National Aeronautics and Space Administration

VIPER

The first lunar surface resource mapping mission: Overview and Status

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Briefing to the NASA-USGS Workshop on Planetary Resources

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The New Moon….

Not that long ago, we understood the Moon very differently…

We studied from the Earth, from the Moon's surface, and had returned samples to Earth.

General conclusion was:

- Surface was relatively constant
- Essentially no atmosphere
- Bone dry

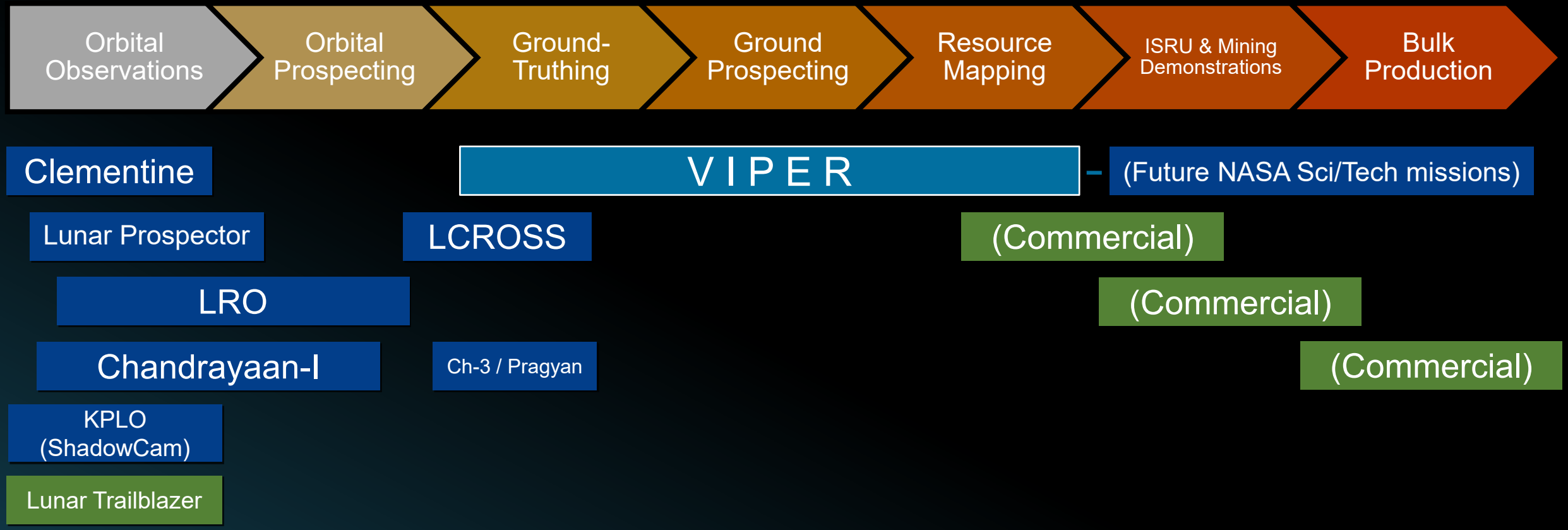
Missions like LCROSS, LRO, LADEE, and others changed all that…

VIPER will help NASA evaluate the potential of In-Situ Resource Utilization (ISRU) from the lunar polar regions

VIPER will characterize the distribution and physical state of lunar water and volatiles at true lunar polar regions (>85deg latitude)

The next great leap in understanding lunar water's potential is to map these volatiles at human scale

The Evolution of Lunar Polar Volatiles Exploration



VIPER <u>bridges</u> government and commercial interests

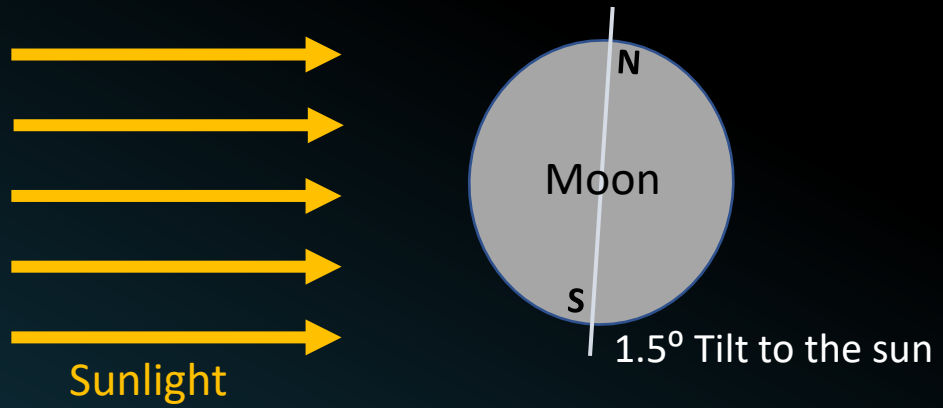
VIPER addresses volatiles science & mapping, in support of sustaining a human presence on the moon

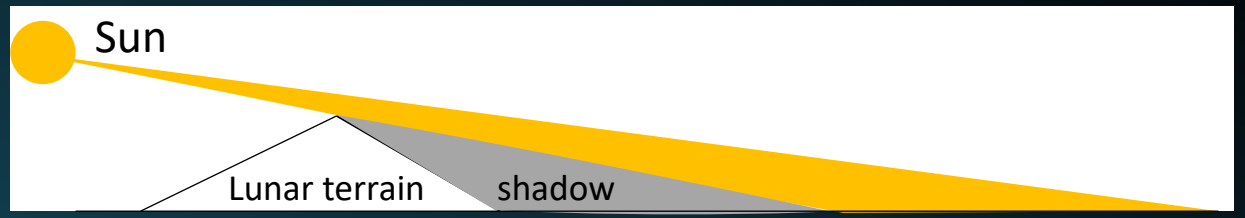
The Moon and those polar region shadows…

At the Lunar poles, the sun casts long shadows

These shadows are both an opportunity and a constraint

Water ice is trapped in the cold, shadowed areas, but a solar-powered rover needs to carefully plan time and power management in these shadowed regions





Highest sun elevation VIPER will see (6°)

The rover's avg speed: 0.6 – 1.0 cm/s

Shadow edges' speed: 0.1 – 1.8 cm/s

VIPER traverse planning is essential !

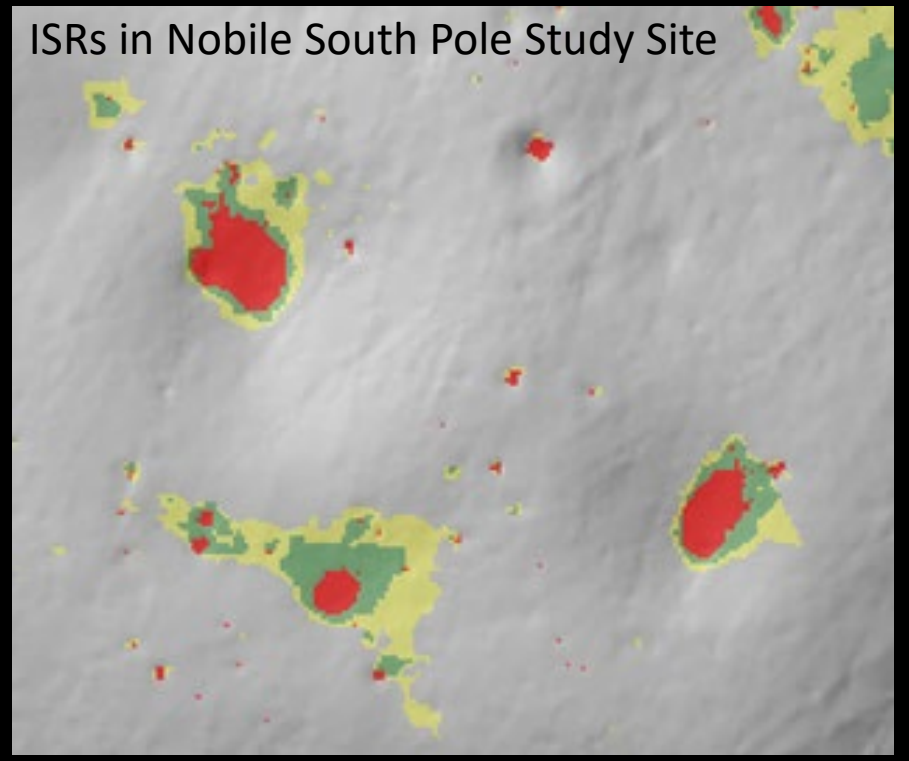
Where will VIPER explore?

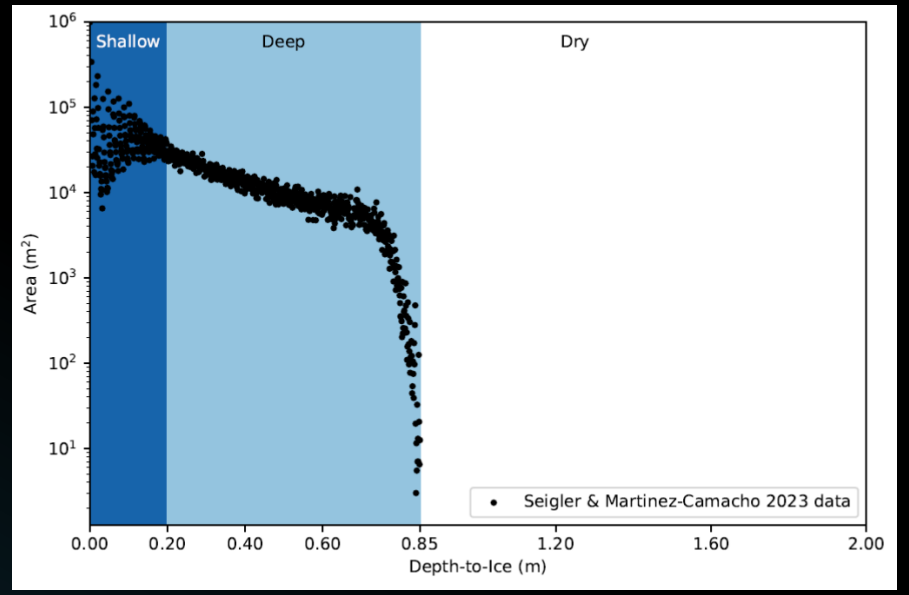
VIPER will explore four polar **"Ice Stability Regions"** (ISRs)*:

- **"Surface"** - Ice potentially stable on the surface (PSRs)
- **"Shallow"** - Ice stable within 20cm from the surface
- **"Deep"** - Ice stable between 20-85cm from the surface
- **"Dry"** - Ice *not likely* stable below 85cm from the surface

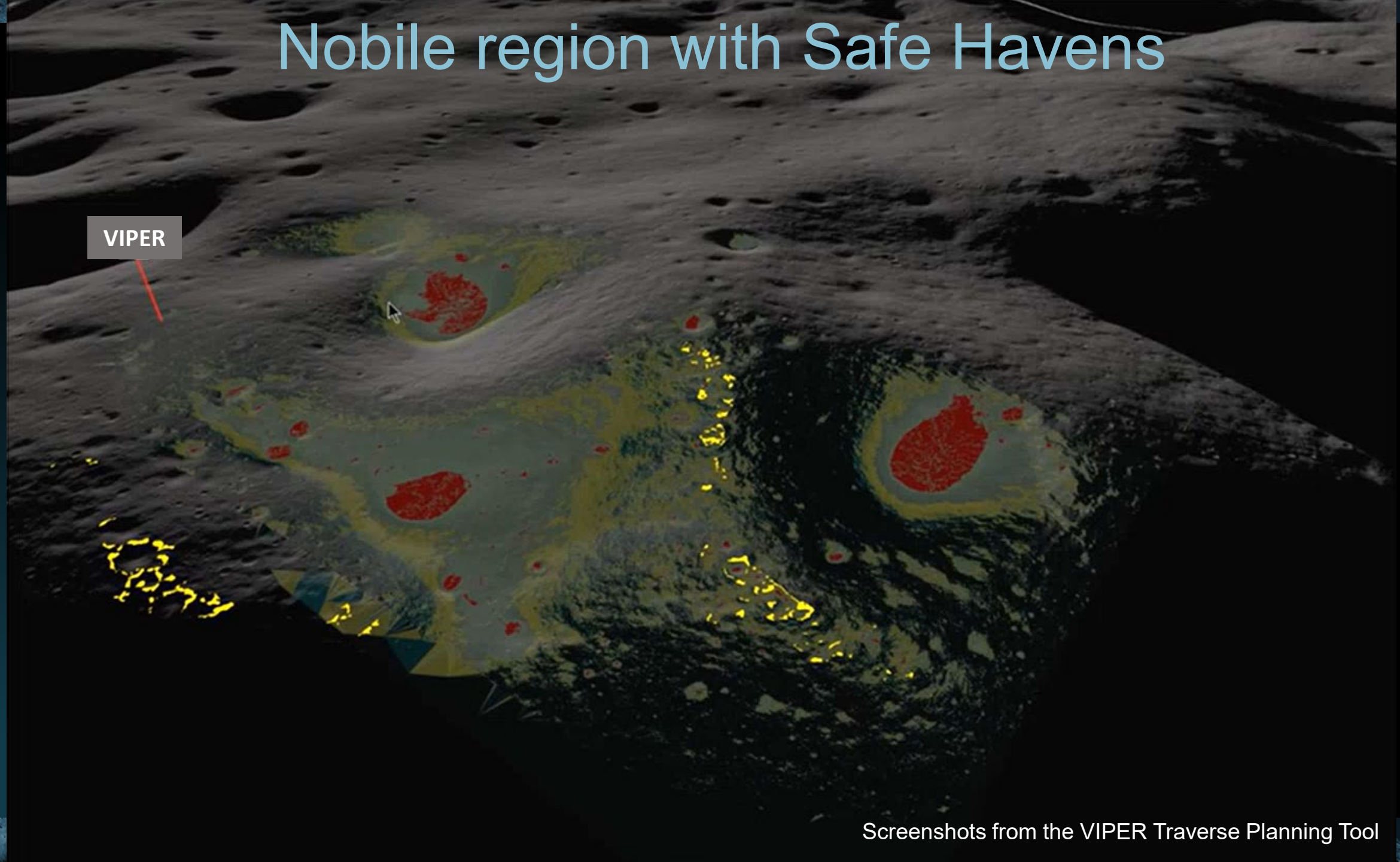
VIPER characterizes thermal environments and geologic settings of Permanently Shadowed Regions (PSRs), Transiently Shadowed Regions (TSRs), Micro cold traps, and peaks of near-eternal light.

** ISR's are based on the predicted thermal stability of ice with depth*



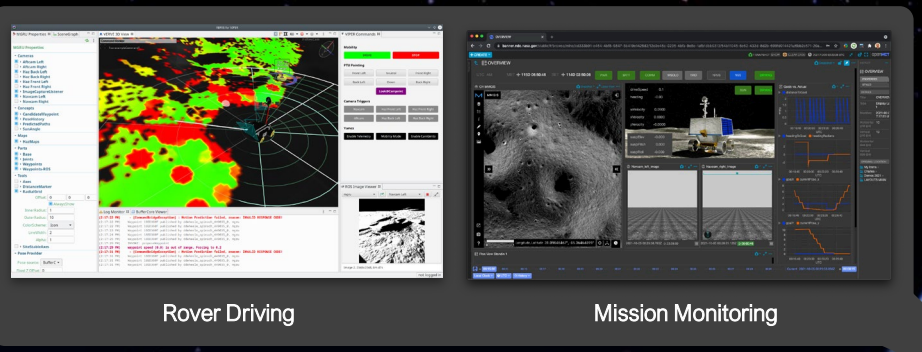


Nobile region with Safe Havens



Screenshots from the VIPER Traverse Planning Tool

VIPER Mission Systems



KSC
MSOLO

JSC
Rover Systems & Thermal

ARC
Systems & Execution

Comms round trip ~6 - 10 sec

Science Station

Astrobotic Lander

Waypoints ~ 5 m

Traverse Points ~ 50 m

Drill A

Drill B

Drill C

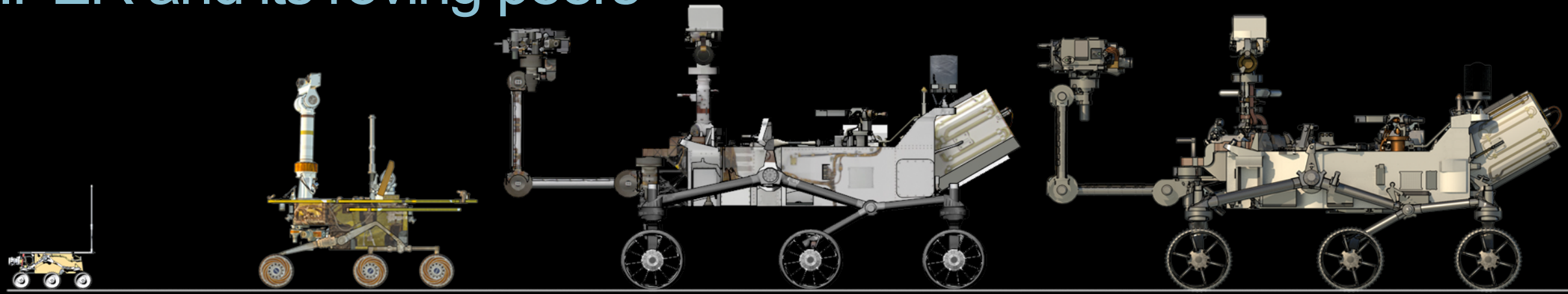
Science Station

Area of Drill Opportunity

Nobile Crater Area, Moon South Pole

Low light angle at poles

VIPER and its roving peers



Sojourner (1996)
0.6m x 0.5m x 0.3m
11kg
Top Speed: 0.5cm/s
Plutonium-238 RHUs

Mars Exploration Rover (2004)
1.6m x 2.3m x 1.5m
180kg
Top Speed: 5cm/s
Plutonium-238 RHUs
"Spirit" & "Opportunity"

Mars Science Laboratory (2011)
3.0m x 2.8m x 2.1m
900kg
Top Speed: 4cm/s
Plutonium-238 MMRTG
"Curiosity"

Mars 2020 Rover (2020)
3.0m x 2.7m x 2.2m
1025kg
Top Speed: 4.2cm/s
Plutonium-238 MMRTG
"Perseverance"

Lunokhod 1 & 2 (1970/1973)
2.3m x 1.6m x 1.5m
840kg
Top Speed: 55cm/s
Polonium-210 heat source

Lunar Roving Vehicle (1971/1972)
3.1m x 1.6m x 1.5m
210kg
Top Speed: 500cm/s
2 silver-zinc 36 volt batteries

1 meter

Yutu (2013/2019)
1.5m x 1.1m x 1.1m
140kg
Top Speed: 5cm/s
Plutonium-238 RHUs

VIPER (2024)
1.5m x 1.5m x 2.0m
430kg
Top Speed: 20cm/s
Electric heaters only

VIPER Surface Segment

Lighting/Imaging Testing at NASA-ARC

Engineering Unit Rover in front of slopes with craters

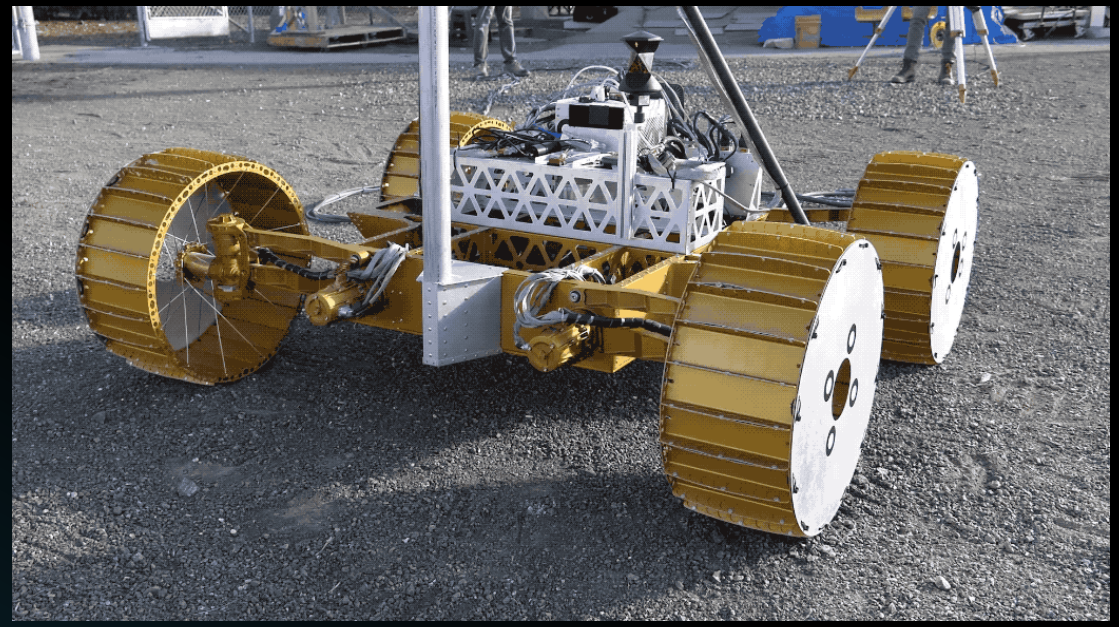
Engineering Unit Rover NavCam view with Sun Simulator from behind

Rock field for hazard map testing with sun simulator on the right

First combined VIPER-Astrobotic lander “rampway” testing

Lander Ramp Egress Testing @ NASA-ARC

VIPER team is exploring alternative gaits



"Sink tank" standard locomotion testing

"Inch-worming" sink tank locomotion testing

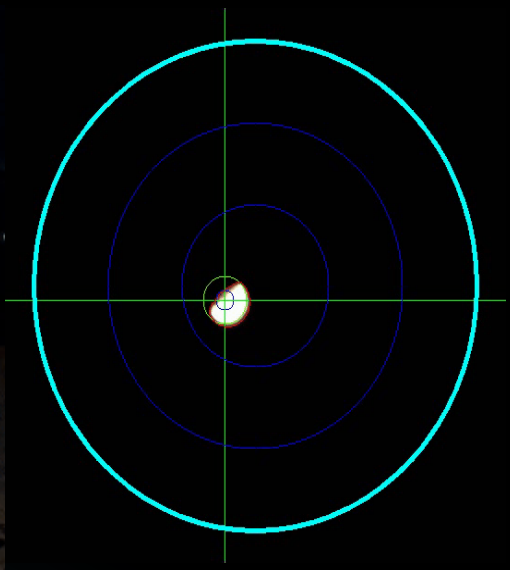
Engineering Unit Rover Climb Entrapment (@30 deg)

Engineering Unit Rover in “Sink Tank”

VIPER Testing Rover Pose Estimation

- Night testing of High Gain Antenna tracking using star tracker and IMU, over various terrains

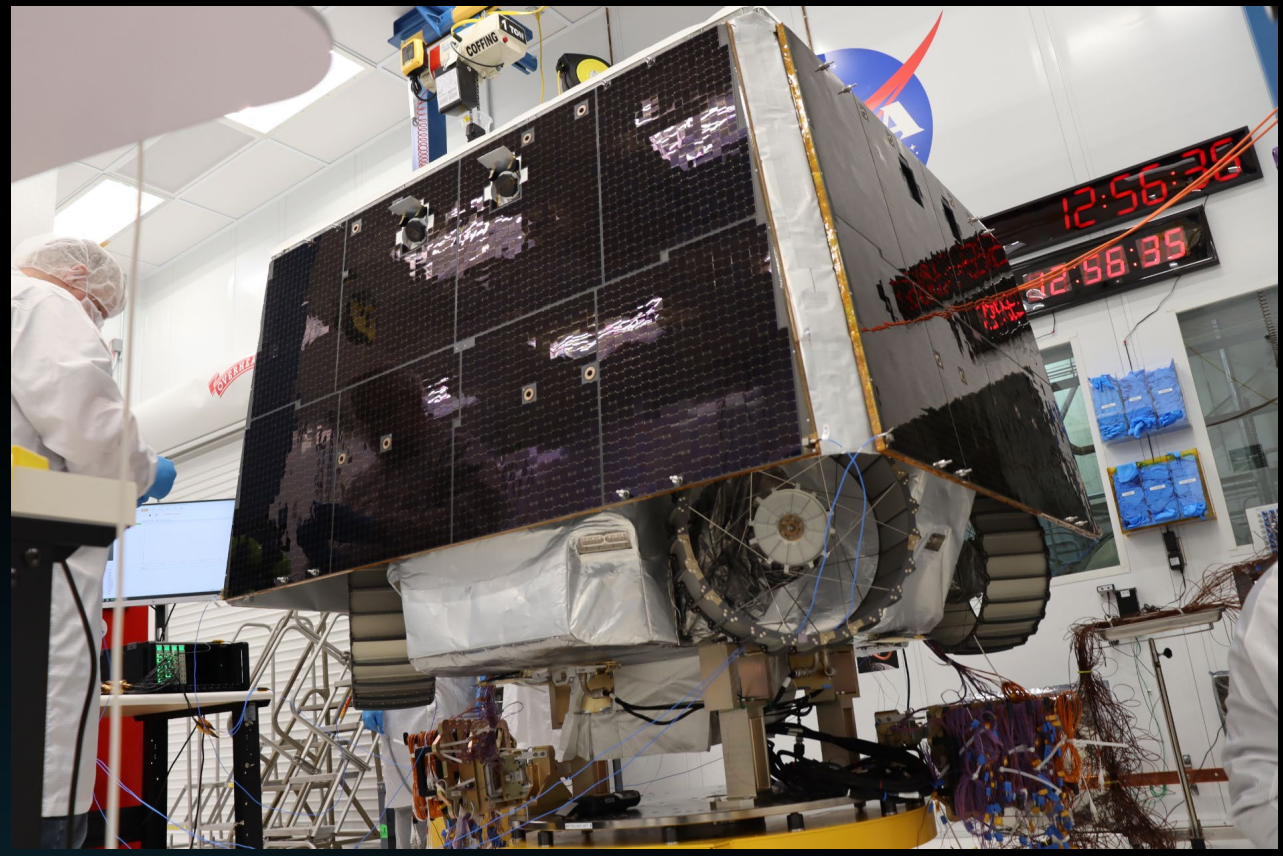
Pointing while roving (video of moon from HGA gimbal)



VIPER Flight Vehicle Build

Wheel installation (yours truly on the wrench)

VIPER is 94% built!

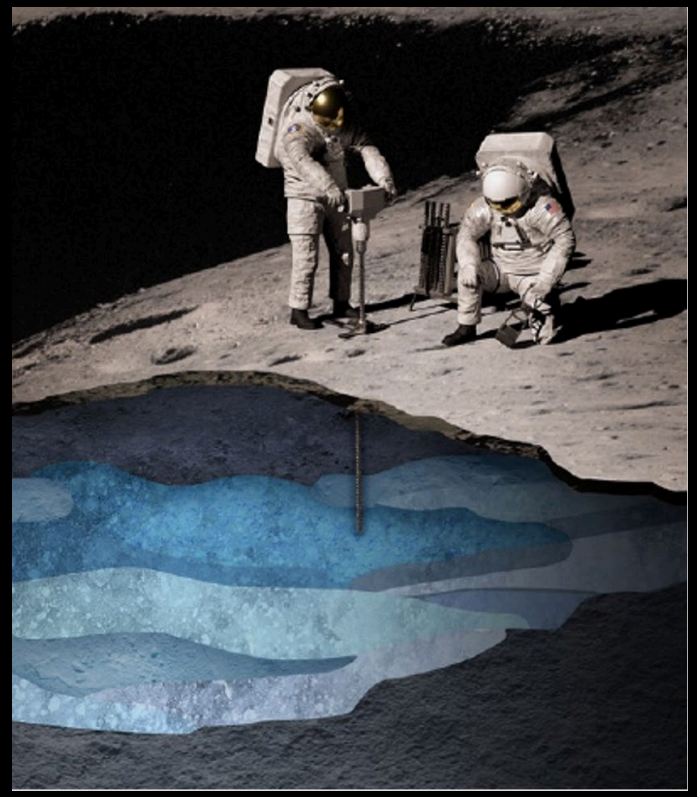


Solar arrays installed…

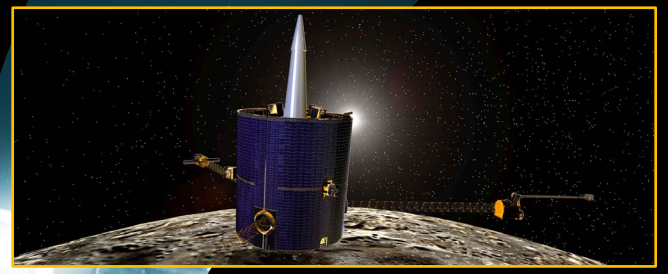
VIPER Operational “sims” ongoing at the NASA-ARC Multi-Mission Operations Center

VIPER Mission Summary & Status

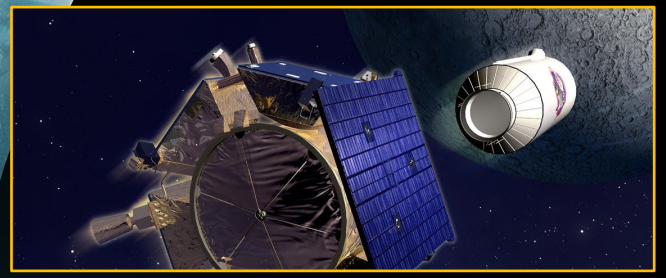
- VIPER is the first off-world resource mapping mission
- VIPER will pioneer real-time robotic mission operations with feed-forward to Artemis human missions
- VIPER provides health & safety data for Artemis astronauts
- VIPER rover is 94% built
  - *Next-up: Environmental test*
- VIPER has been rehearsing operations for months now
- VIPER is scheduled for 2024 lunar delivery (CLPS)
- VIPER has studied alternate gaits in case VIPER gets stuck
- VIPER continues to optimize lunar traverse plans
  - Using AI-infused tools to optimize rover capabilities & constraints



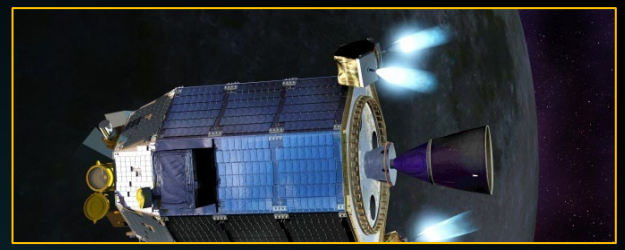
NASA-ARC Lunar Missions



Lunar Prospector (Launched 1998, $38M*)
- First global surface composition
- Polar volatiles & global magnetic maps



LCROSS (Launched 2009, $79M*)
- Impacted lunar south pole
- Evidence for water ice in cold, shadowed regions



LADEE (Launched 2013, $204M*)
- Lunar atmosphere and dust
- First deep space laser communication

Resource Prospector (2014-2019, $86M)
- Mobile resource prospecting Research & Tech project

VIPER (Launching 2024, ~$500M*)
- Robotic rover at lunar pole
- In-situ resource prospecting & mapping

*Not including launch or lander

Other VIPER (team) talks at this Workshop:

Today:

- 08:45-09:15 *Dan Andrews, NASA:* ***VIPER: The first lunar surface resource mapping mission***
- 11:00-11:15 *Tony Colaprete, NASA*: ***Lunar Resource Exploration: Practical Implementation and Mission Design Considerations***
- 11:15-11:45 *Jennifer Heldman & Tony Colaprete, NASA:* ***Lunar Resource Observation Gaps***

Thursday:

Post-workshop tour: ***The Science and Technology Behind the VIPER Mission***

- 08:15-08:30 Assemble @ awning, Building 3 Conference Center for van pick up
- 08:30-09:00 Real-time science operations: N240A MMOC Mission Science Center, **presenter: Dr. Darlene Lim, NASA**
- 09:15-09:45 AI-enabled tactical mission planning N269-137, demo, **Presenter: Ed Balaban, NASA**
- 09:45-10:15 High-resolution lunar terrain mapping; Tour Group A/B N269-179, presentation, **Presenter: Ross Beyer, NASA**
- 10:15-10:45 High-fidelity rover simulator & interactive rover driving N269-137, demo; Tour Group A/B, **Presenter: Mark Allan, NASA**
- 11:00-11:30 Mobility engineering unit and outdoor rover testbed Roverscape, demo, **Presenter: Terry Fong, NASA**

Thank You!