



VIPER Rover Overview and Mobility and Hardware

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VIPER Rover Overview

Mass

- Launch: 490 kg (with lander I/F), roving: 447 kg

Dimensions: 1.7m x 1.7m x 2.5m

Power

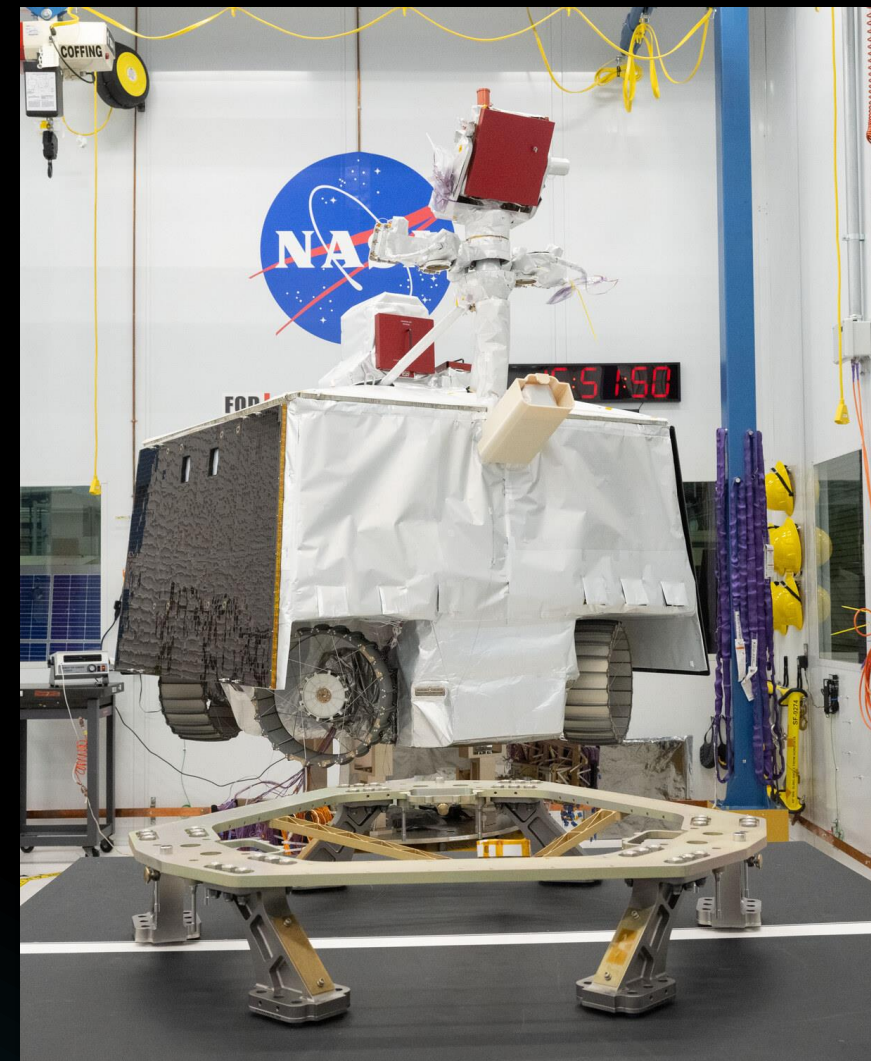
- Solar arrays: 320W per panel (450W on corner)
- Battery capacity (start of life @ 0C): 5,420 W-hr

Communications

- X-band Direct-To-Earth (no relay)
- Transmit: 250 sps / 8 Msps (min/max)
- Receive: 250 sps / 75 ksps (min/max)
- Gimballed high gain + fixed low-gain antennas

Unique Environments

- Temperature extremes
 - 50 hours survival in low power mode
 - 9 hours ops in permanently shadowed region
- Demanding lighting
- Uncertain lunar pole trafficability



VIPER Rover Overview

Subsurface excavation
1m TRIDENT Drill

Power
Solar Array (3-sides)
2x Batteries (internal)

Localization
Star tracker
IMU (in warm box)

Situational Awareness
4x Hazard Cameras
6x Hazard Lights
Aft stereo camera pair

Prospecting & Evaluation
Mass Spectrometer Observing
Lunar Operations (MSolo)
Instrument

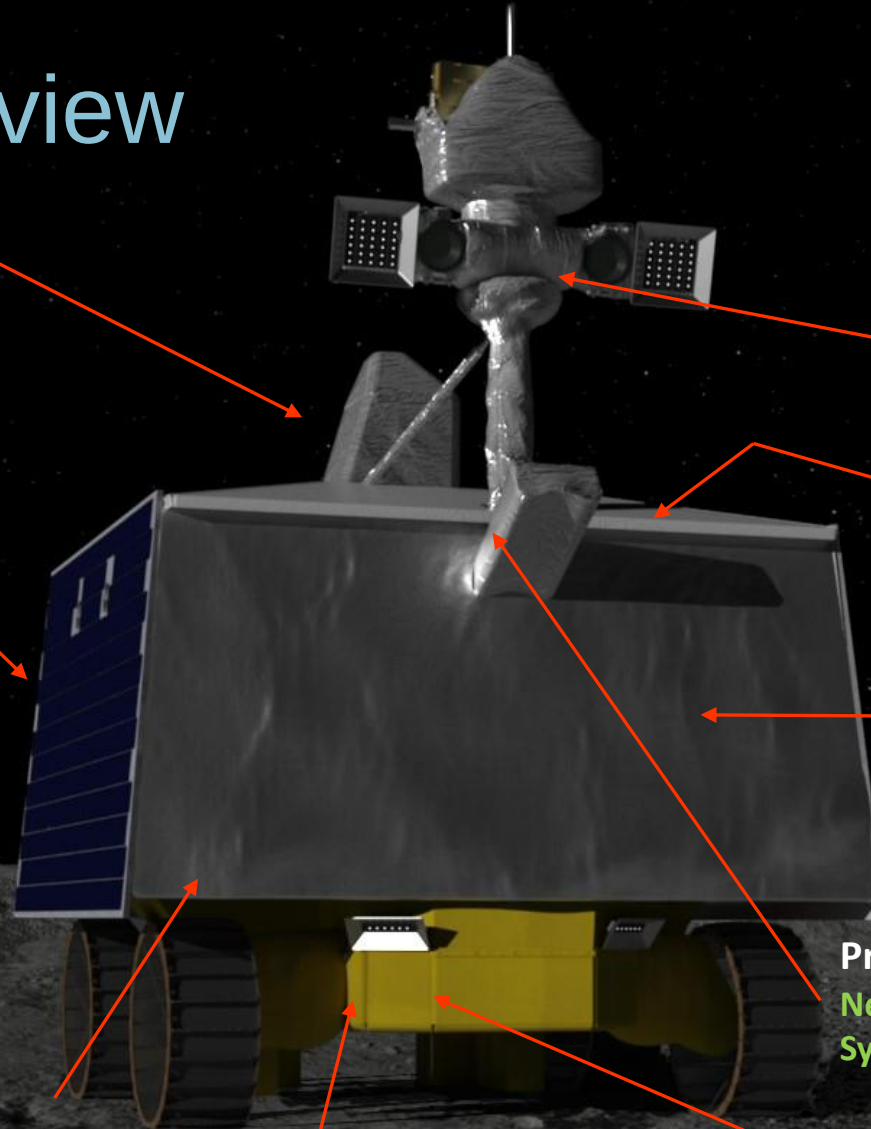
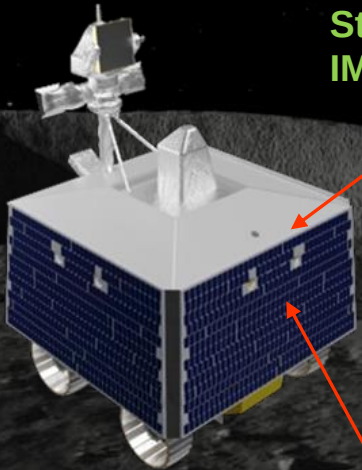
Mast
Nav cameras/lights (gimballed)
High gain antenna (gimballed)
Low gain antenna

Thermal Management
Radiators (on top)
Looped heat pipes (as transport)

Rover Control
Flight Avionics (in warm box)

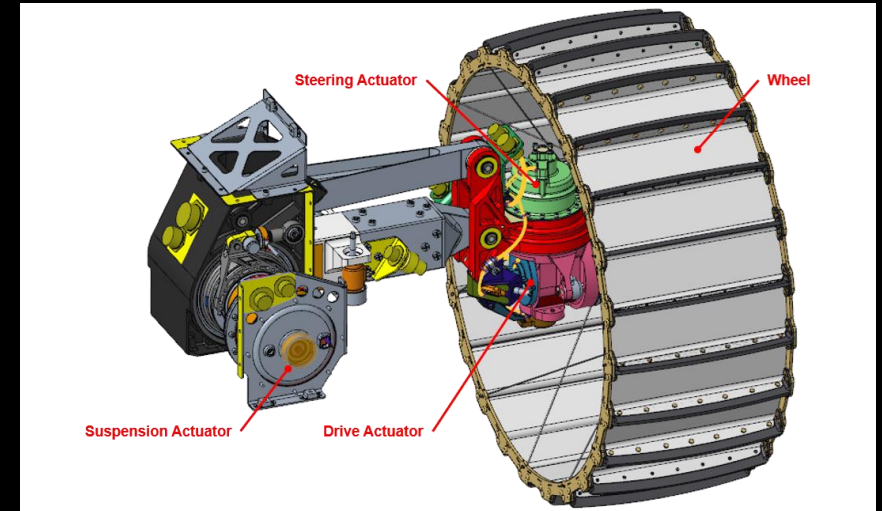
Prospecting
Neutron Spectrometer
System (NSS) Instrument

Prospecting & Evaluation
Near Infrared Volatiles
Spectrometer System (NIRVSS)
Instrument



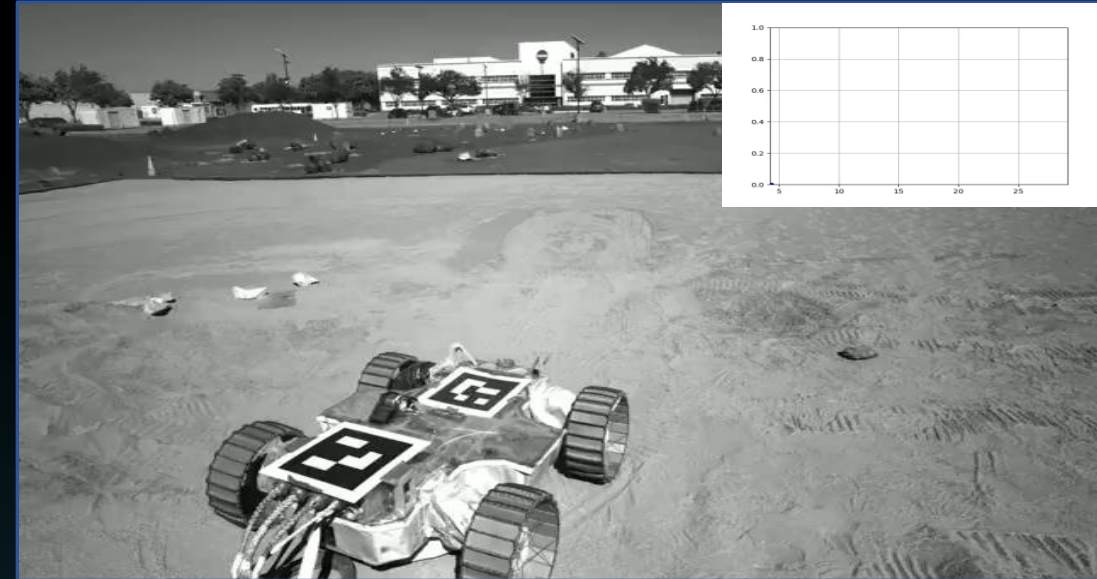
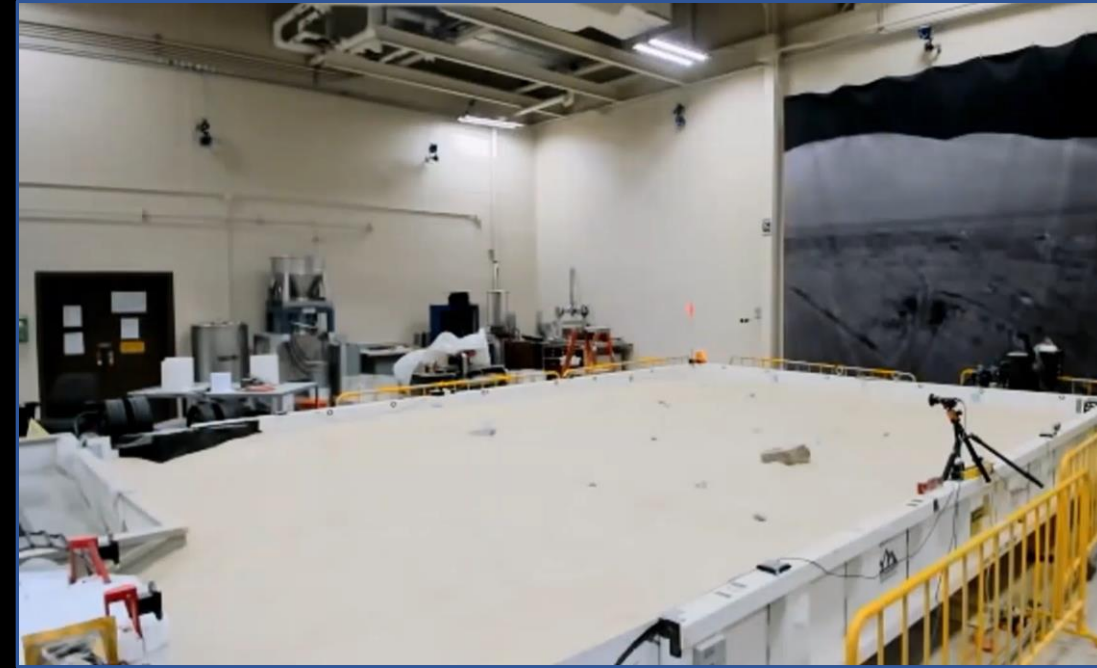
Mobility Overview

- Four-wheel architecture
 - Slopes up to 15 deg (reqt)
 - Obstacles to 15 cm (reqt)
 - Mobility system qualified to 2x20 km surface life
 - Launch restraints on suspension and steering
- Wheel Modules
 - Wheels: diameter 50 cm, with 2.5 cm grousers, spoked
 - Drive: top speed 20cm/s, nominal speed 10 cm/s
 - Steering: explicit with +/-50 deg range
 - Suspension: adjustable with individual wheel downforce control
 - IMU feedback used for chassis pitch/roll control
 - Adjustable ground clearance from 7-43cm
- Motor Controllers
 - Each avionics box controls 6 BLDC actuators
 - 20A output current peak for 10 sec per axis
 - Two wheel modules controlled by each box
 - Current, voltage, temperature, load cell measurement
 - Cascaded control loops: Position -> Velocity -> Current
 - Contained within warm box



Mobility Cont.

- Driving Modes
 - Omni-directional driving with sun on corner
 - Maximizing power generation
 - Hybrid mobility
 - Entrapment escapement
 - Inch-worming/crawling
 - Precision movement
 - Slip/embedding detection
- Moon Gravity Representation Units (MGRU)
 - VIPER Flight Unit unable to support its own weight on earth
 - Basic configuration is lunar weight
 - Mobility only: power, control, computing off board
 - Can “violate” lunar weight to add capability
 - Examples: cameras, mast, lighting
 - V&V, driver training, ops scenario development



Egress Engineering/Training (2021-2024)



Gimbals Overview

- Pan-tilt units for high gain antenna and navigation cameras pointing
 - High Gain Antenna Gimbals
 - Height: 2.3 meters
 - Pan: 400 deg range, ~ 14 deg/s
 - Tilt: $+25/-29$ deg, ~ 8 deg/s
 - Navigation camera Gimbals
 - Height: 2 meters
 - Pan: 400 deg, ~ 14 deg/s
 - Tilt: $+0/-77$ deg, ~ 8 deg/s
 - Speeds designed to match rover rotating in place/falling off rock at minimum voltage
 - Hardstops for each joint
 - Frangibolt launch restraints on each axis
- Motor control common with mobility motor controllers

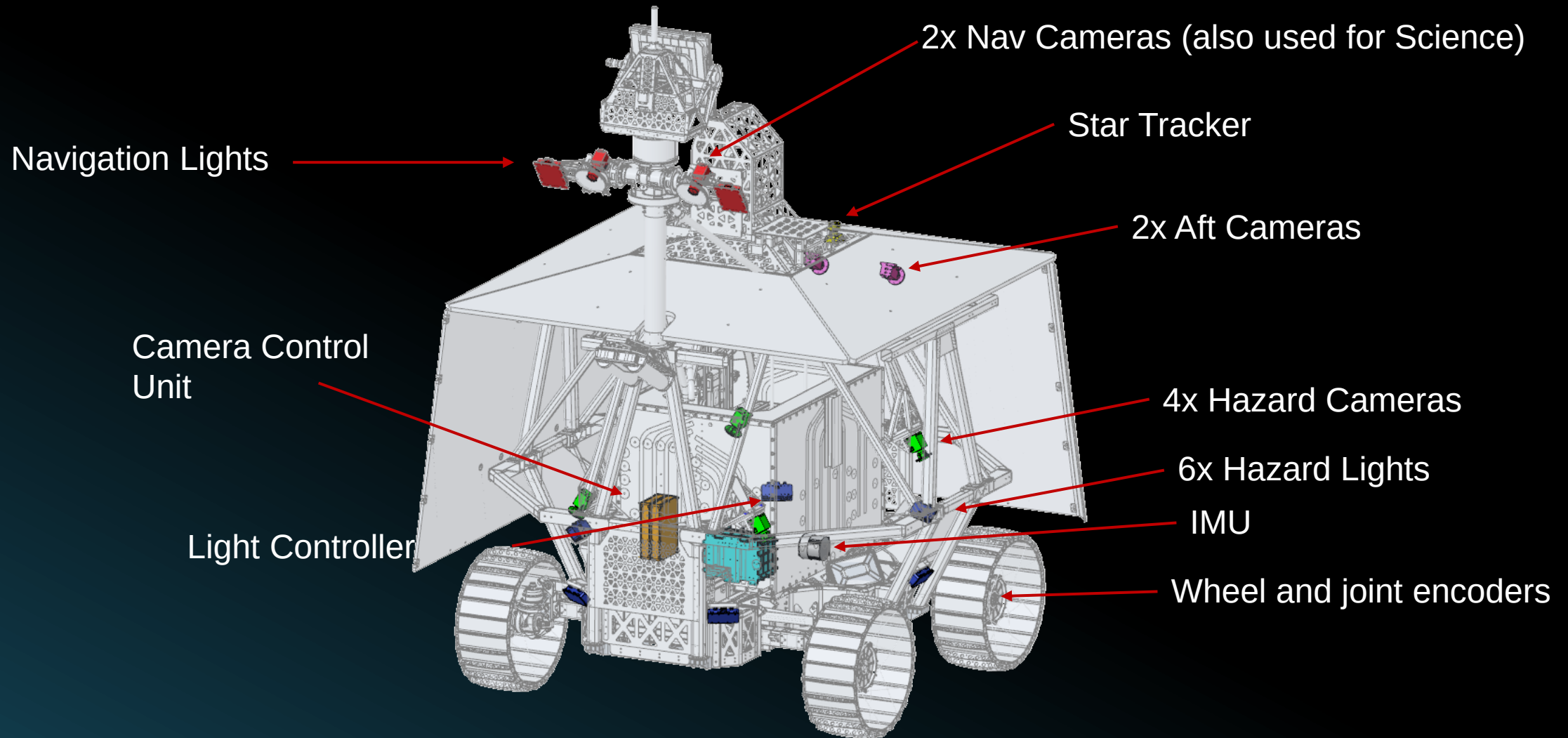


Gimbal Controlled by Flight Mtr Ctrl in TVAC



Pointing at moon HGA while roving

VIPER Navigation Hardware



Camera Qualification and Calibration

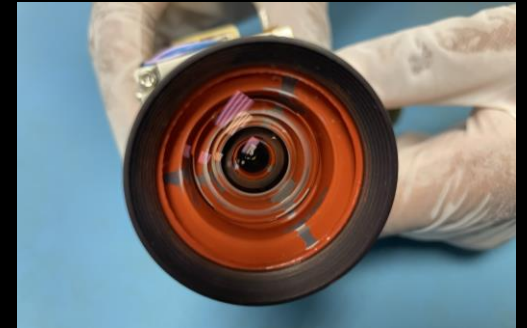
VIPER Visible Imaging System (VIS)

- 8x cameras: 2x NavCams, 4x HazCams, and 2x AftCams.
- In-house lens/body integration and flight qualification of NavCams.
- NavCams satisfied Wide FOV, Low Distortion, and additional Metric Stereo requirements.

Testing & Calibration

- Acceptance testing of MTF, depth of field, and field of view; geometric calibration for all cameras.
- Pre-launch calibration of optical geometry (all cameras).
- In-mission calibration of NavCams using rover-mounted “checker board” targets.

*NavCam lens
close-up*



*Camera MTF
testing*



*Rover-mounted
checker board
calibration targets*

Lunar Rover Lights

VIPER Lighting System

- Lighting for human driving and robot navigation in PSRs
- 8x LED-array lights and avionics qualified for Lunar polar conditions
- Blue wavelength tuned for sensitivity in Permanently Shadowed Regions.

NavLights

- “Headlights” tuned for long-range stereo imaging and decision making

HazLights

- “Parking lights” provide near-field illumination needed for maneuvering and inspection of wheels



NavLights flashing during burn-in tests



NavLight EDU Testing



HazLights covering terrain near wheels

Star Tracker

First use of a star tracker on a planetary rover

- Compares positions of stars in view to an on-board star catalog to estimate attitude

ST benefits for VIPER

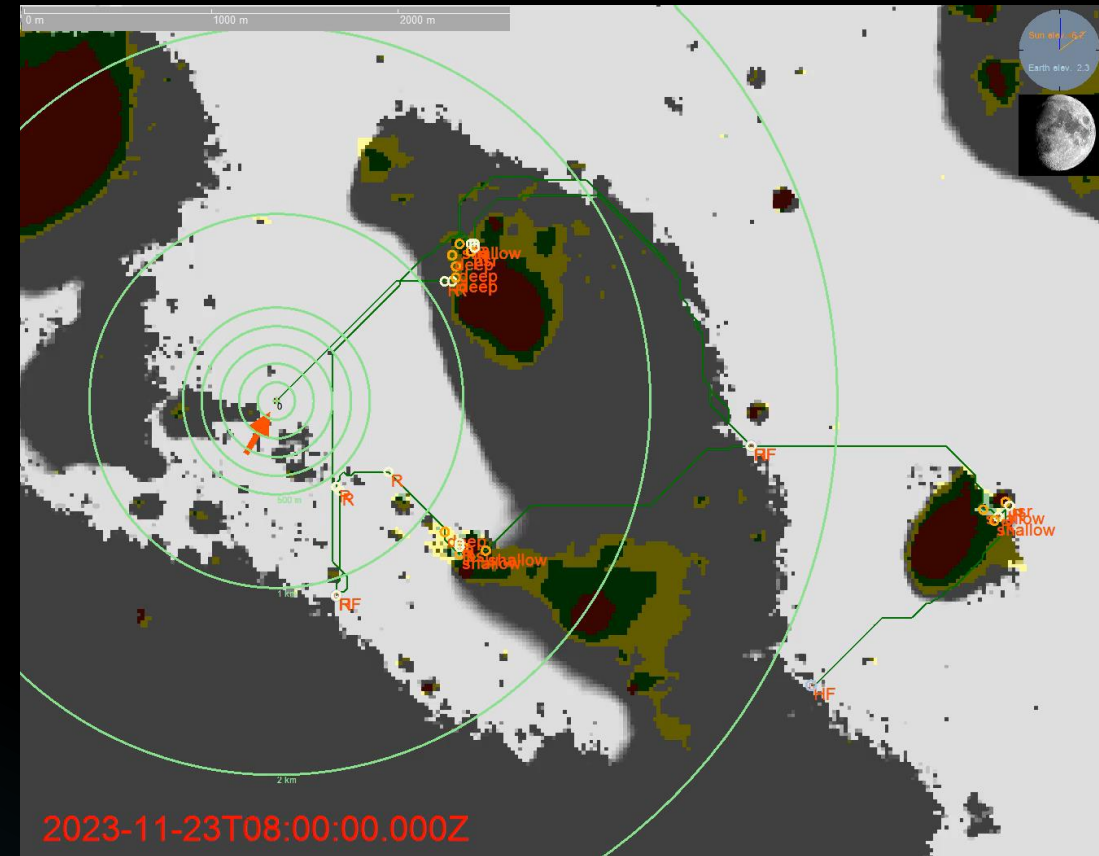
- Provides absolute orientation far better than our orientation requirements
 - Arcsecond measurement accuracy
- "Drop in" orientation solution with dedicated compute resources and software outputting final navigation products
- Perfect for lunar environment which has no atmosphere
- No views of the sun in Lunar polar PSRs (sun is low on the horizon)



VIPER Star Tracker made by Rocket Lab (formerly Sinclair Interplanetary) ST-16RT2, 28V dual RS-485 with short rigid baffle

Thermal Environmental Driving System Design

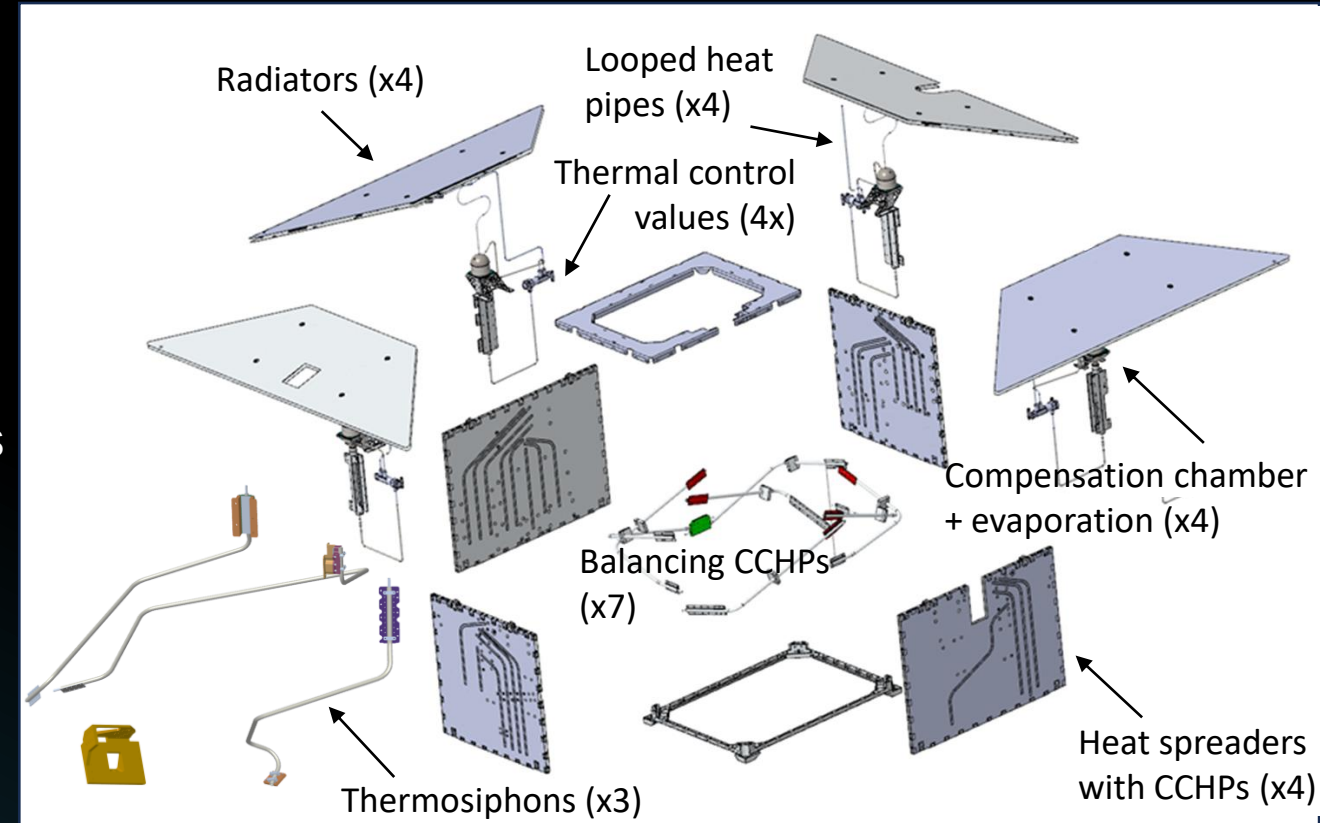
- To satisfy VIPER full mission success science requirements, the rover operate
 - multiple lunar days of operation on the lunar surface and ...
 - Requiring extended shadow survival multiple times
 - in Permanently Shadowed Regions (PSR)
 - in full sunlight
- The extended shadow survival drives much of the VIPER design
 - Reject heat when operating in sunlight
 - Disconnect radiators in cold environments
 - Specialized hibernation circuitry in IAU/PDU
 - Wakeup timers
 - Heater circuits for systems that need heat but can be kept colder than available thermostats



Possible VIPER Traverse at Nobile Site in 2023
Rover location notated by arrow, pauses are

Thermal system overview

- VIPER's Outer Mold Line of VIPER defined by solar arrays, radiators, mast and mobility
- Core of vehicle is the thermal management system
 - Avionics boxes attached to heat spreaders forming warm box
 - Heat rejection through radiators
 - Heat transport
 - warm box->radiator using looped heat pipes
 - instruments->warm box using thermosiphons
 - Thermal control value shuts down radiators at 10C
 - Thermal isolation through multiple levels of multi-layer insulation (MLI) and ULTEM blocks
 - Heaters, thermostats, sensors
- Post system TVAC correlation is underway
 - VIPER ran 57 hours on battery during TVAC
 - Different boundary conditions



Closing Remarks

- VIPER approach
 - Purchase proven components when available
 - Example: same core battery components as Orion
 - Do engineering development when possible
 - Example: IAU/PDU derived from LADEE mission's IAU/PDU
 - Develop technology development only necessary
- Many on the team spent much of their career working tech development
 - Investment in people along with the technologies the people develop