



Innovations in Cislunar Infrastructure

Communications

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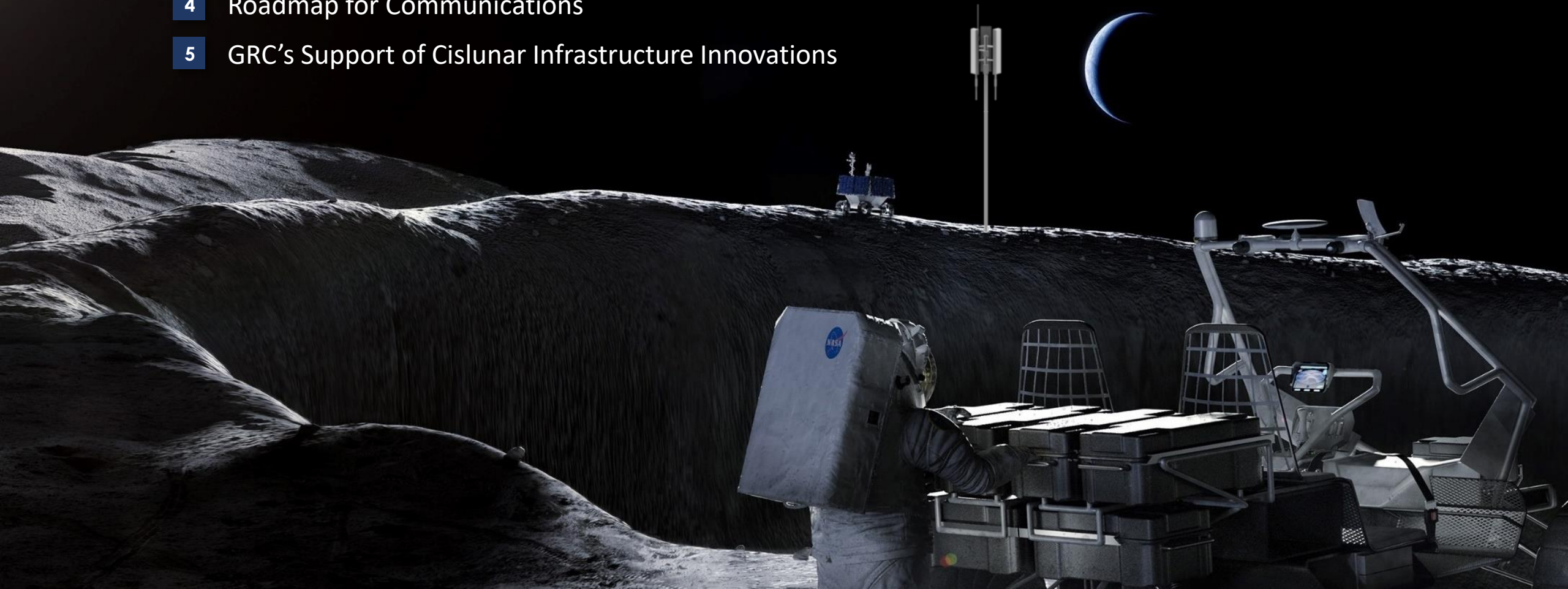
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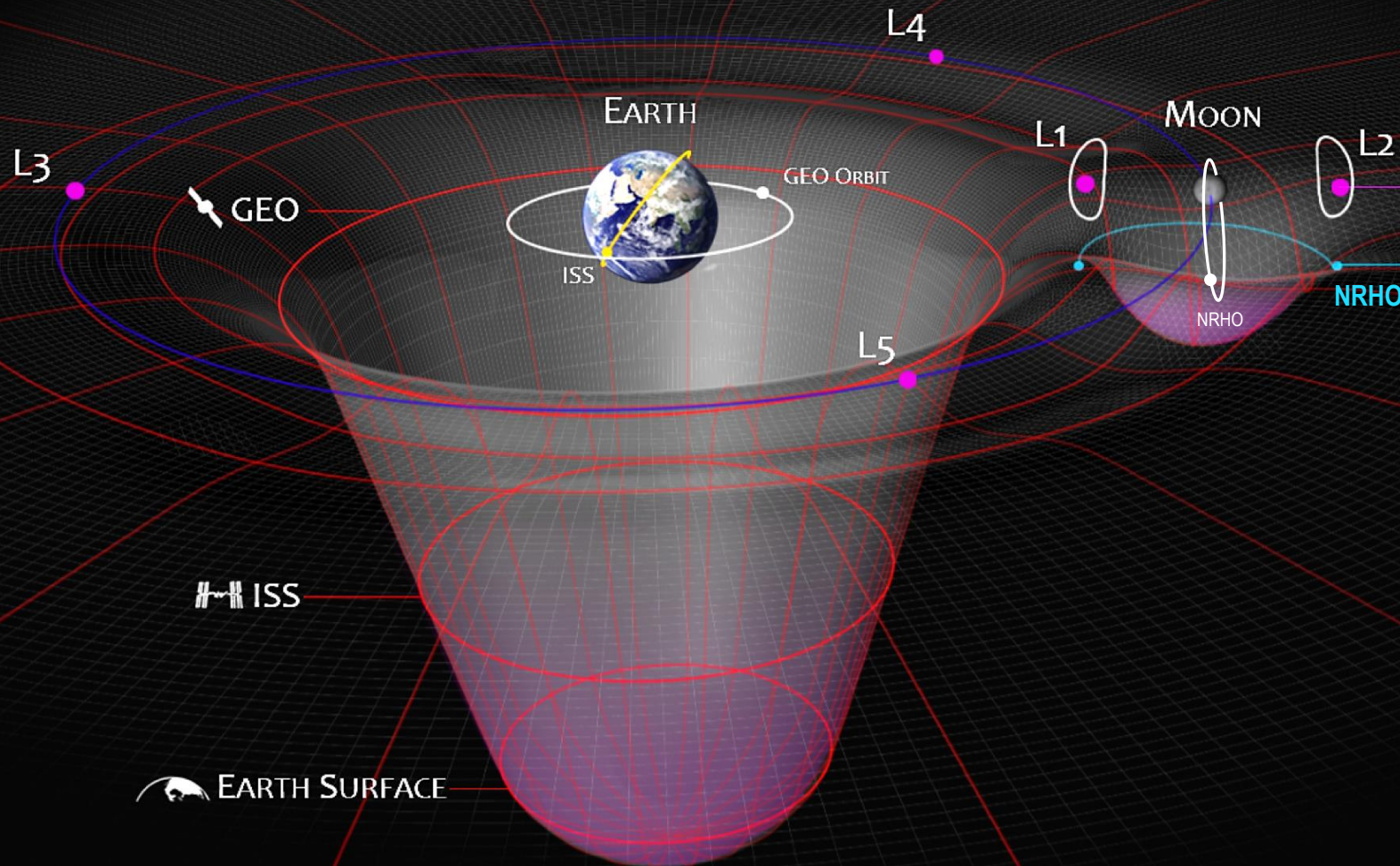
Presentation Agenda



- 1 Map of Cislunar Space & NRHO
- 2 Rapid Increase in Lunar Missions
- 3 Cislunar Communications Infrastructure
- 4 Roadmap for Communications
- 5 GRC's Support of Cislunar Infrastructure Innovations



Map of Cislunar Space & the Advantages of NRHO



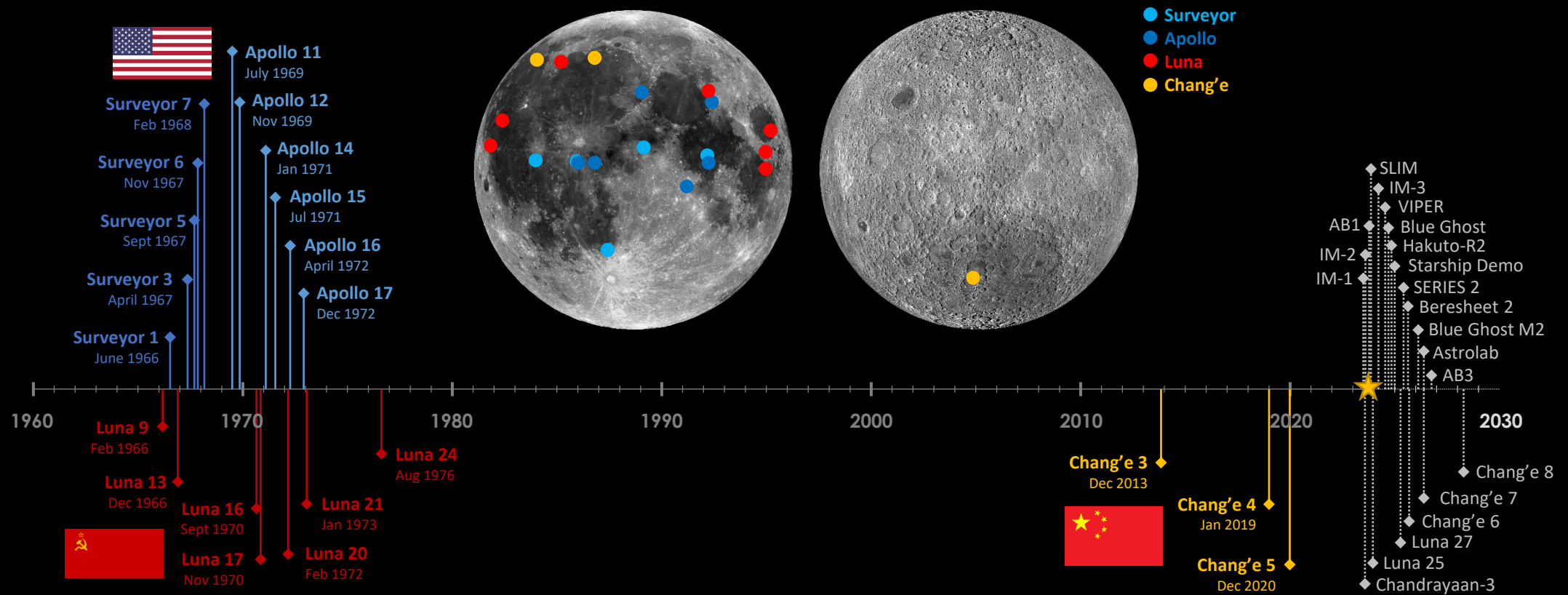
Location Advantages of NRHO

- Only 3 – 5 days away from Earth yet farther than Apollo went
- Ideal mission aggregation location
 - Lunar Surface, Mars and Asteroids all accessible for less than 2.5 km/sec
 - Cryogenic oxygen & hydrogen used to inject to cislunar without requiring ZBO
- The next “high ground” beyond GEO
 - L2 for Lunar far-side science
 - L1 for Earth observations
 - All cislunar for low latency teleoperations of lunar assets
- Access to local resources (ISRU)
 - Lunar gravity assists
 - Lunar surface volatiles
 - Asteroidal material
- Accessible by NASA, commercial, and international launch systems

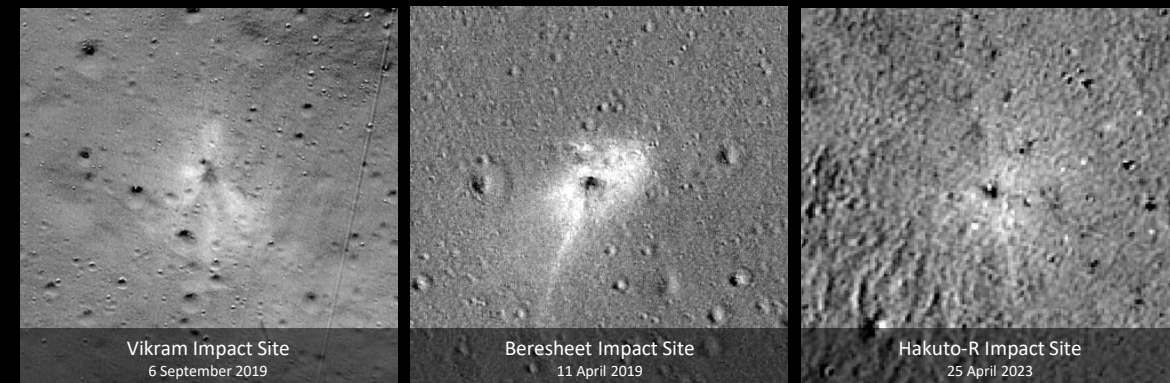
Environment Advantages of NRHO

- True deep space radiation environment
 - Similar to Mars system & transit there
 - No van Allen belts
- Benign orbital debris environment (for now)
- Minimal station keeping requirements
- Some stable orbits (e.g. L4, L5)
- Orbital phasing and transfer for minimal energy
- Infrequent/avoidable eclipse periods
- Thermal environment compatible with cryogenic oxygen and methane

The Rapid Increase in Lunar Missions



- Total Successful Soft Lunar Landings: **21**
- The three Chang'e landers are presently the only successful landings since 1976.
- Chang'e-4 is the closest to the South Pole (and the only landing on the far side), but at 45.4 °S latitude it is still over 1350 km from the pole – about the distance from Cleveland to Orlando





LUNAR MISSIONS

2021–2025

NASA CLPS DELIVERY GOALS

- | | |
|--|---|
| PEREGRINE-1
ASTROBOTIC
★★★ | GRIFFIN-1 & VIPER
• Search for volatiles, below surface and in shadowed regions |
| 1ST NOVA-C
• Plume/surface interactions, charged particles near surface
• Lander prop tank gauge test | 2ND NOVA-C
• Drilling for volatiles |
| XL-1
• Regolith volatiles composition
• Surface terrain & mineralogy | BLUE GHOST
• Characterize Earth's magnetosphere and Moon's interior |
| CP-11
• Lunar Magnetic Anomalies | DRAPER
• Geophysics of the Schrödinger Basin |

KEY

- ★ CLPS DELIVERY
- 🌐 INTERNATIONAL-LED
- 👤 HUMAN EXPLORATION
- 🔬 SCIENCE
- 🚀 SPACE TECHNOLOGY

Source: J. Kearns, "Lunar Discovery and Exploration Program Update," NASA Science Mission Directorate, 2023.

2023

1ST NOVA-C
INTUITIVE MACHINES
★★★

PEREGRINE-1
ASTROBOTIC
★★★

ARTEMIS I
UNCREWED FLIGHT TEST
+ CUBESATS

KPLO

2ND NOVA-C
INTUITIVE MACHINES
★★

LRO

THEMIS-ARTEMIS

CAPSTONE

GRIFFIN-1
ASTROBOTIC
★

2021

2022

2024

ARTEMIS II
CREWED FLIGHT TEST

GATEWAY
PPE & HALO

BLUE GHOST
FIREFLY
★★★

CP-11 3RD NOVA-C
INTUITIVE MACHINES
★★

UNCREWED
LANDER
DEMO

VIPER
NASA
★

DRAPER
★★

LUNAR
PATHFINDER
★

CS-3
SELECTION
FORTHCOMING
★

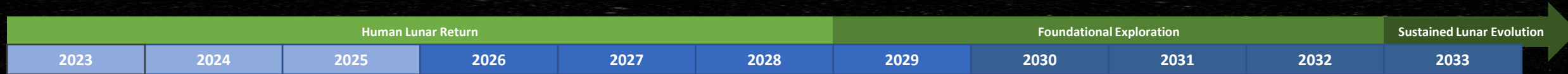
2025

ARTEMIS III
CREWED SURFACE
MISSION

CREWED
LANDER
DEMO

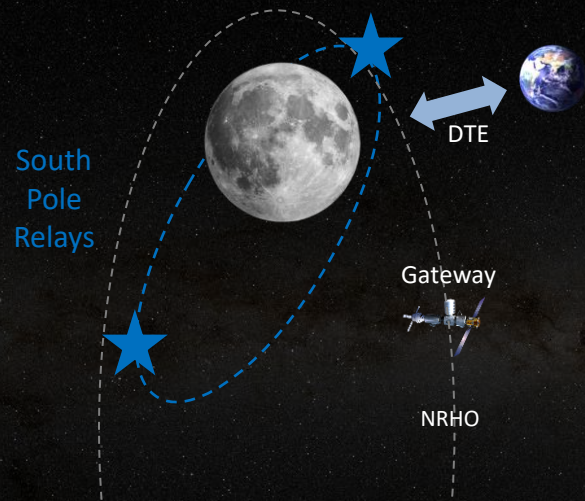
ORBITAL
MISSIONS

SURFACE
MISSIONS



CPNT Initial Phase

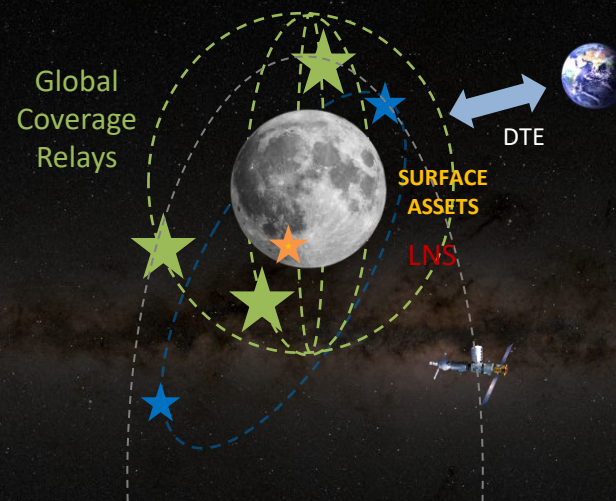
(by 2024-2025)



- DTE service for Near Side, lunar orbiters and surface missions
- Large increase in data rates and volumes
- Intensive relay service for South Pole and a selected area of the Far Side
- Initial PNT service and initial lunar surface networking near vehicles
- LunaNet interoperability established from the beginning

CPNT Growth Phase

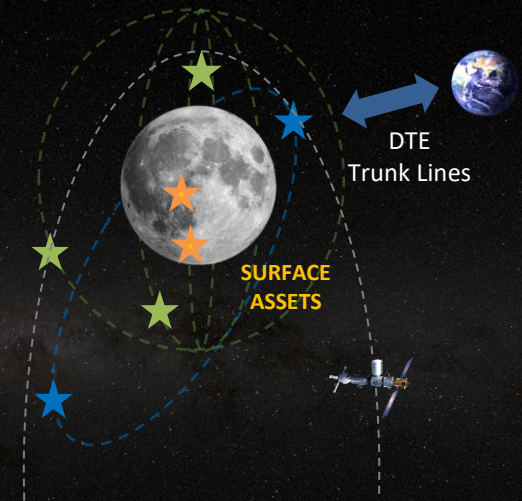
(2026 - 2030)



- Continued DTE service for Near Side
- Expanded relay service for South Pole and multiple Far Side regions
- Limited relay service for other globally-dispersed locations and orbiters
- Lunar Navigation Service (LNS) for PNT
- Expanding surface networking capability leveraging new elements (LTV, etc.)
- Introduction of optical links

CPNT Desired Future State

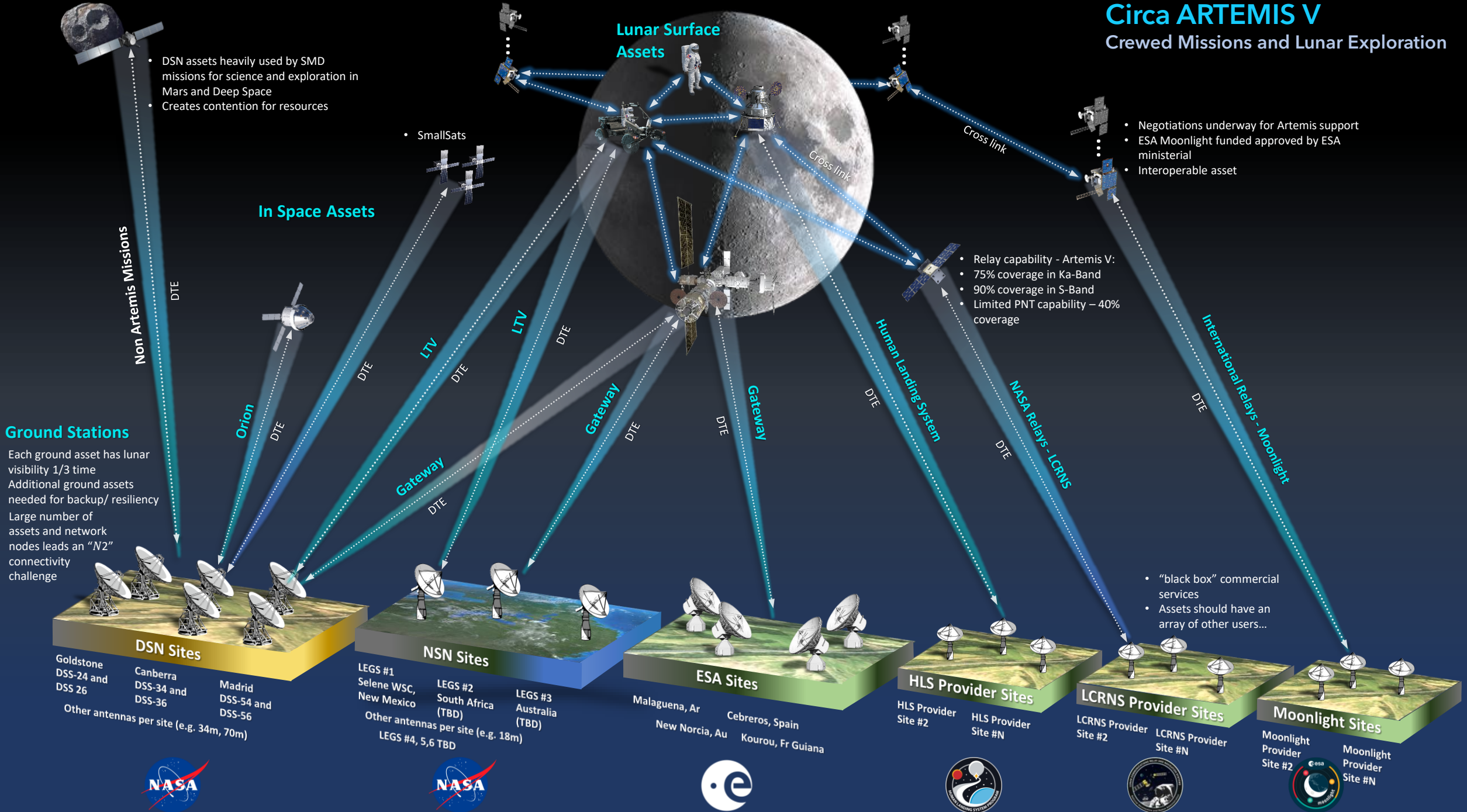
(2030+)



- Satellite constellations with multiple operators functioning as cooperative set of networks
- Intensive coverage of specific regions and regular coverage of all regions
- Optical trunk line links
- Growth of surface network capability (PR, Habitat)

Circa ARTEMIS V

Crewed Missions and Lunar Exploration





34-Meter Antenna Upgrades

- Upgrades to two Deep Space Network (DSN) antennas at each of the three complexes (totaling six upgraded antennas)
- Simultaneous operations – S+Ka-band or X+Ka-band, simultaneous Ka-band
- Increased data rates – greater than 100Mbps downlink in Ka-band



18-Meter Antenna Subnet Development (LEGS)

- A dedicated new set of antennas, designed to support lunar missions, to help alleviate the user load on the DSN
- Minimum of three sites around the Earth for continuous coverage
- NASA pursuing build of LEGS sites #1-3
- Commercial services to add additional capacity – add assets as demand grows and to meet redundancy / resiliency needs



Lunar Relay and Interoperable Lunar Network

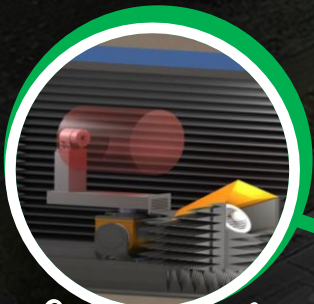
- Removes DTE line-of-sight comm constraint & reduces user burden
- Initial relay deployment targeted at South Pole and Far-Side
- Networking and PNT services
- Commercial service procurement approach for the relay



International Partnerships And Contributions

- SCaN seeking contributions for both Earth based and Lunar C&N assets
- Priority 1: Direct-to-Earth assets that meet or exceed LEGS performance
- Priority 2: Lunar relay comm and PNT services
- Priority 3: Lunar surface comm and PNT capabilities

Glenn's Aerospace Communications Facility



Compact Antenna
Test Range



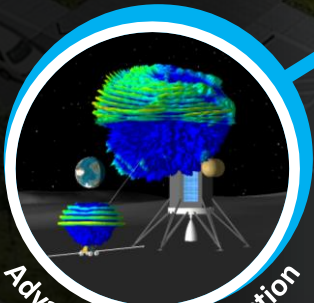
10m Horizontal Planar
Near Field Range



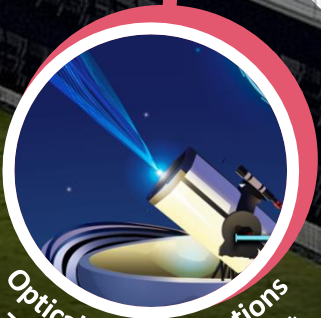
Cylindrical / Spherical
Near Field Range



3.7m Fast Tracking
Ground Station



Advanced HITL Emulation
for Communications



Optical Communications
Technology Development



RF Characterization
of Materials

