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NASA's Efforts to Commercialize Communications Services for Missions in Near-Earth Space

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Abstract

The National Aeronautics and Space Administration (NASA) Space Communications and Navigation (SCaN) Program enables high-speed, robust, secure, and cost-effective space communications and navigation services to current and future science and exploration missions. Consistent with National Space Policy [1], NASA is pursuing the use of demonstrated commercial services for all its future near-Earth requirements through a flexible, multi-provider approach that minimizes risks to the user missions while creating a competitive market to support user missions. Progress toward this goal is advancing in multiple key areas including direct to Earth (DTE), space-based relay (SR), technology investments, required spectrum regulatory changes and mission engagement and infusion.

The push to increase commercial DTE usage is already underway, with a target for near-complete transition in 2024. The primary components of SCaN's DTE strategy include increasing commercial service allocations by leveraging current commercial network providers and enabling seamless onboarding of additional providers into the network. A more gradual approach is planned for the transition to commercial space-based relay services to allow for demonstration and operationalization for users in the 2030s. In June of 2022, six satellite communications (SATCOM) vendors were awarded a combined $278.5 million through Funded Space Act Agreements (FSAAs) for the first cycle of demonstration and validation activities. The end-to-end service capabilities being targeted are based on existing NASA operational mission needs. Accordingly, each company has proposed a technical approach to lower costs, increase flexibility, and improve performance for a broad range of missions.

Transitions to commercial services are dependent on the technologies and capabilities that address gaps in existing commercial capability. Wideband and multi-lingual user terminals are being developed to bridge differences in industry services. Building on ground demonstrations completed in 2021, the Johns Hopkins Applied Physics Lab (APL) will be flight testing a multi-lingual wideband terminal (payload) and demonstrating connectivity to both government and commercial relay services.

NASA holds a leadership role in multiple civil space standards bodies and international coordination groups to ensure that standards supporting interoperability are developed with defined functions, interfaces, and performance. However, to successfully meet commercialization objectives, NASA seeks to collaborate with industry, and as applicable adopt or adapt to commercially defined standards. As such, NASA joined the 3rd Generation Partnership Project (3GPP) as an official member in 2021 to advocate for the inclusion of space missions as a unique user segment in future 5G non-terrestrial networks, and to better understand the scope of 3GPP releases and implications for space users. Further, engagement in Spectrum regulatory bodies is being undertaken to augment existing space-Earth and inter-satellite frequency allocations available for both government and commercial space systems.

This paper addresses the recent progress toward NASA's commercial space communications transition objectives and how key challenges are being navigated.

Acronyms/Abbreviations

Acronym	Definition
3GPP	3rd Generation Partnership Project
AI	Agenda Item
APL	Applied Physics Laboratory
BAA	Broad Agency Announcement
C&N	Communications and Navigation
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CIS	Commercial Innovations and Synergies
COTS	Commercial Orbital Transportation Services
CSP	Communication Services Project
DTE	Direct to Earth
DTN	Delay/Disruption Tolerant Networking
DSN	Deep Space Network
FSAA	Funded Space Act Agreements
FSS	Fixed Satellite Service
FY	Fiscal Year
GEO	Geosynchronous Earth Orbit
GoCo	Government-owned and Contractor-operated
GPS	Global Positioning System
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
ITU	International Telecommunication Union
KGS	Kuiper Government Solutions
KSAT	Kongsberg Satellite Services
LEGS	Lunar Exploration Ground Sites

Acronym	Definition
LEO	Low Earth Orbit
MEWG	Mission Engagement Working Group
MI&SS	Mission Integration and Special Studies
MOC	Mission Operation Center
MSS	Mobile Satellite Service
NASA	National Aeronautics and Space Administration
NextSTEP-2	Next Space Technologies for Exploration Patnerships-2
NIB	Non-Interference Basis
NSN	Near Space Network
O&M	Operation and Maintenance
PExT	Polylingual Experimental Terminal
RF	Radio Frequency
RFI	Request for Information
RFP	Request for Proposal
SATCOM	Satellite Communications
SCaN	Space Communications and Navigation
SR	Space Based Relay
SS	Sources Sought
SSC	Swedish Space Corporation
TDRS	Tracking and Data Relay Satellites
U.S.	United States
WRC	World Radiocommunications Conference

1. Introduction

NASA has developed a strategic plan to transition to commercial space communications services that is commensurate with the state of the market. Market growth for private sector Communication and Navigation (C&N) services represents an opportunity for NASA to develop a service portfolio with multiple vendors, which results in a robust and flexible architecture for the user community while simultaneously contributing to market stimulation and growth. Further, SCaN anticipates significant savings in infrastructure, ongoing operations, and maintenance costs by leveraging commercial industry service offerings. NASA is working toward two primary goals: (1) the expansion of commercial DTE services from current levels to near 100% by 2024, building on the existing commercial partnerships and integrating new providers, drawing from an existing and growing market; (2) the demonstration and operationalization of commercial space-based relay services for future users in the 2030s, leveraging the approach used by the Commercial Orbital Transportation Services (COTS) demonstration and subsequent Commercial Resupply Services acquisition. Capability demonstrations are applicable for different classes of NASA missions and suitable for other customers. The intent is to develop a demonstration portfolio of commercial capabilities that in the aggregate will address future NASA mission needs for reliable, robust, and cost-effective communications and navigation services. NASA is identifying and pursuing major activities and milestones required over the next 10 years, spanning DTE, space-based relay, technology investments, required spectrum regulatory changes and mission engagement and infusion.

2. Technical Needs

The existing NASA networks—the Near Space Network (NSN) and Deep Space Network (DSN) —represent a global capability, combining NASA, and commercial partner providers. NASA's efforts to maximize the use of commercial services must start from the existing operational state and create a path forward that does not compromise mission operations. NASA's NSN offers direct to Earth and space-based relay services to mission users. Commercialization efforts are focused on Near-Earth space and will drive changes within the operations and infrastructure of the NSN. The DTE component of the NSN is currently a blend of facilities and service arrangements spanning government-owned sites that are government/contractor operated (GoCo), NASA antennas operated by a university partner (Alaska Satellite Facility), and commercially-owned-commercially-operated sites provided by Kongsberg Satellite Services (KSAT) and Swedish Space Corporation (SSC). NASA already purchases service time from commercial, and university partners totalling ~60% of required mission passes. While DTE services within the NSN span a range of owner/operator types, the space-based relay component of the NSN is a unique system, built specifically to support NASA orbital users, and is owned and managed by NASA with the support of a prime contractor responsible for operations and maintenance (O&M). The fleet of Tracking and Data Relay Satellites (TDRSs) has evolved over the decades, with the most recent generation of spacecraft launched between 2013 and 2017. The TDRS fleet assets are expected to support users into the mid-2030s allowing time for demonstration and capability validation for comparable commercial services, but recent spacecraft failures have highlighted the need for the timely progress toward commercial alternatives.

In near-Earth space, SCaN provides services to customers both internal NASA and external – Other Government, International Partner, and commercial – mission users. The NSN supports users at various orbits, mission phases and frequency allocations, and data delivery needs. Near-Earth space includes the volume from the surface of the earth extending to 2,000,000 km. Missions within this volume are grouped into Earth Proximity missions, and Beyond GEO missions. The current NSN mission set are located primarily in Earth Proximity, however as the service catalogue expands, the network will support the entire service volume of Near-Earth space. Services are provided based on the categories defined in the following table.

Table 1: Summary of Current C&N Support in Near Earth Space

Orbits	Earth Proximity	LEO (Low Earth Orbit) (Sub-orbital, polar, mid latitude, equatorial)
		GEO
	Beyond GEO	Highly Elliptical Orbits
		Lunar
		LaGrange
Frequencies	DTE Assets	VHF, S-Band, X-Band, and Ka-Band
	SR Assets	S-Band, and Ka-Band
Mission Phases	Launch	
	Launch and Early Operations	
	Operations (high / low-rate routine data delivery, contingency)	
	Disposal	

The intention is to meet the current C&N support capabilities using commercial services. For missions currently reliant on government DTE assets, SCaN plans to transition these users to commercially operated capabilities that are compatible and known to exist. However, commercial space relay providers will not be required to provide backward compatible services due to the spectrum allocations used by commercial SATCOM operators. All new missions will be required to use commercial services while existing SR users will be allowed to continue on the previous service until mission conclusion.

The majority of NASA supported users in near-Earth space employ civil space communications standards, such as the Consultative Committee for Space Data System (CCSDS), to ensure interoperability and allow for cross-support across users and C&N assets from multiple entities. There are two CCSDS protocols that SCaN currently supports – CCSDS File Delivery Protocol (CFDP) and Delay/Disruption Tolerant Network (DTN). The former is for delivering files; the latter can deliver files, frames, or packets. SCaN is working to position the user community to take advantage of DTN and less congested frequency bands such as Ka-Band.

Although TDRS and DTE assets have had Ka-Band capabilities since the 2000's very few operational missions are using these capabilities (See Figure 1). The shift to commercial services offers the opportunity to shift user community mentality and take advantage of higher performance C&N frequencies and standards. As NASA makes the shift to commercial services, the standards solution should not be mandated by the civil space community but instead be developed with participation from the commercial community. Commercial standards are evolving, giving NASA the opportunity to engage in development that supports NASA mission needs. One standard with broad adoption outside of NASA worthy of consideration, and available commercially in existing DTE providers, is the Digital Video Broadcasting - Satellite - Second Generation (DVB-S2) set of protocols.

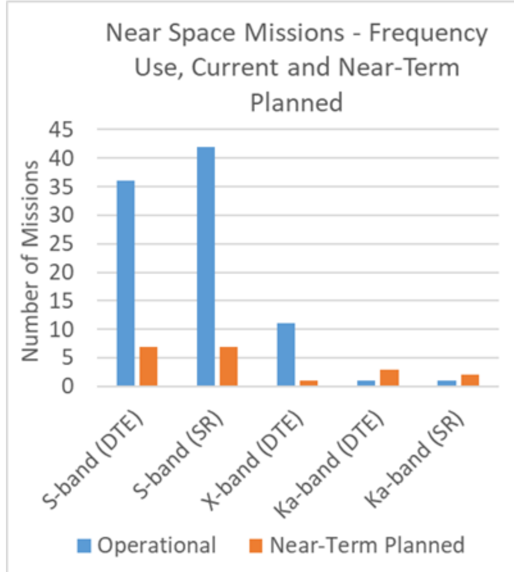

Figure 1: Earth Proximity Mission Frequency Use

3. Strategy to Acquire Available Commercial Services

NASA is pushing forward to explore and acquire the mature services and capabilities currently offered by commercial industry. The Commercial Innovations and Synergies (CIS) Office at Goddard Space Flight Center (GSFC) works to address the need for continuous engagement with industry to meet commercialization goals. The priorities are (1) to identify new providers through a series of engagement initiatives, (2) conduct market research and trends analysis, (3) facilitate Request for Information (RFI) releases and collaborate on acquisitions, and (4) engage with the mission community through events as well as the Mission Engagement Working Group (MEWG) which is co-chaired by CIS and NSN. As the interface between customers, missions, providers, and organizations, CIS is uniquely positioned to help enable a successful commercial transition.

3.1. NSN Procurement Strategy

The CIS and the NSN teams are collaborating to establish an integrated approach to obtaining market research and develop and refine the acquisition strategy for commercial services. RFIs focused on commercial capabilities for support of both DTE and Lunar were released and evaluated in late 2020. A DTE Sources Sought was released in Q4 FY21 which, in addition to DTE service for near-Earth missions, included Lunar Exploration Ground Segment (LEGS) capabilities and requirements. The Sources Sought laid the groundwork for a Request for Proposal (RFP) released in Q1 2023. The procurement is intended to provide NASA with a single avenue to procure communication and navigation services that are secure, reliable, and affordable, so that all NSN mission users will receive the services required by their mission within their latency, accuracy, and availability requirements. Procurement success will be based on meeting the following objectives:

- Provide affordable, accurate, secure, and timely delivery of communication and navigation services from multiple vendors for existing and future NASA scientific, technology and human spaceflight missions from the Earth's surface up to 2 million km, including those on the lunar surface or in lunar orbit.
- Deliver communication and navigation services that ensure astronaut safety and meet performance and mission assurance objectives for both human and robotic missions.
- Solicit commercial vendors to validate their ability to provide communication and navigation services such that all users receive the services required by their mission within latency and accuracy requirements.
- Offer opportunities for commercial vendors, after capability validation, to be considered for follow-on operational services.

- Provide a mechanism to regularly incorporate new communication and navigation services, technology upgrades, and improved processes and products through an on-ramp feature that allows for additional awards and further competition as industry develops additional capabilities.
- Encourage development of commercial capabilities that provide services to a diverse range of mission customers, of which NASA will be only one.
- Foster competition and create opportunities for new, emerging communication and navigation service providers.

As mentioned in the Draft RFP [2], near Space DTE services are defined as secure services through ground assets that provide line of sight communications and tracking services to orbital and sub-orbital scientific, technology and human spaceflight missions. DTE service providers under NSN Services contract will need to successfully validate the communications and navigation capabilities in applicable Near Space service region(s). The NSN has defined capability validation milestones as follows: (1) Service Concept, (2) Service Requirements, (3) Service Design, (4) Service Integration, (5) Service Test, (6) Service Verification, and (7) Service Validation. These milestones ensure that support functions provided by the provider will comply with government requirements of service. Upon successful completion of capability validation, the service providers will be eligible to compete for operational services in applicable Near Space service regions (see Table 2).

Table 2: Service Regions in Near Earth Space

Number	Region	Description
1	Earth Proximity	Altitudes from the Earth's surface to GEO
2	GEO to Cislunar	Altitudes from GEO to 500,000 km. This region includes users on the lunar surface, and users in the Earth-Moon Lagrange points
3	xCislunar	Includes the remainder of Near Space altitudes from 500,000 km to 2 million km. This region includes the Earth-Sun L1 and L2 points

Space relay services are defined as Category 2 in the NSN RFP. The focus for the current acquisition is to capture Lunar Relay services to support the Artemis missions. Based on the needs of the Artemis campaign, the RFP outlines a set of minimum requirements for the Lunar relay and phasing for the development of complete service capabilities. The incremental development of lunar relay capabilities will ensure that service volumes, coverage periods and service types will expand as needed over the course of the planned lunar missions. The RFP outlines service increments as Alpha, Bravo and Charlie, progressing toward the initial operational capability for the relay (see Figure 2).

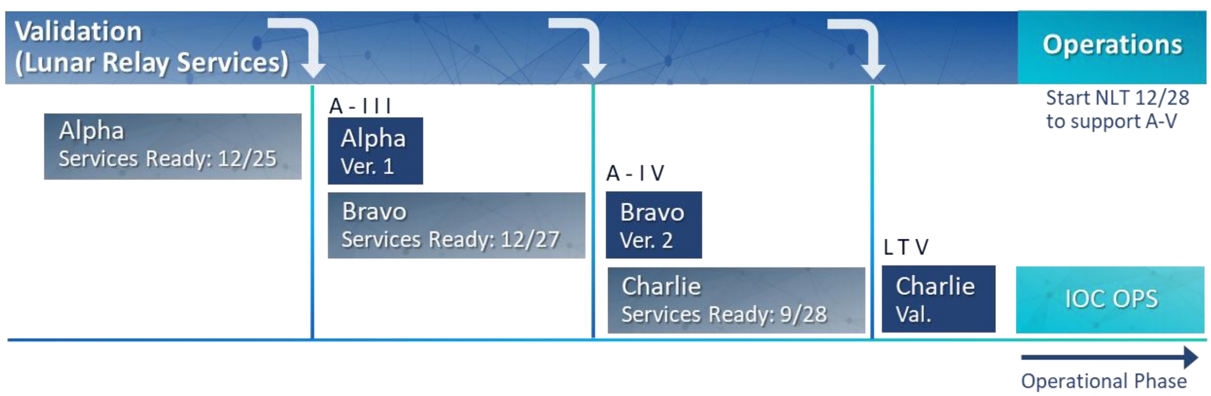

Figure 2. Initial Operational Capability Phases Timeline and Approach

During the development of the NSN services RFP, the lunar relay service definitions and requirements were adjusted based on industry feedback following the Draft RFP release in June 2022. Industry feedback was collected over the course of two Industry Day events held in July and September of 2022. These events provide the industry perspective and lead to refinement of the Lunar relay requirements, schedule, and business case. Beyond the collaboration with industry, NASA incorporated feedback from across the agency and within the international civil space community to ensure the Lunar relay approach is integrated across all interested parties.

NASA will continue to periodically perform market analysis as industry develops additional DTE and Space Relay capabilities, technological advancements, and maturation in this space. If warranted, requests for proposals will be developed to on-ramp additional vendors as industry emerges with new candidates and capabilities, and to accommodate mission specific needs.

3.2. Near Earth Space Relay Acquisition Strategy – SATCOM Capability Development and Demonstration

The transition to commercial space relay will be enabled, in part, by the demonstration efforts being led by the Communications Services Project (CSP) at the Glenn Research Center (GRC). Six SATCOM vendors were selected in June 2022 for the first cycle of capability development and demonstration activities. NASA is leveraging multiple demonstrations to explore which services, technologies, and partnership strategies best fulfil mission requirements. As NASA seeks to join the thriving commercial communications market in space, the intention is to avoid a prescribed approach given to providers but rather seek specific capabilities and validate current services to ensure all desired functions are met. The overall objective is the development and operation of end-to-end space satellite communication with a near-Earth orbiting spacecraft and a Mission Operation Center (MOC). Capability development supports the design, development and test of the elements not currently supported for commercial SATCOM services with a spacecraft. Each demonstration partner has developed a unique approach to demonstrate service offerings before the end of calendar year 2026.

NASA awarded a combined $278.5 million through FSAAs for the development and demonstration activities. Funding will be distributed over the course of the demonstrations upon the successful completion of milestone reviews. Inmarsat Government Inc., Kuiper Government Solutions (KGS) LLC, SES Government Solutions, Space Exploration Technologies, Telesat U.S. Services LLC, and Viasat Incorporated are planning to demonstrate space relay capabilities for NASA as summarized in Table 3.

Table 3: FSAA Awardees and Proposed Approaches for the Demonstrations

Vendor	Award	Demonstration Scope	Final Milestone
Inmarsat	$28.6M	• RF geostationary orbiting L-band relay network for low-rate SATCOM services to spacecraft and launch vehicles • Routine missions, contingency operations, launch and ascent, and early operations phase communications	CY25
Kuiper Government Solutions	$67M	• Commercial optical low-Earth orbiting relay network for high- and- low-rate SATCOM services to spacecraft in low-Earth orbit • Routine missions, contingency operations, and early operations phase communications.	CY25
SES Government Solutions	$28.96M	• RF geostationary orbiting C-band and medium-Earth orbiting Ka-band relay networks for high- and- low-rate SATCOM services to spacecraft in LEO • Routine missions, contingency operations, launch and ascent, and early operations phase communications	CY26
Space Exploration Technologies (SpaceX)	$69.95M	• Optical low-Earth orbiting relay network for high-rate SATCOM services to spacecraft in LEO • Routine missions, contingency operations, launch and ascent, and early operations phase communications	CY25
Telesat US Services	$30.65M	• RF geostationary orbiting C-band and low-Earth orbiting Ka-band relay networks for high- and- low-rate communications services • Routine missions in LEO	CY26
Viasat	$53.3M	• RF geostationary orbiting Ka-band relay network for high- and low-rate communications services to spacecraft in LEO • Routine launch and missions	CY26

3.3. Commercial Capability Study Strategy

CIS leverages industry engagement initiatives include OneLink briefings to a wide industry audience to share NASA objectives and needs, UpLink meetings where NASA experts meet one-on-one with interested commercial entities, and Capability Studies designed to identify future technology needs and enhance communication by engagement with industry and academia (see Figure 3). The CIS team released Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) Omnibus Broad Agency Announcement (BAA) Appendix O in March 2022. The BAA Appendix O is an initial industry led capability study to explore and demonstrate future enhancements and innovative communication capabilities needed for NASA's communication and navigation missions. The study will help NASA and its stakeholders understand advancements in RF capabilities. The primary objectives for the first round of studies to be executed through the BAA are as follows: (1) understand innovations and advancements in RF compatibility testing that will lead to efficiencies of NSN RF architectures; (2) understand the barriers, challenges, and solutions associated with integration of optical communications ground terminals into the NSN architecture; and (3) understand innovations and advancements in implementation of software defined radios and cloud computing assets into the NSN architecture. The BAA structure is designed to support the easy addition of future study areas as SCaN and the NSN identify future needs.

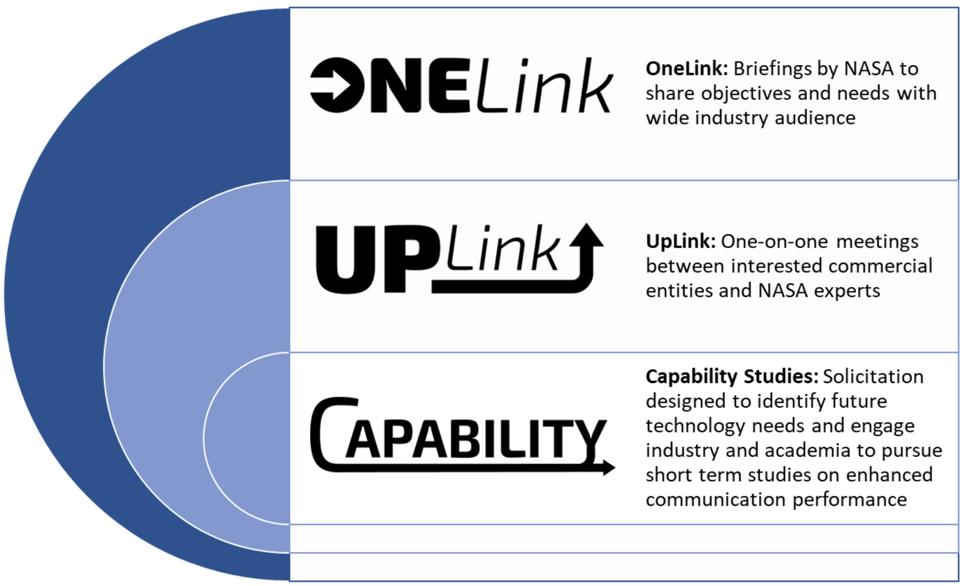

Figure 3: CIS Industry Engagement

In addition to industry led capability studies demonstrating industry service offerings, the CIS can evaluate current services through RFIs which focus on specific activities or functions. An example is the RFI released for One-Way Doppler Tracking for Artemis I. The RFI builds on interest within the community in the Artemis Campaign to evaluate tracking capabilities already readily available within the industry. CIS industry engagement during 2023 will be focused on 3GPP standards and technology.

4. Mission Transition to Commercial Services

Current NASA missions will continue to be supported by existing SCaN network services while future NASA missions may adopt the commercial SATCOM services resulting from the demonstrations. Ensuring continuity of service for the NSN Space Relay will provide time for the CSP demonstrations and possible subsequent operationalization activities as needed. A commercial space relay capability is intended to replace the government owned TDRS fleet. To ensure a successful transition of relay services NASA is carefully studying and planning for TDRS flyout. Current projections based on fleet health ensure continuity of service for the current missions using TDRS through the early 2030's. However, recent spacecraft failures have led to reevaluation of the flyout planning. The assessment process for the TDRS fleet begins with a spacecraft state of health assessment, leading to an end state options trade, followed by loading analyses. These steps produce the results which inform constellation projections and anticipated configurations over time allowing SCaN to gauge the load which the network will be able to support.

The number of users supported by TDRS will be gradually reduced corresponding to the capacity indicated by the constellation projections. An updated constellation assessment is underway, following the failure of the F9 TDRS spacecraft.

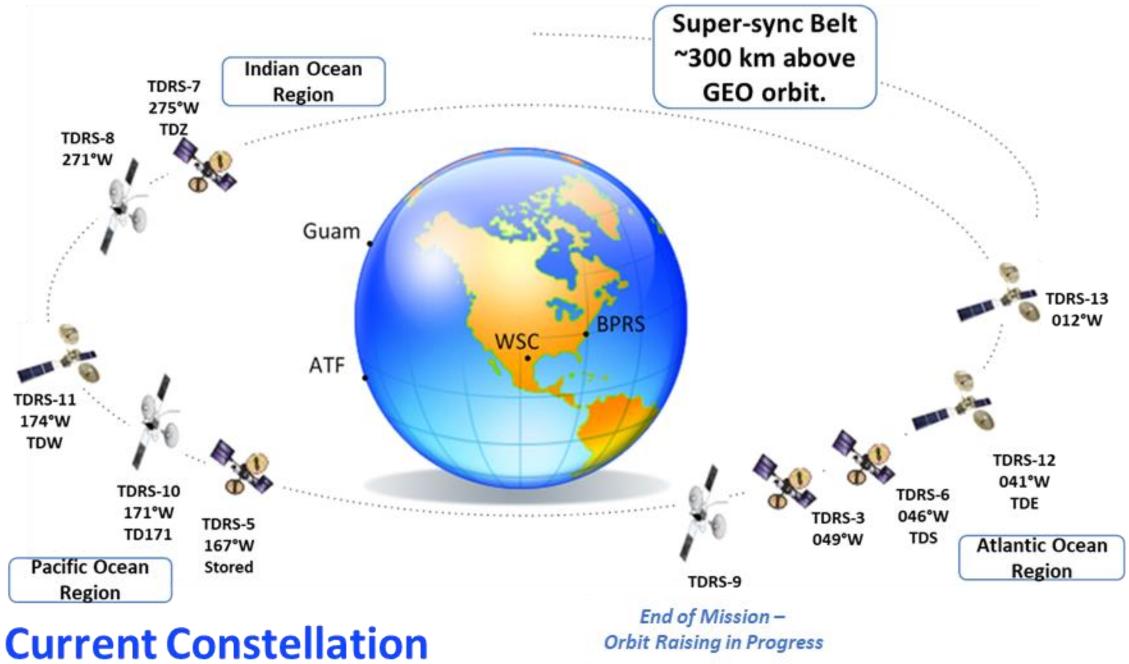

Figure 4: TDRS Constellation

As NASA works to acquire and study new commercial services and capabilities there will be an associated cost of services paid to industry. The cost of services is anticipated to challenge the current cost model NASA uses to provide network services to missions. This presents a multifaceted problem which NASA must address to ensure a smooth transition away from government managed networks. Operating, maintaining, and sustaining the government-owned network infrastructure is a significant portion of SCaN's budgetary responsibility. Commercialization represents an inherent reduction in government owned assets and services. However, it will likely be necessary to preserve certain government unique functions leading to a minimum maintained cost for government O&M. Concurrent with the increase in commercial services it is anticipated there will be an increase in demand for services. This increase in demand for services may lead to a greater aggregate price paid for services in the long term. Further, in the current mixed model of both government and commercial assets, SCaN can complete load balancing, moving passes to government assets when necessary to accommodate a reduced budget profile. As DTE services are fully commercialized, NASA may lose this load balancing ability and full funding would be required for mission support. With the proposed DTE commercialization goal, the ability of government assets to provide support for load balancing will be limited. Beyond these budgeting factors it is also likely that NASA will occasionally need to invest in technology or new capabilities to bridge gaps in commercial offerings. In addition, further SATCOM demonstrations are anticipated after the completion of the current set demonstrations and will need to be funded. SCaN will need to capture and project these cost factors into a robust cost model which will inform the budget process. these cost factors A notional estimate of the possible cost trends are shown in Figure 5.

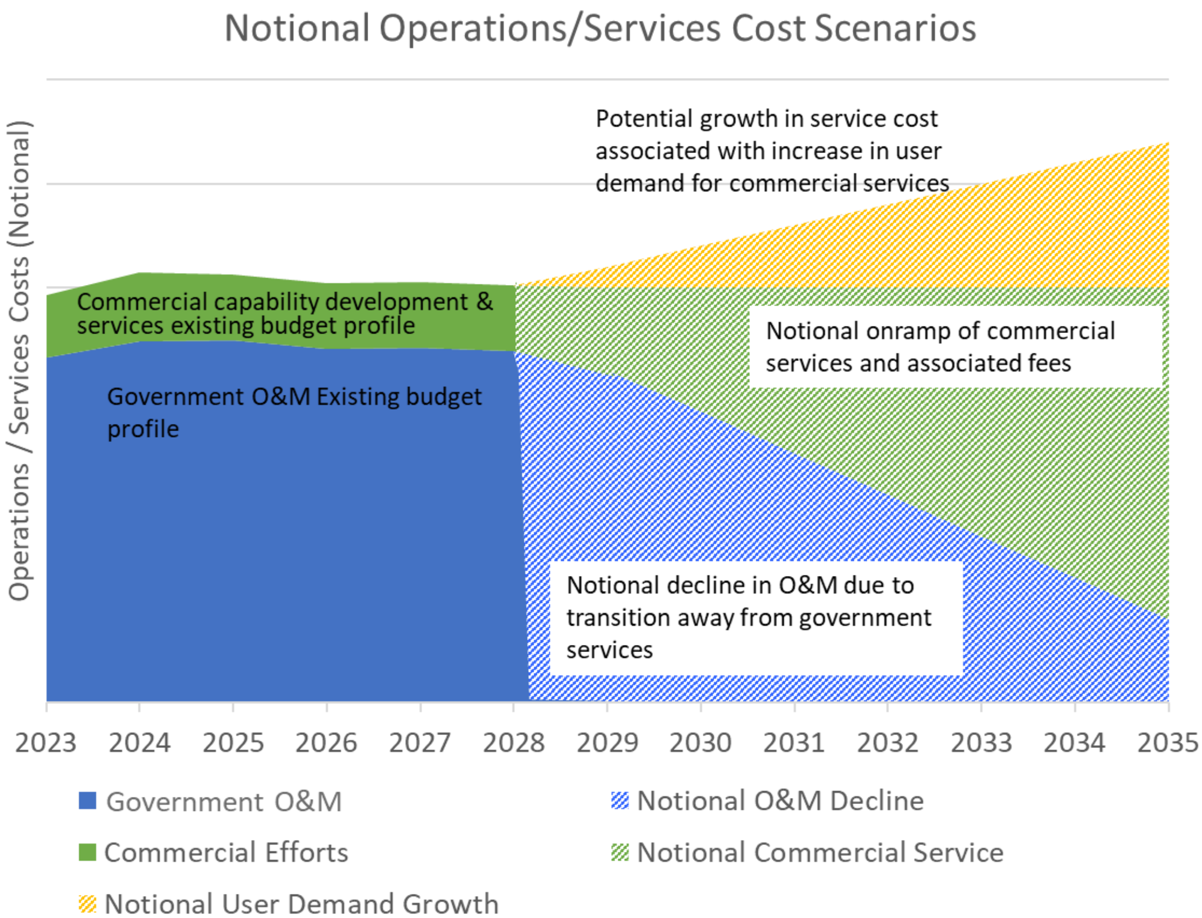

Figure 5: Notional Network Operations / Services Cost

5. Enabling Technology for Commercial Service Transition

One of the primary anticipated gaps in service for commercial SATCOM will be availability of space certified terminals for users providing motivation for NASA's strategic technology investment in flexible terminals. NASA mission users represent a unique user type for the current commercial SATCOM community. However, interest in terminal development is not limited to NASA. For example, the DoD is working toward a hybrid architecture that enables international, commercial and DoD SATCOM services to be managed as a single enterprise. They have identified a technical need for a flexible terminal that will enable users to access multiple disparate networks and seamlessly roam between networks [5]. The technical needs and description of this terminal matches the capabilities and functionality of NASA's flexible terminal.

NASA is pursuing multilingual radios that operate across wide ranges of spectrum ("wideband") and implement multiple radio standards. The term "multilingual" indicates the capability for the radio to communicate with different systems which may implement proprietary protocols and waveforms. Terminal development is intended to mitigate the risk associated with vendor lock-in stemming from user terminals only compatible with single networks. NASA's investment is aimed to ensure more robust support for the user missions once on orbit through access to multiple networks. Two ground-based experiments to demonstrate proof-of-concept terminal operations were completed by GRC and APL in 2021. Building on the success of the ground demonstrations, APL was selected to proceed with preparations to execute a flight demonstration project. The target is to develop and demonstrate a wideband and multilingual user terminal by the end of 2024.

This flight demonstration titled the Polylingual Experimental Terminal (PExT) will demonstrate the feasibility of seamless on-orbit user roaming across multiple commercial relay services for a space-based user. PExT will provide future Low Earth Orbiting science missions with the ability to operate over a wide variety of commercial services in lieu of relying solely on the Tracking and Data Relay Satellite System (TDRSS). Potential synergy / overlap between PExT demonstration participants (Telesat, Inmarsat, and SES O3b) and the CSP demonstration awardees is notable.

The PExT terminal will operate within a 25.25 GHz – 31 GHz (Return) and 17.7 GHz – 23.55GHz (Forward) frequency assignment capable of interfacing across multiple Ka-band space assets (commercial, government and military). All NASA's commercial SATCOM partners across the various demonstration activities (both CSP and APL) operate within the forward and return frequency assignments of the PExT terminal. Targeted capabilities will include establishing backwards compatibility to TDRS (KaSA Forward/Return), and DVB-S2 services with Inmarsat-Global Xpress, Telesat BlackJack and potentially O3b mPOWER. A rendering of the payload is shown in Figure 6.

Figure 6: Preliminary Flight Terminal Layout for the PExT Payload

Emerging engineering opportunities over the course of the development may lead to changes in the planned demonstration activities. The approach establishes broad network diversity and compatibility and provides end-to-end operational data through communications with constellations in different orbits, coverage areas, and latencies. The purpose is not only to prove that a single terminal is capable of operating under these varied conditions but also to inform future missions of trade-offs, network constraints, and expected concept of operation (CONOPS) on each network so that users can make informed decisions when selecting providers.

In keeping with the goal of reducing government services to the greatest extent possible, the intention is to transition the PExT terminal (radio and payload) to commercial production and eventually, the goal is to reach a point where commercially provided multi-lingual terminals are catalogued and available the same way TDRS-compatible terminals are today. Commercial transition is underway after the Frontier Radio used in the PExT terminal was licenced for use by RocketLab. RocketLab will leverage the Frontier radio for the Inmarsat Elera L-band user terminal to be used in the CSP demonstration. Although industry has demonstrated interest in the PExT payload and various components feasibility for production of these terminals will depend upon a robust user set.

6. Policy, Standards and Interoperability Strategy to Enable Commercial Services Usage

Currently, U.S. commercial (non-Federal) space and supporting Earth stations have access to most RF bands available for space services; indeed, significantly more commercial satellites operate in space service bands than do NASA satellites. To augment existing space-Earth and inter-satellite frequency allocations available for space systems, both government and commercial, NASA will pursue appropriate regulatory recognition for the use of mobile satellite service (MSS) and fixed satellite service (FSS) systems for space-to-space use. At present use of frequency allocations in the FSS and/or MSS involve spectrum risks unless operation is on a non-interference basis (NIB). Such NIB operations are currently occurring with commercial MSS providers such as Inmarsat, GlobalStar, and Iridium supporting primarily low data rate CubeSats. However, NIB operations result in a mission risk as use would be subject to termination if interference to incumbent services in the frequency band of use were to result. It is unlikely that missions other than short duration, low cost, cube-sat like missions would be willing to take on such a mission risk.

To augment these existing space-Earth and inter-satellite frequency allocations available for space systems, the U.S. supported the inclusion of agenda items (AIs) for the World Radiocommunication Conference in 2023 (WRC-23) and 2027 (WRC-27). The WRC-23 agenda item proposes consideration of the use of FSS frequencies allocations to support inter-satellite links between FSS systems and space system users. Nominally, the revised radio regulations (for FSS use) will come into force in January 2025. Missions operating using FSS relays prior to 2025 would have to operate on a non-interference basis.

NASA envisions a future configuration where missions can be seamlessly shifted between DTE assets in response to real-time situations. The inherent challenge in this vision is to ensure all DTE services are approved for each mission which may be unattainable with the current regulatory approach. NASA is actively working with other interested partners to identify an approach to achieve the needed regulatory changes.

The agency is working to develop a standards-based approach for interoperability which is inclusive of commercial industry as commercial services increase within the NASA networks. NASA holds a leadership role in multiple civil space standards bodies and international coordination groups to ensure that standards supporting interoperability are developed with defined functions, interfaces, and performance. In the long-term both industry and the civil space community recognize the benefits of interoperability. However, the communications market in space is still evolving quickly, and may not be positioned to take advantage of interoperability immediately. Constant industry engagement will not only position NASA to contribute to the development of standards but will provide perspective on the best time to begin the process of implementing interoperability within industry.

NASA is pursuing multiple options for continuing development of interoperability standards. NASA joined 3GPP as a provisional (observer) participant in 2020 and subsequently joined as an official member in 2021. The CIS office is dedicated to increasing the industry base for communication and navigation services to missions. CIS serves as the point organization for continued efforts to further NASA interests in standards bodies like 3GPP. In parallel with the focused 3GPP engagement involving Near Earth use cases, a Space Communications Consortium is under consideration by CSP with collaboration from interested parties. This group is intended to provide an agnostic view of solutions to improve telecommunication in space across all collaborators (commercial, government, etc.).

7. Conclusion

The availability of new commercial network resources to support NASA missions in some sense is subject to the same challenges which have been observed in the deployment and adoption of updated communications technologies such as Ka-band capabilities, namely a conservative preference for heritage approaches which are perceived to be lower risk. The mission developers are focused on the science objectives; communications services are a support mechanism that must be a benign and reliable part of the mission operational architecture. This dynamic applies to both transitioning to use of new ground-based resources as well as space-based relays but is likely to be more challenging for the relay case. SCaN is fostering and pursuing the required shift in organizational mentality and method which will allow for the transition to commercial services to be successful. Ongoing outreach, communicating the importance of the transition, will be a key component in making the change, as will direct engagment with the mission community.

Beyond the near-Earth commercialization activities, SCaN seeks to promote the development of a commercial market for C&N service in the Lunar and eventual Deep Space regions. Therefore, SCaN is working to incorporate interoperable, scalable, feature-appropriate commercial solutions into the overall Lunar architecture supporting Artemis and future lunar surface C&N users. Initially, these efforts are aimed toward beginning the transition of new technology into future operational architecture. The intention is to leverage as much as possible of the perspectives and lessons learned in near-Earth space toward a functional multi-provider network for Lunar C&N services.

References

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