2024 Planetary Science Technology Symposium

VIPER Software: Rover, Planning, and Ops

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PESTO
Planetary Exploration Science Technology Office

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 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 Simulator (RSIM)

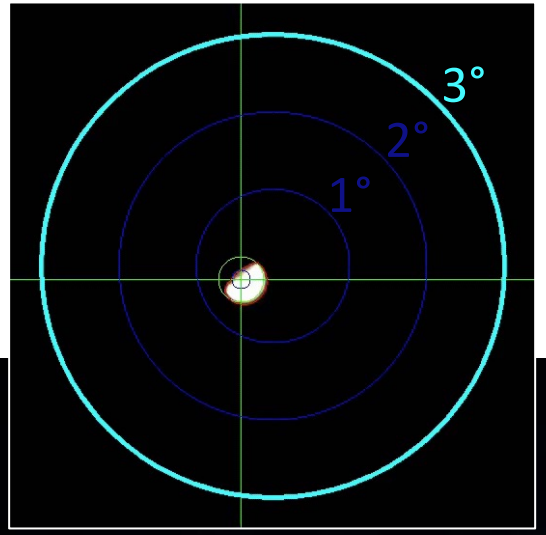
- Integrated lunar surface mission simulator based on Gazebo Classic simulator with custom VIPER plugins
- Used for VIPER software development + mission ops training

Rover 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

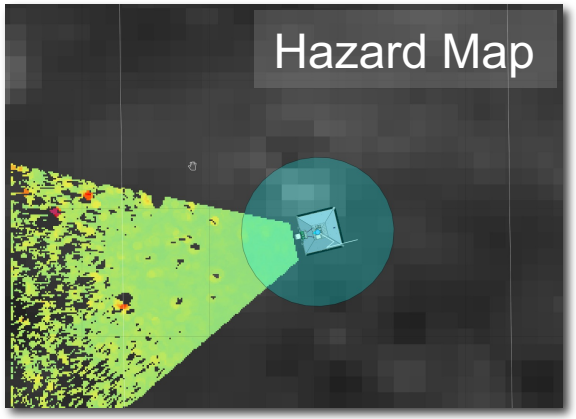
view of the Moon from the HGA gimbal

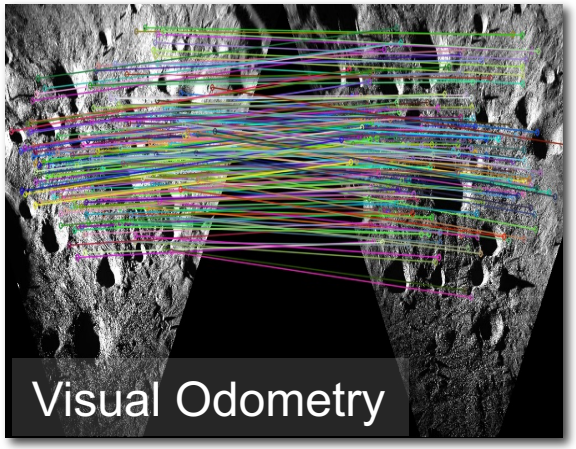


Rover Ground Software

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

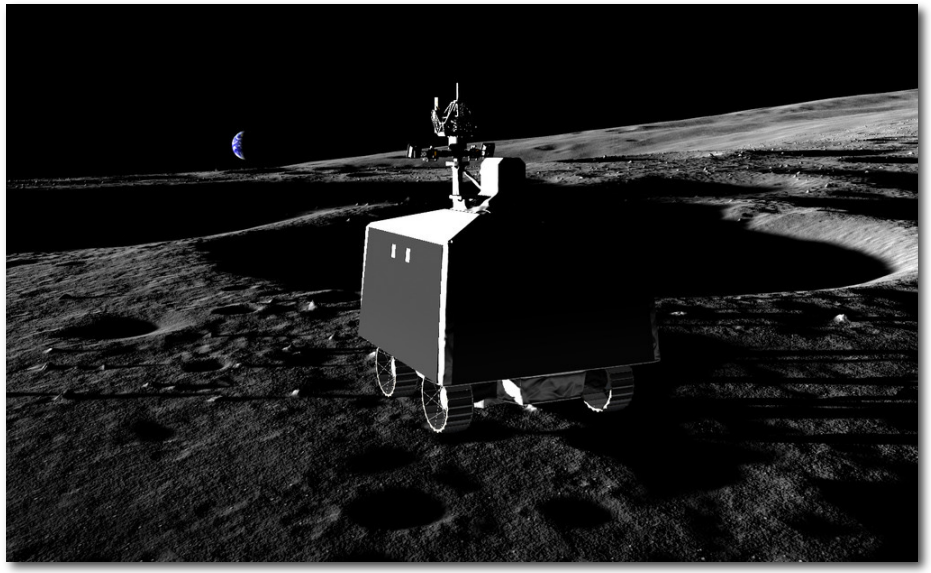


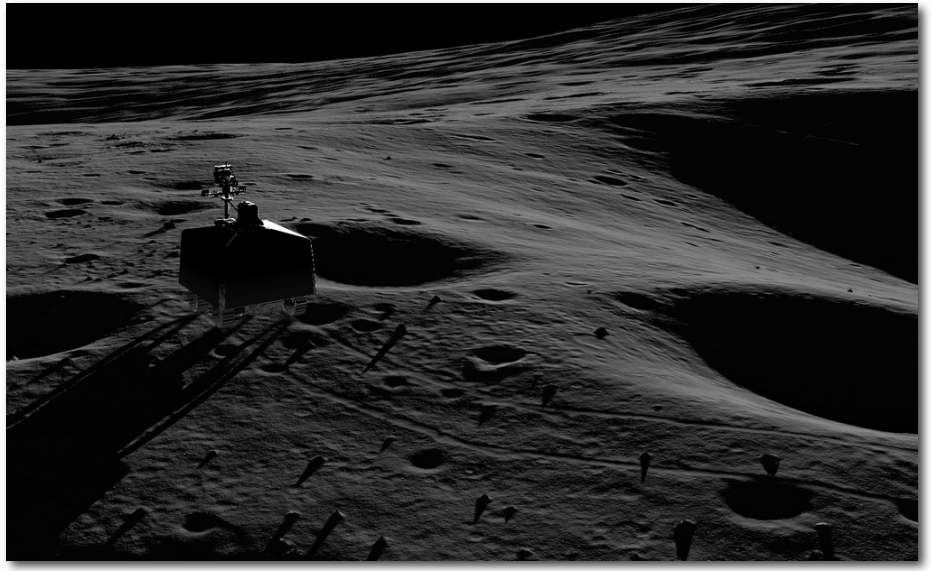


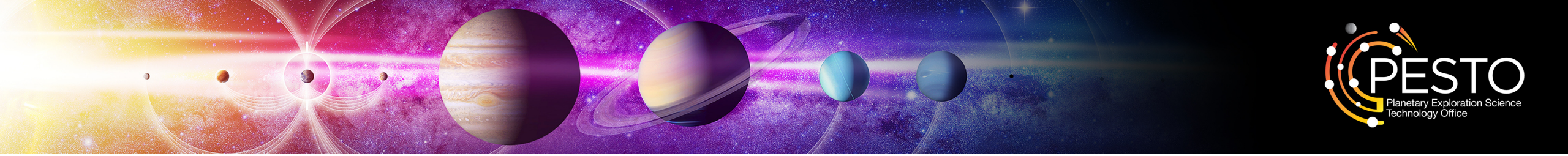
Rover Simulator (“RSIM”)

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 emphemeris
- Based on Gazebo Classic r11
  (with many customizations)







Mapping Software

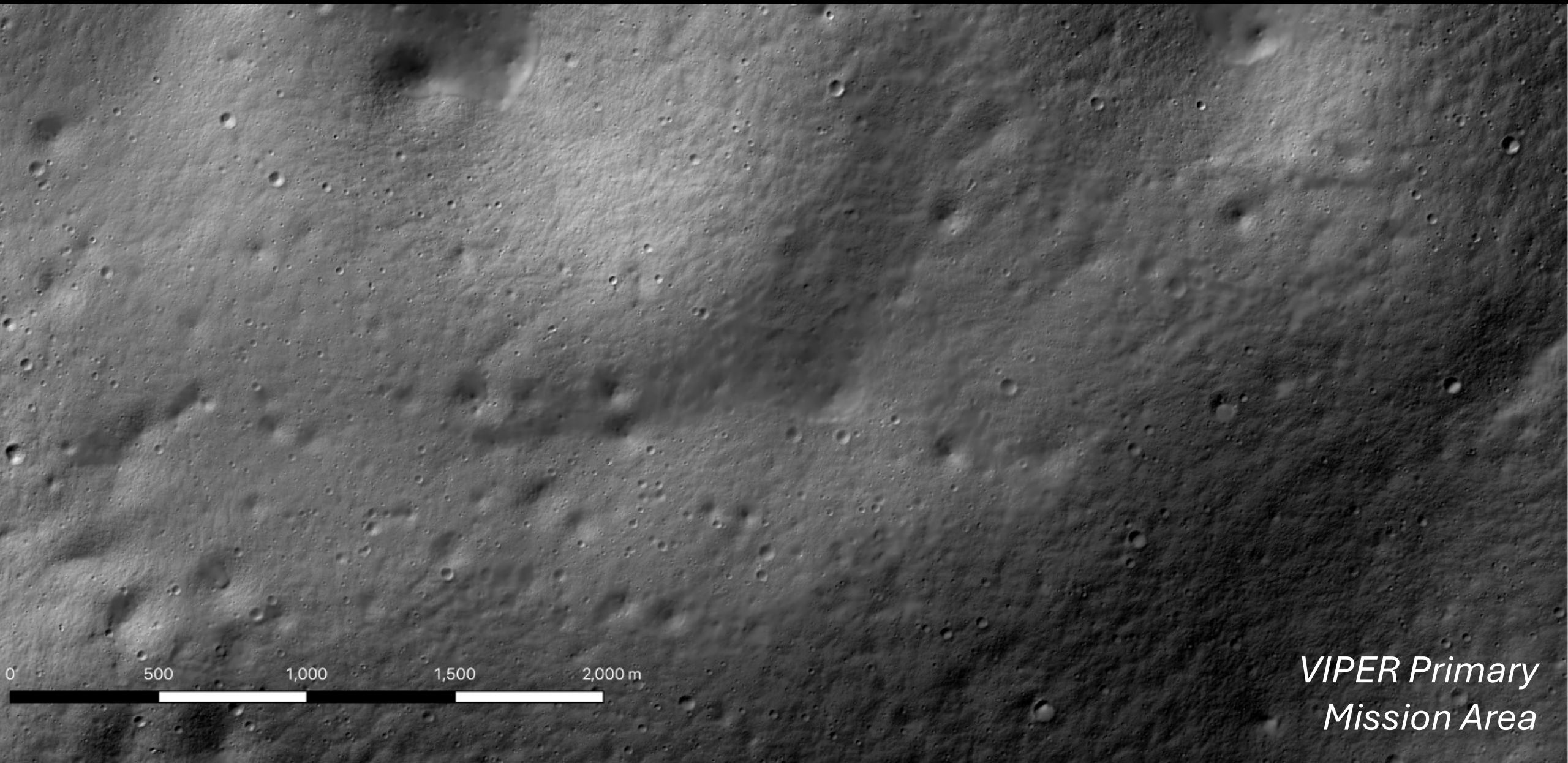
Ames Stereo Pipeline for DEM Production

- 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

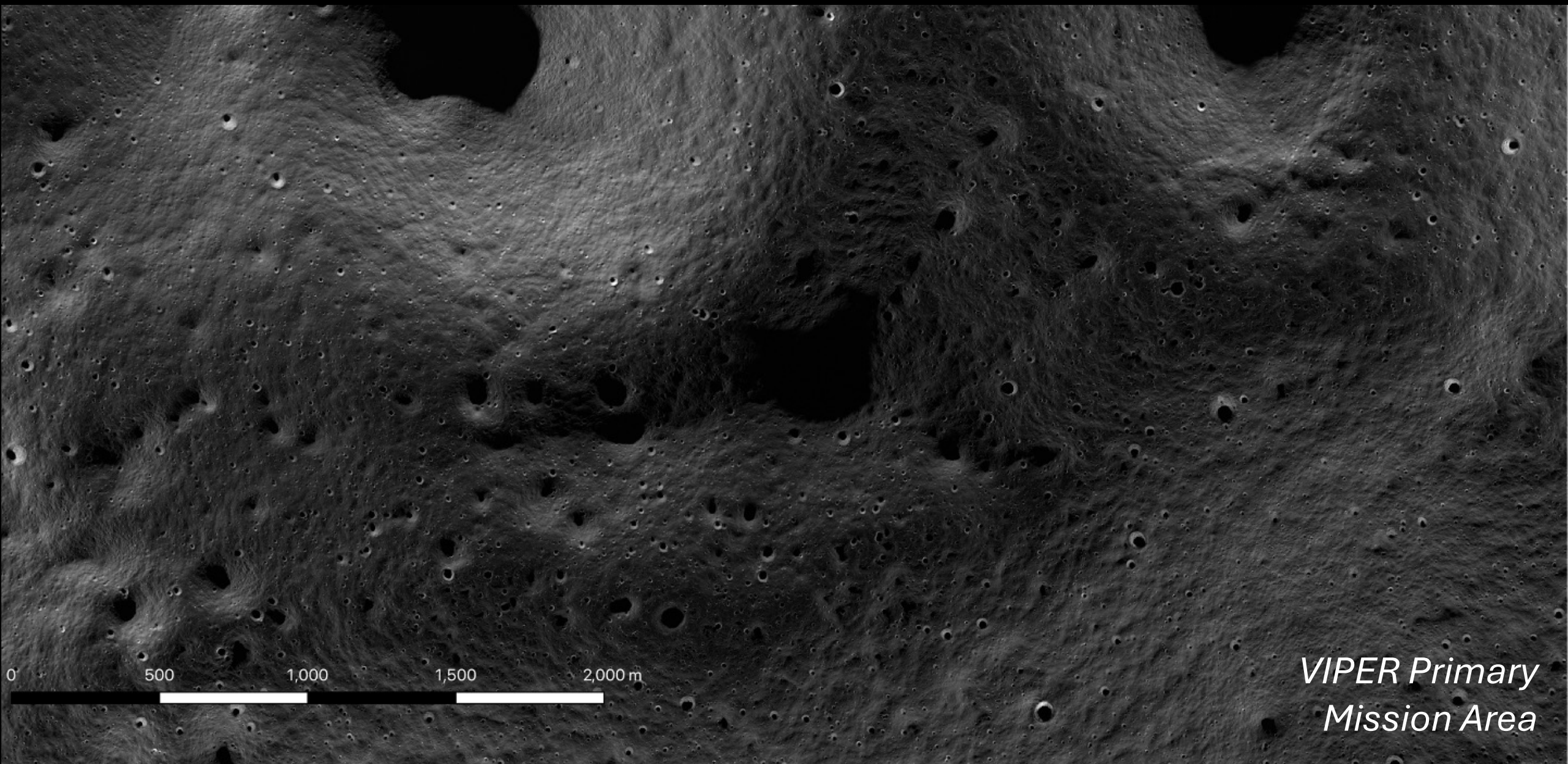
VIPER Synthetic Terrain Generation Tools

- 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)

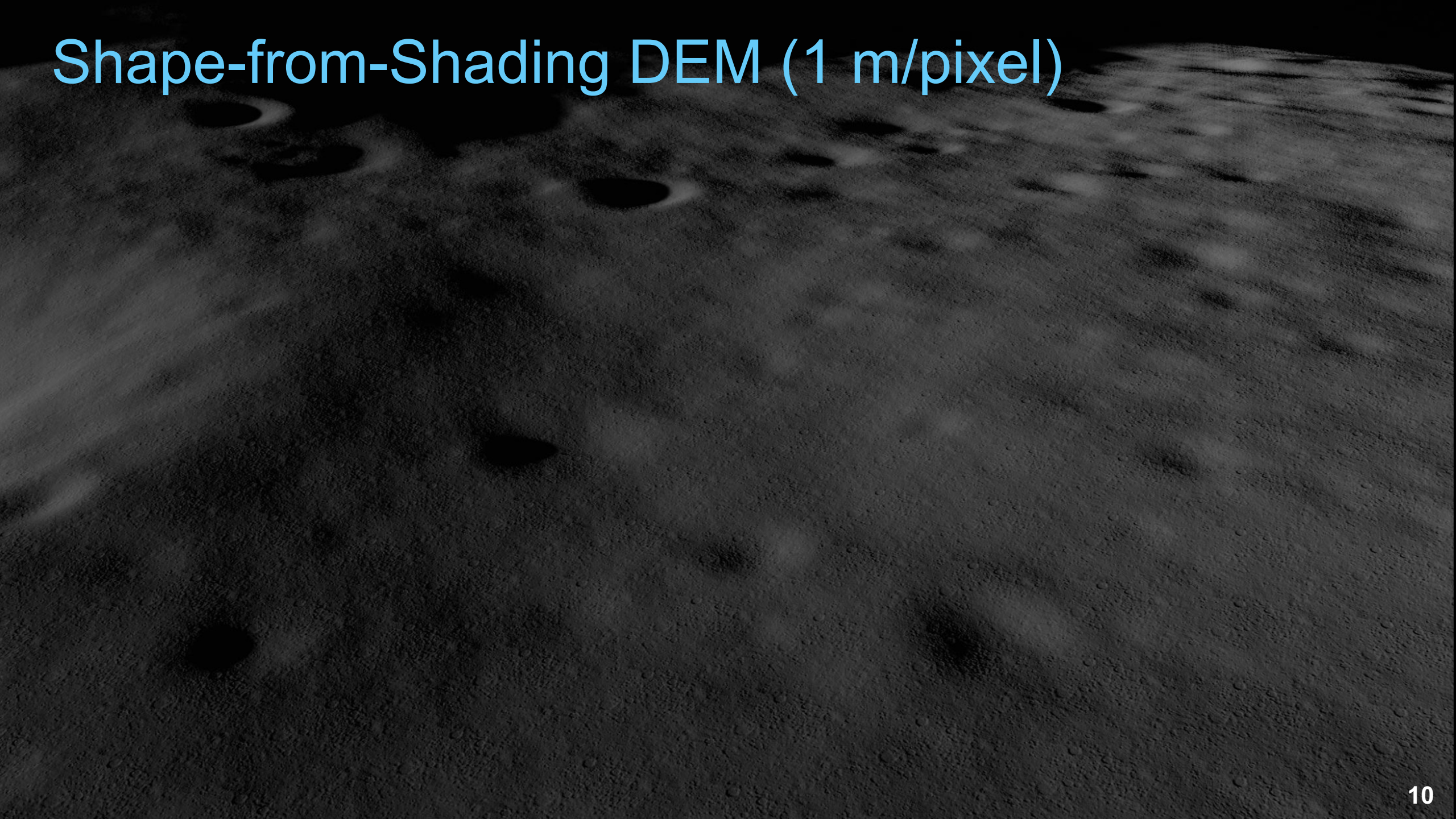
Shape-from-Shading DEM (1 m/pixel)



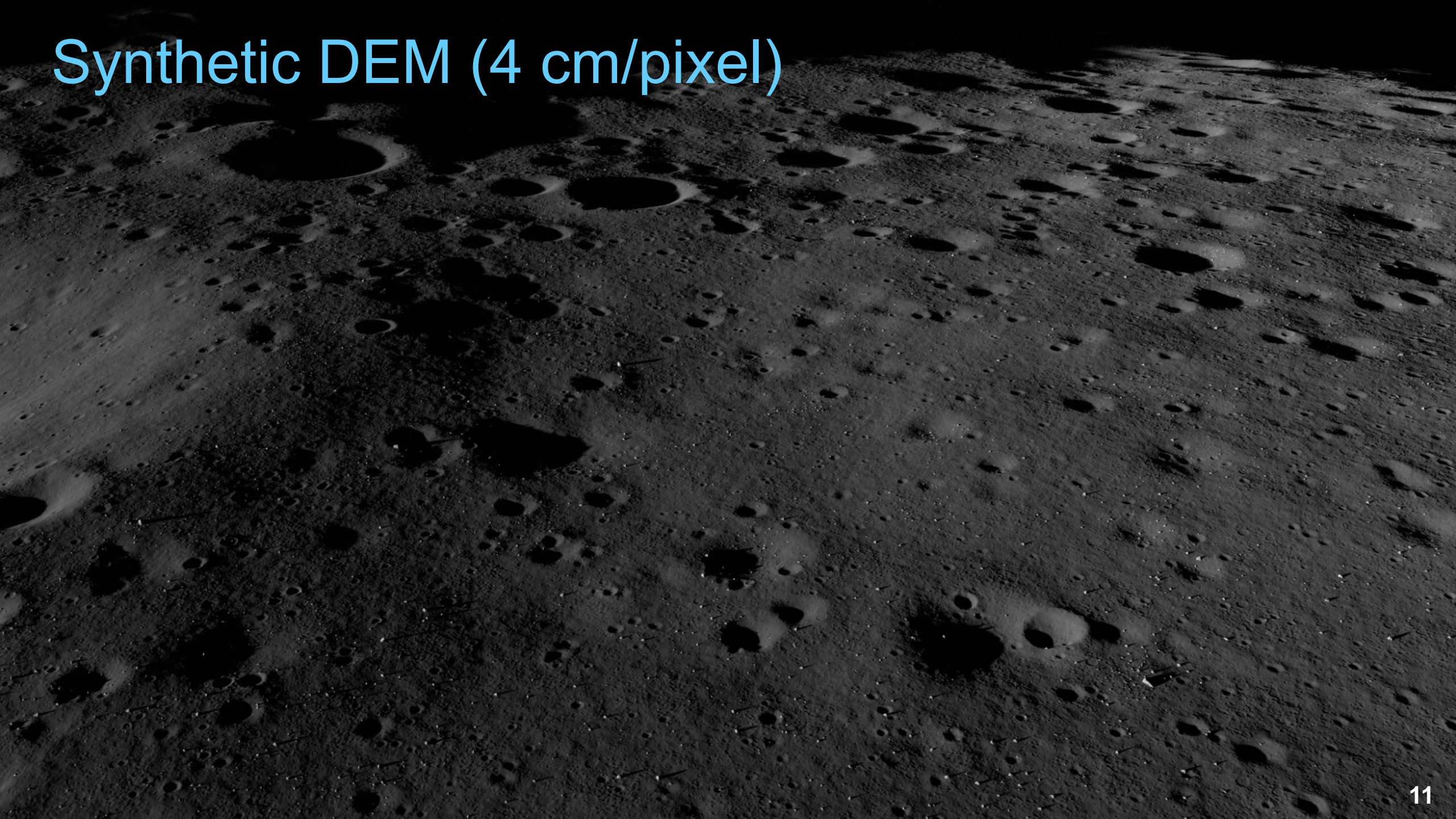
Maximally Lit LROC Mosaic



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



Synthetic DEM (4 cm/pixel)



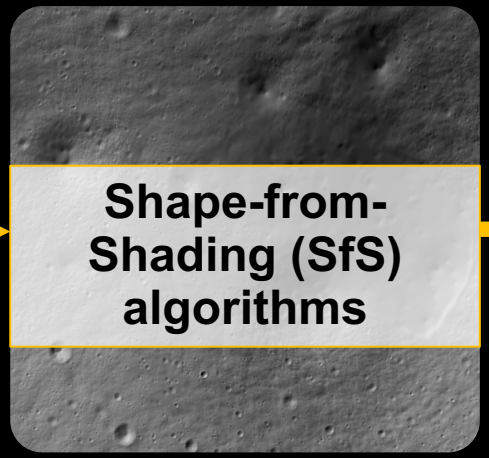
VIPER Surface Mission Planning Process

High-Resolution Terrain Models

Science and Planning Models

Strategic Planning

Tactical Planning



LRO data

DEMs

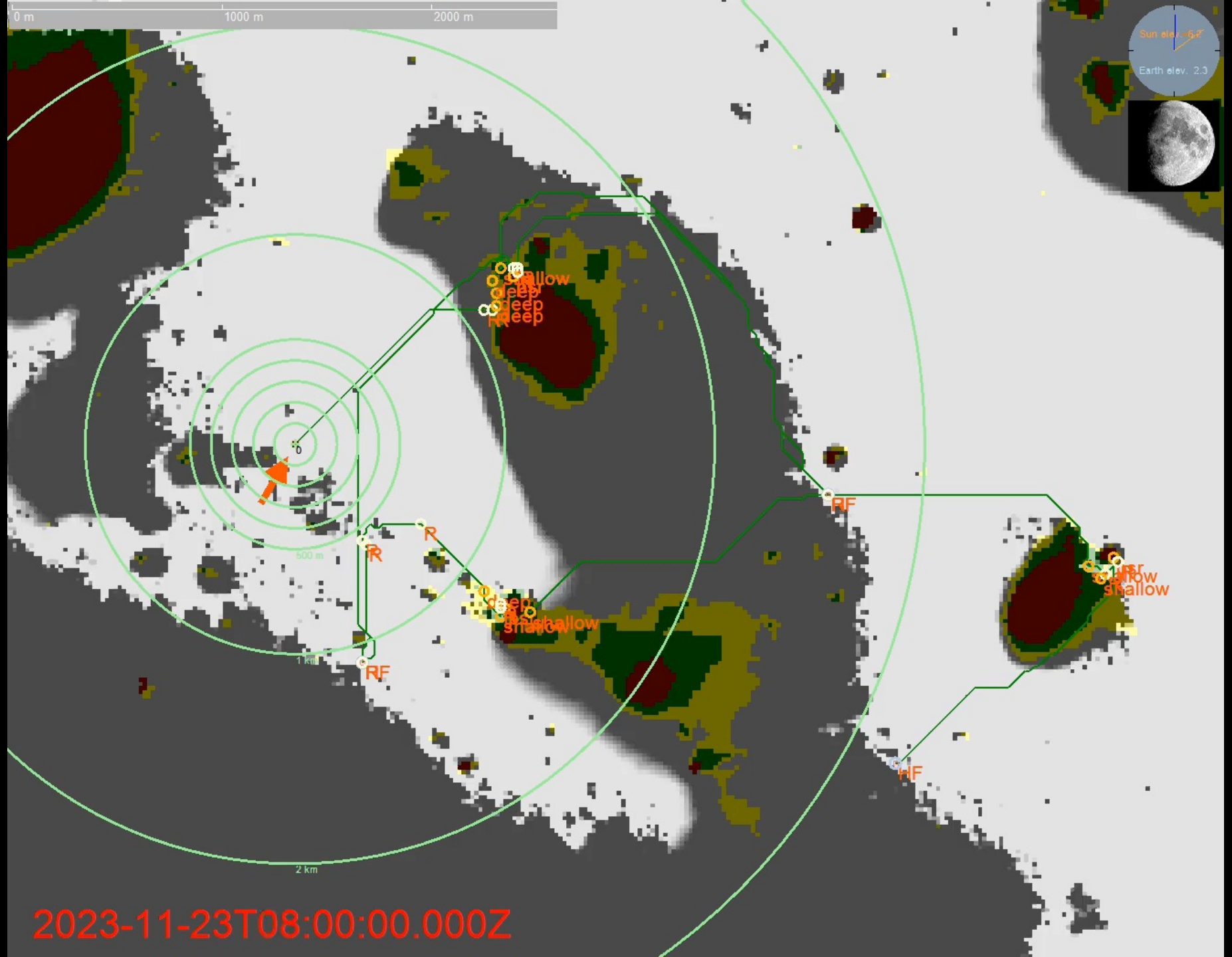
Planning data set

Strategic traverse

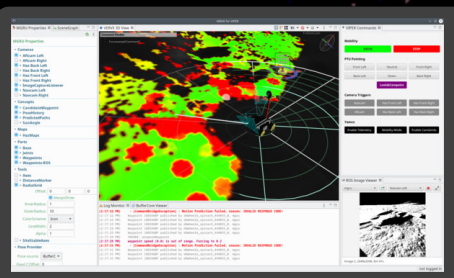
Tactical traverse

2023-11-23
to
2024-03-07

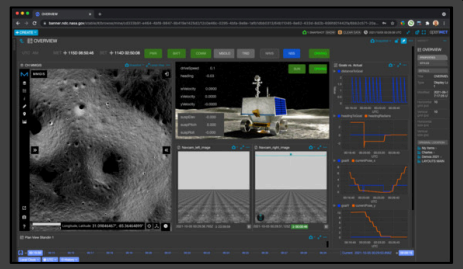
106 days



Mission Operations



Rover Driving



Mission Monitoring

KSC
MSOLO

JSC
Rover Systems & Thermal

ARC
Systems & Execution

Comms round trip ~6 - 10 sec

Lander

Science Station

Traverse Points
~ 50 m

Waypoints
~ 5 m

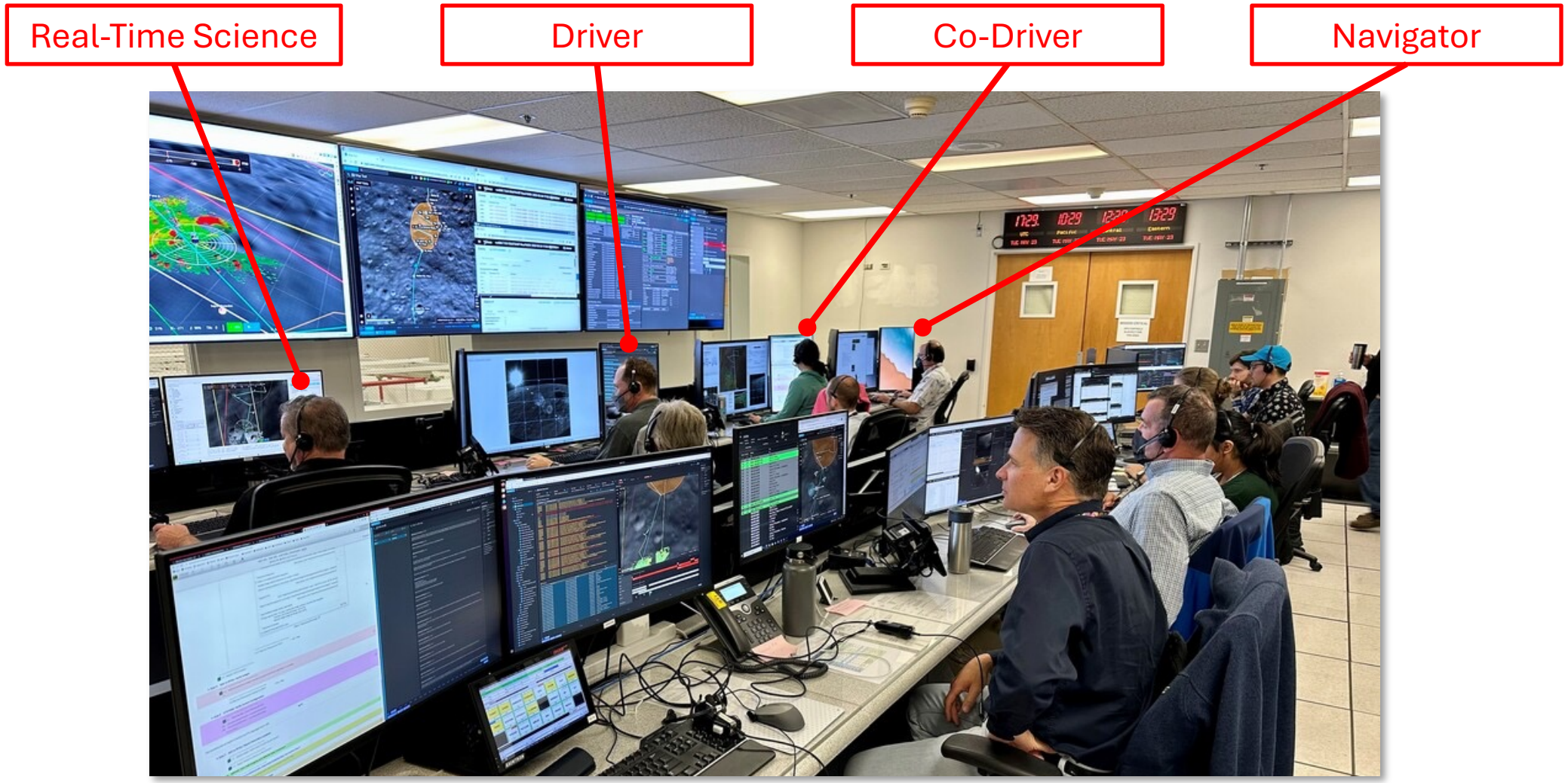
Drill A

Drill B

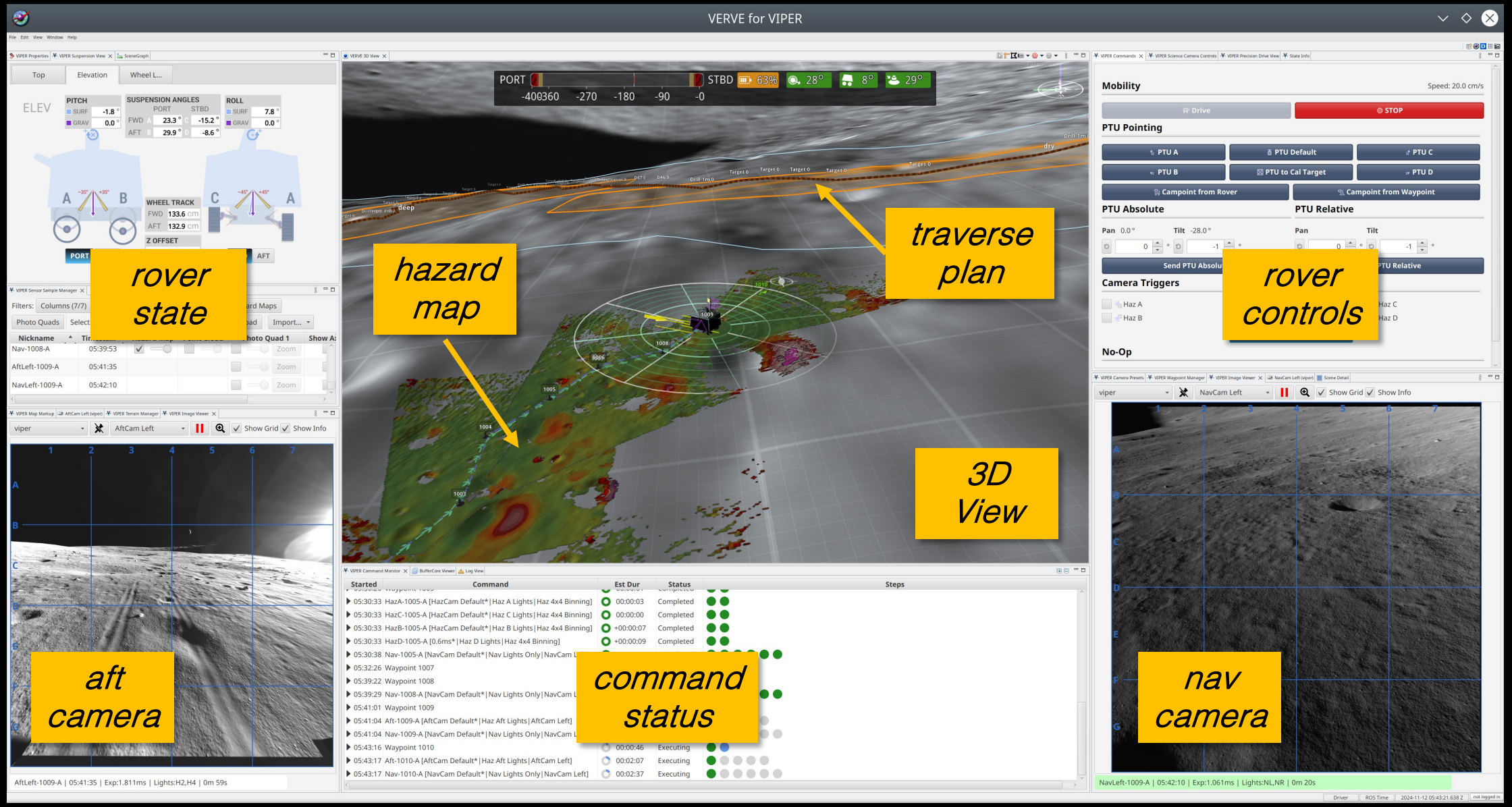
Drill C

Science Station

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


Real-Time Science
Driver
Co-Driver
Navigator

Rover Driving Interface (VERVE)



Waypoint-based Rover Driving