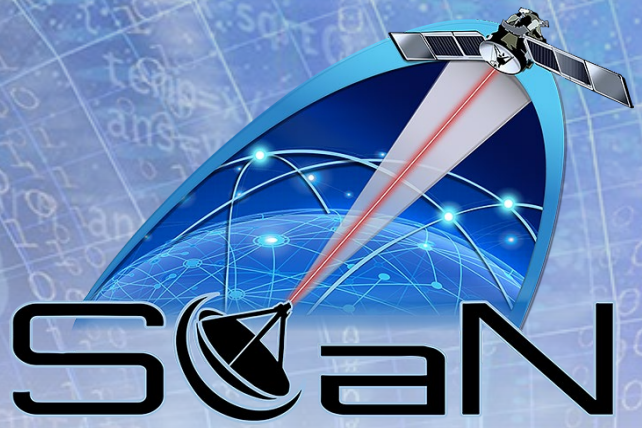
National Aeronautics and Space Administration



NASA Lunar Surface Communication/Navigation OneLink

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Goals of OneLink and Reverse Industry Day

- Develop industry's understanding of the government's current vision regarding lunar surface communications and navigation.
- Provide industry with the opportunity to meet with the government to provide input
- Encourage participants to submit comments during one-on-one sessions.

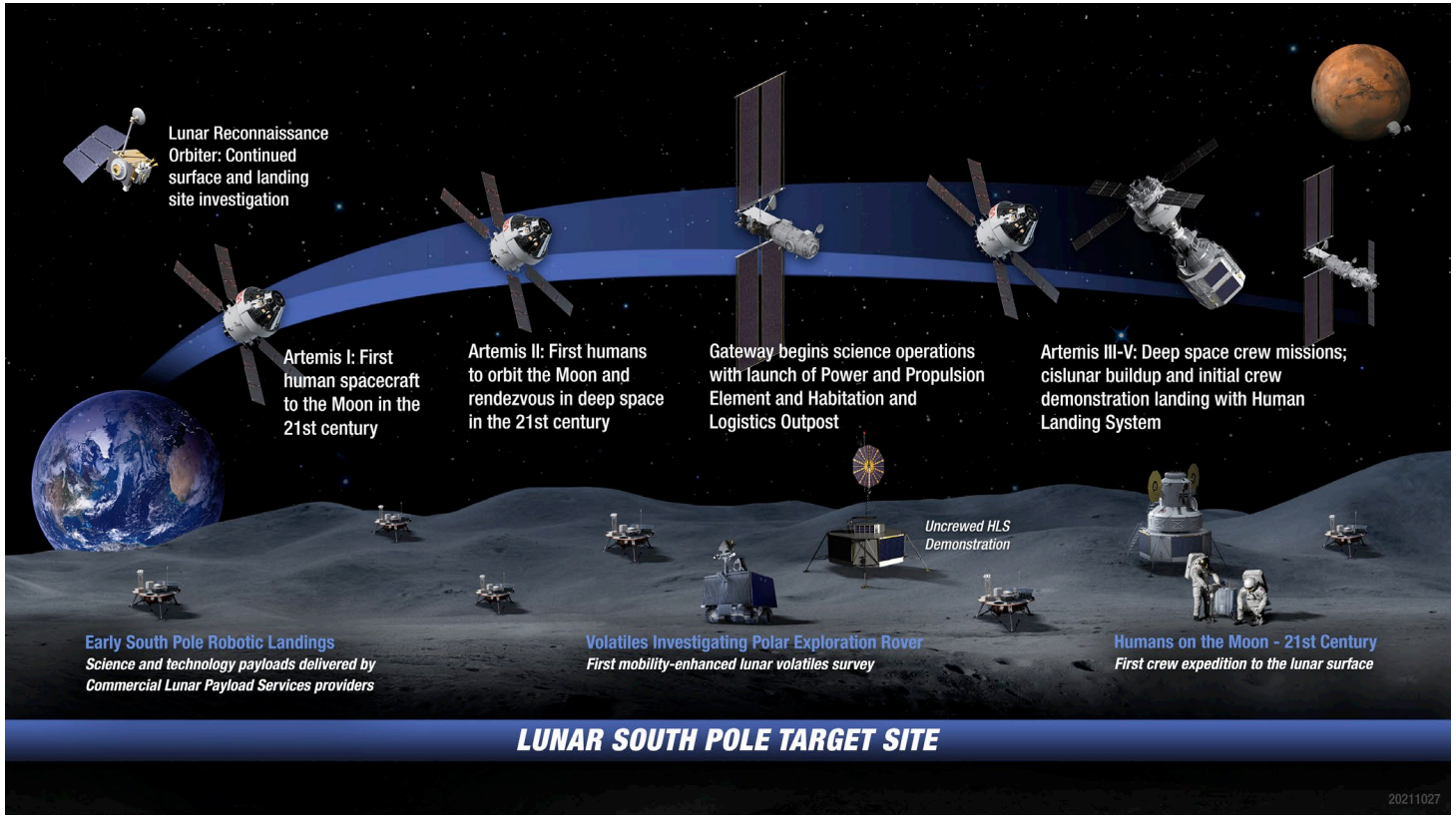
Today's Activity – Lunar Surface Comm and Nav Services

- NASA is exploring the potential utilization of telecommunication networking systems and services on the lunar surface based on open, commercially-maintained standards such as from 3GPP as part of a strategy to provide service for the expanding lunar presence.
- At today's event, we intend to convey NASA's interests and timelines for lunar networking and its relation to the Artemis program.
- NASA is interested in hearing from:
  - Potential providers of a future commercial service to users on the lunar surface and cis-lunar environment, of which NASA would be a customer.
  - Providers, developers, and integrators of technology that may provide components, products, and systems for a future a telecommunications network to operate and survive the harsh environment of space.

Notional Overview of the Artemis Program

Exploring the Moon for scientific discovery, economic benefits, and inspiration.

- Artemis I (2022) – Flight test of Space Launch System (SLS) rocket and Orion capsule around the Moon.
- Artemis II (est. 2024) – Flight test of SLS rocket and Orion with crew around the Moon.
- Artemis III (est. 2025) – Human Landing System (HLS) Starship flight. Crew return to the lunar surface.
- Artemis IV (est. 2027) – Crewed mission to Gateway and lunar surface.
- Artemis V (est. 2028) – Sustainment phase and Lunar Terrain Vehicle (LTV) for lunar surface operation



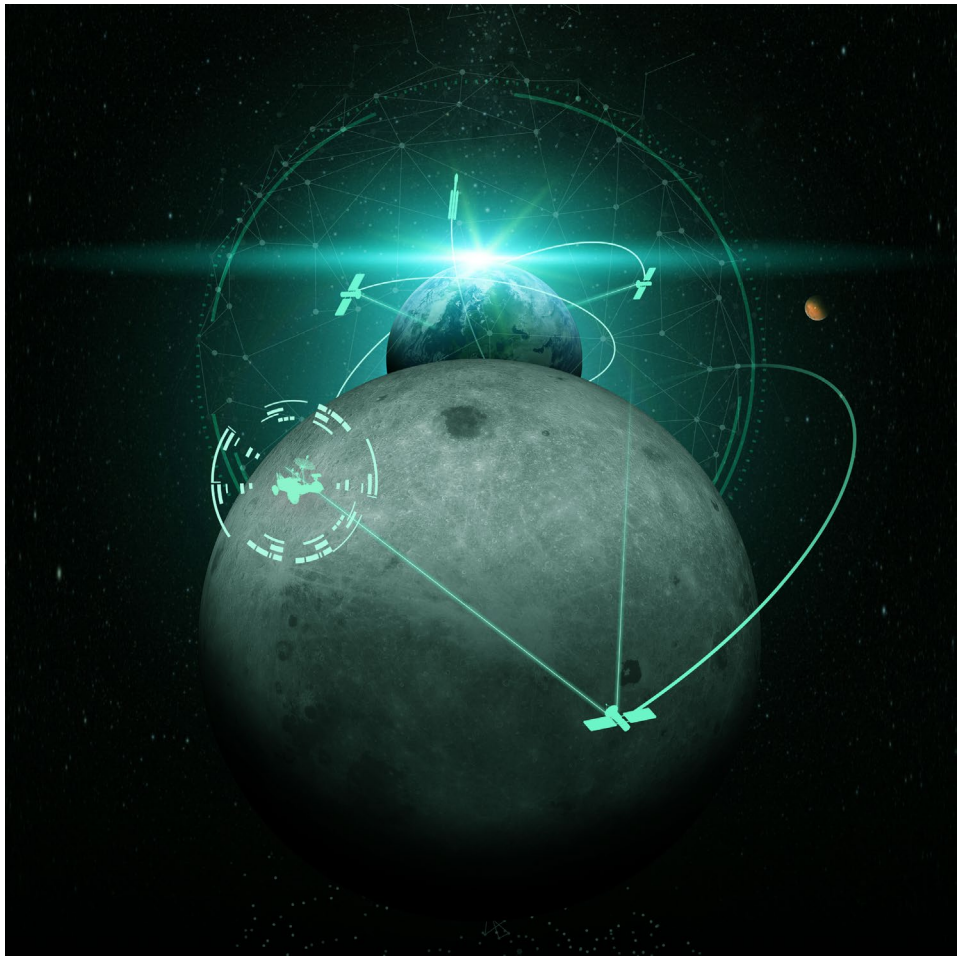
Space Communications and Navigation (SCaN) Overview

NASA's **Space Communications and Navigation (SCaN)** program office builds, operates, and maintains NASA's two primary communications networks – the Near Space Network and the Deep Space Network.

These networks allow spacecraft near and far to send critical tracking, telemetry, command, and science data to Earth.

SCaN also investigates new communications and navigation technologies so that these networks can support advanced missions.

NASA SCaN is embracing commercial capabilities across multiple areas, including communications and navigation.



3GPP, Commercial Standards, and the Lunar Surface

- Over the past 10 years NASA has explicitly used the *mobile smartphone experience* as a descriptive goal for the evolution of the NASA communication networks and services
- NASA intends to evaluate the implementation of a commercially established and maintained standard for telecommunication protocols used for communication between lunar surface elements
- The 3rd Generation Partnership Project (3GPP) is an umbrella organization known for the development and maintenance of mobile telecommunications standards
  - NASA is beginning its engagement in 3GPP at a technical and standards level
  - NASA wants to explore the applicability of 3GPP standards to lunar surface networking

Can NASA use 3GPP or other commercial telecom standards for the lunar surface “as is” or with small modifications managed/made by the standards organization?

Current 3GPP Coordination Across NASA

NASA has been instrumental behind a Consultative Committee for Space Data Systems (CCSDS) Working Group promoting the use of 4G / LTE, along with other wireless technologies, for surface communications

- CCSDS 883.0-R-1 (2022) to recommend interoperable LTE configurations for high-data-rate proximity wireless networks

NASA is investigating the use of 4G / LTE technologies in the lunar environment by awarding a Tipping Point contract to demonstrate space rated 4G/LTE hardware near the Lunar South Pole

- Base station on lander, deployable rover with user equipment
- Demonstration will support detailed analysis into 4G/LTE performance
- Emulate and characterize LTE networks within NASA's lunar communications architecture
- Characterize propagation environment and model development/enhancement

SBIR/STTR subtopic on Lunar 3GPP Technologies was approved for the FY23 solicitation.

- Topic: H9 - Space Communications and Navigation | Subtopic: H9.04 - Lunar 3GPP Technologies
- Phase I contracts last for 6 months (SBIR) or 13 months (STTR) with a maximum funding of $150k. Phase II contracts last for 24 months with a maximum funding of $850k.

NASA studies continue to investigate the applications of directly using 5G from the lunar surface (Ref **)

While previous efforts have been utilizing 4G / LTE, we suspect any future operational lunar network will be based on a later 3GPP Release (5G and beyond)

** Reference: https://ntrs.nasa.gov/citations/20220015268

B. Edwards, R. Wagner, M. Zemba, W. Millard, S. Braham, K. Gifford, O. Somerlock, 3GPP Mobile Telecommunications Technology on the Moon, IEEE/AIAA Aerospace Proceedings, Mar 2023.

Lunar surface and vicinity potential use cases and services

Science and Human Exploration Use Case

- Surface operations
  - Fixed
    - Habitat
  - Mobility
    - Lunar Terrain vehicle (LTV)
    - Personnel
  - Robotics – In-situ Resource Utilization

Potential Services:

- Lunar Surface Services (user to user)
  - Telecom, e.g., 3GPP
  - Wi-Fi
  - Legacy voice
- Direct to Earth from surface
- Orbiting Relay Services from surface
  - Lunar Gateway - NRHO
  - Lunar Relay and Navigation Service

Reference: https://blogs.nasa.gov/artemis/2020/10/28/lunar-living-nasas-artemis-base-camp-concept, Credit: NASA

Considerations

How Will Future Lunar Surface Networking Architectures Support the Following:

1. Long duration human exploration and science experiments on both the near and far-side of the Moon.

2. Sustained Artemis base camp operations with high data volumes even when crew are not present and frequent, longer, and more complex human and robotic mobility operations.

3. Surface communications among science and human exploration mission users (e.g., LTV, rover, habitat, etc.)

4. Interoperable communications and navigation services to support users NASA, other government agencies, international entities, commercial companies, and more.

5. NASA's investment in the international and U.S. government standards for communications and navigation:
   - LunaNet Interoperability Specification
   - International Communication System Interoperability Standard (ICSIS)

6. NASA's plans for use of orbiting relays that are providing communication and navigation services to the lunar surface and cis-lunar environment

Reference: https://esc.gsfc.nasa.gov/projects/LCRNS, Credit: NASA

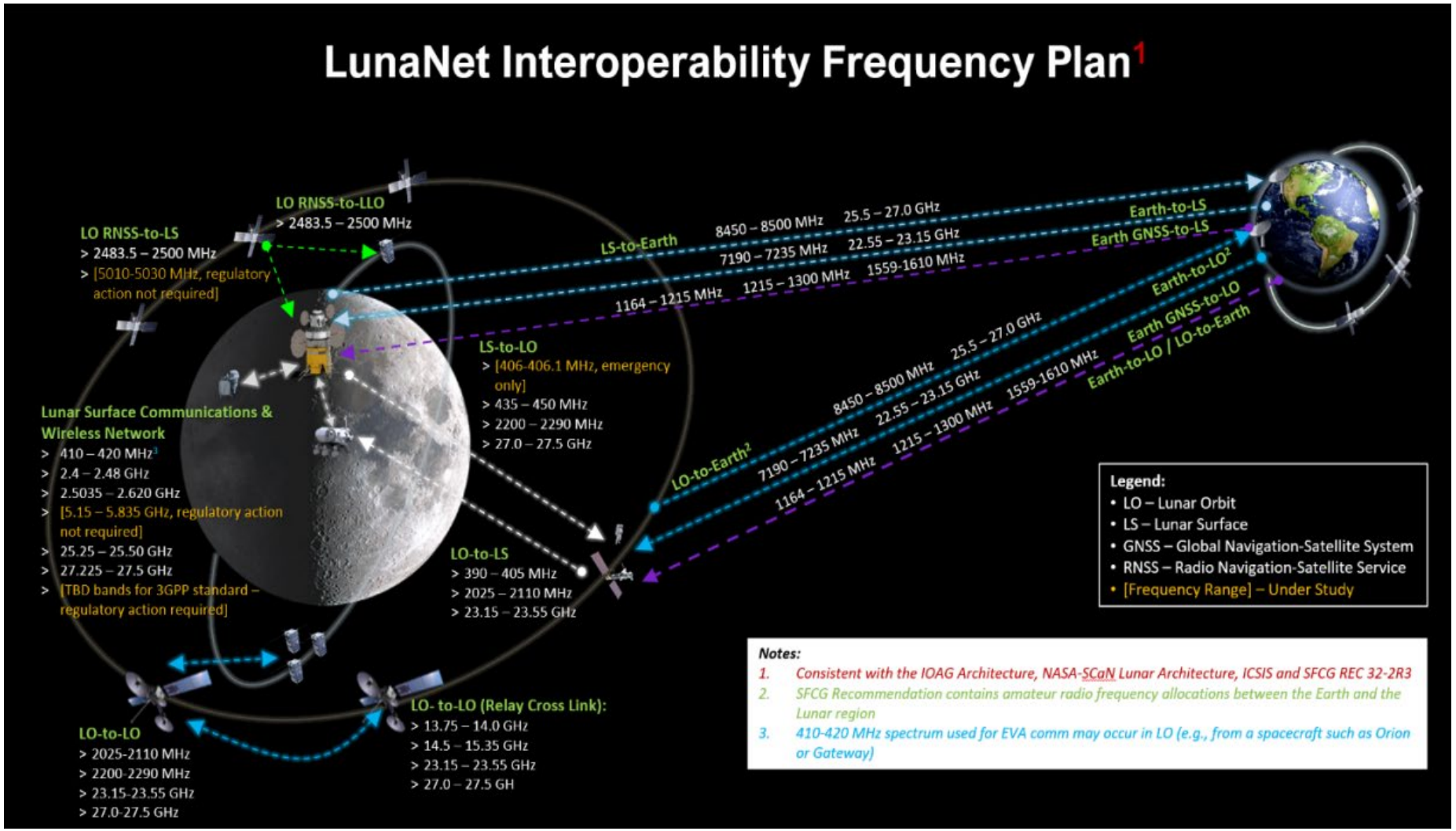
Lunar Spectrum Planning – Current Approach

Spectrum planning coordination with:

- Interagency Operations Advisory Group (IOAG)
- National Telecommunications and Information Administration (NTIA)
- Space Frequency Coordination Group (SFCG)

SFCG Rec 32-2R4 also recommends the following:

- Earth-based GNSS to lunar orbit and lunar surface:
  - 1164-1215 MHz
  - 1215-1300 MHz
  - 1559-1610 MHz
- In-situ Lunar based RNSS to lunar orbit and lunar surface
  - 2483.5-2500 MHz



Reference: LunaNet Interoperability Specification Document Baseline
https://esc.gsfc.nasa.gov/static-files/Draft%20LunaNet%20Interoperability%20Specification%20Final.pdf

Lunar Surface Communications - Current Approach

“Baseline” surface comm architecture:

- Major elements (e.g., HLS, LTV, PR) communicate with lunar relay, Gateway, or direct to Earth according to frequency plan and International Communication System Interoperability Standard (ICSIS) formats
- EVA suits use an existing UHF time shared signal format (“legacy voice”) to communicate with each other, and to their host vehicle (LTV, PR, or HLS).
- Wi-Fi is available within range of any host vehicle for short range, high bandwidth, low criticality communications.

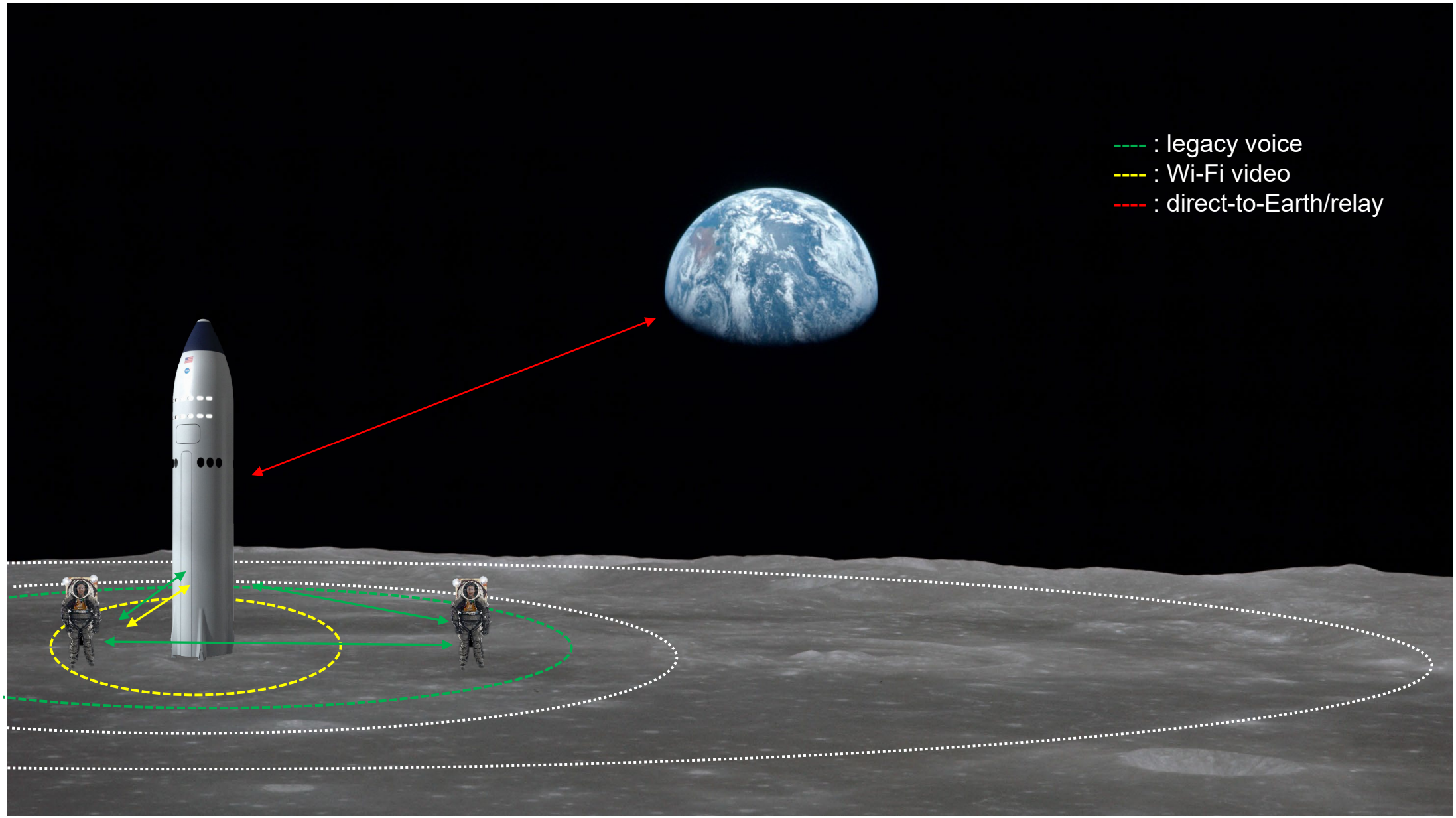
Potential Opportunities:

- Additional and standardized way for elements to communicate with each other
- Aggregate data from multiple elements to reduce lunar relays, Gateway, and Earth asset utilization
- Wi-Fi range limited, and current EVA Wi-Fi is criticality-3, with potential for criticality-1 use
- Expansion for later Artemis missions: science platforms, multiple EVAs, vehicles and modules

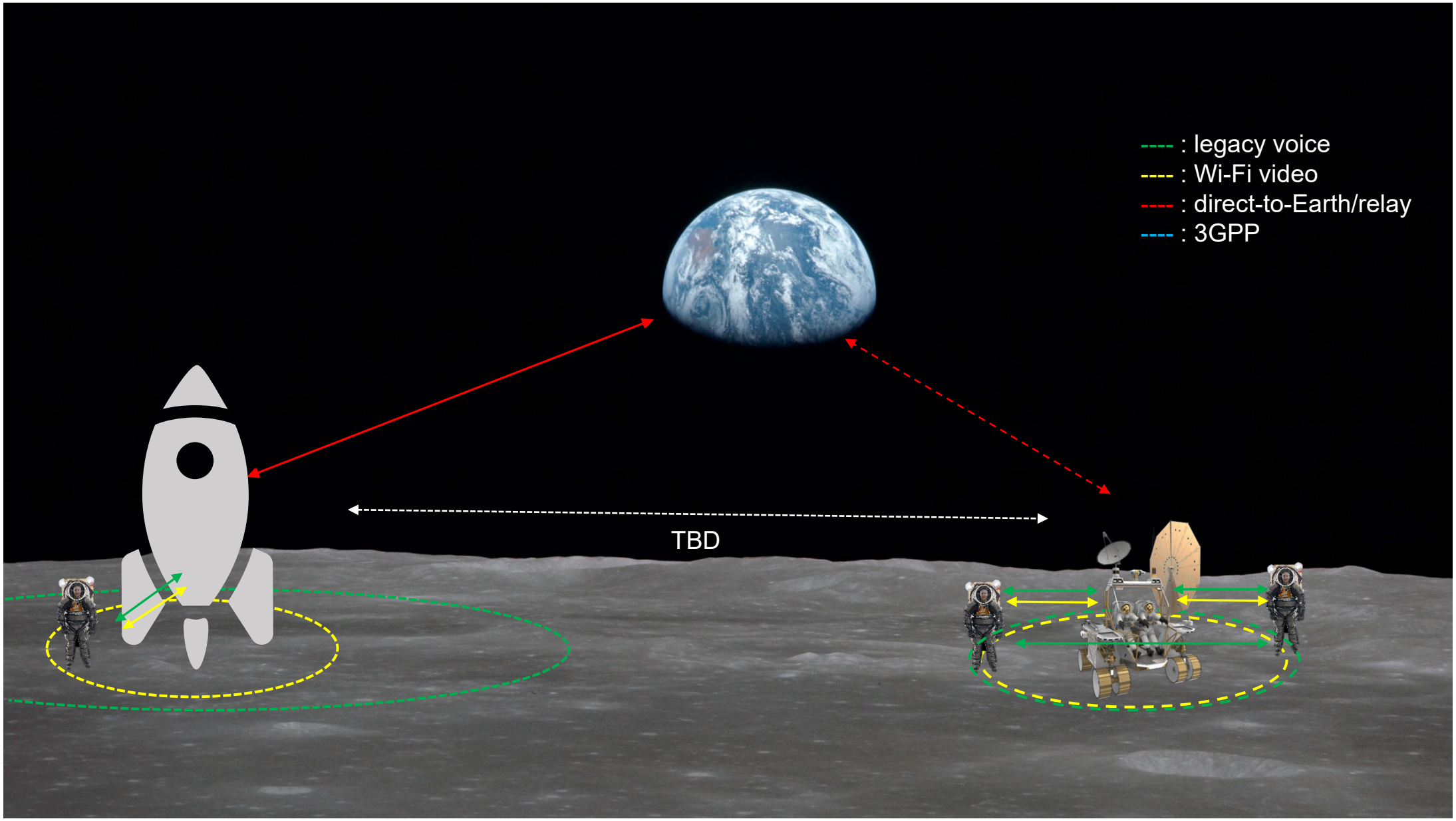
EVA – Extravehicular Activities HLS – Human Landing System
PR – Pressurized Rover LTV – Lunar Terrain vehicle
LCRNS – Lunar Comm Relay and Navigation System

Lunar LTE Tipping Point Demonstration Concept

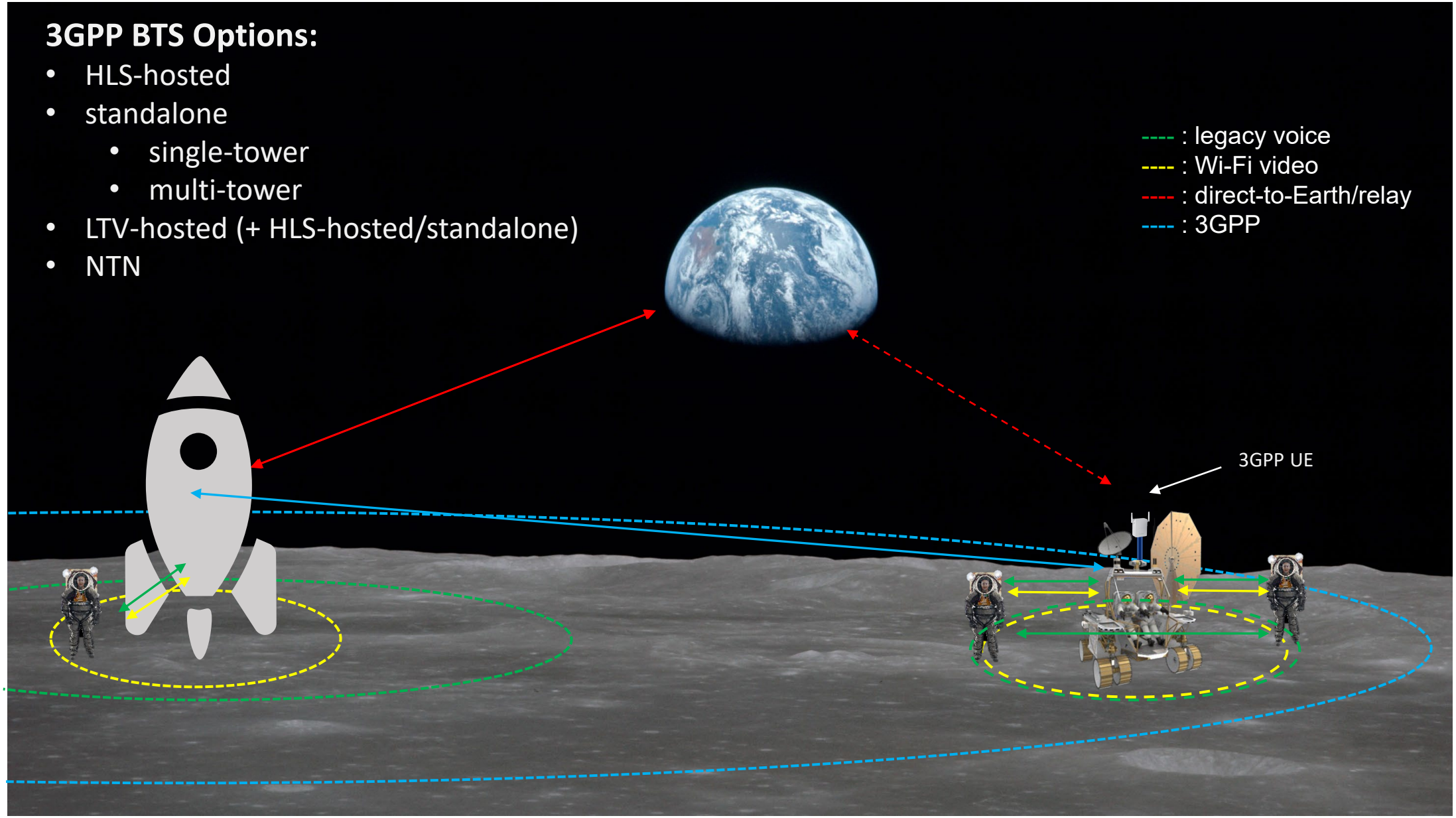
Notional Artemis III Surface Communications Architecture



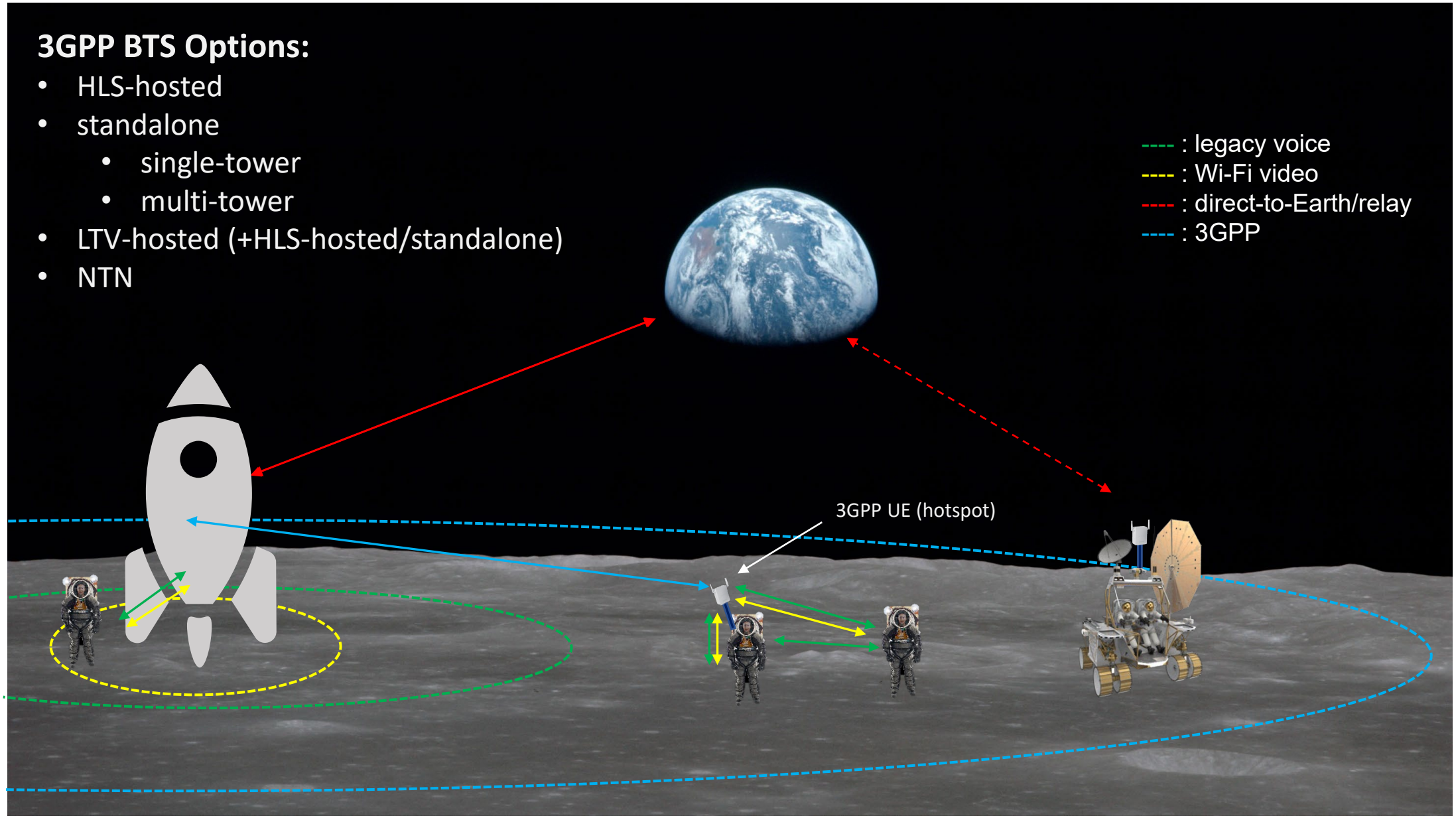
Notional Artemis V Surface Communications Architecture



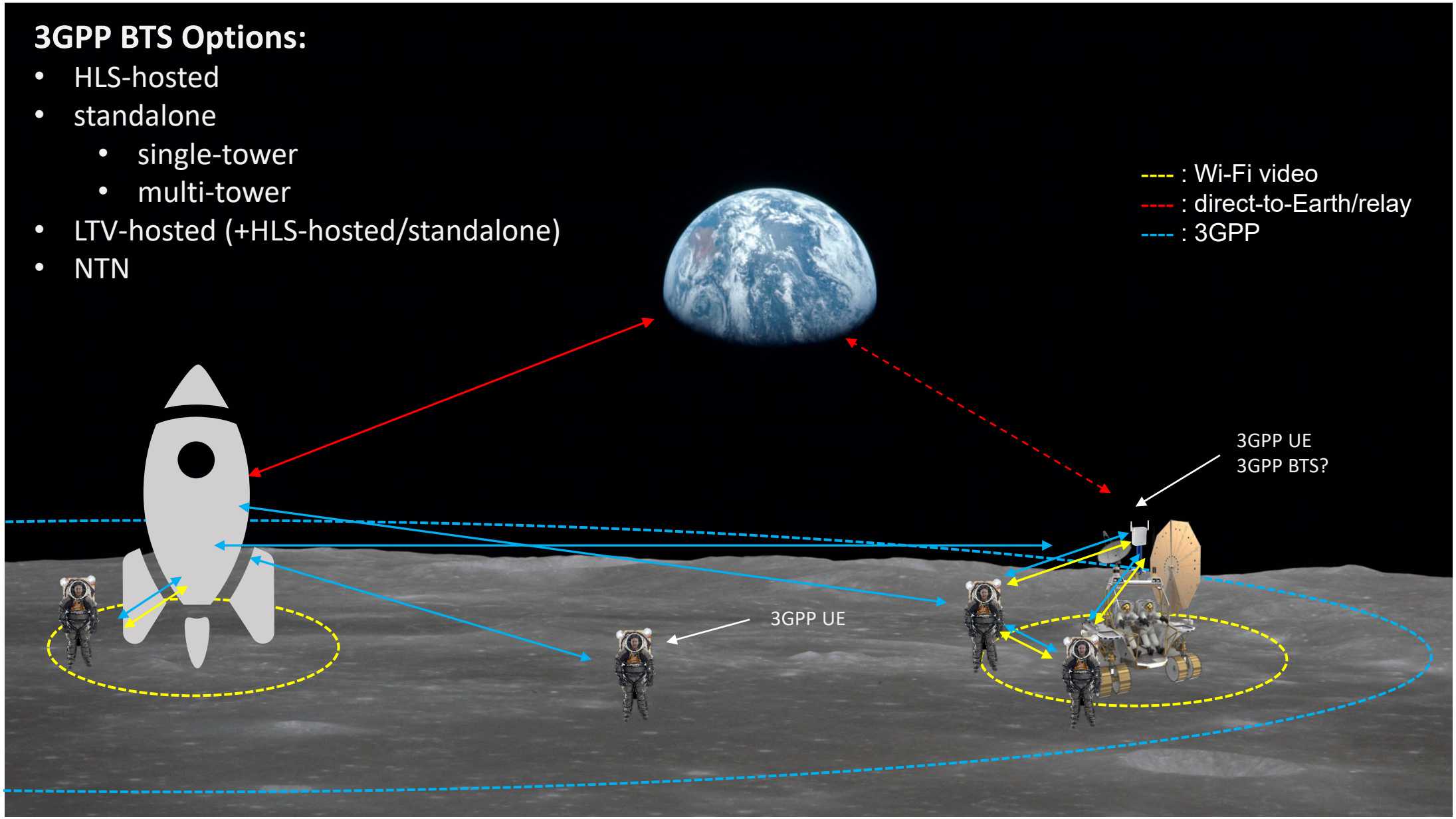
Notional Artemis V 3GPP Extension (nominal)



Notional Artemis V with 3GPP Extension (walkback)



Notional Full 3GPP Artemis V



User Equipment (UE)

Surface UE to accommodate user needs

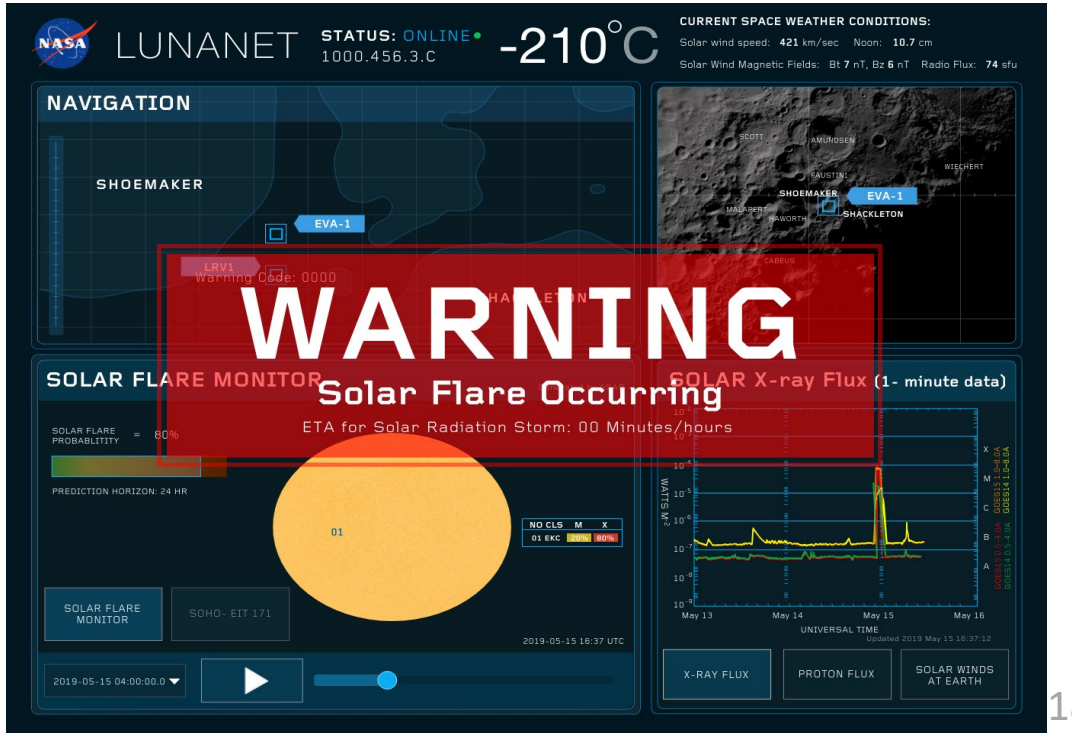
- Throughput and environment concerns (e.g., thermal, power, radiation, dust)

Satellite-based UE potential applications:

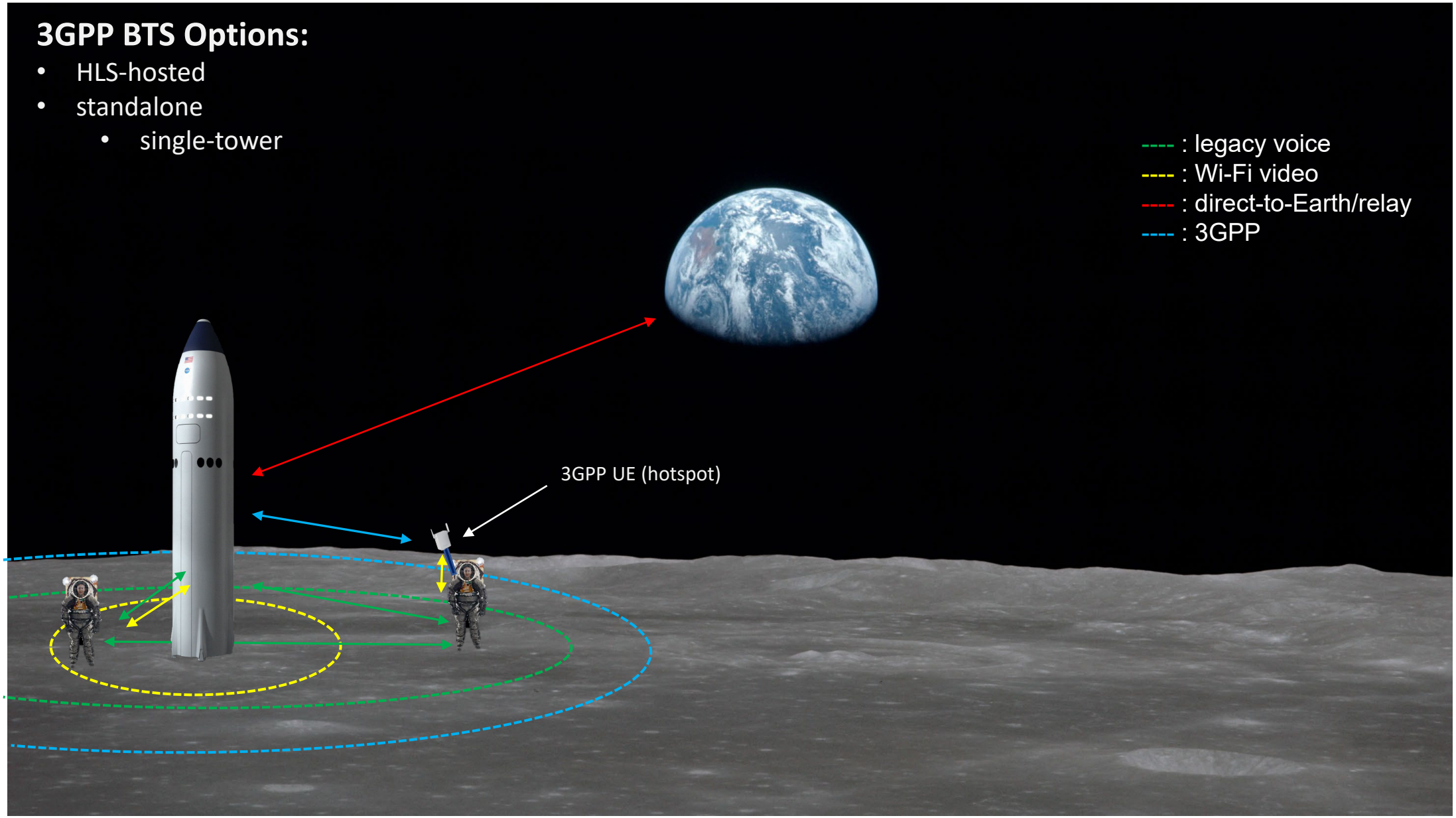
- Scientific experiments in orbit
- Proximity communications with EVA astronauts in orbit
- Proximity communications for formation flying spacecraft
- Monitoring of space based autonomous systems

Satellite-based UEs share some technical challenges with official 3GPP NTN use cases, but there are also some unique challenges:

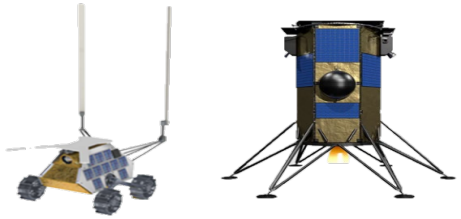
- Multi-user access
- Dynamic range and transmit power control
- Variation in round-trip delay



Notional Artemis III Potential Demonstration Concept



3GPP Development Roadmap



Lunar LTE Tipping Point

- robotic-class
- single band
- older 3GPP release (LTE)

Approach:

- Validate use of emerging telecom standards on lunar surface
- Build industry experience for human missions and move toward criticality-1 support
- Build NASA confidence in 3GPP for mission-critical applications
- Motivate the lunar 3GPP spectrum push
- Build toward Artemis V feature set

Artemis Base Camp (multi-tower)

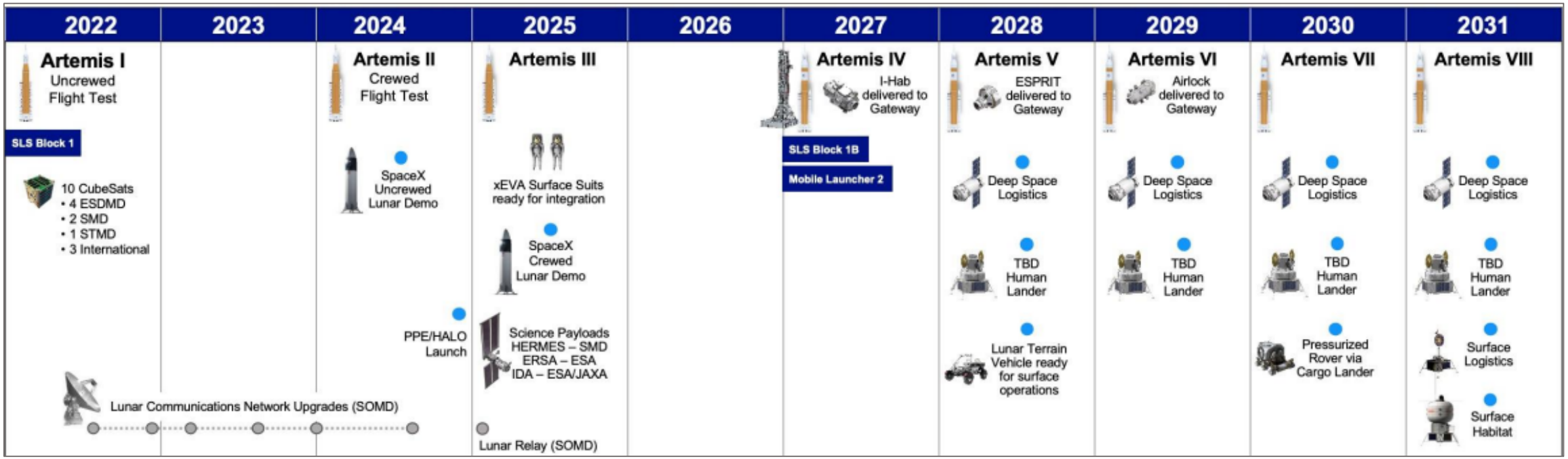
Artemis V Surface Network

- human-rated, mission critical
- (likely) multi-band
- Current or updated 3GPP release (5G?)

Q3 2023 — **2028**

Telecom (3GPP) demonstrations → Telecom (3GPP) service providers →

Moon to Mars Planning Manifest, FY23 Budget Request Version

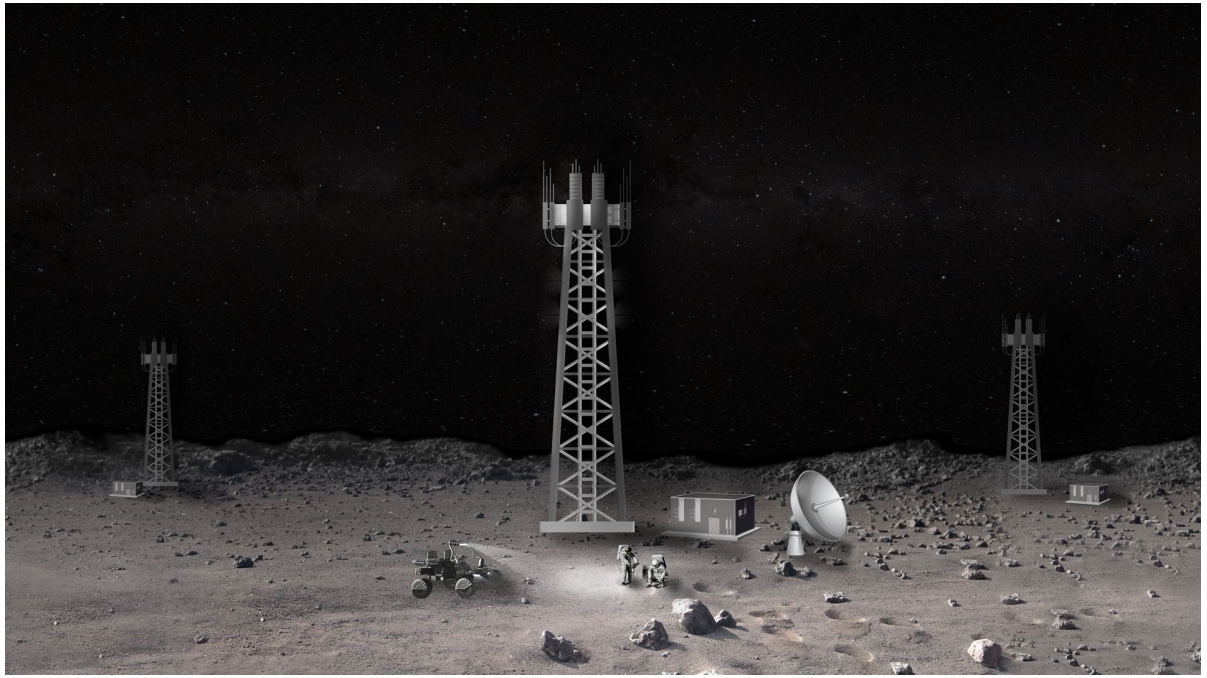


These dates are rough estimates based on the latest publicly available budget request. These are subject to change based on future decisions.

Reference: https://www.nasa.gov/sites/default/files/atoms/files/fy23_nasa_budget_request_summary.pdf

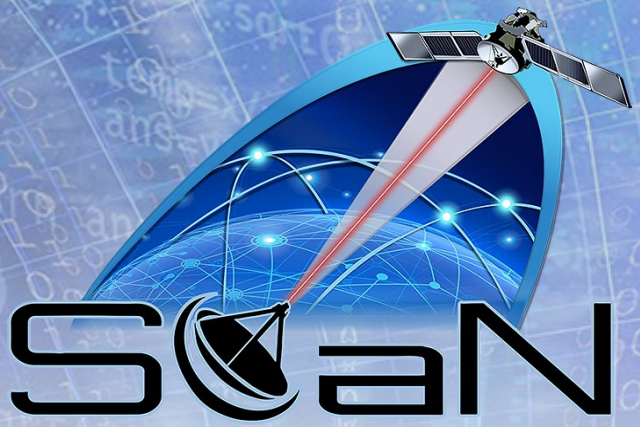
Concluding Remarks

- The NASA Artemis missions are forging a path to return humans to the lunar surface and operate as an outpost and proving ground for future Mars exploration.
- NASA is studying the use of telecommunication networking systems and services on the lunar surface based on open, commercially-maintained standards, such as 3GPP.
- NASA seeks industry input on potential approaches and other considerations of surface communications and navigation operations through Reverse Industry Days on November 10 and 17th.



Industry Feedback

- NASA is studying potential cost-effective solutions/approaches to implement communication and navigation services and systems for lunar surface exploration by leveraging terrestrial telecom systems and technology.
- NASA wants to hear from prospective service providers, component developers, system providers, system integrators, and other subject matter experts on deploying telecom services to the lunar surface.
- If you haven't already, sign up for a one-on-one session with NASA. There, you can discuss your company's capabilities and ideas for lunar networking. Sign up by emailing Ali Hale at Alexandra.g.hale@nasa.gov



Backup

Acronyms

- 3GPP - 3rd Generation Partnership Project
- CCSDS - Consultative Committee for Space Data Systems
- CIS - Commercialization, Innovation, and Synergies
- CLPS - Commercial Lunar Payload Services
- DSN – Deep Space Network
- ESA – European Space Agency
- ESDMD – Exploration Systems Development Mission Directorate
- HLS – Human Landing System
- IOAG - Interagency Operations Advisory Group
- ISRU – In-site Resource Utilization
- ERSA – European Radiation Sensors Array
- EVA – Extravehicular Activities (spacewalks)
- GNSS – Global Navigation Satellite Services
- HALO - Habitation and Logistics Outpost (HALO)
- HERMES – Helio-physics Environmental and Radiation Measurement Experiment Suite
- ICSIS - International Communication System Interoperability Standard
- IDA (ESA/JAXA) – IDA Asteroid
- IP – International Partner
- JAXA – Japan Aerospace Exploration Agency
- LCRNS – Lunar Comm Relay and Navigation Service
- LTE – Long Term Evolution
- LTV – Lunar Terrain Vehicle
- NASA – National Aeronautics and Space Administration
- MSR - Mars Sample Return
- NRHO – Non-Rectilinear Halo Orbit
- NTN – Non-Terrestrial Network
- PPE – Power and Propulsion Element
- PR – Pressurized Rover
- RNSS - Radio Navigation Satellite Services
- SCaN – Space Communication and Navigation
- SFCG - Space Frequency Coordination Group
- SLS – Space Launch System
- SMD – Science Mission Development
- SOMD - Space Operations Mission
- STMD – Space Technology Mission Directorate
- TDMA – Time Division Multiple Access
- TP – Tipping Point
- TRL – Technology Readiness Level
- TT&C – Tracking Telemetry and Control
- UE – User Equipment
- Wi-Fi – Wireless Fidelity
- xEVA – Exploration Extravehicular Activities
- VV – Visiting Vehicles