

2024 Planetary Science Technology Symposium

VIPER Software: Rover, Planning, and Ops

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VIPER Rover Software

Rover Flight Software (**RFSW**)

- Runs on rad-hard (RAD 750) and rad-tolerant (AiTech SP0-S) CPUs
- Utilizes Core Flight System (cFS)
- Provides low-level hardware interfaces, mobility control, relative localization, error checking, and device/payload services

Rover Simulator (**RSIM**)

- Integrated lunar surface mission simulator based on Gazebo Classic simulator with custom VIPER plugins
- Used for VIPER software development + mission ops training

Rover Ground Software (**RgSW**)

- Runs at mission control on desktop computing
- Implemented as an ensemble of Robot Operating System 2 (ROS2) nodes
- Performs navigation, mapping, and generation of rover driver decision support data (e.g., hazard maps)

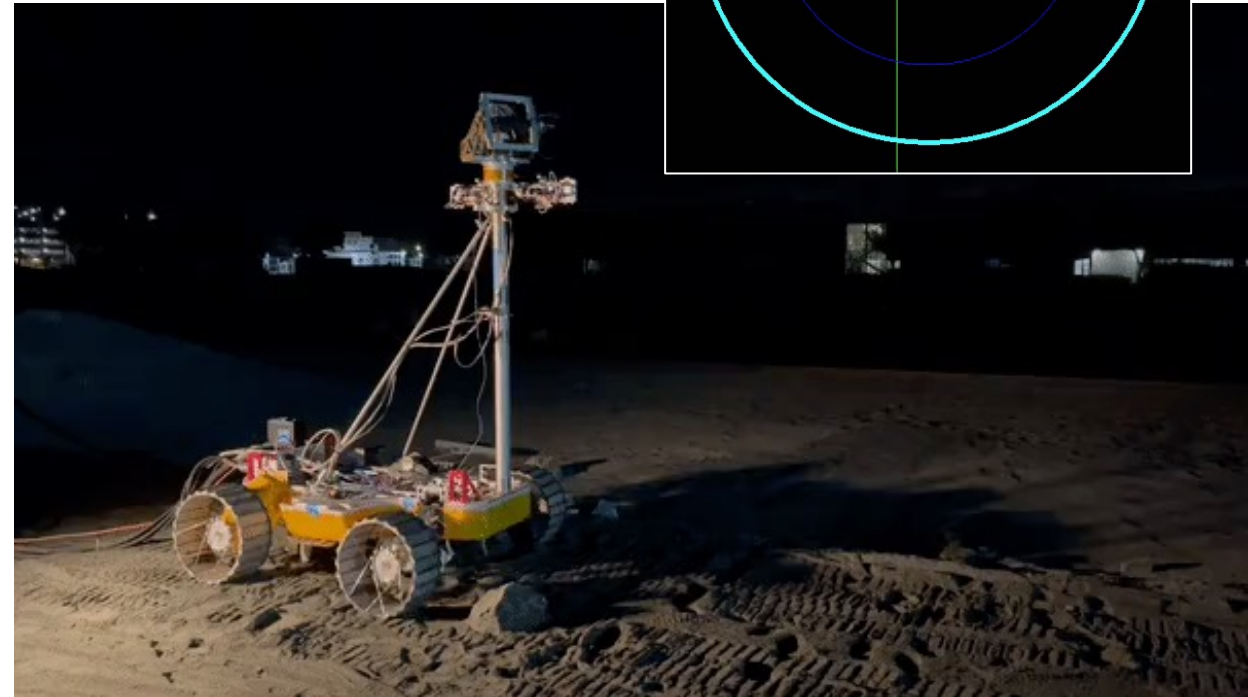
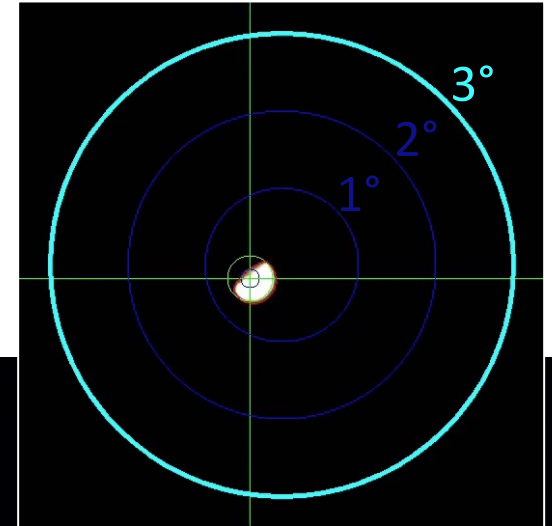


Rover Flight Software

Innovations

- On-board software for lunar rovers using cFS (14 custom apps & C++ framework)
- Real-time directional comm antenna pointing while driving over rough terrain
- Autonomous comm recovery fault management capability
- On-board relative pose estimation using star tracker, IMU, odometry
- On-board image capture and pre-processing (including ICER compression)
- DevOps: continuous integration system with automated virtualized test environment

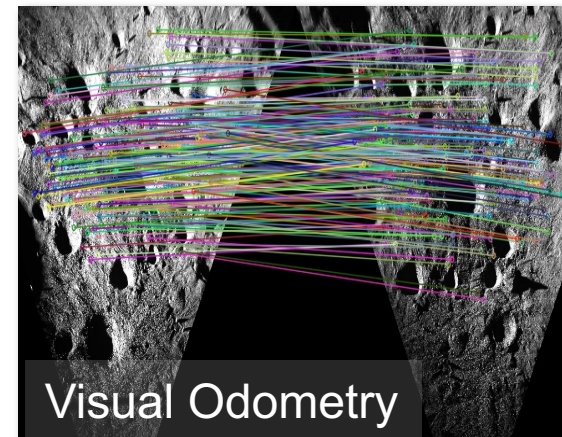
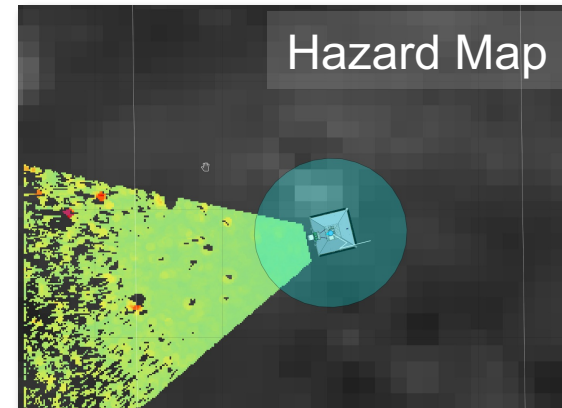
*view of the
Moon from the
HGA gimbal*



Rover Ground Software

Innovations

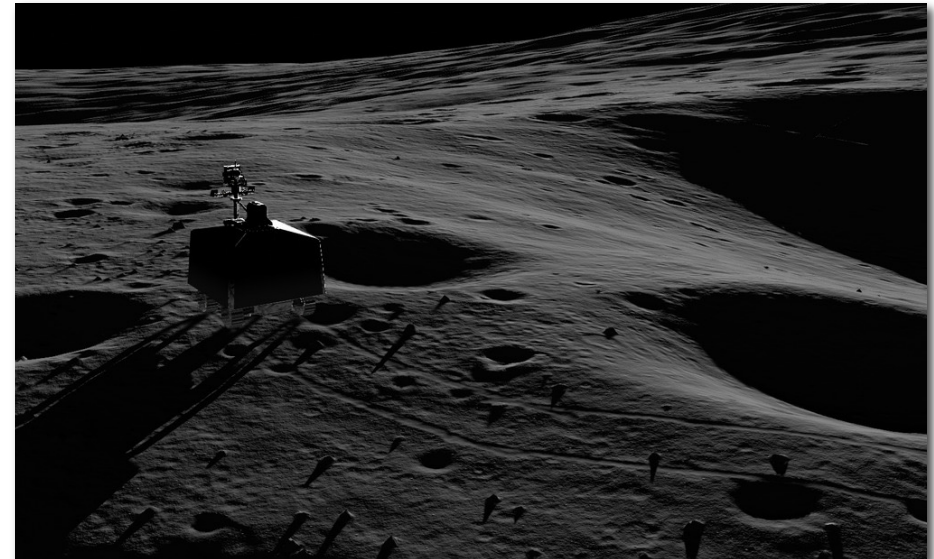
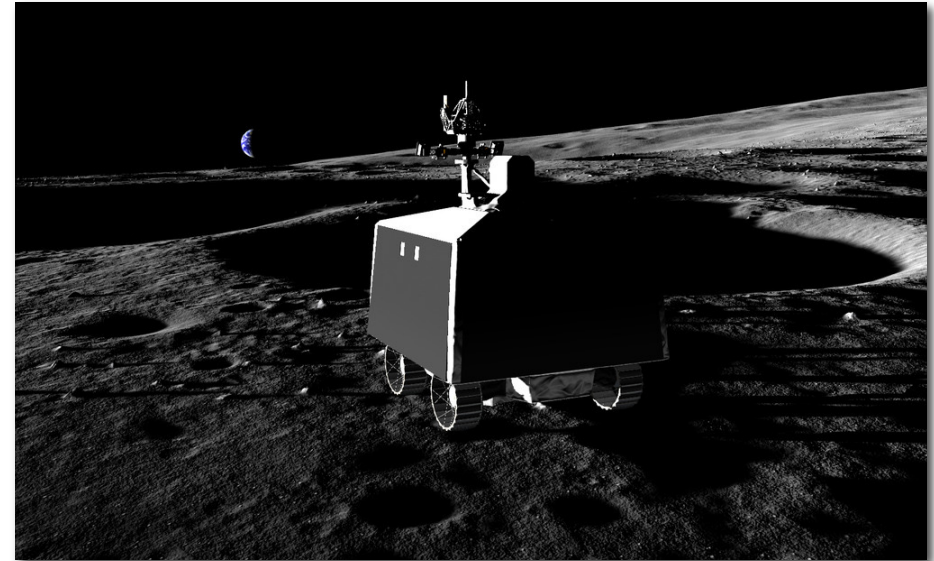
- Off-board software for lunar rovers using the Robot Operating System 2 (ROS 2)
- Relative pose estimation using stereo-vision based visual odometry (VO)
- Absolute pose estimation using stereo-vision based terrain registration (TR):
3D point matching to high-res orbital DEM
- Localization combines on-board pose estimate with VO and TR to achieve best estimate of current pose and past trajectory
- Automated geometric terrain hazard assessment for “hazard map” generation



Rover Simulator (“RSIM”)

Key Features

- High dynamic range rendering
- Real-time shadows
- Support for high resolution terrains (cm/pixel)
- Rover wheel tracks and slip modeling
- Rover lights with custom pattern
- High-fidelity camera modeling
- Lunar regolith reflectance model
- Accurate Sun & Earth ephemeris
- Based on Gazebo Classic r11 (with many customizations)



Mapping Software

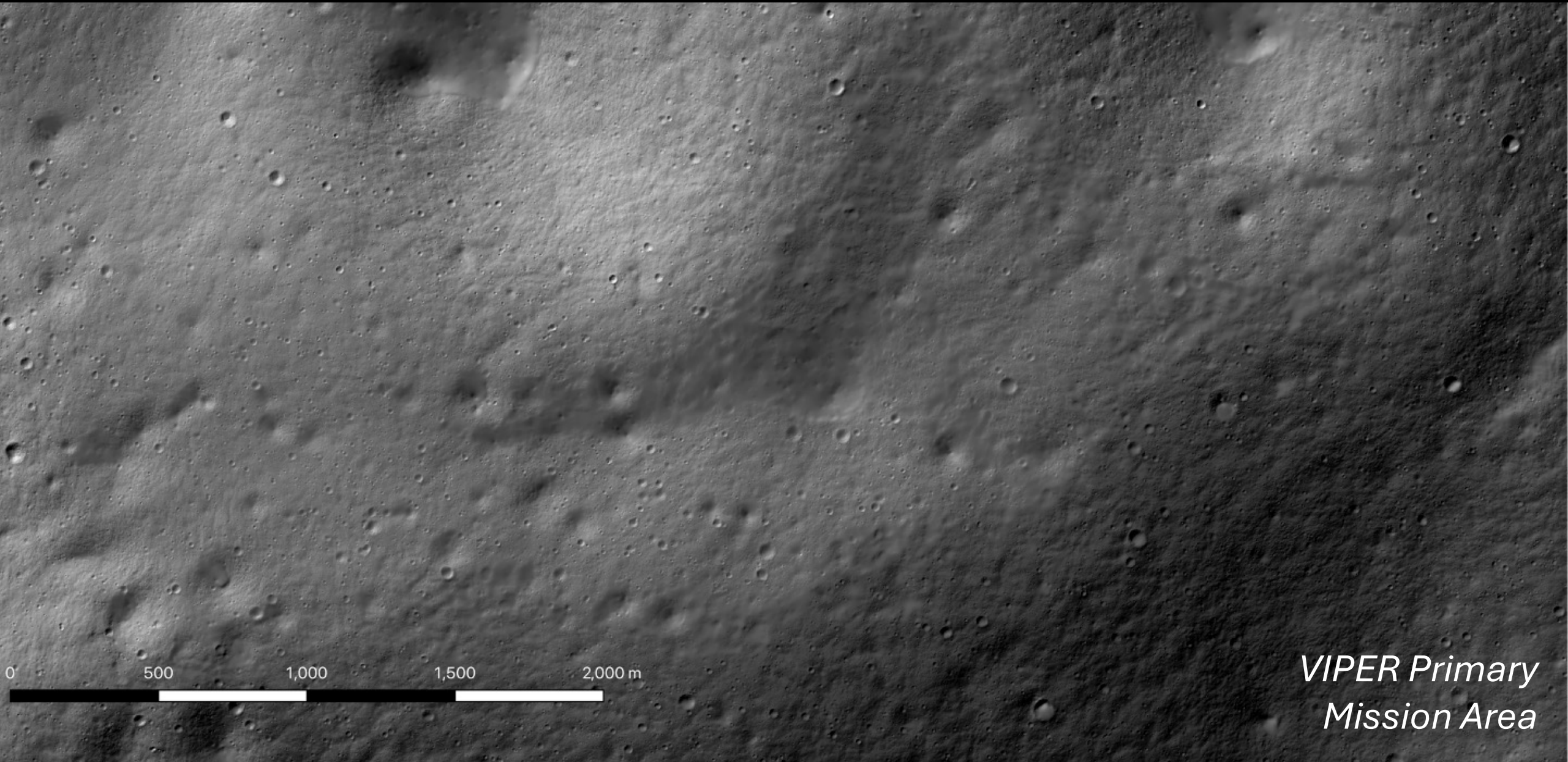
Ames Stereo Pipeline for DEM Production

- Automated stereogrammetry
- Command-line processing tools for desktop, cloud, and supercomputing
- C++ code on GitHub with pre-built binaries (Apache 2 license)
- Photoclinometry (“shape from shading”) used to produce DEMs at near the available image resolution: **1 m/pixel for the Moon**
- Mosaicing and bundle adjustment used to combine many dozens of images to produce map data products

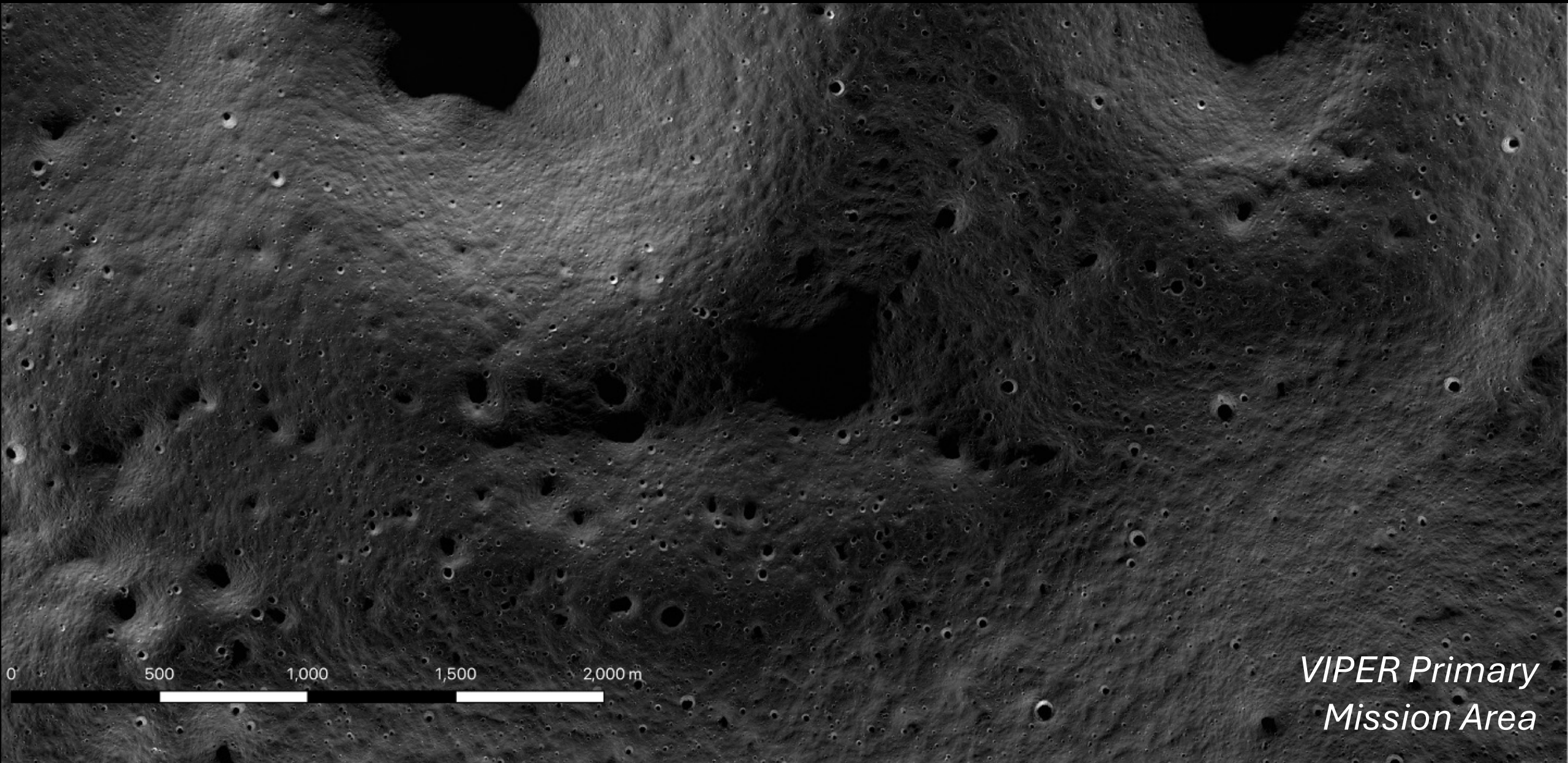
VIPER Synthetic Terrain Generation Tools

- Scientifically plausible, synthetic terrain at very high resolution (e.g., 4 cm/pixel)
- Begin with highest resolution maps (source) derived from orbital data
- Add synthetic craters and rocks based on size-frequency distributions (derived from planetary science research)
- Apply landscape diffusion to appropriately age shape of degraded craters
- Generate other map assets (e.g. normal maps, slip maps, rock masks)

Shape-from-Shading DEM (1 m/pixel)

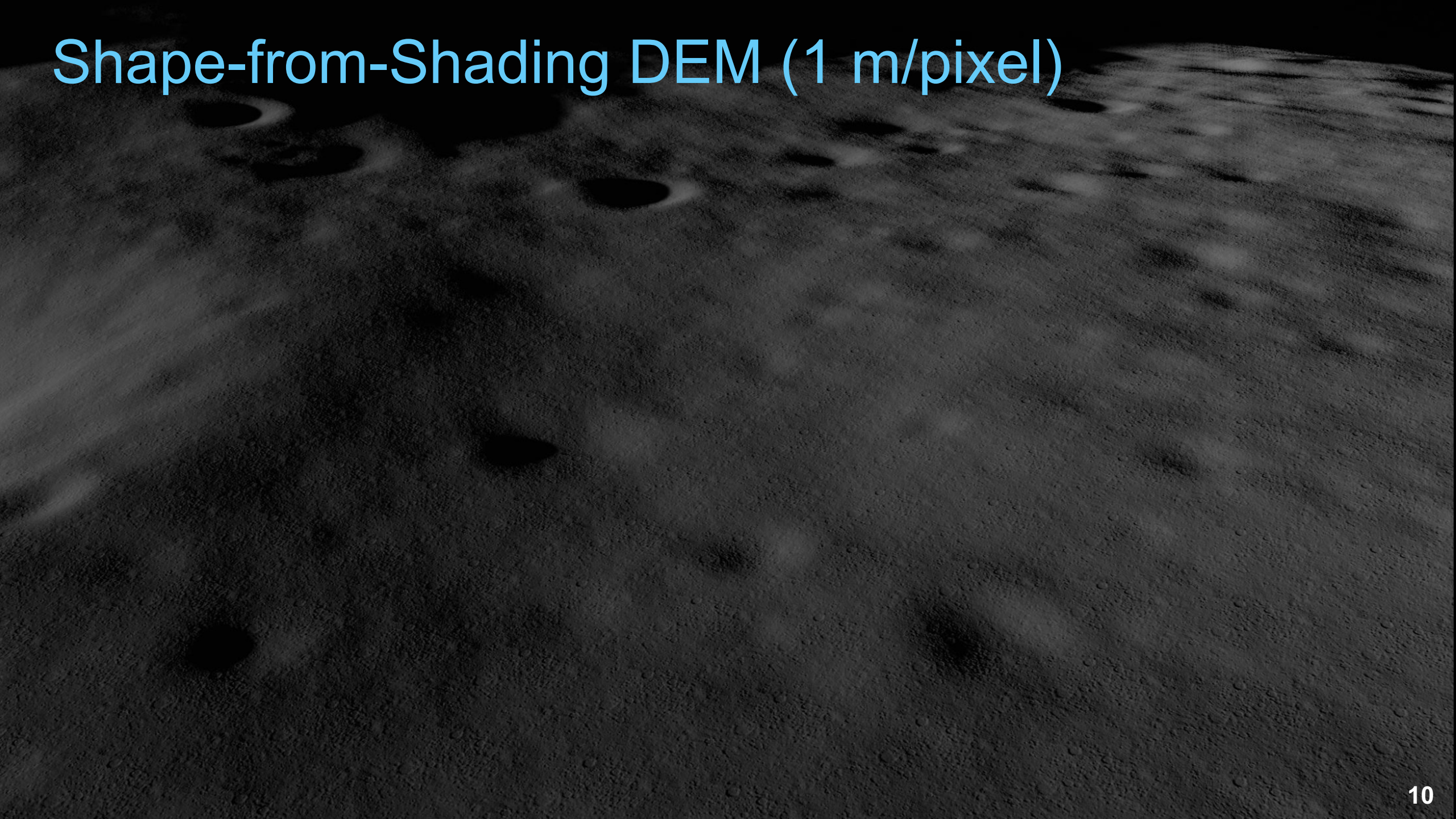


Maximally Lit LROC Mosaic

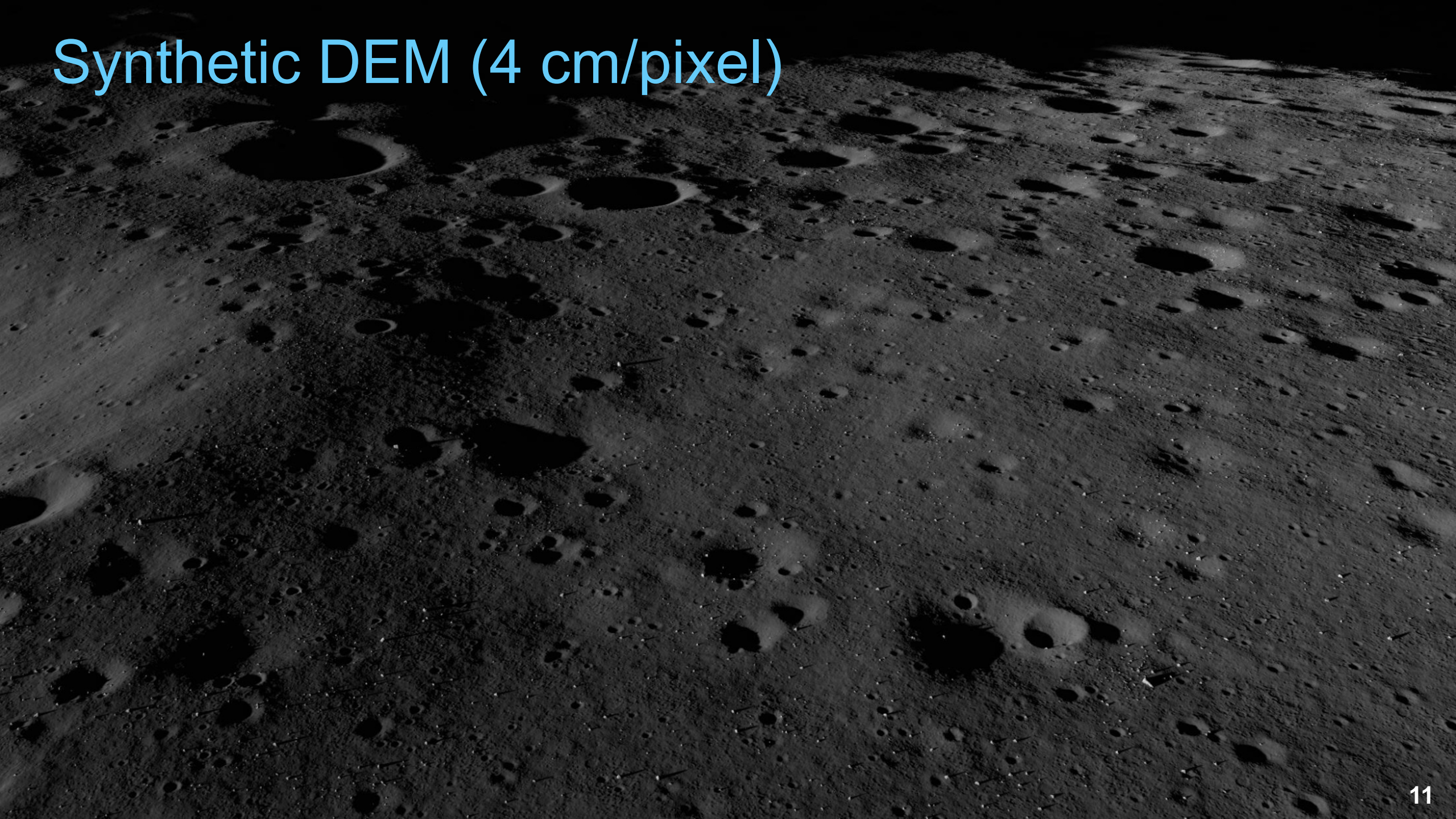


*VIPER Primary
Mission Area*

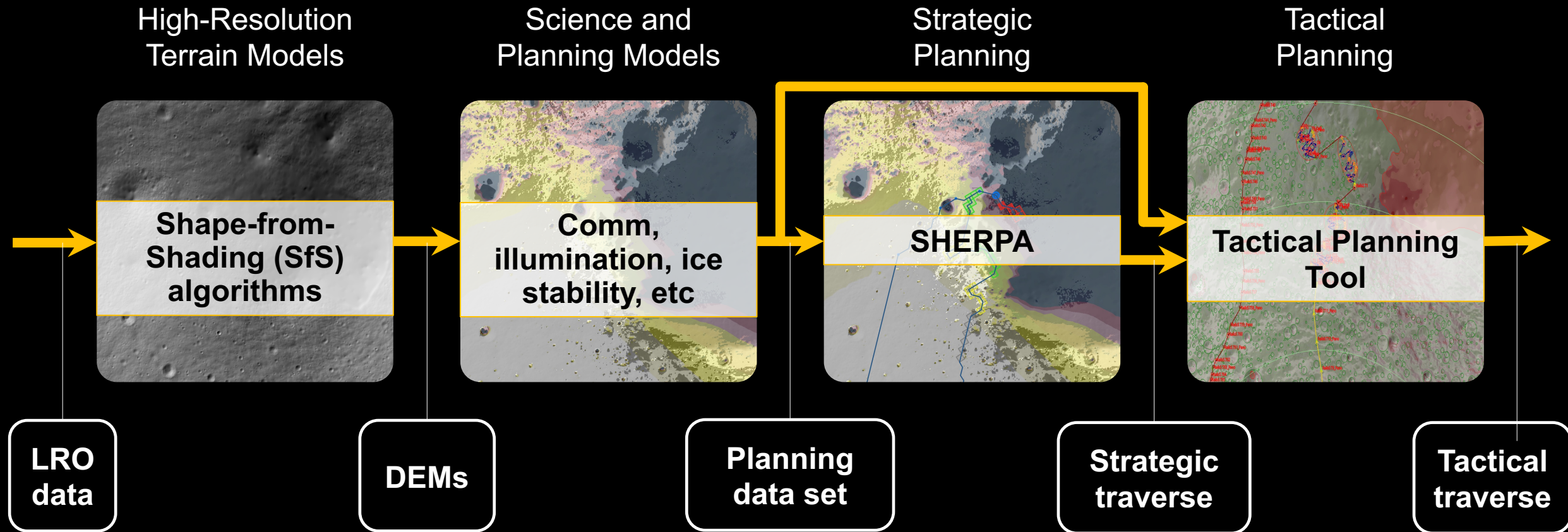
Shape-from-Shading DEM (1 m/pixel)



Synthetic DEM (4 cm/pixel)

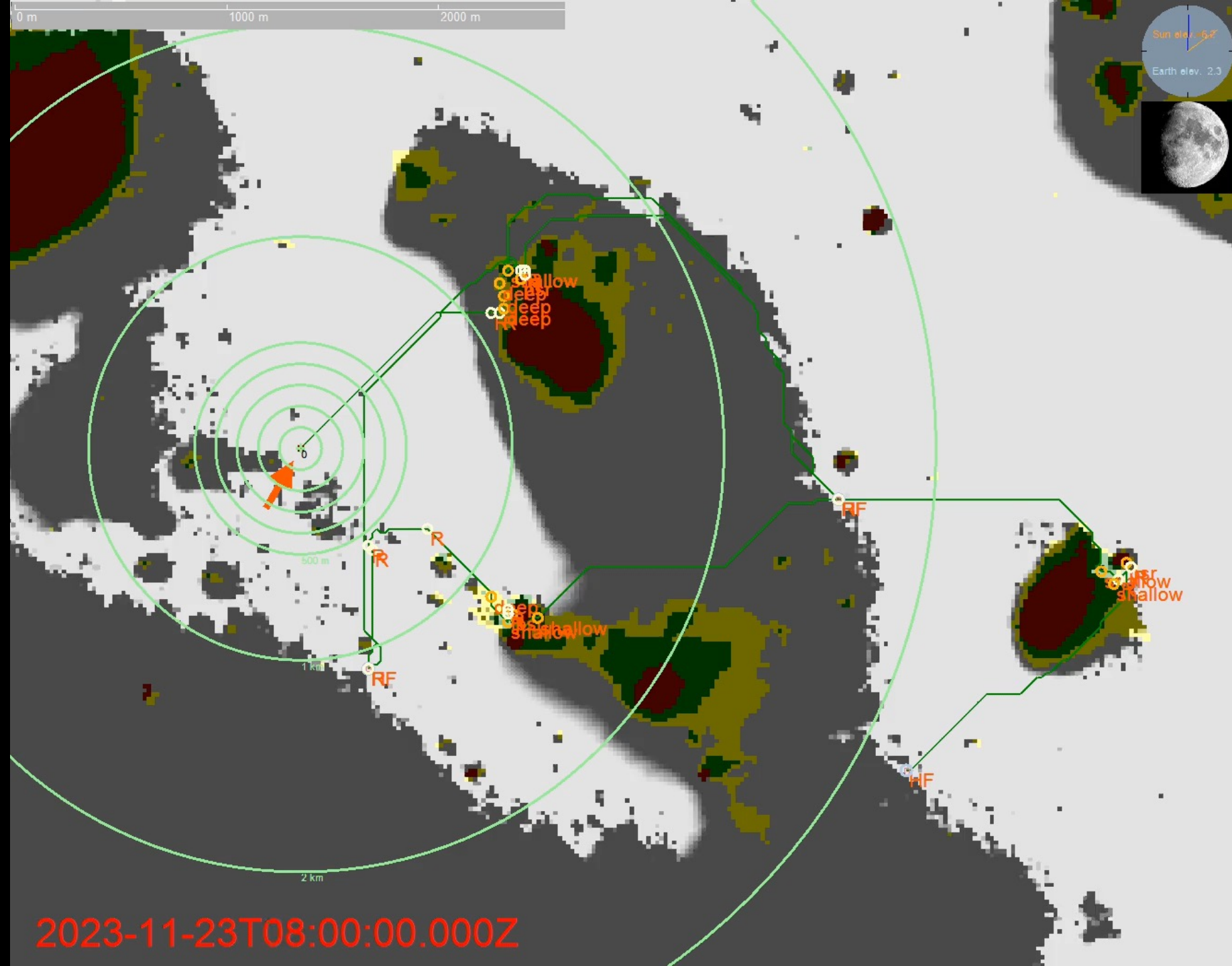


VIPER Surface Mission Planning Process

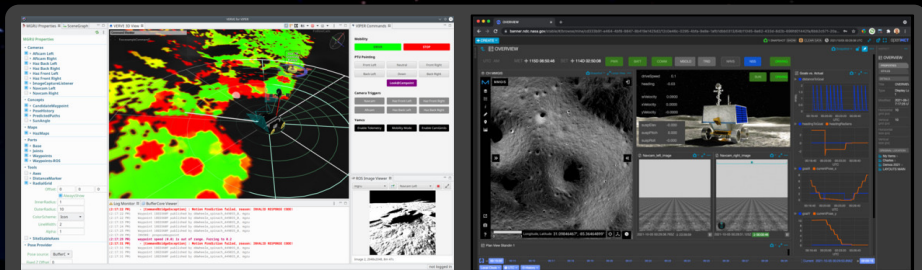


2023-11-23
to
2024-03-07

106 days



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

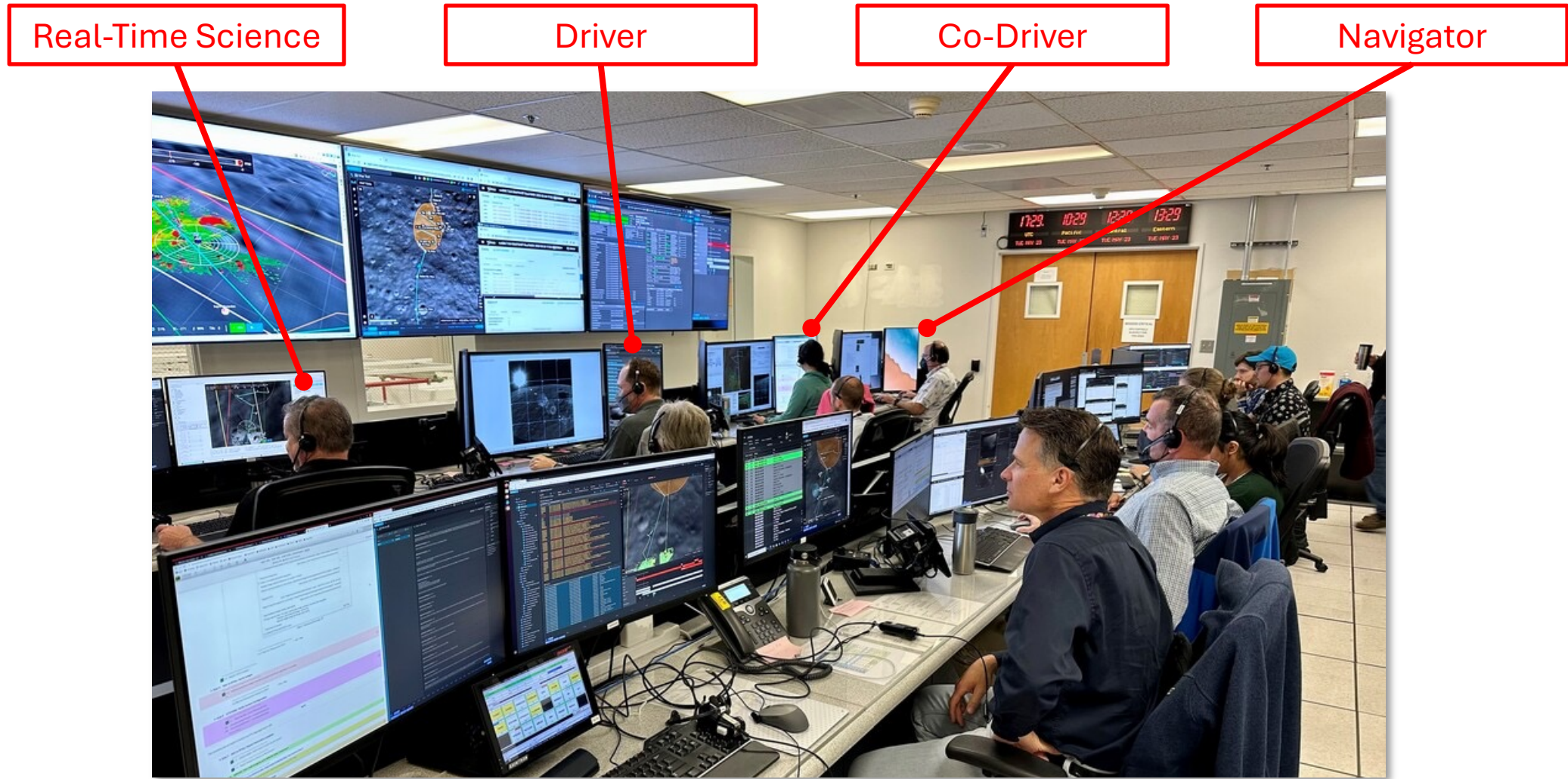
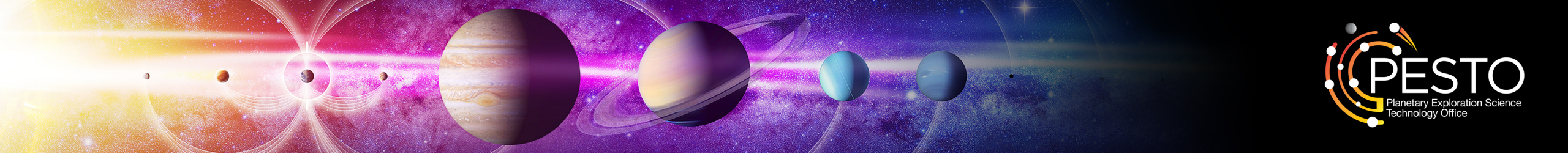
Drill A

Drill B

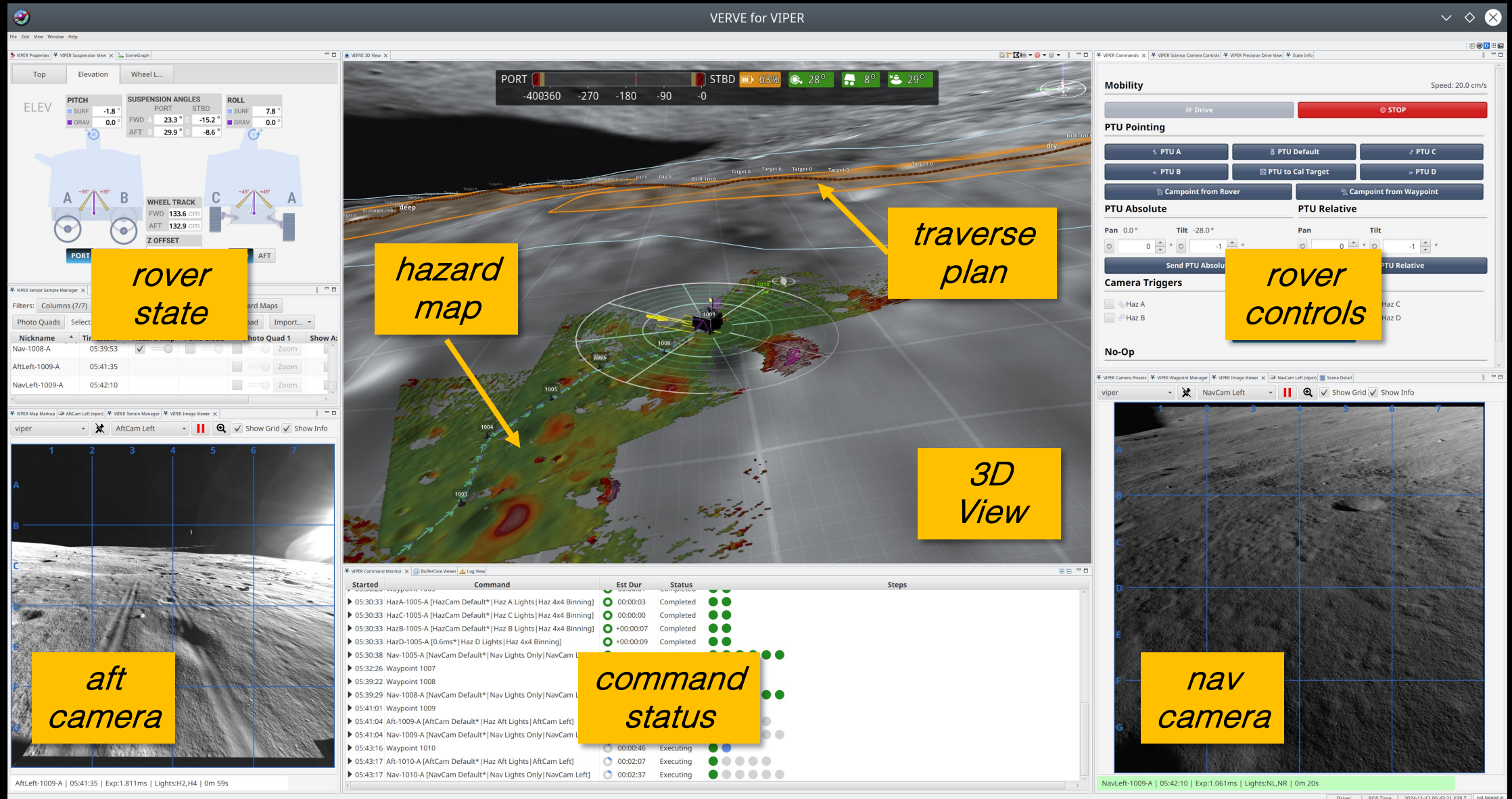
Drill C

Science Station

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



Rover Driving Interface (VERVE)



Waypoint-based Rover Driving

The screenshot displays the VIPER 3D View interface, which is used for controlling the rover. The main window shows a 3D terrain map with a rover and a mission plan. The interface includes several panels:

- VERVE 3D View:** The main 3D terrain map showing the rover's position and the mission plan. It includes a color-coded elevation scale from -400 to 0.
- VIPER Commands:** A panel for controlling the rover's mobility and PTU pointing. It includes buttons for Drive, STOP, PTU A, PTU B, PTU C, PTU D, PTU Default, PTU to Cal, and PTU Relative. It also includes a section for Camera Triggers with checkboxes for Haz A, Haz B, Haz C, Haz D, NavCam Stereo, and AltCam Stereo.
- VIPER Precision Drive View:** A panel for controlling the rover's suspension and drive. It includes buttons for DRIVE_CART, SUSP_CART, DFT_ON, and ATT_ON. It also includes a section for Z Offset and a section for ATT_ON and ATT_OFF.
- VIPER Command Monitor:** A table showing the status of various commands. The table has columns for Started, Command, Est Dur, and Status.
- VIPER Image Viewer:** A panel for viewing the rover's camera feeds. It includes a section for NavCam Left and a section for VIPER Camera.
- VIPER Sensor Sample Manager:** A panel for managing sensor samples. It includes a section for Sample Types and a section for Show/Hide.

The interface also includes a status bar at the bottom showing the rover's position, speed, and other information. The status bar indicates the rover is at 1015, with a speed of 20.0 cm/s. The status bar also shows the date and time: 2024-11-16 02:23:26.373 Z.

RSIM