

# HOW PUBLIC PRIVATE PARTNERSHIPS ENABLE NASA FUTURE SPACE COMMUNICATION NEEDS

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## Abstract

The NASA Space Communications and Navigation (SCaN) Program is responsible for providing communication and navigation services to scientific and human space exploration missions. SCaN's current Space Network provides radio frequency (RF) relay services to near Earth space missions via Tracking and Data Relay Satellites (TDRS). SCaN plans to offer a new generation of relay services beginning in 2025, including the addition of optical communications capabilities and enhanced RF capabilities. The primary drivers behind the development of these next generation relay network services are to enhance communication and navigation services with significantly reduced development and operational costs. Several approaches being considered for implementation of these services are through government owned capabilities, through commercial service providers, or a combination of the two. One approach receiving a great deal of attention is the use of Public-Private Partnerships (PPP) to develop and provide capabilities or services. Utilizing Public-Private Partnerships allows NASA and commercial entities to share the investment, standards, and risks of developing and testing new or enhanced capabilities which can benefit both NASA and the commercial space communication industry. The capabilities developed under the PPP can then be used to support the growth of the commercial satellite communications industry while simultaneously being introduced into NASA operations to provide service to future NASA missions as part of the NASA Next Generation Architecture. Partnerships formed for this purpose can also serve as the basis for further NASA acquisition activities where government and industry can continue to share the cost, risk, and benefits of space communications capability development and operations. This objective is consistent with the 2010 National Space Policy stated principles: "The United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship." [1]

NASA has conducted several internal studies as well as externally funded studies with industry to define the next generation space communication architecture. NASA has approached the commercial industry through a Request for Information (RFI) to define further the next generation architecture and has conducted numerous internal and external studies. The results are promising and are shaping the approach to utilize Public Private Partnership to achieve NASA's objectives while reducing costs. The commercial satellite industry has begun to deploy high performance, high throughput global satellite constellations which have the potential to provide communication services to NASA Missions. Commercial satellite manufacturers have advanced their processes to rapidly design, build, and deliver, reliable communication satellites using minimum government oversight.

In this paper, we will 1) describe the NASA Next Generation Architecture, Concept of Operations (ConOps), and salient characteristics; 2) Discuss the rationale of Public-Private Partnerships to achieve NASA's next generation communication architecture; and 3) Summarize the preliminary analysis performed to date and describe the path forward.

## 1. Introduction

The NASA Space Communications and Navigation (SCaN) Program Office was formed in 2007 to provide a unified space communications and navigation network infrastructure capable of meeting robotic and human exploration mission needs. Today, these communication and navigation services are provided by the Near Earth Network (NEN), the Deep Space Network (DSN), and the Space Network (SN). As technologies mature and the needs of future missions change, SCaN must continually evolve its infrastructure and capabilities. Furthermore, several of NASA's key communication systems are approaching their end-of-life and are in need of replenishment or replacement. The Next Generation Architecture is being developed to provide the strategy and architectural concept for revitalizing SCaN's Networks through the 2040's. The Next Generation Network capabilities are expected to be developed and deployed over time. Following a disaggregated services approach, initial capabilities of the Next Generation Architecture are envisioned to become operational starting in 2025. [2]

Space exploration in 2025 and beyond will require innovative communication solutions to support unconstrained science, autonomous operations, and increased interaction with robotic and human communication capabilities. International cooperation in space exploration is increasing, driving a need for augmented communications capabilities. Also, growing security threats require new approaches to secure space communications. All of these are important considerations in the Next Generation Architecture. [2]

In defining the next stage of development, the SCaN program is looking at Public Private Partnerships as a viable option. The goal of public private partnerships between NASA and commercial entities is to reduce NASA development and operations costs for providing services, foster new U.S. space commercial markets and expertise, and enable an affordable, sustainable, flexible, and secure next generation open architecture for space communications and navigation to meet U.S. civilian, military, and commercial needs. The flexibility of the future system will help NASA meet the dynamically changing needs of missions, allow commercial entities to provide services and capability to both non-government and government customers using the same architecture, and lower NASA's development and operations cost while infusing new and emerging technologies, capabilities, and services. NASA's investment with commercial entities seeks to accelerate the availability of new services and capabilities and advance US commerce in space. It will also enable advanced US commercial communication relay capabilities. [1]

NASA Glenn Research Center initiated a request for information (RFI) in September 2017 to gauge commercial interest in forming public private partnerships with NASA on shared satellite development, provision of communication or navigation capabilities or services in low Earth orbit or outside of low Earth orbit, or development or validation of technology. NASA's investment with commercial entities seeks to accelerate the availability of new services and capabilities and advance US commerce in space. [1]

In Section 2 of this paper, NASA's Next Generation Architecture and Concept of Operations (ConOps) are presented to provide the context for developing its future communication networks through public and private partnership. In section 3, the rationale for public private partnerships is discussed. Section 4 details the options of different concepts of public private partnerships. Section 5 presents the benefits of the partnership and lastly, section 7 details the summary and path forward.

## 2. NASA Next Generation Architecture and Concept of Operations (ConOps)

Today's Earth Network consists of the Near Earth Network (NEN), the Space Network (SN), and the Deep Space Network (DSN). The NEN is a collection of ground stations (both NASA and commercially owned and operated), shown in Figure 1 below, located around the world providing services to user mission spacecraft typically in Earth orbits. The Space Network is a constellation of geosynchronous satellites providing data and navigation services to user mission spacecraft in Earth or lunar orbit. In addition, the DSN ground stations on Earth provide destinations for planetary networks such as at Mars or individual planetary satellites. [2]



**Figure 1 NASA Space Communication and Navigation Current Networks [3]**

## 2.1 Transition to Next Generation

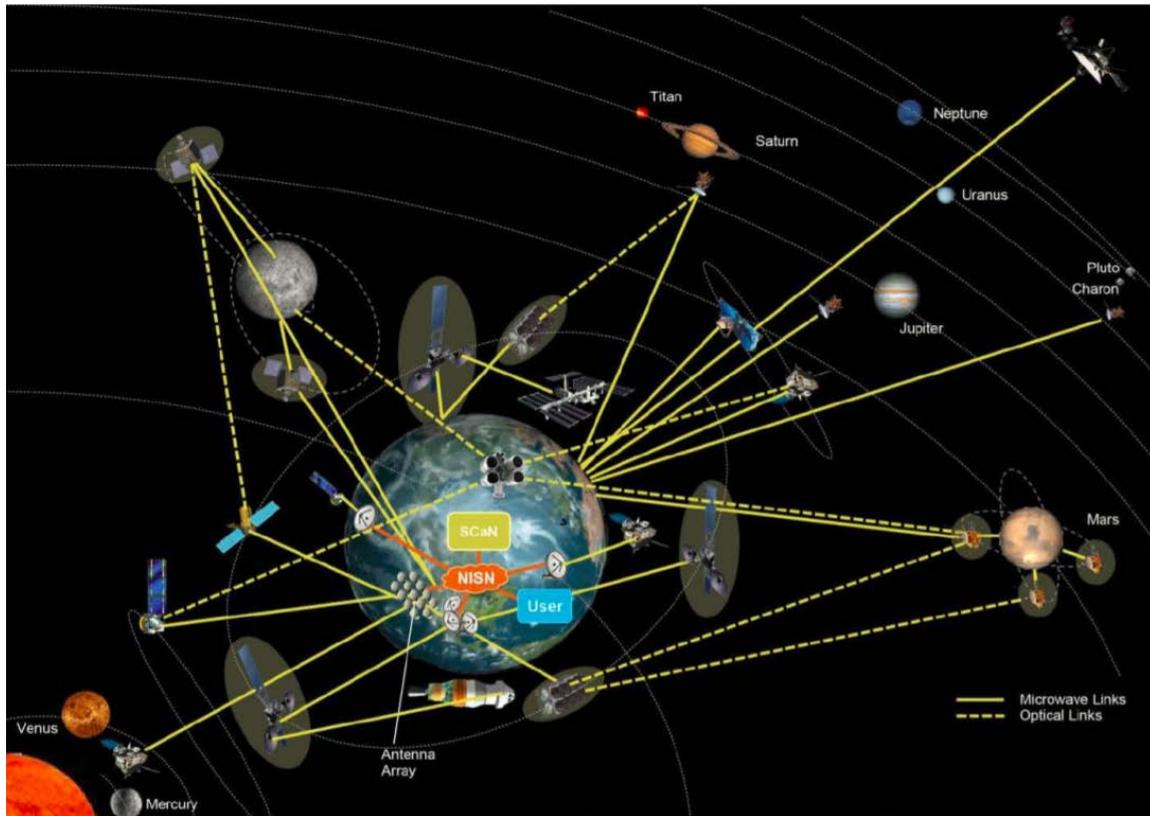
NASA's portion of the Earth Network Ground Segment will evolve from the current SN, NEN, and DSN into NASA's Space Communication and Navigation (SCaN) Control and Ground Segment (SCGS). NASA's Earth Network Space Segment will evolve from the current Tracking and Data Relay Satellite System (TDRSS) into the future Earth Relay capability. NASA's Earth Relay may operate in Geosynchronous Earth Orbit (GEO) as well as other orbits and may include dedicated relay and tracking satellites, hosted payloads for relay and/or tracking functions, Commercial Service Providers (CSP), and other options. The Earth Network provides service in the near Earth domain (out to 2 million kilometers, Mkm). The SCGS will operate the future Earth Relay segment. [2]

The vision of the Next generation SCaN architecture is to:

- "shrink" the solar system by connecting the principle investigator more closely to the instrument, the mission controller to the spacecraft, and the astronaut to the public.
- Improve the mission's experience and reduce mission burden – the effort and cost to design/operate spacecraft to receive services from SCaN network.
- Reduce network burden – the effort and cost required to design, operate, and sustain the ScaN network as it provides services to missions.
- Apply new and enhanced capabilities of terrestrial telecommunications and navigation to space leveraging other organizations' investments.
- Enable growth of commercial services for missions currently dominated by government capabilities.
- Enable greater international collaboration and lower costs in space by establishing an open architecture with interoperable services that can be adopted by international agencies and as well as NASA. [4]

One of the drivers to transition to the Next Generation Architecture, represented in Figure 2 below, is augmentation of near Earth relay satellite infrastructure with optical communications to provide unprecedented data throughout and replenishing near Earth relays beginning in 2025 to enable new science opportunities. A second driver is coverage of the lunar vicinity, polar regions, and far-side for lunar communications driven by human exploration and coordination with international partners and

the demonstration of deep space gateway technologies and reliability, as well as the assembly and departure point for Mars exploration campaign. A third driver is the build-up of Mars communication and navigation infrastructure for robotic and human exploration to augment science satellite relays with dedicated Mars relays for greater capacity due to the fact the Mars reconnaissance orbiter (MRO) is expected to reach the end of its life in 2025 timeframe.



**Figure 2 NASA Future Space Communication and Navigation Architecture (SCaN)**

Figures 3 and 4 below show the evolution of NASA's space communication networks, from 2025 to 2040. The initial operational capability of the SCGS and Earth Relay will occur around 2025 driven by the need to replace the capacity of TDRSS as its satellites are retired. Today's networks will gradually become the legacy architecture during the transition towards the future architecture. That legacy architecture remains in the picture because those spacecraft and ground stations will continue to provide service as long as they can be kept operational and as long as they have missions to support. Some legacy architecture assets such as antennas and TDRS satellites are expected to remain operational until 2040 and beyond. Over the next 25 years, it is anticipated that communication and navigation capabilities pioneered by international space agencies will be augmented by commercial capabilities [2].

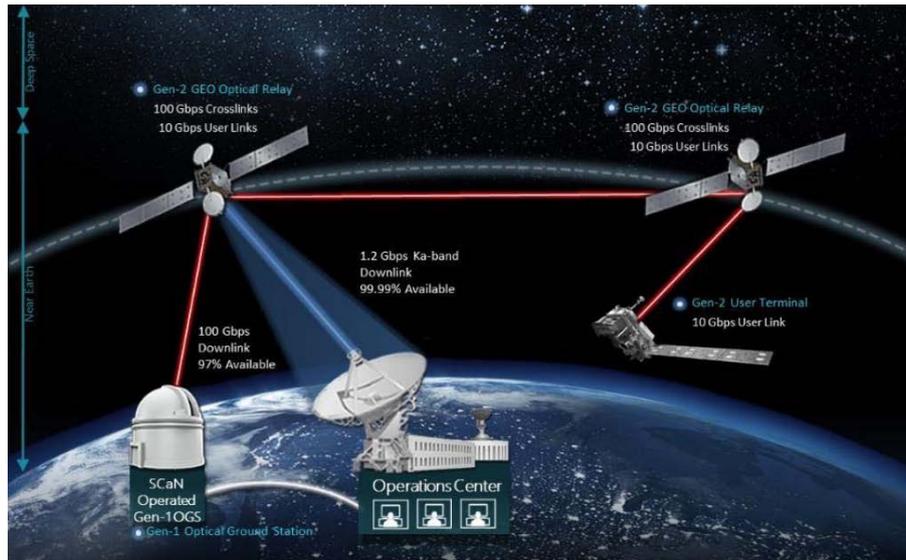


Figure 3 Initial Earth Network Architecture Concept [4]

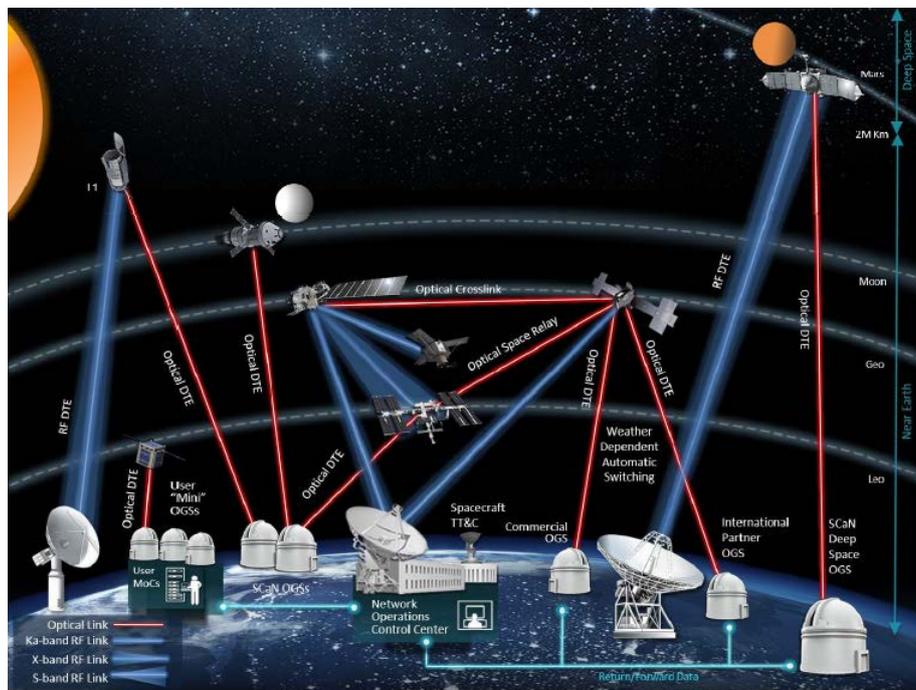


Figure 4 "2040" Earth Network Architecture Concept [4]

The "2040" Earth Network Architecture Concept plans to include:

- Full coverage network with relay orbiters in GEO/MEO & possible other orbits.
- Optical use, cross links with ground telescopes provide continuous optical support
- Mix of NASA, commercial & international service providers
- Ground/space assets for low end-to-end forward/return data latency
- Services provided to 2M km (limit of near Earth spectrum) [4]

The Next Generation Architecture will be seen from the mission perspective to be a standard set of services and interfaces available from a variety of provider access nodes. Similar to the terrestrial mobile networks, system complexity will be hidden "inside the box" and the specific implementation

done by the provider will not be seen by the mission. This will allow the provider to evolve the implementation as technology and funding allow. As the implementation evolves, the mission may see increased availability, new or enhanced services, new or enhanced interfaces, and/or reduced operations costs and complexity. [2]

The end-state architecture will provide the future missions with enabling services that minimize burden and constraints placed upon the mission. In the near-Earth environment, communication and navigation services will be available on-demand or, in the case of high rate and critical services, by schedule. Recognizing the trend towards increasing system autonomy, the scheduled services may be requested autonomously by mission platforms or mission operation centers (MOCs) and may become available within seconds or minutes of a request. [2]

The SCaN Program offers a range of space communication and navigation services and capabilities to enable the next generation of NASA’s science and exploration missions and global collaborations. These services allow missions to share the costs of critical space infrastructure and eliminate individual and costly mission facilities providing a cost-effective national resource for space exploration. In the end-state of the Next Generation architecture, missions will receive common services across near-Earth and deep space. The interfaces and protocols used will be common across all networks to the fullest extent practical, taking into account the physics, mission constraint, and operational differences between near-Earth and deep space missions. [2]

## 2.2 Concept of Operation

The SCaN Network will provide services in a manner that combines the best attributes of the SCaN service provisioning of today, along with best attributes of commercial telecommunication service provisioning. Figure 5 shows a schematic of how the mission’s platforms and ground systems will interact with the SCaN ground segment (SCGS) and the space segments of the Earth Network, Lunar Network, and Mars Network when scheduling and receiving service. The general concept of operations will be the same in all three space segments, but the specific details may vary to suit the specific needs in each region. [2]

SCaN and its service interfaces will become highly automated in-service provisioning, greatly reducing the labor required for both SCaN and the missions. For instance, link connections will become adaptive (e.g. using cognitive techniques), changing parameters such as coding, data rate, etc, for optimal throughput. The system will provide three methods for scheduling and providing services to the missions: on-demand service; pre-planned service; and user-initiated service. Pre-planned service will be highly automated for scheduling, while on-demand and user-initiated service will be completely automated. [2]

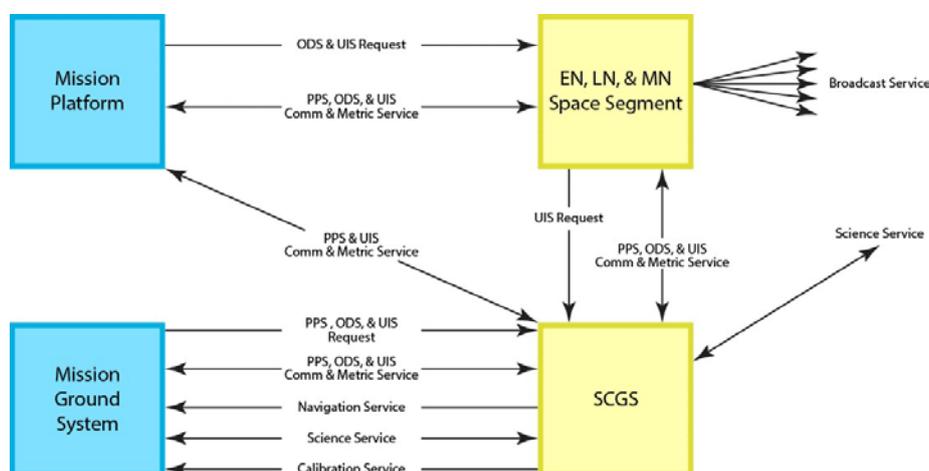


Figure 5 2040 SCaN Network Service Provision [2]

On-demand service provides low data rate forward and return services via relay for TT&C and other uses. It will be available in regions serviced by the Earth, Lunar, and Mars Networks. Service will be initiated by the mission platform or ground system, and the SCA Network will set up the service nearly instantaneously. On-demand service can be configured to be “always listening” and can be available without a request. Sufficient capacity will be available to provide very high availability according to the QoS agreed to with the missions. The implementations of these services are expected to be optimized for availability, so the necessary trades are expected to lead to lower performance, such as data rates, as compared to other parts of the network. [2]

Pre-planned service will be an evolution of the current method of scheduling, using an automated algorithm using inputs such as mission priority, data criticality, etc, to develop the schedule for communication, metric, and science services. Pre-planned service is initiated from the mission ground system via a request to the SCA Service Request System (SRS). It is intended for use in areas where user-initiated service is not available (such as in deep space DTE links) to cover known service needs such as critical events, and when it best fits the mission needs. It also covers other services such as Navigation, Science, and Calibration Services that do not require direct interaction with the mission platform. [2]

User-initiated service (UIS) is a new scheduling method that allows the mission to schedule service within a short scheduling window from both the mission platform and ground system. The UIS request can come from either the mission platform to the SCA space segments or from the mission ground system to the SCGS depending on the mission need. UIS can provide service through any SCA Network assets, including relays and ground stations. The UIS request will include information on the service required such as data volume, latency requirements, radio parameters, etc, that allow SCA to provision the service, along with positional information such as ephemerides in order to establish the link connection. The SCA Network will have enough capacity to support the UIS requests according to a QoS agreed to during the mission planning. Only high priority UIS requests such as emergencies may be able to override existing service schedules. [2]

Broadcast service provision is currently envisioned through the space segments as the means to provide full orbital coverage, but some features could be provided from the ground via SCGS. The broadcast signal design itself may provide the means for mission onboard autonomous navigation through radiometric or optometric means. Other data carried on the broadcast service may provide other information to enable autonomous user operations, such as network status, GPS corrections, and space weather data or warnings. [2]

The initial architecture deployment is an early instantiation of the Next Generation Architecture. NASA will refine its plans over the next few years as the existing relay satellite system changes and system trade studies are conducted. NASA’s current initial 2025 concept is described below. [2]

The service paradigm of the 2025 era will provide services using a combination of the existing methods and the first steps toward the full Next Generation Architecture methods. The SCA Network will continue to provide services to existing missions using the current methods as required. Two new relay satellites around Earth are envisioned. User-initiated service and on-demand service will be available via the Earth relay nodes, and those nodes can forward requests to the new common SCA Service Request System for scheduling of existing assets. Single-point, automated service request scheduling will be implemented for pre-planned services for all SCA ground stations and relays. New metric and broadcast services will be available on the new Earth relay. [2]

The initial deployment will start in approximately 2025, driven by the need to replace the capacity of TDRSS as its satellites are retired. Today’s networks gradually become the legacy architecture during the transition to the future architecture. The legacy architecture remains while the TDRSS satellites and ground stations continue to provide service to missions. Some legacy architecture assets such as antenna and TDRS satellites are expected to remain operational until 2040 and beyond. [2]

Figure 6 depicts the early deployment of the near-Earth architecture including the new service offerings through a combination of upgrades to existing systems and launch of the initial Next Generation relay satellite nodes. New services include optical communications, internetworking using IP and DTN, use of the CCSDS Universal Space Link Protocol (USLP) for both forward and return link

layer protocol, broadcast service, asynchronous end-to-end messaging, and UIS service. These services may have limited coverage and capacity until full deployment is reached. [2]

The initial deployment features high-rate (~10 Gbps) optical terminals to support a minimum of two (TBR) simultaneous user mission spacecraft in low earth orbit. Onboard the optical relay satellite, high-rate (~100 Gbps) optical crosslinks are used between relays to bring the data to ground stations located in the US. The same (~100 Gbps) capacity is available for the optical space-to-ground link to bring the data to the gateway ground station. To complement the optical link, a high-rate Ka-band (or other suitable RF frequency band) is available as backup for the data relay to the gateway ground station. A Ka-band or S-band link will be used for satellite command and control. On-board data processing and routing among communication links will be used to enable space internetworking. Open commercial and international standards will be used for interoperability among commercial and partner assets (e.g. relays, ground stations). Satellite control and data communication links will be secure and resilient. [2]

### 2.3 Optical Technology Development

NASA is developing optical communication technology and operational capabilities in order to meet the Next Generation Architecture objectives, as described below. The NASA/JPL Optical Communication Telescope Laboratory (OCTL), shown in Figure 6 below, was built for dedicated research and development toward supporting free-space laser communications from space. The facility has been used to support multiple optical communication technology demonstrations in the past, and is currently undergoing major upgrades to support future missions. As the upgrades are completed, the OCTL will become Optical Ground Station (OGS)-1 to support NASA's future optical communication needs, and ultimately become an operational capability. The 1 m diameter aperture provides an adequate collection area for expected laser signals from near-Earth, lunar and Lagrange point satellites. The OCTL facility is located at the Table Mountain Observatory near Wrightwood, CA. A second ground station, OGS-2, will be located in Maui, Hawaii. OGS-2, shown in Figure 7 below, will have a 60 cm receive aperture, a 15 cm transmit aperture, and be located within an approximately 5.5 meter diameter dome. Both OGS-1 and OGS-2 are being outfitted to support the Laser Communication Relay Demonstration (LCRD), flying in 2019. [2, 8, 9]



**Figure 6 Optical Communications Telescope Laboratory located at Table Mountain Observatory [2]**



**Figure 7 OGS-2 Telescope and Dome located in Maui, Hawaii [2]**

NASA is currently developing optical terminals for both GEO relays (20 cm) and user terminals (10 cm). Generation-1 of this technology will be demonstrated on the LCRD mission for the GEO optical relay, and the Integrated LCRD LEO User Modem and Amplifier (ILLUMA) for a user terminal on the International Space Station (ISS). The Gen-1 terminals, shown in Figure 8 below, will be capable of 1.24 Gbps, using DPSK modulation. The Generation-2 terminals, beginning development in 2018 and shown in Figure 9 below, will be capable of 10 Gbps for the user terminal (10 cm), and 100 Gbps for the GEO relay terminal (20 cm). Compared to the Generation-1 terminals, these will have consolidated modem and controller electronics, and will incorporate commercial off-the-shelf integrated photonics modems for reduced size and power consumption. [2, 8, 9]

There is an ongoing activity on International Interoperability Standards Development for Space Optical Communications and Regulatory Considerations regarding laser safety and the emerging technology of laser communication. These activities will allow the commercial sector to interoperate and provide services to the NASA next generation architecture. [10, 11]

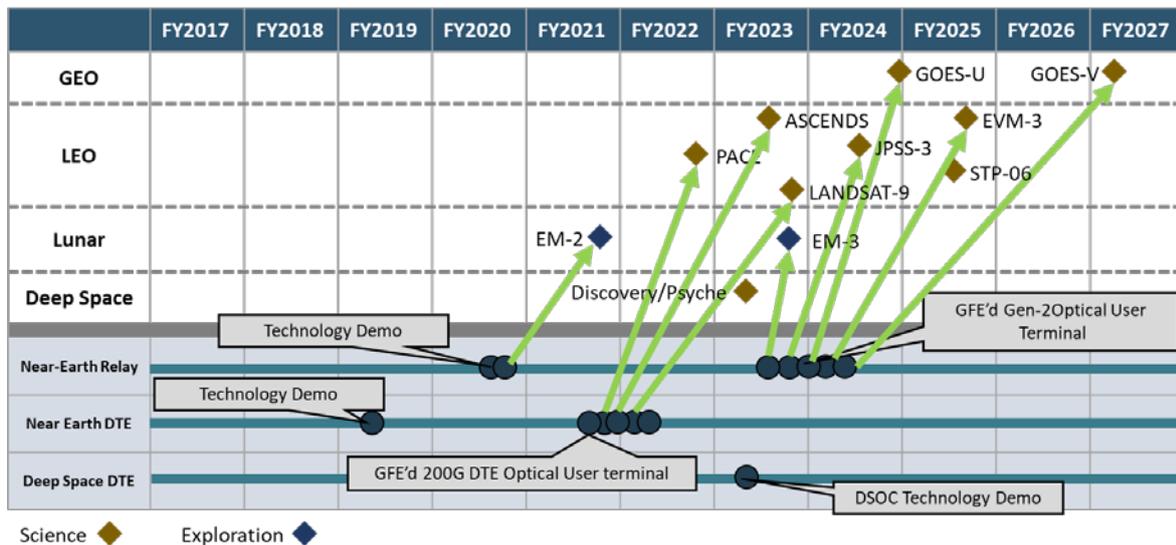


**Figure 8 Model of Generation-1 User Terminal [2]**



**Figure 9 Generation-2 GEO Relay Terminal Components [2]**

NASA's plan for Optical Infusion, shown in Figure 10 below, is to apply Space Technology Mission Directorate (STMD) & SCA&N optical communication technology investment to science & exploration missions to transition optical communications to operations. SCA&N will provide GFE terminals to NASA missions for direct or relayed services. STMD & SCA&N will provide optical relay & ground stations to return data mission users. [9]

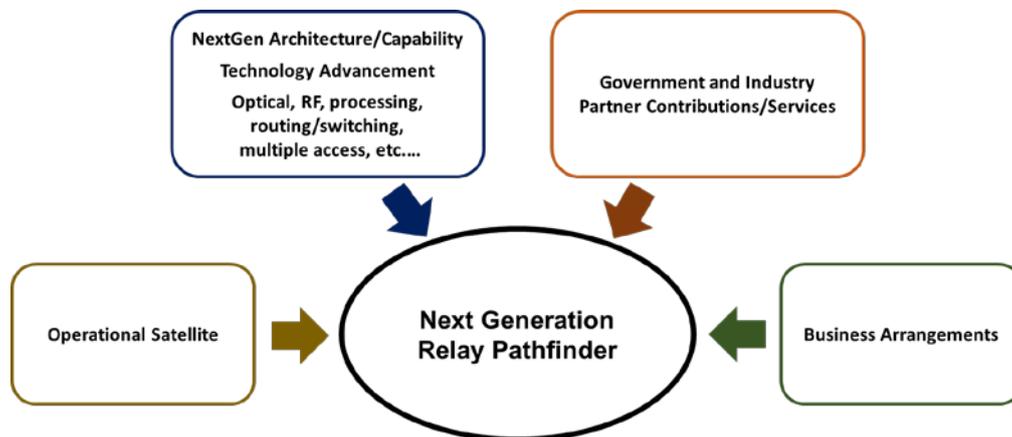


**Figure 10 NASA's Future Target Missions to implement Optical Communications [9]**

### 3. Public Private Partnership

The augmentation of the space relay satellite network over the next decade will include adding optical communications capability along with enhanced RF capabilities and services to enable new and greater scientific discovery, improve communication and navigation services, and reduce development

and operations costs. One approach to augmentation that NASA is considering is the use of Public-Private Partnerships consistent with the 2010 National Space Policy, to develop and provide capabilities or services for NASA's future space network. Public-Private Partnerships allow NASA and commercial entities to develop and introduce new capabilities into NASA's operational services by shared investment, standards, risks, and benefits. These new capabilities may help foster the growth of the commercial satellite communications market (from low Earth orbit to the Moon and beyond) and provide benefits to future NASA missions in alignment with NASA envisioned Next Generation Architecture. Figure 11 below highlights the four major components to create public private partnerships for the Next Generation Relay Pathfinder project. [4]



**Figure 11 Aspects of the Next Generation Relay Pathfinder [4]**

“[Badri] Younes, SCan Associated Administrator suggested in “TDRS Launch Marks End of an Era,” Space News – August 18, 2017 [4] that those future data relay satellites might be owned and operated by commercial entities rather than NASA. ‘NASA’s optimum goal is to push the technology to enable the commercial sector such that these services can be provided by commercial providers, and NASA will not need in the future to build these kinds of capabilities,’ he said. ‘They can become a user, like any other user.’”

### 3.1 Rationale of Public-Private Partnerships

Such public private partnerships may form the basis of future acquisition activities to help share the cost and risk of developing and providing these capabilities and services and provide savings and benefit to both the potential Partner (or Partner(s)) and Government. The 2010 National Space Policy of the United States provides comprehensive guidance for all government activities in space, including NASA's. The principles' section of the policy states, “The United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship.” The National Space Policy further defines the term “commercial” as: “The term ‘commercial,’ for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers. To promote a robust domestic commercial space industry, departments and agencies shall:

- Purchase and use commercial space capabilities and services to the maximum practical extent when such capabilities and services are available in the marketplace and meet United States Government requirements;
- Modify commercial space capabilities and services to meet government requirements when existing commercial capabilities and services do not fully meet these requirements and the potential modification represents a more cost-effective and timely acquisition approach for the government;

- Actively explore the use of inventive, nontraditional arrangements for acquiring commercial space goods and services to meet United States Government requirements, including measures such as public-private partnerships, hosting government capabilities on commercial spacecraft, and purchasing scientific or operational data products from commercial satellite operators in support of government missions [1]

### 3.2 Benefits of Public Private Partnerships

The goal of the partnerships between NASA and commercial entities is to reduce NASA development and operations costs for providing services, foster new U.S. space commercial markets and expertise while enabling an affordable, sustainable, flexible, and secure next generation open architecture for space communications and navigation to meet U.S. civilian, military, and commercial needs. The flexibility of the future system will help NASA meet the dynamically changing needs of missions, allow commercial entities to provide services and capability to both non-government and government customers using the same architecture, and lower NASA's development and operations cost while infusing new and emerging technologies, capabilities, and services. [1]

NASA's investment with commercial entities seeks to accelerate the availability of new services and capabilities and advance US commerce in space. It will also enable advanced US commercial communication relay capabilities. [4]

Public private partnerships create mutual benefits including:

- A new way of working with industry
- Shared cost/risk/revenue across participants
- Establish commercial standards
- Transitions advanced technologies to marketplace
- New markets and services
- Establish open and interoperable architecture
- Significant contributions to the national economy [4]

### 3.3 Public Private Partnership Options

NASA has been exploring two options to enable public private partnerships in satellite communications. The first option is to develop and deploy a shared spacecraft to introduce innovative optical and enhanced RF capabilities, providing operational services to NASA through shared investment, standards, risks, and benefits. The second option is to foster the growth of the commercial satellite communications market (from low earth orbit to the moon and beyond). [4]

There are two types of potential partnership concepts that have emerged, the technical concept and the business concept.

In the technical concept, there are three divisions: [4]

1. Shared satellite development – New optical or enhanced RF capability
  - Share spacecraft bus resources
  - NASA Provided Optical communication payload
  - Host or hosted payload model (e.g. multiple payload on bus)
2. Optical and RF commercial services
  - Demonstrate space market: multiple supplies, multiple customers (non-government)
  - Address NASA's user space terminal needs to allow non-exclusive services (e.g. user space terminals operable with multiple commercial or government services)
  - Interoperable standards/interfaces
3. Subsystem Technology Advancement/demonstration as part of NASA Payload
  - Advance TRL and infuse new capability for future business/customers
  - Technology assessments – Partners have the opportunity for NASA to assess their proposed technology's applicability to the Next Generation architecture in ground testing.

In the business concept, there are two divisions: [4]

1. Business case and partnership – Partners discuss commercial market assessment, objectives, benefits, risks, and risk mitigation approaches associated with partnership.
  - Business model/plan/strategy

- Customers: both non-government and government (NASA one of the many)
  - Competitive environment: multiple suppliers, barriers to market entry (more than one supplier)
  - Preferred time to market and operational lifetime
  - Incentive for NASA market and operational lifetime
  - Incentive for NASA missions to use the service (aspects of operations)
  - Return on investment goals and commercial operations timeframe/duration to make return on investment (want commercial investment, not NASA investment in the service itself – different from COTS model)
2. Cost-share and contributions – Partners discuss their proposed contributions (financial and in-kind), financial approach, and anticipated NASA contributions and their benefits.

NASA plans to offer its own potential resources in the partnership, including: [4]

1. On-orbit payload accommodations/capacity
  - Space to ground links capacity/bandwidth (RF or optical TBD)
  - Cross links capacity/bandwidth (Optical)
  - On-board processing or memory capacity
  - On board backup subsystems or components configured to benefit Partner and NASA and reduce mass and complexity to the spacecraft.
2. Ground operations capacity
  - Satellite/payload operations from white sands, New Mexico
  - Optical payload data operations from Table Mountain facility, Wrightwood, California or Maui, Hawaii
3. Expertise
  - NASA's Spaceflight personnel expertise
  - Development and spaceflight analysis or test data
  - Risk mitigation approaches
  - Unique facility and services

These new partnership agreements could complement traditional procurement approaches for the development, flight, and operations of the space communications capability. Partnership activities may range from technology assessments, flight validations of new technologies, up to simply providing commercial services. [1]

Depending on the details of the partnership, NASA is considering all potential partnering approaches, including procurements under the Federal Acquisition Regulation (FAR) as well agreements under its *other transactions authority* (51 U.S.C. § 20113(e)). These approaches could include funded, unfunded, reimbursable, cost sharing or cooperative agreements. As needed for potential future activities, NASA will also negotiate the Partner's access to NASA's spaceflight resources; satellite payload or bus systems, ground stations, technical expertise, facility, flight or test analysis or data, aspects of risk mitigation, or other resources. Use of additional Government resources such as facility, services, and Government developed technologies may require the negotiation of a separate agreement with NASA. [1]

#### **4. Status and Path Forward**

NASA Glenn Research Center initiated a request for information (RFI) in September 2017 to gauge commercial interest in forming public private partnerships with NASA on shared satellite development, provision of communication or navigation capabilities or services in low Earth orbit or outside of low Earth orbit, or development or validation of technology. NASA's investment with commercial entities seeks to accelerate the availability of new services and capabilities and advance US commerce in space. The RFI requested information on a technical plan from industry. The technical plan and approach needed to include the technical capability and concept, development, production, and demonstration, development standards, technical risks, and shared resources. The RFI also requested an explanation on the relevance to NASA's Next Generation Architecture, including network perspective and user mission perspective. Lastly, the RFI requested a business plan and approach that included a business overview, business development plan, business partnerships, partnership agreement and compliance, business risk management, and proposed use of government resources. The RFI also asked for a cost description, including investment cost and cost basis, service cost,

cost/revenue saving/sharing, cost risk. [1] NASA has completed its review of the RFI submissions from industry. The findings have identified this as a potential for public private partnerships to enable NASA Next Generation Architecture.

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