Artemis III EVA Mission Capability for de Gerlache-Shackleton Ridge

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Background

- NASA has committed to sending humans to the Moon no earlier than 2025
- Mission objectives will be scientific, commercial, industrial, inspirational, and explorational.
- Achieving goals will depend upon a balance of competing priorities and constraints:
  - Technical capabilities of lander, spacesuit, tools, and human
  - Mission priorities: tech demos, science, public outreach
  - Lunar mission location:
    - Terrain acceptability for lander and EVA traverse
    - Landing proximity to areas of geological interest
    - Communications and navigation capabilities
    - Thermal environment and solar illumination
- Will astronauts be able to collect H_2O or other volatiles on EVA 1?
- Are there potential geological unit boundaries near proposed landing?

Credit: NASA

Approach

- Determine vehicle and suit hardware limitations using requirements documents for Human Landing System (HLS) and suit (xEVA)
  - These assumptions may be conservative if actual hardware exceeds requirements
- Assess science and other mission objective priorities during spacewalks
- Identify possible landing location that meets hardware requirements using LROC NAC and LOLA images
  - Determine proximity to craters for potential volatile sampling
  - Determine if potential geological unit boundaries may be near landing area based on changes in crater density

Assumptions and Data Sources

- The Human Landing System will have slope tolerance that is at least 8 degrees. This limit is inferred from [1] HLS-S-R-0071 Surface Operations Vertical Orientation
- Astronaut in suit must be able to walk up, down, across a 20-degree slope [2]
- The xEVA suit shall operate:
  - For a minimum of 8 hours of EVA operation [2]. Nominal EVA excursion is 6 hours +/- 2 hours. [3]
  - For 1 hour of contingency capability to protect suit system failures. [3]
  - After exposure to 2 hours of the thermal environment of Permanently Shadowed Regions (PSRs)
- Walking rate = 2km/hr. [4]
- Distance from lander limited by contingency return capability. Walking distance = 1.67 km, expected radial distance = 1.38 km [4]
- Time percentage in solar illumination at studied landing location = 56.1% annually [5]

Landing Location

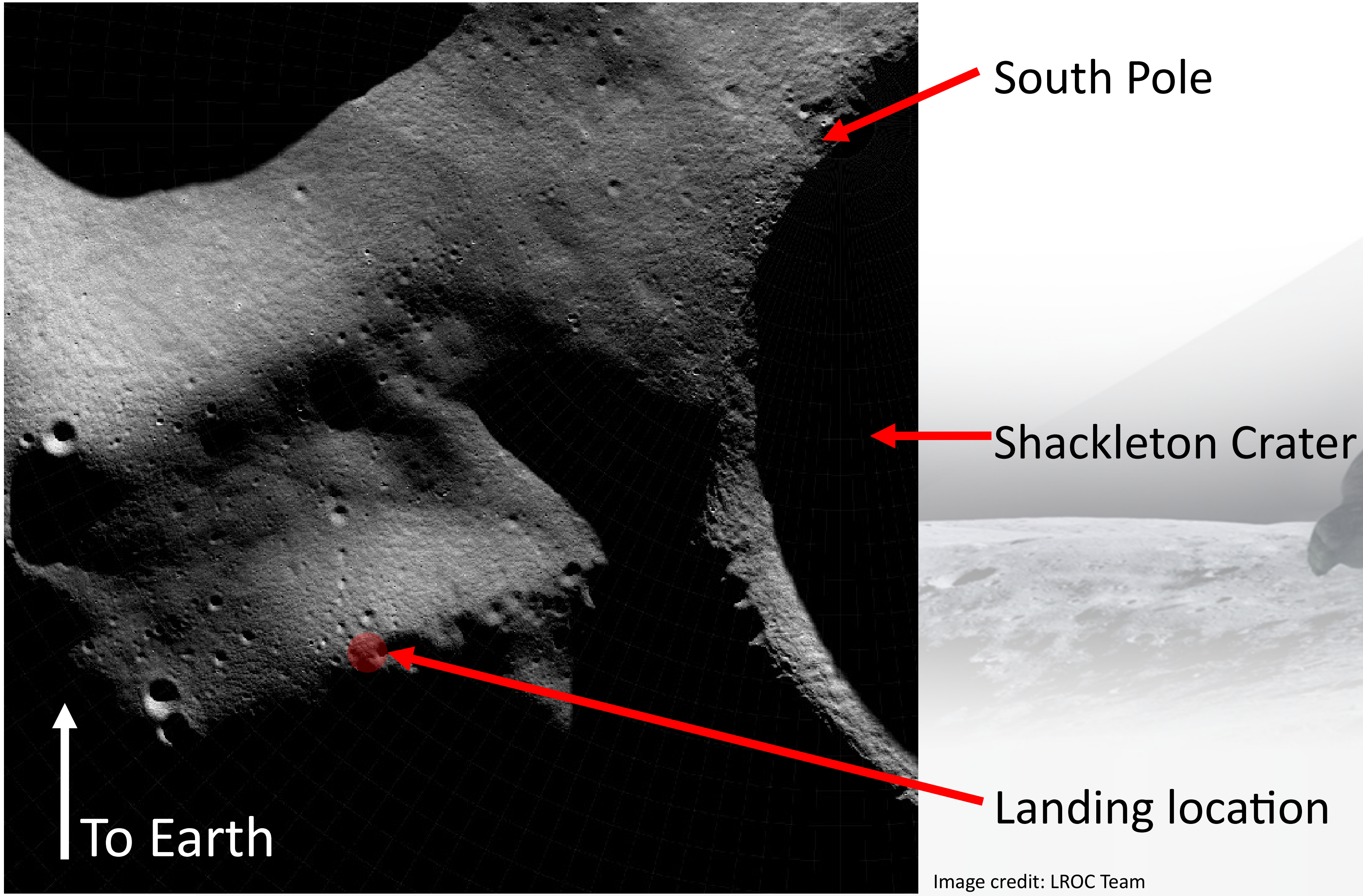
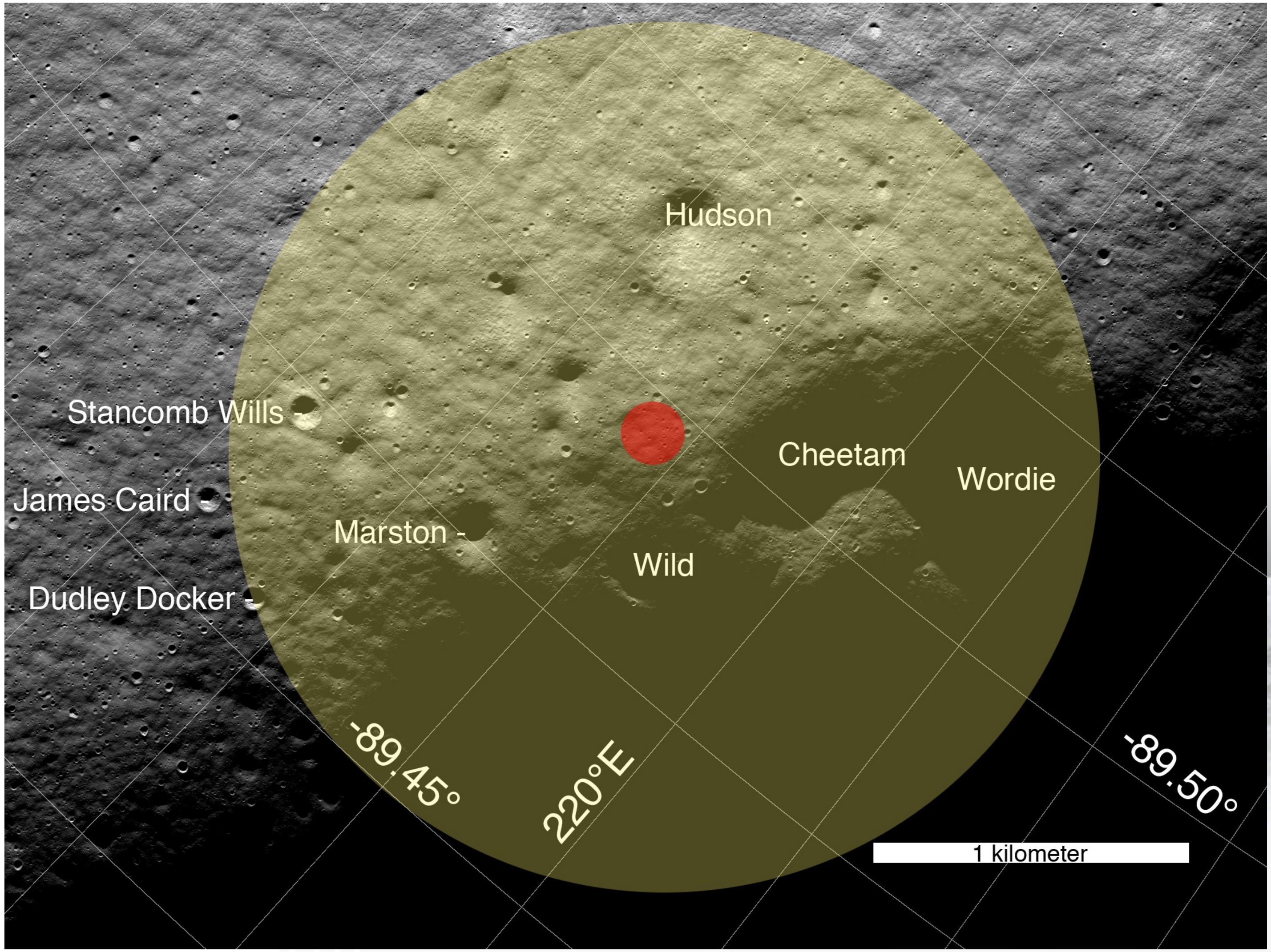


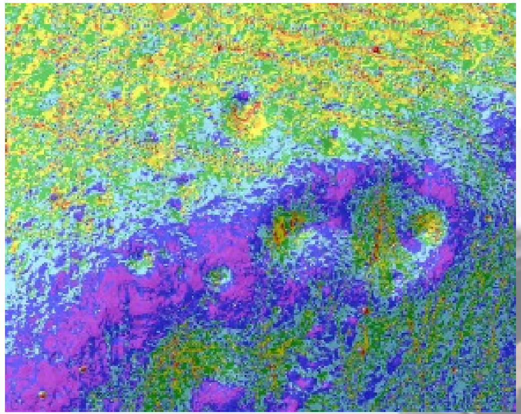
Image credit: LROC Team

Tough Competent Teamwork Responsibility Discipline Confidence Vigilance

Landing Location - Slope



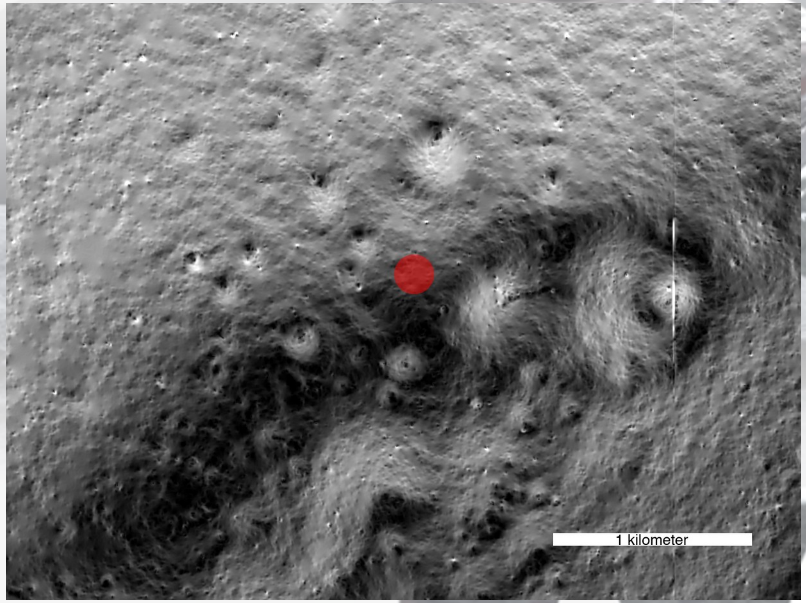
Red = 100 m radius landing circle w/ slope <5deg. Yellow = max walking range 1.38 km radius



Slope (degrees)

- 0 – 5
- 5 – 10
- 10 – 15
- 15 – 20
- 20 – 25

[6] LPI, 2214 (2019)



LOLA 5 meter DTM

Image credit: LROC Team

Landing Location - Lighting, Geology, Thermal, Comm

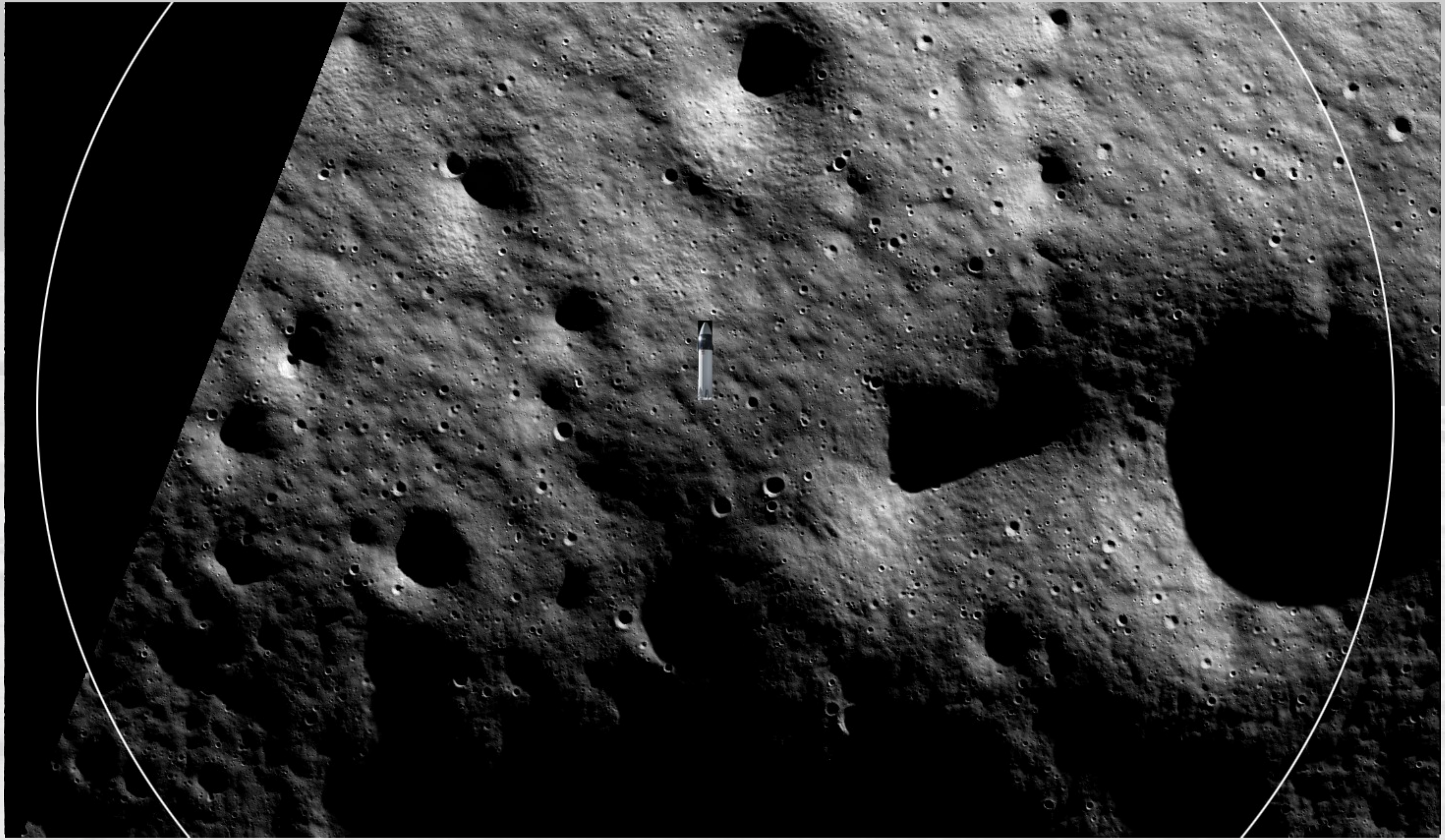
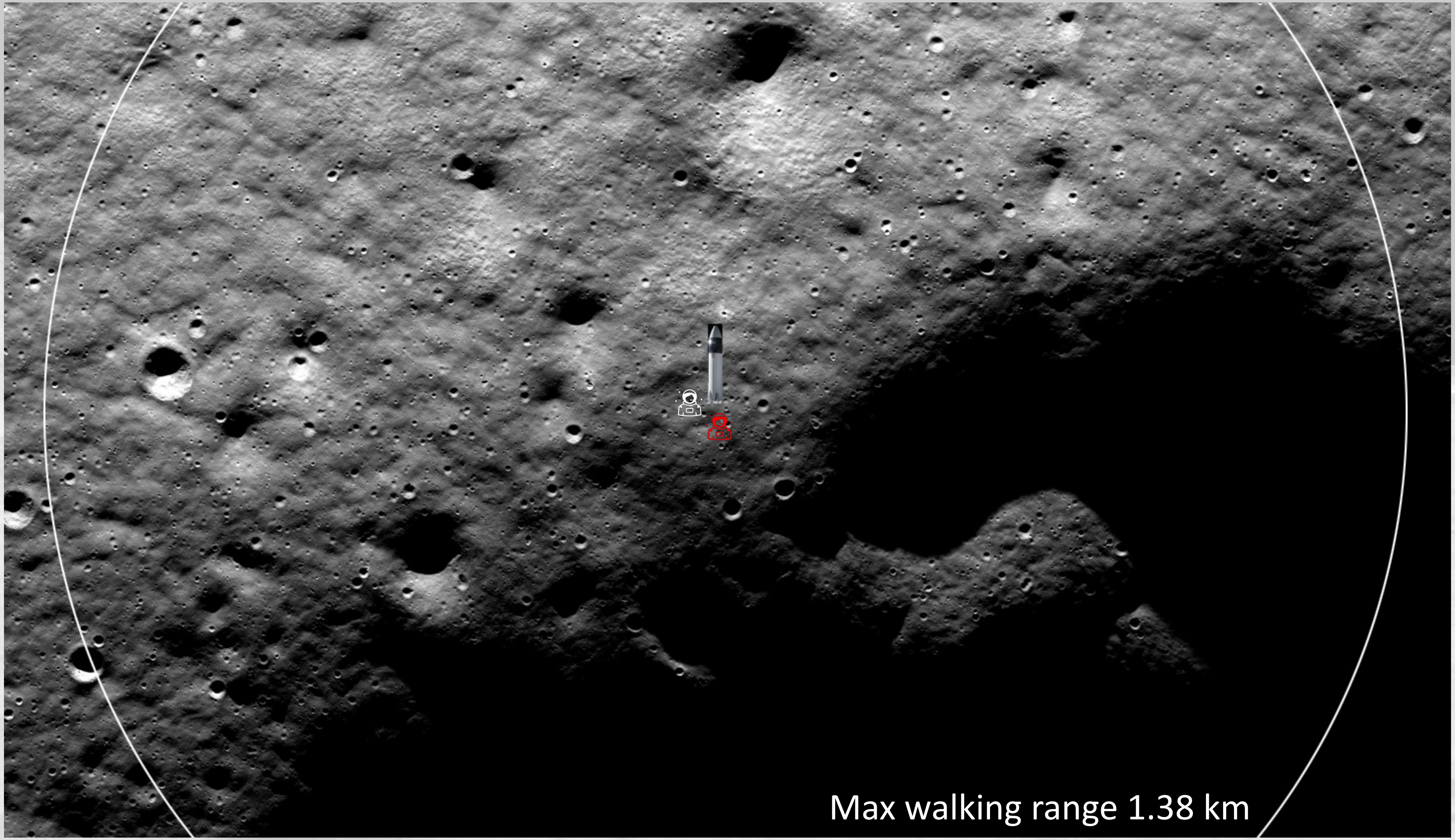


Image credit: LROC Team

- Solar lighting provides benign thermal conditions for lander, and EVA crew.
- Visual navigation should have adequate illumination for majority of EVA.
- Lander will have line of sight to Earth or Gateway for communication.

EVA 1 Timeline - Egress

Egress (0:45)

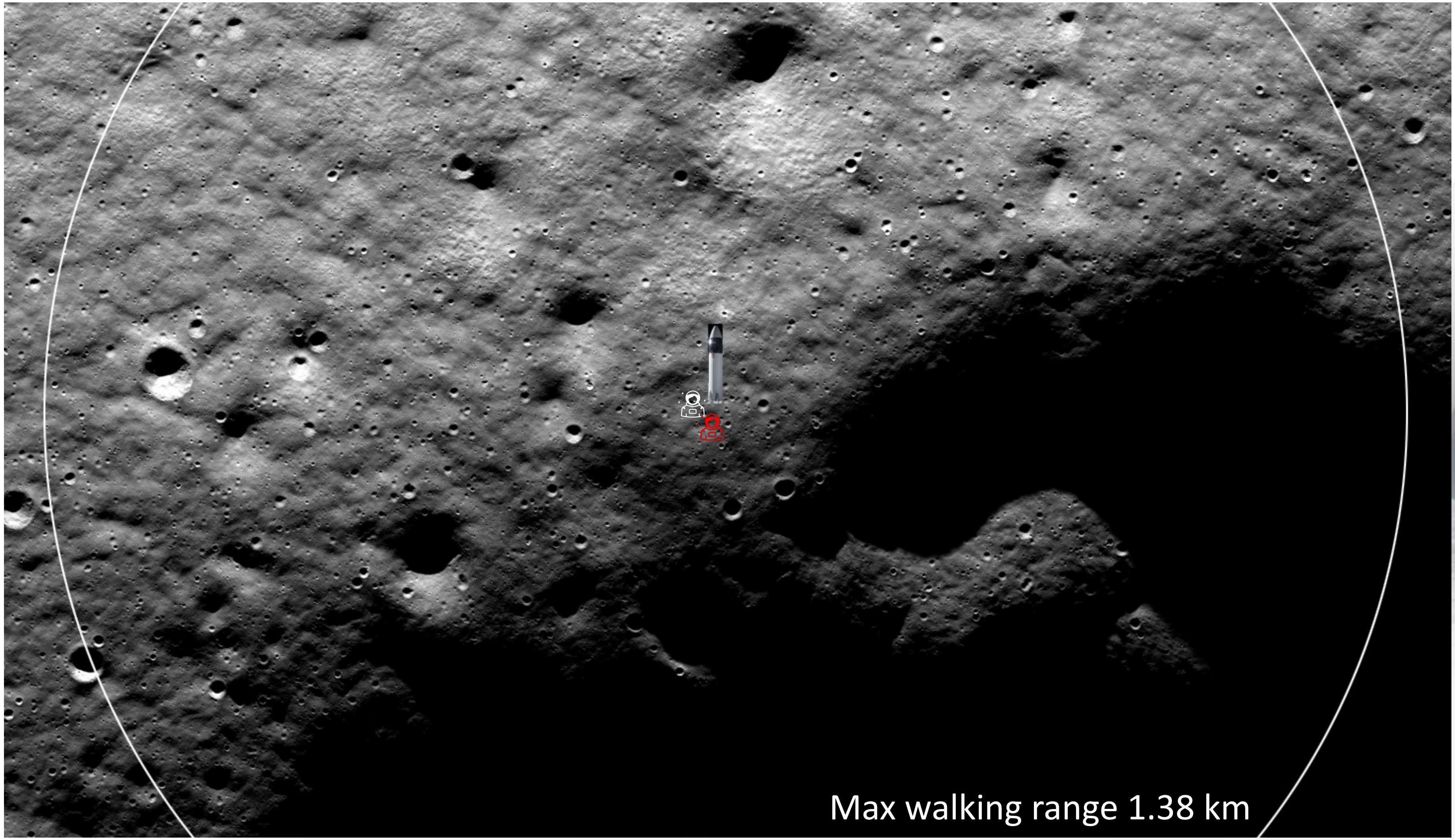


- Umbilical disconnect
- Fall protection
- Descend ladder/elevator
- Tool retrieval/setup
- “one small step”

Image credit: LROC Team and NASA

EVA 1 Timeline – Contingency Sample/Inspection

Egress (0:45)	A



A: 0:45-1:00

- Contingency Sample
- HLS Inspection

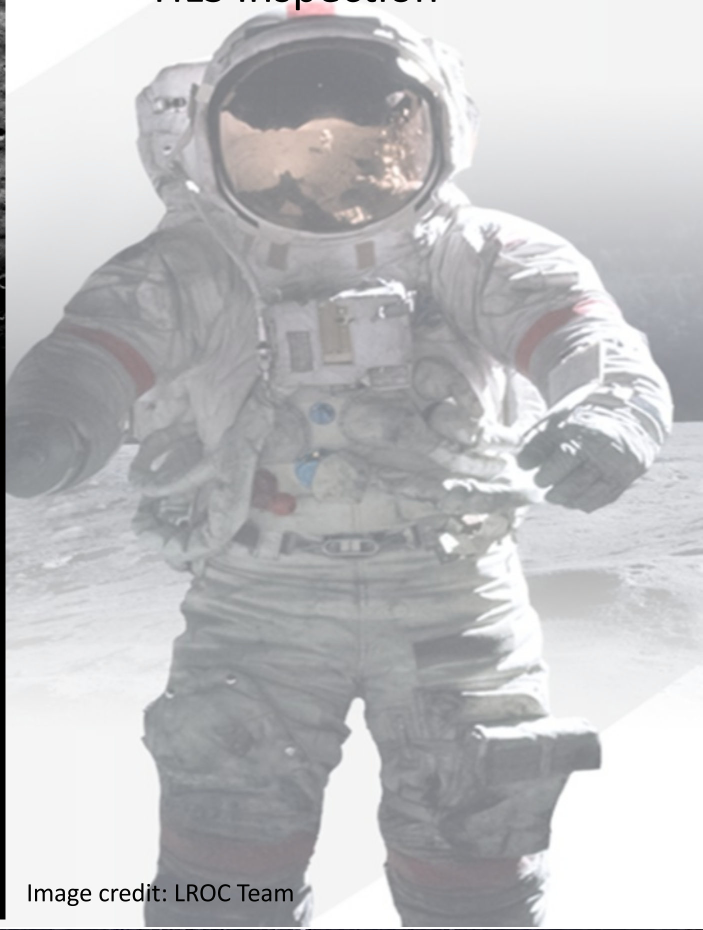
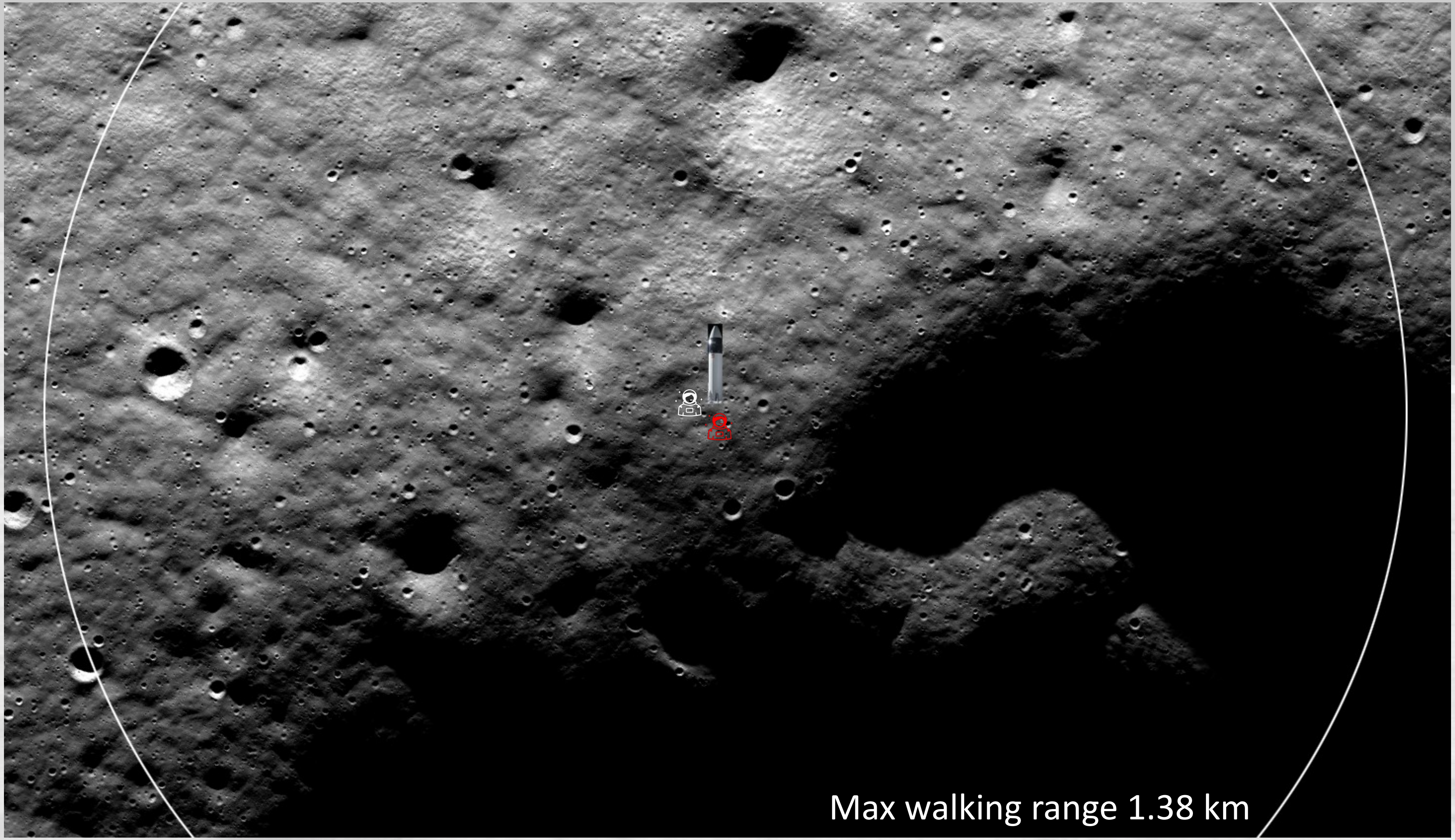


Image credit: LROC Team

EVA 1 Timeline – Public Outreach/VIP Call

Egress (0:45) | A | B

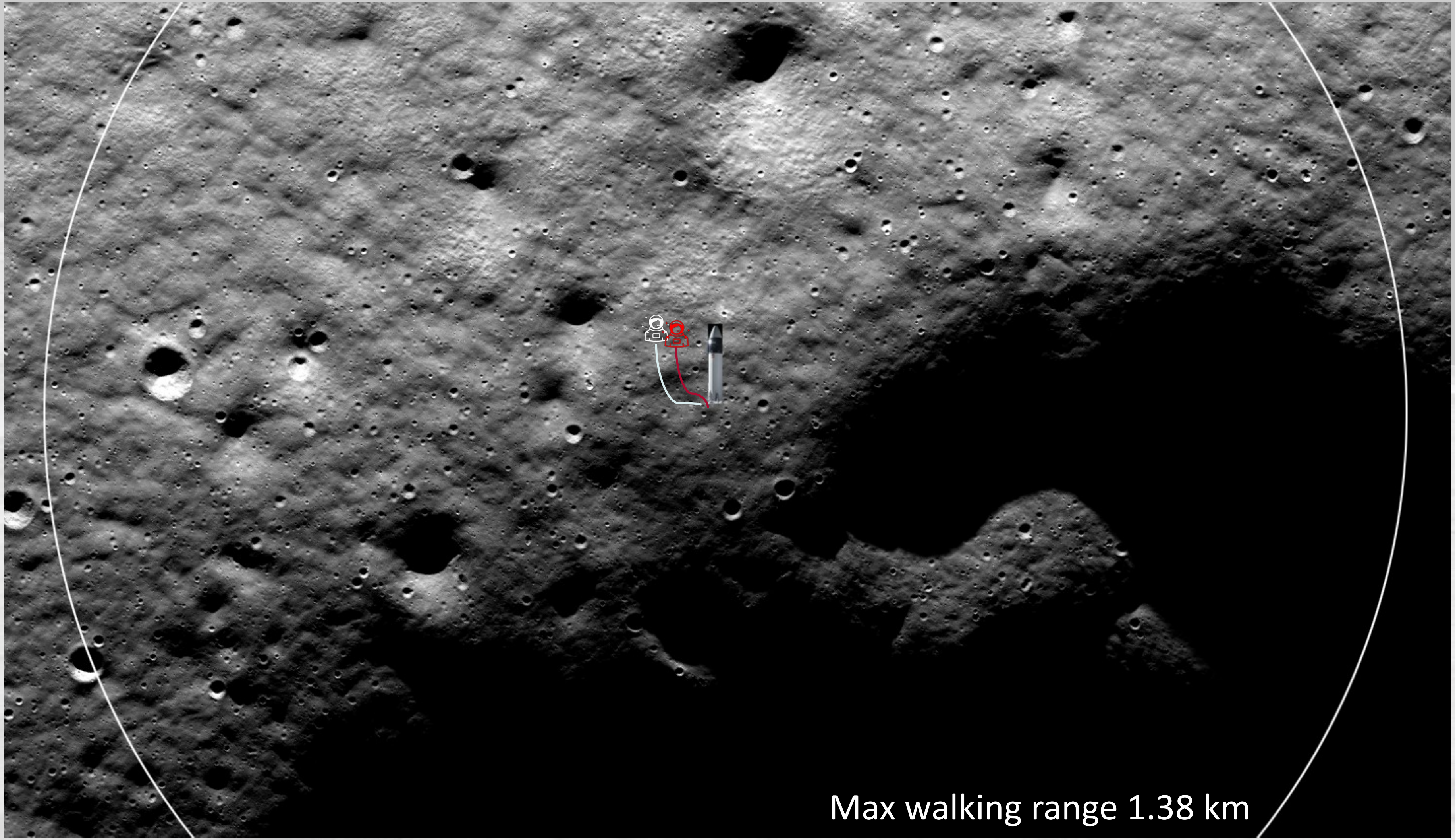


- B: 1:00-1:15
- Public Affairs
  - Inspirational words
  - Call with president
  - Flag

Image credit: LROC Team and NASA

EVA 1 Timeline – In-Situ Instrument Deploy

Egress (0:45)	A	B	Instrument



1:15-1:45

- Short translation away from HLS ascent plume.
- Instrument deployment and activation.

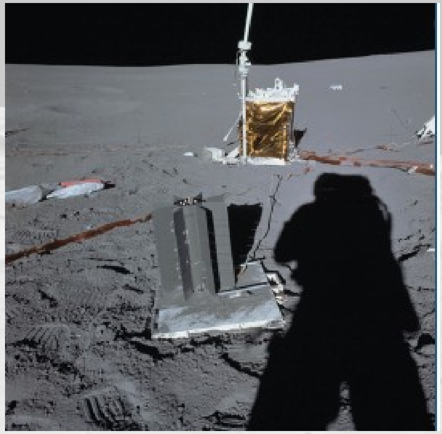
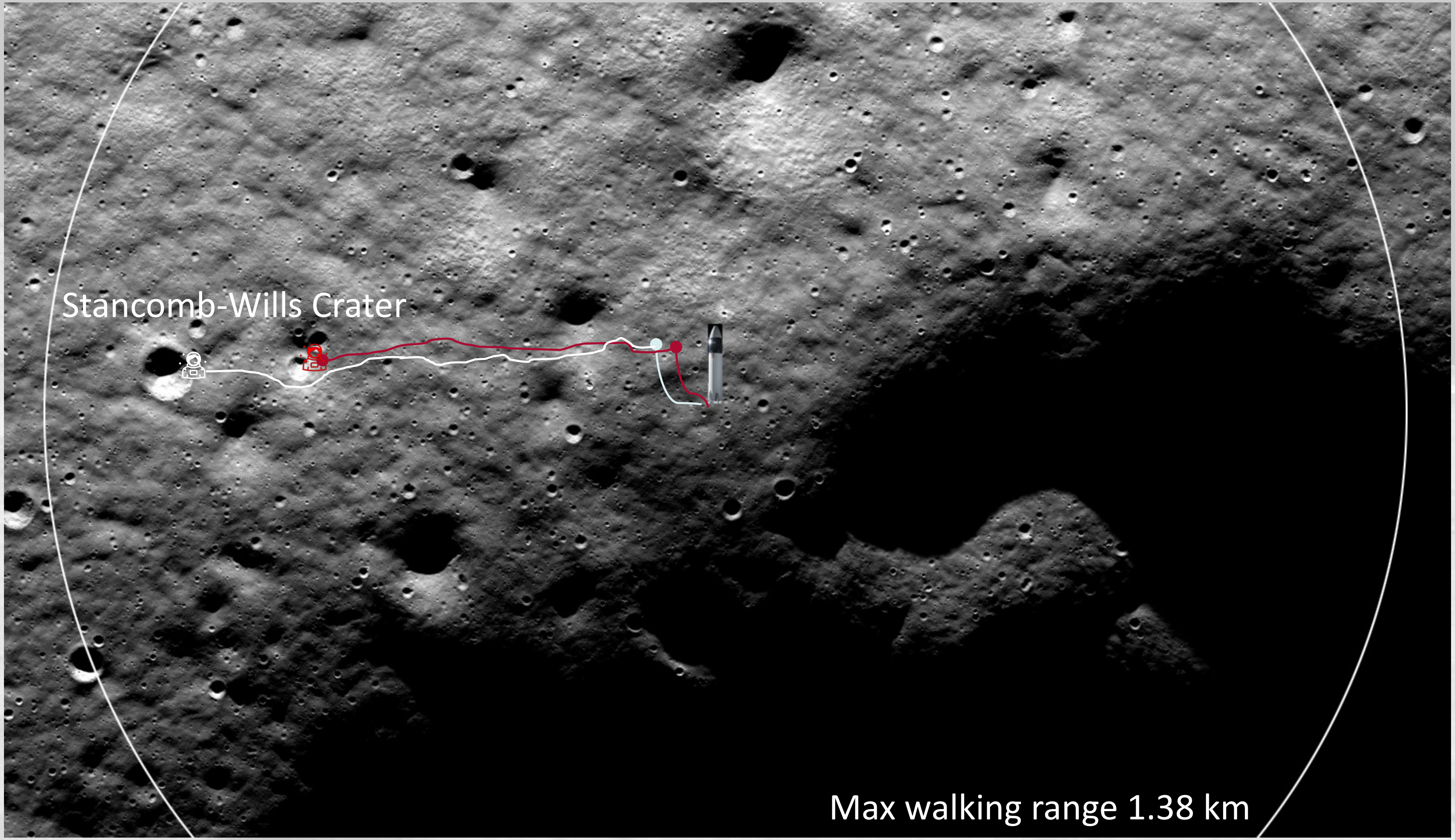


Image credit: LROC Team and NASA

EVA 1 Timeline – Traverse and Sample 1

Egress (0:45)	A	B	Instrument	C	Sample 1



1:45-2:15 traverse

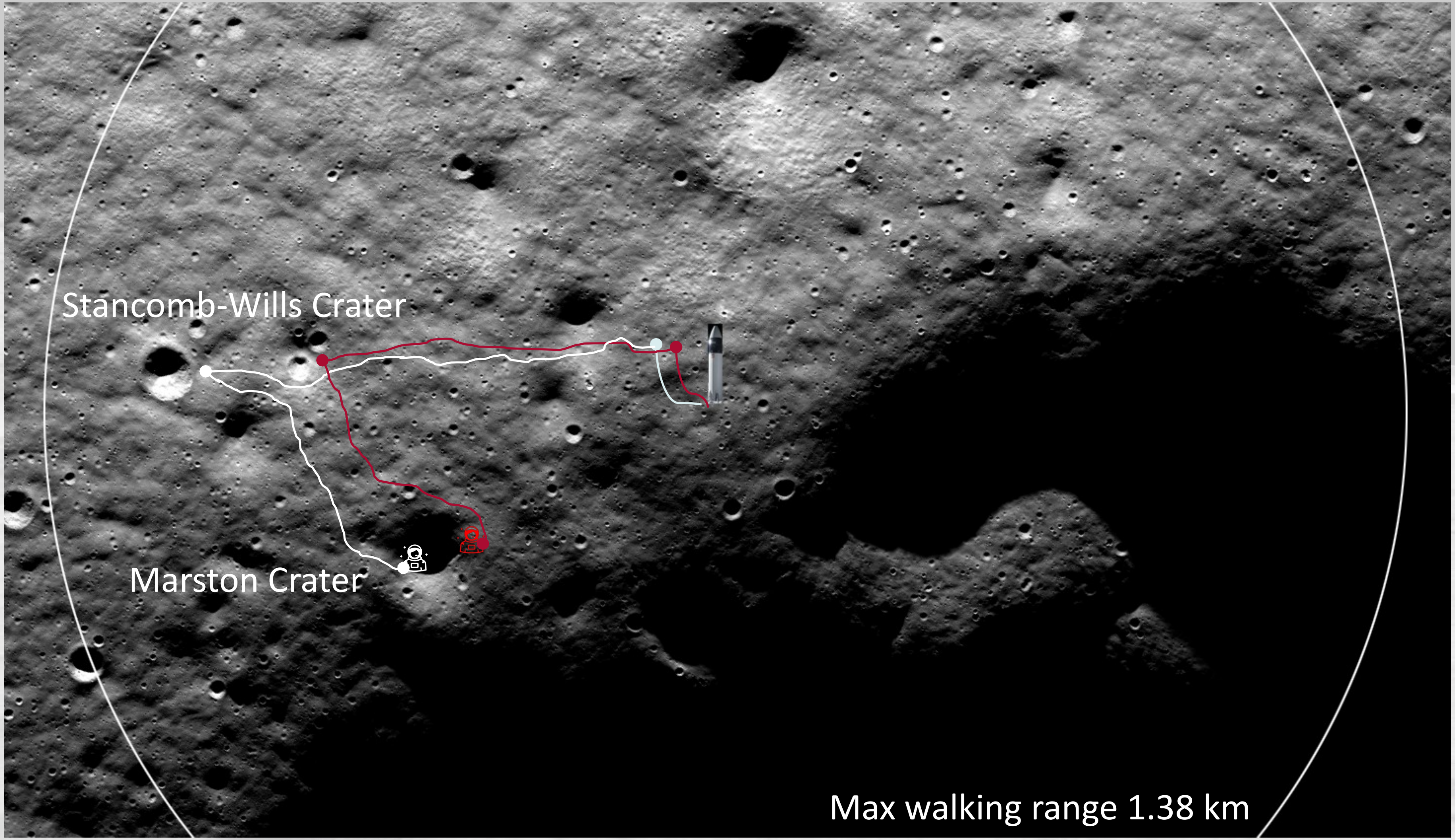
2:15-2:45

- EV1 and EV2 collect sealed core, small clast and regolith surface samples near small young craters

Image credit: LROC Team and NASA

EVA 1 Timeline – Traverse and Sample 2

Egress (0:45)	A	B	Instrument	C	Sample 1	Traverse	Sample 2



2:45-3:15 traverse

3:15-4:30 Volatile Sampling

- EV1 and EV2 collect sealed core, small clast, sealed surface
- Deploy volatile monitor

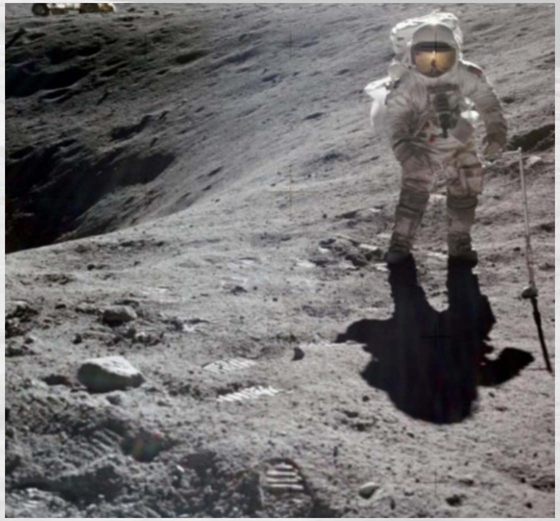
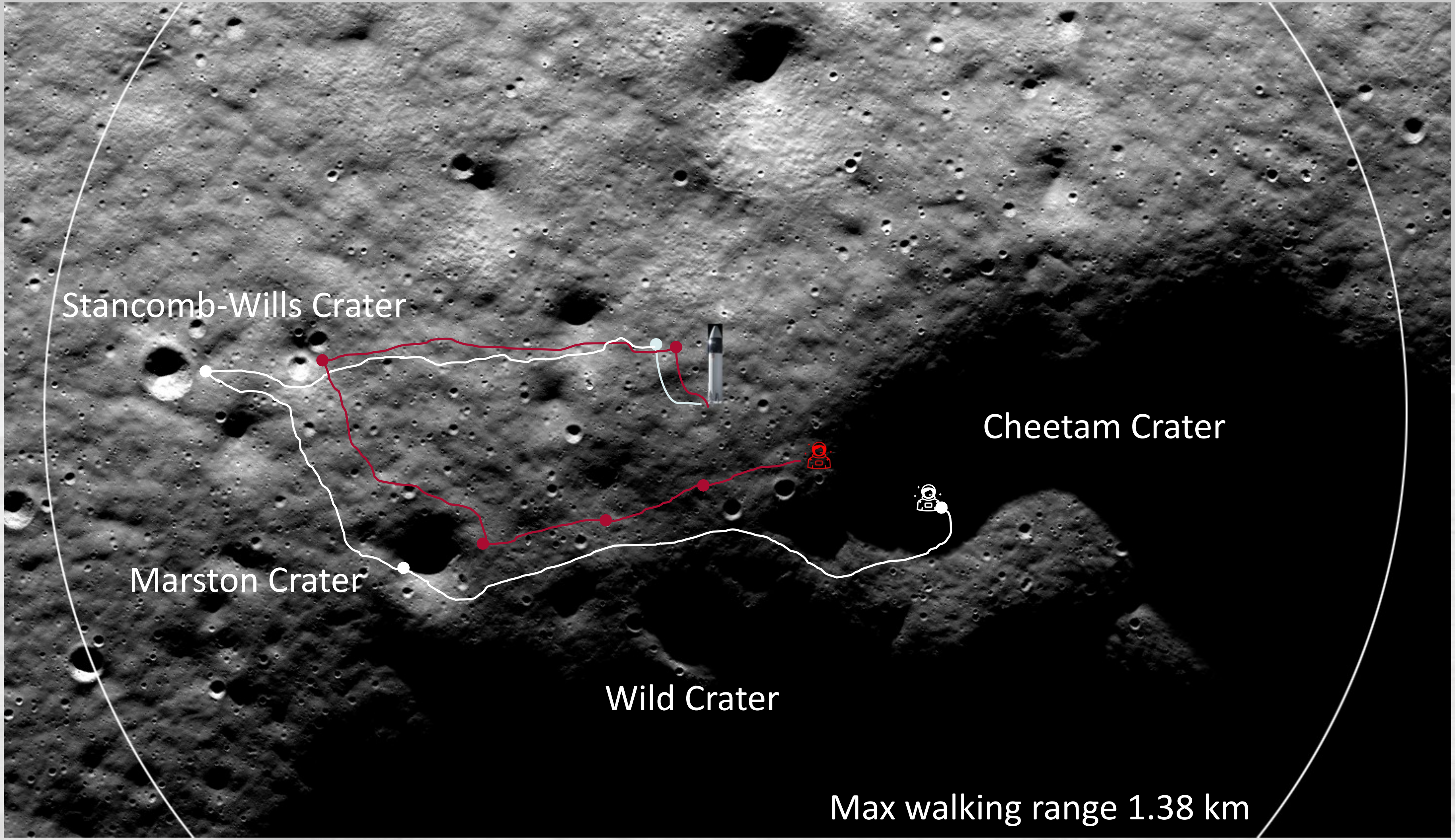


Image credit: LROC Team and NASA

EVA 1 Timeline – Traverse and Sample 3

Egress (0:45)	A	B	Instrument	C	Sample 1	Traverse	Sample 2	Traverse	Sample 3



4:30-5:00 traverse

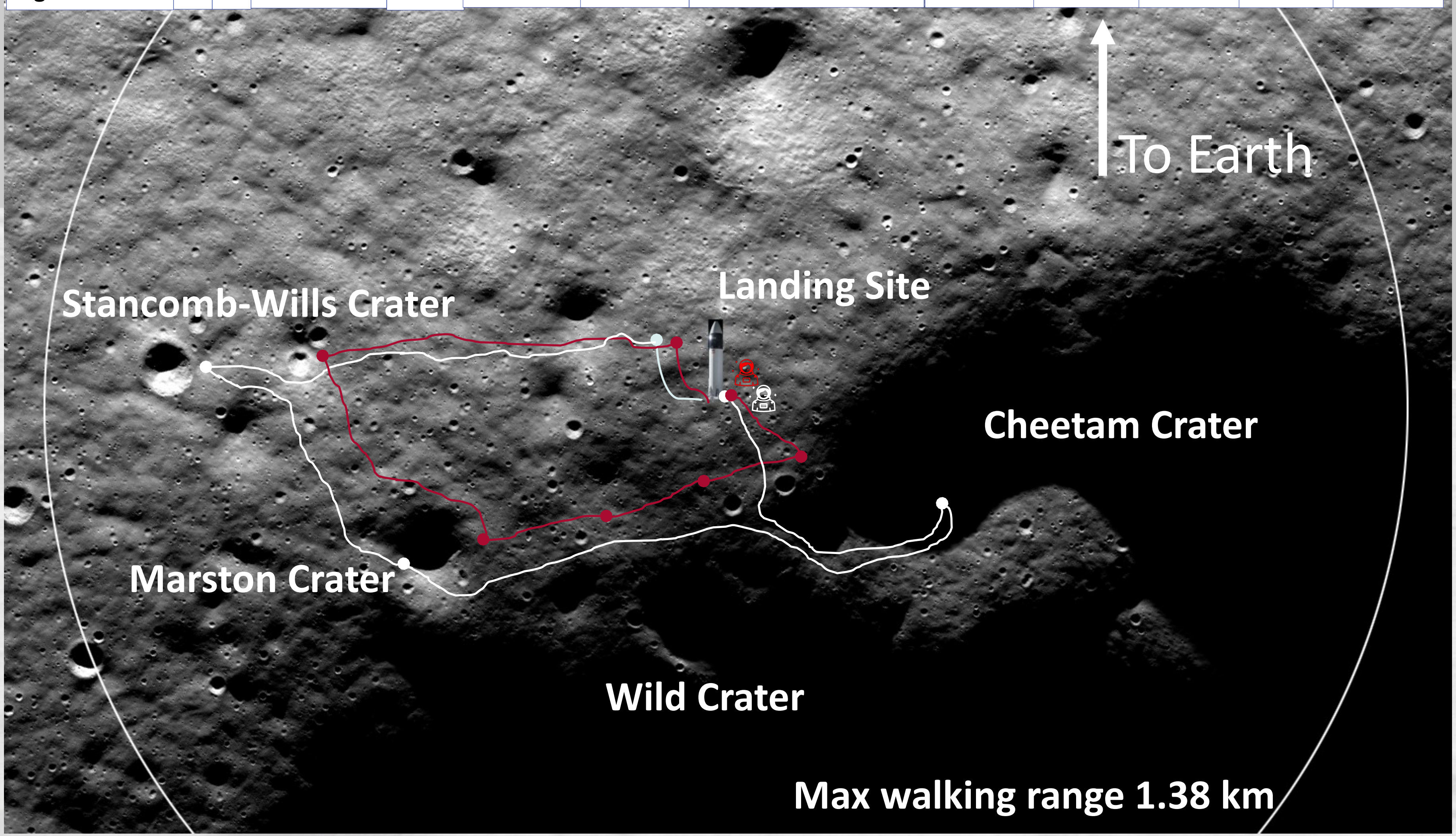
5:00-5:30
- EV1 sealed core
- EV2 characterize unit boundary along traverse w/ small and large clast samples

Image credit: LROC Team and NASA

EVA 1 Timeline – Traverse and Ingress

0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00

Egress	A	B	Instrument	C	Sample 1	Traverse	Sample 2	Traverse	Sample 3	Traverse	Dust	Ingress



5:30-6:00 Traverse to lander
6:00-6:30 Dust removal
6:30-7:15 Ingress

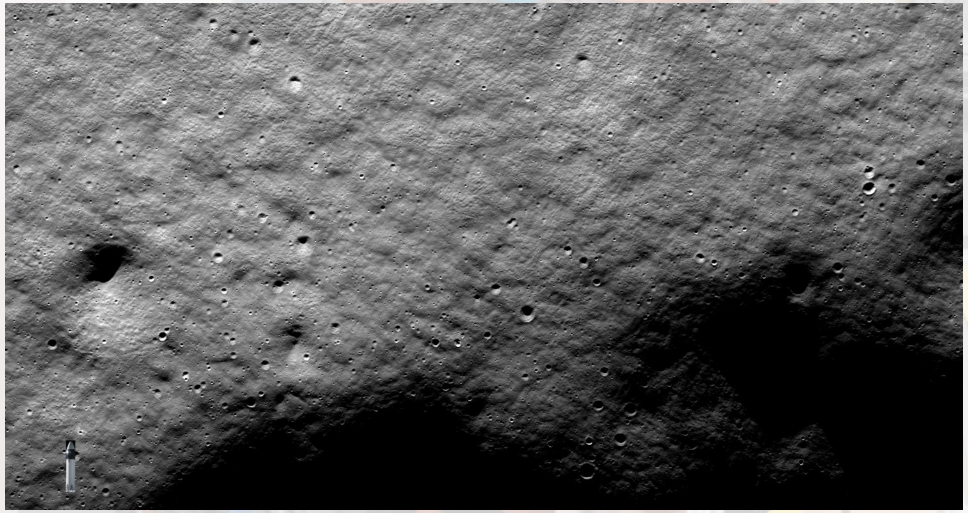
- Tool stow
- Fall protection
- Ascend ladder/elevator
- Ingress airlock, close hatch

Image credit: LROC Team and NASA

Results

- The connecting ridge between Shackleton and de Gerlache craters does appear to meet environmental requirements and have proximity to areas of high geological value with potential for entrapped volatile collection.
- Crater density does show a sharp change in small, young craters to the South of landing location indicating a possible geological boundary as a target for exploration.

EVA Trainer and astronaut testing lunar EVA techniques in simulated polar lighting conditions during Desert RATS 2021.



Crater density change indicating geological boundary. Landing location lower left.

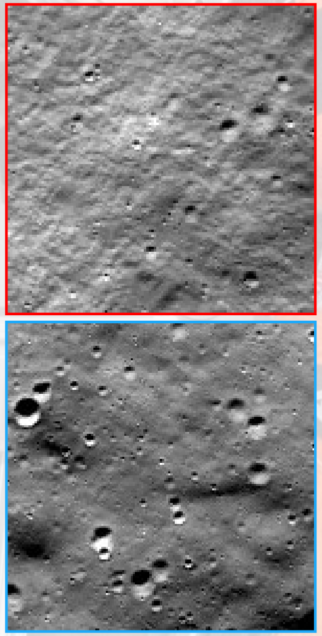


Image credit: LROC Team and NASA

Discussion

- Artemis III will likely not have means for humans to descend into large PSRs due to crew safety associated with steep slopes and extreme thermal environments.
  - It is unknown if more accessible smaller craters at the poles have sufficient cold traps to retain volatiles
  - Robotic exploration of larger PSRs can bridge gap until human capability improves with more advanced rovers and mountaineering equipment.
- Detection of hydrogen from orbital remote sensing may be an indirect indication of water ice. In-situ and returned sample analysis in environmentally preserved containers will be critical for understanding volatile origin.
- Although other landing locations may prove to better meet Artemis objectives, the process used to assess locations would be similar. NASA's science mission directorate is currently performing similar studies to refine candidate landing locations.
- Crater density evaluation near the landing site may show similar saturation equilibrium for older, larger impacts. The difference is mostly in small, young crater counts. It is possible that different terrain slope, or secondary impacts are biasing relative age assessment of the boundary areas.

Summary and Conclusion

- The Shackleton – de Gerlache ridge has areas with very promising conditions for a potential Artemis mission:
  - Low slope to accommodate lander stability requirements
  - Sufficient slope to allow human traverse within a 1.38 km radius from lander
  - Proximity to potential geological boundaries and many craters of various size and age
  - High availability of sunlight for thermal control and power generation
  - Frequent line of site to Earth for persistent communication in the event the Gateway communication relay is not available.

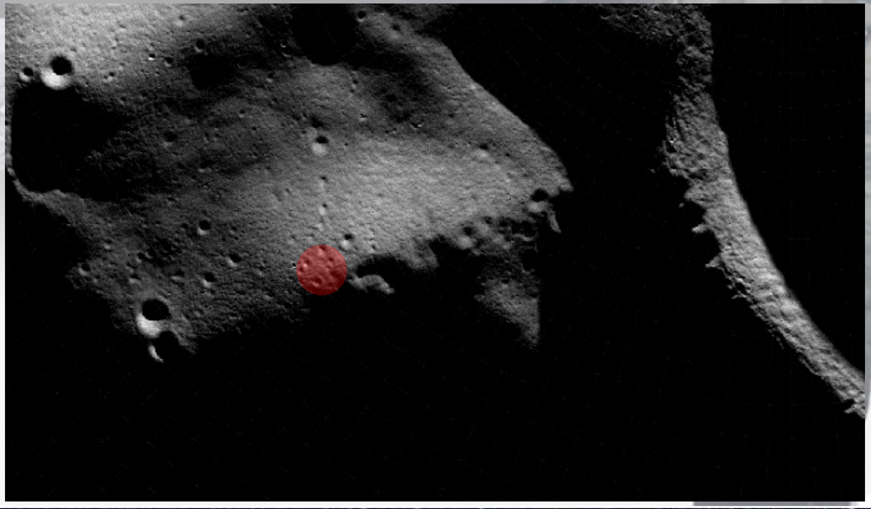


Image credit: LROC Team

References

- [1] *Sustained Phase Human Landing System (HLS) Program System Requirements Document*, (2021), NASA, HLS-RQMT-006
- [2] *XEVA System Requirement Document Attachment J-02* 80JSC021R0006, (2021), NASA
- [3] *Artemis III Science Definition Team Report*, (2020) NASA/SP-20205009602.
- [4] Del Greco, J., et al, 2021. Artemis III EVA Distance Trade.
- [5] E.J. Speyerer, M.S. Robinson, *Persistently Illuminated Regions at the lunar poles: Ideal sites for future exploration,* Icarus 222 (2013) 122-136
- [6] LPI Contribution 2214, 2019. *Slope Map of the Moon's South Pole Ridge*