

National Aeronautics and Space Administration

Space Communications in Support of the Artemis Program

SPACEOPS 2021: The 16th International Conference on Space Operations

> Philip Baldwin (Presenter)

- Greg Heckler
- Andrew Petro
- Jim Schier
- Jeff Berner
- Wendy Evans
- Erica Weir

NASA's Artemis Program

- In 2019, NASA was charged to return to the moon within five years
- NASA was already on the path for lunar exploration, with the hope to execute it in the 2028 timeframe
- The new directive accelerated NASA's plans by 4 years and has resulted in major changes to the development activities
- From a communication standpoint, NASA created a standards framework to be used for international and commercial partnerships
  - The International Communication System Interoperability Standards (ICSIS) baselined in March 2019
  - Through these standards compatible solutions could be achieved for the various communication elements



"...at the direction of the President of the United States of America, America will return to the moon within the next five years, and the next man and the first woman on the moon will be American astronauts."

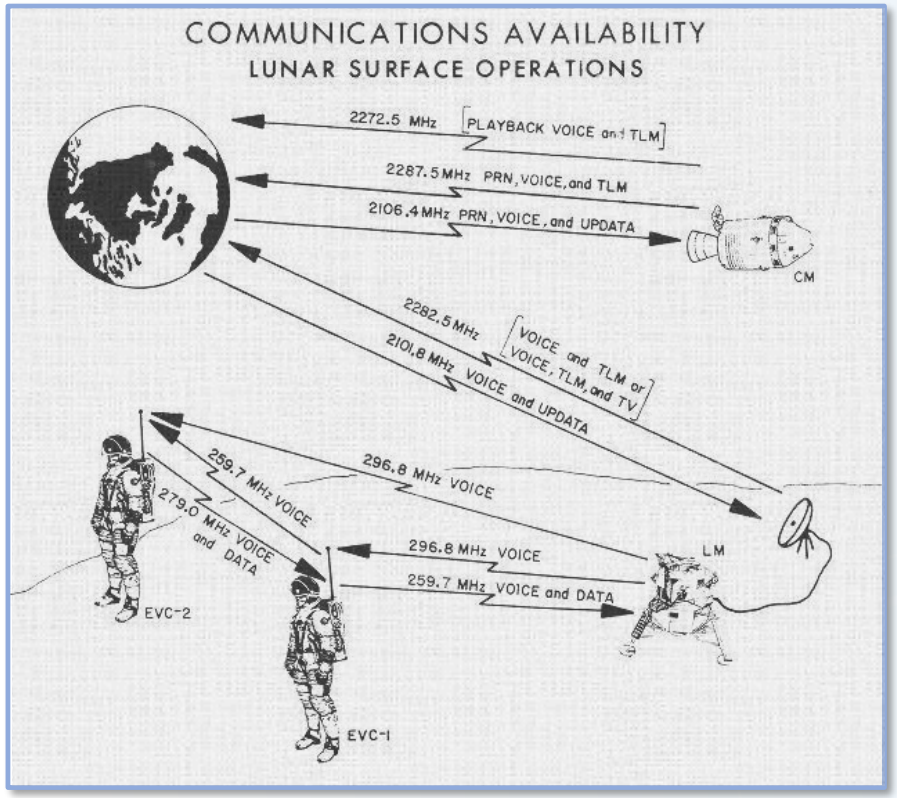
Mike Pence
Speech on the 50th Anniversary of the Apollo 11 Moon Landing
March 26, 2019

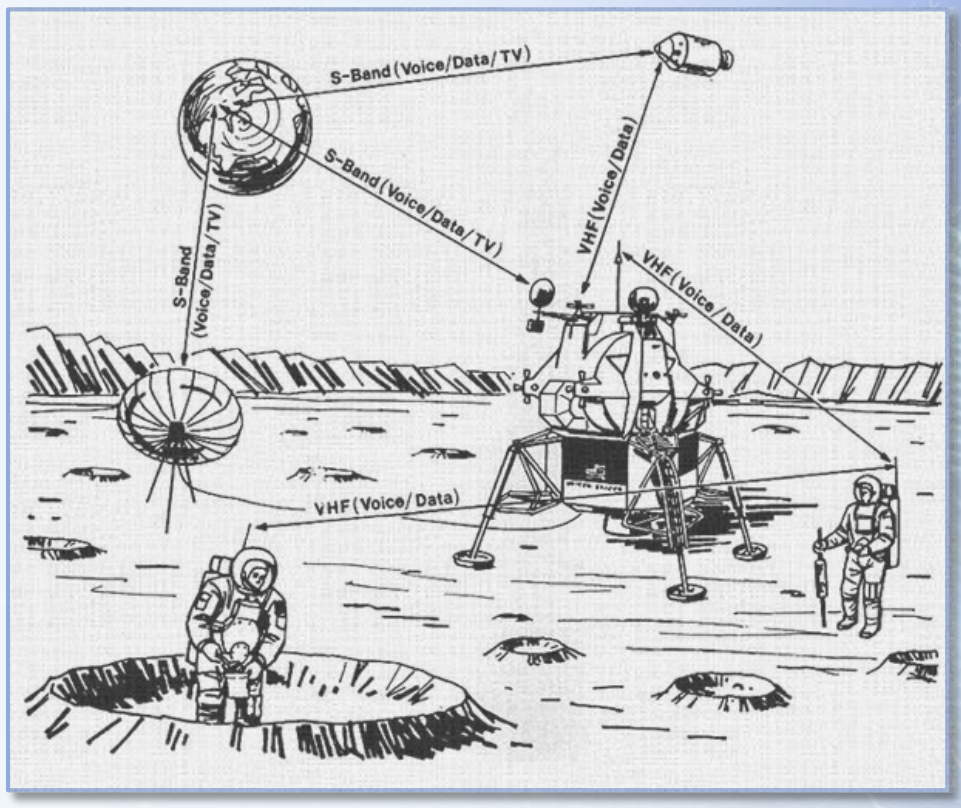
Apollo Communication Schema

- **NASA's communication networks have come a long way since providing support for the Apollo missions**

  - Previous maximum data rate: 51.2 kbps or 1.6 kbps real-time

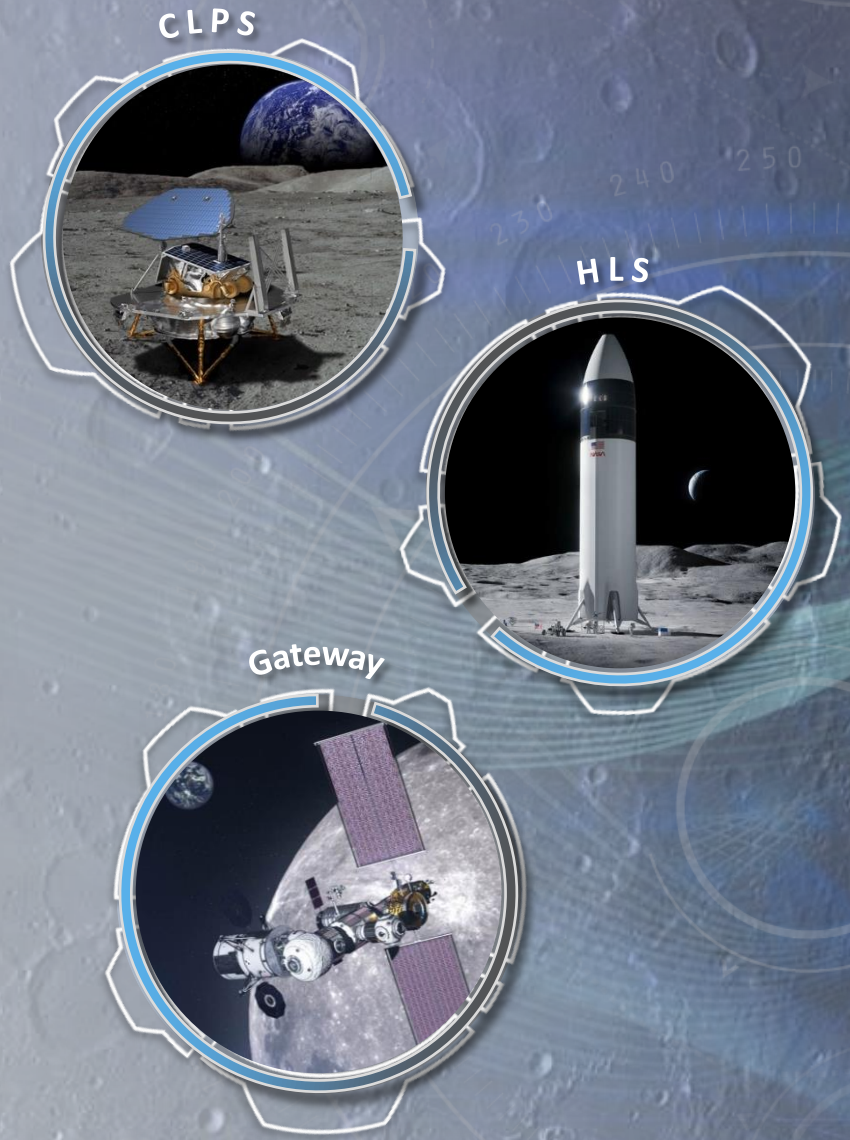
  - Current maximum data rate: 150 Mbps





Capturing the Dynamic Artemis Requirements

- Artemis missions continue to evolve over time, as mission's requirements are further matured, this is especially true as contracts are awarded
- The Artemis program consists of multiple elements for gateway, international plans, science missions, commercial plans
- Recent emphasis has been on human exploration, but the science and robotic missions that enable the human exploration cannot not be overlooked
- SCaN has been working closely with all of the elements of the Artemis team to gather the communication specific requirements and needs to ensure the enhanced communications services to be provided will meet our lunar objectives



User Requirements

- SCaN has collected the following preliminary requirements from the Artemis Program
- These requirements are based on the need to support the following activities: 4k video, telemedicine, remote operations, tracking of the health and safety of astronauts, and other tasks that may not have been needed during the 1960s and 1970s during the Apollo missions



Parameter	Current Known Requirement
Initial Science Payload Mission	**Current Baseline Requirement**
Data Volume	4 GB/day
Landing Site	Moon's Schrödinger Basin: ~ latitude: 75° South, longitude: 133° East
Mission Duration	12 earth days
Initial Human Exploration Mission	
Data Volume	Greater than science payload but not defined
Landing Site	Latitude within 6° of Moon's South Pole
Surface Mission Duration	7 earth days
Data Rates	Minimum video transmission: 5-10 Mbps Minimum EVA: 20-30 Mbps (downlink) Normal EVA: 40 Mbps (downlink)
Additional Information	Data requirements will increase during extravehicular activities (EVA), planning for 4-8 hours of EVA per day

Artemis Plan

Communications Approach



Communications Approach

> Three tightly coupled activities are being implemented to provide the necessary services needed for the upcoming robotic, scientific and human spaceflight Artemis missions



Lunar Relay Leveraging the LunaNet Framework

- A set of standards being applied to both the lunar relay communication systems but also with the diverse user set of government, commercial, and international partners



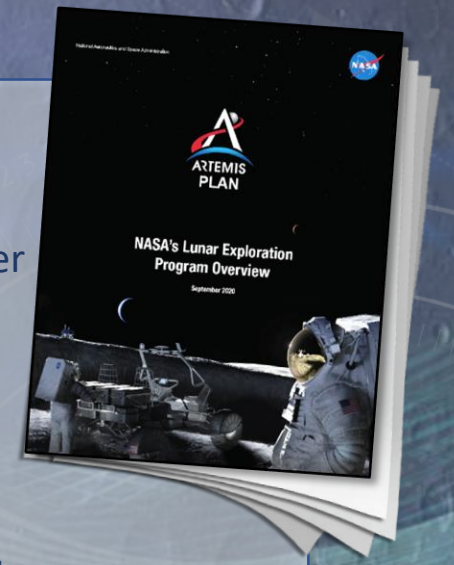
18-Meter Class Antenna Subnet Development

- A new set of antennas, designed to support lunar missions, to help alleviate the user load on the current 34-meter subnet



34-Meter Antenna Upgrades

- Upgrades to two Deep Space Network (DSN) antennas at each of the three complexes (totaling six upgraded antennas)



1 “18-meter class” is in reference to an antenna that meets or exceeds performance (G/T and EIRP) of an industry standard 18-meter antenna

Artemis Core Elements and Systems

Space Communications

LUNANET



Key Components and Functions

- Networked communication services
- Lunar PNT services
- Science and alert services
- Architected to accommodate NASA, commercial, and international partner assets
- Inclusive of lunar relay, lunar surface, and Earth assets
- Mars forward architecture

LunaNet is envisioned as a framework of standards, protocols, and interfaces to support a scalable communications and navigation network for NASA and other partners in cis-Lunar space. LunaNet will provide the basis for seamless robotic, science, and human operations by providing networked communication, PNT, science, and alert services. The LunaNet architecture is scalable to meet immediate mission needs at the Lunar south pole and Lunar far side and to provide global Lunar coverage as demand grows.

LUNAR GROUND STATIONS



Key Components and Functions

- Global network of 18-meter class antennas
- Services compatible with DSN's 34-meter subnet
- Additional capacity for Artemis systems
- Potential for commercialization

Lunar Ground Stations (LGS) will create a global network of 18-meter class antennas critical to meeting future demand for communication and tracking services created by sustained Lunar exploration. Additional capacity is required to service Artemis robotic and support elements such as CLPS, LSSMS, GLS, and LunaNet. Migrating traffic from the DSN's 34-meter subnet to the new LGS will preserve DSN capacity for NASA's planetary science missions and human exploration of Mars. NASA will pursue opportunities for commercial entities to provide LGS service.

DEEP SPACE NETWORK



Key Components and Functions

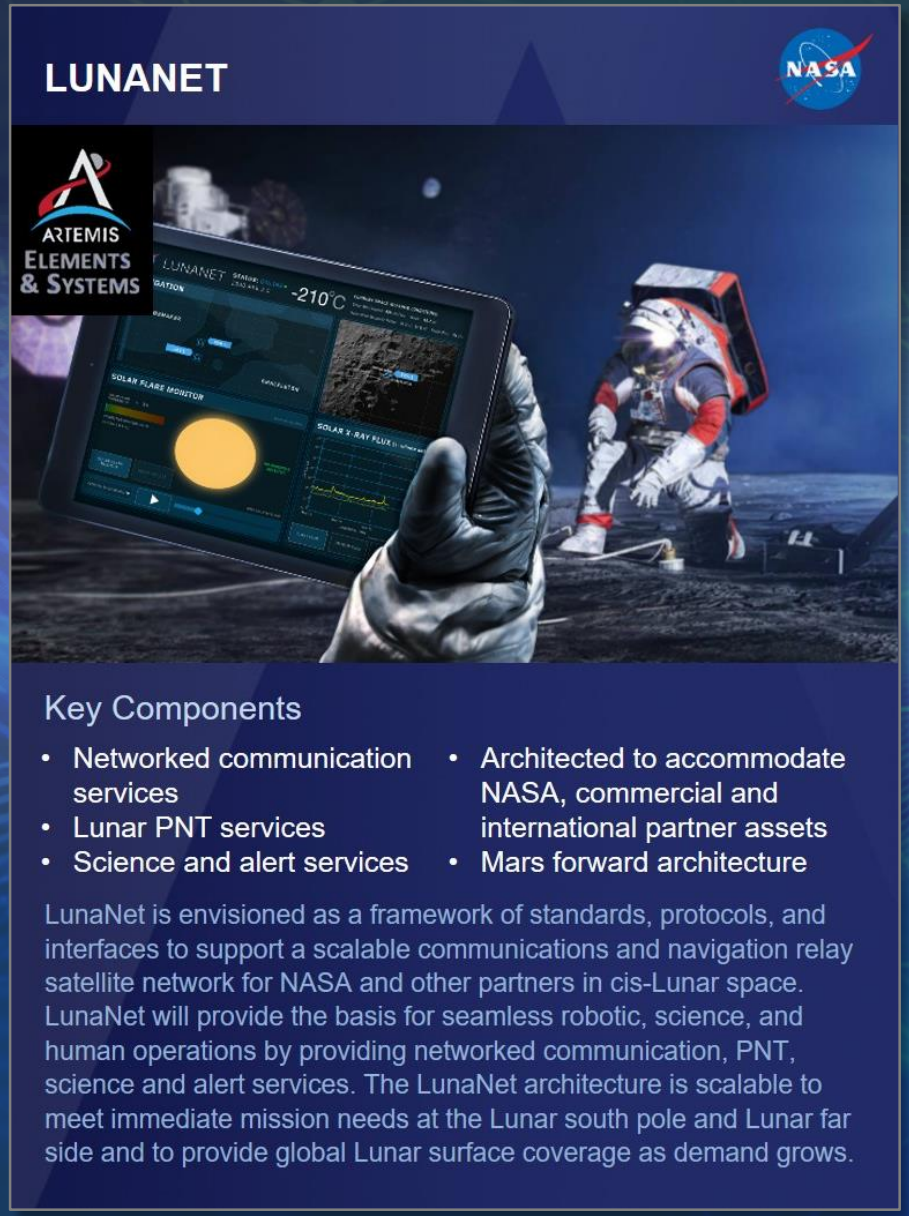
- Upgraded to provide 100 Mbps downlink, 20 Mbps uplink
- 2 antennas upgraded at each DSN complex: Goldstone, Canberra, and Madrid
- Services compatible with international partner ground stations

Upgrades to the Deep Space Network's (DSN) 34-meter subnet will provide continuous high-rate command and telemetry services to the Gateway, Human Landing System, and other Artemis space systems. These new services are required to support human operations at the Moon and to return high volumes of scientific data from payloads planned for the Gateway and the Lunar surface. The Deep Space Network upgrades are critical to meeting the nation's challenge to land humans on the Moon by 2024 and following human exploration of Mars.

Lunar Relay Leveraging the LunaNet Framework

- In October 2020, NASA released a Request for Information (RFI) “Lunar Communications and Navigation Relay Services” to begin to engage with potential lunar relay communication providers

- NASA, working with other agencies, international partners, and commercial vendors, is seeking to define a framework of mutually agreed-upon standards to be applied by all users and service providers in a set of cooperating networks.



34-Meter Antenna Upgrades

- The following upgrades are planned for completion by 2024 in the three DSN complexes, Canberra, Madrid and Goldstone
  - Near Earth Ka-band uplink
  - Simultaneous Ka-band uplink and downlink
  - Simultaneous operation of S- and Ka-band or X- and Ka-band
  - Ka-band data rates ≥ 100 Mbps downlink and ≥ 20 Mbps uplink
  - X-band date rates ≥ 2 Mbps downlink and ≥ 5 Mbps uplink
  - Low latency data processing ≥ 150 Mbps
  - Necessary International Communication System Interoperability Standard (ICSIS) coding, modulation and ranging standards [3]
  - Delay/Disruption Tolerant Networking (DTN)



18-Meter Class Antenna Subnet Development

- For the purpose of mitigating the DSN loading risk associated with planned Mars and science missions, NASA is investigating a new 18-meter class subnet
- The 18-meter class subnet may be utilized by other NASA missions when not supporting lunar missions
- This subnet will be a combination of government and commercial assets, with the pioneering system potentially being a government system for commercial providers to leverage



Other Core Capabilities



Global Navigation Satellite System (GNSS)

- Vision for Gateway
  - Multi-GNSS-based System sharing PPE's gimballed Earth-pointed high-gain communications antenna
  - Phase 1: Develop receiver based on existing NavCube 2.0 hardware (minimum Galileo/GPS E1/L1 band)
  - Phase 2: Enhanced Gateway receiver based on Phase 1 lessons learned; multi-GNSS, multi-band receiver, improved performance, improved algorithms
- Benefits
  - Multi-GNSS system provides onboard, real-time autonomous navigation
    - Reduces SCaN network load for metric tracking data
    - Spacecraft position, velocity, and time in seconds vs. hours for ground-tracking
  - Provides accurate position and terrestrial time to science payloads for measurement registration

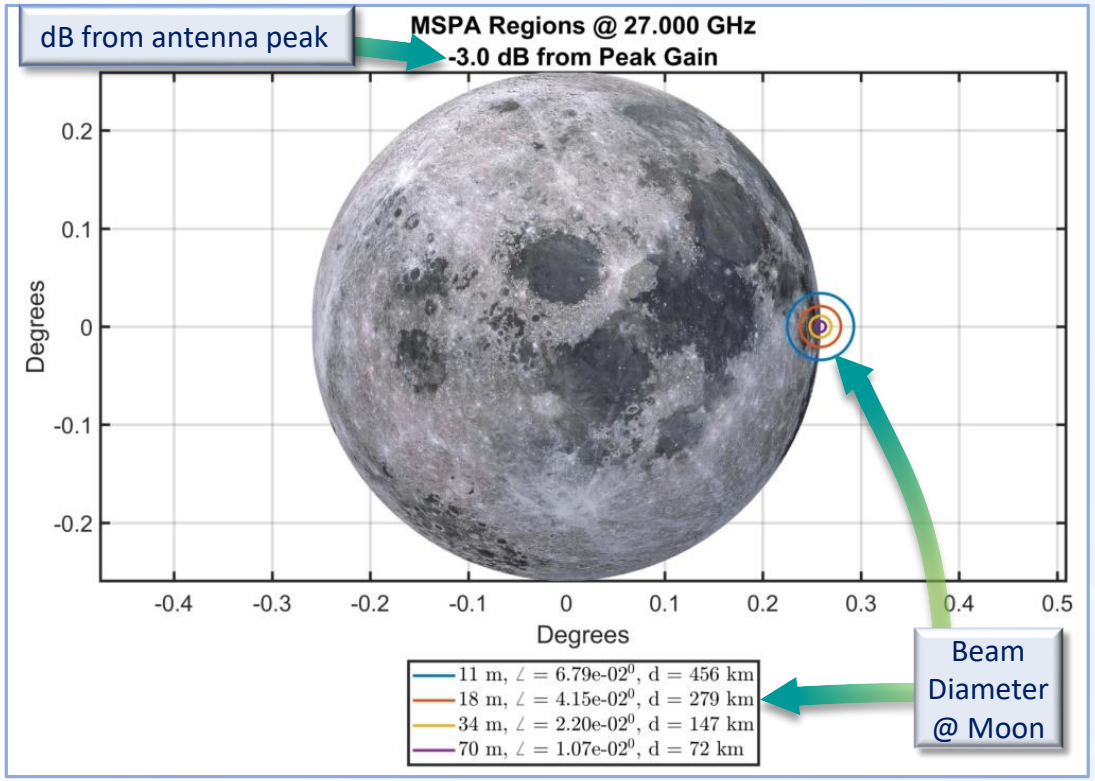


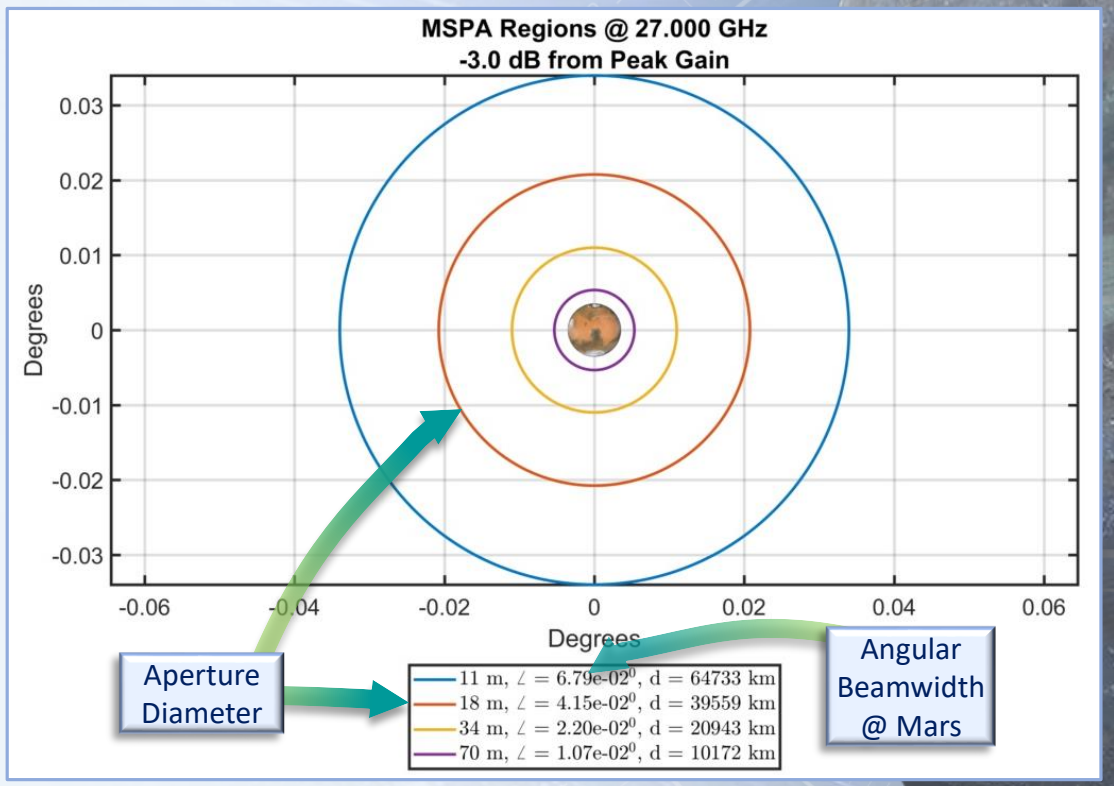
Build on experience with successful high-altitude GPS application: Magnetospheric Multi-Scale Mission (MMS) demonstrated success at 29.3 Earth radii (50% of lunar distance)



Multiple Spacecraft Per Aperture (MSPA)

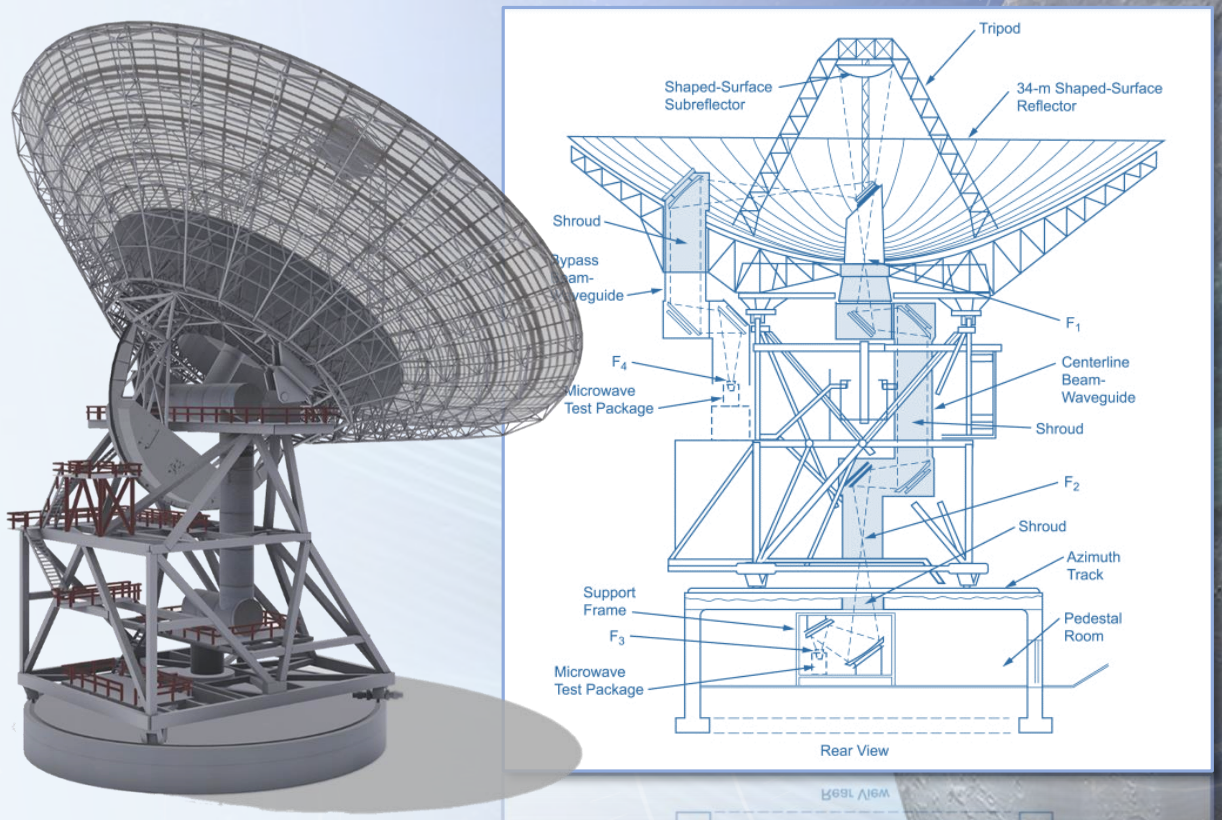
- The planned communication ConOps, requiring simultaneous direct-to-Earth (DTE) links, will stress the current and planned capacity of the DSN ground networks
- MSPA is a special configuration which allows for an antenna to receive data simultaneously from multiple spacecraft, allowing for more efficient use of each DSN asset
- With the major constraint that all spacecraft must be within the Earth station's beam width





Simultaneous Frequency Communication

- Artemis missions require high data rates that can be provided through Ka-band capabilities
- It is anticipated that there will be multiple lunar elements needing connectivity back to Earth, at multiple frequencies
- The DSN antennas use dichroic mirrors to route the beam to various feeds to support various frequencies
- The DSN antennas dichroic mirrors / mirror configuration will be updated to allow for simultaneous communication in multiple bands (for uplink and downlink)
- Possible configurations include, but are not limited to: S- and K-band, X- and K-band, K-band only



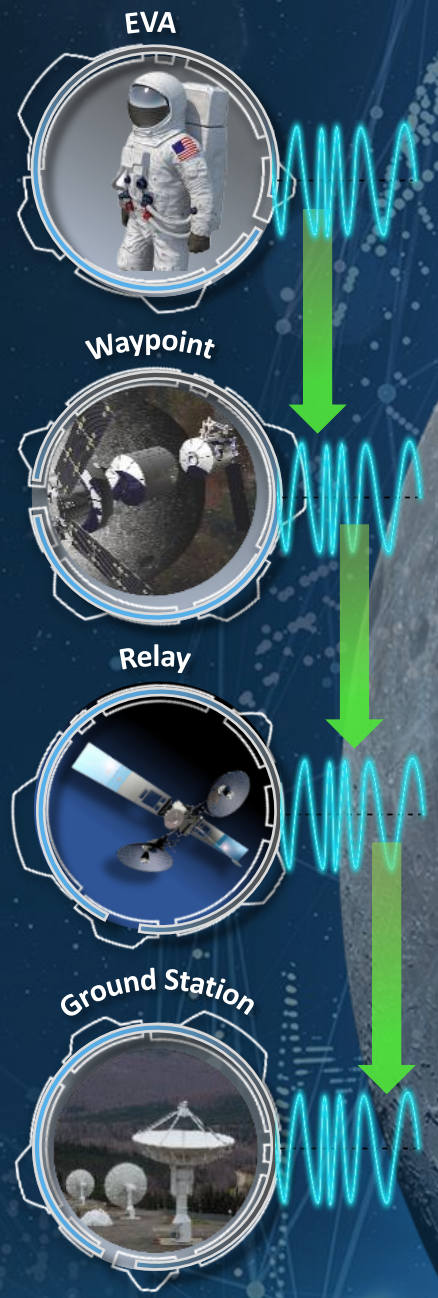
Delay/Disruption Tolerant Networking

Application

- The reliability of DTN networks enables it to create a solar system wide internet.
- The DTN protocol can operate independently or in tandem with current protocols, allowing it to easily integrate with any agency or private entity with access to space.

Advantages

- The DTN protocol enables more robust and efficient data transmissions resulting in more usable bandwidth, this also takes advantage of the multiple network paths available with a DTN based network.
- With the store and forward mechanism the data can be sent via multiple available network paths, this ensures the data will be transmitted even if some links are cut off.
- The DTN protocol also allows for data priority levels to be set, ensuring that the most important data is transmitted and received first.



Conclusion

- NASA is embarking on a new journey of human exploration and science discovery that will land the first woman and first person of color on the Moon
- Like Apollo, Artemis will need enabling infrastructure and innovative technology to achieve its mission objectives
- A vital component of the future success of the Artemis missions will be enhancement of the communication and navigation services
- These additional services can then be used by future missions, including those exploring Mars and other planets in our solar system



Thanks!

To learn more about NASA Space Communications and Navigation:

- **Website**: https://www.nasa.gov/scan
- **Facebook**: NASASCaN
- **Twitter**: @NASASCaN
- **SCaN Now**: https://scan-now.gsfc.nasa.gov/
- **Email**: support@scan.nasa.gov

Contact Information for Philip Baldwin:

- **LinkedIn:** https://www.linkedin.com/in/pjbaldwin
- **Email:** philip.j.baldwin@nasa.gov
- **Employee Profile**: https://youtu.be/CwrJMhMys7o

18