THE STATUS OF NASA SCAN's EFFORTS TO INTEGRATE COMMERCIAL SATELLITE COMMUNICATION SERVICE PROVIDERS INTO THE NEAR SPACE NETWORK

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1. Abstract

The National Aeronautics and Space Administration's (NASA) Space Communication and Navigation (SCaN) program intends to deliver operationally ready commercial space-based communications relay services to missions by 2031. The high-throughput, demand-responsive networks that commercial providers are building and operating will remove long-standing network constraints, enhancing mission capability and data-return.

NASA's strategy is to be one of many users leveraging commercial capability to amplify NASA's buying power. NASA's needs are similar to those of the wider community, including the commercial remote sensing community that benefits from the low latency provided by space-to-space connectivity. The expansion of the traditional SATCOM users, from terrestrial, maritime, and aeronautical, to be inclusive of space-based users builds on the existing trend toward the intersection of space and terrestrial network capabilities.

A plan to achieve NASA's commercial space-based relay objective is being executed by the Communications Services Project (CSP). CSP awarded six Funded Space Act Agreements (FSAAs) in 2022 to demonstrate end-to-end services that meet multiple NASA mission use cases, ranging from routine operations (Telemetry, Tracking and Command (TT&C)) and high data rate return, to launch and early operations support. The FSAA Partners as a cohort have completed the equivalent of the Critical Design Review (CDR) stage and are transitioning to flight demonstrations taking place between late 2024 and 2027. CSP is implementing a lifecycle approach including definition of future service needs, acquisition, validation,

and transition to operations. Ultimately, the operational services will be part of a Near Space Network (NSN)-managed service catalog designed to enable the NASA mission user community. Critically, this transition hinges on flyout of the Tracking and Data Relay Satellite constellation managed by NASA, and no longer allowing new missions to plan for, or be built to leverage, that legacy capability.

Although several vendors intend to offer network-specific user terminals to the community, NASA is working in parallel to mitigate risk of vendor lock-in and provide a robust solution for missions. To reach this objective, SCaN is funding a flight demonstration of a wideband terminal dubbed "Polylingual Experimental Terminal" (PExT), led by the Applied Physics Laboratory. The PExT effort will demonstrate compatibility with multiple commercial offerings, as well as NASA's Tracking and Data Relay Satellite (TDRS) Ka-band services. Preparation is underway to transition the current technology-readiness level (TRL) level 7 (TRL-7) terminal to a commercially available product.

This paper will provide a discussion of CSP demonstration progress, the path forward to validate and operationalize commercial services for the mission community, details and benefits of the wideband terminal, progress toward the PExT flight demonstration. The broader set of long-term activities to continue to partner with industry will also be described. NASA's continued commitment to our relationship with the commercial industry is essential for capability evolution, and ensures emergent services remain in alignment with NASA needs.

2. Introduction

The National Aeronautics and Space Administration's (NASA) Space Communication and Navigation (SCaN) program manages an integrated portfolio of space communications and navigation (C&N) capabilities that includes both the in-house capabilities (assets and skilled personnel) and the acquisition of commercial services. Based on prior Agency level decisions, the TDRS fleet will not be replenished. SCaN will maintain and fly out the constellation based on spacecraft health. Although the most recent generation of spacecraft are projected to last into the 2040's, earlier generations are anticipated to fail over the next several years, reducing the overall capacity of the constellation to support mission users. Continuing to add new users to the network will perpetuate the challenge and contention for the decreasing capacity and create unacceptable risk to missions in the 2030s. Further, continuing to allow new missions to use the government assets undermines NASA's efforts, consistent with National Space Policy, to leverage commercial services [1]. As such, NASA is pursuing a clean transition to commercial services for future missions, removing the additional burden from the declining TDRS fleet.

SCaN now has a focused team dedicated to capability development that is responsible for evolving the network and supporting a transition to commercialization. This paper will discuss SCaN's partnerships with industry and their progress to date on numerous demonstrations – including in SCaN's Communications Services Project (CSP) Funded Space Act Agreement (FSAA) partners, as well as its wideband Polylingual Experimental Terminal (PExT) – in addition to outlining plans to validate and operationalize commercial services for the mission community and continue maturing partnerships with industry.

3. Commercialization Approach and Communications Services Project Demonstration Progress

The Office of Management and Budget (OMB) consistently communicated for over a decade that NASA should transition away from TDRS services, aligning with National Space Policy to maximize utilization of commercial capabilities able to meet government needs and requirements. NASA has a set of historic user needs which still exist today and will need to be met with future space relay services. Historically, the human space flight community has driven the need for high coverage and low latency service to maintain continuous connectivity with crew. SCaN is anticipating different roles in the transition to commercial space relay service depending on the mission stakeholder group being served. The following grouping for missions and users has been established: the International Space Station (ISS) and Supporting Vehicles, Commercial LEO Destinations (CLD) and Supporting Vehicles, Commercial Launch Vehicles, Artemis Human Spaceflight, and Science/Robotic Missions. For the International Space Station (ISS), SCaN will continue to provide service through TDRS through the deorbit of the station currently anticipated in 2030-2031. CLD and Commercial Launch Vehicles are expected to take advantage of commercial services with SCaN as a facilitator of as these Business-to-Business relationships. Artemis Human Spaceflight is expected to initially utilize TDRS, but in the long-term be supported by a mixture of NASA-facilitated services

(via government or commercial assets) as well as communications capabilities offered through Artemis partners and vendors. Within the NASA science community, SCaN will provide TDRS continuity for existing missions while new users transition to NASA acquired relay services. The Artemis Human Spaceflight and the Science community are expected to become the primary driver for space relay services facilitated by SCaN in the future.

To meet these space relay needs, SCaN formulated the Communications Service Project and entered into Funded Space Act Agreements (FSAA) in June 2022 with six commercial satellite communication (SATCOM) companies – Inmarsat Government Inc., Kuiper Government Solutions (KGS) LLC, SES Government Solutions, Space Exploration Technologies, Telesat U.S. Services LLC, and Viasat Incorporated – to develop and demonstrate space-based relay services for NASA missions in low Earth orbit (LEO). CSP is actively partnering with industry to provide commercial space relay communications services for NASA missions near Earth. CSP's goal is to validate and deliver these commercial communication services to the Near Space Network by fiscal year 2031. CSP provided $278.5 million in funding these partners who collectively are investing over $1.5B.

The diversity of architectures, as shown in Figure 1, will be beneficial to NASA and other similar users. The partners encompass capabilities spanning low Earth to geosynchronous orbit, low to high frequencies, and integration of optical cross-links. These diverse SATCOM-as-a-service offerings represent a new paradigm for NASA users, moving from a constrained or fixed network capacity to networks with the ability to support 10's of thousands of users simultaneously, with on-demand capabilities akin to cellular networks. The architectures and services will also support greater user autonomy and have the potential to unleash new modes of science and remove long-standing network constraints.

The FSAAs with each vendor are unique based on their services and proposed milestones. Since the awards were made in 2022, the vendors as a cohort have completed critical design review stage efforts and are pivoting to flight demonstrations. It is critical to note that these are meaningful flight demonstrations with mission partners that represent mission use cases critical to NASA. For example, Planet operates hundreds of Earth imaging satellites, a mission not dissimilar to many NASA Earth Science Division spacecraft, and relies mostly on ground station support. Decreasing data latency and throughput is advantageous to companies like Planet. Planet has partnered with several teams to participate in the demonstrations as users of the new services.

Preparations for flight demonstrations are on track, with the partners completing a variety of preparatory steps such as SES's Ka-band ground testing with mPOWER successfully conducted with Planet's LEO flight-representative terminal [2], and Kuiper's completion of the Protosat portion of their test campaign [3].

Highlighting the success of the partnership approach and encouraging a "one of many" paradigm in which providers have an array of users and business prospects, SpaceX announced that Vast's Haven-1 space station will use Starlink optical services [4]. The 2025 mission is the first external customer to select Starlink 100Gbps capability.

Partners	Service Type	Use Case	Frequency	Architecture	Demo. Targets
amazon | project kuiper	File Delivery	Science data	Optical	LEO	Q3 FY25
					Q1 FY26
SPACEX	File Delivery	Mission data	Optical	LEO	Q1 FY26
Viasat +Inmarsat	File Delivery	Science data	Ka-Band	GEO	Q2 FY26
	Direct Access	LEOP and TT&C	L-Band	GEO	
	Direct Access	Launch	L-Band	GEO	Q1 FY26
					Q4 FY25
SES	File Delivery	Science data	Ka-Band	MEO	Q4 FY25
	Direct Access	TT&C	C-Band	GEO	
TELESAT	File Delivery	Science data	Ka-Band	LEO	Q1 FY27
	Direct Access	LEOP and TT&C	C-Band	GEO	

Figure 1: Overview of CSP FSAA capabilities and mission demonstration partners

4. Commercial Services for the Mission Community (CSP Path Forward)

As the demonstrations continue, SCaN and CSP have defined a forward path to target a portfolio of services by 2031, as shown in Figure 2. CSP has already defined a draft framework for level 3 service requirements which are currently and will continue to be matured with participation from the stakeholder mission community. Service requirements will be used in both award decisions and during evaluation of operational readiness.

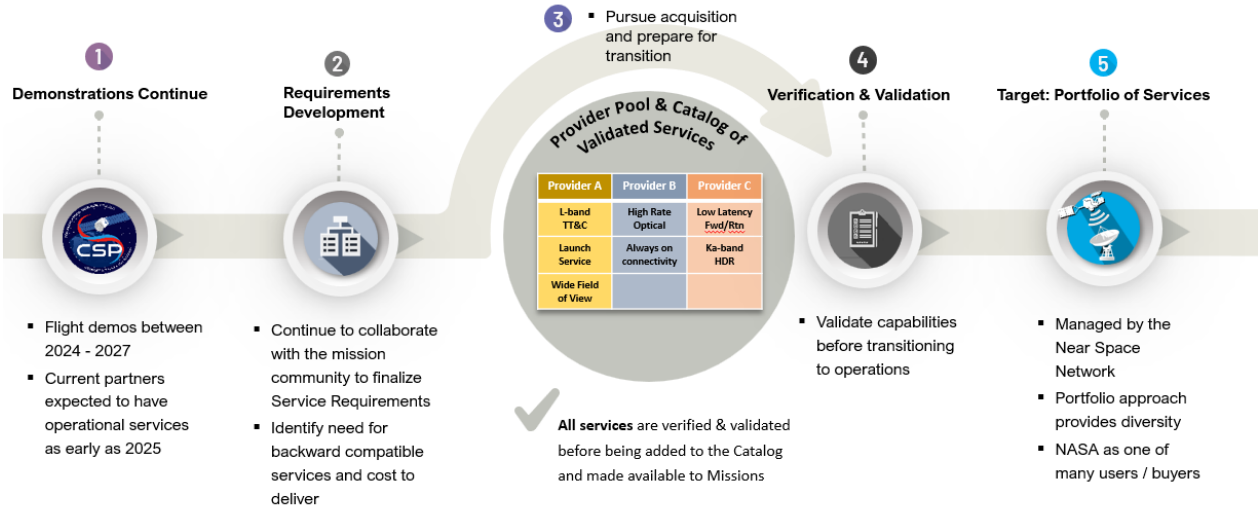

Figure 2: CSP Operational Services Moving Forward

A critical question to be explored by the program as requirements are developed and the team moves to approval of an acquisition strategy, is if and how backward compatible services—e.g., services compatible with TDRS—must be obtained. If backward compatibility is deemed necessary, a cost/benefit and implementation trade space will be explored. Placing unique requirements into the services solicitation has cost ramifications as does pursuing a tailored approach such as through hosted payloads. Results of stakeholder engagement, combined with commercial readiness reviews, will inform a recommendation as to whether or not the services scope should include backward compatibility for specifically enumerated missions and, if needed, how specific services providing backwards compatibility for missions will be acquired. SCaN is targeting requirements definition completion and resolution of the backward compatibility question in the early Fiscal Year (FY) 2026 timeframe.

SCaN will pursue a fair and open service procurement, tentatively set for FY 2027, where NASA's current demonstration partners will compete with other vendors across the industry. NASA missions represent a diverse set of space relay needs spanning objectives from continuous crew connectivity for Human Spaceflight to earth observation and coordinated science needs for LEO science missions. It is possible that a single provider may not adequately meet the entire set of mission needs; missions will likely need to utilize multiple services—not unlike operations today which often combine use of TDRS and Direct-to-Earth (DTE) services. Thus, CSP is aiming to create a portfolio of providers and services which cover all the needs and use cases prevalent for NASA missions.

After contract award, services will be evaluated and certified based on user needs and provider offerings. Validation activities will be executed to ensure services meet operational services and are ready for NASA users. In this commercial partnership paradigm, the validation efforts will be industry-led, with NASA personnel providing oversight and review of the artifacts and data products associated with each milestone. At the conclusion of the validation period, NASA will lead an Operational Readiness Review (ORR) on a per vendor basis. The ORR will recommend (or not) certification at this juncture. The ORRs are the key milestones representing the handoff from the development team (CSP) to the operational team within the Near Space Network. Operational services are targeted by 2031.

5. Wideband Terminal and PExT Flight Demonstration

In parallel with the FSAA demonstrations, SCaN is investing in the development of 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. These wideband and multilingual radios will allow NASA missions to access communication services from multiple providers, as illustrated in Figure 3, despite provider use of proprietary implementation approaches, and mitigates the risk associated with vendor lock-in stemming from user terminals that are only compatible with single networks. In some sense, NASA is promoting interoperability on the user terminal side, in the absence of interoperability on the network/provider side, creating an opportunity for more diverse commercial service through early investment, in an effort to build momentum and help the market see the long-term business opportunity.

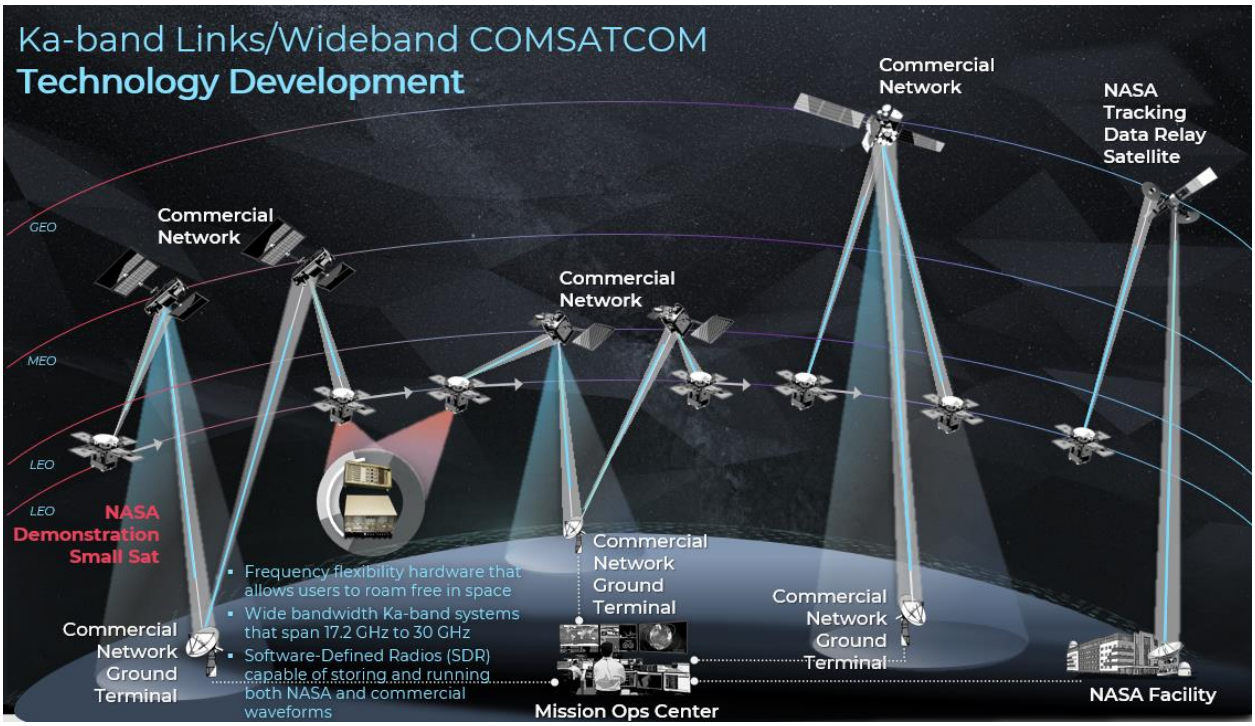

Figure 3: Wideband Terminal Conceptual Operations Overview

NASA is working with the Johns Hopkins Applied Physics Lab (APL) to launch a multi-lingual wideband terminal demonstration mission: the Polylingual Experimental Terminal (PExT). The Polylingual Experimental Terminal (PExT) will demonstrate the feasibility of seamless on-orbit user roaming across multiple commercial relay services to provide future Low Earth Orbiting science missions with the ability to transfer its commanding, telemetry, and science data in near real-time to the ground in lieu of relying on TDRS services. The versatility of the wideband terminal is additional important based on the portfolio model in which multiple providers are anticipated to provide potentially non-overlapping services. For example, a wideband multilingual terminal would allow a mission to use a launch telemetry/command service from one provider, and a data delivery service from another, while only carrying one payload that spans both service frequencies and protocols.

PExT completed spacecraft integration (illustrated in Figure 4) and environmental testing at York Space Systems, with a launch planned on SpaceX Falcon 9 Transporter 13 no earlier than February 2025. During the six-month flight demonstration, PExT will execute real-time, on-orbit roaming across constellations in a Ka-band system with different orbits, coverage areas, and latencies: TDRSS' heritage Ka-band Single Access service, Inmarsat Global Xpress in Geostationary Earth Orbit (GEO), and O3b mPOWER in Medium Earth Orbit (MEO). Initial data transmission rates to be demonstrated are 90Mbps forward and 375 Mbps return, with future data rates projected up to 490 Mbps forward and 1 Gbps return.

Figure 4: PExT Installed on the York Spacecraft Bus

The PExT terminal is currently a TRL 7 / flight demonstration effort; future work is required to push the terminal to a real "catalog" available item as well as exploring wideband terminals in lower bands (L- and S-band operations), which is anticipated to be less challenging than Ka-band based on the variety of terminals in these lower frequency bands already on the market today. APL is working to identify a clear path to commercialization for the flight terminal and components after the demonstration period to transition this product into use and enable adoption of commercial services broadly among near future science missions. The team continues to build on early successes such as Rocket Lab's licensing of the APL's software defined radio as the "Frontier-S" [5]. RocketLab has continued to build on the Frontier platform with development of an X-band radio.

NASA continues to actively engage with industry to help develop wideband capabilities, including the recent Broad Agency Announcement (BAA) award to CesiumAstro for a design/study of a space-qualified wideband active phased array terminal [6]. The next step is to collaborate with the mission community to identify more specific terminal targets that address their needs. Cumulatively, these efforts seek to bridge the gap between missions and the commercial providers of hardware, easing the transition to commercial relay services. Long-term, terminals of varying size and capability will allow missions to take advantage of commercial Earth-relay services within the constraints of spacecraft size, mission class, and mission lifetime.

6. Spectrum Regulatory Activity

A key aspect of enabling commercial communications services across the agency will depend on securing additional spectrum allocations for commercial space relay services. To augment existing space-Earth and inter-satellite frequency allocations available for space systems, both government and commercial, NASA is supporting efforts within the U.S. domestic spectrum regulatory process and at the international level to gain regulatory recognition in the ITU Radio Regulations for space-to-space uses of select frequency bands allocated to the Fixed Satellite Service (FSS) and Mobile Satellite Service (MSS). This recognition will ensure that NASA users operating with commercial space-based networks and services have a claim to protection from harmful radio frequency interference, and that such users are compliant with NASA SCaN policy to use only authorized spectrum for operations.

Modifications to the ITU Radio Regulations are proposed, negotiated, and accepted at World Radio Conferences (WRC) that are held roughly every four years. In the lead-up to the WRC in 2019 (WRC-19), NASA, through participation in the U.S. delegation to the WRC, successfully advocated for the inclusion of an agenda item for WRC-23 on studying the feasibility of spectrum sharing between proposed space-to-space operations in select FSS frequency bands, including Ka-band (27.5 - 30 GHz), and other incumbent systems. Through analyses and negotiations during the WRC-23 cycle, NASA was successful in modifying the ITU Radio Regulations to allow such uses of FSS frequency bands. This approval also presents opportunity in these bands for the infusion of SCaN's wideband terminal, bridging multiple provider frequencies and TDRS Ka-band as noted in the prior section.

During the WRC-23 cycle, NASA also supported the U.S. administration in creating an agenda item for WRC-27 to similarly study the feasibility of spectrum sharing between proposed space-to-space operations in select MSS frequency bands, including L-band (1.5 / 1.6 GHz) and S-band (2.4 GHz), and other incumbent systems. This authorization would enable services to users by offerings like Inmarsat's InRange

and InCommand. Furthermore, from a mission payload perspective, L- and S-band operations represent similar levels of capability and user burden. A preliminary agenda item for World Radiocommunications Conference 2031 (WRC-31) is also being considered to address use of C-band. This is relevant given that two of the current CSP FSAA vendors include C-band operations, but the community faces a distinct long-term challenge with C-band based on potential spectrum clearing in the band to support terrestrial 5G.

7. Partnering with Industry

To facilitate the rapid integration of commercial capabilities into current and future NASA missions, SCaN utilizes a host of NASA resources to gain access to timely market analysis, validation processes, and innovative partnership opportunities. The Commercialization, Innovation, and Synergies (CIS) Office within Goddard Space Flight Center's Exploration and Space Communications Projects Division both serve as drivers for this critical initiative through pioneering approaches to industry engagement and collaboration, further propelling SCaN's commercialization efforts forward into a new era of space exploration.

In July 2023, CIS inaugurated an innovative outreach initiative, Launch Pad, to provide a platform for the NASA SCaN community to engage with emerging, niche commercial players on a weekly basis. The initiative gives companies an opportunity to brief NASA on cutting-edge technologies and innovations that could support current and future NASA missions. Companies are encouraged to present on a wide range of communication and navigation topics including, but not limited to optical communications, phased array ground systems, lunar interoperability standards, network planning and scheduling, and precision clocks. An immediate benefit of Launch Pad has been the timely and consistent flow of relevant market analysis for the NASA SCaN community. The CIS Industry Engagement team then uses that market analysis to examine key themes emerging throughout industry to guide and inform NASA activities.

To further ensure that SCaN meets NASA's commercialization objectives, CIS utilizes two key outreach mechanisms to connect the commercial community to NASA SCaN leadership and inject industry into NASA's most critical communication and navigation activities. CIS OneLink sessions serve as a platform to inform and educate industry on current and future SCaN activities, standards, priorities, and upcoming solicitations. These regularly hosted forums serve to keep the commercial community in the know and at the ready to support NASA to evolve and progress shared mission goals in the national interest. This dialogue, however, is not one way. The CIS Industry Engagement team regularly hosts Reverse Industry Days to enable and encourage industry to share commercial capabilities and partnership opportunities with NASA. CIS Reverse Industry Days have served the vital purpose of informing SCaN on critical capabilities being offered throughout industry that have the current and future ability to augment government systems. Additionally, these forums have provided the market analysis needed to make informed decisions regarding NASA's commercialization roadmap and industry's readiness to support Agency missions.

The CIS Industry Engagement team also utilizes formal solicitation vehicles to partner with industry to conduct innovative industry studies and encourage industry responses to NASA's most pressing communication and navigation needs. The CIS Capability Studies program utilizes NASA's Next Space Technologies for Exploration Partnerships (NextSTEP) Omnibus BAA as a vehicle to solicit innovative industry studies to support SCaN activities on an annual basis. Since 2022, CIS has successfully executed two rounds of studies and is currently in the process of a third. The CIS Industry Engagement team has also successfully released three Requests for Information (RFI) on a host of topics to ensure the SCaN community has a consistent procession of industry input.

8. Conclusion

The Tracking and Data Relay Satellite system has been a critical and enduring part of NASA's space communications legacy. At the time of its inception, the capabilities and services afforded to the mission community through TDRS were unique and transformational, transitioning NASA to highly available (24x7) communications particularly tuned to supporting human space flight operations in LEO. Over the decades, the science community has also benefited from TDRS, particularly the advantages of on-demand and multiple access services that enable time sensitive science operations, as well as the coverage and reliability needed during launch and early orbit and in the event of spacecraft emergencies and recovery efforts. The expectations for, and reliance on, TDRS, raises the importance of handling the transition to commercial services in a transparent and deliberate way. SCaN's continued stakeholder involvement in both the TDRS constellation flyout discussion and the onramp of commercial services through CSP has

been critical for the transition progress made to date and will continue to be a cornerstone of forward work. Writ large, coordination with stakeholders regarding communication of future requirements is a focal point for SCaN moving forward.

Looking to the future, the potential benefits to NASA for harnessing commercial capabilities will be transformative. Commercial SATCOM systems leap beyond the inherent capacity-limitation of TDRS to provide high-throughput capability that goes from supporting dozens of missions on a schedule to tens of thousands of on-demand users. Beyond those communication offerings, the variety of emerging networks represent new platforms in the space ecosystem, with the potential to unlock previously unimaginable science collection opportunities.

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