



LUNAR SURFACE COMMUNICATIONS ARCHITECTURE: **Challenges of Operating in the Lunar Environment**

Michael Zemba
PI, Lunar Surface Propagation
NASA Glenn Research Center

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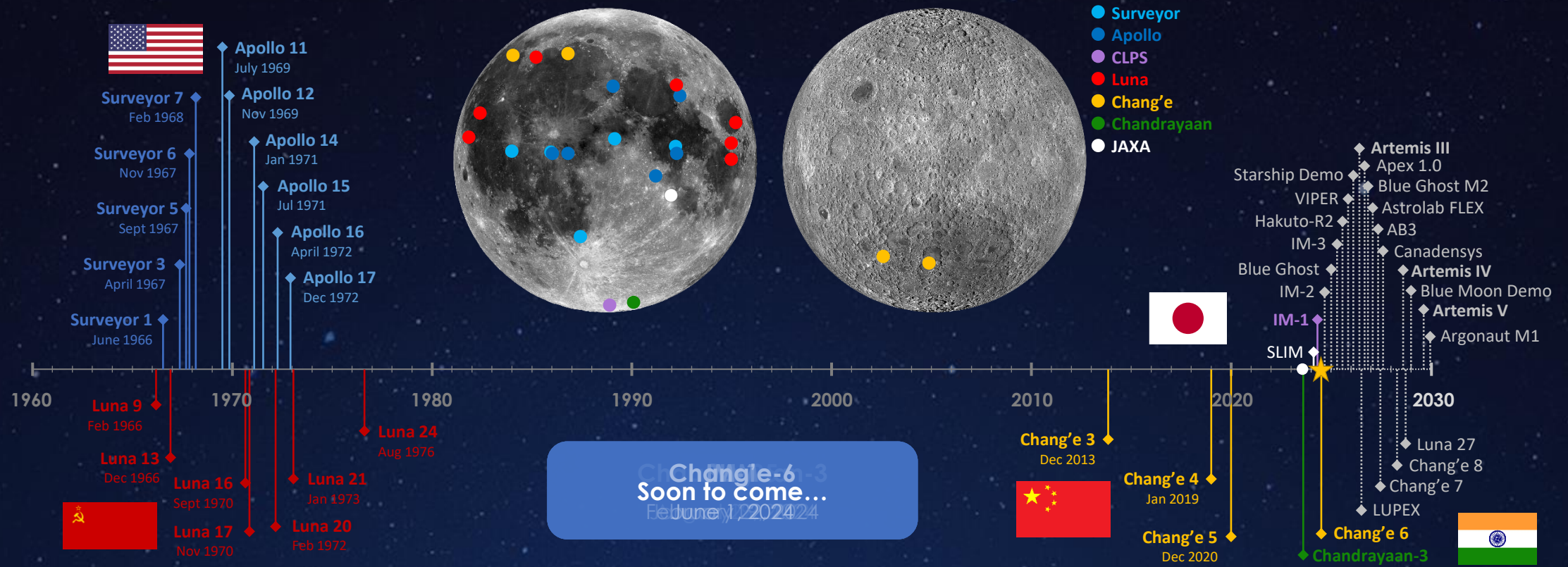
Presentation Agenda



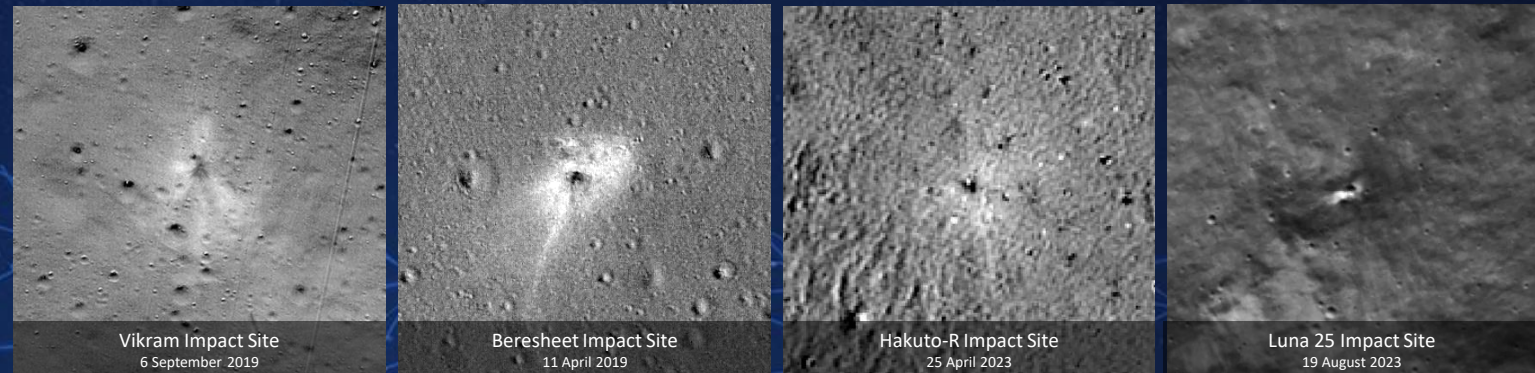
- 1 Why do we need Lunar communications infrastructure?
- 2 How did we do it last time?
- 3 What makes the south pole challenging for communications?
- 4 How does our modern technology fare?



Why do we need lunar communications infrastructure?



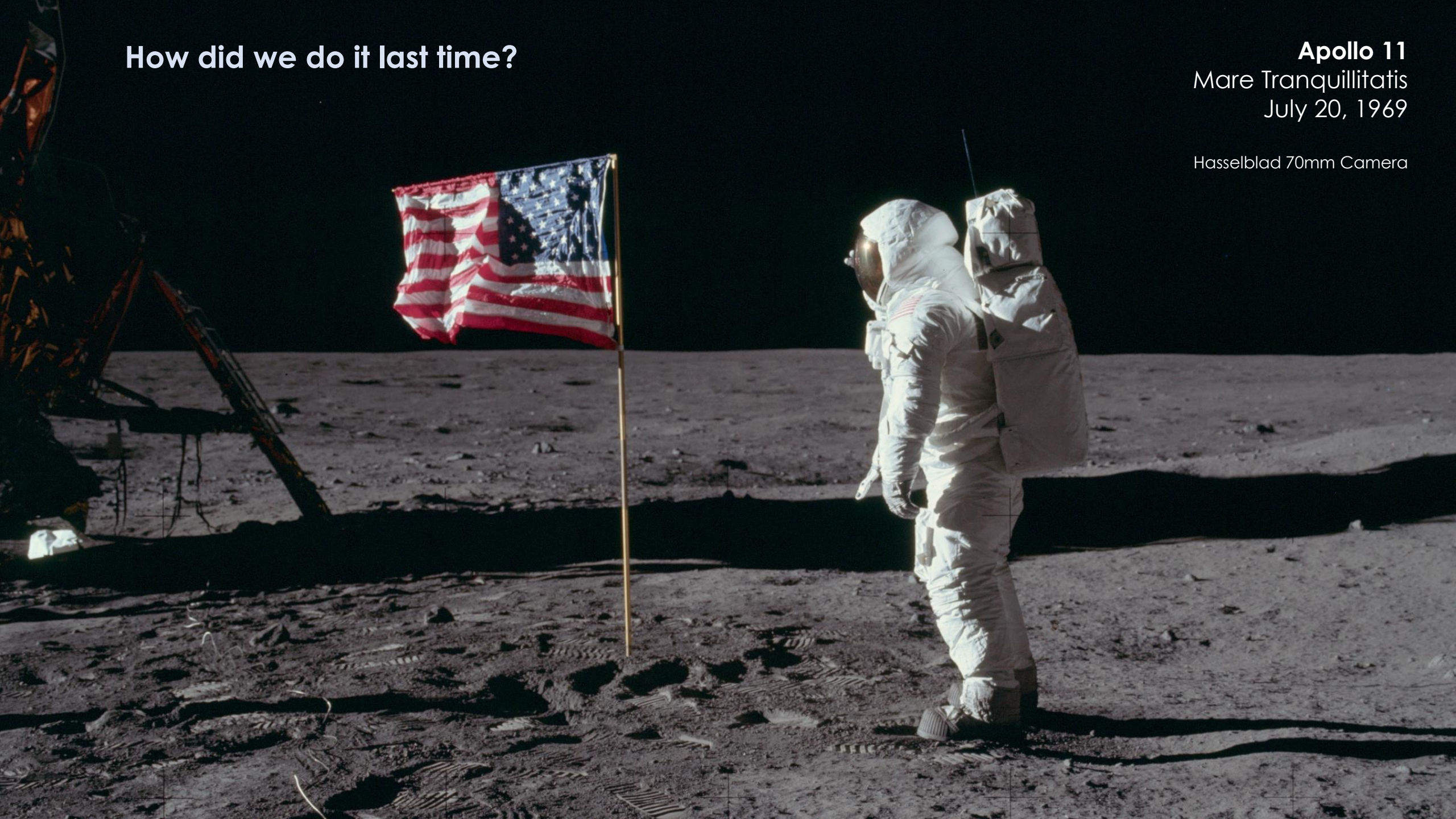
- Total Successful Soft Lunar Landings: 25
- 2024 is already tied for **most successful lunar landings** (there were also three each in 1966, 1967, 1972)
- The frequency of Lunar missions is now higher than at any point in history. IM-1 is the closest to the South Pole at 80.2 °S latitude, about 300 km from the pole.



How did we do it last time?

Apollo 11
Mare Tranquillitatis
July 20, 1969

Hasselblad 70mm Camera



Apollo 11

Mare Tranquillitatis

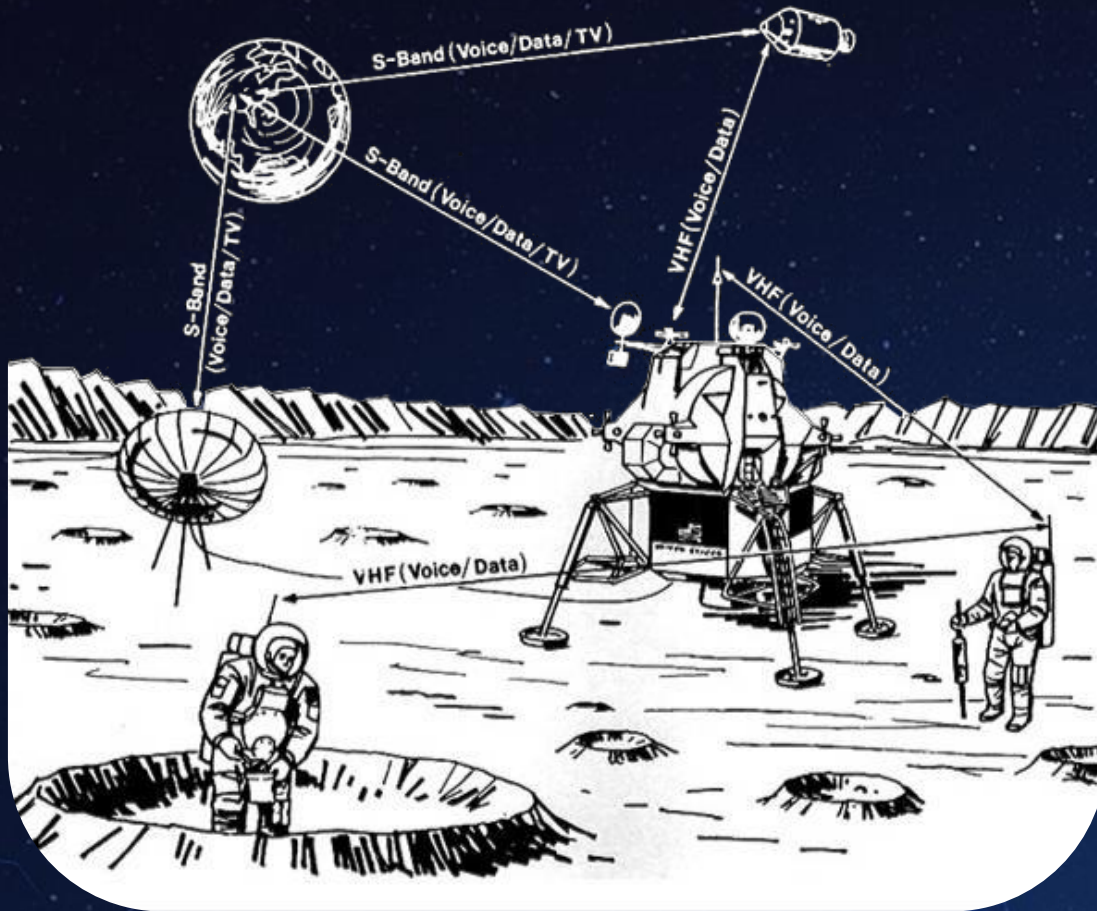
July 20, 1969

Westinghouse SSTV Camera

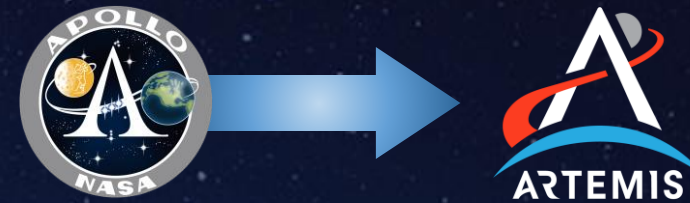
320p, 10 FPS



How did we do it last time?



Apollo's EVA Communications Architecture

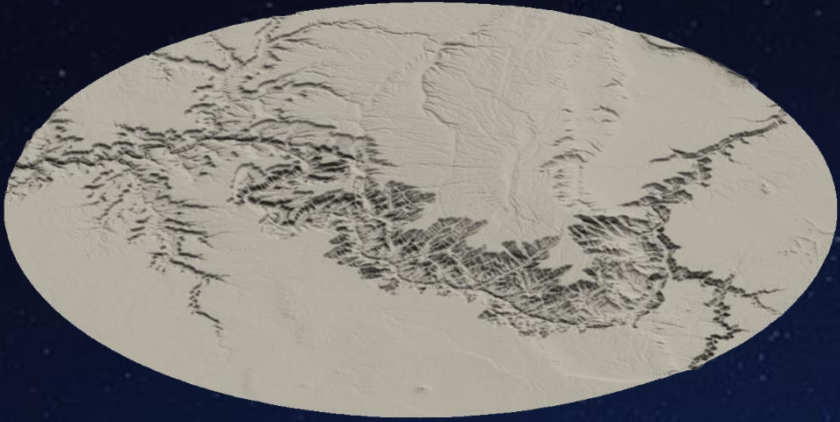


The more ambitious missions of the Artemis program require a more capable communications architecture.

As compared to the Apollo missions, Artemis requires:

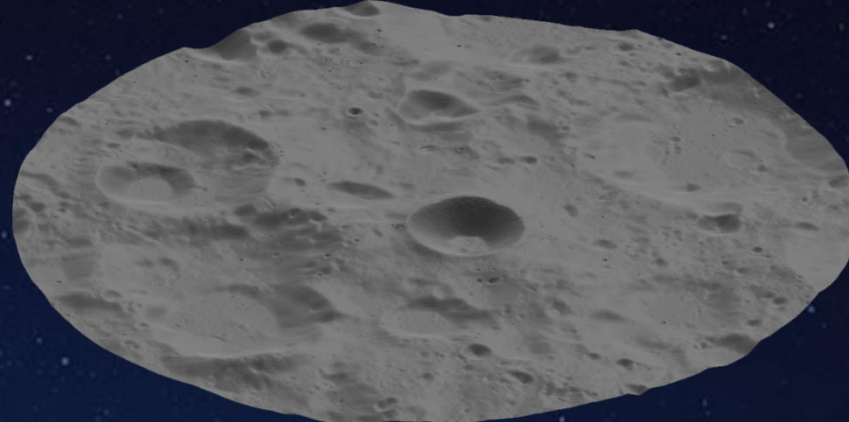
- Much Higher Surface-to-Surface Data Rates
- Increased Range (2 – 10 km)
- Increased Number of Users / Devices
- Tolerance of More Challenging Propagation Environments
- Tolerance of More Challenging Illumination Conditions
- Less reliance on direct-to-Earth links
- Longer Mission Durations

What makes the south pole challenging for communications?



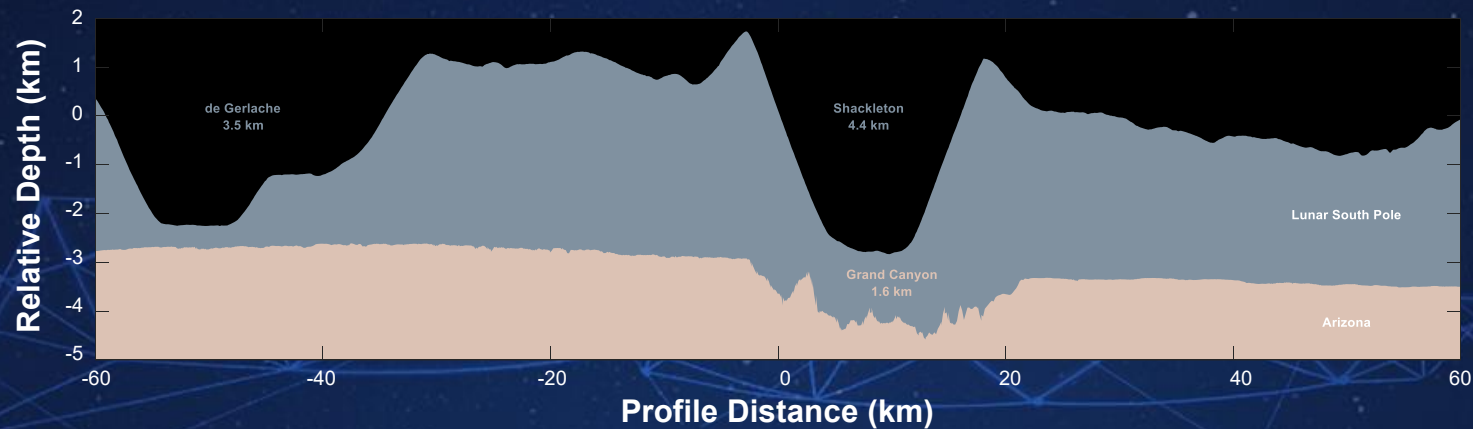
Grand Canyon, Arizona

Map Center	36.272 °N, 112.243 °W
Map Radius	75 km
Max Altitude	2.813 km
Min Altitude	0.546 km
Altitude Range	2.267 km

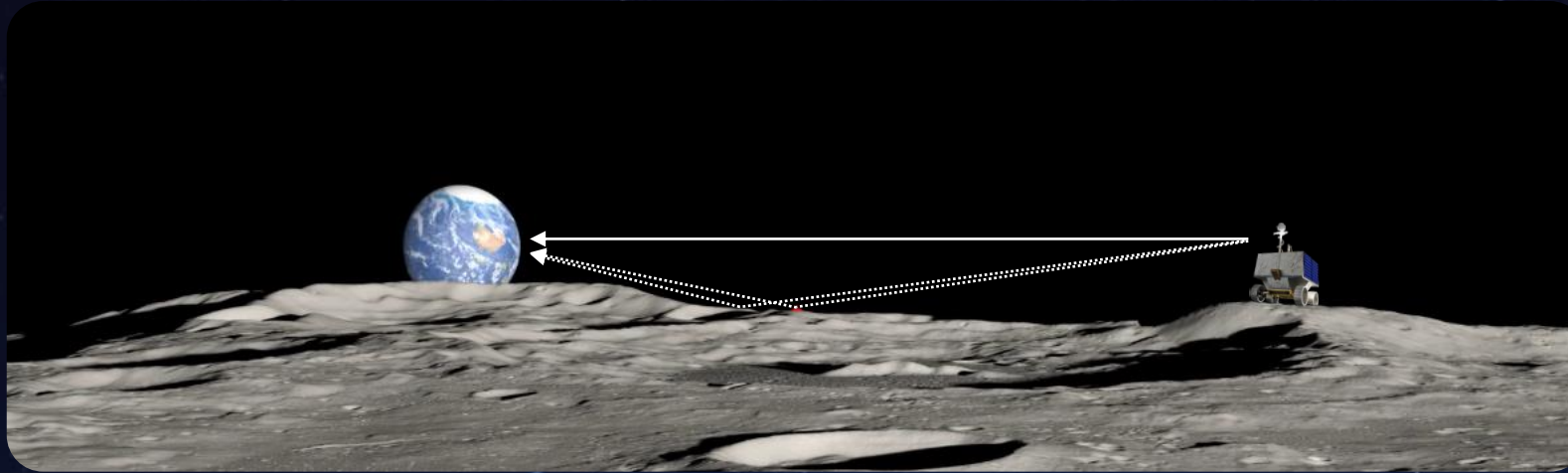


Lunar South Pole

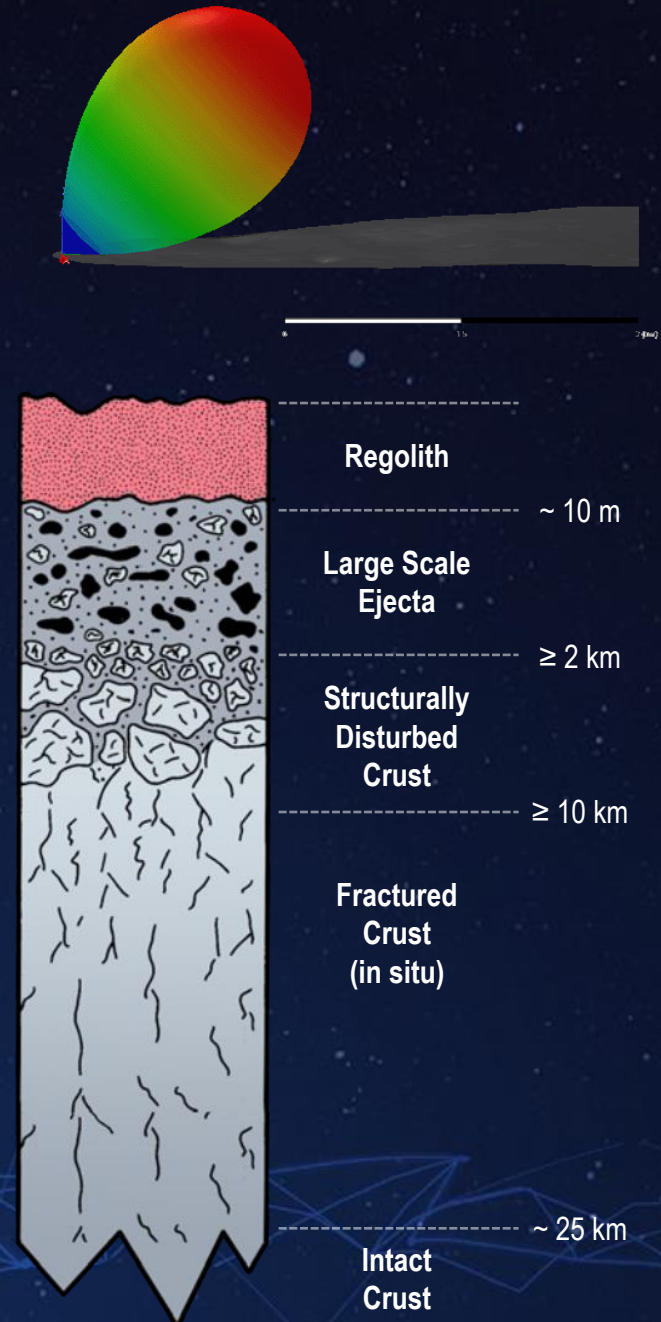
Map Center	90.000 °S, N/A °E
Map Radius	75 km
Max Altitude	1.963 km
Min Altitude	-4.379 km
Altitude Range	6.342 km



What makes the south pole challenging for communications?



- The topography of the south pole is extreme
- Earth is only visible for 2 weeks per month
- Earth is always within $\sim 10^\circ$ of the horizon
- Deep, low-loss regolith layer adds uncertainty to analysis
- Earth is always near the direction of 0° longitude
- The sun never rises or sets, casting long shadows that complicate solar powered operations

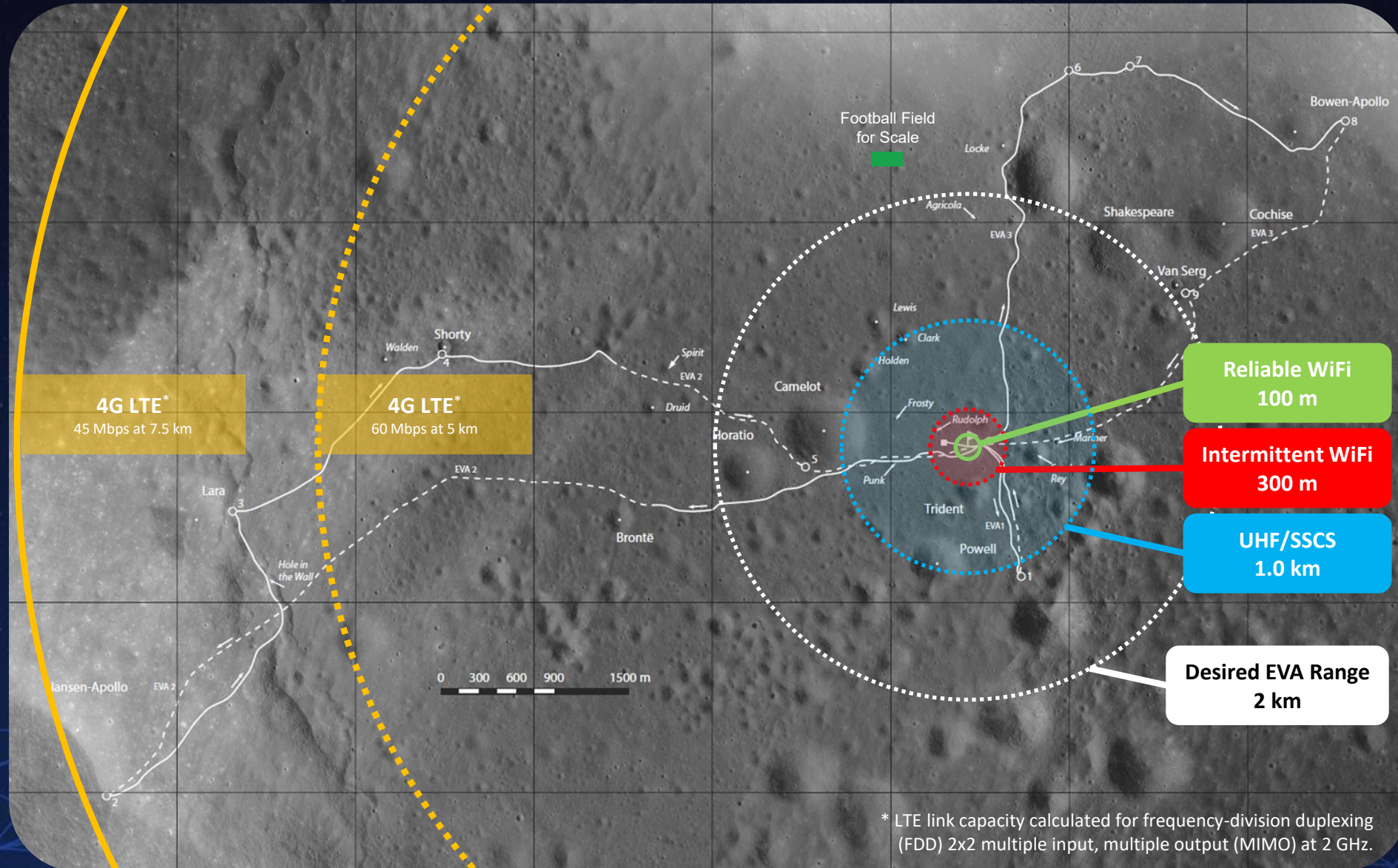


How does our modern technology fare?



Comparing the ranges of modern standards with Apollo's longest rover traverse:

- Apollo 17's LRV drove up to 7.4 km from the lander.
- The Apollo LRV had direct-to-Earth link, with no link to the lander.
- Wi-Fi and SSCS generally do not cover the desired 2 km EVA radius.
- 4G LTE hosted on a lander offers theoretical link capacity of up to 20 Mbps at 10 km, including a 5 dB margin.



* LTE link capacity calculated for frequency-division duplexing (FDD) 2x2 multiple input, multiple output (MIMO) at 2 GHz.

Predictability and Adaptability are Critical

As an example, let's plan a hypothetical mission to Malapert Massif, considering:

- Early missions will bring their own infrastructure (i.e., your lander is your cell tower).
- Pinpoint landings on the moon remain a challenge.

- Is the difference between LOS and RF coverage enough to salvage this mission as originally planned?
- How much confidence do you have in your RF modeling, and its accuracy at this specific location, to say yes or no?

- [1] M. Pierce, "NASA Technology Enables Precision Landing without a Pilot", Phys.org. September 2020. [\[URL\]](#)
[2] S. Pillai, "Engine calibration, landing site expansion for Chandrayaan-3: Lessons from 2019." Hindustan Times, July 15 2023. [\[URL\]](#)
[3] Rishitosh K. Sinha et al., "Geological characterization of Chandrayaan-2 landing site in the southern high latitudes of the Moon", Icarus, Vol. 337, 2020. [\[URL\]](#)
[4] S. Kaczmarek, "Going Back to the Moon? Choose a Lander Wisely." Online Article. [\[URL\]](#)

Notional Example:

Line-of-Sight (LOS) Viewsheds at Malapert Massif

30m Lander to 2m EVA

