3GPP/5G Based Lunar Surface Communications

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Introduction

- Apollo astronauts used Very High Frequencies (VHF) radios to communicate amongst themselves and S-band microwaves for Earth. Modern space communications now encompass Ultra High Frequencies (UHF) systems and antennas that enable communications for near and far missions.

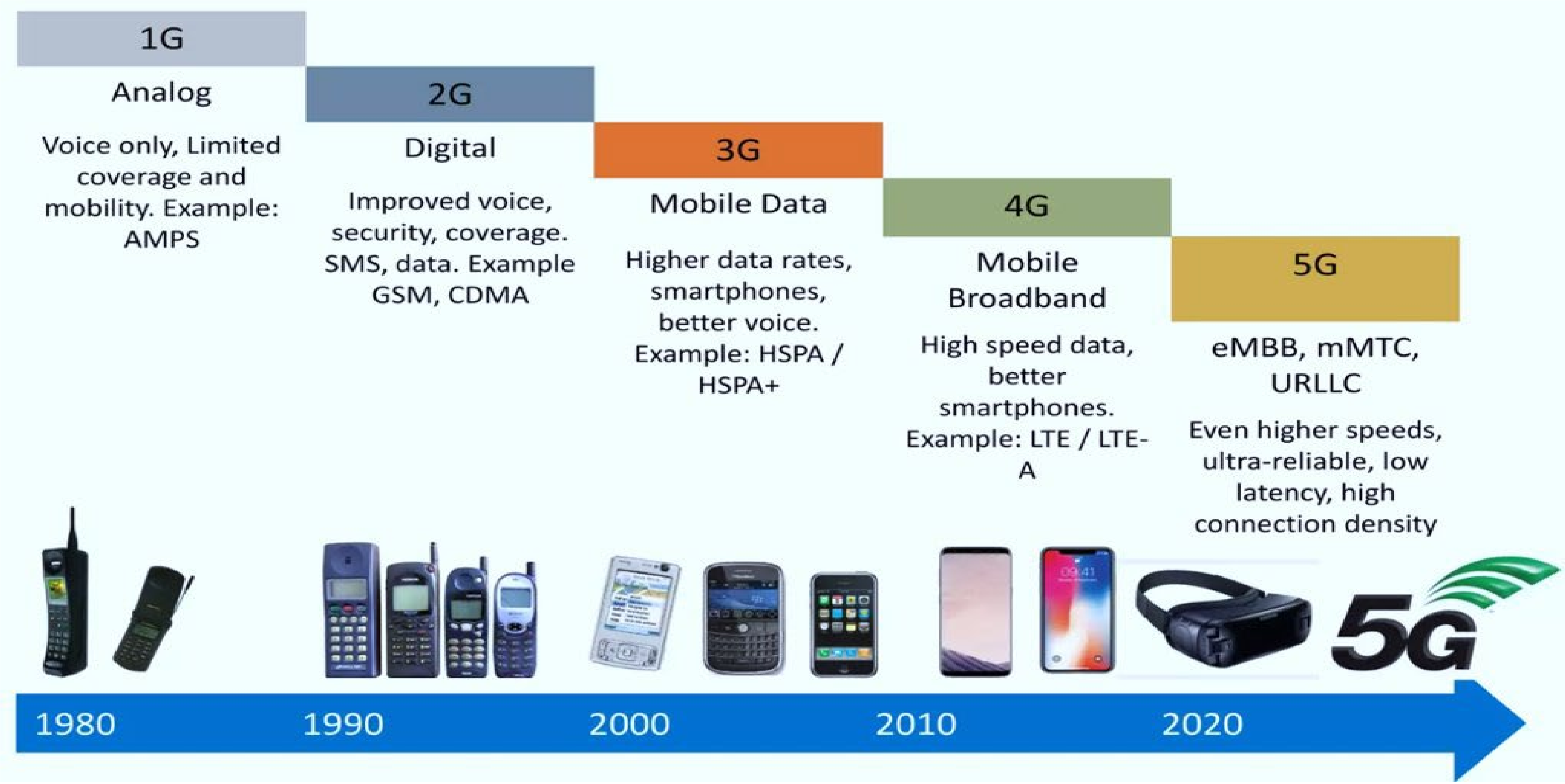
- Wireless communication technology in cell phones and other mobile devices has evolved over the decades. Today 3GPP/5G networks stand as the global wireless standard.

- The 3rd Generation Partnership Project (3GPP), is a conglomerate of major standards organizations, governing the cellular evolution and developing protocols for mobile telecommunications.

- In collaboration with commercial entities, NASA is investigating 3GPP specifications to cater to lunar surface communication and application needs for the 'Moon to Mars: Human Lunar Return' project.

- This presentation delves into advancements in 3GPP/5G technology and its potential to surpass legacy communication systems on the moon.

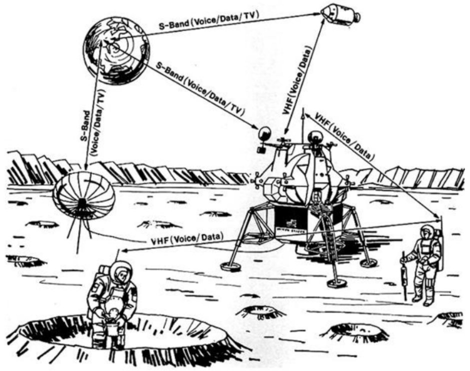
3GPP Evolving Cellular Communications



3rd Generation Partnership Project (3GPP) is an umbrella organization for the development of mobile telecommunications standards. 3GPP delivers the "smart-device networking experience" – ubiquitous, imperceptible, interoperable, user-managed sessions

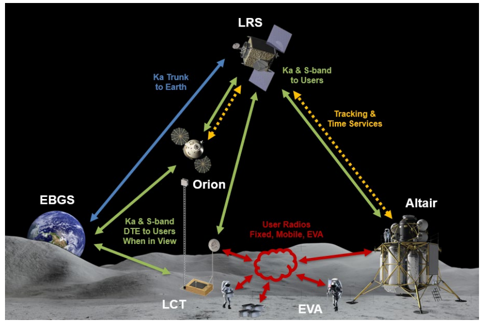
Brief History Lesson on Lunar Communication

Apollo 17 astronauts walked 180m from the lunar module to the lunar rover, an S-band system was used to connect Earth direction to the orbiting command service module and lunar module. The LM had a chassis-mounted steerable S-band reflector as well as a crew-deployable 3-meter reflector; images were grainy, with significant latency.



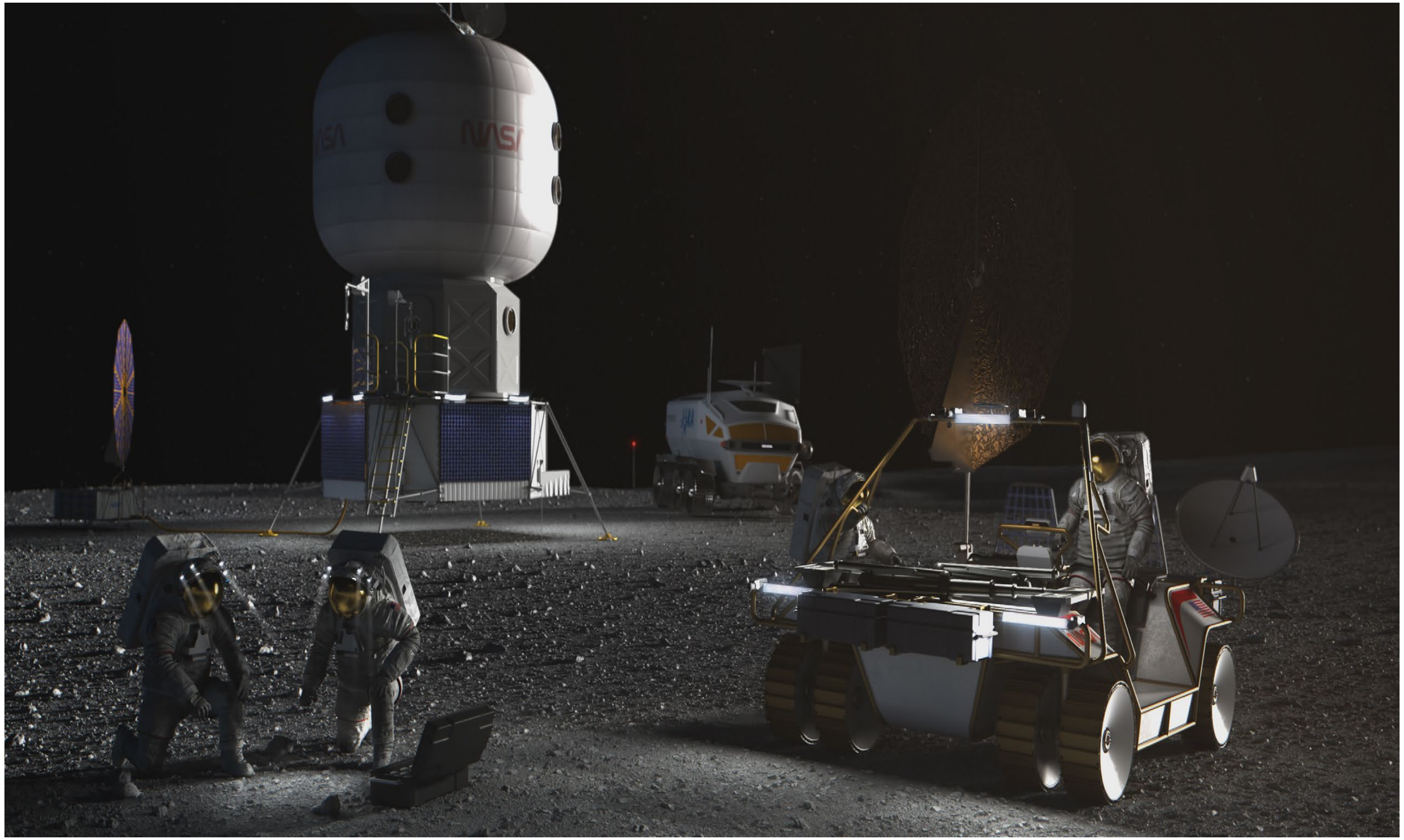
Credit: Electronics World Magazine

The Constellation program 2005-2010 brought additional technology advancement with the need for orbiting relays, surface assets, robust PNT services and flexible surface networking, using Ka-Band link to increase downlink data rates.



The Artemis program is a Moon exploration program led by the United States' NASA and was formally established in 2017 via Space Policy Directive 1. The Artemis program is intended to reestablish a human presence on the Moon for the first time since Apollo 17 in 1972. The program's stated long-term goal is to establish a permanent base on the Moon to facilitate human missions to Mars.

2023: Moon-to-Mars (M2M), Human Lunar Return (HLR) Segment



The Moon-to-Mars (M2M) architecture is a long-term blueprint for deep space exploration that leverages experience in the near-Earth and Lunar domains to chart an achievable course for human exploration of Mars and beyond.

Goal: Create an interoperable global lunar utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence on the lunar surface for a robust lunar economy without NASA as the sole user, while accomplishing science objectives and testing for Mars.

NASA'S MOON TO MARS STRATEGY AND OBJECTIVES DEVELOPMENT – 2023
m2m_strategy_and_objectives_development.pdf (nasa.gov)

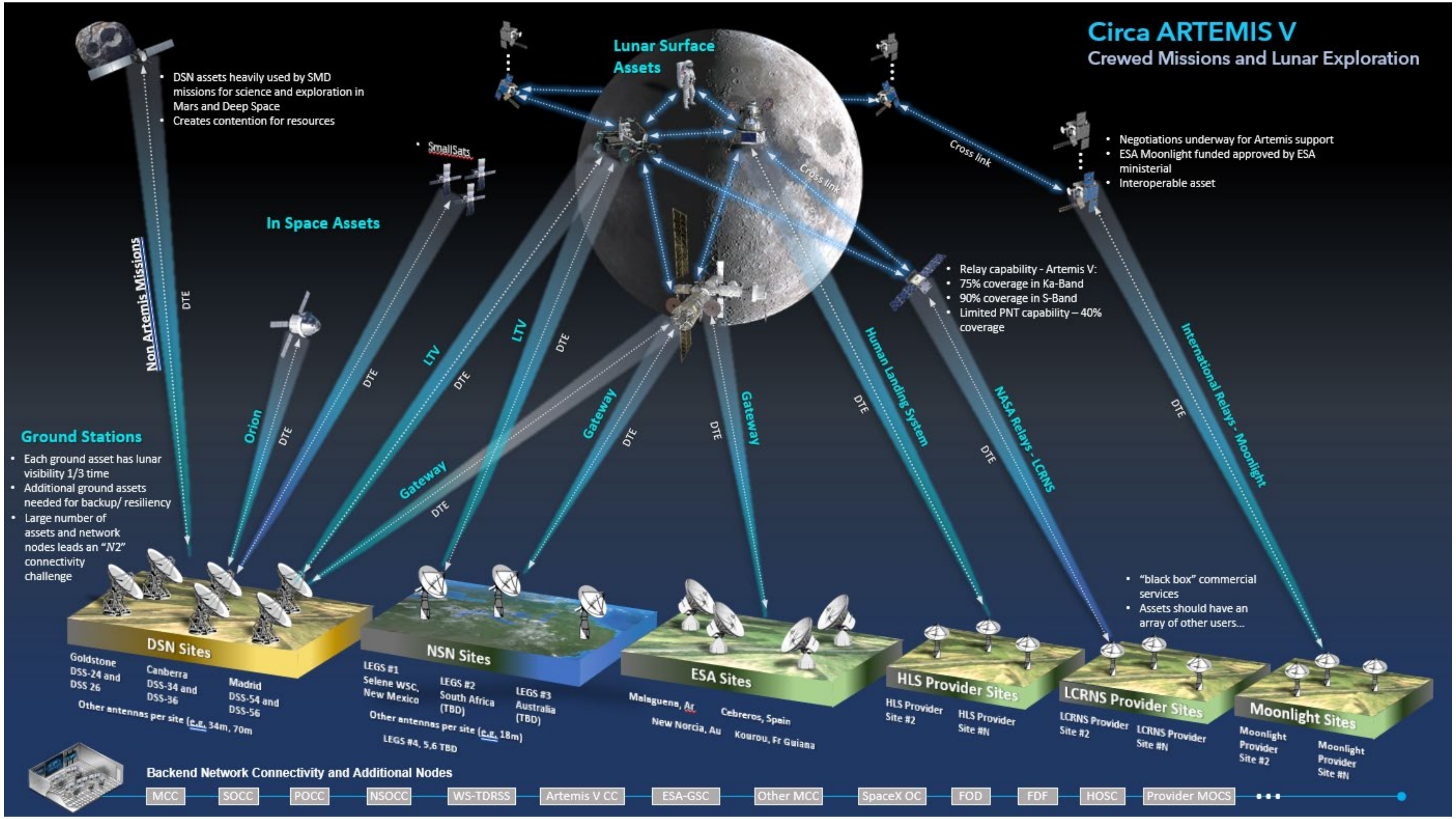
M2M Lunar Infrastructure (LI) & Recurring Tenets (RT)

Maps directly to Communication, Position, Navigation & Timing (CPNT) Architecture

- LI-2L: Develop a lunar surface, orbital, and Moon-to-Earth communications architecture capable of scaling to support long term science, exploration and industrial needs.
- LI-3L: Develop a lunar position, navigation and timing architecture capable of scaling to support long term science, exploration, and industrial needs.
- LI-6L: Develop Demonstrate local, regional, and global surface transportation and mobility capabilities in support of continuous human lunar presence and a robust lunar economy
- RT-1: International Collaboration: refers to partnering with the international community to achieve common goals and objectives. 3GPP is an international collaboration partnership;
- RT-2: Industry Collaboration, refers to partnering with US industry to achieve common goals and objectives. Industry collaboration also extends to cislunar space and anticipated for Lunar Communications Relay & Navigation Services (LCRNS
- RT-7: Interoperability, refers to enabling compatibility and commonality (technical, operations and process standards) among systems, elements and crews throughout the campaign. NASA participation in 3GPP, RF, Spectrum and Wi-Fi consortiums as well as CCSDS Wireless Green book development
- RT-9: Commerce and Space Development, refers to fostering the expansion of the economic sphere beyond Earth orbit to support US industry and innovation. CCSDS Wireless Green book

Define the end-to-end architecture that provides high bandwidth, high availability communications between integrated networks and mission systems to exchange data between the Lunar surface assets and Earth.

Solving for Lunar Communication Challenges with CPNT Architectures



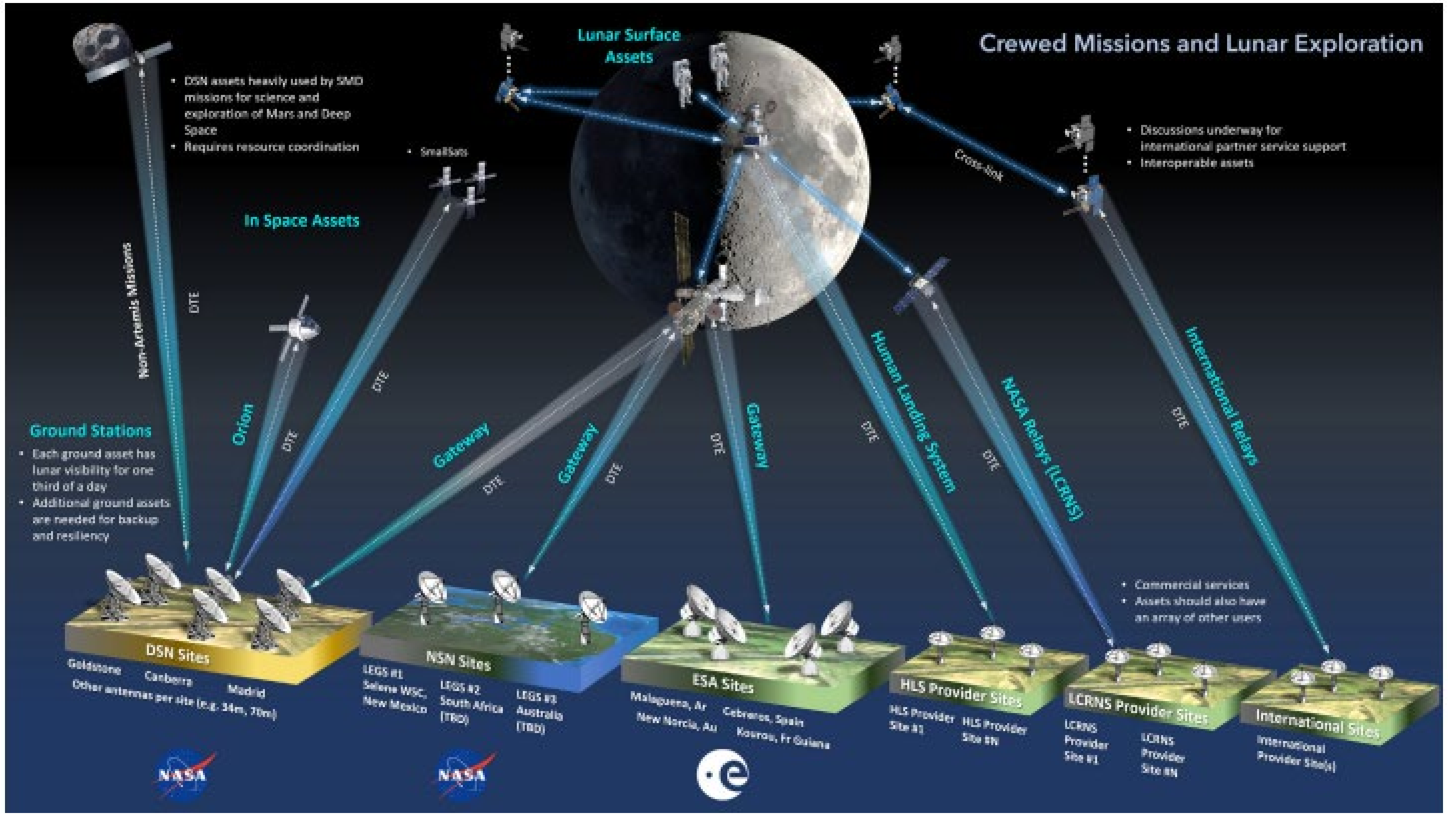
The Communication, Position, Navigation and Timing (CPNT) architecture will be developed through a combination of assets on Earth, in lunar orbit, and on the lunar surface deployed in incremental phases.

Overview of Lunar Communications and Navigation sub-architecture for the Human Lunar Return segment

Early Lunar CPNT Architecture Challenges

Communication Delays: The delay for Earth-Moon communications is about 1.25 second (distance is ~ 380,000 km, the speed of light is ~300,000 km/s). Every time mission control says something, it takes 2 seconds for the astronauts to respond.

Lunar Environment: Future missions want to explore the lunar poles where craters existing which may contain water and ice needed for human presence. At the south pole the earth is visible on 2weeks of every month limiting DTE comm, constraining solar power and requiring lunar assets to withstand harsh temperatures without solar power and dust.

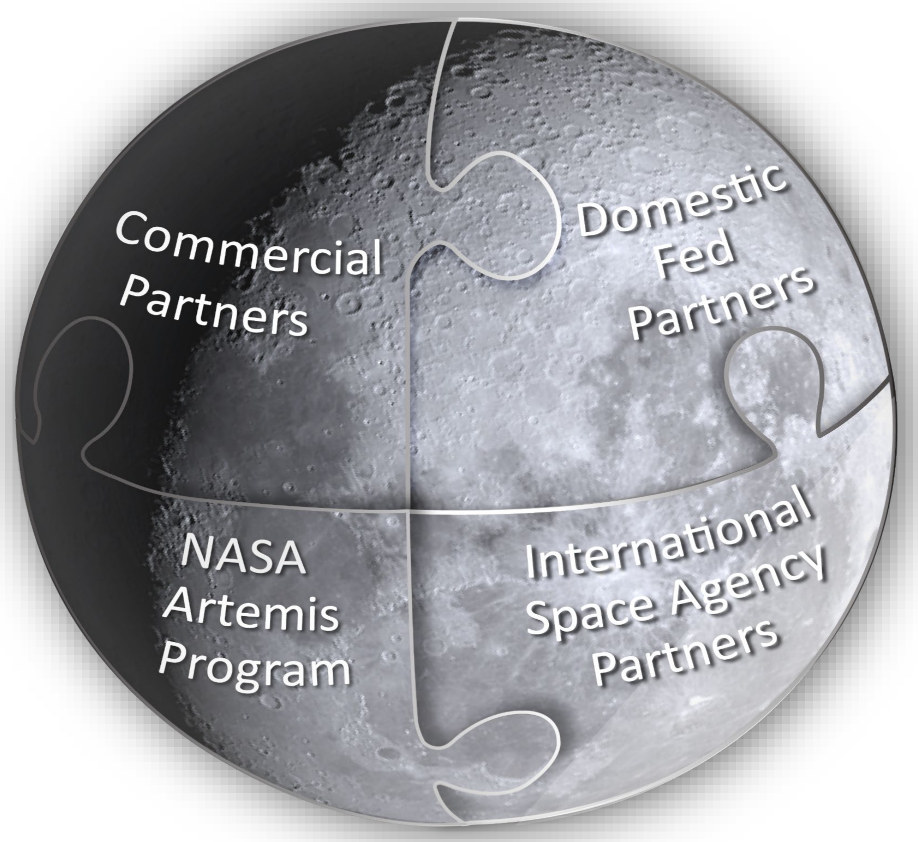


Lunar Terrains: NASA terrains are challenging for rovers and astronauts implicating the need for longer communication ranges and extended video ranges

Challenges of the polar and far side of the moon require constant CPNT and drive the need for orbital relays.

Lunar Spectrum Challenges

- Radio frequency is a limited natural resource that is regulated nationally and internationally.
- Space radiocommunications frequencies are shared (some terrestrial frequencies are channelized and “sold”)
- UN Outer Space Treaty of 1967, Artemis Accords
  - Peaceful and responsible use of space, including celestial bodies for the greater good of humankind
- Existing International spectrum policy and regulations only permits a certain types of intentional radiation in the Shielded Zone of the Moon (SZM)
  - Multiple Conferences ratified the Union’s commitment to protect the shielded area of the Moon for radio astronomy service and passive space research (1971 and 1979).



Benefits of Using 3GPP for Lunar Surface Communications

- 3GPP is intended for long range; current Space to Space Communication System (SSCS) and Wi-Fi are intended for close range.
  - *Current Artemis EVA distance requirements (2km) can be met by 3GPP and was proven in Tipping Point exercises with NASA as well as contingencies if the Astronaut needs to walk back to the HLS/LTV (10km).*
- 3GPP based network could be used for longer range connectivity with Position, Navigation and Timing (PNT) services (i.e. interoperability with orbiting satellites).
- 3GPP can enable more exploration and aggregation of data among science users versus using direct to earth or lunar communication relays.
- 3GPP provides wide area coverage on the moon from a tower or landing vehicle.
- 3GPP releases will enable more capabilities enabling a successful transition from legacy space communications.

3GPP A GLOBAL INITIATIVE

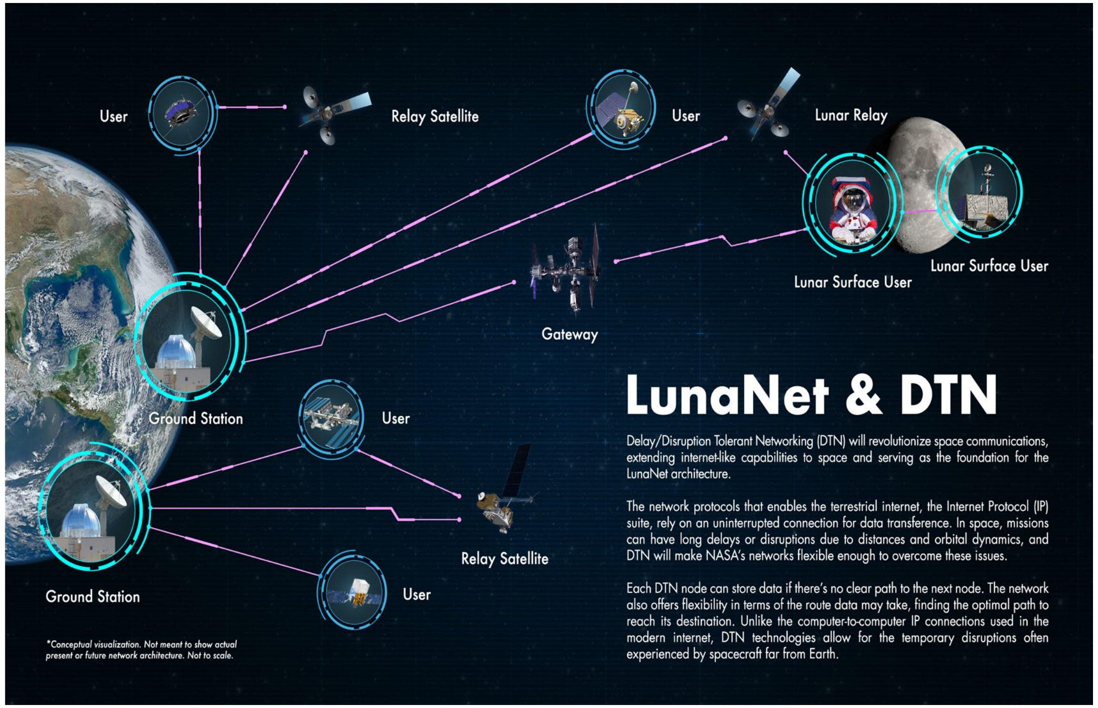
LunaNet: Empowering Artemis with Communication Interoperability

Services:

- **Navigation:** The architecture will provide missions with access to key measurements necessary for onboard orbit determination and guidance system operations, or surface positioning.

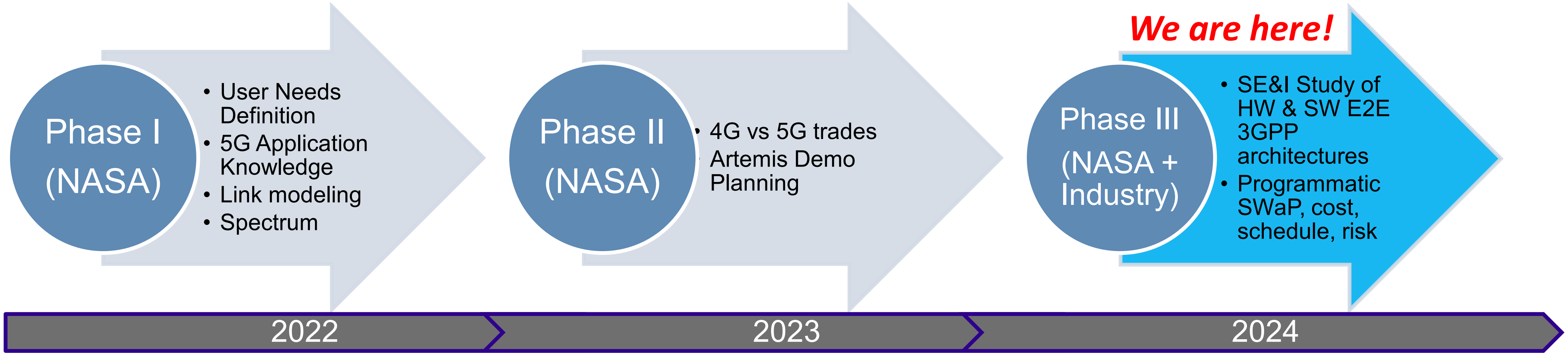
- **Detection and Information:** LunaNet detection and information services provide alerts and other critical information to users.

- **Networking:** communication down to Earth is reliant on pre-scheduled links with either a space relay or a ground-based antenna.



NASA SCaN & Lunar 3GPP Capability Development*

- Advance lunar 3GPP development via NASA Procedural Requirements 7120.8 activity
- Capability development evolved into 3 phases



Goals for the Technology used in a 3GPP Lunar Surface Network Architecture:

- ❑ Build on NASA's *LunaNet* framework
- ❑ Support Artemis mission operations
- ❑ Prepare for the expansion of a lunar science & exploration
- ❑ Adopt a commercial industry communication standard

* NASA Space, Communication and Navigation (SCaN) Program

3GPP Use Cases for the Moon

Immediate Application Needs:

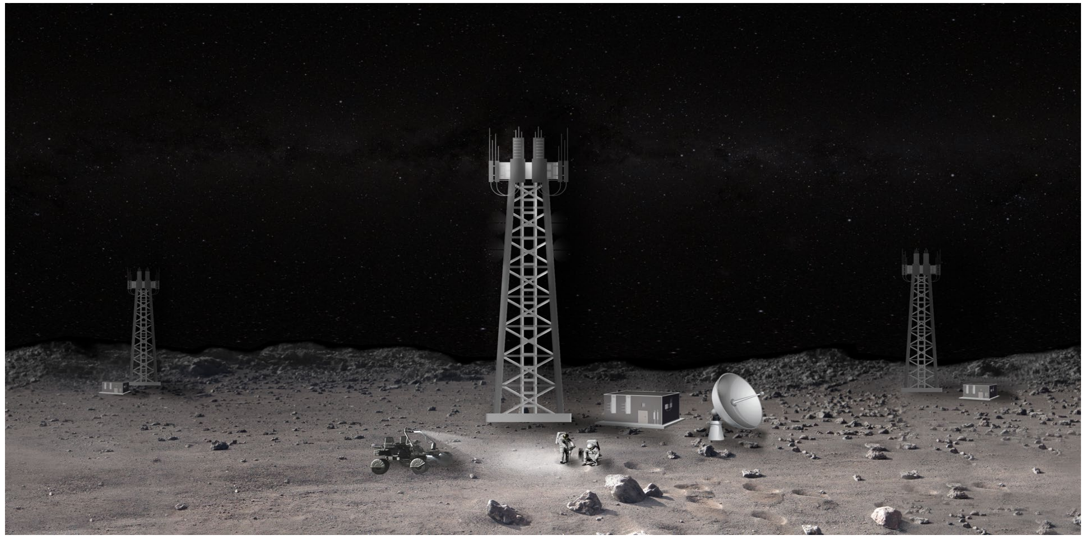
- xEVA to HLS @2km (voice, video, telemetry)
- Walk-back (Up To 10km) If LTV Contingency
- Sets up developmental technology for future missions
  - Ex: SSCS is a 5 Single Input Multiple Output System, insufficient for Artemis V+

For Human Lander Return Segment:

- xEVA to HLS @10km (voice, video, telemetry)
- xEVA to LTV @TBDkm (voice, video, telemetry)
- TBD payload (ex: camera, SMD package, EVA supporting element) to HLS @TBDkm (high data rate telemetry)

For future segments (above plus):

- xEVA-to-xEVA, Pressurized Rover, Habitats



Summary

- Wireless communication technology in cell phones and other mobile devices has evolved over the decades. Today 3GPP/5G networks stand as the global wireless standard. The evolution of 1G to 5G continues.

- A brief history of NASA communication protocols including VHF, UHF and Wi-Fi.

- An introduction to the Moon to Mars, Human Lunar Return efforts within NASA and globally along with how 3GPP architectures meet pre-defined tenets with NASA’s strategy.

- Solving communication and lunar spectrum challenges with a Communication, Position, Navigation and Timing Architecture using 3GPP.

- Progress NASA SCaN & other NASA centers supporting a 3GPP evolution on the moon using Government national, international partners, commercial and university partners to help implement a 3GPP lunar surface communication architecture to ensure Moon to Mars objectives are interoperable and scalable.

Thank you