Astro-1 Honors 2020
Class 3: Getting to the Moon and Surviving

Dr. Jatila van der Veen

Project Scientist, Physics Department, UCSB

Adjunct Professor of Astronomy, SBCC

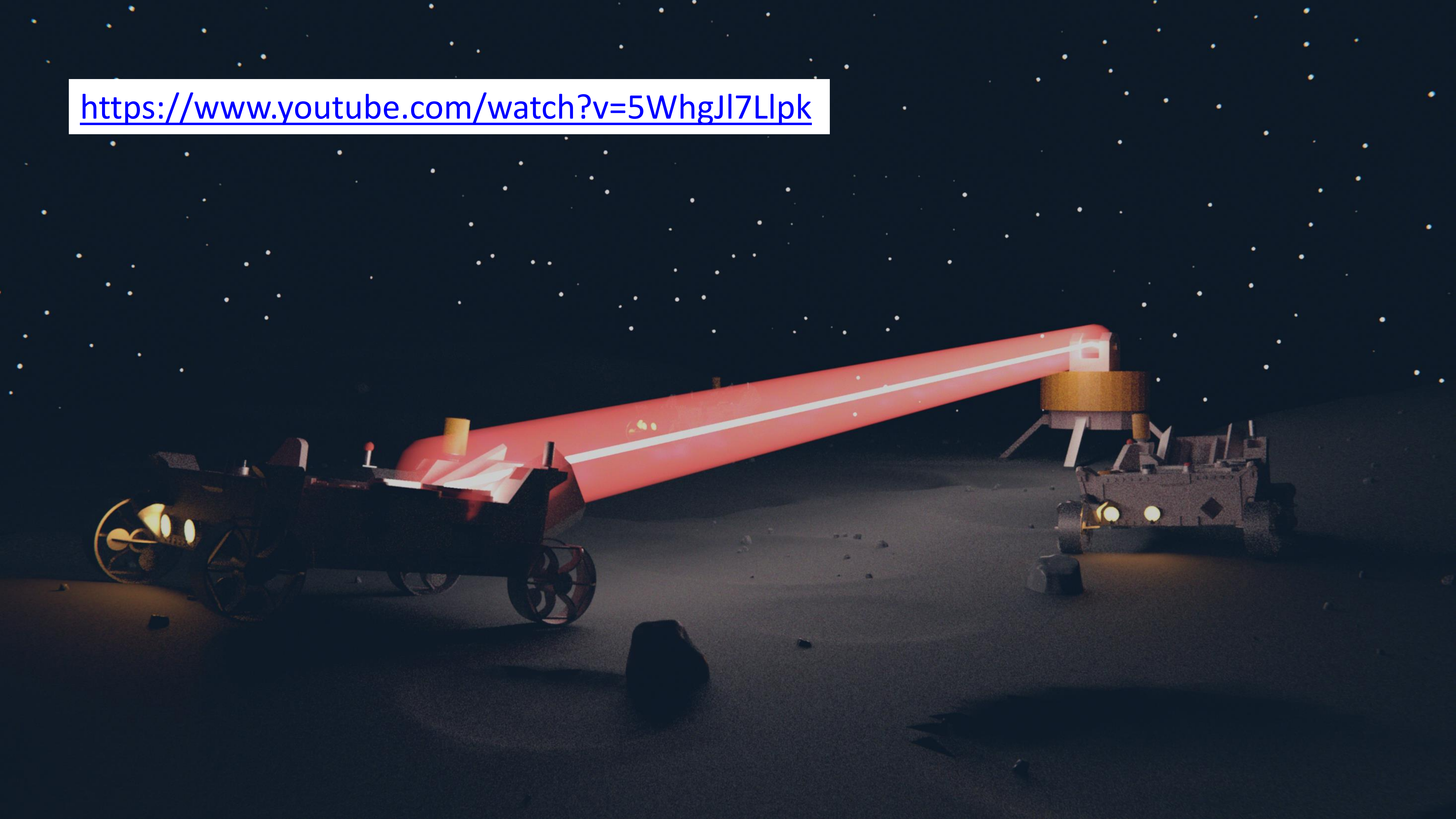
News from SpaceRef, Jan. 27th

ESA is working on a pair of twin rovers to search for life-supporting elements on the Moon

See:

http://spaceref.com/moon/twin-rovers-could-lead-the-search-for-life-supporting-elements-on-the-moon.html

https://www.esa.int/Science_Exploration/Space_Science/SMART-1/New_lunar_south_polar_maps_from_nobr_SMART-1_nobr https://www.youtube.com/watch?v=5WhgJl7Llpk



Problems we will address today:

1. Getting to the Moon

2. Hazards to overcome in order to survive on the Moon

3. Likely places to develop a human colony on the Moon

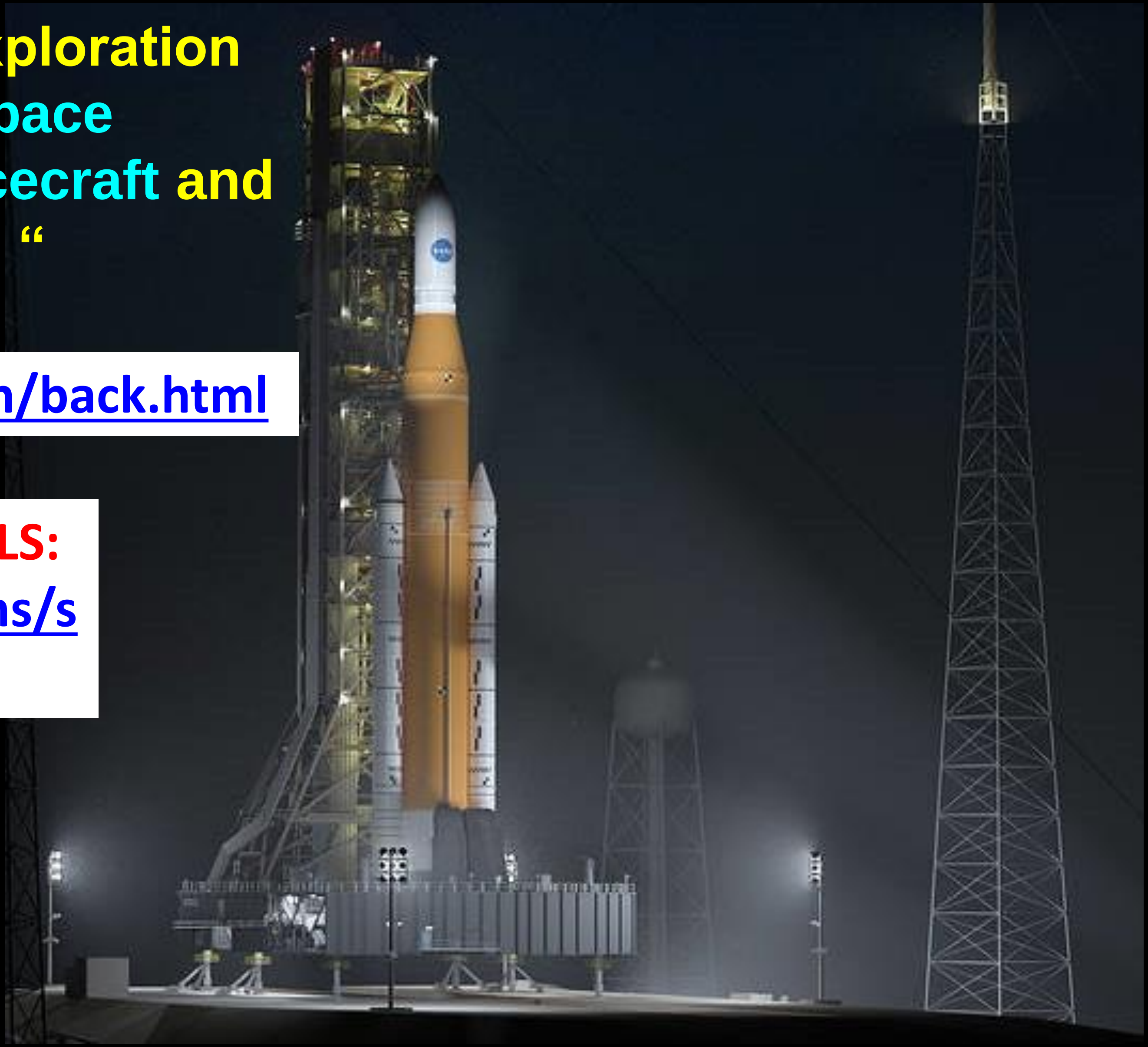
Earth Rise: An artist’s rendering shows Skidmore, Owings & Merrill’s vision for an expanding lunar colony.

1. Getting to the Moon

"NASA's backbone for deep space exploration is the biggest rocket ever built, the Space Launch System (SLS), the Orion spacecraft and the Gateway lunar command module. "

https://www.nasa.gov/specials/apollo50th/back.html

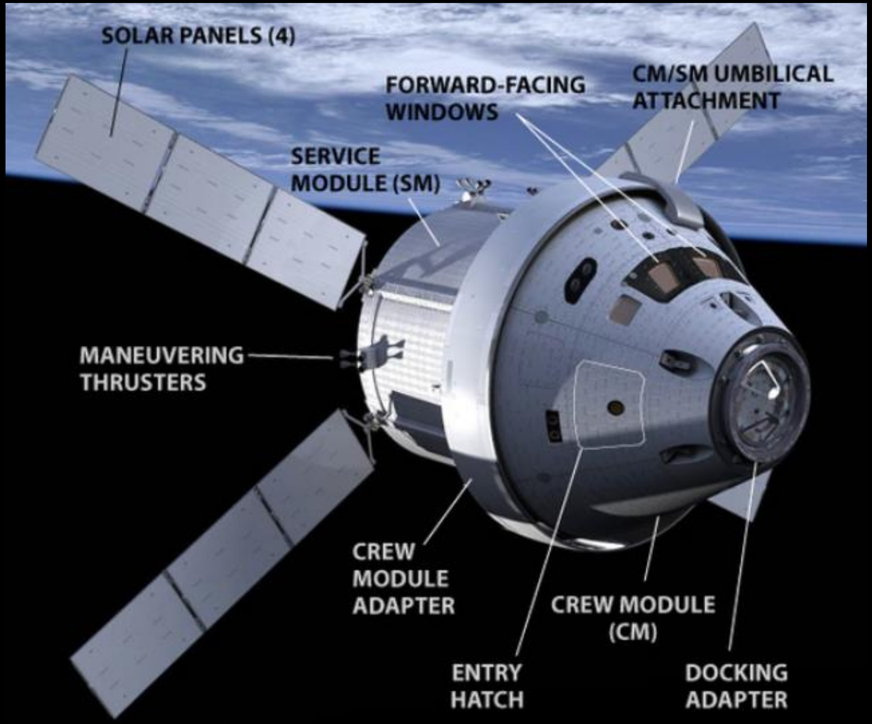
NASA's website detailing progress on the SLS:
https://www.nasa.gov/exploration/systems/sls/factsheets.html



3 components in the NASA lunar launch scenario:

1. Space Launch System (SLS)

2. Orion Spacecraft

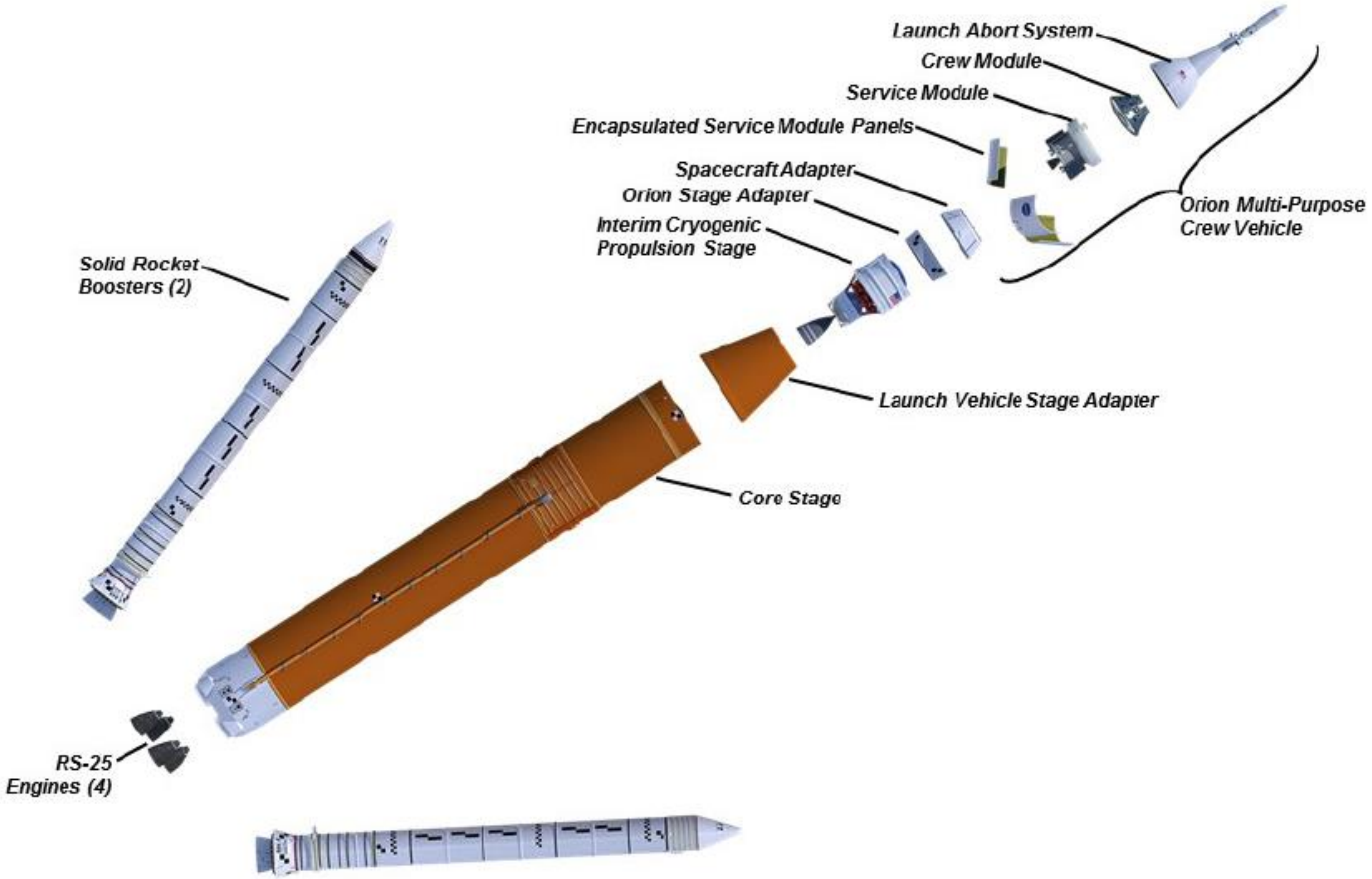


3. Gateway Lunar Orbiter

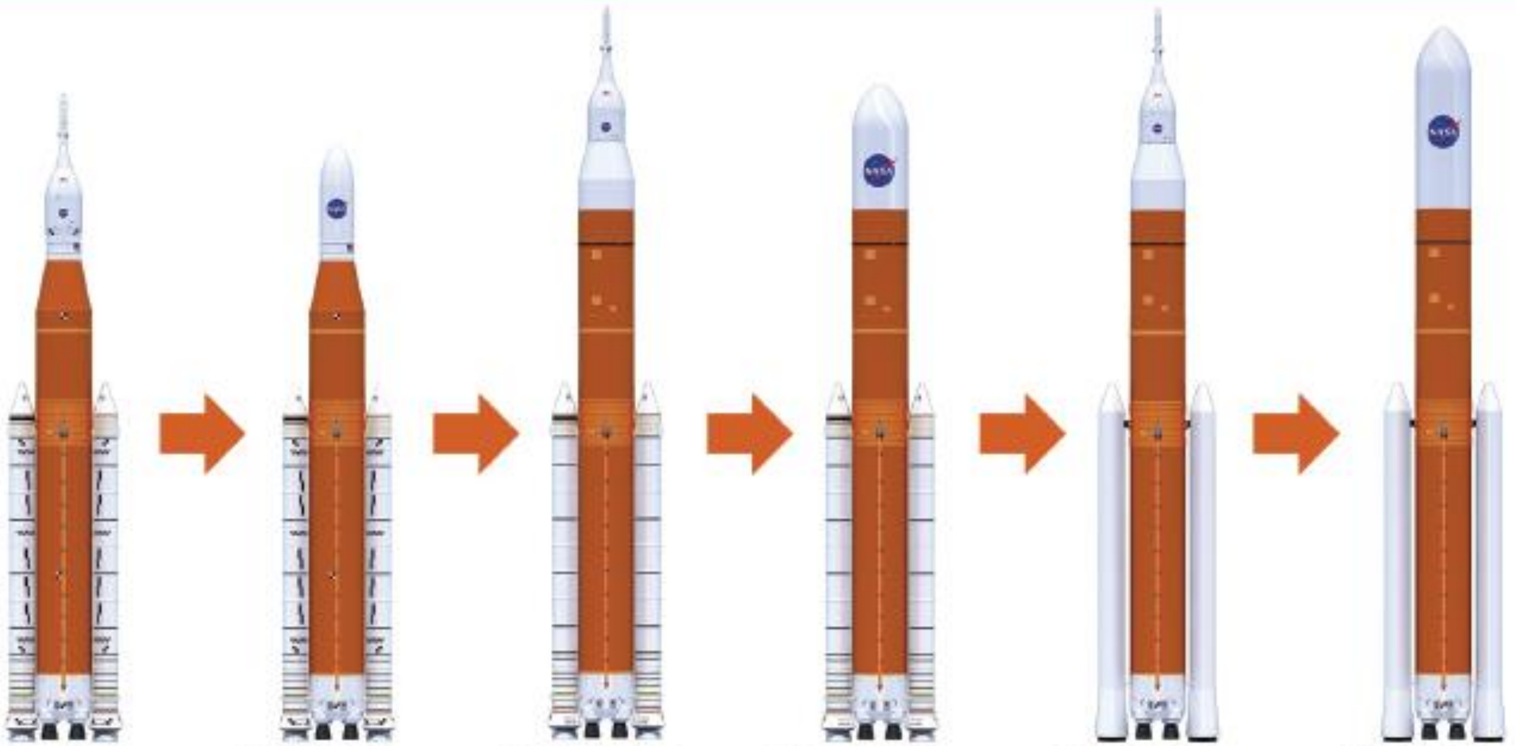
See an overview of the program:

https://www.youtube.com/watch?v=vl6jn-DdafM

Block 1 - Initial SLS Configuration



SLS Evolution



	SLS Block 1 Crew	SLS Block 1 Cargo	SLS Block 1B Crew	SLS Block 1B Cargo	SLS Block 2 Crew	SLS Block 2 Cargo
Payload to TLI/Moon	> 26 t (57k lbs)	> 26 t (57k lbs)	34-37 t (74k–81k lbs)	37-40 t (81k–88k lbs)	> 45 t (99k lbs)	> 45 t (99k lbs)
Payload Volume	N/A*	9,030 ft³ (256m³)*	10,100 ft³ (286m³)*	18,970 ft³ (537 m³)	10,100 ft³ (286 m³)*	34,910 ft³ (988 m³)
Maximum Thrust	8.8M lbs	8.8M lbs	8.8M lbs	8.8M lbs	11.9M lbs	11.9M lbs

* Not including Orion/ Service Module volume

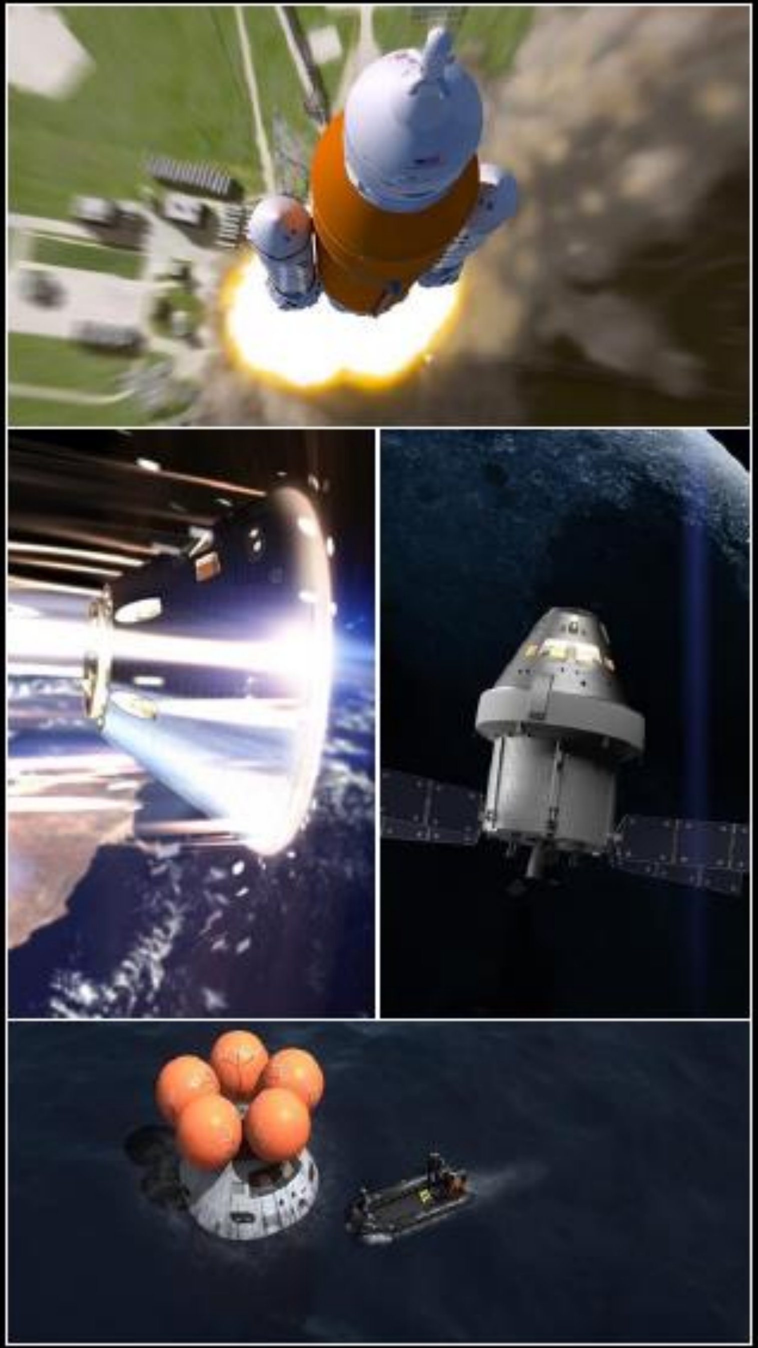
NASA has designed the Space Launch System as the foundation for a generation of human exploration missions to deep space, including missions to the Moon and Mars. SLS will leave low-Earth orbit and send the Orion spacecraft, its astronaut crew and cargo to deep space. To do this, SLS has to have enough power to perform a maneuver known as trans-lunar injection, or TLI. This maneuver accelerates the spacecraft from its orbit around Earth onto a trajectory toward the Moon. The ability to send more mass to the Moon on a single mission makes exploration simpler and safer.

Test mission without people. See https://www.nasa.gov/experience-artemis-1

ARTEMIS I Mission Priorities

A flight test that will enable NASA to fly crew to the Moon and back on Artemis II:

1. **Demonstrate Orion heatshield at lunar entry velocities**
2. **Operate Systems in Flight Environment**
3. **Retrieve Spacecraft**
4. **Complete Remaining Objectives**: Perform residual mission in the absence of system failures and conduct all mission content as planned



The SLS core stage, the largest rocket stage ever built by NASA, 212 feet tall, 27.6 feet in diameter. Propellant tanks hold a total of 733,000 gallons of liquid oxygen and liquid hydrogen to fuel the four RS-25 engines during launch.

The core stage was designed by NASA and Boeing in Huntsville, Alabama, then manufactured at NASA’s Michoud Assembly Facility in New Orleans by lead contractor Boeing, with input and contributions from more than 1,100 large and small businesses in 44 states.

SLS core stage is currently (end of January, 2020) undergoing tests at Stennis Space Center in St. Louis, Mississippi. From there it will go to KSC in Florida.

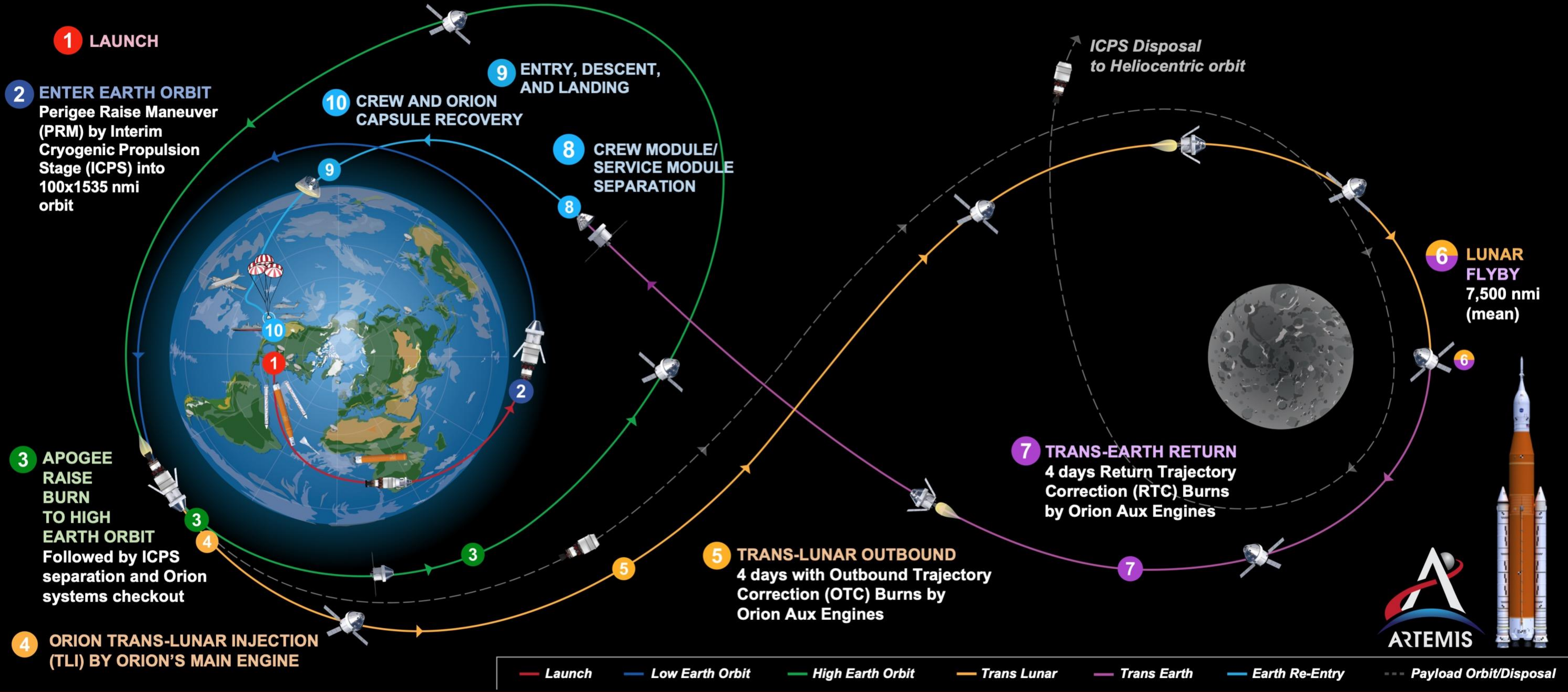
Space Launch System Liquid Hydrogen Tank Test
https://www.nasa.gov/exploration/systems/sls/index.html
See video #3

Launch of Artemis 1 planned for end of 2020 or mid 2021.

Frist crewed mission with SLS and Orion, scheduled to launch and fly by the Moon in 2023.

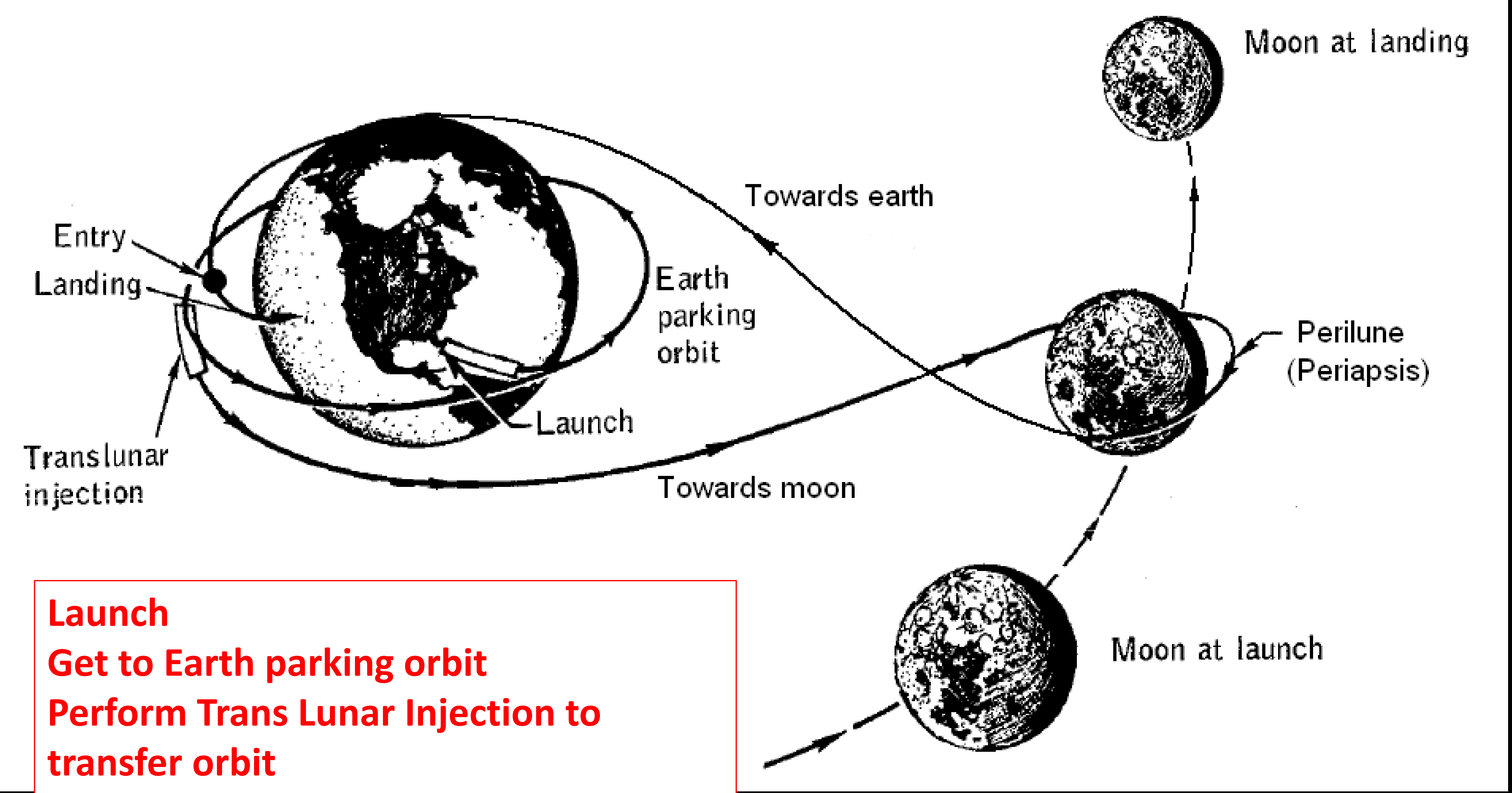
ARTEMIS II

Crewed Hybrid Free Return Trajectory, demonstrating crewed flight and spacecraft systems performance beyond Low Earth Orbit (LEO)



SLS Configuration (Block 1) with Human Rated ICPS | 15x1200 nmi insertion orbit | 28.5 deg inclination

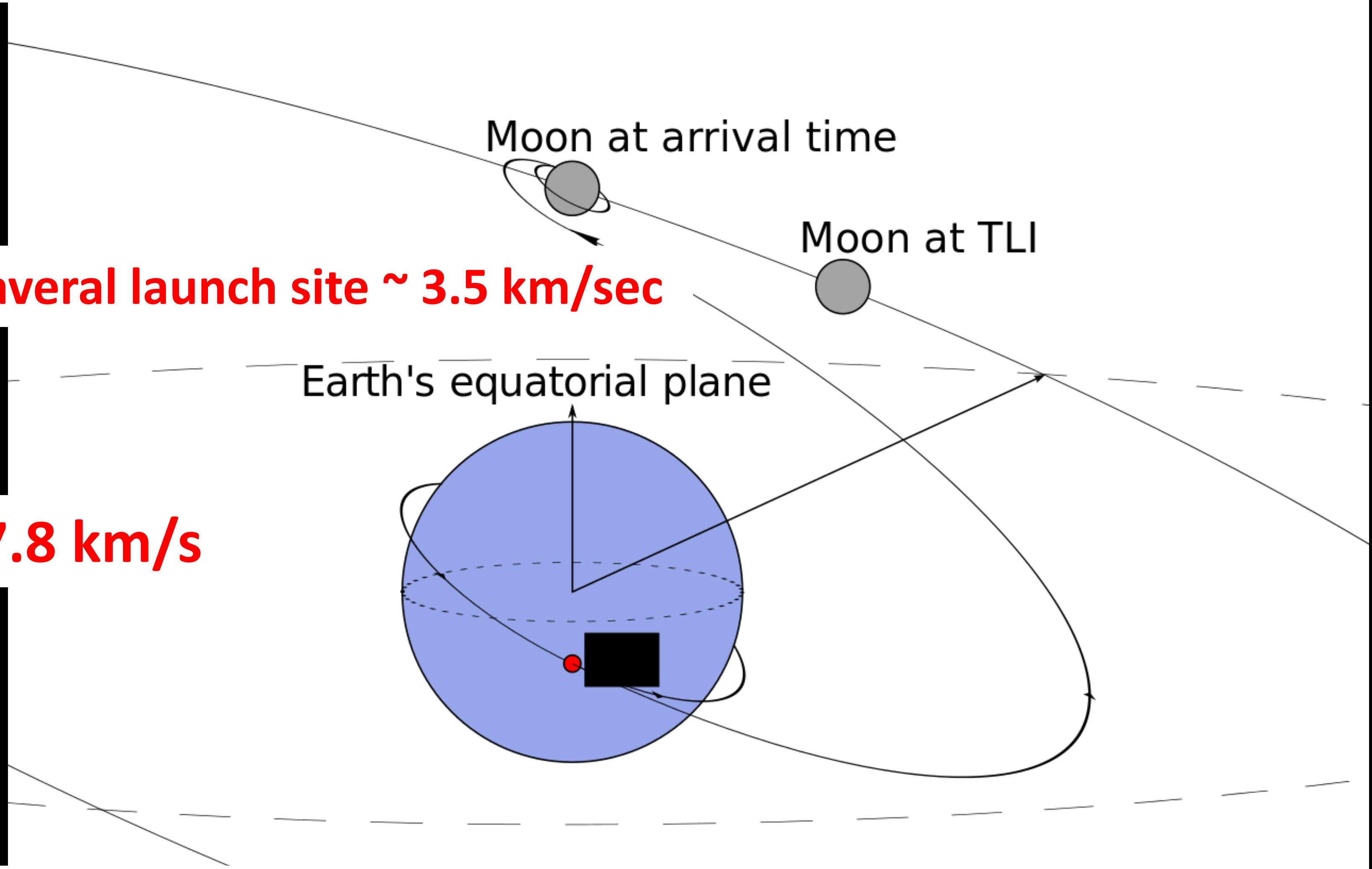
4 astronauts | Mission duration: 10 Days | Re-entry speed: 24,500 mph (Mach 32)



Launch
Get to Earth parking orbit
Perform Trans Lunar Injection to transfer orbit
Catch up with Moon, and transfer to a lunar orbit

https://en.wikipedia.org/wiki/Trans-lunar_injection

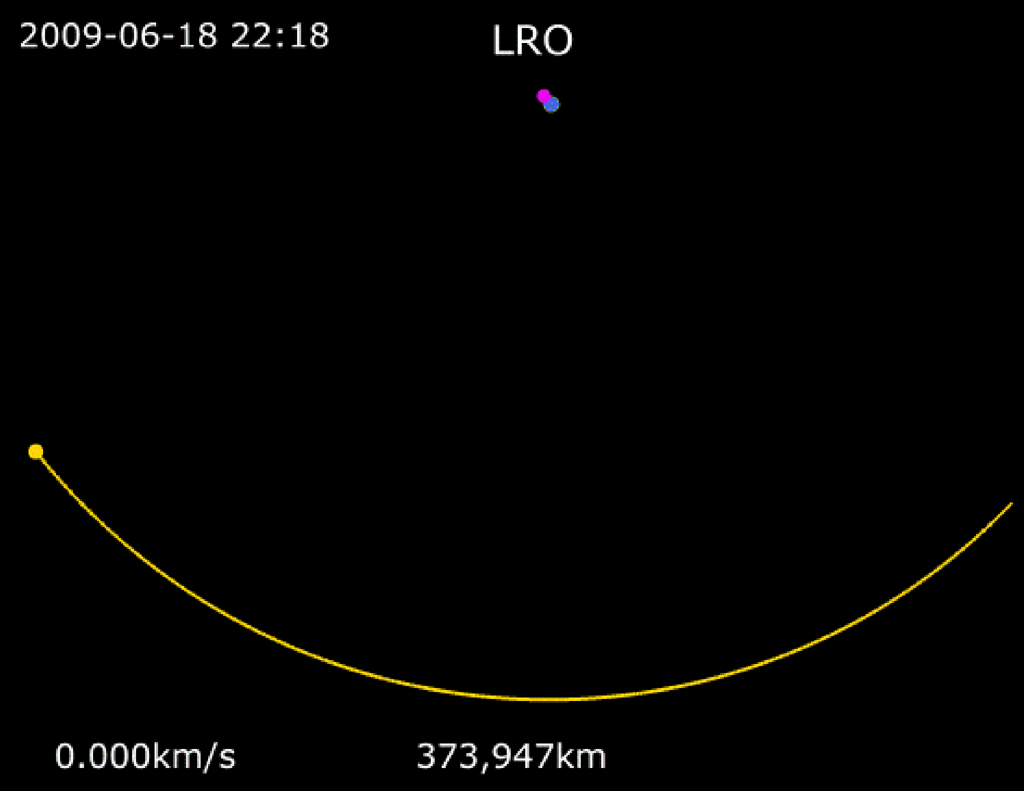
Lunar transfer, perspective view. TLI occurs at the red dot near Earth.

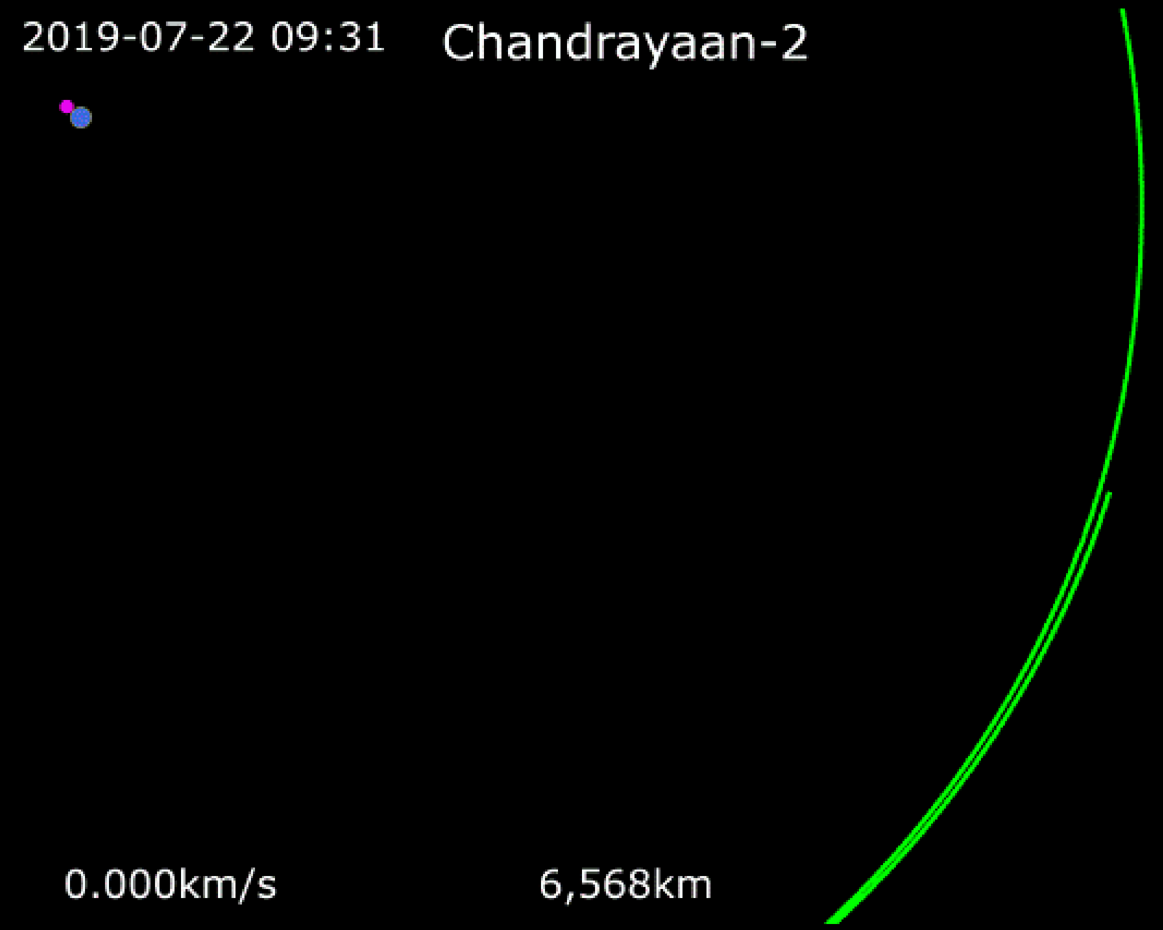


rotational velocity at Cape Canaveral launch site ~ 3.5 km/sec

Earth parking orbit ~ 7.8 km/s

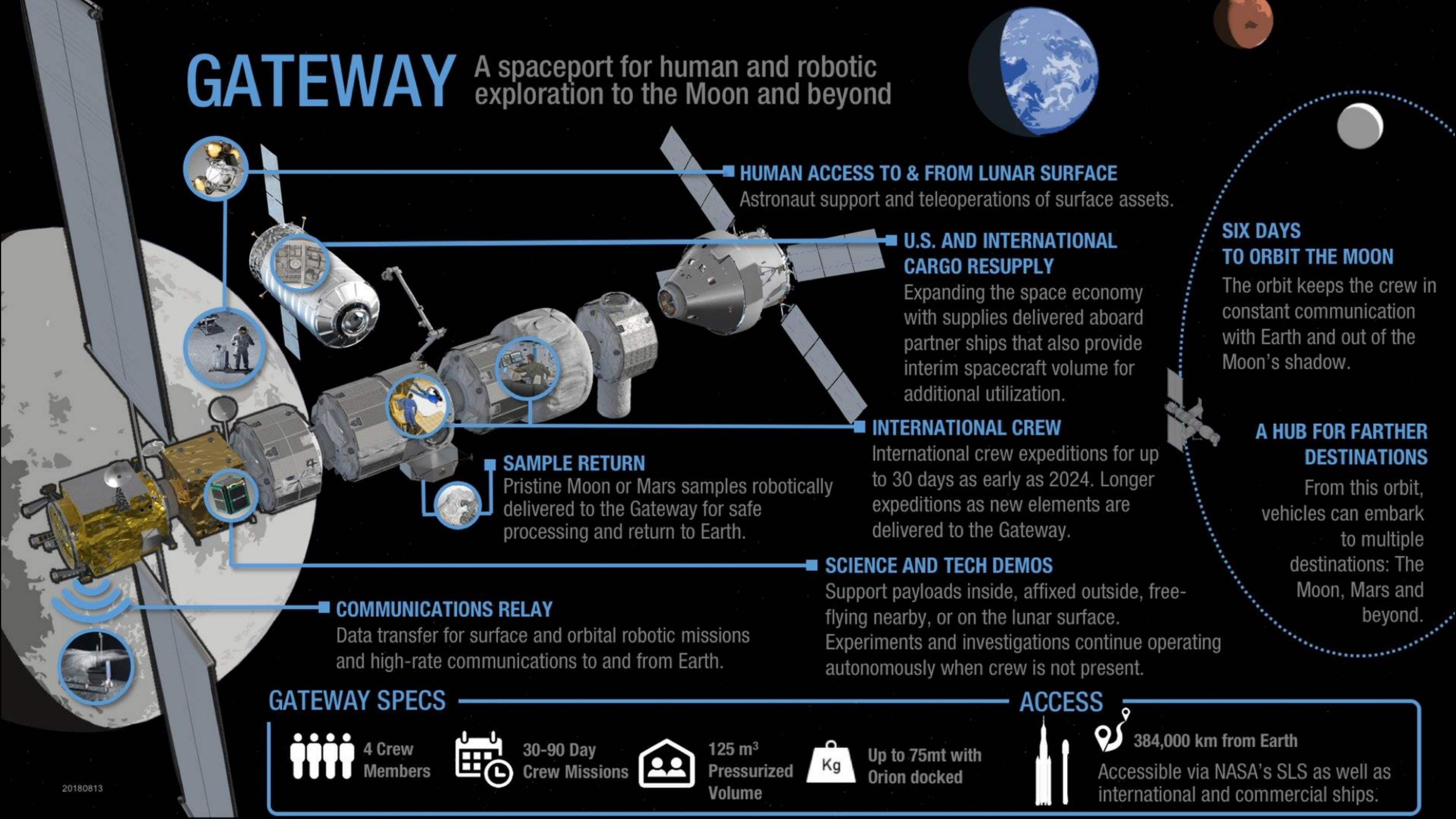
Translunar orbit: spacecraft must get to ~ 10.4 km/sec





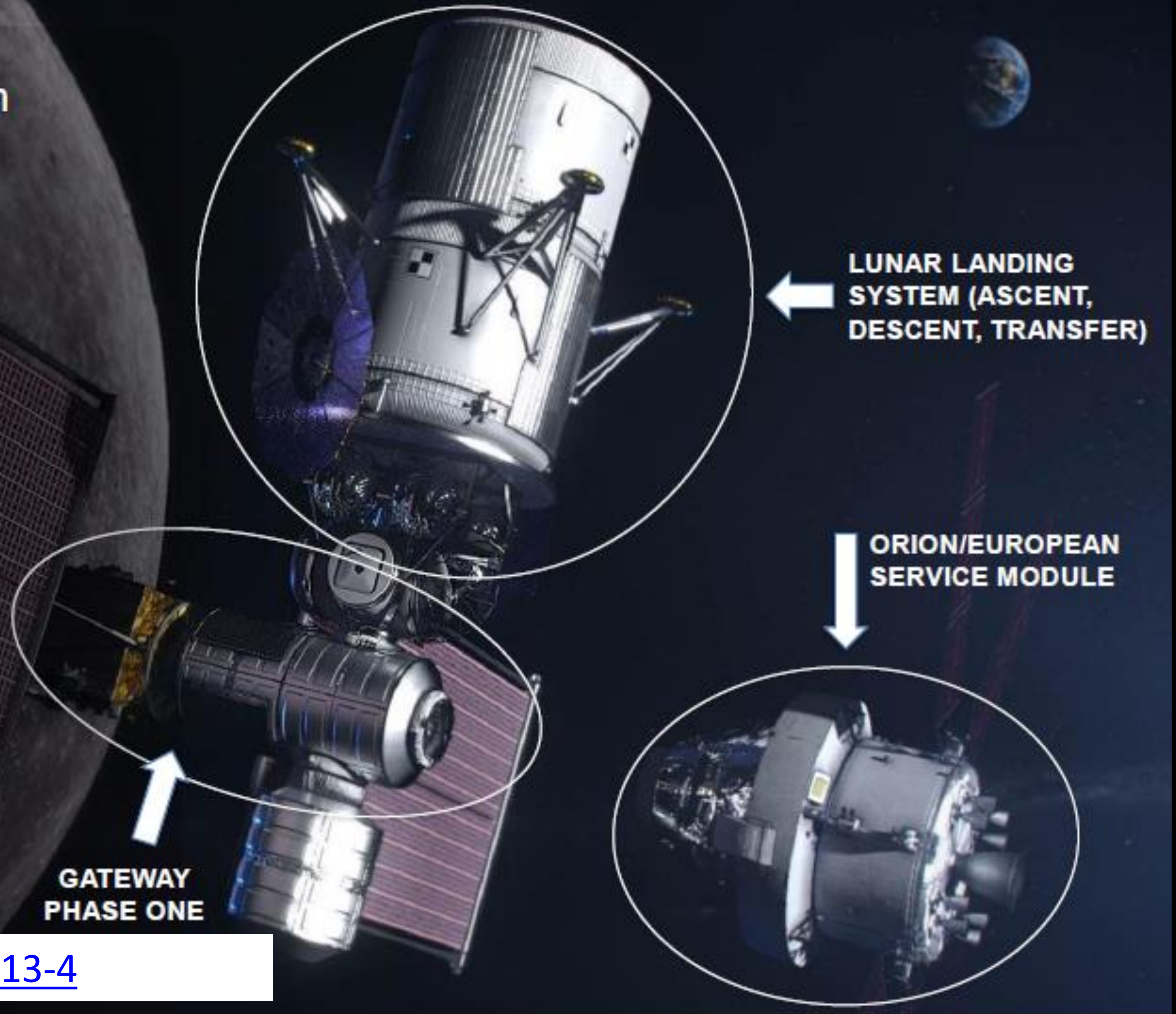
Examples of launching from Earth to LEO, performing Trans Lunar Injection to Keplerian orbit with the Earth and Moon at the two foci.

https://en.wikipedia.org/wiki/Trans-lunar_injection

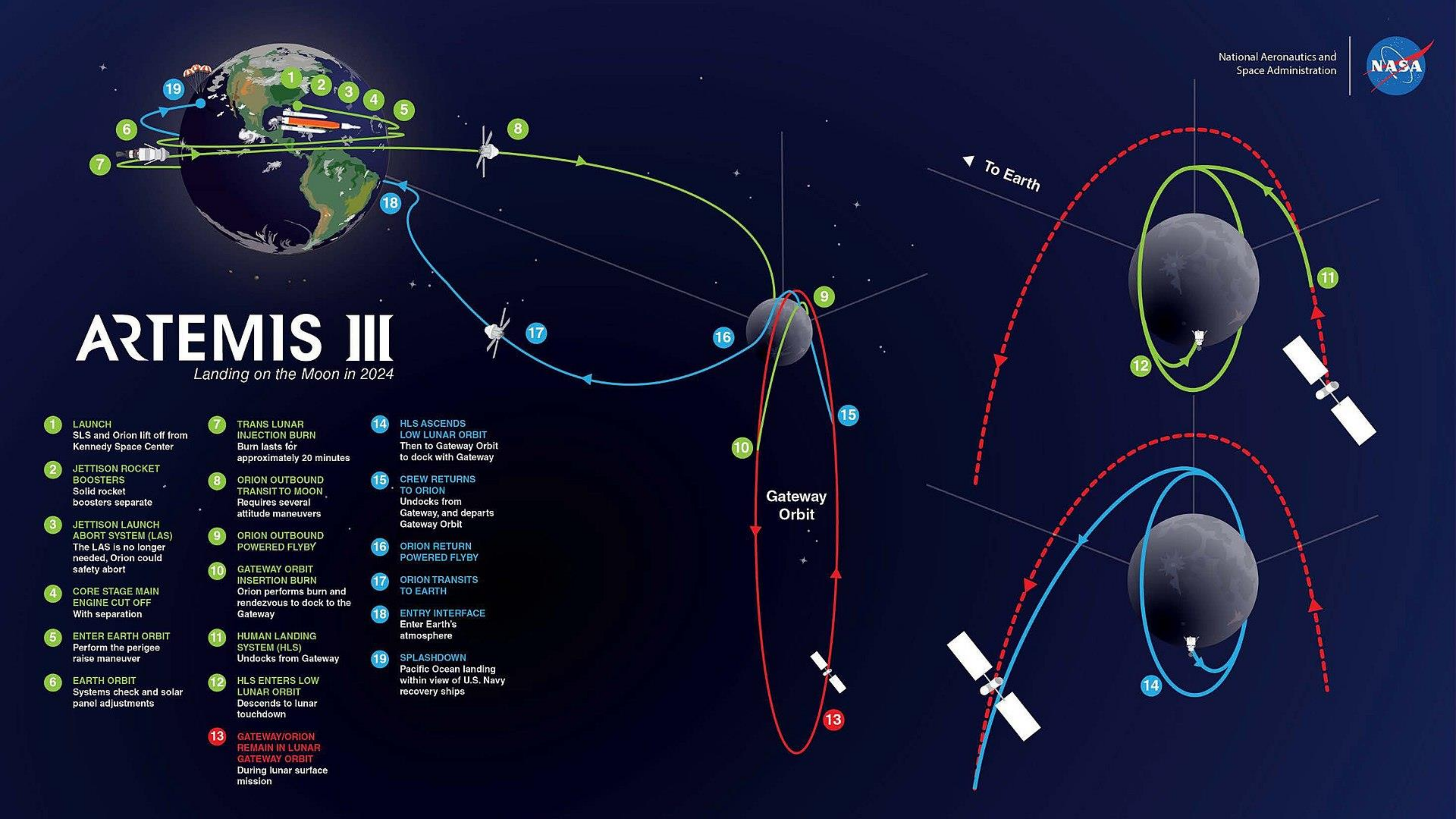

GATEWAY
A spaceport for human and robotic exploration to the Moon and beyond
HUMAN ACCESS TO & FROM LUNAR SURFACE
Astronaut support and teleoperations of surface assets.
U.S. AND INTERNATIONAL CARGO RESUPPLY
Expanding the space economy with supplies delivered aboard partner ships that also provide interim spacecraft volume for additional utilization.
INTERNATIONAL CREW
International crew expeditions for up to 30 days as early as 2024. Longer expeditions as new elements are delivered to the Gateway.
SAMPLE RETURN
Pristine Moon or Mars samples robotically delivered to the Gateway for safe processing and return to Earth.
SCIENCE AND TECH DEMOS
Support payloads inside, affixed outside, free-flying nearby, or on the lunar surface. Experiments and investigations continue operating autonomously when crew is not present.
COMMUNICATIONS RELAY
Data transfer for surface and orbital robotic missions and high-rate communications to and from Earth.
SIX DAYS TO ORBIT THE MOON
The orbit keeps the crew in constant communication with Earth and out of the Moon's shadow.
A HUB FOR FARTHER DESTINATIONS
From this orbit, vehicles can embark to multiple destinations: The Moon, Mars and beyond.
GATEWAY SPECS
4 Crew Members
30-90 Day Crew Missions
125 m³ Pressurized Volume
Kg
Up to 75mt with Orion docked
ACCESS
384,000 km from Earth
Accessible via NASA's SLS as well as international and commercial ships.
20180813

Gateway Enables Exploration of the Moon and Mars

- Initial Gateway focuses on the minimum systems required to support a 2024 human lunar landing while also supporting Phase 2
- Provides command center and aggregation point for 2024 human landing
- Establishes strategic presence around the Moon – US in the leadership role
- Creates resilience and robustness in the lunar architecture
- Open architecture and interoperability standards provides building blocks for partnerships and future expansion



https://www.youtube.com/watch?v=_T8cn2J13-4


National Aeronautics and Space Administration
NASA
ARTEMIS III
Landing on the Moon in 2024
1 LAUNCH
SLS and Orion lift off from Kennedy Space Center
2 JETTISON ROCKET BOOSTERS
Solid rocket boosters separate
3 JETTISON LAUNCH ABORT SYSTEM (LAS)
The LAS is no longer needed, Orion could safety abort
4 CORE STAGE MAIN ENGINE CUT OFF
With separation
5 ENTER EARTH ORBIT
Perform the perigee raise maneuver
6 EARTH ORBIT
Systems check and solar panel adjustments
7 TRANS LUNAR INJECTION BURN
Burn lasts for approximately 20 minutes
8 ORION OUTBOUND TRANSIT TO MOON
Requires several attitude maneuvers
9 ORION OUTBOUND POWERED FLYBY
10 GATEWAY ORBIT INSERTION BURN
Orion performs burn and rendezvous to dock to the Gateway
11 HUMAN LANDING SYSTEM (HLS)
Undocks from Gateway
12 HLS ENTERS LOW LUNAR ORBIT
Descends to lunar touchdown
13 GATEWAY/ORION REMAIN IN LUNAR GATEWAY ORBIT
During lunar surface mission
14 HLS ASCENDS LOW LUNAR ORBIT
Then to Gateway Orbit to dock with Gateway
15 CREW RETURNS TO ORION
Undocks from Gateway, and departs Gateway Orbit
16 ORION RETURN POWERED FLYBY
17 ORION TRANSITS TO EARTH
18 ENTRY INTERFACE
Enter Earth's atmosphere
19 SPLASHDOWN
Pacific Ocean landing within view of U.S. Navy recovery ships
Gateway Orbit
To Earth

Achieving 2024 – A Parallel Path to Success

Artemis will see government and commercial systems moving in parallel to complete the architecture and deliver crew

CREW

NASA Programs SLS and Orion

Artemis 1

First flight test of SLS and Orion as an integrated system

Artemis 2

First flight of crew to the Moon aboard SLS and Orion

Artemis 3

First crew to the lunar surface; Logistics delivered for 2024 surface mission

Between now and 2024, U.S. industry delivers the launches and human landing system necessary for a faster return to the Moon and sustainability through Gateway.

Commercially Provided Elements

CARGO

PPE

Power and Propulsion Element arrives at NRHO via commercial rocket

Pressurized Module

Small area for crew to check out systems prior to lunar transfer and decent

Human Landing System

Transfer

Transfers lander from Gateway to low lunar orbit

Descent

Descends from Transfer Vehicle to lunar surface

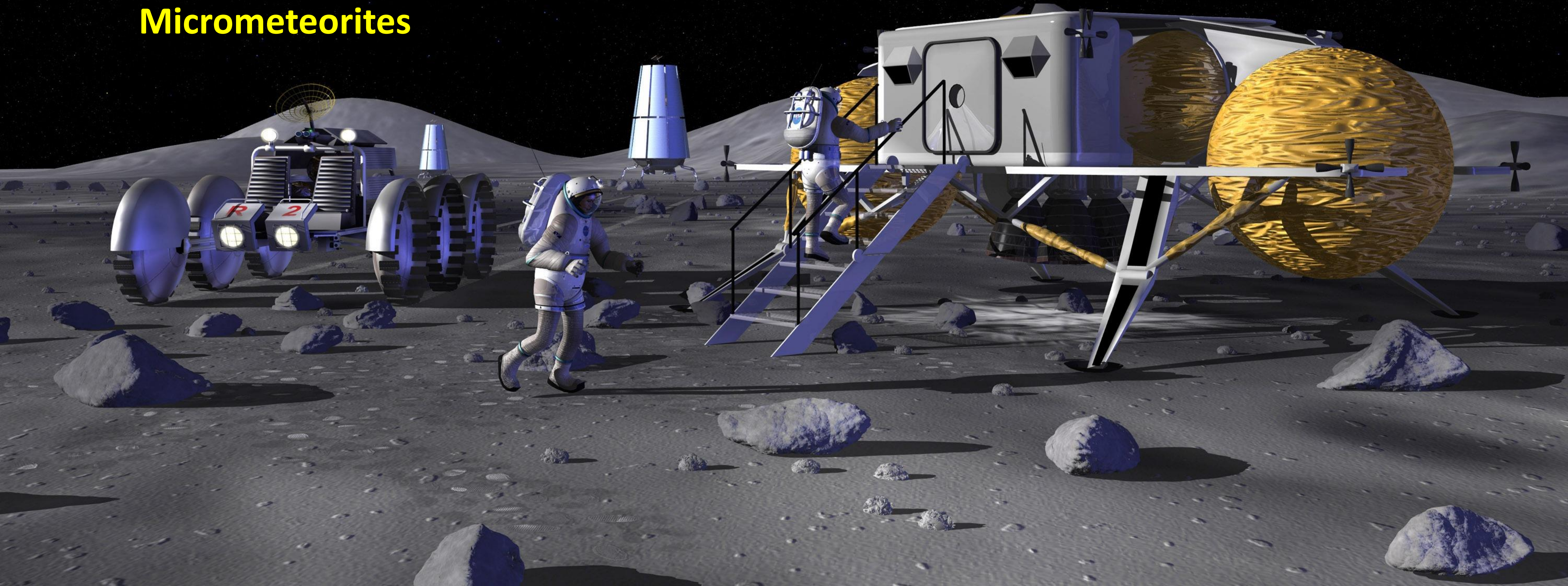
Ascent

Ascends from lunar surface to Gateway

Up to three commercial rocket launches, depending on distribution of the Transfer, Descent, and Ascent functions.

2. Hazards to overcome in order to survive

- Space radiation
- Lunar regolith
- Low gravity
- Micrometeorites



No long lasting effects on Scott, the twin who spent a year on the ISS.

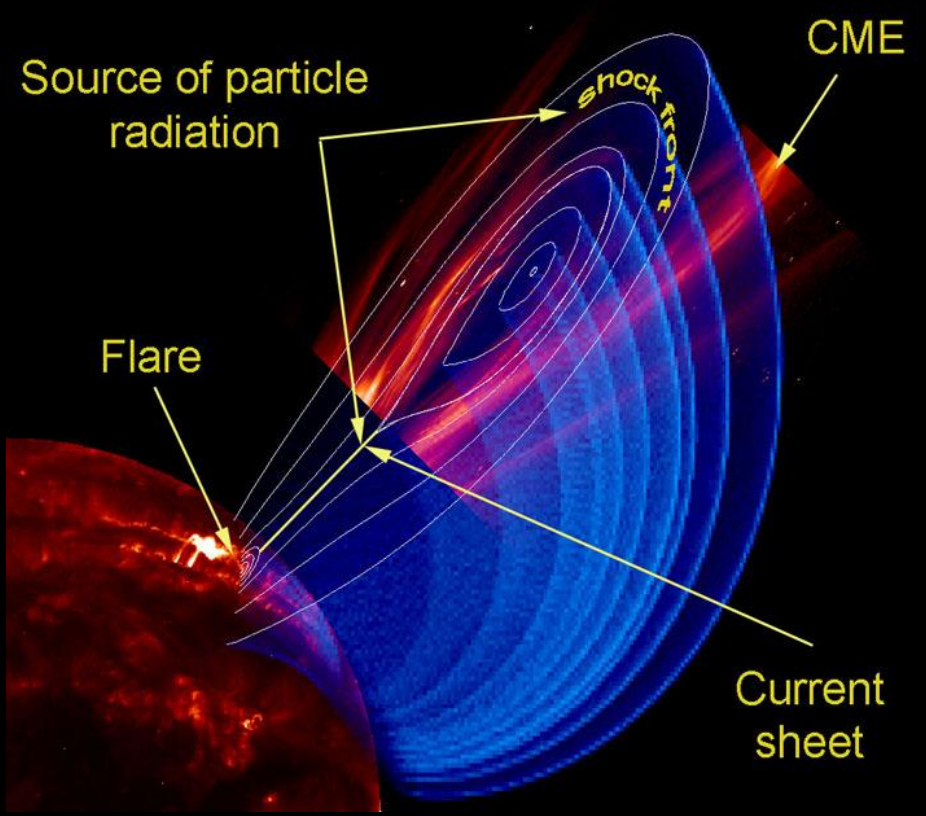
BUT – he was in LEO (Low Earth Orbit), still protected from space radiation by the Earth's magnetic field.

For astronauts going into deep space, they are subject to dangerous radiation.

NASA's Twin Study: Twin astronauts Mark and Scott Kelly. Scott spent one year on the ISS. No changes in his DNA were found, but there were changes in his gene expression.

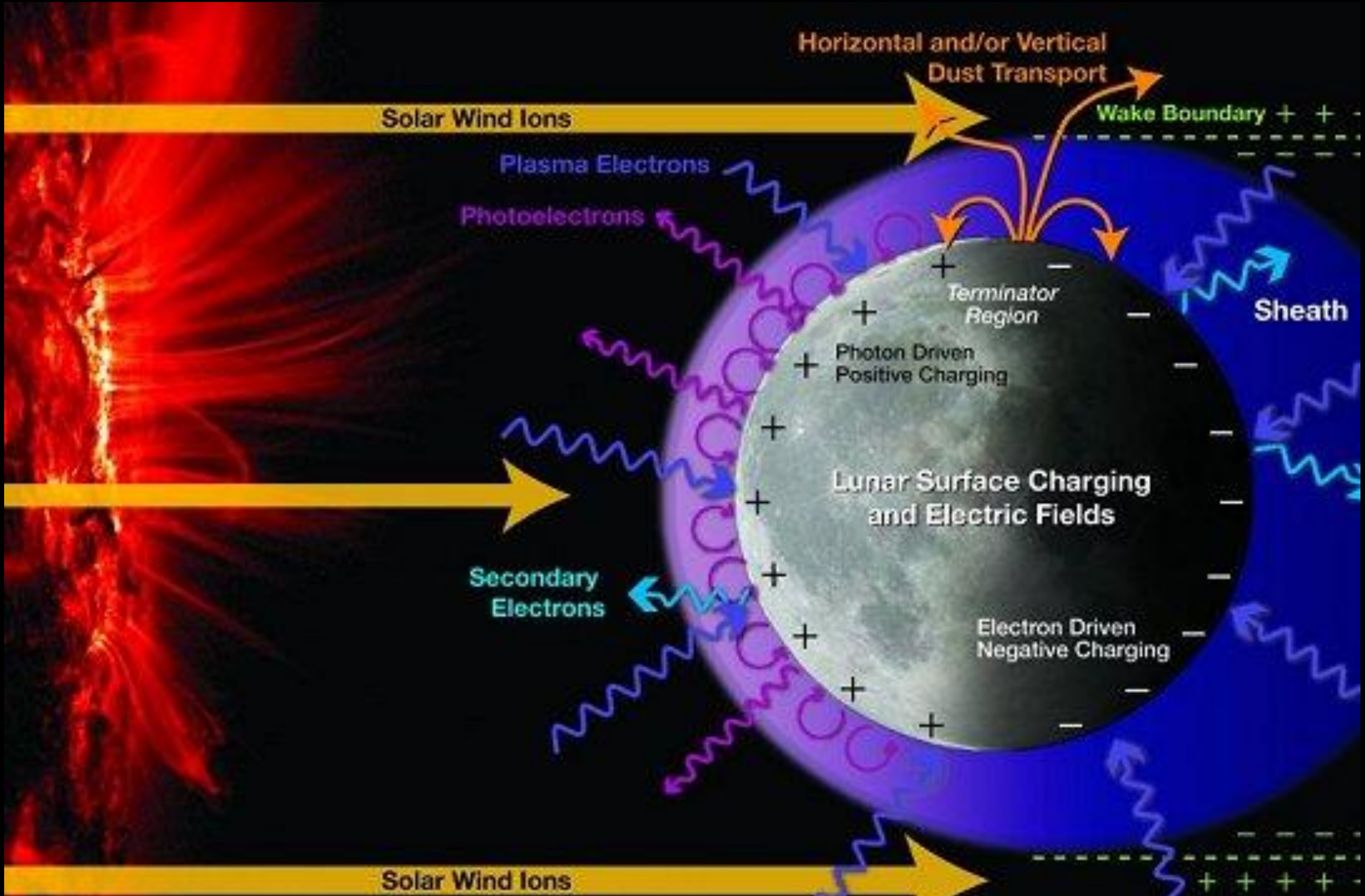
COURTESY NASA

https://www.nasa.gov/feature/positive-negative-or-neutral-it-all-matters-nasa-explains-space-radiation

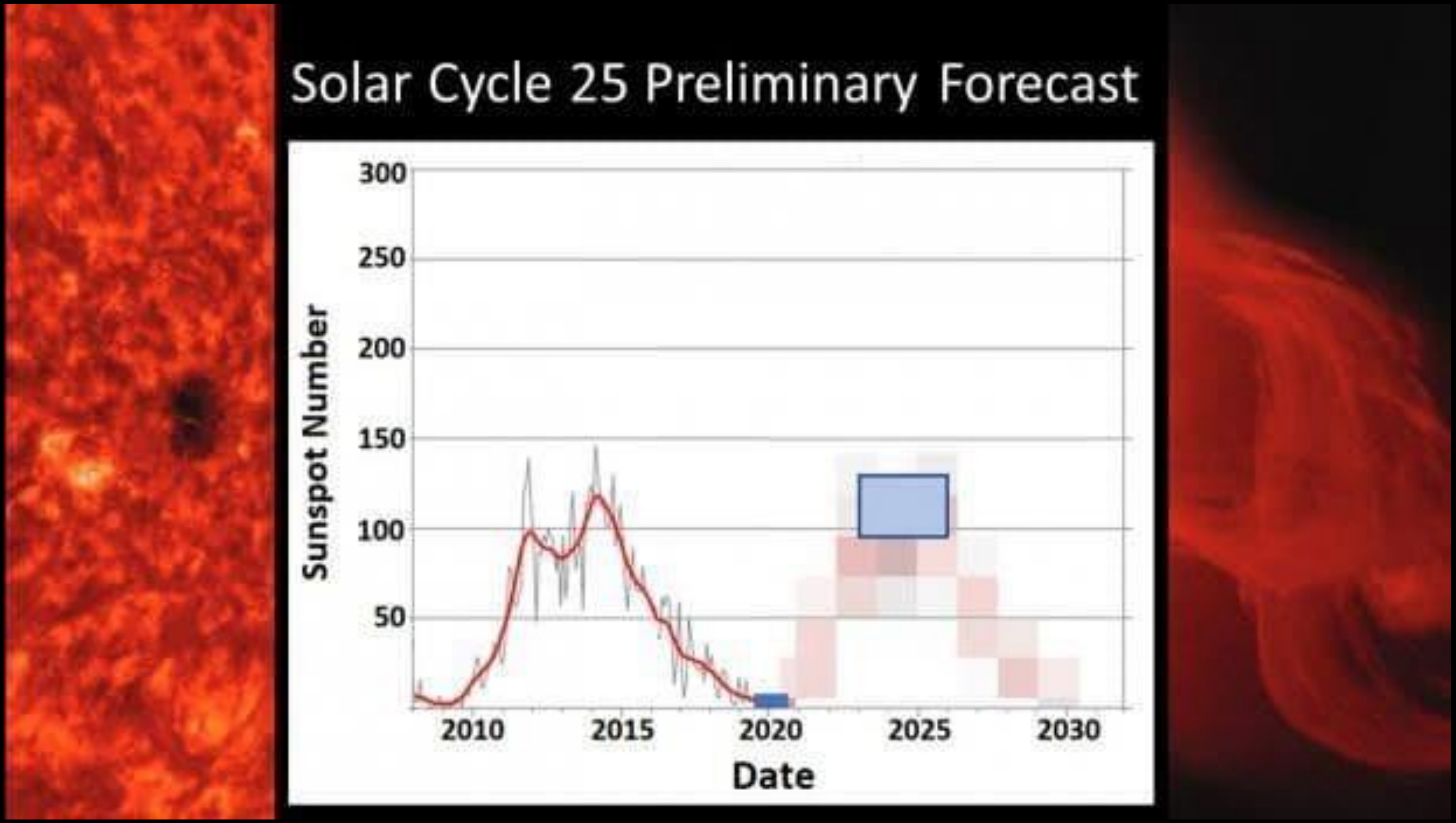


Ionized particles from the Sun

Galactic cosmic rays (GCRs) are of most concern to NASA. It is challenging to shield against GCRs. They come from exploding stars called supernovae.



Lunar surface blasted by radiation from the Sun. Credit: Jasper Halekas and Greg Delory of U.C. Berkeley, and Bill Farrell and Tim Stubbs of the Goddard Space Flight Center



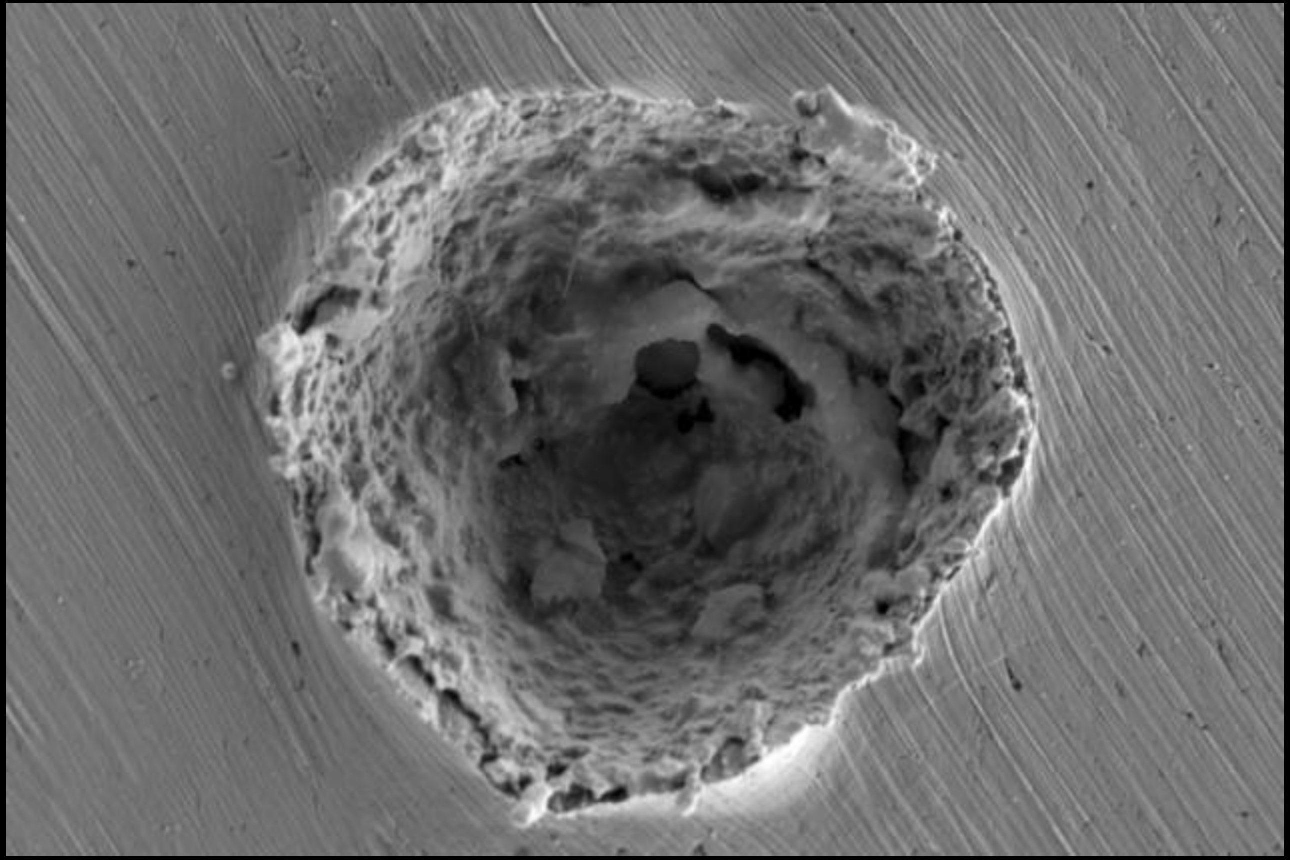
Predicted solar cycle between 2020 and 2024 – solar activity will be increasing, hence more solar wind particles and increased potential for CMEs and solar flare events between 2023 and 2026.
https://www.swpc.noaa.gov/news/solar-cycle-25-preliminary-forecast

Toxicity of lunar regolith:

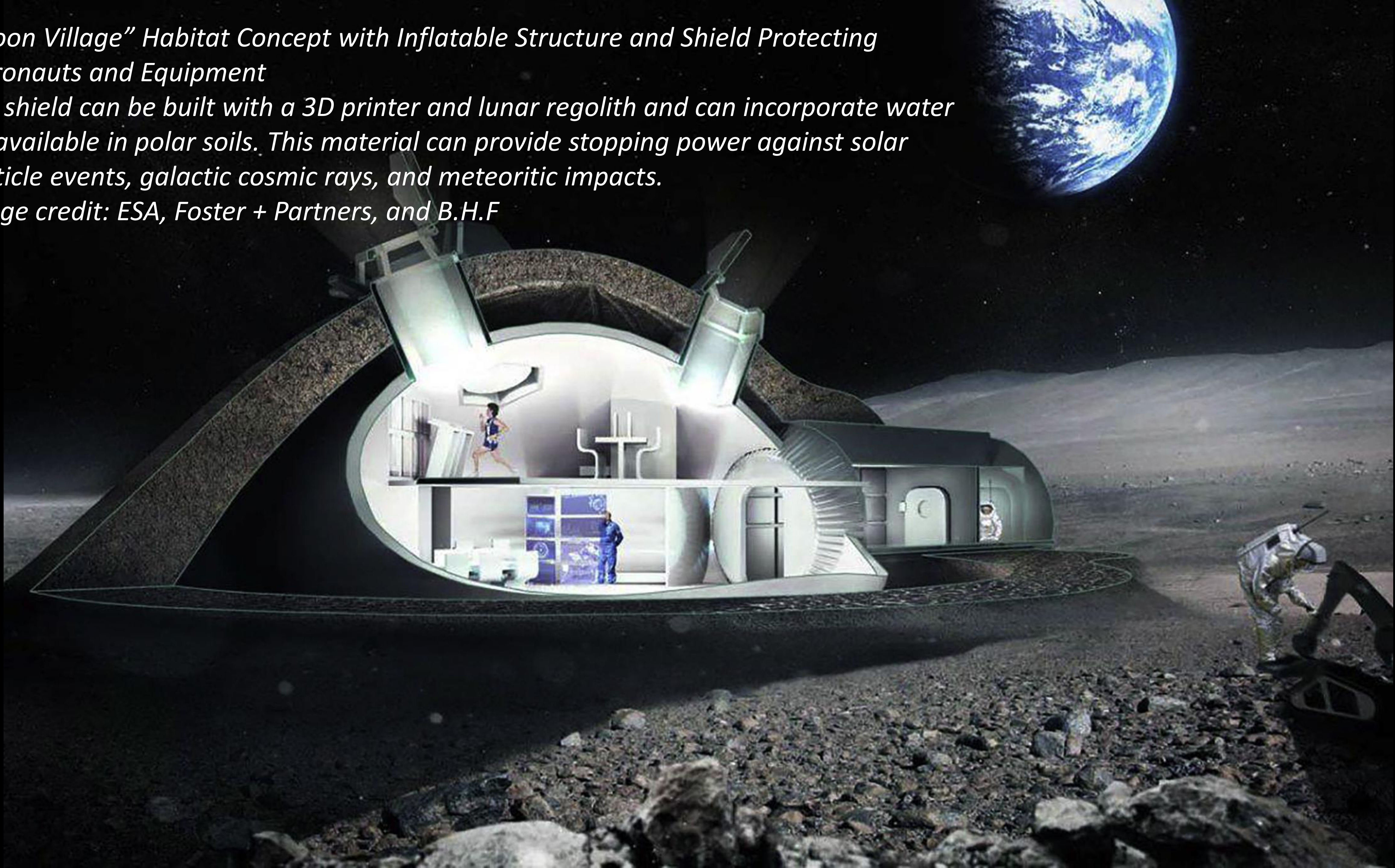
* Eye damage
* Lung damage
* Skin damage

In low g regolith particles are carried more easily by blood stream.

Sharp particles are abrasive to skin, lungs, eyes, and clothing.



Micrometeorite damage to a surface in LEO. Similar damage can occur on the Moon where micrometeorites land at upwards of 10 km/second.



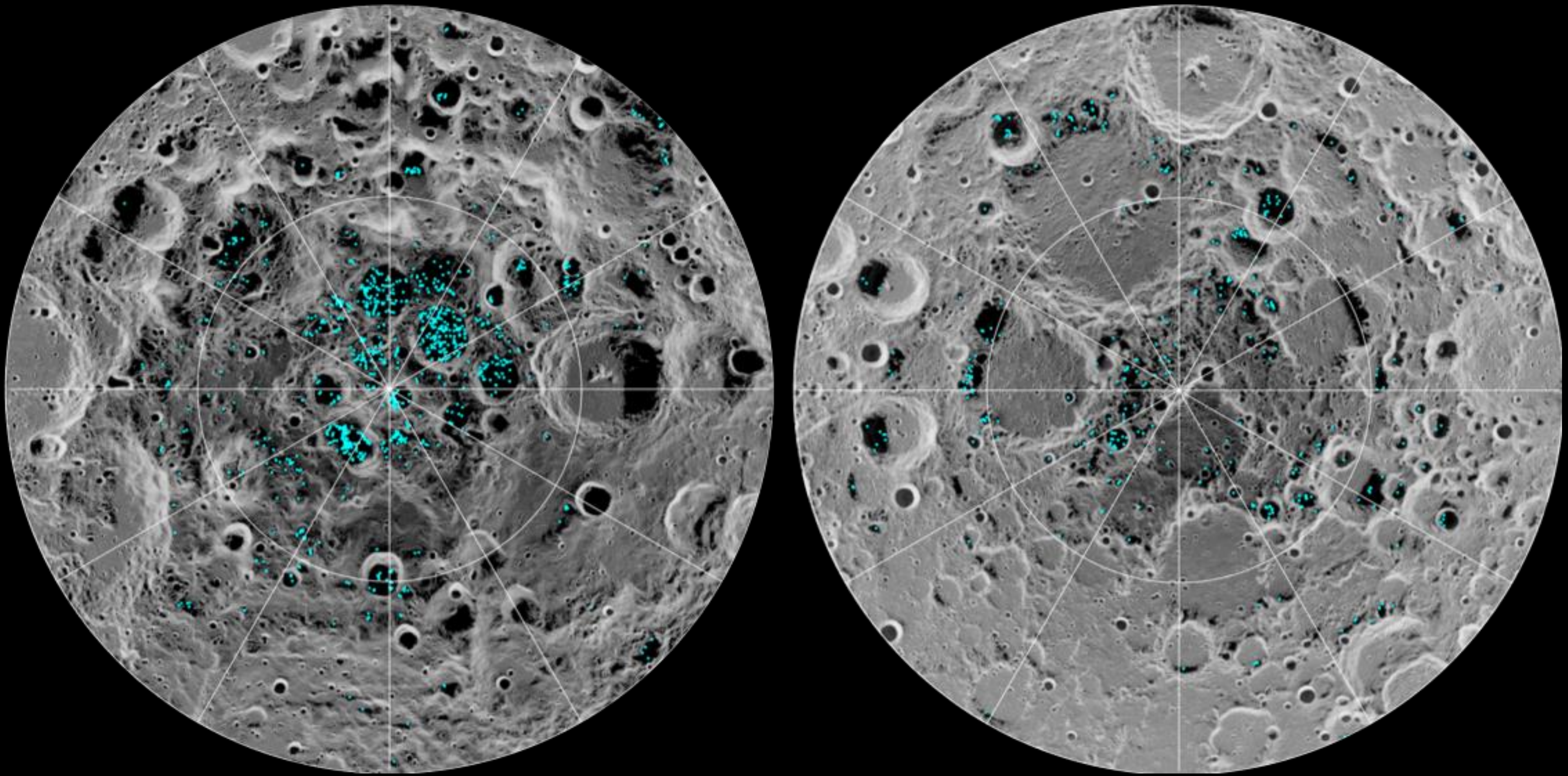
“Moon Village” Habitat Concept with Inflatable Structure and Shield Protecting Astronauts and Equipment

The shield can be built with a 3D printer and lunar regolith and can incorporate water ice available in polar soils. This material can provide stopping power against solar particle events, galactic cosmic rays, and meteoritic impacts.

Image credit: ESA, Foster + Partners, and B.H.F

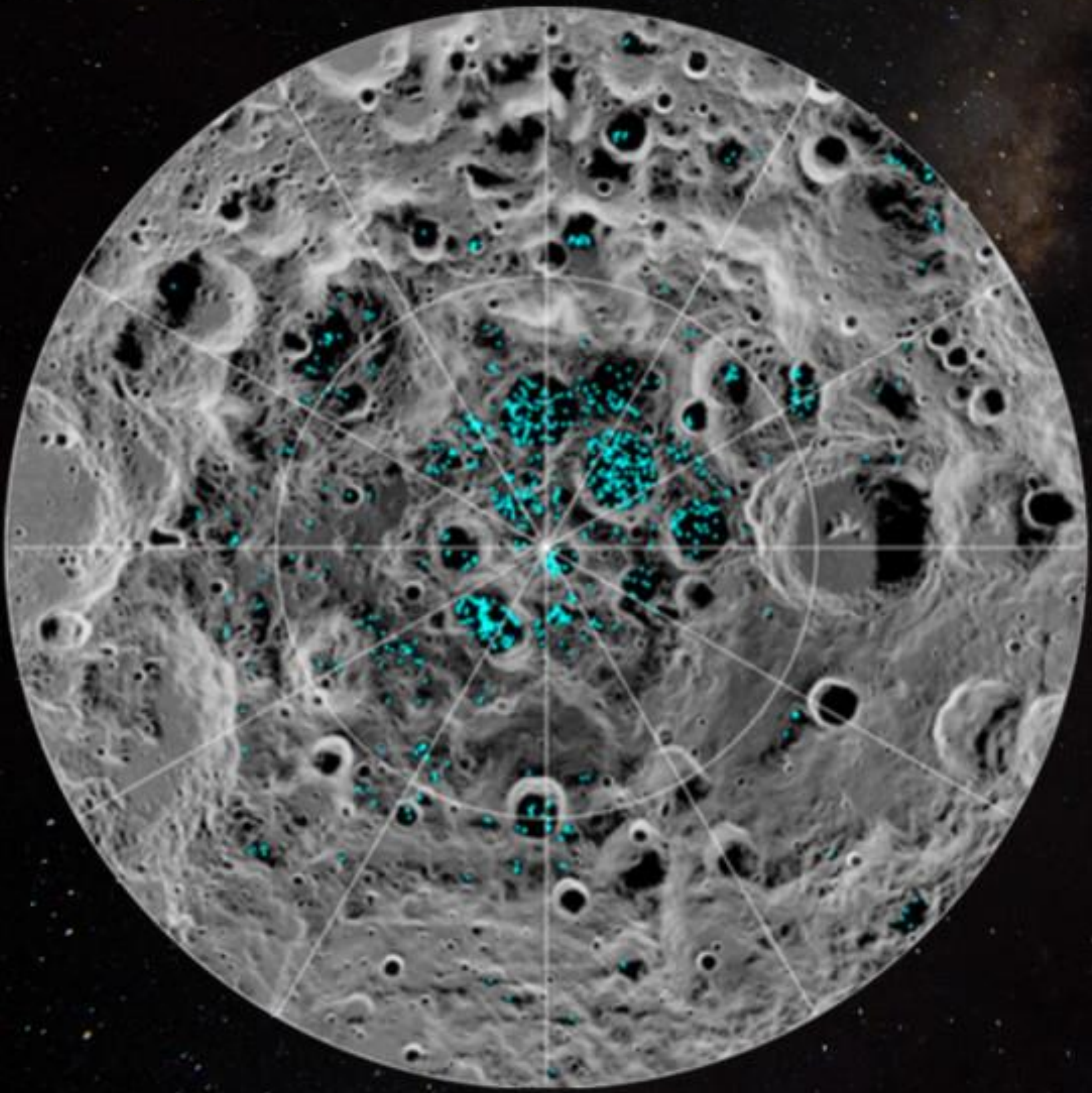
1.5 metric ton block at ESTEC in Noordwyk was 3D printed from lunar regolith simulant.

3. Likely places to develop a human colony on the Moon

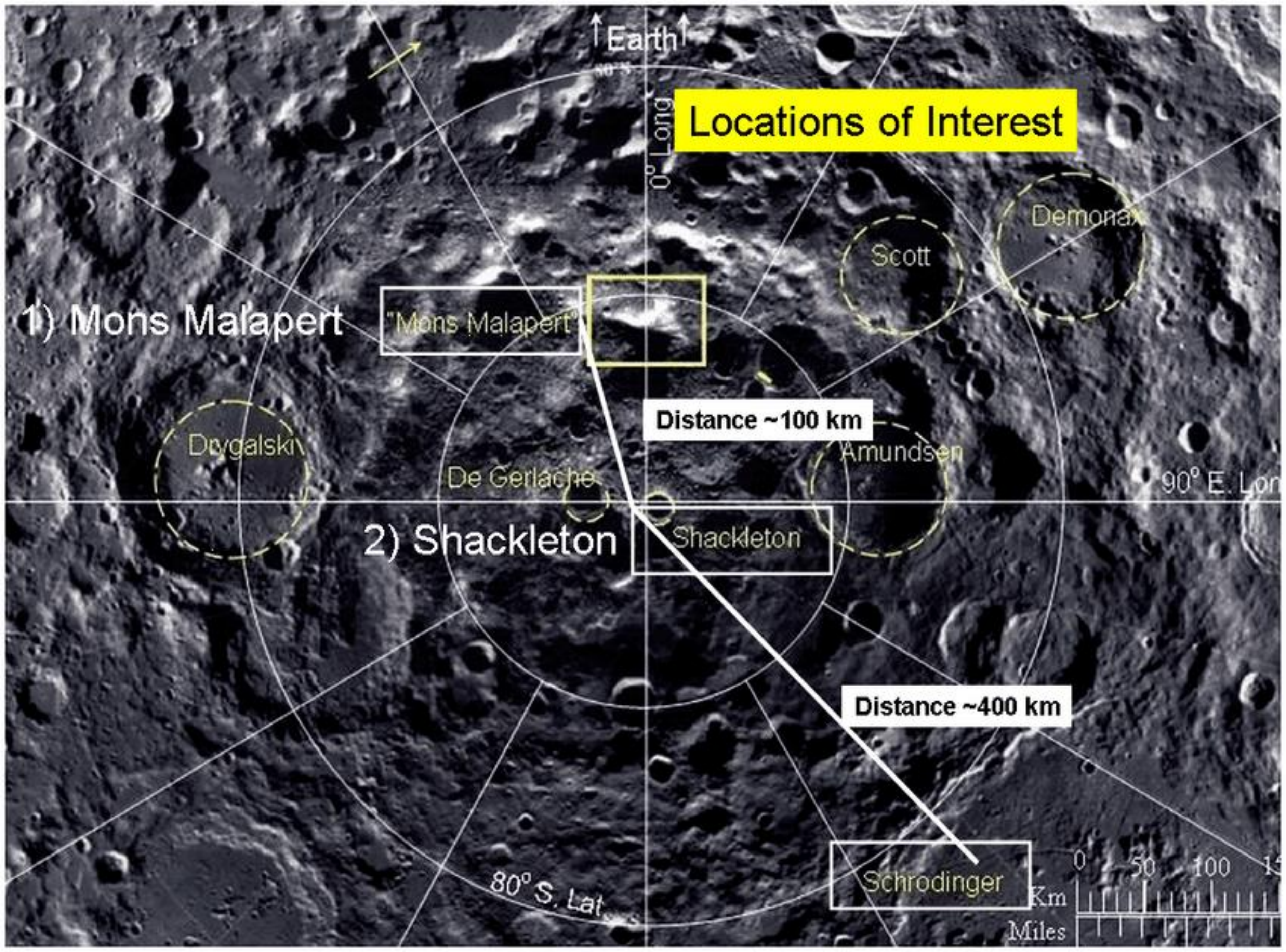


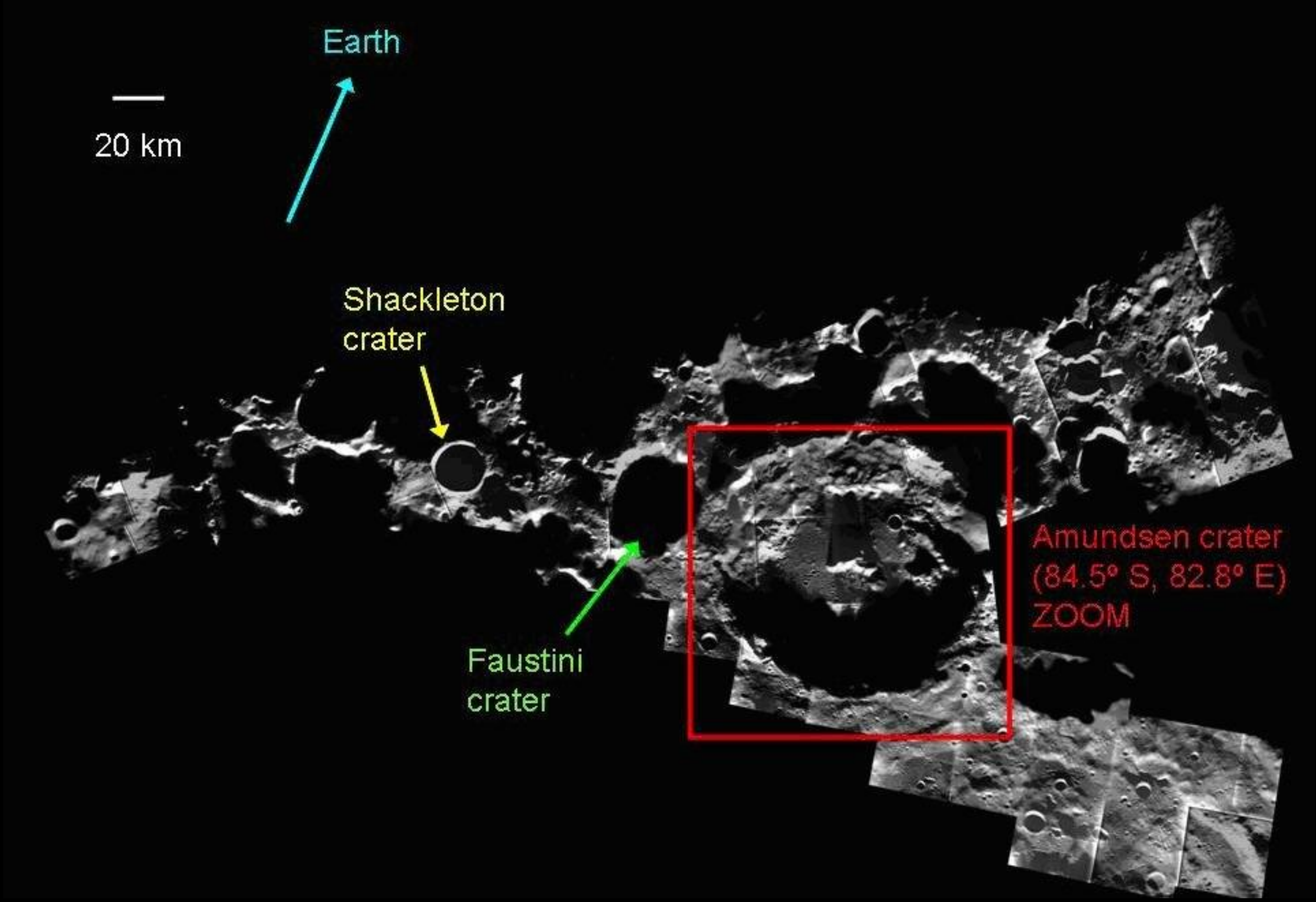
ICE CONFIRMED AT THE MOON'S POLES

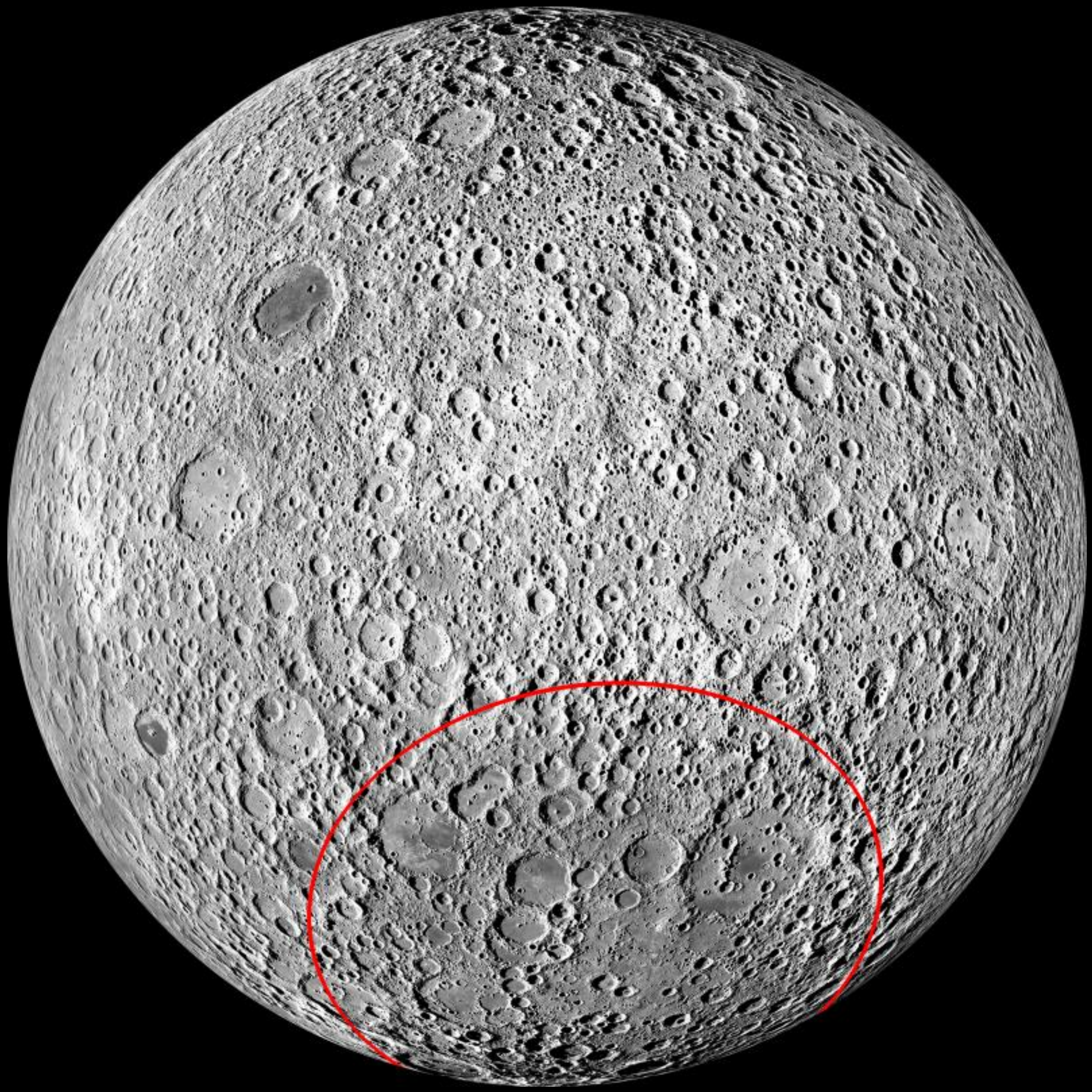
- Scientists have observed evidence of lots of ice in craters on the South Pole of the moon.
- Nasa is aiming to send astronauts here by 2024 with a reusable lunar landing system.



- The presence of ice means that moon water could potentially be used as a resource for future missions.
- Moon water could help astronauts explore the moon for longer or even stay there.


Earth
Locations of Interest
0° Long
80° S. Lat
90° E. Lon
1) Mons Malapert
"Mons Malapert"
Scott
Demonax
Distance ~100 km
Drygalski
De Gerlache
Amundsen
2) Shackleton
Shackleton
Distance ~400 km
Schrodinger
Km
Miles
0
50
100


Earth
20 km
Shackleton crater
Faustini crater
Amundsen crater (84.5° S, 82.8° E) ZOOM

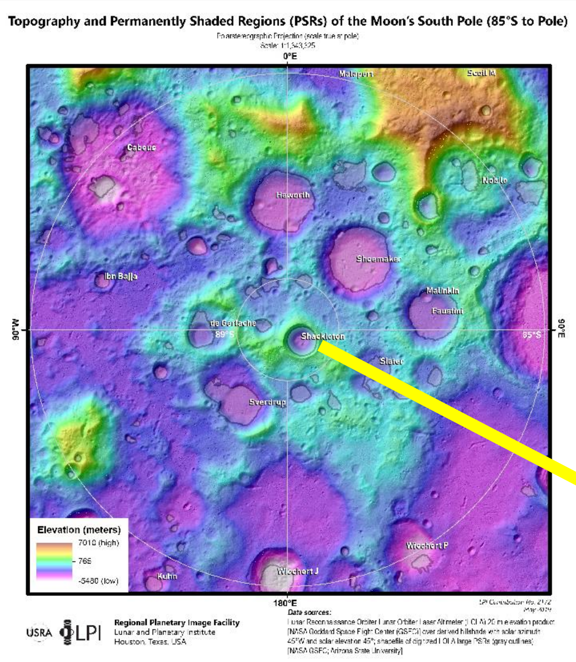


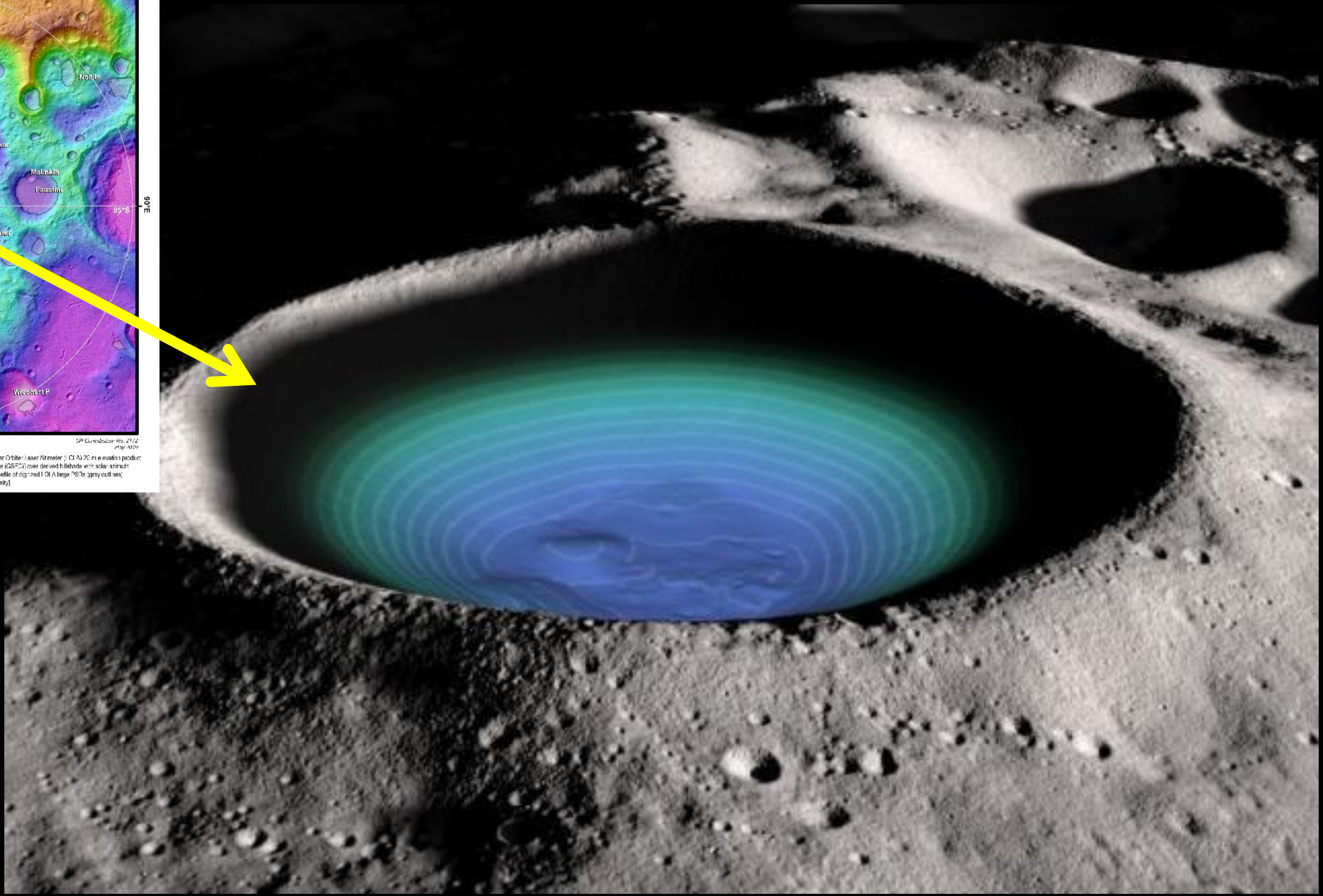
South Pole – Aitken Basin structure

6,000 – 15,000 km^2 in south pole craters are in permanent shadow.

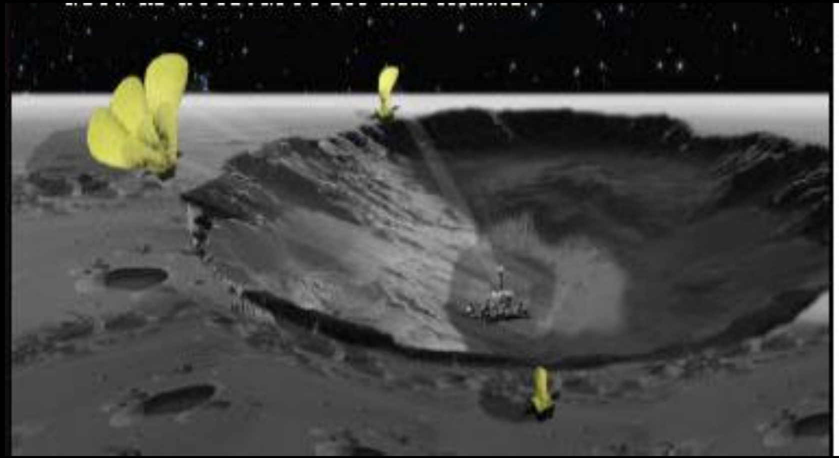
Aitken Basin is a giant impact crater, ~2500 km across and 12 km deep at its lowest point.

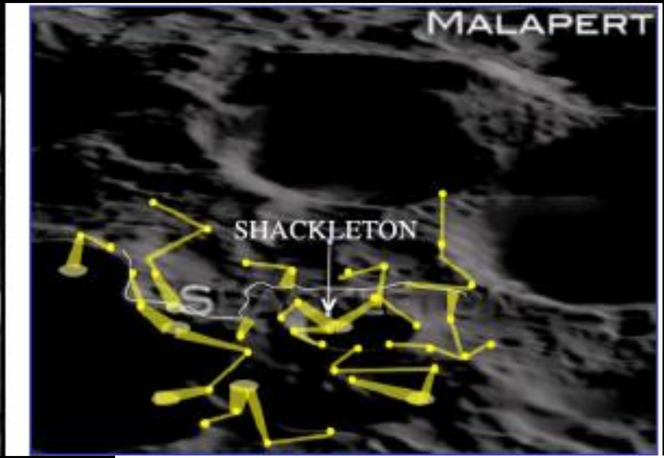
Likely contains numerous PSRs with water and other volatiles, and possibly mantle materials churned up by the impact.





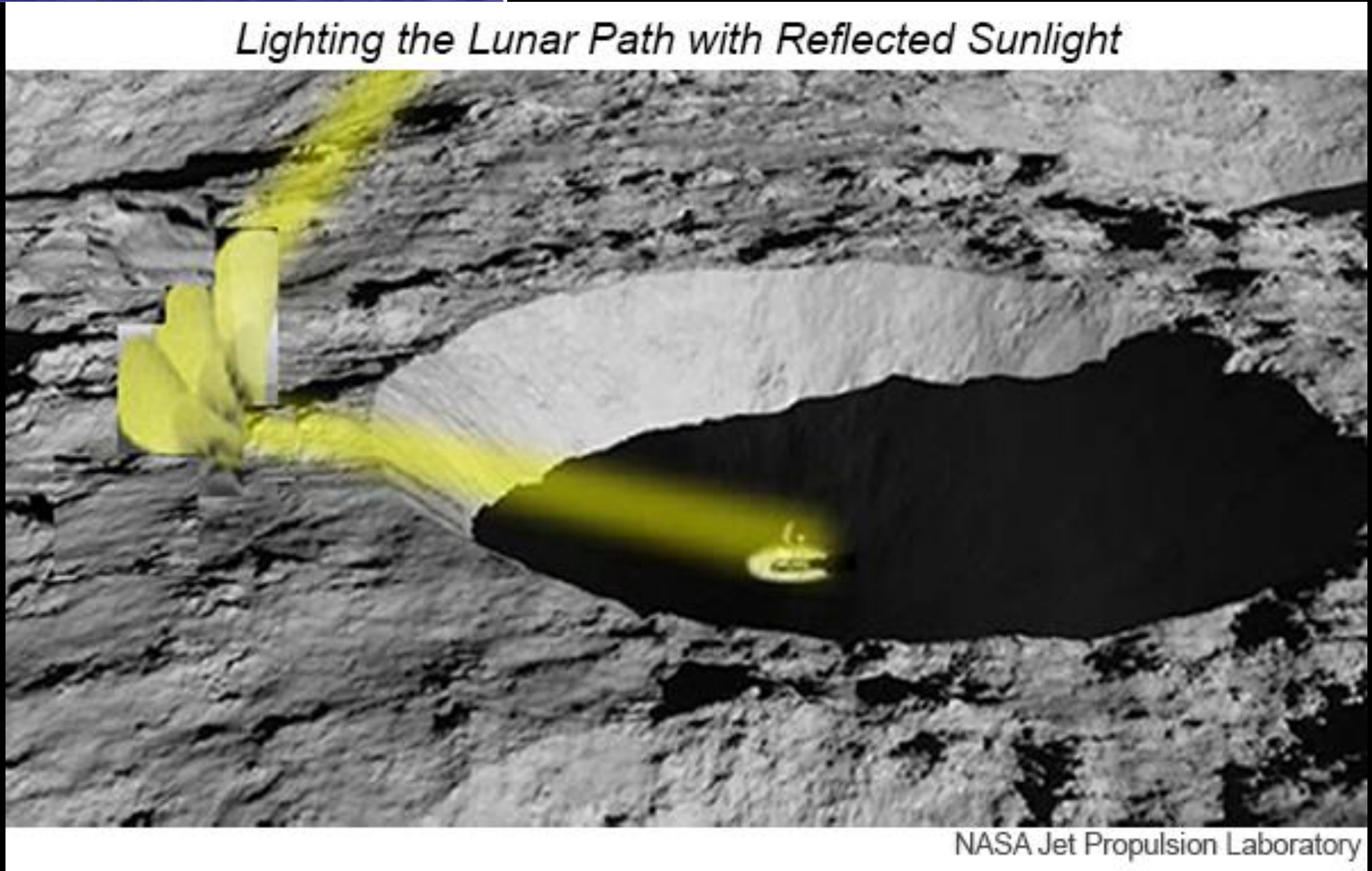
Shakelton Crater at the Lunar South Pole – interior is completely in shadow. This crater has been named as a potential site for NASA's lunar outpost.

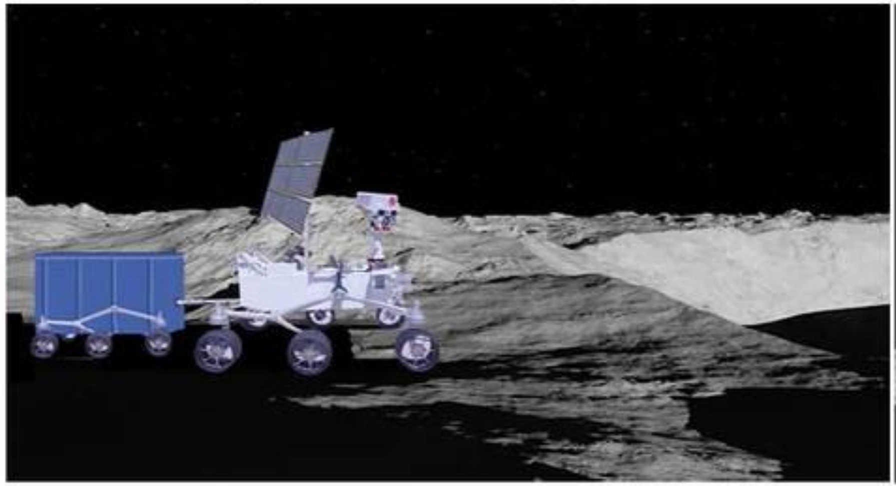




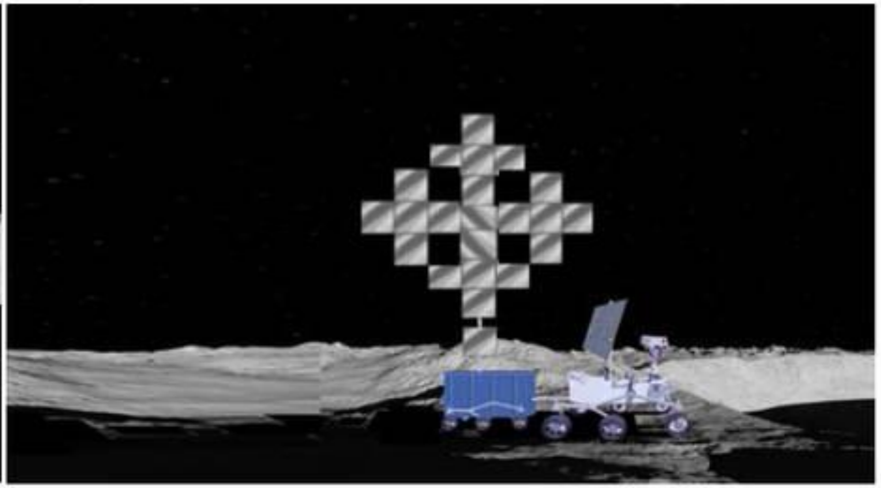
https://www.nasa.gov/feature/trans-formers-for-lunar-extreme-environments-ensuring-long-term-operations-in-regions-of/

Illuminating Shakleton Crater

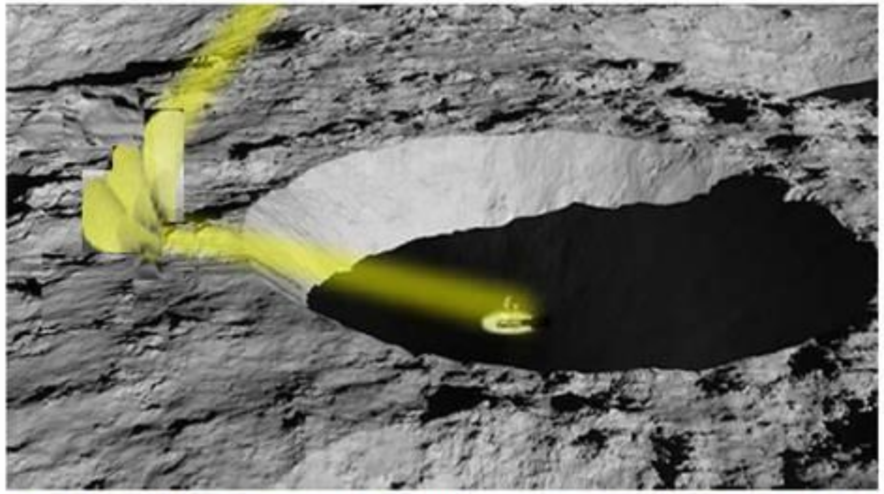




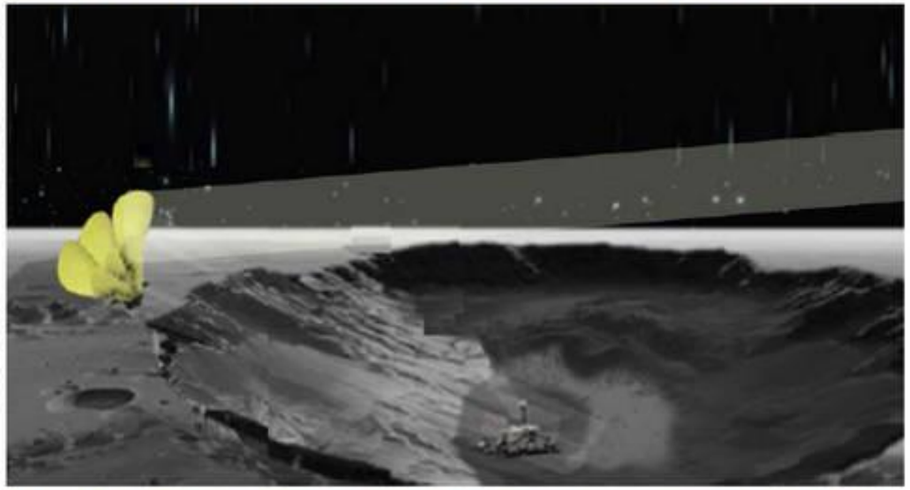
The rover makes its way out of the landing module, transporting a compactly folded TF, and approaches the rim.



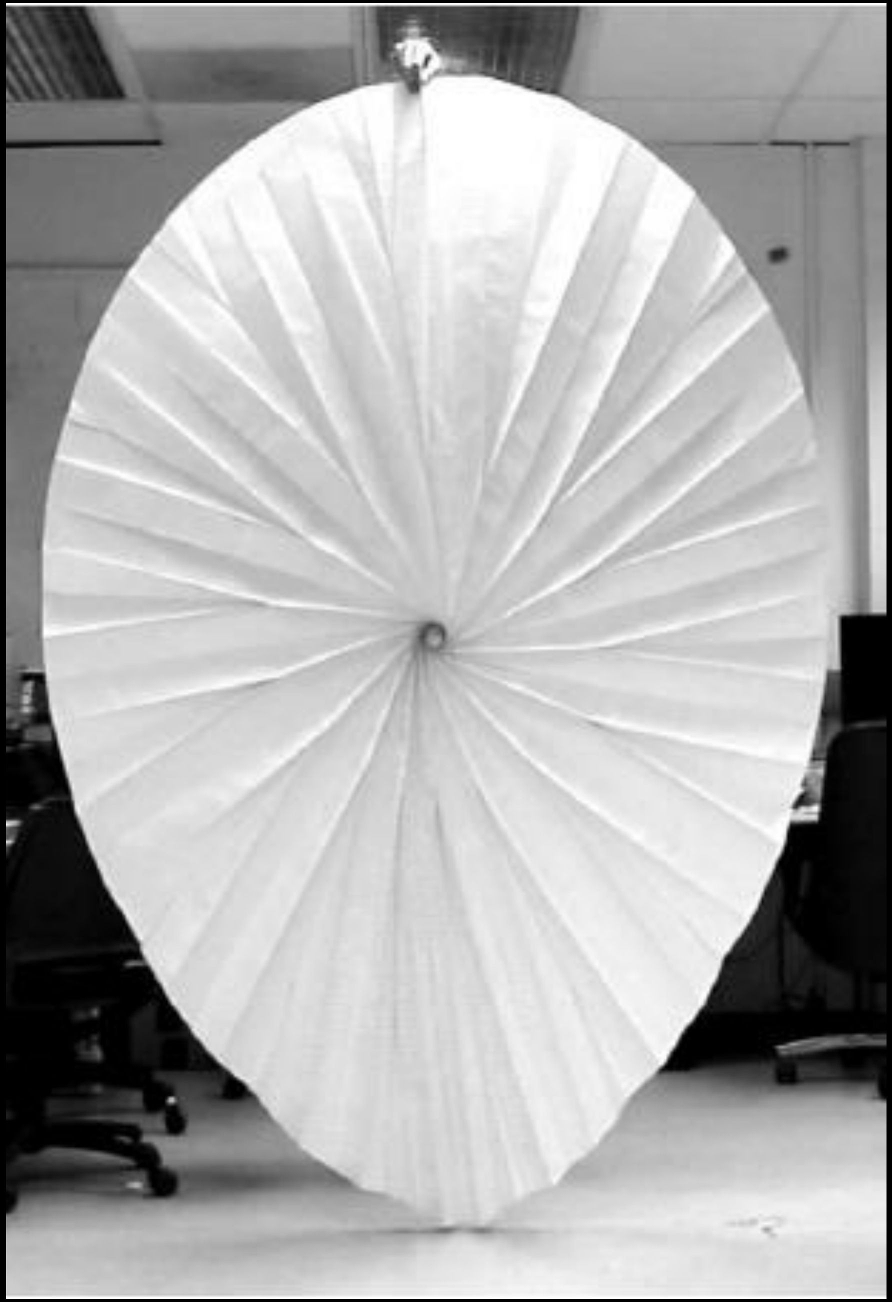
The TF unfolds to reflect sunlight into the crater—it is placed at a location that provides line-of-sight coverage of the planned ER path, and, under its own actuation, adjusts its position/posture for improved stability, A crosslet origami unfolding is depicted.



The ER starts its descent into the crater. The TF continuously tracks the ER, lighting its path with reflected sunlight. As the ER reaches areas with ambient temperatures below 100K, it is powered and warmed by the TF projected energy.



The TF continuously adapts its reflector shape, precisely tracking the moving ER, pointing the reflected energy onto its solar arrays, and controlling the beam as required for the ER to examine its surroundings and to take measurements.



Make solar panels out of very thin PV material which can be folded for transport.

ESA: Building a Moon Base

https://www.esa.int/ESA_Multimedia/Videos/2016/02/ESA_Euronews_Moon_Village