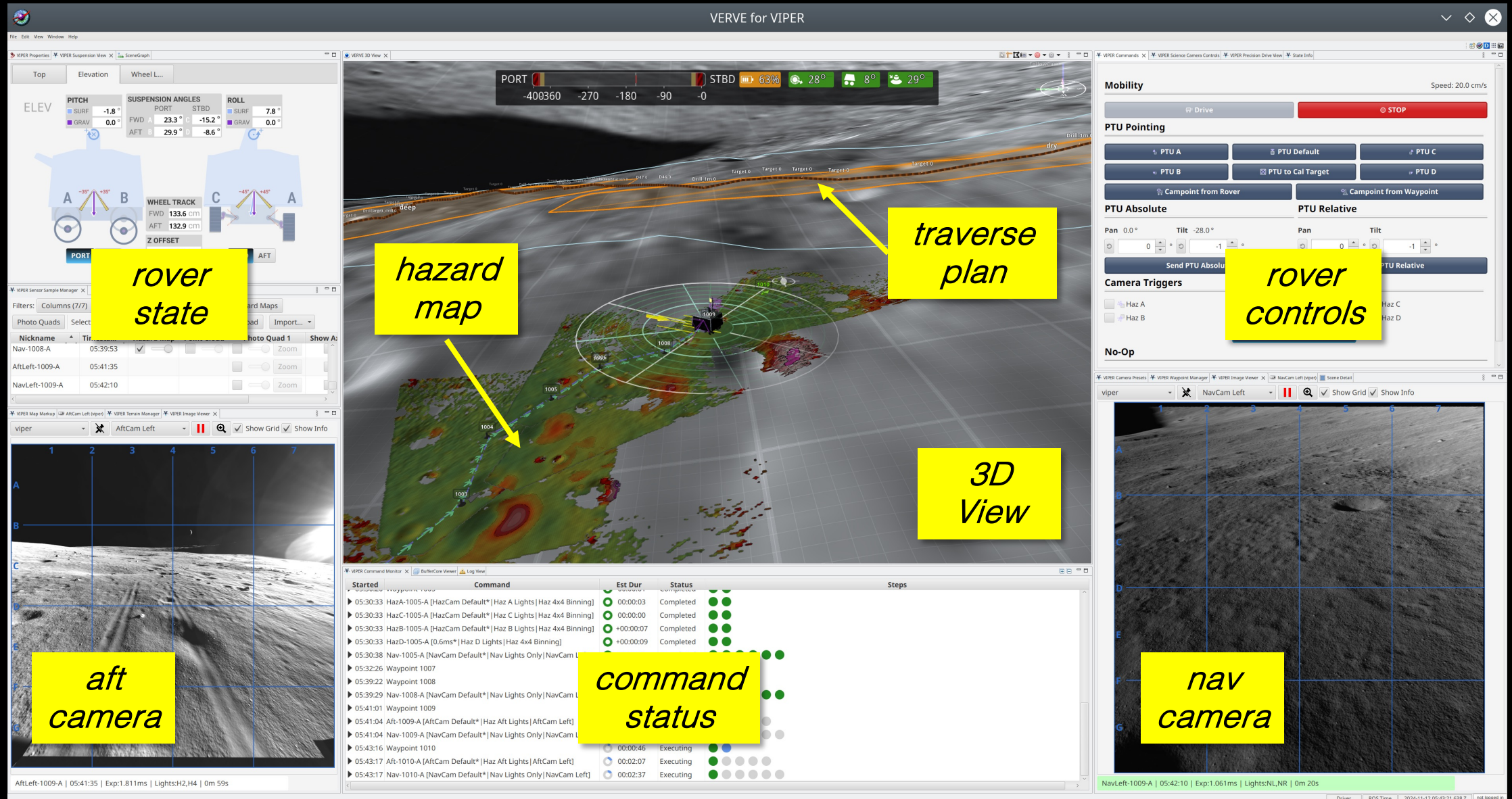
Command Cycle (4-5 min duration)

- 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

VERVE 3D View



VERVE Command Monitor

Started	Command	Est Dur	Status
01:50:33	Waypoint 1010	00:00:02	Completed
01:50:49	Set Pan/Tilt (-11.2°/-21.1°)	+00:31:57	Overdue
01:50:56	Nav-1010-A [NavCam Default*] Nav Lights ...	+00:02:39	Completed
01:53:23	Waypoint 1011	00:00:08	Completed
01:53:47	Set Pan/Tilt (-22.7°/-13.2°)	+00:28:59	Overdue
01:53:49	Nav-1011-A [NavCam Default*] Nav Lights ...	+00:08:11	Completed
02:01:49	Waypoint 1012	00:00:08	Completed
02:01:58	Set Pan/Tilt (2.6°/-17.2°)	00:00:09	Completed
02:02:05	Nav-1012-A [NavCam Default*] Nav Lights ...	+00:00:49	Completed
02:03:20	Set Pan/Tilt (-42.3°/-16.4°)	00:00:11	Completed
02:03:27	Nav-1012-B [NavCam Default*] Nav Lights ...	+00:13:37	Completed
02:10:28	Waypoint 1013	00:00:06	Completed
02:17:19	Set Pan/Tilt (21.8°/-25.2°)	00:00:08	Completed
02:17:30	Nav-1013-A [NavCam Default*] Nav Lights ...	+00:02:48	Overdue
02:19:56	Set Pan/Tilt (-50.7°/-14.6°)	00:00:09	Completed
	Nav-1013-B [NavCam Default*] Nav Lights ...	+00:02:35	Overdue
		00:00:19	Executing

VERVE Suspension View



VERVE Commands

Mobility

Speed: 20.0 cm/s

Drive STOP

PTU Pointing

PTU A PTU Default PTU C

PTU B PTU to Cal PTU D

Campoint from Rover Campoint from Waypoint

PTU Absolute PTU Relative

Pan Tilt Pan Tilt

Send PTU Absolute Send PTU Relative

Camera Trigg...

Haz A NavCam Stereo Haz C

Haz B AltCam Stereo Haz D

Trigger

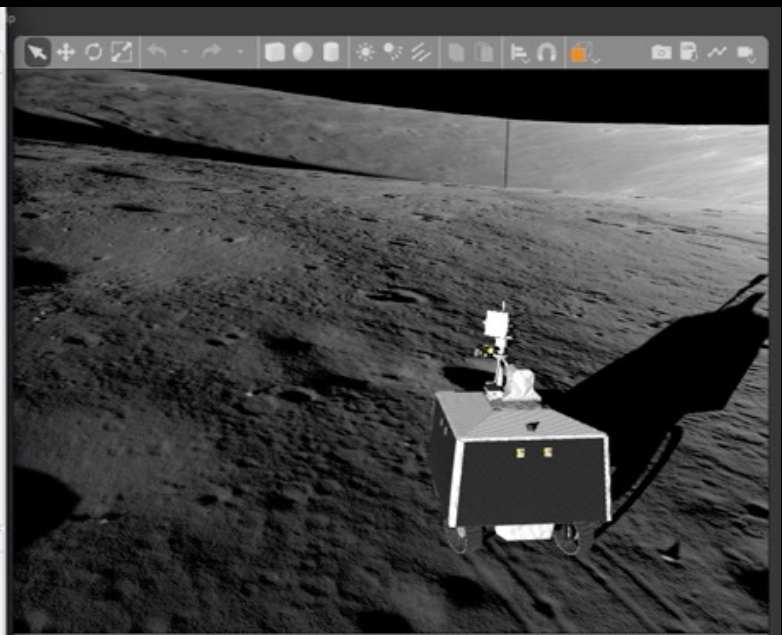
VERVE Precision Drive View

DRIVE_CART SUSP_CART DFT_ON ATT_ON

Z Offset 36.5 cm

ATT_ON ATT_OFF

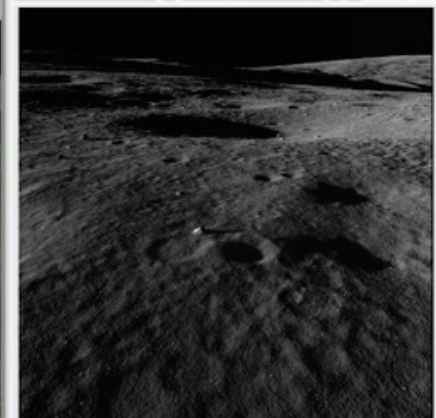
rover simulator



Real Time Factor: 0.65 Sim Time:

VERVE Image Viewer

NavCam Left



NavLeft-1013-B | 02:20:39 | Expt:1.441ms | Ughts:NL,NR | 1m 20s ✓CAM ✓ROV

VERVE

14

Refine waypoint + command motion

The screenshot displays the Verve 3D View interface, which is used for controlling a rover. The main window shows a 3D terrain map with a rover positioned on it. The map includes a color-coded elevation scale from -400 to 0. The rover is shown in a 3D perspective view, with its shadow cast on the terrain. The interface includes several panels:

- VERVE 3D View X:** The main 3D terrain map.
- VERVE Commands X:** A panel with buttons for Drive, STOP, PTU A, PTU B, PTU C, PTU D, PTU Default, PTU to Cal, Campoint from Rover, and Campoint from Waypoint.
- VERVE Precision Drive View X:** A panel with buttons for DRIVE_CART, SUSP_CART, DFT_ON, ATT_ON, and ATT_OFF.
- VERVE Command Monitor X:** A table showing a list of commands and their status.
- VERVE Image Viewer X:** A panel showing a 2D image of the rover's camera feed.
- VERVE Sensor Sample Manager X:** A panel showing a list of sensor samples and their status.

The **VERVE Command Monitor** table is as follows:

Started	Command	Est Dur	Status
01:50:33	Waypoint 1010	00:00:02	Completed
01:50:49	Set Pan/Tilt (-11.2°/-21.1°)	+00:32:24	Overdue
01:50:56	Nav-1010-A [NavCam Default*] [Nav Lights ...]	+00:02:39	Completed
01:53:23	Waypoint 1011	00:00:08	Completed
01:53:47	Set Pan/Tilt (-22.7°/-13.2°)	+00:29:27	Overdue
01:53:49	Nav-1011-A [NavCam Default*] [Nav Lights ...]	+00:08:11	Completed
02:01:49	Waypoint 1012	00:00:08	Completed
02:01:58	Set Pan/Tilt (2.6°/-17.2°)	+00:00:09	Completed
02:02:05	Nav-1012-A [NavCam Default*] [Nav Lights ...]	+00:00:49	Completed
02:03:20	Set Pan/Tilt (-42.3°/-16.4°)	00:00:11	Completed
02:03:27	Nav-1012-B [NavCam Default*] [Nav Lights ...]	+00:13:37	Completed
02:10:28	Waypoint 1013	00:00:06	Completed
02:17:19	Set Pan/Tilt (21.8°/-25.2°)	00:00:08	Completed
02:17:30	Nav-1013-A [NavCam Default*] [Nav Lights ...]	+00:03:07	Completed
02:19:56	Set Pan/Tilt (-50.7°/-14.6°)	00:00:09	Completed
02:20:39	Nav-1013-B [NavCam Default*] [Nav Lights ...]	+00:03:02	Overdue
		00:00:08	Executing

The **VERVE Sensor Sample Manager** table is as follows:

Filters:	Columns (7/7)	Sensors (10/10)	Edit:	Hazard Maps	Photo Quads
Select:	Sample Types (4/4)	Show/Hide	Reload	Import...	
estamp:	Hazard Map	Point Cloud	Photo Quad 1	Show Axes	
1:23:44	✓			Zoom	
1:38:35	✓			Zoom	
1:40:18	✓			Zoom	
1:42:52	✓			Zoom	
1:45:03	✓			Zoom	
1:51:10	✓			Zoom	
1:54:00	✓			Zoom	
2:02:17	✓			Zoom	
2:03:28	✓			Zoom	
2:17:32	✓			Zoom	
2:20:39	✓			Zoom	

The **rover simulator** window shows a 3D perspective view of the rover on the terrain. The **VERVE Image Viewer** window shows a 2D image of the rover's camera feed.



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 than efficiency.

For additional information:

Terry Fong

NASA Ames Research Center

terry.fong@nasa.gov

+1.650.604.1349

