National Aeronautics and
Space Administration

VIPER

# Overview

## Volatiles Investigating Polar Exploration Rover

Daniel Andrews, PM

European Lunar Symposium

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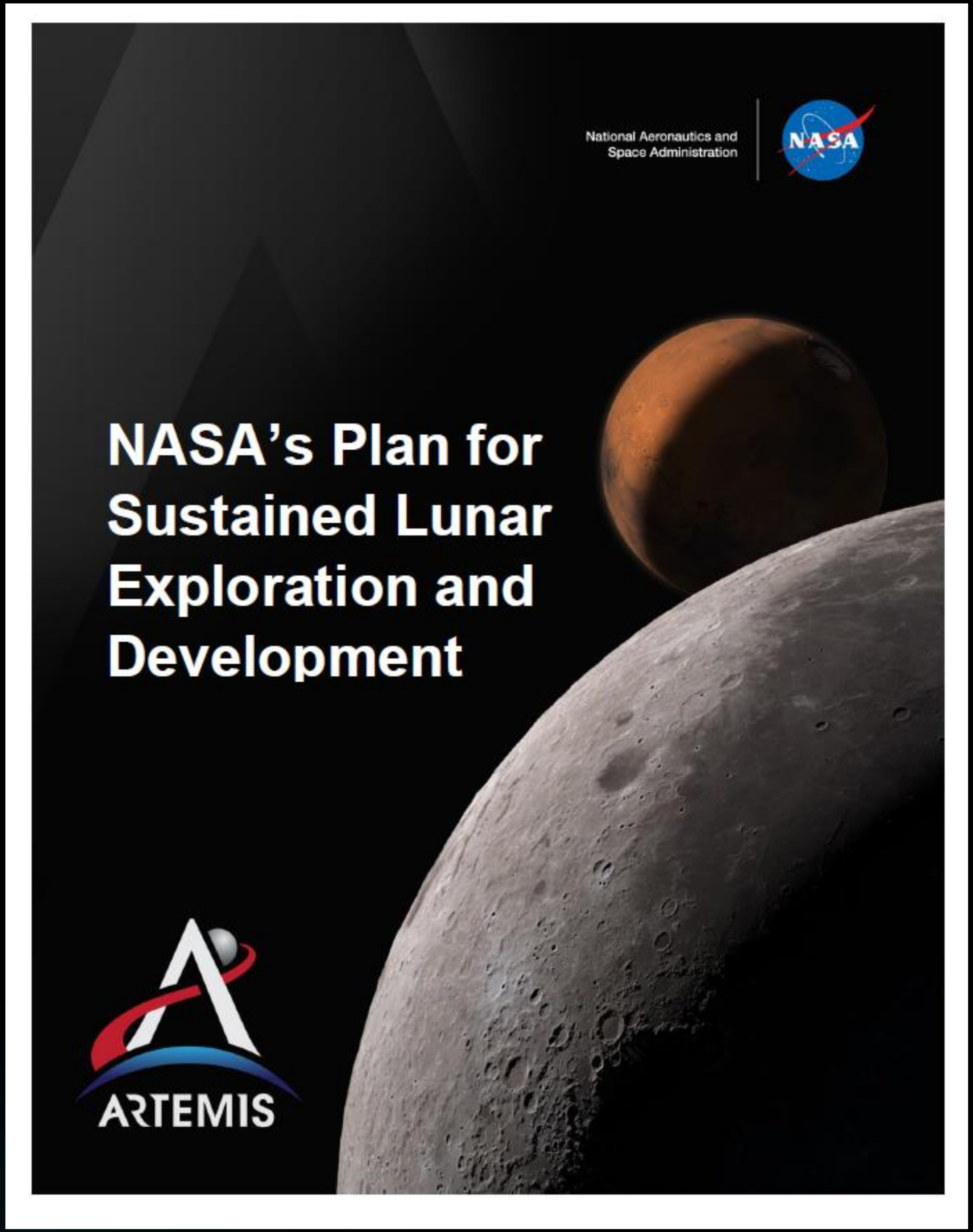
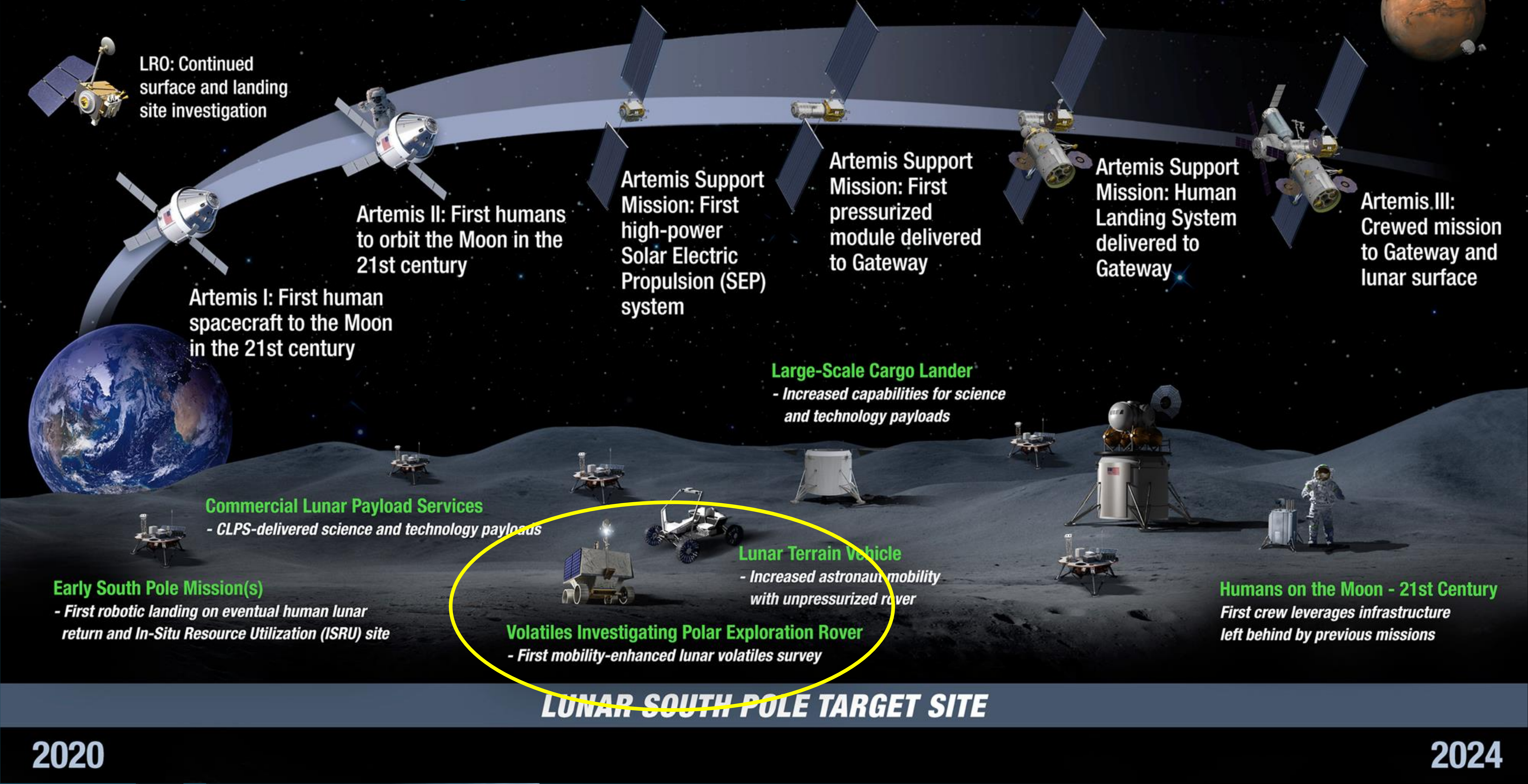
# VIPER & Artemis

Our return to the Moon begins with robots.  NASA's new Commercial Lunar Payload Services (CLPS) initiative will deliver its next robotic lunar rover, the Volatiles Investigating Polar Exploration Rover (VIPER)

VIPER will conduct science investigations of the lunar volatiles at the Moon's South Pole. The data produced by VIPER will inform future in-situ resource utilization (ISRU) technologies.



# Humans Return by 2024



# Why VIPER?

## Direct measurement of polar volatiles

- *LCROSS ground-truthed the water* - VIPER will reveal the lateral / vertical distribution and physical state / composition of the volatiles
- *Q: Are some polar regions better than others (feasibility, economics, safety)?*

## Enables research into In-Situ Lunar Resources

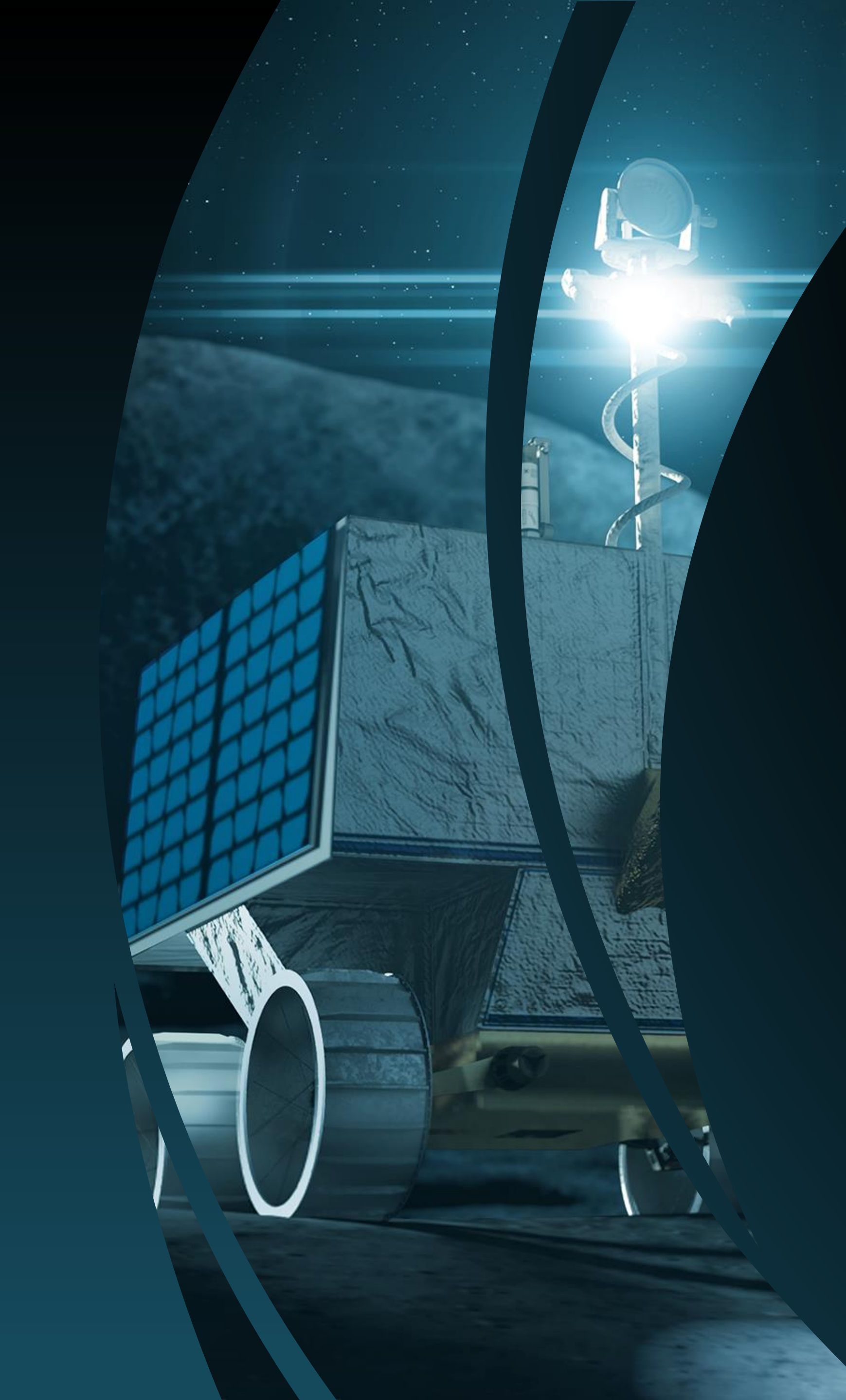
- VIPER will Build Lunar resource maps, steering the future commercial marketplace
- Understand ore grade availability of lunar volatiles for human sustainment and fuel

# Where will VIPER explore?

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

- **Surface:** Ice expected stable at the surface - Permanently Shadowed Regions, (PSRs)
- **Shallow:** Ice expected stable within 50cm of surface
- **Deep:** Ice expected stable between 50-100 cm of the surface
- **Dry:** Ice *not* expected (top meter to be *too warm* to be stable)

**ISRs based on the predicted thermal stability of ice with depth*

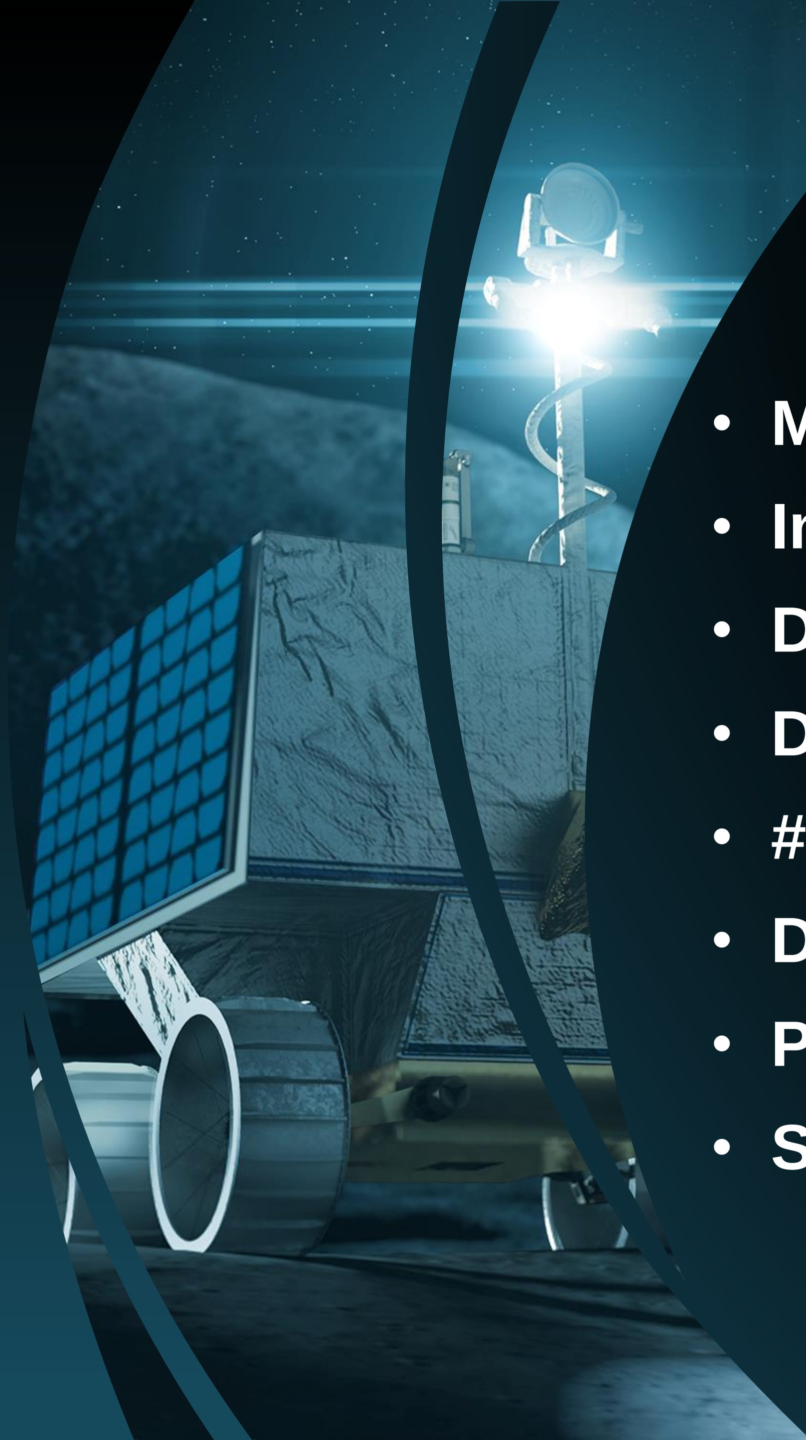


# VIPER Performance Specs

- **Mass:** ~475kg (1050lbs) **Power (peak):** ~450W
- **Comms (DTE[1]):** X-band
  - 256kbps (high-gain) Moon-to-Earth (as high as 4Mbps)
  - 2kbps (omni) Earth-to-Moon
  - Ground: DSN 34m dishes: Canberra, Goldstone, Madrid
- **Dimensions:** 1.5m x 1.5m x 2.5m (5ft x 5ft x 8ft)
- **Top Speed:** 20cm/s (0.5MPH)
- **Expected Cold Environment:** -230degC (-382degF)
- **Prospecting Speed:** 10cm/s (0.25MPH)
- **Distance Travelled (goal):** 20km (~12mi)
- **Lunar delivery:** CLPS[2] commercial contract

[1] DTE = Direct-To-Earth
[2] CLPS = Commercial Lunar Payload Services

# VIPER Science Specs



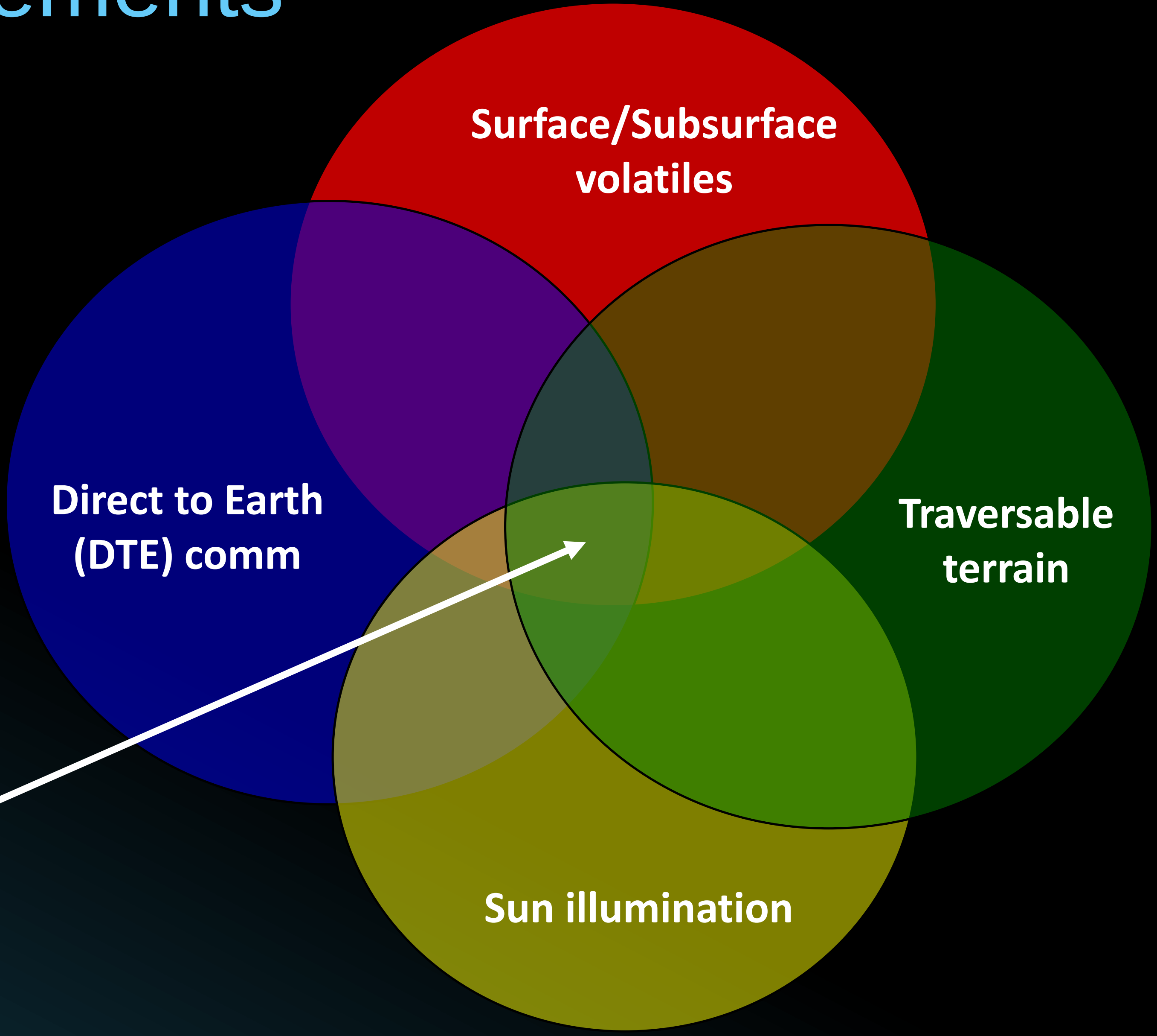
- **Mission Duration:** 100+ earth days
- **Instruments:** Neutron, Near-IR, and Mass Specs; 1m Drill
- **Detectable H2O Concentration:** 0.5% (by weight)
- **Drill Depth:** 1m (~3ft)
- **# of Surface Assays (drill sites):** 18
- **Dark Survivability:** 96hrs (VIPER driving case)
- **PSR Working Duration:** 6hrs (Resource Prospector driving case)
- **Surface Traverse Plan baselined:** @CDR (Q2/FY21)

# Landing Site Requirements

**Good candidate polar landing sites meet these four criteria:**

1. Surface/Subsurface Volatiles
2. Reasonable terrain for traverse
3. Direct view to Earth for communication
4. Sunlight for duration of mission for power

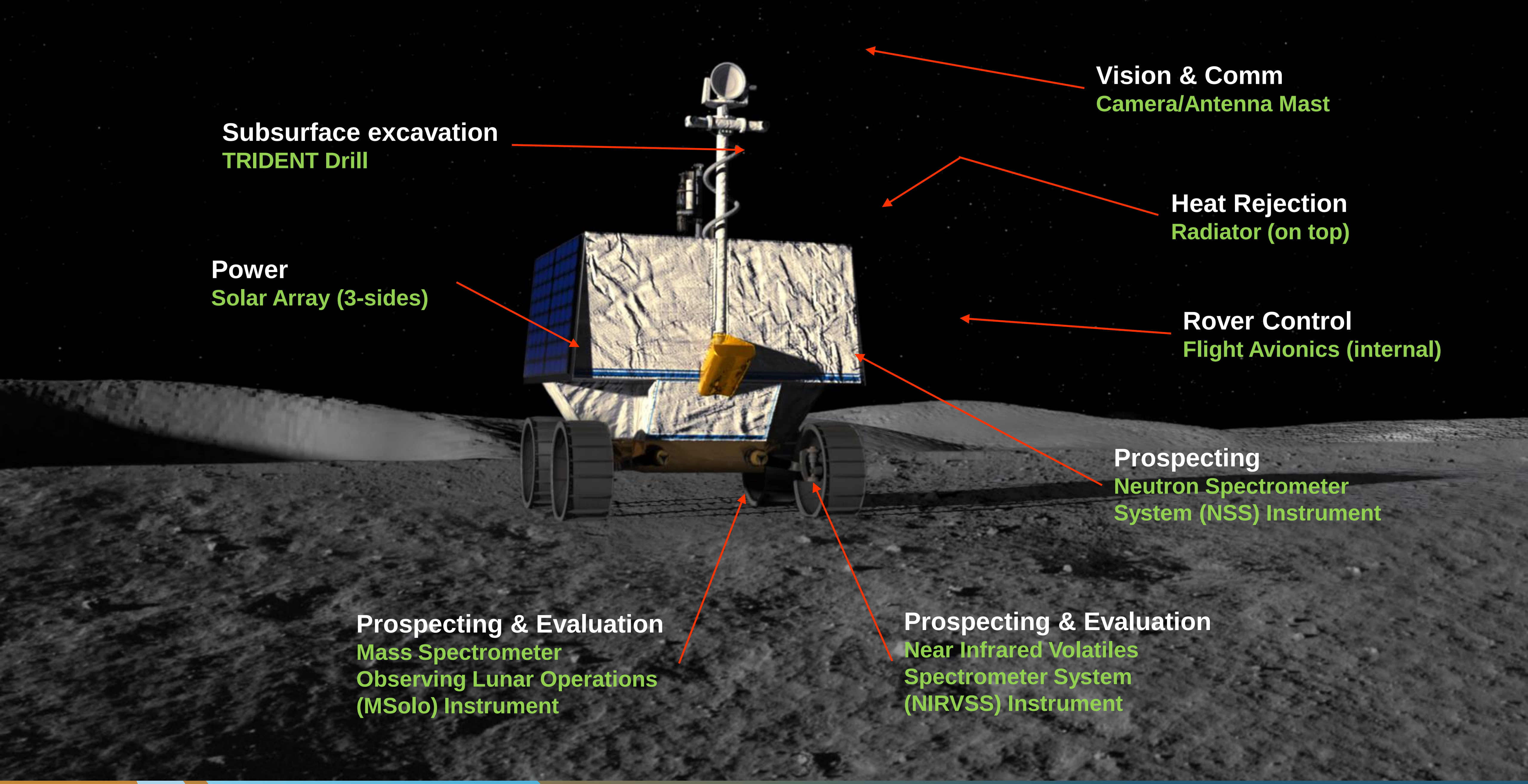
**VIPER needs to find the intersection of these constraints**



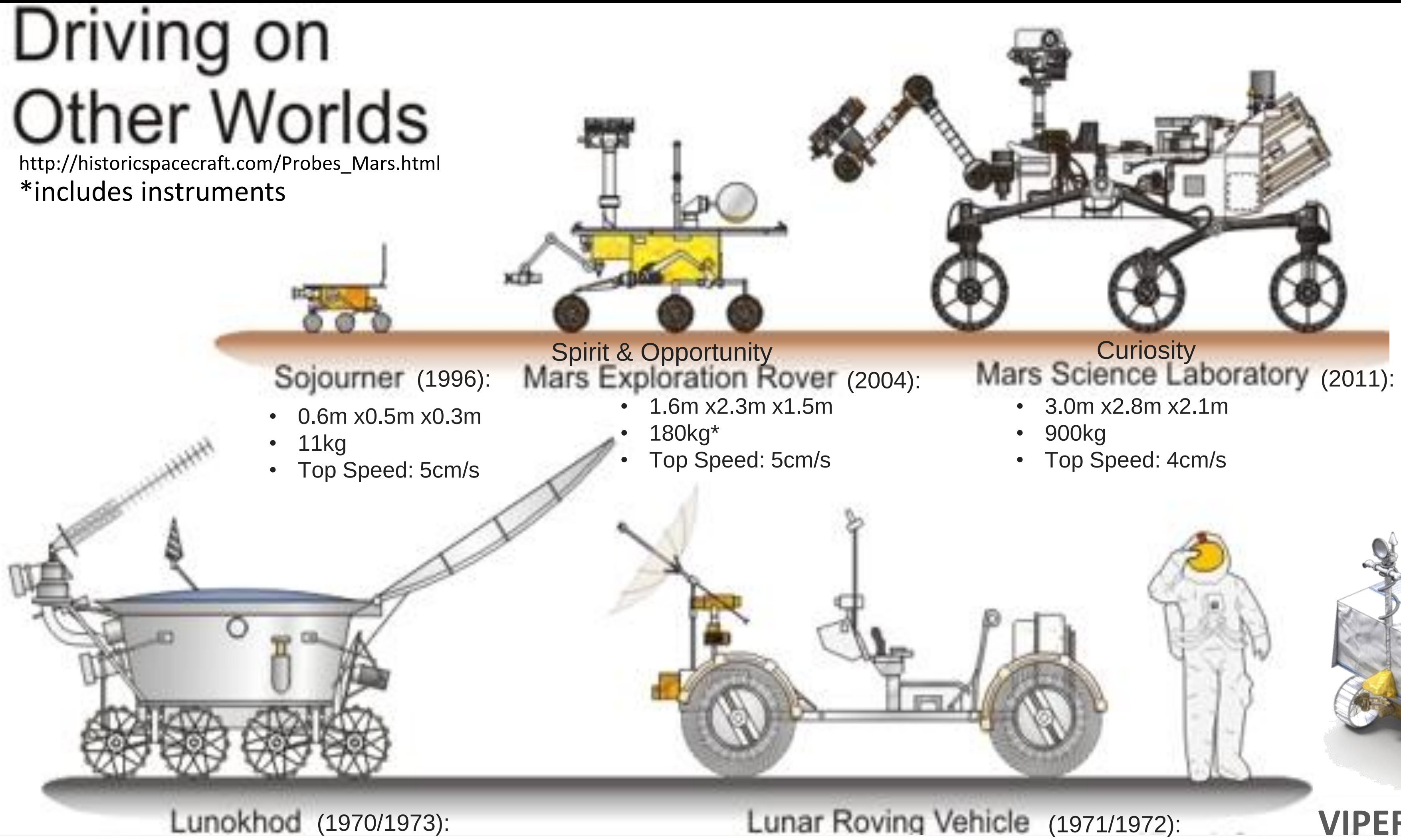
# The VIPER “Surface Segment”

(Roving Instrument Platform)

# VIPER Surface Segment (Rover + Instruments)



# Historical Planetary Rovers & VIPER




http://historicspacecraft.com/Probes_Mars.html

*includes instruments

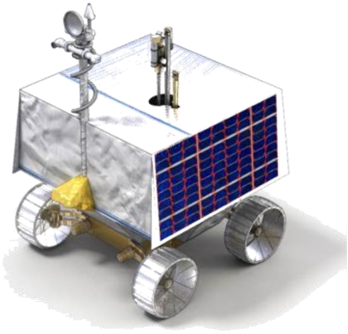
**Sojourner** (1996):
- 0.6m x0.5m x0.3m
- 11kg
- Top Speed: 5cm/s

**Spirit & Opportunity — Mars Exploration Rover** (2004):
- 1.6m x2.3m x1.5m
- 180kg*
- Top Speed: 5cm/s

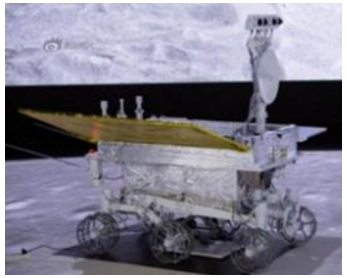
**Curiosity — Mars Science Laboratory** (2011):
- 3.0m x2.8m x2.1m
- 900kg
- Top Speed: 4cm/s

**Lunokhod** (1970/1973):
- 1.3M x1.6m x1.5m, 840kg
- Top Speed: 55cm/s

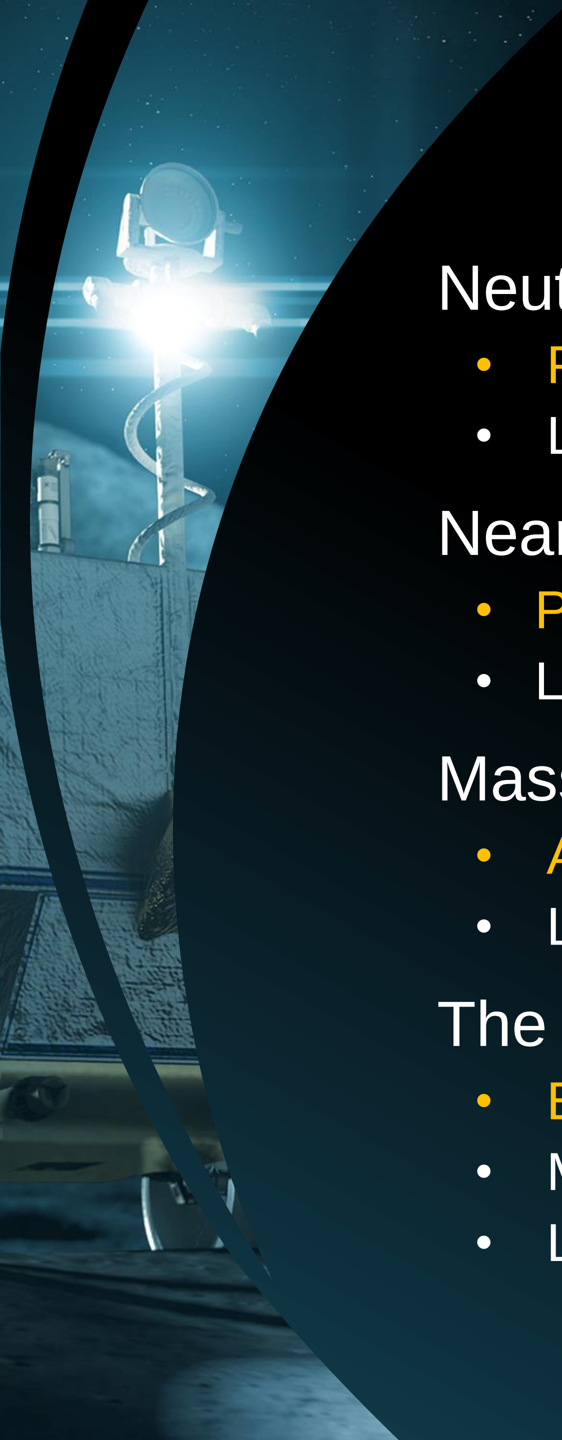
**Lunar Roving Vehicle** (1971/1972):
- 1.3M x1.6m x1.5m, 840kg
- Top Speed: 500cm/s



**VIPER** (2022):
- 1.5m x1.5m x2.0m, 300kg
- Top Speed: 20cm/s



**Yutu** (2013):
- 1.5m x1.1m, 140kg
- 5cm/s



# VIPER Science Manifest

## Neutron Spectrometer System (NSS) NASA-ARC

- Prospects for hydrogen-rich materials while roving, mapping the distributions
- Located on the front of the rover to have an unobstructed view of the lunar surface

## Near InfraRed Volatiles Spectrometer System (NIRVSS) NASA-ARC

- Prospects for surface water and oxide "frosts", as well as mineralogical context
- Located under the rover studying water/volatiles abundance while roving & drilling

## Mass Spectrometer observing lunar operations (MSolo) NASA-KSC

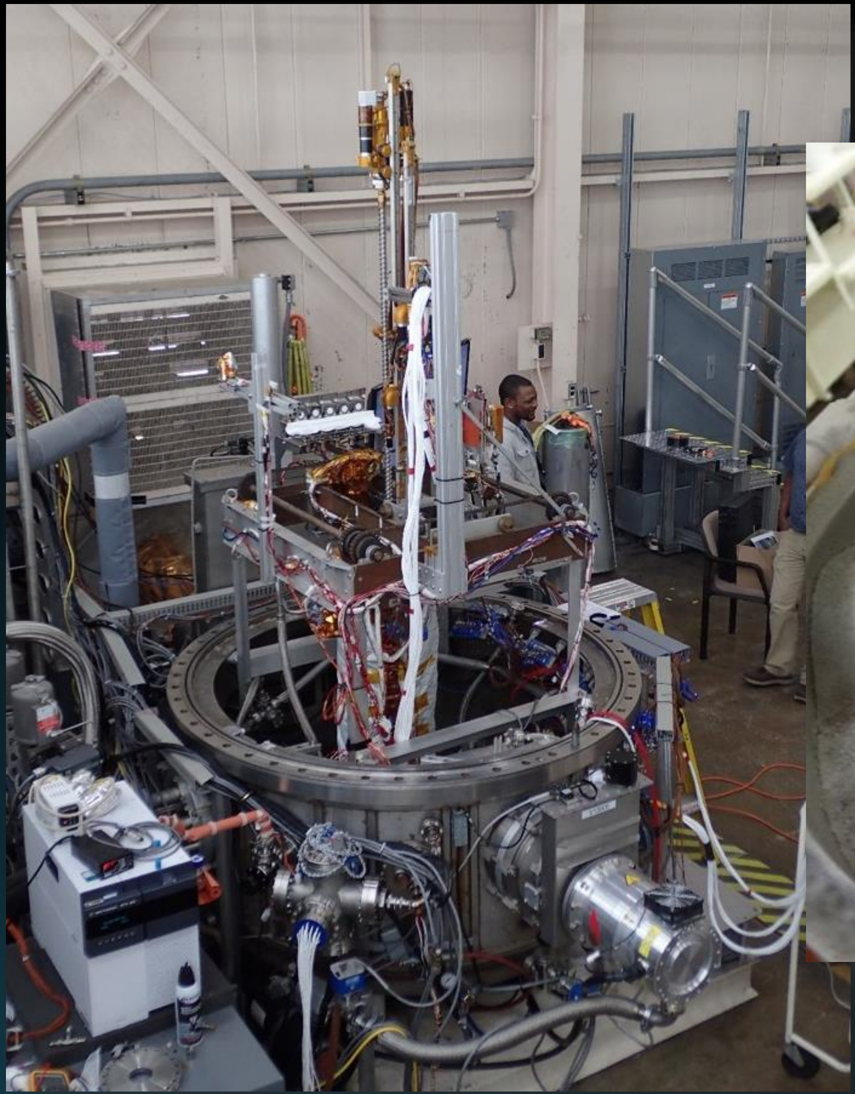
- Analyzes volatiles excavated through rover traversing and drilling
- Located under the rover studying water/volatiles abundance while roving & drilling

## The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) HBR[1]

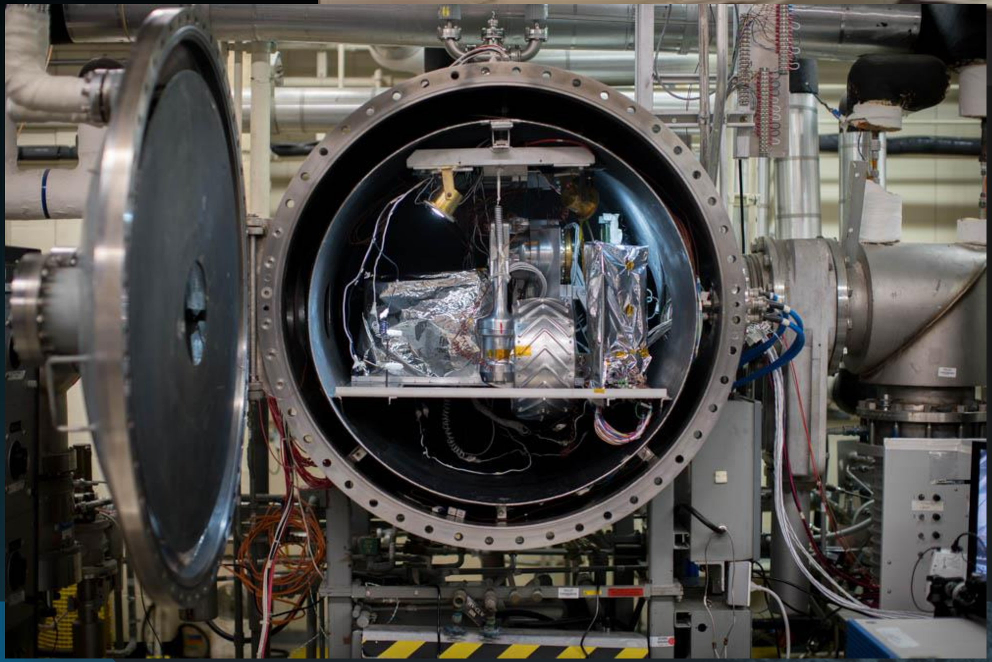
- Excavates lunar regolith to a depth of 1-meter, in 10cm increments
- Measures forces, displacements and temperatures for regolith bulk properties
- Located under the center of the rover to minimize volatiles solar sublimation

[1] HBR = HoneyBee Robotics

# VIPER Environmental Test

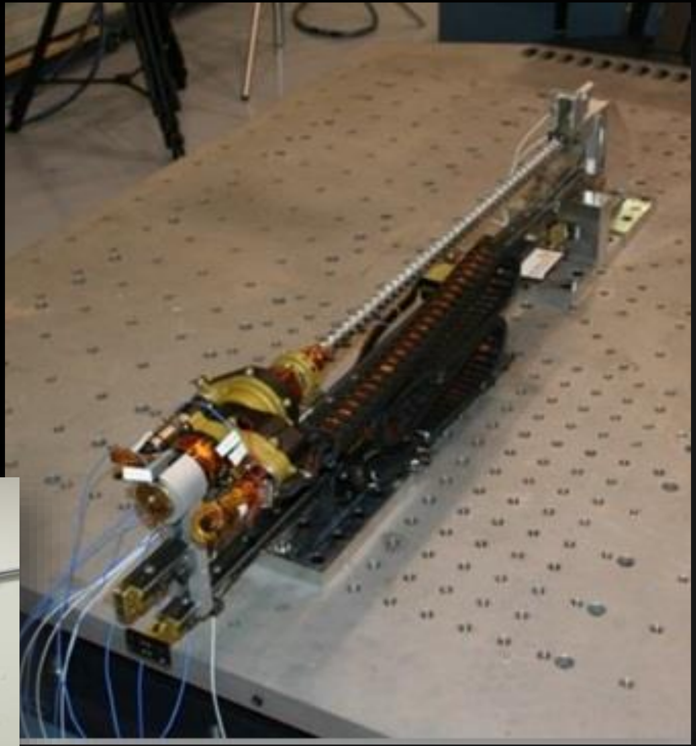


- Drill testing at NASA-GRC’s VF-13 TVAC chamber
- Studying volatiles loss while drilling a meter deep into lunar soil
- Using engineered lunar-like soil conditions, doped with 5% water and chilled to -100C



TVAC chamber testing of VIPER rover wheels & steering assemblies @ NASA-JSC

TVAC chamber Z-axis testing of VIPER rover



Drill undergoing Vibration testing

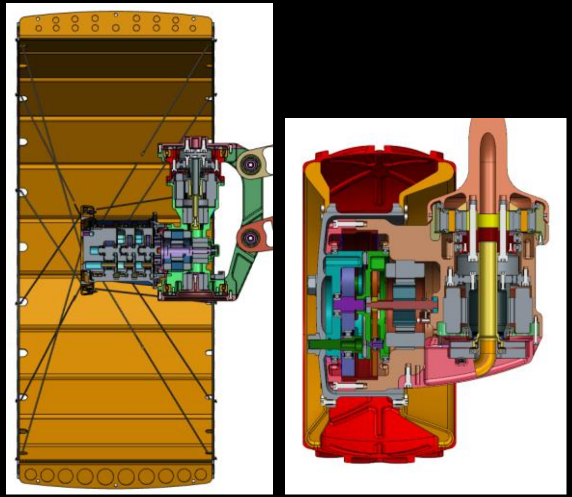
TVAC chamber Z-axis testing of VIPER rover

Studying impacts of the poor lighting and long shadows in polar regions

Field testing in the dark
- NASA-ARC Roverscape

15º upslope with 45º cross slope

Crab-walking tests with the new 1A wheel. Studying traction performance while avoiding overlapping wheel tracks.



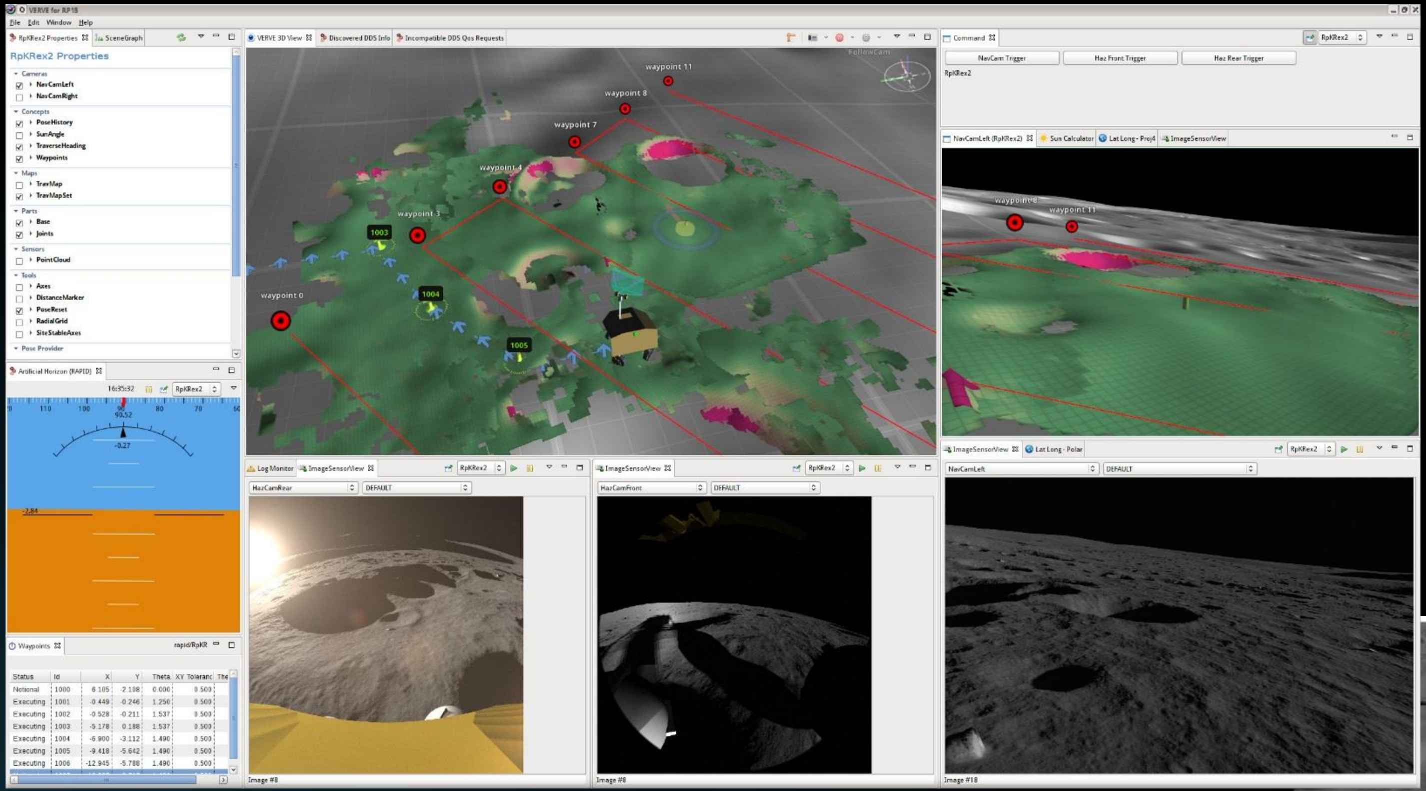
20º upslope

Rover undergoing soil environments testing

NASA-GRC Simulated Lunar Operations Lab (SLOPE)

Rover regolith simulant testing: NASA-KSC Regolith Lab

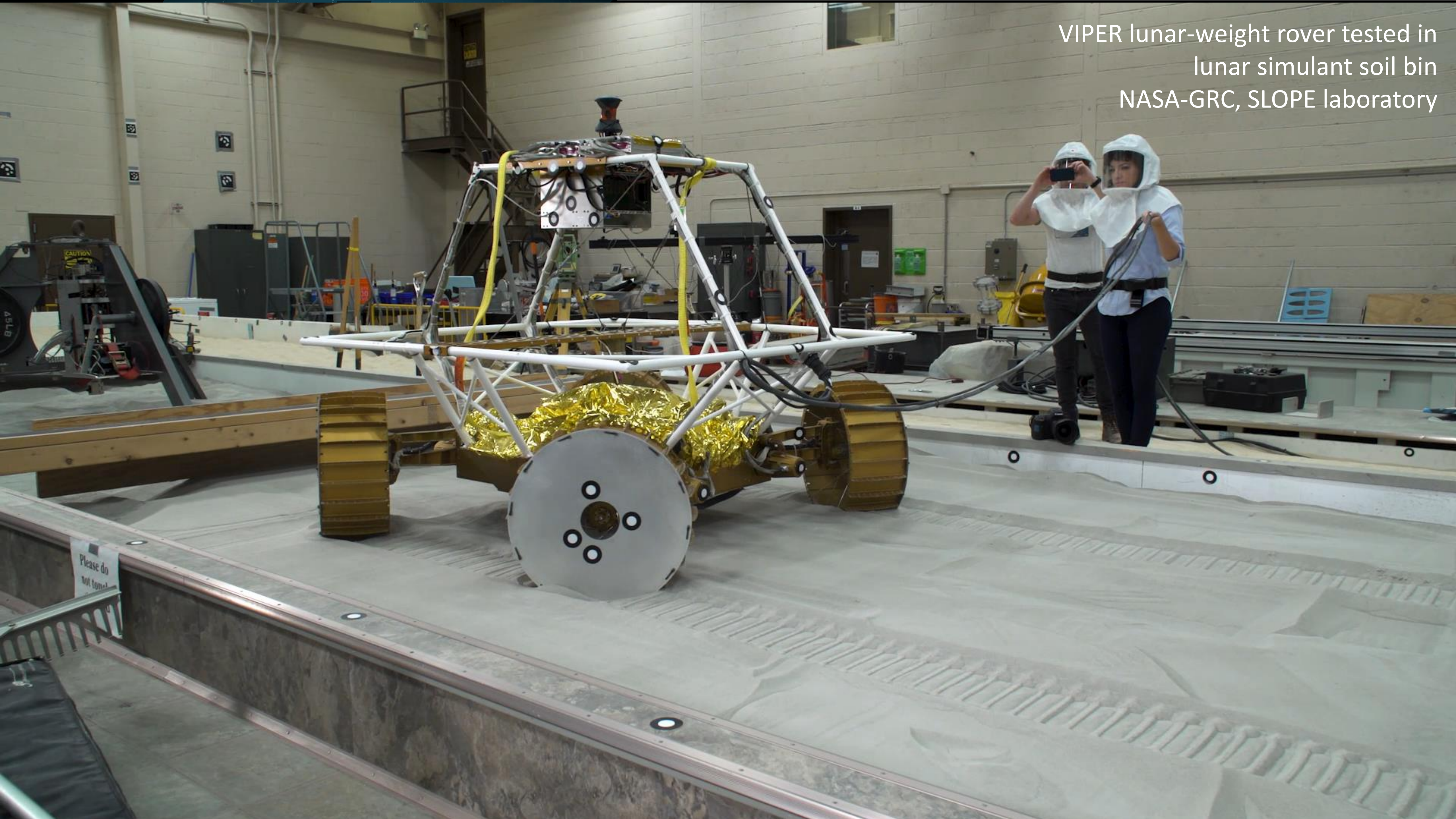

Rover auto-leveling testing
NASA-JSC, B9 Highbay




Powerful, fully-synthetic, lunar terrain sim based on Digital Elevation Maps (DEM)

– Establishing driver decision-making times

Rover Driving Simulator Capability
NASA-ARC Lunar Operations Lab



VIPER lunar-weight rover tested in
lunar simulant soil bin
NASA-GRC, SLOPE laboratory


"Swimming"…
x64

# Questions?

# VIPER Neutron Spectrometer System (NSS)

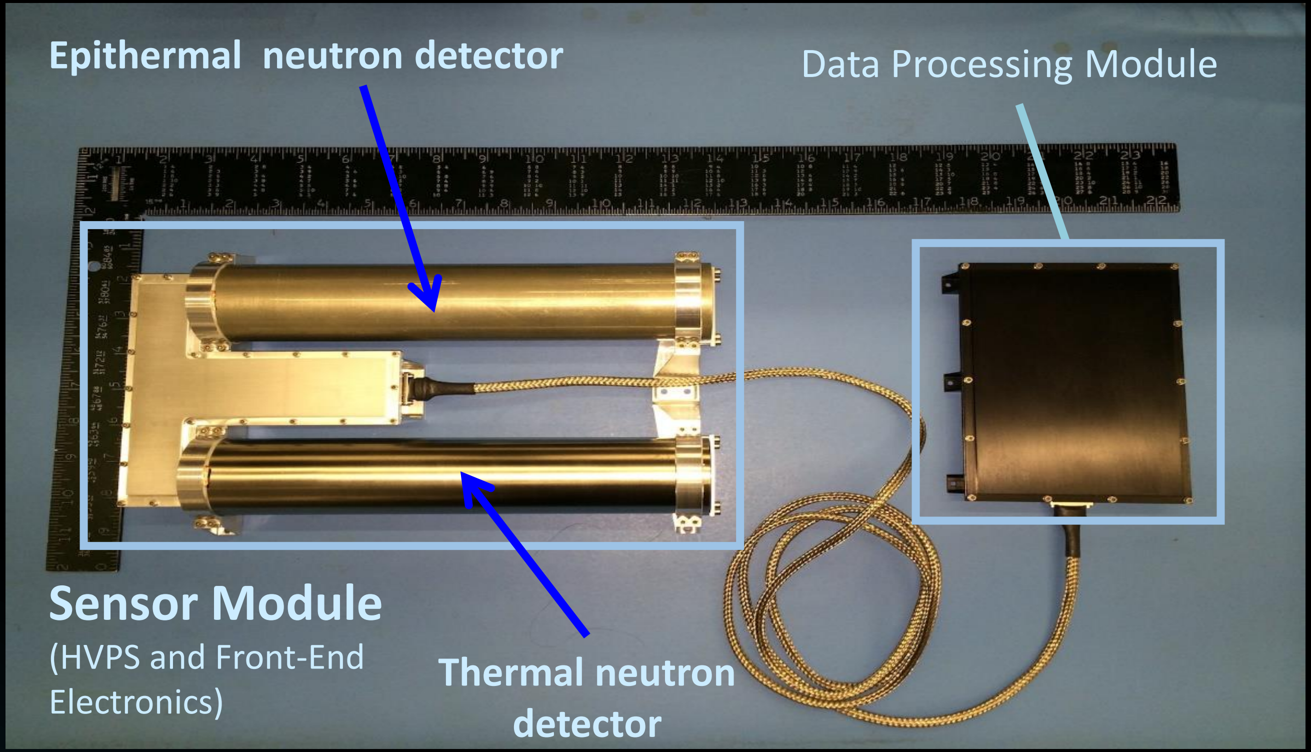
**NSS (NASA ARC, Lockheed Martin ATC)**
PI: Rick Elphic (NASA ARC)

**Instrument Type:** Two channel neutron spectrometer

**Key Measurements:** NSS assesses hydrogen and bulk composition in the top meter of regolith, measuring down to 0.5% (wt) WEH to 3-sigma while roving

**Operation:** On continuously while roving

| Instrument Name | NSS |
| --- | --- |
| Mass [kg], CBE | 1.9* |
| Dimensions [cm] | Sensor Module:<br>21.3 x 32.1 x 6.8<br>Data Processing Module:<br>13.9 x 18.0 x 3.0 |
| Power [W] | 1.6 |
| Sensitivity | WEH to ≥0.5 wt% water-equivalent at 10 cm/s |
| Accuracy | 5 – 10% absolute |



# VIPER Near InfraRed Volatiles Spectrometer System (NIRVSS)

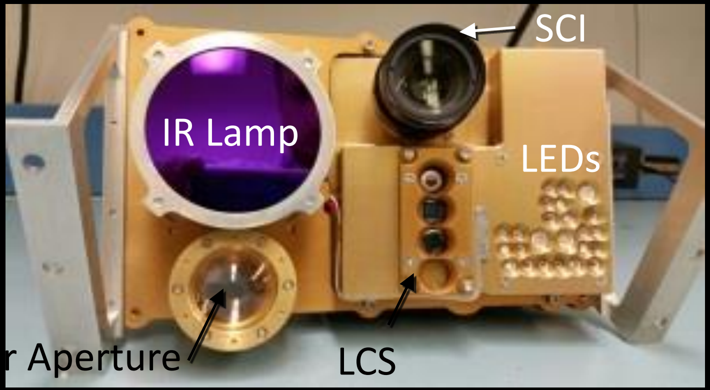
**NIRVSS (ARC, Brimrose Corporation)**
PI: Anthony Colaprete (NASA ARC)

**Instrument Type:** NIR Point Spectrometer, 4Mpxl Panchromatic Imager with 7 LEDs, four channel thermal radiometer
**Key Measurements:** Volatiles including $H_2O$, OH, and $CO_2$ and, minerology, surface morphology and temperatures
**Operation:** On continuously while roving and during drill operations
**Primary Measurements:**

- *AOTF NIR Point Spectrometer:* 1300-4000nm
- *Spectrometer Context Imager (SCI):* 4Mpxl imager with seven LEDs between 340-940nm
- *Longwave Calibration Sensor (LCS):* IR flux and surface temperature down to <100K to ± 5K
- *Lamp*: Dual filament tungsten lamp provides even, calibrated light source when in shadow

Spectrometer

Bracket Assembly



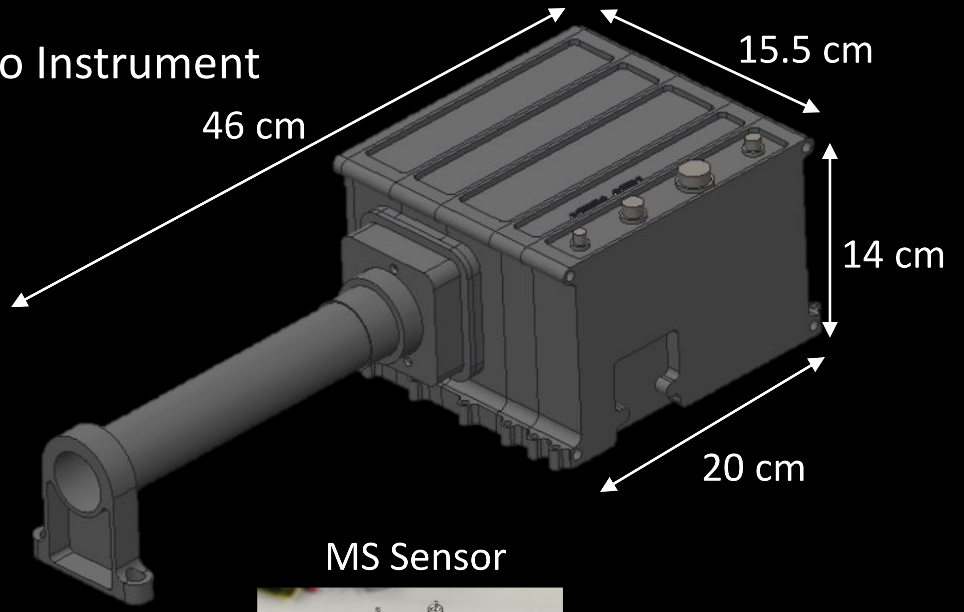

| Instrument Name | NIRVSS |
|---|---|
| Mass [kg] | 3.57 kg (not including Fiber) |
| Dimensions [cm] | Spectrometer Module: 18x18x8.5<br>Observation Bracket: 20.4x13x15.1 |
| Power [W], Avg | Spectrometer = 12<br>Bracket Assembly = 5.26<br>Lamp = 12.3 |
| Sensitivity | Range: 1.2 to 4.0 mm<br>SNR>100 at 2 and 3 mm<br>Water Ice to <0.25% |
| Accuracy | Radiance to <25% |

# VIPER Mass Spectrometer Observing Lunar Operations (MSolo)

**MSolo (KSC, INFICON)**
PI: Janine Captain (NASA KSC)

**Instrument Type:** Quadrupole mass spectrometer
**Key Measurements:** Identify low-molecular weight volatiles between 2-100 amu, unit mass resolution to measure isotopes including D/H and $0^{18}/0^{16}$
**Operation:** Views below rover and at drill cuttings, volatile analysis while roving and during drill activities

MSolo Instrument




MS Sensor

| Instrument Name | MSolo |
|---|---|
| Mass, CBE | 6 kg |
| Dimensions | 15.5 x 20 x 46 cm |
| Power | Average 35 W while scanning |
| Detectors | Faraday Cup (MDPP* 1.5e-12 Torr) |
| | Electron Multiplier (MDPP* 2e-15 Torr) |

*MDPP – minimum detectable partial pressure @ m/z 28 with open ion source

# VIPER The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) Drill

**TRIDENT (Honeybee Robotics)**
PI: Kris Zacny (Honeybee)

**Instrument Type:** 1-meter hammer drill
**Key Measurements:** Excavation of subsurface material to 100 cm; Subsurface temperature vs depth; Strength of regolith vs depth (info on ice-cemented ground vs. ice-soil mixture).
**Operation:** Performs subsurface assays down to 100 cm in <1 hr, depositing cuttings at surface for inspection

| Instrument Name | TRIDENT |
|---|---|
| Mass [kg], CBE | 18 (includes launch locks). Can be reduced for lander deployment. |
| Dimensions (stowed) [cm] | 27 x 22 x 177 (for 1-m depth). Can be reduced for lander deployment. |
| Power [W] | Idle: < 5<br>Augering: ~20 nominal, 175 max<br>Percussion: 0 nominal, 150 max |
| Telemetry (while operating) | ~3.4 kbits/s |

TRL6 Drill

Lunar cryo-chamber tests at GRC