SpaceOps-2021,8,x1373

Space Communications in Support of the Artemis Program

Philip A. Baldwin[1], Gregory W. Heckler[1], Andrew Petro[1], James Schier[1], Jeff Berner[2], Wendy Evans[3], and Erica Weir[3]

[1] National Aeronautics and Space Administration, 300 E Street NW, Washington D.C. 20546, philip.j.baldwin@nasa.gov, gregory.w.heckler@nasa.gov, andrew.j.petro@nasa.gov, james.schier-1@nasa.gov
[2] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, jeff.b.berner@jpl.nasa.gov
[3] Teltrium Solutions, LLC, 6406 Ivy Lane, Greenbelt, MD 20770, wendy.c.evans@nasa.gov, eweir@teltrium.com

Abstract

NASA has been challenged to send the first woman and first person of color to the South Pole of the moon by 2024. Named the Artemis Program, this effort serves as a proving ground for the greater Moon-to-Mars campaign and establishes a lunar outpost by 2028. The Artemis Program relies on simultaneous operation of multiple flight assets separated by large angular distances that require a unique communication strategy and is a departure from the previous Apollo-era architecture. NASA's Space Communications and Navigation (SCaN) Program is designing a scalable, extensible, and reusable network architecture to provide communication and navigation services in support of lunar exploration. This architecture serves at the foundational infrastructure, paving the way for future exploration of Mars. In pursuance of this new architecture, the SCaN Program is augmenting NASA's space communications networks by upgrading the current 34-meter beam waveguide antenna systems and incorporating an 18-meter class subnet. This paper presents an overview of NASA's plans to provide high data rate communication and navigation services for lunar exploration efforts including: operations concepts to support the lunar communications architecture, major network enhancements and new capabilities, and a Mars-forward approach that maximizes the reuse of these capabilities. Capabilities include: (1) Delay/Disruption Tolerant Networking (DTN), (2) Multiple Spacecraft Per Aperture (MSPA, also known as Multiple Spacecraft Per Antenna), and (3) Simultaneous Ka-band uplink and downlink. The mid-2020s era is a historic opportunity to advance NASA's space communications infrastructure as humans return to the moon and continue to interplanetary exploration, starting with Mars. The space communication infrastructure is a lifeline that supports these endeavors, furthering humankinds' exploration and understanding of the universe.

Acronyms

Acronym	Definition
BP	Bundle Protocol
BWG	Beam Waveguide
CAPSTONE	Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment
CCSDS	Consultative Committee for Space Data Systems
CFS	Core Flight System
CLPS	Commercial Lunar Payload Services
DSN	Deep Space Network
DTN	Delay/Disruption Tolerant Networking
EIRP	Effective Isotropic Radiated Power
EVA	Extravehicular Activities
FSS	Frequency Selective Surface
GEONS	GPS-Enhanced Onboard Navigation System
GNSS	Global Navigation Satellite System

GPS	Global Positioning System
G/T	Gain to Noise Temperature Ratio
HALO	Habitation and Logistics Outpost
HEOMD	Human Exploration and Operations Mission Directorate
IAF	International Astronautical Federation
ICSIS	International Communication System Interoperability Standard
IETF	Internet Engineering Task Force
ION	Interplanetary Overlay Network
KARI	Korea Aerospace Research Institute
KBPS	Kilobits Per Second
KPLO	Korea Pathfinder Lunar Orbiter
LNA	Low Noise Amplifiers
LTP	Licklider Transmission Protocol
LTV	Lunar Terrain Vehicle
MBPS	Megabits Per Second
MMS	Magnetospheric Multi-Scale Mission
MSPA	Multiple Spacecraft Per Antenna
NASA	National Aeronautics and Space Administration
NRHO	Near-Rectilinear Halo Orbit
NSN	Near Space Network
PACE	Plankton, Aerosol, Cloud, Ocean Ecosystem
PNT	Position, Navigation, and Timing
PVT	Position, Velocity, and Time
PPE	Power Propulsion Element
RFI	Request for Information
SCaN	Space Communications and Navigation
SLS	Space Launch System
VIPER	Volatiles Investigating Polar Exploration Rover

1. Introduction

The NASA Artemis Program is responsible for returning astronauts to the moon, while creating the foundation for human exploration to Mars and beyond. This initiative will result in a variety of elements including, but not limited to, lunar landing systems, rovers, the Gateway, science instruments, and an all-encompassing Artemis Base Camp. This new wave of human exploration will be achieved through the application of a set of advanced capabilities. NASA intends for this to be a collaborative venture that will engage the greater space community through partnerships with both commercial space industry and international space agencies.

NASA currently manages two well-established space networks, the Deep Space Network (DSN) and the Near Space Network (NSN), that provide communications for all NASA missions as well as supporting some commercial and international missions. The Space Communications and Navigation (SCaN) Program in the Human Exploration and Operations Mission Directorate (HEOMD) is responsible for managing and directing the activities of these two networks. The communication and navigation services provided by the DSN and the NSN are fundamental to this initiative and, as with the rest of the Artemis program, will require utilization of new technologies to achieve the ambitious data rates and unprecedented near real-time communication. The SCaN program has put into motion the creation of a new scalable, extensible, and reusable lunar network architecture framework, dubbed LunaNet, that has an focus on space communications on and around the moon. This paper discusses the ground network upgrades that will support the Artemis missions, which will be key enablers for the LunaNet infrastructure development. SCaN's critical communications elements in support of lunar exploration, will also be key for future Mars human exploration.

It is understood that minor adjustments to the Artemis Program schedule may occur, but are unlikely to affect the communication and navigation capability or capacity requirements or its projected timeline. In general, communications infrastructure is tested and ready for operational use well ahead of its projected mission support period. The Artemis Program plan and systems driving communications and networking requirements and implications for the proposed end state architecture are described further in Section 2.

2. Artemis Program Requirements and Proposed End State

Artemis is a robust multi-year effort bringing together assets and capabilities from NASA, industry, and partners [1]. Communications and navigation requirements will be driven by the number of assets, their diverse locations and the tempo of missions. The early part of the decade is comprised of the first Commercial Lunar Payload services (CLPS) missions including Volatiles Investigating Polar Exploration Rover (VIPER), a golf-cart-sized rover, the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) CubeSat placed into a near rectilinear halo orbit—the future home of the Gateway—and a sequence of launches of the Space Launch System (SLS) and Orion spacecraft in both uncrewed and crewed test flights leading up to the 2024 landing. There are fourteen CLPS providers currently on contract and eligible to bid on payload deliveries to the Moon, with plans for twice yearly deliveries of science instruments to the lunar surface. Commercial companies, through CLPS programs or independent missions, may choose to leverage the communications architecture that is being developed. The Gateway, with its first modules, the Power Propulsion Element (PPE) and the Habitation and Logistics Outpost (HALO), will be launched in 2023. Once in lunar orbit, the Gateway will be used for scientific operations as well as supporting subsequent human use as a crew quarters before and after visiting the lunar surface. Close coordination between the SCaN program and the Artemis program will continue to ensure requirements are completely defined, an initial set of minimum requirements for the first lunar missions are provided in Table 1.

Table 1. Minimum Requirements for Initial Lunar Missions

Parameter	Current Requirement
Initial Science Payload Mission	
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

The following cards (Figure 1: Artemis Plan Core Mission Element Cards) represent the primary components which are currently either in-development or at the early stages of formulation for Artemis missions on the Moon. Projects such as LunaNet, Deep Space Network (DSN), and the Lunar Ground Stations are depicted in summary cards and are intended to represent a snapshot rather than a full encapsulation of every system required for human-robotic lunar exploration [1].

Figure 1. Artemis Plan Core Mission Element Cards

As missions continue into the latter portion of the decade, NASA will turn its sights to establishing a more sustained capability. At the lunar South Pole, an Artemis Base Camp will be developed to support longer expeditions on the lunar surface. Planned Base Camp elements include a lunar terrain vehicle (LTV, or unpressurized rover), a habitable mobility platform (pressurized rover), a lunar foundation habitation module, power systems, and in-situ resource utilization systems. This incremental build-up of capabilities on and around the Moon is essential to establishing long term exploration of Earth's nearest neighbor and preparing for human exploration of Mars.

In planning to support communications and navigation needs for this diverse and evolving set of assets, SCaN has identified attributes of the "end state" architecture that will be required, and architecture implementations that will address these needs. The attributes and architecture upgrades, capacity increases, and capability deployments are introduced in Table 2, and further described in subsequent sections.

Table 2. Lunar Architecture Communications and Navigation Attributes and Proposed Implementations

Attribute / Requirement	Proposed End State Architecture / Capability	Paper Section
Flexible, interoperable architecture with common standards, protocols, and interfaces to allow diverse users/spacecraft to communicate, collaborate, and share resources	LunaNet Implementation	Section 2
Sufficient capacity to meet lunar vicinity demand but also preserve capacity for science and planetary missions not related to the lunar program	DSN 34-m upgrades 18-m class subnet	Section 3
DTE capability that reduces burden on lunar users, can support high data rates, and multiple simultaneous users	Multiple Spacecraft Per Aperture	Section 4
Ability to support surface assets that may not have continuous line of sight visibility to Earth	Communications relay in lunar orbit	Section 3
An internet-like capability supporting network connectivity between nodes in the cislunar environment	Delay/Disruption Tolerant Networking Infused through LunaNet	Section 4
Position, navigation and timing (PNT) capability to enable precise science, orbital determination, and multi-vehicle proximity operations	Lunar Global Navigation Satellite System	Section 4

With the creation of the Artemis Accords, lunar exploration is to be a collaboration endeavor with both commercial and international partners. To foster this collaboration on the space communications front the LunaNet concept was created. Just as we can now roam with our cell phone in other countries, it's important that lunar elements have similar flexibility to roam around the moon without concern of connectivity. LunaNet is the framework of standards, protocols, and interfaces to support a scalable, interoperable communications and navigation network with nodes provided by NASA, commercial, and international partners, described in detail in [2]. Initially NASA intended on performing the upgrades and capability enhancements in a phased approach that would work up towards the LunaNet final configuration. However, as plans shifted, SCaN determined the various tasks would need to be performed in parallel. The LunaNet framework will be further developed as the baseline capability and capacity upgrades are performed. These asset upgrades discussed later in the paper will eventually be supporting nodes in the LunaNet framework. As the Artemis Program progresses, the nodes participating in the LunaNet-enabled infrastructure will increase.

3. Asset Upgrades and Capacity Increases

3.1. 34-m Upgrades

NASA has studied numerous options for achieving the communication requirements for the Artemis program and has determined that upgrades to DSN's 34-meter (34m) subnet represent the path with the lowest technical and schedule risk. Based on the current set of well-defined lunar elements the following upgrades will provide the needed communication capabilities to fully support the Artemis program:

- 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]
- DTN

The SCaN program will begin the lunar upgrades by focusing on modifications to six of the DSN 34m antenna systems (two at each DSN complex location). These modifications will be deployed systematically to minimize impacts to current users. DSN antenna downtimes are coordinated years in advance to ensure redundancy is maintained for critical events, therefore, shifts in the Artemis schedule will not cause a subsequent change in the DSN antenna downtime schedules. The modifications to the six antennas are planned to be completed by 2024, however some delays have already occurred due to the COVID-19 pandemic, and the feasibility of the current schedule will be reassessed in the coming months.

3.2. 18-m Class Subnet Development

Concurrent to the 34m upgrades, SCaN has begun the process of investigating options for developing an "18m" subnet that would help reduce the lunar load currently projected to stress the capacity of the DSN 34m subnet. Necessary capacity increases will be achieved by making available at least two antenna systems in each earth region, separated by approximately 120-degrees longitude. The data rate requirements for S-, X- and Ka-band are the same as those for the 34m antenna upgrades as noted in the previous section. As a baseline for DTE support SCaN has determined that the eeffective isotropic radiated power (EIRP) and antenna gain to noise temperature ratio (G/T), need to be equivalent to a current state-of-the-art eighteen-meter (18m) class antenna. To close the performance gap from the 34m antenna systems, the "18m" antennas will need cryogenically cooled Low Noise Amplifiers (LNA).

Antennas that will provide lunar support will have the ability to service up to four simultaneous downlinks via the MSPA technique. MSPA will allow for simultaneous support of multiple human and robotic missions on each asset. The networks will be able to provide a low latency telemetry processing capacity of 150 Mbps in each region, to be shared with all simultaneous DTE links. The new 18m class subnet will use the standards, protocols, and interfaces defined by LunaNet.

The 18m subnet will be developed through a combination of government and commercial assets. The first antenna will be developed, and managed as a government asset, and the subsequent 18m class antenna services are to be procured from commercial vendors. SCaN is evaluating additional commercial and international capacity to meet mission needs that exceed SCaN's plan.

3.3. Lunar Relay Satellites

The multitude of lunar surface assets and orbiting spacecraft, in combination with limited surface visibility to Earth and interest in science and exploration on the far side of the moon, cannot be addressed by DTE alone, and have given rise to a need for a lunar relay capability. A relay capability will be needed to support the initial robotic science mission to the lunar far side and will also support the human exploration missions and other robotic activities at the moon. For the robotic missions, real-time transmission will only be needed for critical operations, all other operations will allow for some transmission delay. The requirements for the human exploration will be more stringent, requiring real-time transmission with the primary approach of a Direct-to-Earth link.

NASA released a Request for Information (RFI) "*Lunar Communications and Navigation Relay Services*" in October 2020, soliciting information from potential lunar relay communication providers. SCaN continues to engage with the space community to determine the best way to partner with and/or directly acquire services from commercial industry, other government agencies and international agencies. The implementation of the relay(s), including the size, type, and number of relay satellites, as well as the characteristics of the satellites orbits or locations, are all subject to further analyses and input from interested potential commercial providers.

4. Capability Enhancements

4.1. Global Navigation Satellite System

Situational awareness of your precise location enables all aspects of mission operations and objectives, including but not limited to rendezvous and proximity operations, science observations, formation flying, and lunar landing. This ability to precisely know your location is accomplished through PNT technologies. SCaN currently uses the ground networks to provide navigation services to user missions outside of the range of Global Positioning System (GPS) satellites. However, NASA has been investigating the possibility of extending the GPS navigation capabilities to high altitude applications, allowing for navigation services for lunar assets to be provided by the current GPS network. This will ease the current loading on the networks.

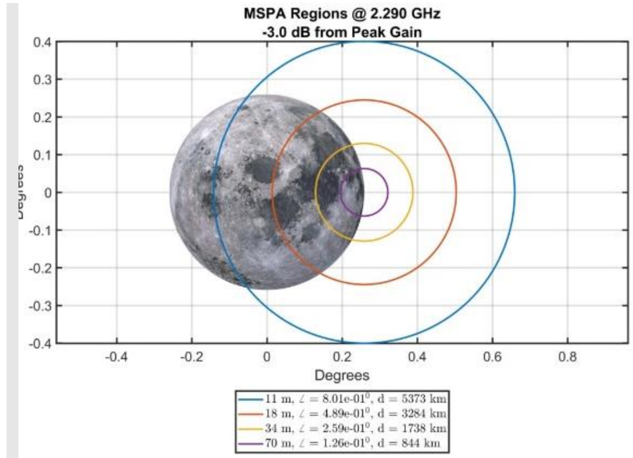
Spacecraft or vehicle PNT, and more specifically Position, Velocity, and Time (PVT) data is essential for both operation and science. SCaN has proposed building on the experience gained with from the legacy navigator receiver onboard the Magnetospheric Multi-Scale Mission (MMS) to use a similar system onboard the Gateway. The MMS is in the extended operations phase of the mission and has successfully demonstrated success with high altitude GPS application at 29.3 Earth radii, nearly half-way to the moon. A navigator-based High-Altitude Global Positioning System (GPS) / Global Navigation Satellite System (GNSS) receiver would enable Gateway to serve as a communication and navigation relay element in lunar space. This could be achieved by incorporating the GNSS infrastructure to the PPE gimballed Earth-pointed high gain communications antenna through a reprogrammable software defined receiver with a wideband GNSS signal. The receiver would be developed based on the existing NavCube 2.0 hardware and will be enhanced [4].

Including the fundamental infrastructure in the PPE will be important for Gateway development to reduce operational costs and complement ground networks by reducing network loading. In addition, PVT data would be available onboard and in real-time, providing accurate PVT information for science measurement registration. Including a navigation filter (GPS-Enhanced Onboard Navigation System (GEONS)) will also allow for operations during maneuvers including collection of accelerometer measurements during maneuvers.

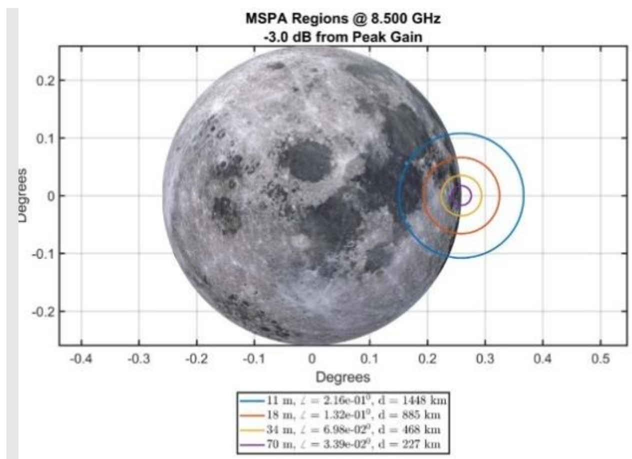
4.2. Multiple Spacecraft Per Aperture Technique

A key component of the lunar communications concept of operations will be the need for simultaneous DTE links. This requirement strains the current and planned capacity of the SCaN ground network. One enabling technology to mitigate this challenge and provide operational flexibility is the Multiple Spacecraft Per Aperture (MSPA) capability, which allows for an antenna to receive data simultaneously from multiple spacecraft. This is achieved by connecting multiple receivers to a single DSN antenna and enabling data reception for a number of spacecraft within the Earth station's beam width.

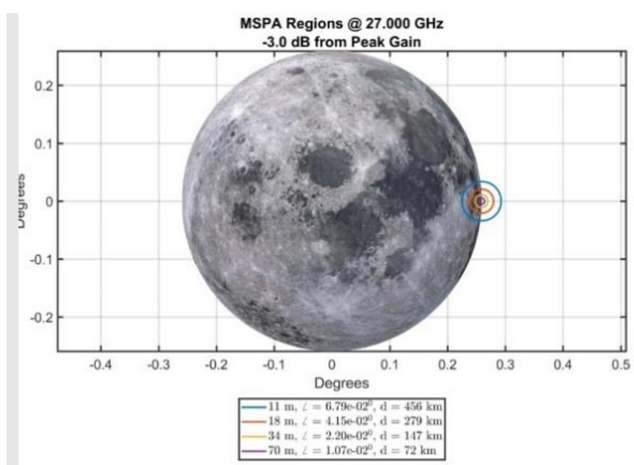
The DSN is currently set up to simultaneously receive signals from four spacecraft in a 4-MSPA configuration, with two-way coherent mode for a single spacecraft and one-way non-coherent reception of signals for three other spacecraft. There are other limitations to MSPA, including the fact that only two of the three bands are available at a given time, in the following configurations: [S/Ka], or [X/Ka]. Reconfiguration of the uplink can be achieved during a pass, to allow multiple spacecraft to share the uplink, but a thirty-minute reconfiguration period is necessary to transfer that two-way coherent mode between spacecrafts. Figure 2 provides three diagrams of MSPA regions for S- (a), X- (b), and Ka-band (c) and subtended angle of the antenna beam (at 3 dB roll-off) and equivalent diameter at the target's distance from the four different ground antenna sizes: eleven meter (11m), 18m, 34m and seventy-meter (70m). The 3 dB roll off is not proscriptive, MSPA can be employed as long as each individual spacecraft link can accommodate the G/T performance penalty. The DSN is investigating enabling an n-MSPA mode, where n is greater than 4, to allow for further ability to address peak demand. The limited geographical coverage of MSPA at the Moon decreases the utility when compared to application at Mars. However, NASA sees demand aggregating in two regions where MSPA can be employed: the near-rectilinear halo orbit (NRHO) orbit near and around the Gateway and also the Lunar south pole.



(a) S-band MSPA Performance



(b) X-band MSPA Performance



(c) Ka-band MSPA Performance

Figure 2. MSPA Performance

4.3. Simultaneous Ka-band uplink and downlink

During the Apollo-era lunar campaign, data rates were on the order of kilobits per second (kbps). In contrast, the Artemis Program requires data rates on the order of Megabits per second (Mbps) enabling high-definition video to be transmitted from the lunar surface. In addition to providing exceptional video footage of the next lunar landing, implementing these high data rate services using Ka-band capabilities is critical for a sustained presence on the lunar surface. Not only downlink, but also high-rate uplinks are needed to enable virtual and augmented reality remote operations and key life-support functions such as telemedicine.

Unlike the DSN 70m antennas, which have the microwave feeds in cones on the reflector dish, the DSN 34m Beam Waveguide (BWG) antennas have the feeds installed in the antenna pedestal basement, as seen in Figure 3. RF mirrors direct the transmitted and received beams through a waveguide tube and point them to a location where the feeds are arranged in a line. Frequency Selective Surface (FSS) plates (aka dichoric mirrors) are used to route the beams to the various feeds. Multi-band operations are done via the design of the dichoric and whether or not it is positioned over a feed. For example, if both S-band and X-band operations are required, the antenna is configured with a dichroic over the S-band feed that reflects S-band to/from the S-band feed and passes the X-band beam and a dichroic that reflects X-band is placed over the X-band feed. If only X-band is needed, then the mirror over the S-band feed is retracted, reducing any losses that the S-band mirror might contribute (the dichroics are designed to have minimal loss and degradation for passed bands, but still, no mirror is better than passing through a mirror).

Adding a new frequency, in this case K-band uplink (22.5 GHz) and downlink (26 GHz) was relatively straightforward. The K-band feed was installed in line after the X-band feed, and a mirror has since been installed over it to reflect the signals. New mirrors were designed and built for the S-band and X-band positions to allow for the passing of the K-band signals. The S-band and X-band positions now have two mirrors each – the S-band position has a mirror that reflects S-band and passes X-band, and a mirror that reflects S-band and passes K-band; the X-band position has a mirror that reflects X-band and deep space Ka-band (the X-band and deep space Ka-band feeds share the same location), and a mirror that reflects X-band and passes K-band. Two mirrors for each position are required, since the frequency span between the different bands that need to be passed is too wide to do with one dichroic (without unacceptable losses). Depending on the desired configuration (e.g., S- and K-band, X- and K-band, K-band only, etc.), the S-band and X-band feeds have one of three configurations above them – no mirror, mirror 1, or mirror 2. In this way, dual band operations with K-band will be efficiently added to six of the DSN 34m BWG antennas (two antennas at each of the three DSN complexes).

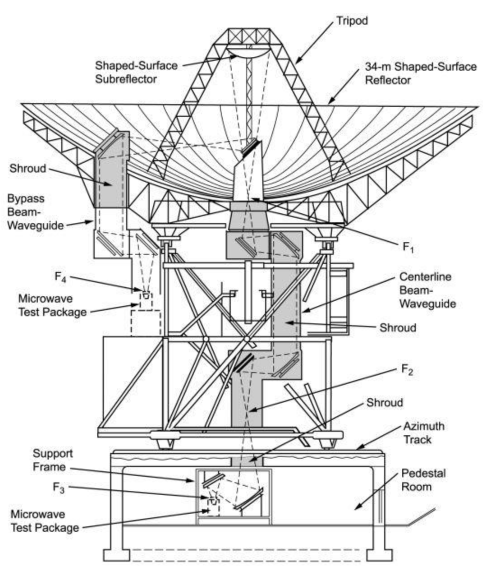


Figure 3. Beam waveguide antenna schematic

4.4. Delay/Disruption Tolerant Networking

One of the network technology building blocks enabling the LunaNet concept is DTN. DTN allows data to be transmitted from one node to another, even when the intermediate links are not simultaneously available. That is, DTN allows for an internet-like approach to spacecraft communications that is designed for and works well in the space environment. DTN encompasses the networking model and defines a set of protocols, or rules, for transmitting information that extends the concepts of the terrestrial internet into the space environment to provide contemporaneous end-to-end connectivity. Much like the terrestrial internet protocol suite, DTN includes network management, security, routing and quality-of-service capabilities. The store-and-forward and automatic retransmission capabilities provided by DTN improve operations, reducing the need to schedule network assets and providing insight into events that would have otherwise been unobserved due to communication outages. Any ground station or spacecraft operating with the DTN protocol suite can interoperate with similarly capable stations and spacecraft operated by other agencies or private entities; interoperability is achievable between DTN-capable assets. The LunaNet architecture baselines DTN as the fundamental component for the provision of network services for all lunar science and exploration. DTN implementations will be a vital part of LunaNet and support the expected diversity in surface and orbital elements at the moon. LunaNet will be built up by a combination of providers – NASA, commercial, and international – and the network layer services provided by DTN are critical for this approach in the same manner that IP networking allows the terrestrial Internet to be built up by many providers.

NASA SCaN is advancing DTN through three core activities: standardization, implementation, and infusion. Development and evolution of standardization of DTN protocols are underway via the Consultative Committee for Space Data Systems (CCSDS) in the civil space arena and the Internet Engineering Task Force (IETF) in the commercial sector. Core DTN protocols including the Bundle Protocol (BP) and the Licklider Transmission Protocol (LTP) are complete and internationally standardized. The updated Bundle Protocol, BP Security, and TCP Convergence Layer specifications are complete with all IETF technical reviews (including Internet Engineering Steering Group), and are in final editorial review. A necessary companion specification to the BP Security document is the Default Security Contexts, and these are slated for review in the spring (2021), with all four specifications being released in the summer of 2021. The CCSDS DTN Working Group is following IETF, and will make relatively short work of the CCSDS versions for the space community. Implementation efforts are intended to produce "deployment" ready sets of DTN components and operations concepts to support rapid update and infusion into missions and networks. The Interplanetary Overlay Network (ION) is one such implementation that is mature and has been operational on the International Space Station since 2016. A DTN flight software implementation, Core Flight System (cFS) Bundle Protocol Application (cFS BP app) and its underlying BP library (BPv6) are already available for use. Lastly, NASA is working to ready the networks to provide DTN services and prepare missions to implement DTN protocols and operate using DTN principles. One of the first lunar missions to incorporate DTN will be the Korea Aerospace Research Institute's (KARI) Korea Pathfinder Lunar Orbiter (KPLO). NASA and KARI have been partnering to conduct DTN tests and demonstrations. Initial ground network nodes will be in place to support both KPLO and Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) missions, as well as additional ground node implementations, which will be incorporated through the mid-2020s.

5. Commercial Industry

To progress toward the lunar architecture and technical capabilities described here, NASA does not intend to develop custom solutions or even buy systems the way landers, capsules, and rovers of the early lunar exploration era were built to detailed specification. Rather, the aim is to engage with a thriving commercial industry and be open to a range of technical solutions, operational strategies, and management approaches as long as they meet the needs of the mission users and comply with spectrum requirements, interoperability goals, and other constraints. The response to a Request for Information issued by NASA in October 2020 indicated strong and diverse interest among U.S. and foreign companies in providing commercial lunar communications services. This dramatic shift in the commercial landscape since the Apollo era has created a U.S. national and NASA agency-level push to capitalize on commercial offerings wherever possible. This is evidenced in National Space Policy, as well as the start of the commercial cargo and crew transportation programs in the early 2000s, up to NASA SCaN's efforts to transition near-Earth communications services to commercial providers by 2030. The notion that commercial industry can and should play a key role in providing communications and navigation services at the moon is a logical extension of this broader strategy.

6. Summary

The NASA Artemis Program is an ambitious endeavor, bringing together international space organizations and commercial partners to meet the goals of re-establishing a permanent human presence on the Moon and creating more dynamic science and commercial opportunities for space resource utilization. To meet the targeted trajectory of the Artemis Program timeline, SCaN is dedicated to facilitating the upgrades and capacity expansion of the networks, facilitating the deployment of lunar relay capability, and the implementation of foundational network architecture approaches to be incorporated in the LunaNet infrastructure, while taking advantage of innovations in the commercial space sector. Successfully deploying a communications and navigation architecture that meets Artemis Program needs, requires incorporation of advanced communication capabilities such as DTN, MSPA, and Simultaneous Ka-band uplink and downlink. In partnership with private industry and international space agencies, SCaN will provide the necessary real-time support for NASA to have a sustained, exploratory presence on the moon, Mars, and beyond.

References

[1] “NASA’s Lunar Exploration Program Overview,” September 2020, https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf (accessed 06 April 2021).

[2] Israel, David, "Communications, Ground and Space Networking - I Oral Presentation," The 16th International Conference on Space Operations 2020, https://spaceops.iafastro.directory/a/paper/id/542/abstract-pdf/SpaceOps-2020,8,1,3,x542.brief.pdf?2019-11-16.19:21:08 (accessed 06 April 2021).

[3] “HEOMD-003, Volume 2 International Communication System Interoperability Standard - Revision A.” 01 October 2020, https://govtribe.com/file/government-file/cis-rfi-0002-baseline-final-dot-pdf, (accessed 06 April 2021).

[4] "STP-H6/XCOM NavCube GPS On-Orbit Validation and Optimization," https://techport.nasa.gov/view/96237 (accessed 06 April 2021).