

To The Moon: How we got there 50 years ago, how we'll go back

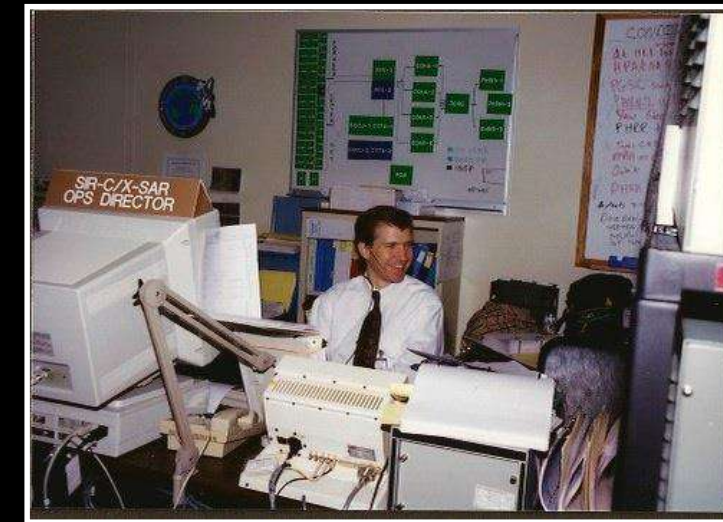
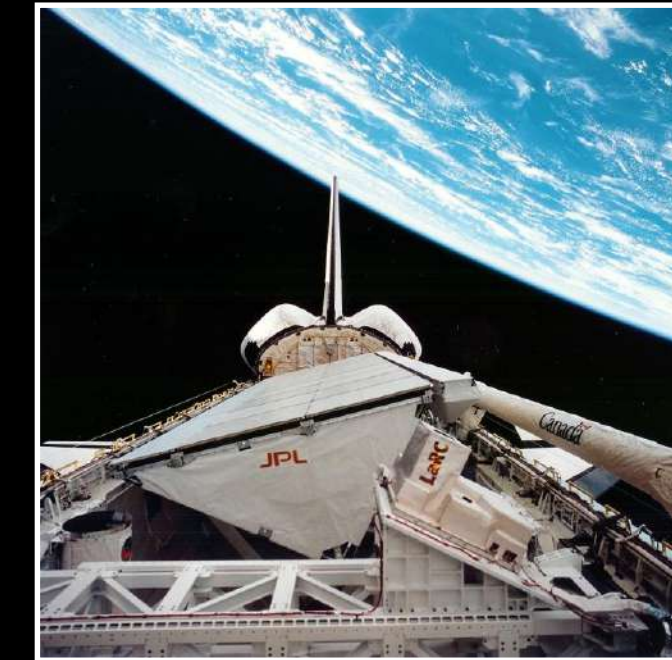
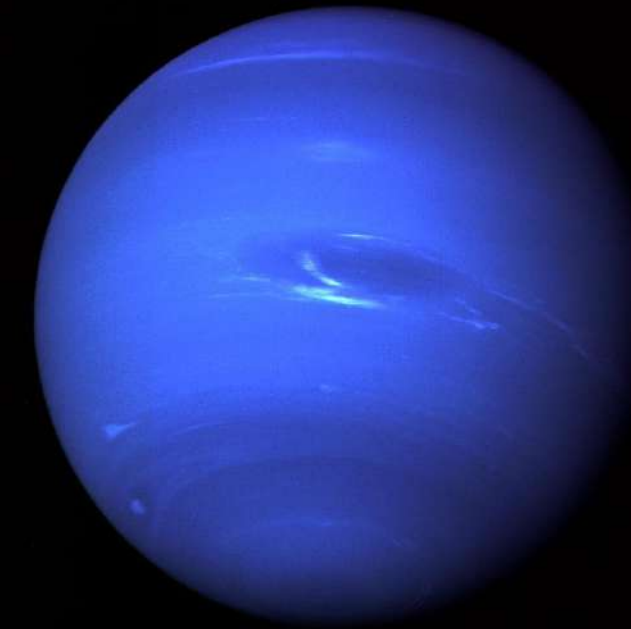
Jay Trimble/NASA Ames Research Center Silicon Valley California

March 13, 2023





Personal Career Highlights



1960's

1981

Space Shuttle Operations

NASA Johnson Space Center

1989

Science Ops
Voyager Neptune

NASA Jet Propulsion Laboratory

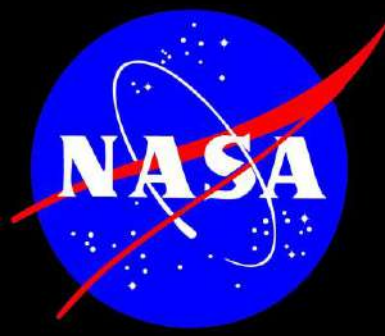
1994

Lead Ops Director
Space Radar Lab 1

NASA Ames Research Center

Now

VIPER Mission
Manager

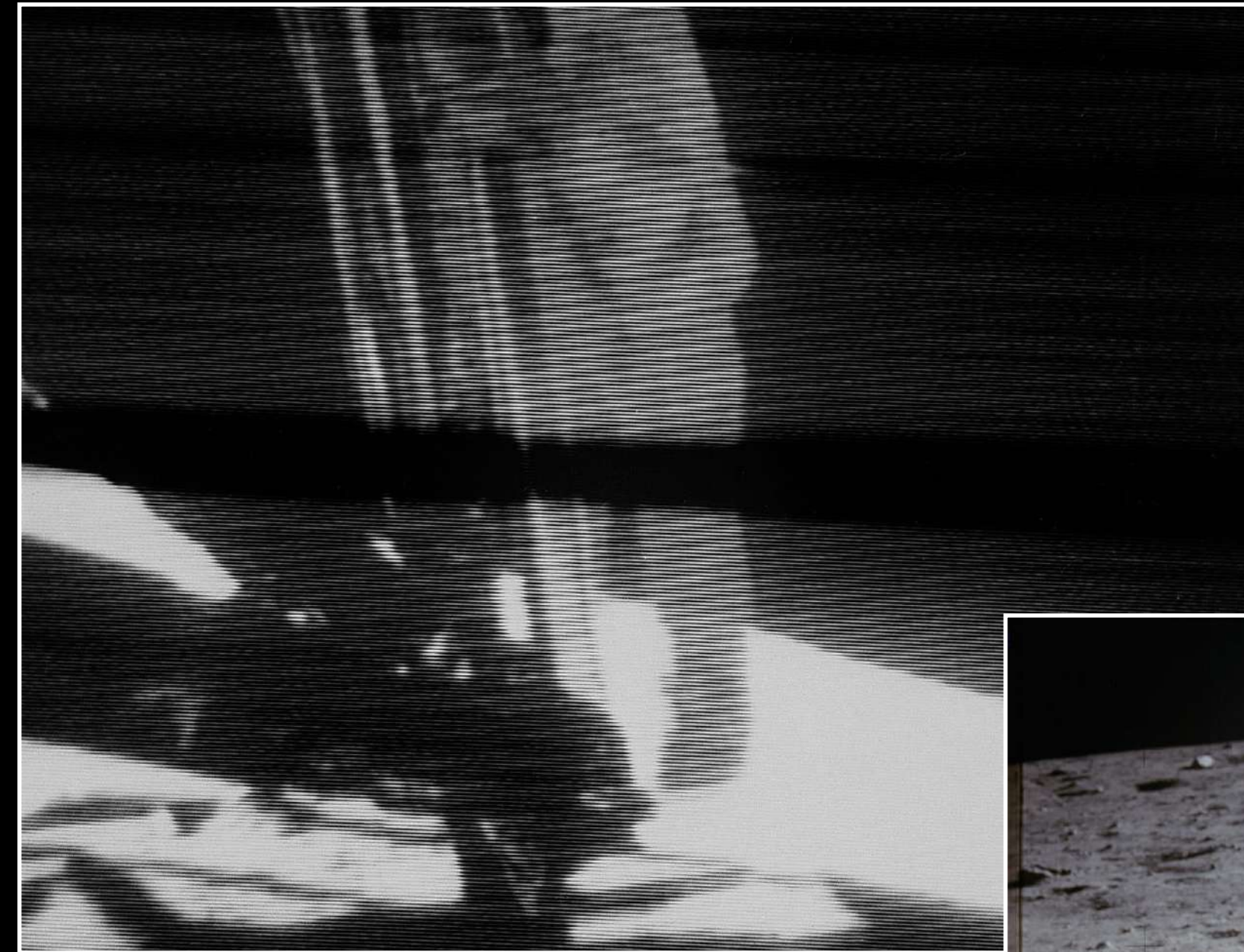


50 Years Ago

50 Years ago today

Neil Armstrong and Buzz Aldrin took the first human steps on another world, while Mike Collins orbited above

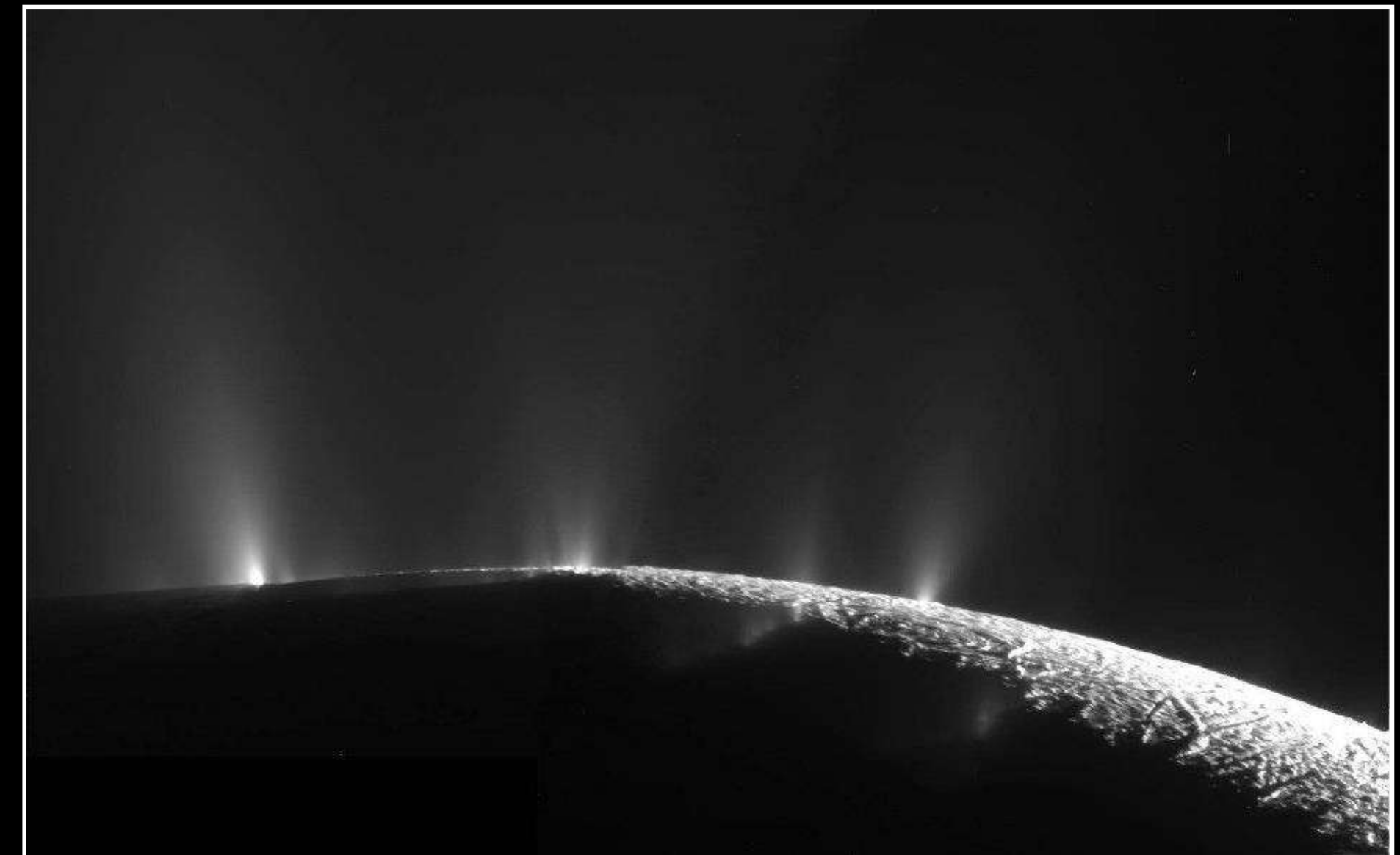
Do you remember the moment?





Since that day in 1969

Robotic explorers have visited every planet in the solar system

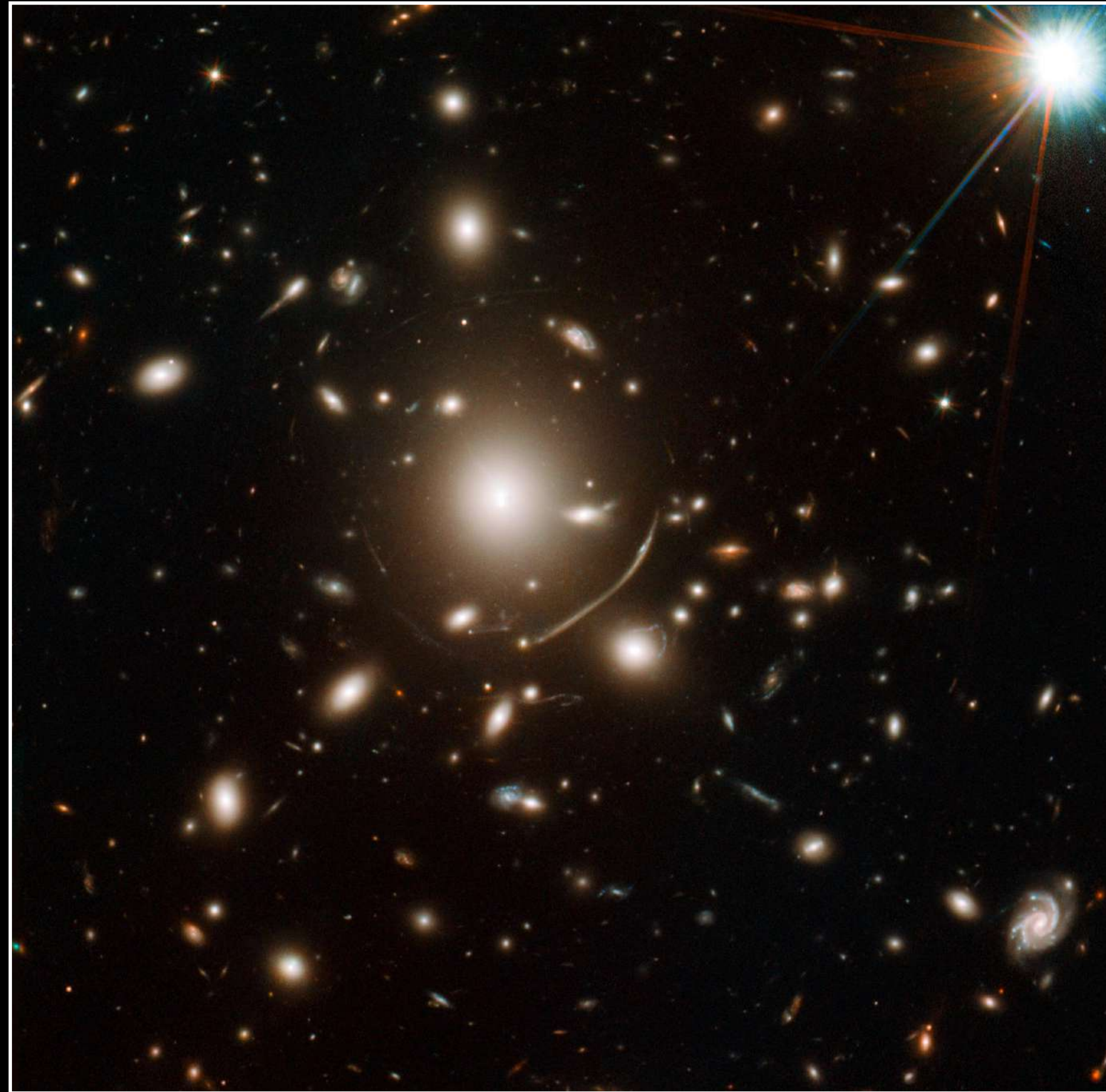


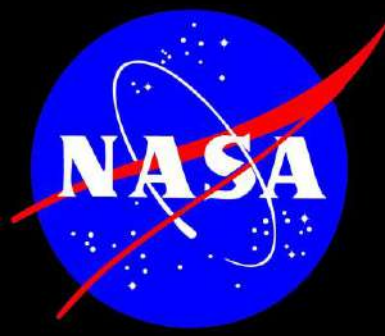


Since that day in 1969

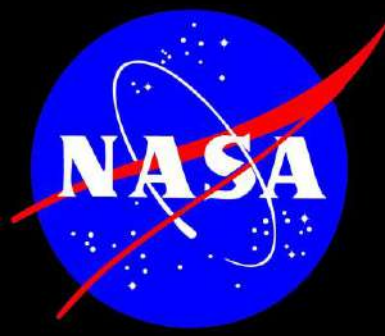
We have extended our senses farther than they've ever been, giving us new perspectives on our place in the Universe

However...





No crewed mission has left Earth orbit since the last Apollo mission, in 1972



A Brief Look Back

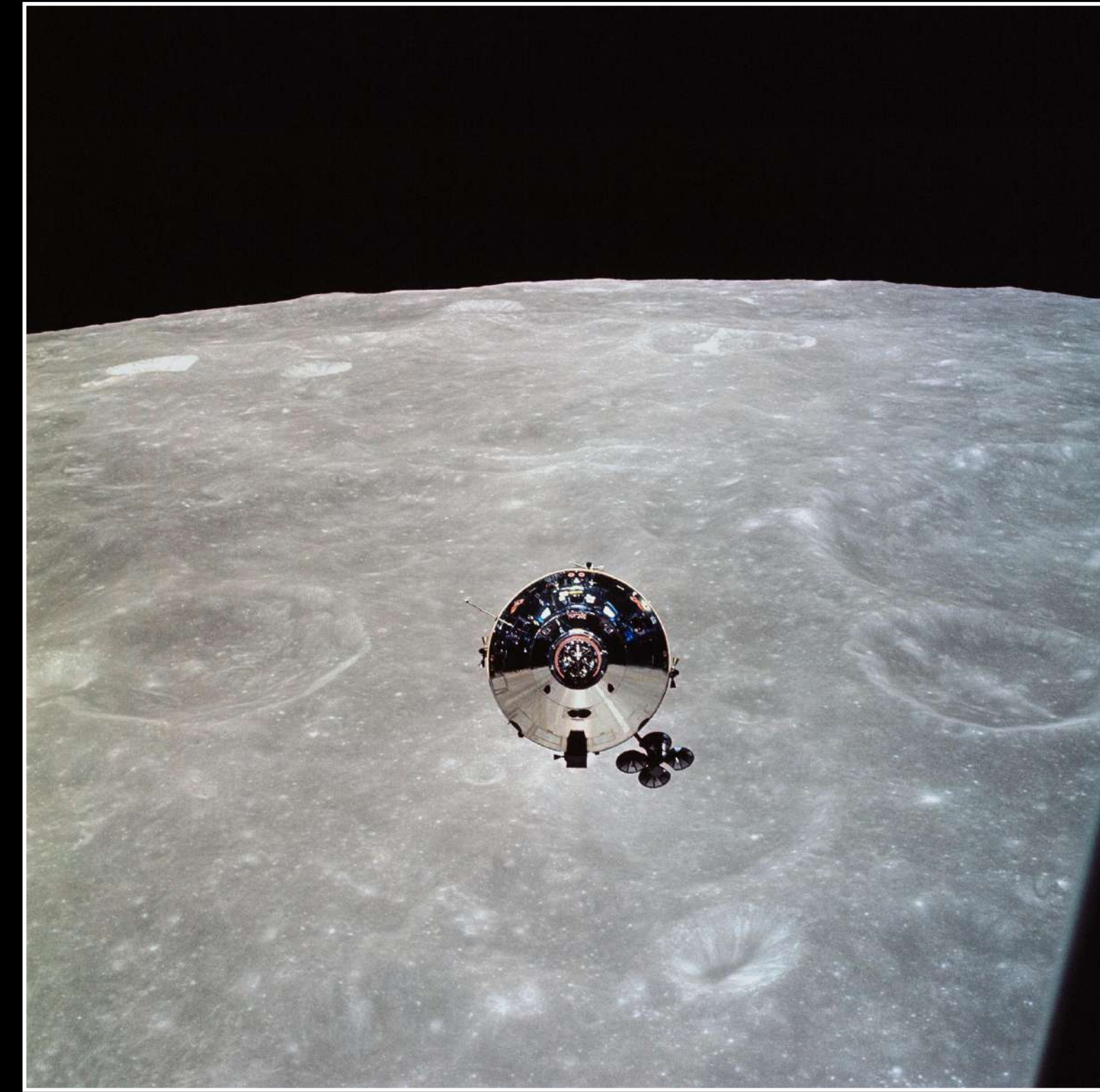
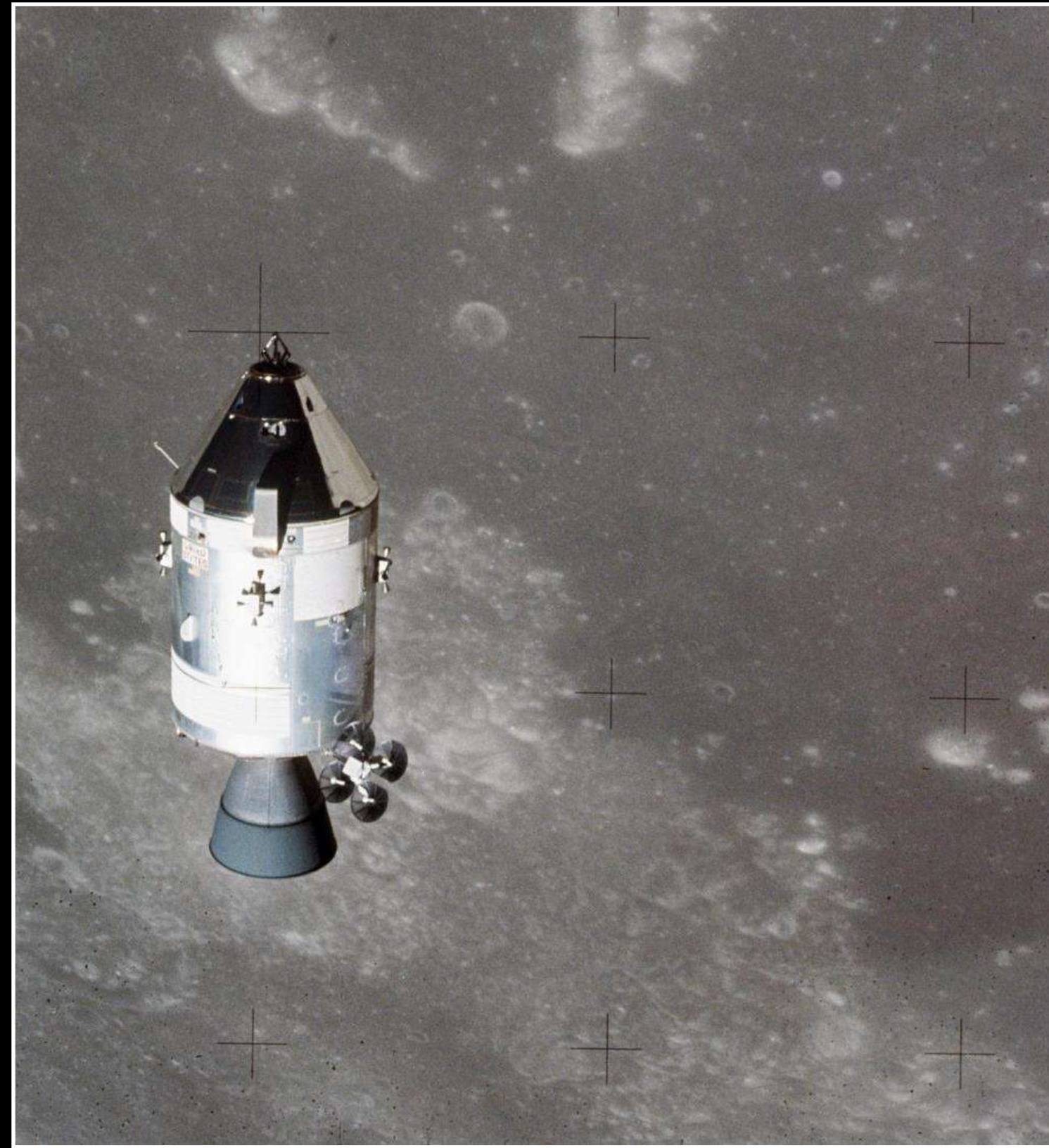




The Saturn 5 Rocket

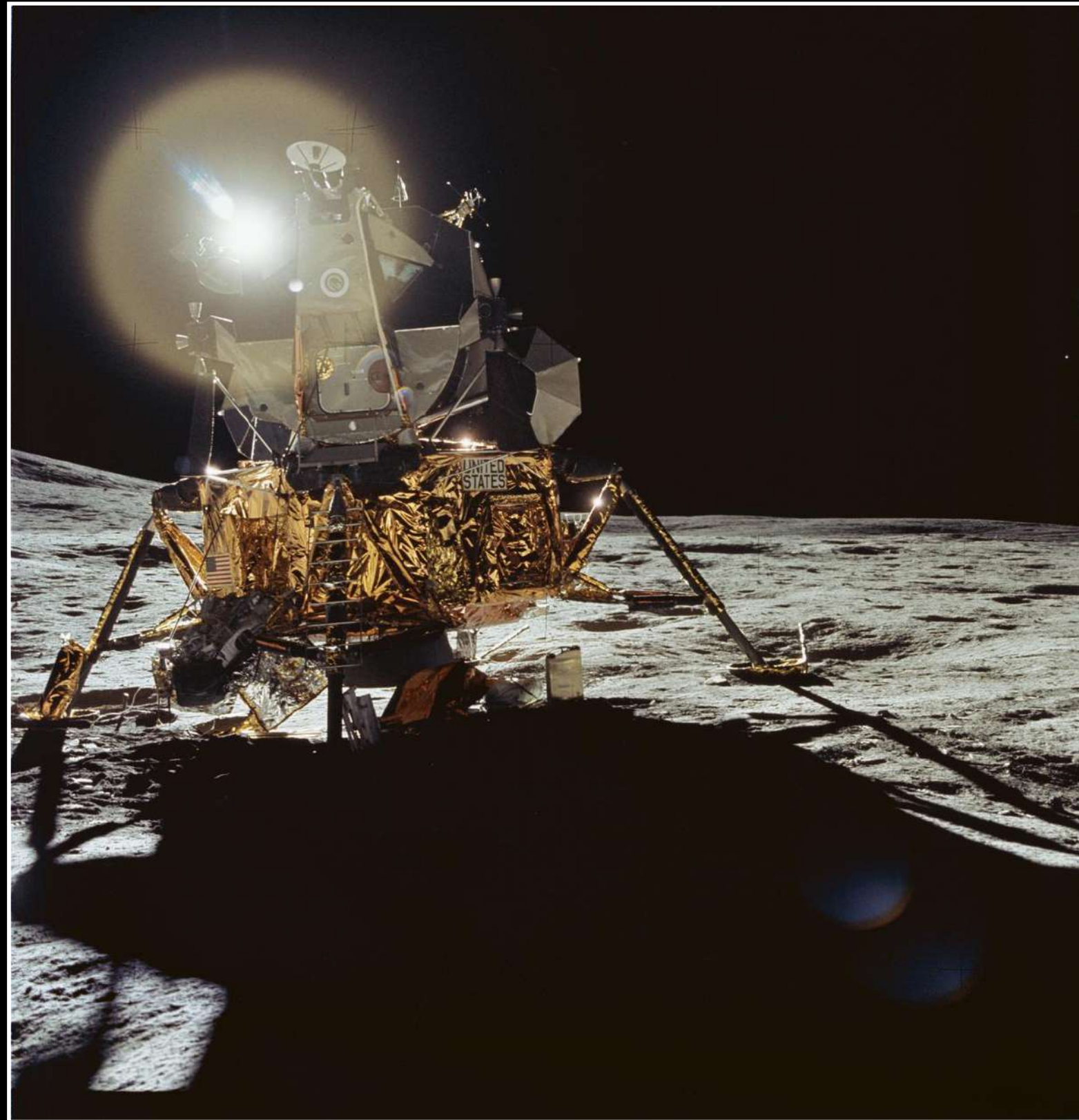


The Apollo Command-Service Module



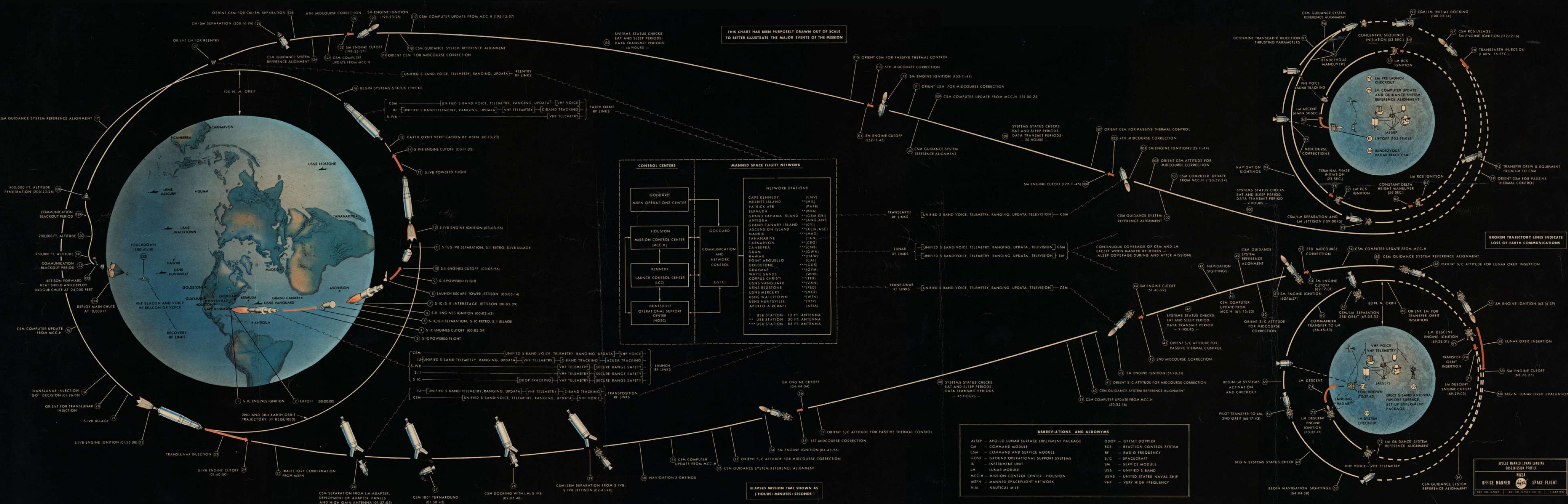


The Apollo Lunar Module





Apollo Lunar Landing Flight Plan



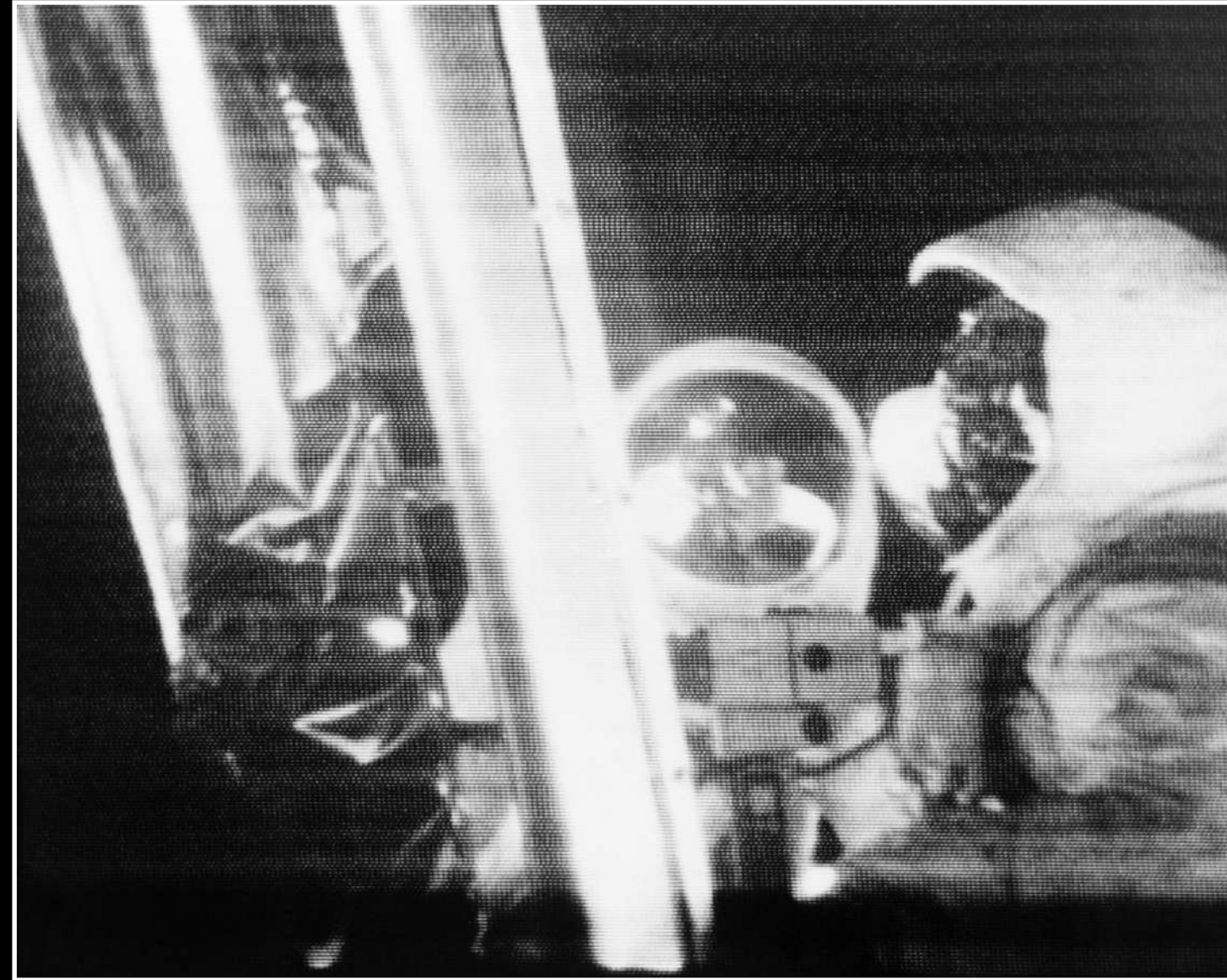
Six Crews Explored the Surface



The first crewed lunar surface explorations, 1969 - 1972



The view from the ground



We watched live on TV, there was no internet!

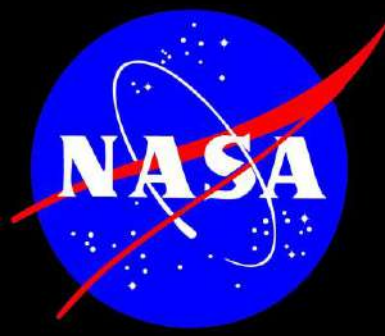


What did we accomplish?

“We went there to find the Moon but instead we found the Earth” - Bill Anders, Apollo 8



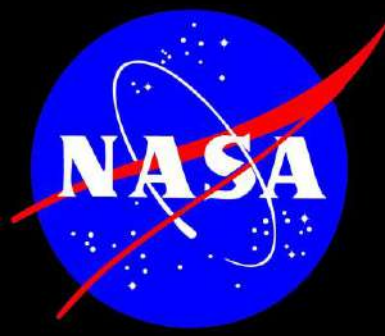
The first Earth-rise seen by human eyes,
December, 1968



What did we accomplish?

Knowledge, Perspective,
Inspiration, Science





A Peacetime Initiative

“The American effort to get to the moon was the largest peacetime government initiative in the nations history. At its peak in the 1960’s nearly 2 percent of the American workforce was engaged... It employed some 400,000 individuals...” -from PBS Chasing the Moon



It Brought us Together

A sense of unity, in the moment

“... I thought that when we went someplace they’d say, well, congratulations. You Americans finally did it. And instead of that the reaction was unanimously, we did it...”

Michael Collins, Apollo 11 command module pilot, referring to the astronauts world tour



Return to the Moon



Enter Artemis: Landing Robots & Humans On the Moon



Lunar Reconnaissance Orbiter: Continued surface and landing site investigation



Artemis I: First human spacecraft to the Moon in the 21st century



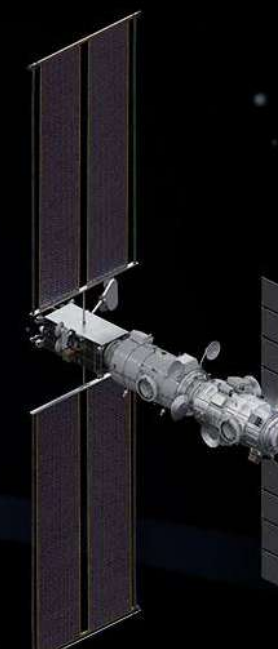
Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st century



Gateway begins science operations with launch of Power and Propulsion Element and Habitation and Logistics Outpost



Artemis III-V: Deep space crew missions; cislunar buildup and initial crew demonstration landing with Human Landing System



Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers



Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey



Uncrewed HLS Demonstration



Humans on the Moon - 21st Century
First crew expedition to the lunar surface



LUNAR SOUTH POLE TARGET SITE



A New Way of Working

Robotic lunar landers to deliver payloads to the surface, and enable new levels of innovation

Failure is not an option?

NASA buys a service - Commercial Lunar Payload Services

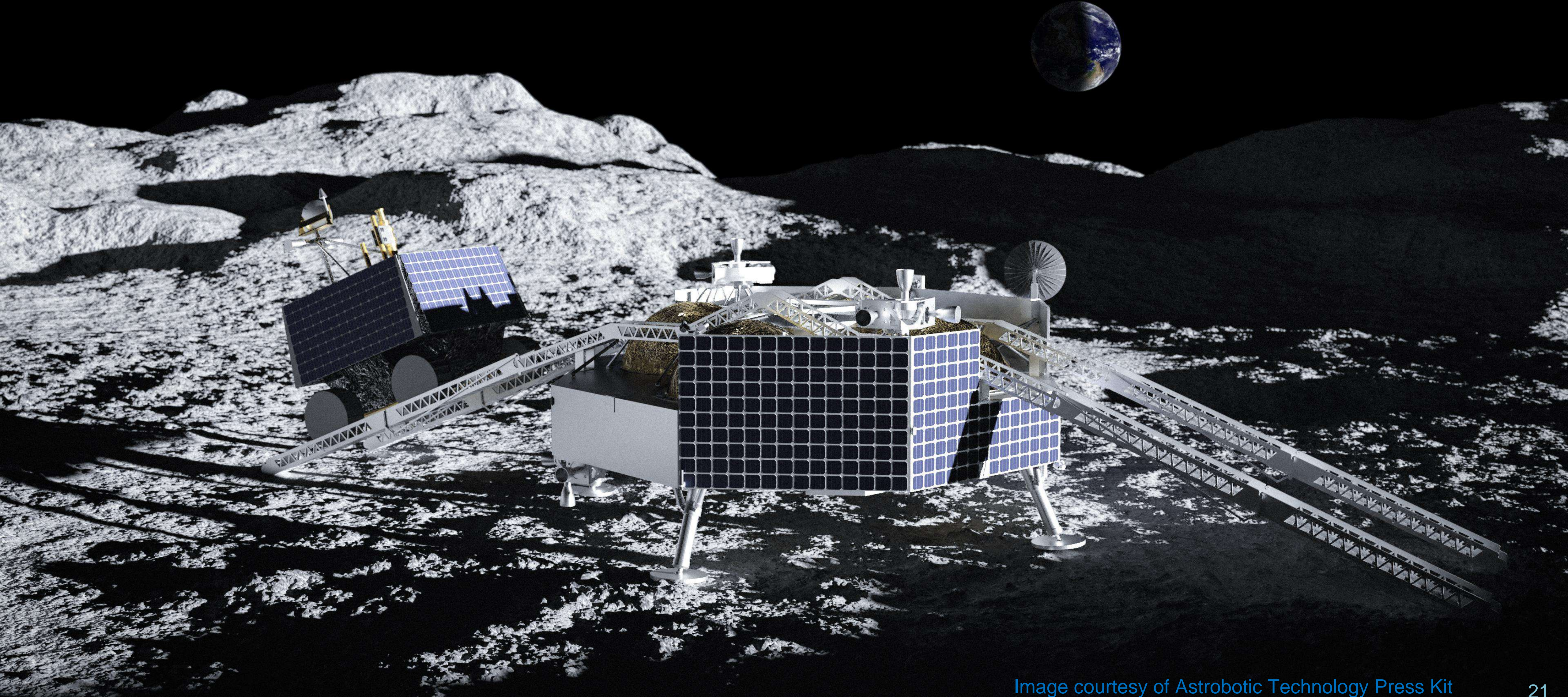
First Missions: Intuitive Machines, Astrobotic



Astrobotic Peregrine Lander

Image Courtesy Astrobotic

Robotic Precursor to the next human mission: VIPER Lunar Rover



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 relative constant
- Essentially no atmosphere
- Bone dry

Recent robotic Missions like changed all that... now we are looking for water at the Lunar Poles





VIPER will characterize the distribution and physical state of lunar polar water and volatiles

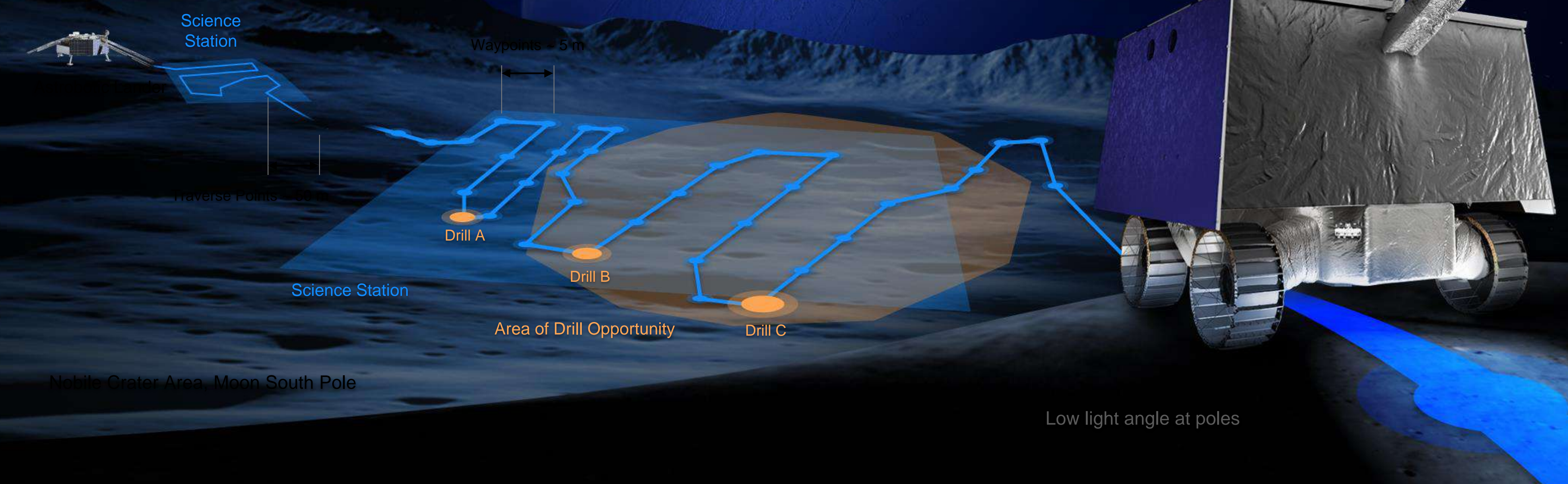
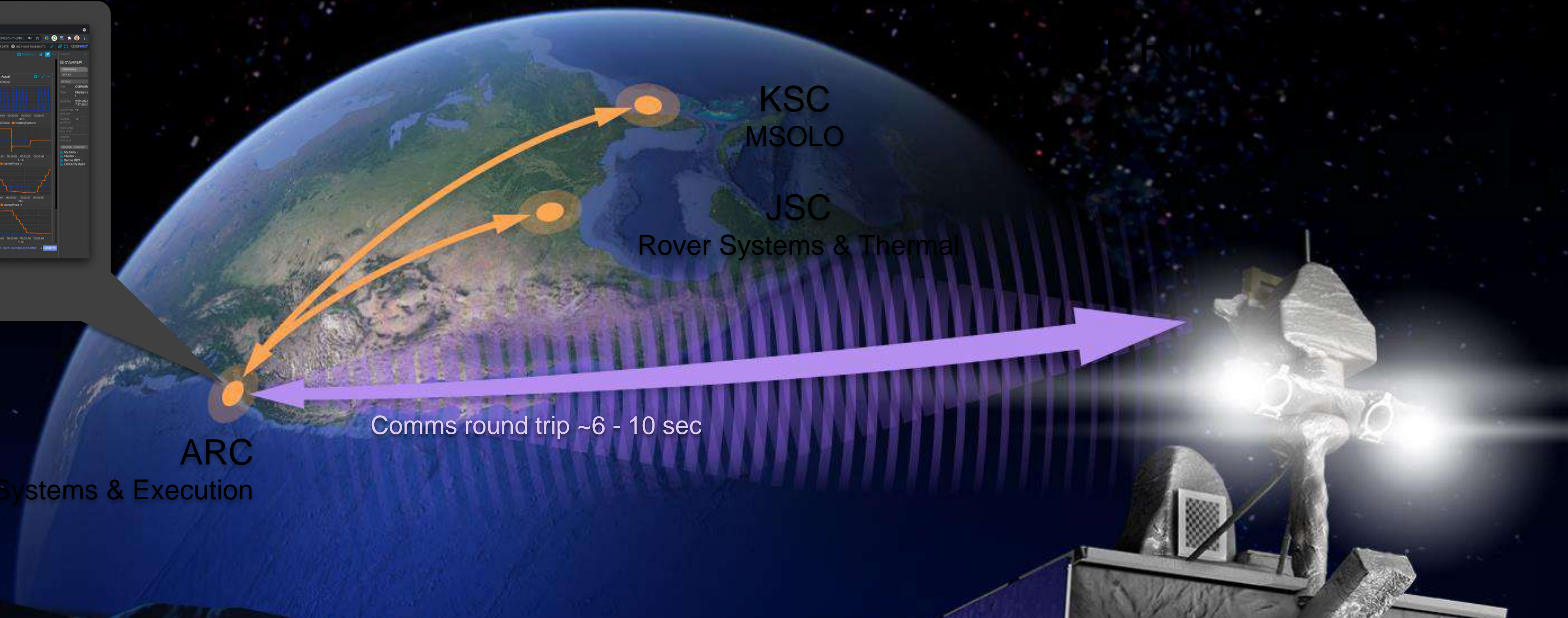
VIPER will help NASA evaluate the potential of In-Situ Resource Utilization (ISRU) from the lunar polar regions



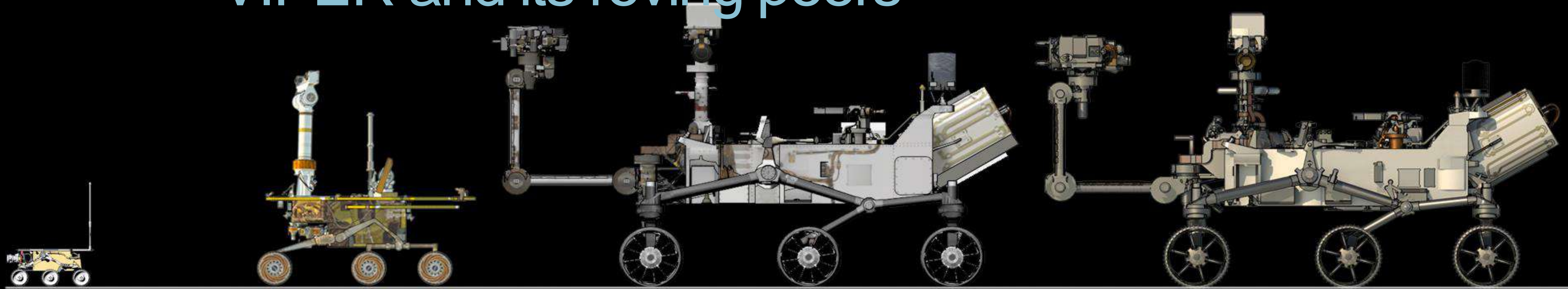
The next great leap in understanding lunar water's potential is to map these volatiles at human scale

Rover Driving

Mission Monitoring



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

Mars Science Laboratory (2011)

3.0m x 2.8m x 2.1m

900kg

Top Speed: 4cm/s

Plutonium-238 MMRTG

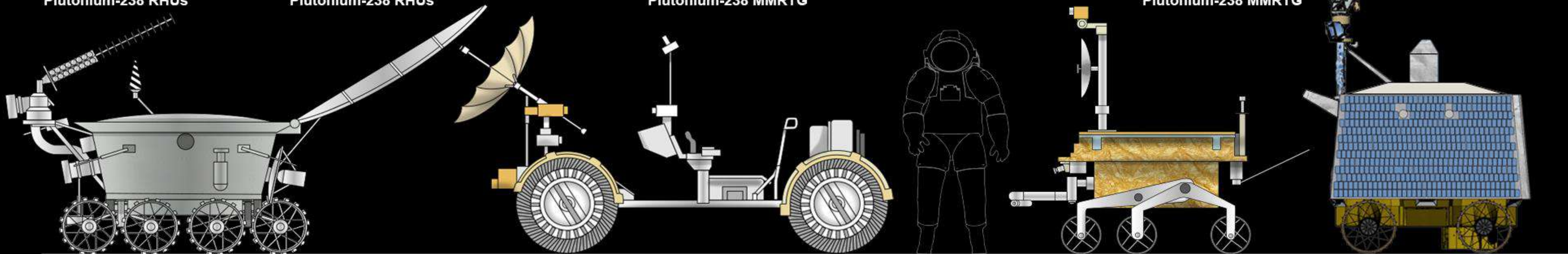
Mars 2020 Rover (2020)

3.0m x 2.7m x 2.2m

1025kg

Top Speed: 4.2cm/s

Plutonium-238 MMRTG



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

Yutu (2013/2019)

1.5m x 1.1m x 1.1m

140kg

Top Speed: 5cm/s

Plutonium-238 RHUs

VIPER

1.5m x 1.5m x 2.0m

430kg

Top Speed: 20cm/s

Electric heaters only





Rockets for Human Missions: SLS



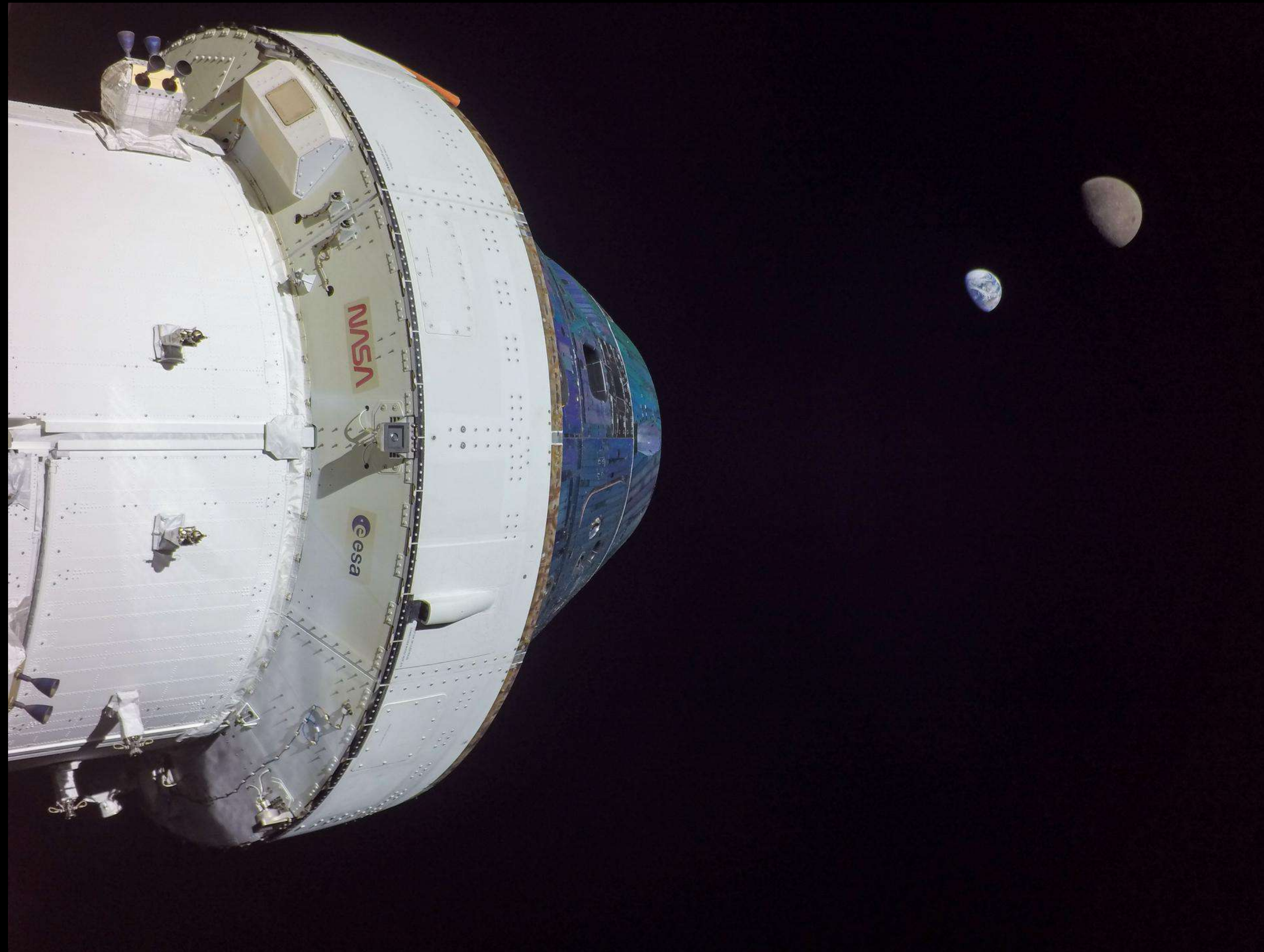


Orion: A New Spacecraft





Human eyes will see this soon



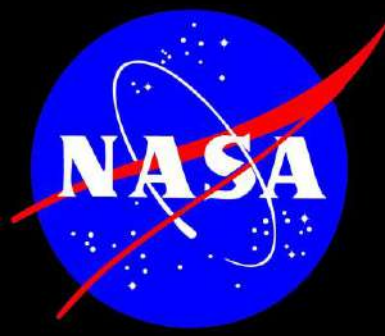
Contrast with
Earth rise, note
humans will see
this on Artemis 2



The Human Landing System

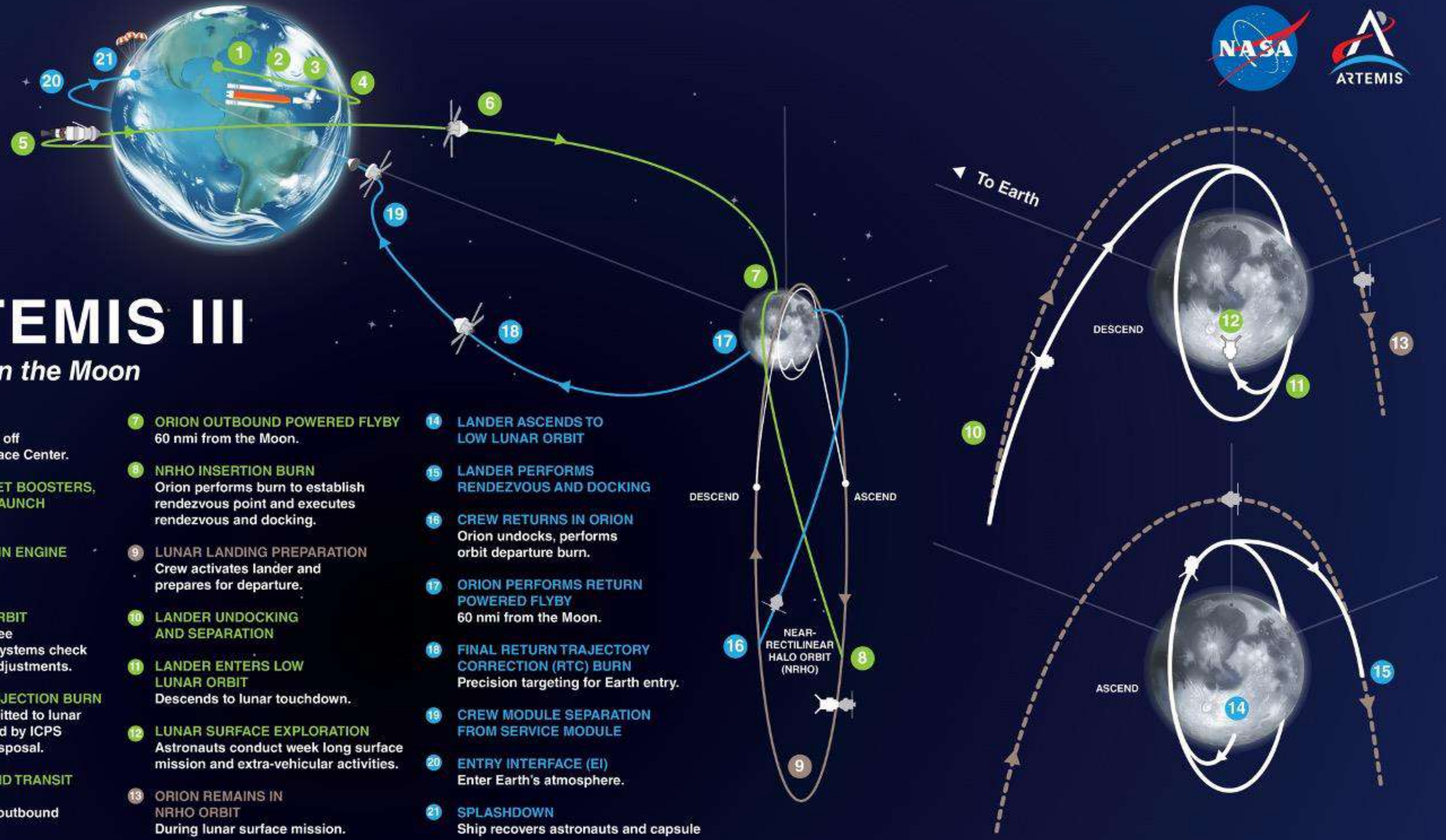
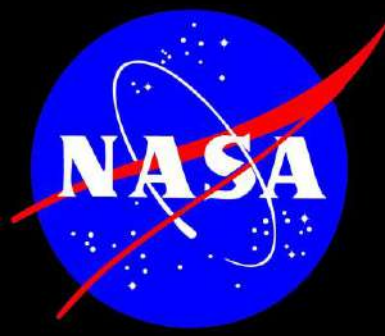


<https://www.nasa.gov/content/about-human-landing-systems-development>



The Next Mission





ARTEMIS III

Landing on the Moon

- 1 LAUNCH**
SLS and Orion lift off from Kennedy Space Center.
- 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 ENTER EARTH ORBIT**
Perform the perigee raise maneuver. Systems check and solar panel adjustments.
- 5 TRANS LUNAR INJECTION BURN**
Astronauts committed to lunar trajectory, followed by ICPS separation and disposal.
- 6 ORION OUTBOUND TRANSIT TO MOON**
Requires several outbound trajectory burns.
- 7 ORION OUTBOUND POWERED FLYBY**
60 nmi from the Moon.
- 8 NRHO INSERTION BURN**
Orion performs burn to establish rendezvous point and executes rendezvous and docking.
- 9 LUNAR LANDING PREPARATION**
Crew activates lander and prepares for departure.
- 10 LANDER UNDOCKING AND SEPARATION**
- 11 LANDER ENTERS LOW LUNAR ORBIT**
Descends to lunar touchdown.
- 12 LUNAR SURFACE EXPLORATION**
Astronauts conduct week long surface mission and extra-vehicular activities.
- 13 ORION REMAINS IN NRHO ORBIT**
During lunar surface mission.
- 14 LANDER ASCENDS TO LOW LUNAR ORBIT**
- 15 LANDER PERFORMS RENDEZVOUS AND DOCKING**
- 16 CREW RETURNS IN ORION**
Orion undocks, performs orbit departure burn.
- 17 ORION PERFORMS RETURN POWERED FLYBY**
60 nmi from the Moon.
- 18 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
Precision targeting for Earth entry.
- 19 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 20 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 21 SPLASHDOWN**
Ship recovers astronauts and capsule



Some of My Favorite Space Resources

Web Sites

Apollo 11 in real time - <https://apolloinrealtime.org/11/>

Apollo 17 in real time - <https://apollo17.org/>

NASA Apollo 50th - <https://www.nasa.gov/specials/apollo50th/>

The Missions - <https://www.nasa.gov/specials/apollo50th/missions.html>

NASA's Eyes: <https://eyes.nasa.gov/>

Movies and Documentaries that you can download or stream

Mission Control: The Unsung Heroes of Apollo

In The Shadow of the Moon

For All Mankind

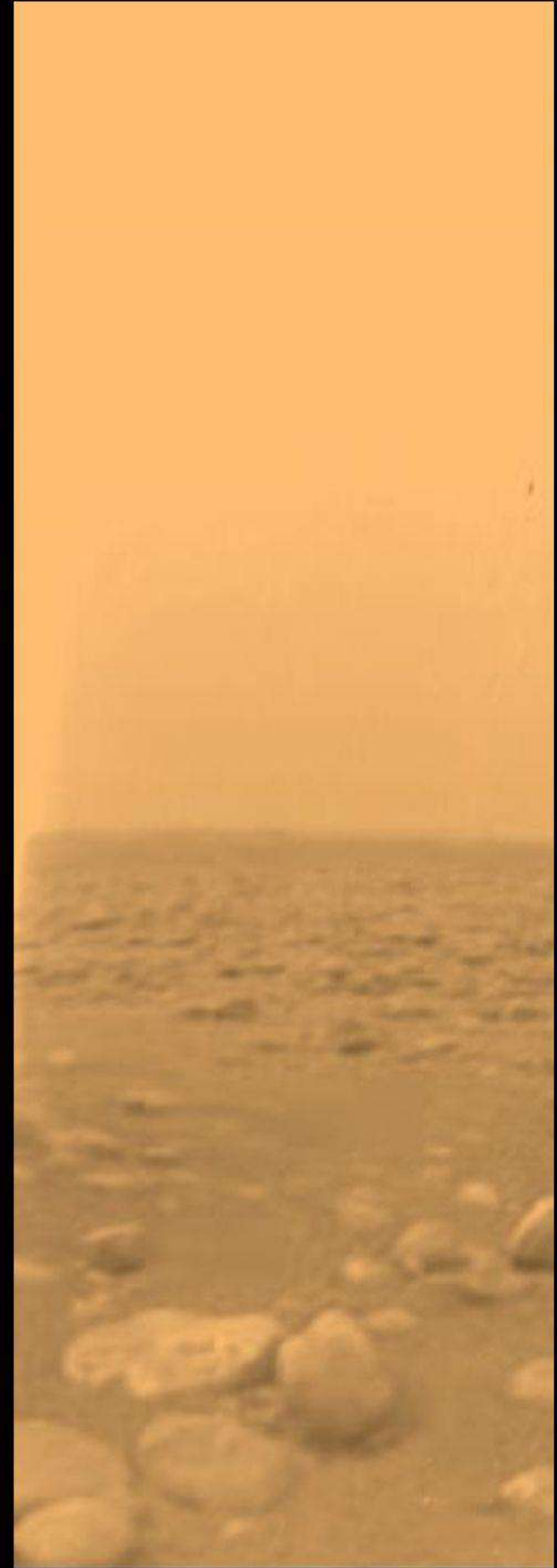
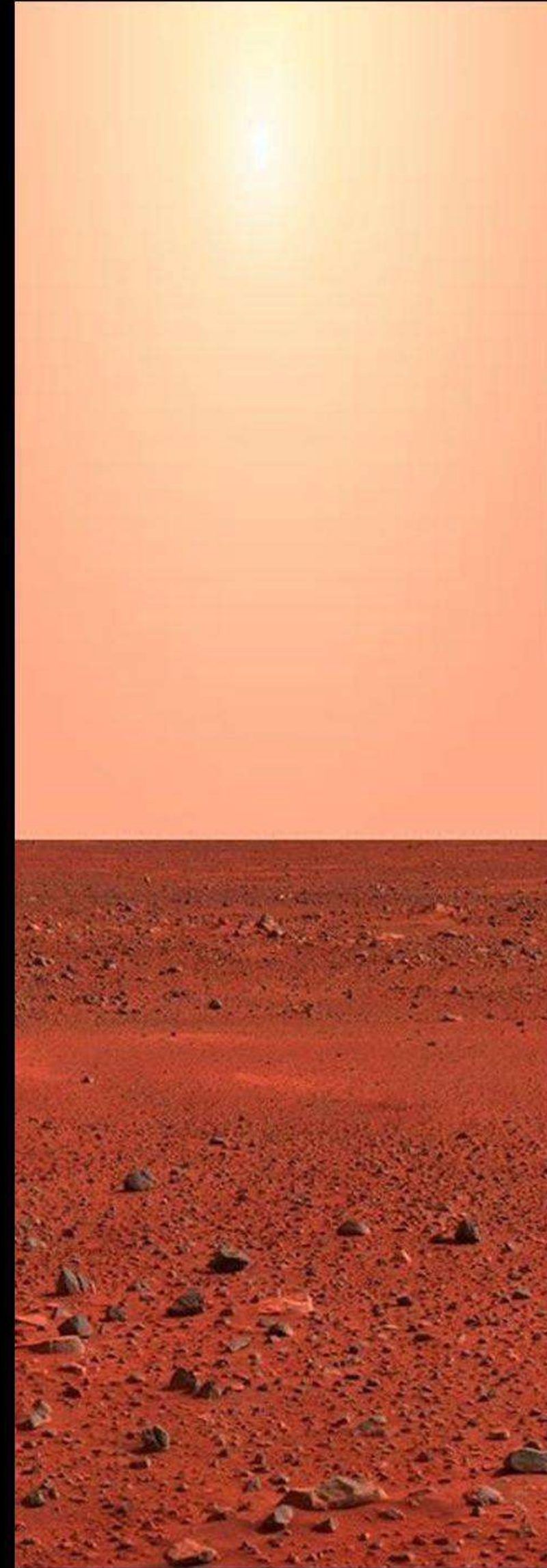
Cool Pictures

images.nasa.gov

photojournal.jpl.nasa.gov



What wonders await?





EXPLORESPACE TECH

TECHNOLOGY DRIVES EXPLORATION