National Aeronautics and Space Administration

Lunar Communications and Navigation :

Integrating Government, Commercial, and International Partner Solutions

Richard Reinhart
NASA Glenn Research Center
Sponsor: Space Communications and Navigation Program

richard.c.reinhart@nasa.gov

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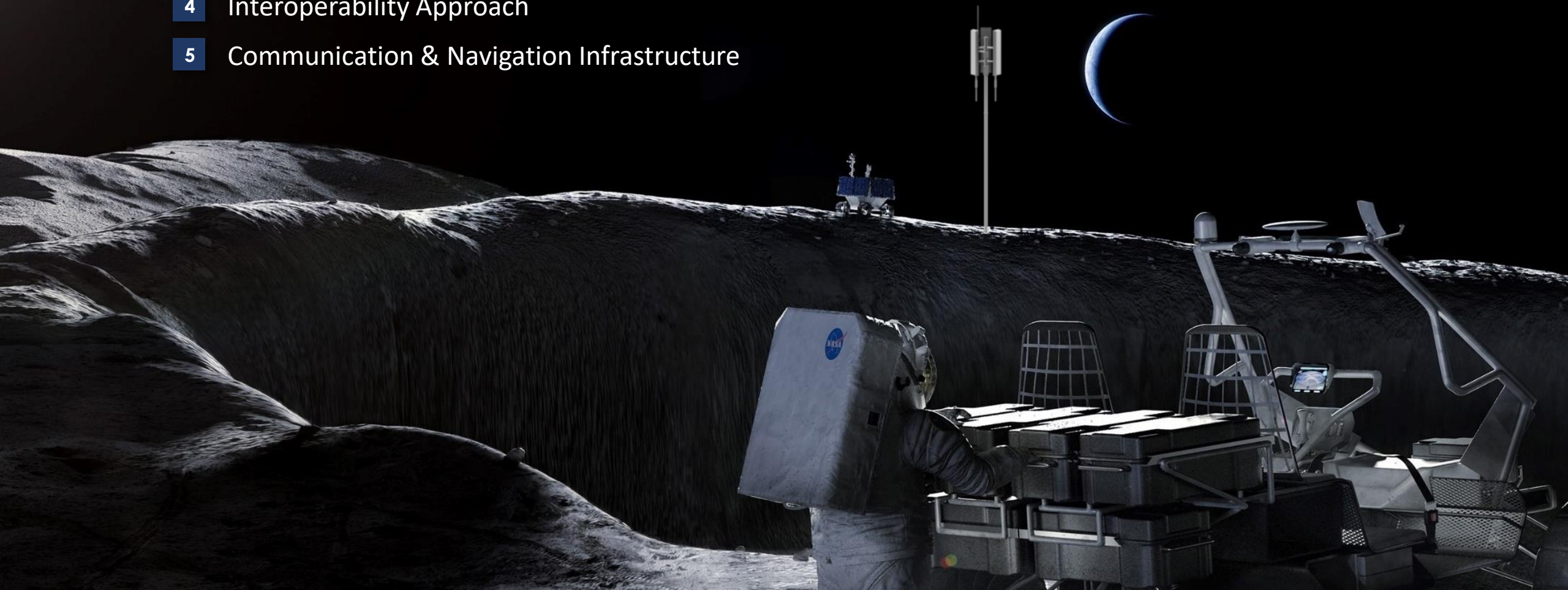
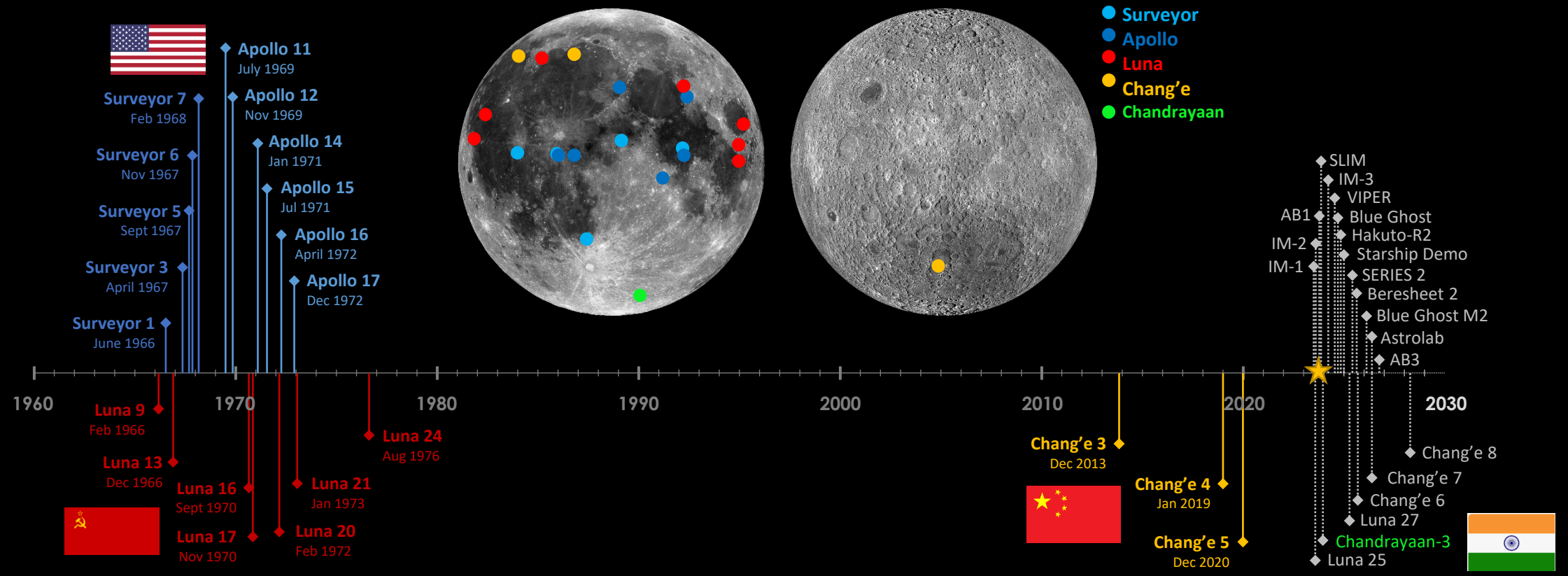
Presentation Agenda

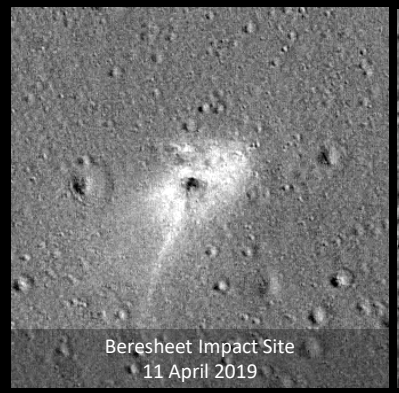
1. Rapid Increase in Lunar Missions
2. Cislunar Communications & Navigation Infrastructure
3. Government, Industry, and International Partner Approach
4. Interoperability Approach
5. Communication & Navigation Infrastructure

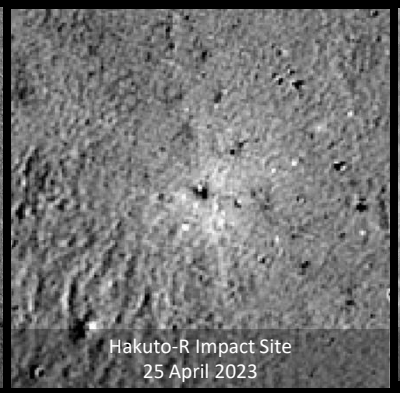


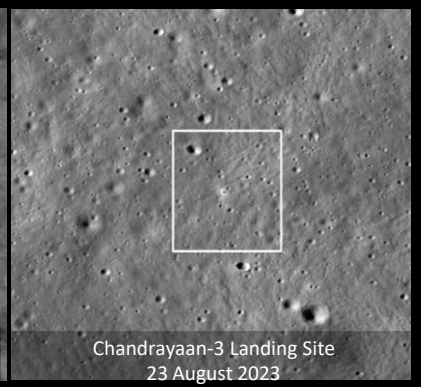
The Rapid Increase in Lunar Missions



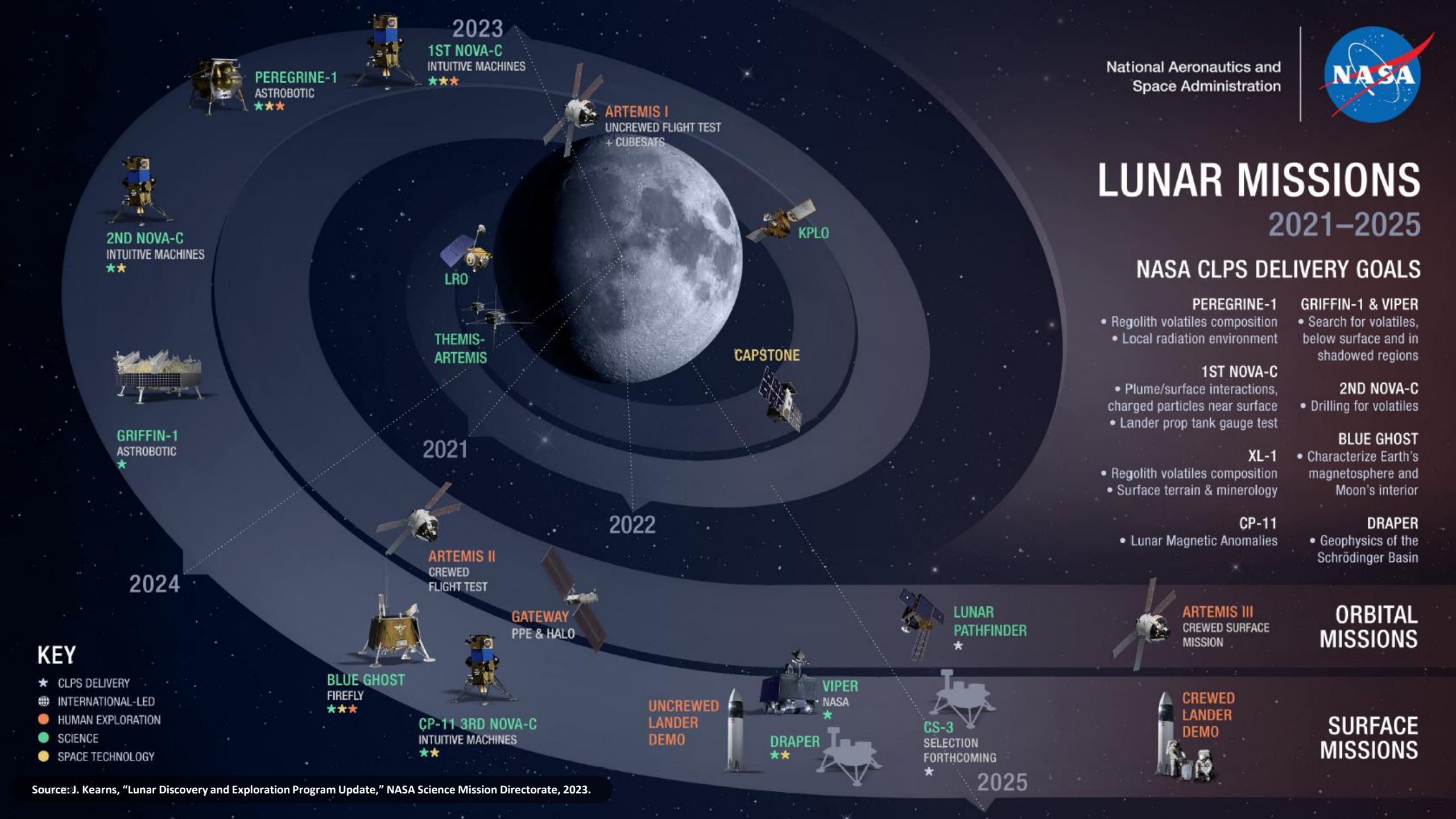
- Total Successful Soft Lunar Landings: **22**
- Three Chang'e and Chandrayaan-3 landers are presently the only successful landings since 1976.
- Chandrayaan-3 is the closest to the South Pole at 69.3 °S lat, 32.3° E long, ~600km from the pole
- Chang'e 4 is the only landing on the far side





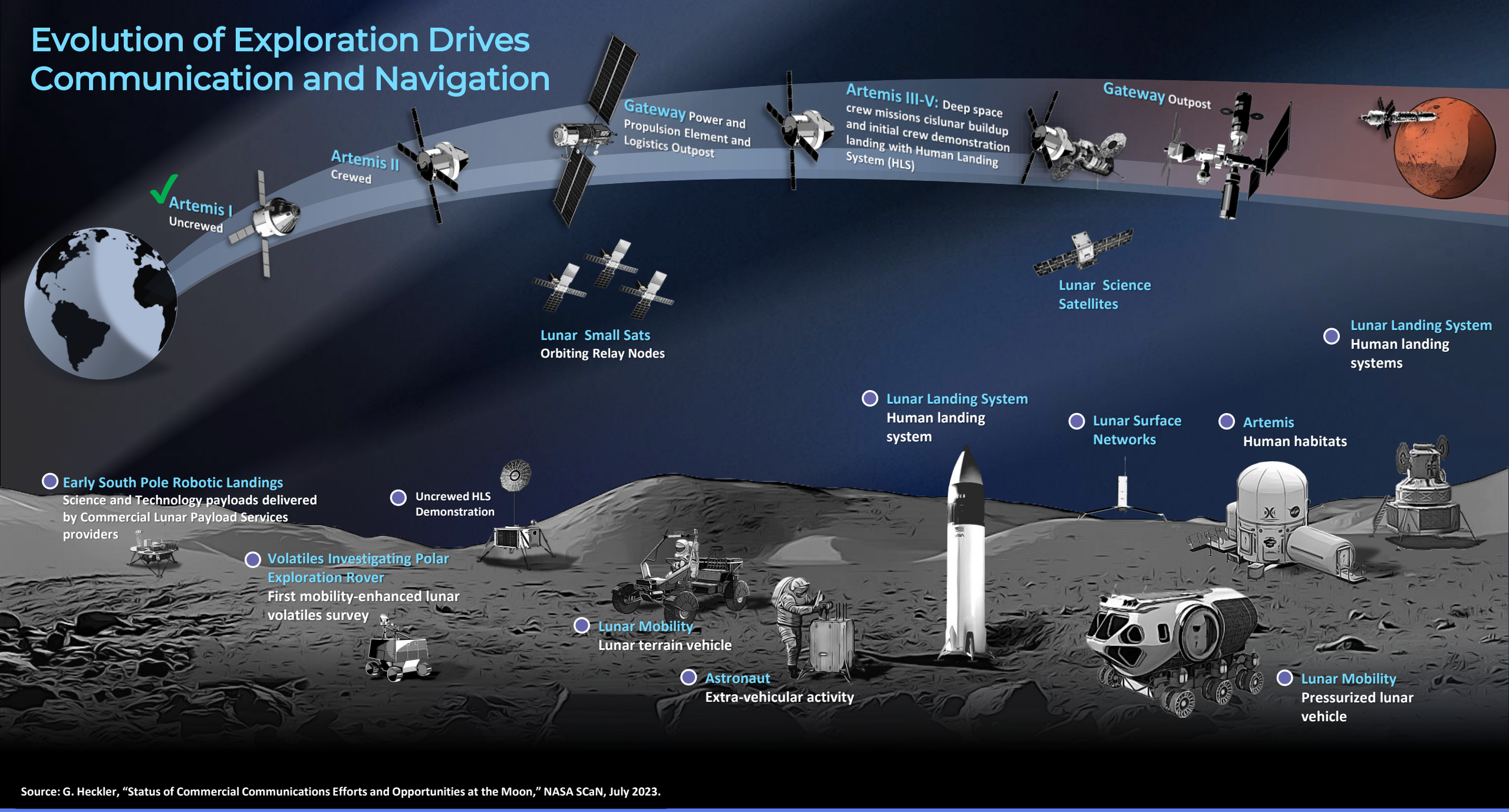


Lunar Reconnaissance Orbiter Camera (LROC) Imagery of recent impact sites. NASA Goddard Space Flight Center



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

Evolution of Exploration Drives Communication and Navigation



Source: G. Heckler, "Status of Commercial Communications Efforts and Opportunities at the Moon," NASA SCaN, July 2023.

Lunar South Pole Region

Communications and Navigation Infrastructure

National Infrastructure

INFRASTRUCTURE: Develop a communications architecture capable of scaling to support long term science, exploration, and industrial needs

- Moon-to-Earth
- Orbital
- Lunar surface

APPROACH DRIVEN BY:

- Earth independence, M2M
- Robustness, resilience
- Complex multi-vehicle surface operations
- Autonomy for lunar robotics
- Highly dynamic scenarios (e.g., landing, rendezvous / proximity operations)
- Services

Commercial Industry

INTEROPERABILITY: Create an interoperable global lunar utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence for science objectives and testing for Mars, without NASA as the sole user.

International Partners

LunaNet – "Lunar Internet" Overview & Interoperability

LunaNet concept is a set of cooperative communication and navigation networks composed of assets from commercial and government providers serving users at the Moon;
Trunk Links, Proximity Links, Surface Network, Navigation

LunaNet: a flexible, extensible, and interoperable lunar comm/nav architecture with key services:

- Communications/Networking
- Position, navigation and timing (PNT)
- Detection, information, notices
- Science

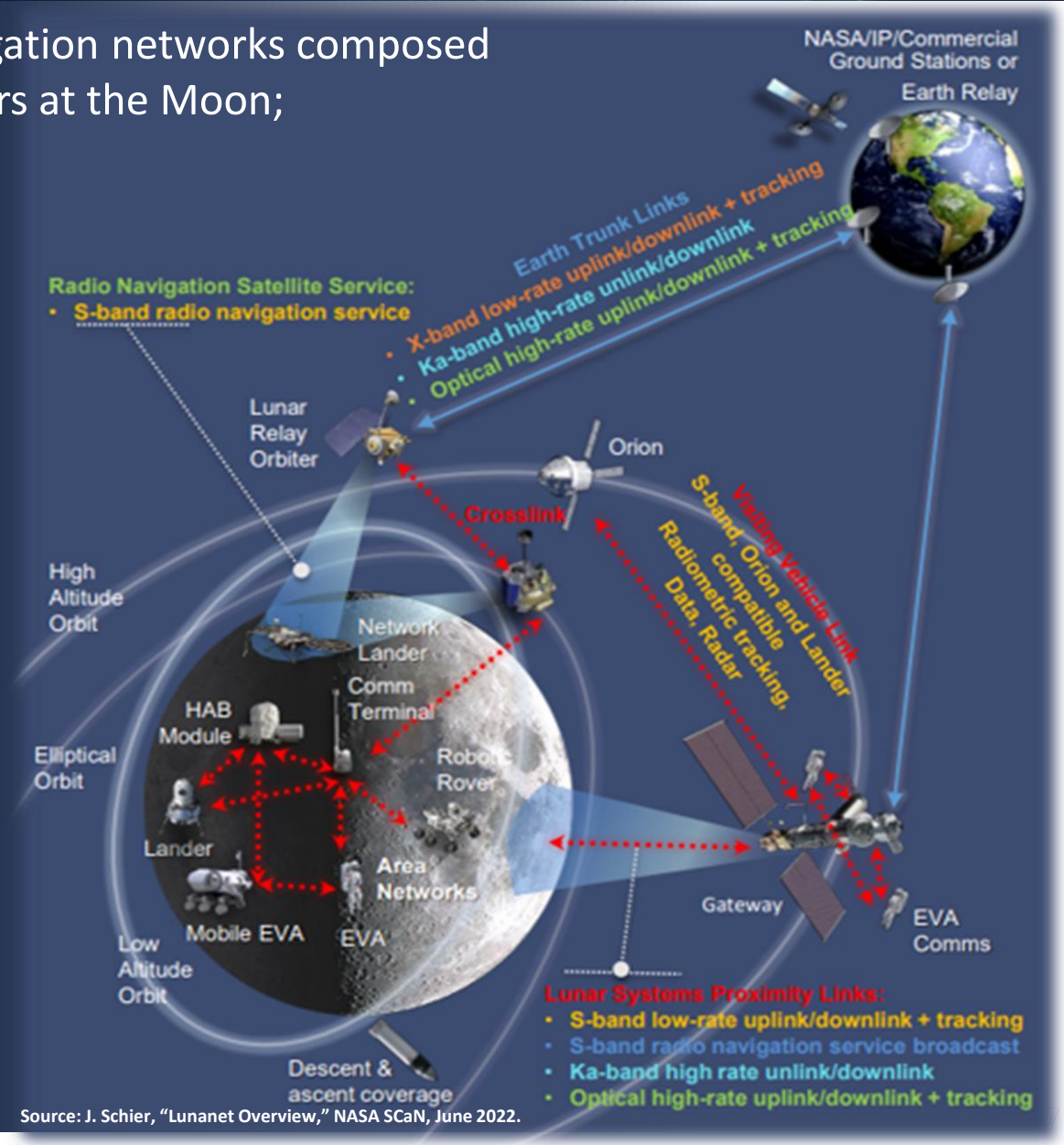
LunaNet is a collaboration focused on interoperability

- Collaboration with industry on the next version (Draft Version 5) of the LunaNet Interoperability Specification – Ver 4 released in Sept 2022
  - > https://www.nasa.gov/directorates/heo/scan/engineering/lunanet_interoperability/
  - > Past industry days with NASA
- The specification defines standards for lunar communications relay and navigation services and interfaces

Interagency Operations Advisory Group (IOAG)

- The Future Lunar Communications Architecture
- International Communication System Interoperability Standards (ICSIS)

Spectrum Planning: ITU, SFCG and NTIA Processes



Source: J. Schier, "Lunanet Overview," NASA SCaN, June 2022.

Space Communications and Navigation (SCaN): Plan for Cislunar Infrastructure

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, 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 Direct-to-Earth (DTE) line-of-sight comm constraint & reduces surface user burden
- Initial relay deployment targeted at South Pole and Far-Side
- Communication, Networking and PNT services
- Commercial service procurement approach for the relay

International Partnerships And Contributions

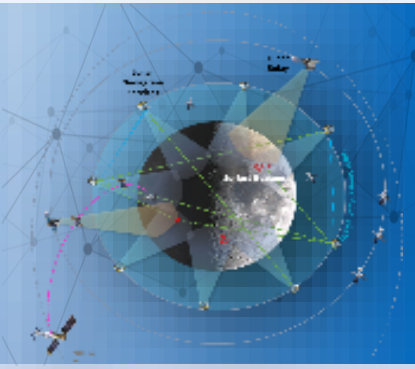
- SCaN seeking contributions for both Earth based and Lunar C&N assets
- Priority 1: Direct-to-Earth assets that meet or exceed LEGS performance
- Priority 2: Lunar relay comm and PNT services
- Priority 3: Lunar surface comm and PNT capabilities

Future Capabilities to Meet Growing Needs

Eventually, capacity increases alone will not be sufficient to meet all Artemis mission needs and will drive **capability** enhancements

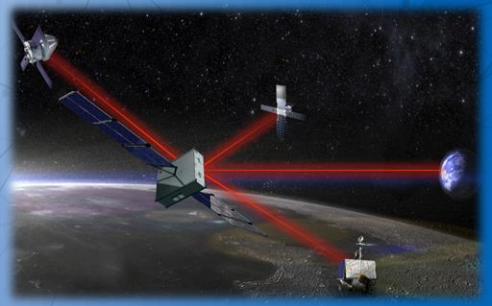
Surface Wireless Communications

- 3GPP/5G cellular technology for a robust lunar surface C&N infrastructure that is scalable to meet long-term needs
- Essential to address surface and orbital link proliferation
- Enables direct surface/local communication and aggregates data for transition to backhaul
- Potential implementation for Artemis V – connectivity between HLS, LTV, and EVA



Lunar Navigation Services

- "Like GPS, but at/ for the Moon"
- Support near term needs for 10-m surface positioning and 50-m HLS landing knowledge requirements
- Long-term support of complex surface ops, Search and Rescue (SAR) functionality, situational awareness, prediction and avoidance
- Continue studies to define long term needs and architecture



Lunar Optical Communications

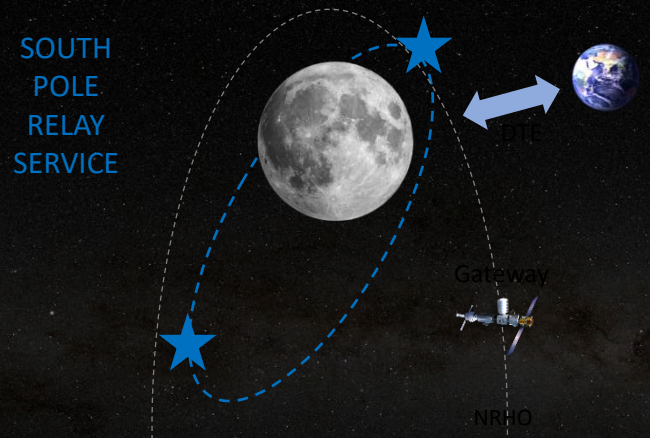
- Optical communications between Earth and Moon (coherent, multi-gigabit) supports high bandwidth needs, data aggregation and relieves spectrum pressure
- LunaNet compatible, with high-speed DTN
- 1m class operational optical ground stations w/adaptive optics

These items are critical initial steps in capability development required for eventual Artemis sustained surface operations

Lunar CPNT Architecture Infrastructure Evolution

CPNT Initial Phase

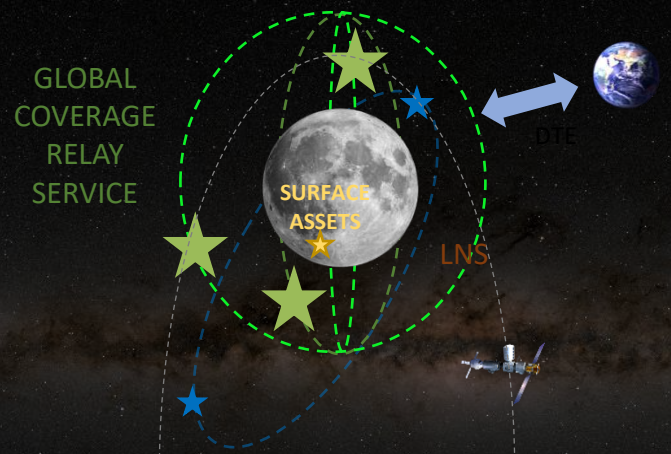
(by 2024-2025)



- ***DTE service for Near Side, lunar orbiters and surface missions***
- ***Intensive relay service for South Pole and a selected area of the Far Side***
- ***Initial PNT service and lunar surface networks***
- ***LunaNet interoperability established from the beginning***

CPNT Growth Phase

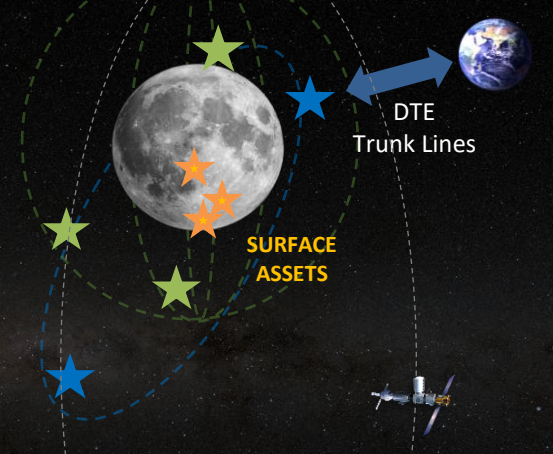
(2026 - 2030)



- ***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***
- ***Expanded Surface networking***
- ***Introduction of optical links***

CPNT Desired Future State

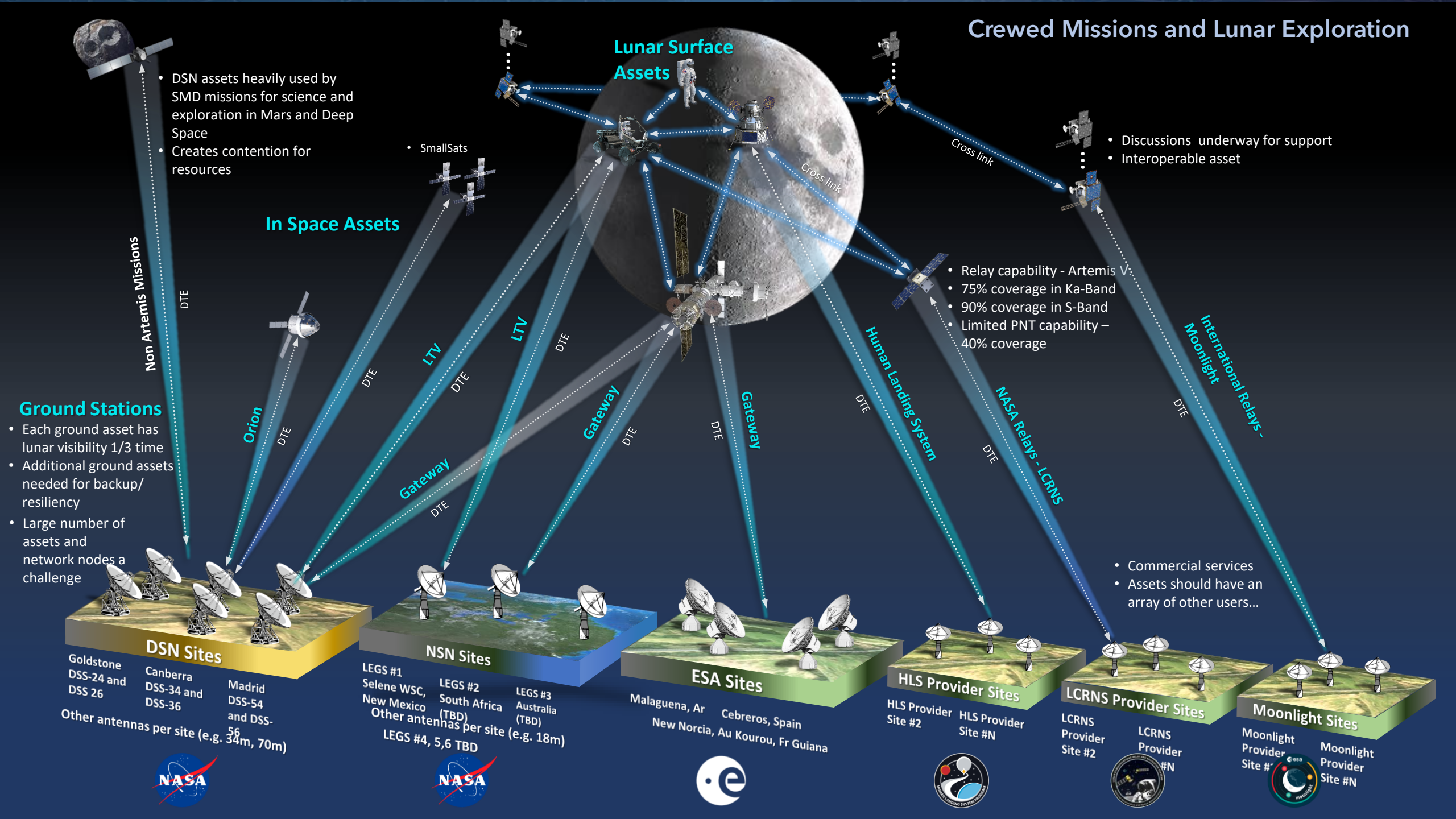
(2030+)



- ***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 assets in multiple locations***

Notional Implementation Approach.

Crewed Missions and Lunar Exploration



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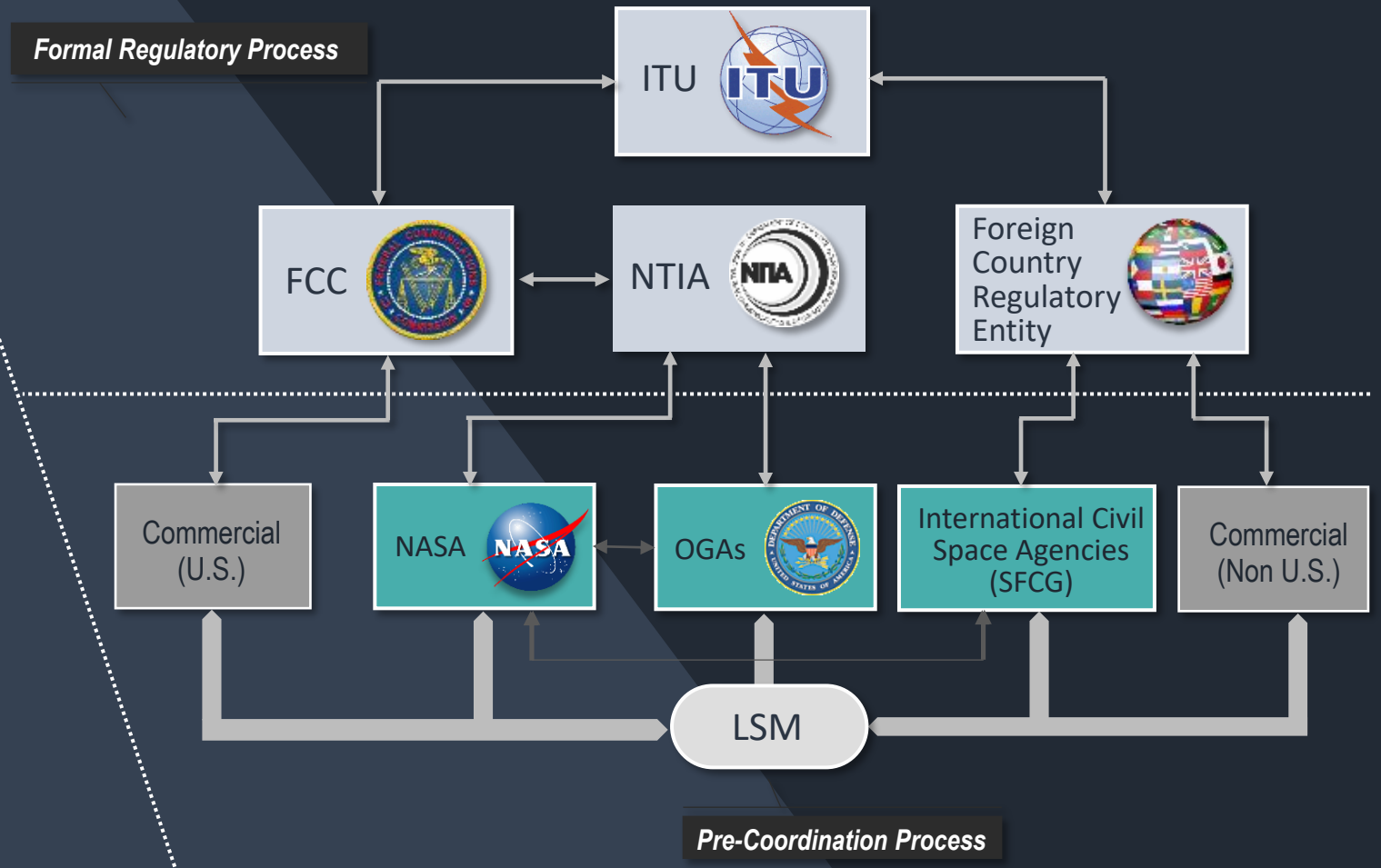
Lunar Spectrum Management International Coordination

- **Lunar Working Group,** chaired by NASA, to assist NTIA IRAC Subcommittees in assessing lunar region spectrum-dependent systems proposals during spectrum certification, ITU filing initiation, and frequency assignment processes.

- **SFCG Administrative Resolution A40-1,** encourages lunar mission planners at member agencies to seek assistance from NASA's LSM during the initial formulation phase to provide current technical, operational and mission information and timely updates to facilitate frequency selection studies and interference analysis.



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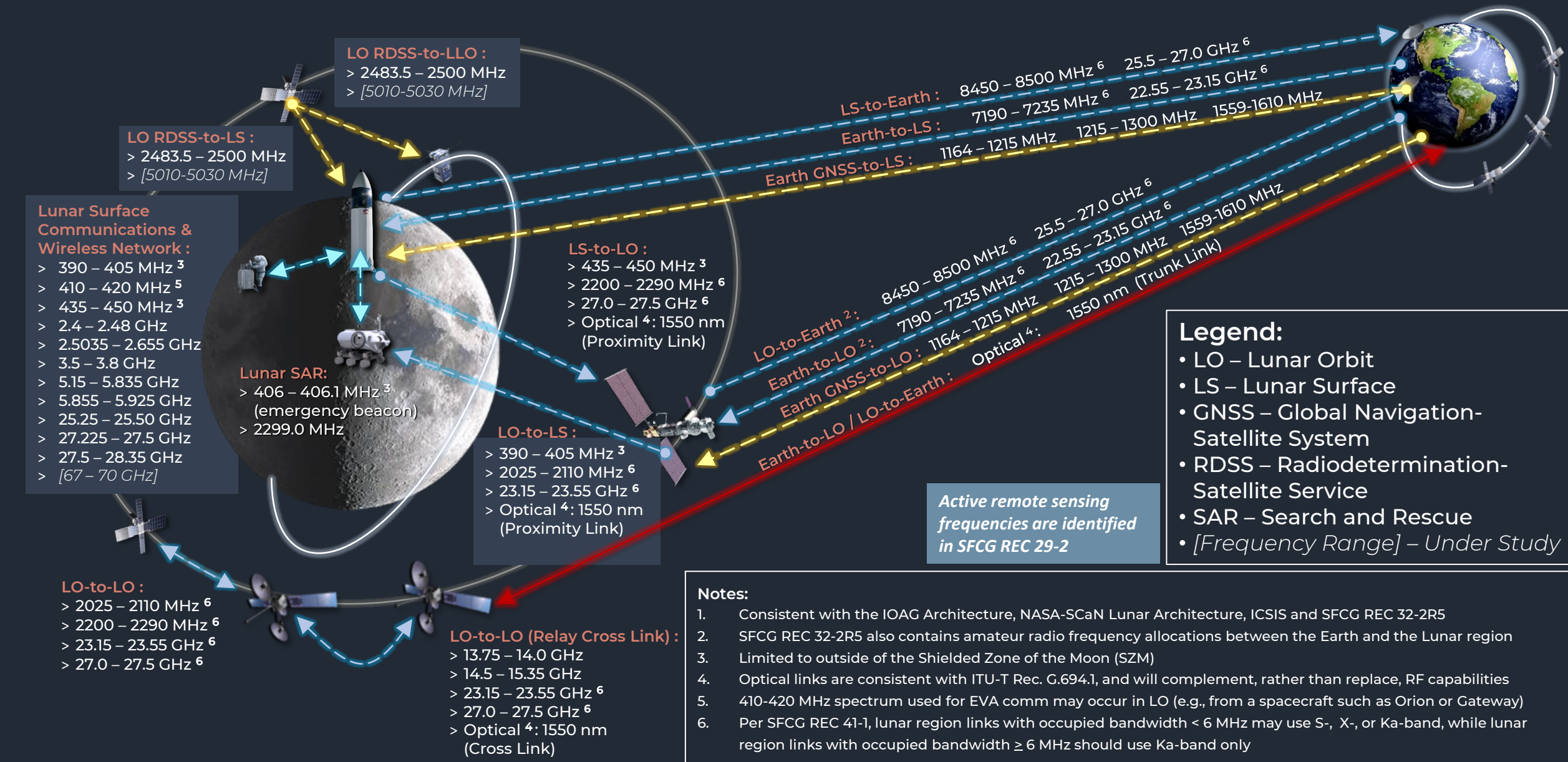
Electromagnetic Spectrum for Lunar Region

Radio Frequency[1] and Optical



Active remote sensing frequencies are identified in SFCG REC 29-2

Legend:

- LO – Lunar Orbit
- LS – Lunar Surface
- GNSS – Global Navigation-Satellite System
- RDSS – Radiodetermination-Satellite Service
- SAR – Search and Rescue
- *[Frequency Range] – Under Study*

Notes:

1. Consistent with the IOAG Architecture, NASA-SCaN Lunar Architecture, ICSIS and SFCG REC 32-2R5
2. SFCG REC 32-2R5 also contains amateur radio frequency allocations between the Earth and the Lunar region
3. Limited to outside of the Shielded Zone of the Moon (SZM)
4. Optical links are consistent with ITU-T Rec. G.694.1, and will complement, rather than replace, RF capabilities
5. 410-420 MHz spectrum used for EVA comm may occur in LO (e.g., from a spacecraft such as Orion or Gateway)
6. Per SFCG REC 41-1, lunar region links with occupied bandwidth < 6 MHz may use S-, X-, or Ka-band, while lunar region links with occupied bandwidth ≥ 6 MHz should use Ka-band only


NASA