NASA'S PROGRESS TOWARD COMMERCIAL SPACE COMMUNICATIONS—SATCOM DEMONSTRATIONS AND WIDEBAND MULTILINGUAL TERMINAL DEVELOPMENT

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Abstract

The National Aeronautics and Space Administration (NASA) Space Communications and Navigation (SCaN) Program is continuing to forge a path toward programmatic and operational transformation enabling commercialization of communications and navigation services to the greatest extent possible for near Earth users. U.S. National Space Policy is driving government agencies to incorporate commercial offerings and services to the maximum extent possible. As such, NASA has no plans to build or deploy additional Tracking and Data Relay Satellites (TDRS), but will seek to fill NASA mission space-relay capability needs using commercial satellite communications (SATCOM) providers and services. The goal is to support an approach that is both flexible to commercial service constructs and provides continuity of support with current assets as long as required. Progress toward commercial services is advancing in two key areas: (1) awards have been made for demonstrations of SATCOM services, and (2) development of wideband and multilingual user terminals has advanced to the flight demonstration phase.

The Communications Services Project (CSP) at Glenn Research Center (GRC), has awarded Funded Space Act Agreements (FSAA) to six industry vendors. Inmarsat Government Inc., Kuiper Government Solutions (KGS) LLC, SES Government Solutions, Space Exploration Technologies, Telesat U.S. Services LLC, and Viasat Incorporated will receive a combined $278.5 million to complete technology development and in-space demonstrations over the next several years. The end-to-end service capabilities being targeted are based on existing NASA mission operational needs. Accordingly, each company has proposed a technical approach to lower costs, increase flexibility, and improve performance for a broad range of missions.

In the current market, industry vendors operate at a range of different frequencies and use variable, sometimes proprietary, coding and modulations schemes. As NASA strives for a network comprised of services provided by multiple distinct suppliers, interoperability is a fitting solution to unify the network. 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.

This paper provides a discussion of the progress toward NASA's commercial space communications goals and consideration of key challenges and next steps.

Acronyms/Abbreviations

Acronym	Definition
3GPP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
AI	Agenda Item
APL	Applied Physics Laboratory
BTS	Base Transceiver Stations
C&N	Communications and Navigation
CCSDS	Consultative Committee for Space Data Systems
COTS	Commercial Off The Shelf, Commercial Orbital Transportation Services
CSP	Communications Services Project
DIU	Defense Innovation Unit
DoD	Department of Defense
DRS	Data Relay System
DTE	Direct to Earth
DVB-S2	Digital Video Broadcasting Satellite Second Generation
EIRP	Effective Isotropic Radiated Power
ESA	Electronically Steerable Array
EVA	Extravehicular Activities
FSAA	Funded Space Act Agreements
FSS	Fixed Satellite Service
FWD	Forward
GEO	Geosynchronous Earth Orbit
GHz	Gigahertz
GRC	Glenn Research Center
HDR	High Data Rate
HPA	High Power Amplifier
ITU	International Telecommunication Union
KaSA	Ka-band Single Access
KGS	Kuiper Government Solutions
LDR	Low Data Rate
LEO	Low Earth Orbit
LEOP	Launch and Early Operations Phase
MEO	Medium Earth Orbit
MOC	Mission Operations Center
MSS	Mobile Satellite Service
NASA	National Aeronautics and Space Administration
NIB	Non-Interference Basis
NTN	Non-Terrestrial Networks
OISL	Optical Inter-Satellite Link
PExT	Polylingual Experimental Terminal
RTN	Return
Rx	Receive
SATCOM	satellite communications
SCaN	Space Communications and Navigation
SDR	Software Defined Radio
SSPA	Solid State Power Amplifier
TDRS	Tracking and Data Relay Satellites
TDRSS	Tracking and Data Relay Satellite System
TRS	TT&C Relay System
TT&C	Telemetry, Tracking and Command
Tx	Transmit
U.S.	United States
UE	User Equipment
WRC	World Radiocommunication Conference

1. Introduction

NASA is moving toward further commercializing its communications and navigation services, consistent with U.S. National Space Policy [1], with the notion of providing access to a variety of networks—inclusive of commercial space-based and ground-based systems—and leveraging this interconnectivity to support current and future science and exploration missions. In pursuit of this vision SCaN seeks to realize an interoperable architecture that relies on a mixture of existing NASA assets and commercial networks and services in the near-term and supports a smooth transition to fully commercial communications services for near Earth users in the long-term. A key piece of the transition to commercial services will be enabled, in part, by the space relay demonstration efforts being led by CSP. Six SATCOM vendors were selected in June 2022 for the first cycle of development and demonstration activities. Including multiple commercial entities enables NASA to explore which services, technologies, and partnership strategies best fulfill NASA's requirements.

Seamless connectivity for missions to different commercial network and assets will be needed to reach a fully commercial service implementation. An interoperable architecture will be achieved by either defining hardware or software interfaces for network technology providers to build system-independent components that can be hosted on third party platforms—e.g., spacecraft terminals that accommodate network characteristics—or by network service providers supporting open network standards on both their terrestrial and space interfaces. NASA is working to address this challenge by investing in the development of wideband interoperable user terminals that can bridge the gap in the near term, while working toward an industry standard solution in the longer term.

Both the space relay service demonstrations and the Wideband Multilingual terminal development are critical to progressing toward NASA's commercial communication goals in a timely fashion.

2. Commercial Space-Based Relay Service Demonstrations

The current private sector offers previously unavailable access to network capabilities to satisfy space user communications and navigation requirements. This growth represents potentially significant savings in infrastructure, ongoing operations, and maintenance costs to NASA. Prior to 2020, space-based relay services for space users were considered to be outside the scope of commercial SATCOM interests. NASA has continuously engaged with commercial industry to monitor the shift in commercial service offerings and determine how and when to integrate services. The CSP at GRC was tasked with identifying, characterizing, and quantifying NASA's future satellite communications needs and with interacting with industry. The CSP team responded by leveraging a NextSTEP-2 Omnibus Broad Agency Announcement (BAA) as the platform to gauge if the market was positioned to provide viable options for space relay service. Subsequently, an Industry Day event held late in 2020 provided the confirmation of industry interest in providing services and paved the way for NASA to continue on plan, beginning with pursuit of Funded Space Act Agreements to execute commercial SATCOM demonstrations.

The demonstrations will focus on both the interface between the commercial relay satellite and the user mission, and between the commercial provider and the mission operations center. Service providers are expected to offer a complete capability, or set of capabilities, that inherently must address provision of a user terminal or other accommodation on the service provider side to deliver service to LEO customers. Services are intended for the following six NASA use cases categories: (1) Launch Support; (2) Launch and Early Operations Phase (LEOP); (3) Terrestrial Support; (4) Low Data Rate (LDR) Routine Missions; (5) High Data Rate (HDR) Routine Missions; and (6) Contingency. The use cases (Shown in Table 1) represent a synthesis of current operational users and their communications and navigation needs accordingly each vendor was given the option to provision services meeting any or all of the use cases [2].

Table 1: Summary of NASA mission Use Cases

Use Case	Missions per Year	Forward Data Rate	Return Data Rate	Examples
Launch	8-10	24 kbps – 1 Mbps	10 kbps – 5 Mbps	SLS, Vega
LEOP	11-14	250 bps – 2 kbps	1 kbps – 10 kbps	Commercial Crew/Cargo to ISS*, Satellites
Terrestrial	10-15	100 kbps – 7 Mbps	4 Mbps – 600 Mbps	High Altitude Balloons
LDR Routine Missions	35-40	0.1 kbps – 16 kbps	0.1 kbps – 4 Mbps	TT&C of Satellites

HRD Routine Missions	35-40		4 Mbps – 600 Mbps	ISS, Science Data Return
Contingency	16	250 bps – 4 kbps	0.5 kbps – 40 Mbps	Satellites

**Requires a higher rating for human spaceflight*

Six vendors were selected with the goal of maximizing the number of demonstrations to mitigate risks associated with a limited vendor pool. Each company has proposed a unique approach to demonstrate service offerings before the end of calendar year 2026.

2.1. Inmarsat

Inmarsat provides global data and communication connectivity solutions for land, sea, and air services via their GEO satellite constellation and ground station network. The company plans to demonstrate low data rate Telemetry, Tracking, and Control (TT&C) service in L-band through its ELERA network for the following use cases: launch Support, LEOP, low data rate routine missions, contingency mission operations communications. The use cases will be demonstrated through two ELERA validations:

- Launch Telemetry – The ELERA capability titled “InRange” will provide real-time launch telemetry relay service over the Inmarsat operational ELERA satellite network.
- Space Relay – The ELERA capability titled “InCommand” will provide a real-time two-way commanding and telemetry link relayed over the Inmarsat operational ELERA satellite network.

NASA will contribute $28.6M toward the Inmarsat demonstration over the course of a 36-month schedule for demonstration activities. Inmarsat plans to complete the final milestone within the scope of the contract by the end of Q1 in calendar year 2026.

2.2. Kuiper Government Solutions

Kuiper Systems LLC is a subsidiary of Amazon whose purpose is to launch a constellation of LEO satellites that will provide low-latency, high-speed broadband connectivity to unserved and underserved communities around the world. Kuiper will utilize its planned LEO constellation of 3,236 satellites, demonstrating an optical LEO relay network for high and low data rate SATCOM services and Ka-band services for the following use cases: low-Earth orbit for routine missions, contingency operations, early operations phase communications.

The FSAA includes four phases: (1) modeling and simulation of Project Kuiper space relay performance for spacecraft and mission data; (2) preparation for on-orbit demonstration of optical inter-satellite links (OISLs) and Ka-band communications capabilities; (3) end-to-end demonstration using up to three Project Kuiper commercial spacecraft to transmit representative mission data to a government or commercial MOC; and (4) integration, launch, and operation of a third-party satellite to demonstrate Project Kuiper network connectivity to a representative user.

Kuiper will receive $67M from NASA over the contract interval with a planned final milestone in Q2 of calendar year 2026.

2.3. SES Government Solutions

The demonstration and follow-on operational service will use a combination of SES’s O3b mPOWER MEO constellation and a GEO constellation for a combined set of high rate and lower rate communications. In 2017, SES announced plans for the next-generation MEO system – O3b mPOWER. The initial constellation of eleven high-performance satellites will launch starting in 2022 and employ intelligent software and extensive ground infrastructure. O3b mPOWER is a terabit-level system with spacecraft design that includes electronically steered phased array antennas capable of up to 5000 spot beams per satellite and data rates from 50 Mbit/s up to 10 Gbit/s. For the CSP demonstration, mPOWER will be used for high data rate, low latency Ka-band data relay communications, mainly for file delivery to/from a near-Earth orbit NASA satellite, while C-band communications through an SES GEO satellite will provide TT&C and assured data access for, lower rate communications.

SES is planning for demonstration activities spanning 4 years and anticipated to conclude in Q3 of calendar year 2026. An award value of $28.96M will be distributed to SES over the course of the demonstration.

2.4. SpaceX

The SpaceX relay service will employ a fully routable resilient mesh network of satellites connected through space via high-speed laser communication links allowing the constellation to operate with fewer ground stations, route data around the constellation, and improve overall latency. Ultimately, the goal is to leverage proven Starlink laser technology to support users such as NASA. Space X will demonstrate optical LEO high data rate SATCOM services for the following use cases: low-Earth orbit for routine missions, contingency operations, launch and ascent, and early operations phase communications.

SpaceX will complete demonstration activities over an estimated 43-month interval. The FSAA award value will total $69.95M upon the projected demonstration conclusion in Q3 calendar year 2026.

2.5. Telesat

Telesat currently operates a fleet of 13 geosynchronous satellites with capabilities at C-band and Ka-Band. A global network (Lightspeed™) composed of 188 LEO satellites is currently being developed for integration with on-ground data networks. Lightspeed™ is planned to include beam hopping technology, ability to dynamically focus multiple Gbps of capacity, optical intersatellite links, and data processing in space.

Telesat plans to demonstrate GEO C-band and LEO Ka-band communication services for high and low-rate services for routine missions in LEO by using an inter-satellite relay terminal hosted on a LEO remote sensing platform. This relay terminal comprises a low-speed, always-on TT&C Relay System (TRS) and a high-speed Data Relay System (DRS).

The timeline for demonstration activities covers 45 months and is planned to conclude in December of calendar year 2025. Over the course of the demonstration Telesat will receive $30.65M from NASA.

2.6. Viasat

ViaSat-3 is a planned global constellation of three geostationary Ka-band communications satellites, set to launch in 2022 and 2023. Viasat offers several types of crosslinking solutions in Ka-band using a phased array antenna. By placing a miniature modem and router on each satellite, the constellation can have full transmit and receive capability for real-time data links. Each satellite is anticipated to deliver at least 1 Terabit of data per second. Viasat plans to demonstrate GEO Ka-band services for high and low-rate services to spacecraft in LEO for launch and routine missions. During the demonstration period, Viasat will evaluate multiple commercial spacecraft as candidate demonstration platforms and down select to one or more demonstration platforms.

Viasat is planning a 45-month demonstration from the FSAA award date. The value of the FSAA awarded to Viasat will reach $53.3M upon successful completion of all the planned activities.

Table 2: Summary of the CSP Capability Development and Demonstration Activities

	Inmarsat Government Inc.	Kuiper Government Solutions	SES Government Solutions	SpaceX	Telesat	Viasat
Demonstration Use Cases						
Launch Support	●		●	●	●	●
LEOP	●	●	●	●	●	
Terrestrial Support					●	
LDR Routine Missions	●	●	●		●	●
HDR Routine Missions		●	●	●	●	●
Contingency	●	●	●	●	●	
Demonstration Support						
Assured Data Delivery	●	●	●	●	●	
File Delivery / Networking		●	●	●	●	
Demonstration Frequency						
L – Band	●					
C – Band			●		●	
Ka – Band		●	●		●	●
Optical		●		●		

Demonstration Relay Orbit						
LEO		●		●	●	
MEO			●			
GEO	●		●		●	●

3. Wideband and Multilingual User Terminals

One of the major challenges associated with commercial space-based providers, is that they all utilize different spectrum allocations and waveforms. In the near-term, 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. These investments mitigate the risk associated with vendor lock-in stemming from user terminals only compatible with single networks and provides a more robust support network for the user missions once on orbit. The intention is to develop and demonstrate a wideband and multilingual user terminal by the end of 2024 and engage with commercial industry to identify and collaborate on potential standards that are commercially supported and can be adopted by NASA missions.

3.1. **Wideband and Multilingual Terminal Ground Demonstrations**

NASA conducted parallel ground-based experiments to demonstrate proof-of-concept terminal operations with GRC and APL. GRC approached the user terminal demonstration considering support for low latency space links across NASA, commercial and DoD assets with the intention of developing a path toward inclusion/standardization across multiple commercial waveforms to a common Software Defined Radio (SDR). In March and April 2021, GRC successfully demonstrated the first ever over-the-air communications with the Wideband terminal prototype, communicating to TDRS and Inmarsat-5 / Global Xpress. The roaming experiment wherein services switched in real-time (less than 30 second downtime) between the government and commercial assets was a highlight of the GRC ground demonstration [3]. The APL demonstration was focused on development of a multi-lingual wideband terminal (payload) to augment on-orbit user high data rate Ka-band connectivity to the ground from low Earth orbit via existing and future on-orbit relay services. APL developed initial payload requirements for the terminal, comprising of a radio, high power amplifier, antenna, and associated interconnects, and then developed a conceptual design across three phases: demonstration, protoflight, and long-term enhancements. The design specified use of the APL Frontier Radio: a SDR platform with heritage on the Van Allen Probes (S-band), Parker Solar Probe (X/Ka-band), Europa Clipper (X/Ka-band), and the Emirates Mars Mission (X-band), "Hope" [4]. Both development activities emphasized use of commercially available products where feasible, and identification of steps required to progress to flight demonstration and further maturation. Detailed information about the ground demonstrations including results and technical details are available in NASA's 2021 Ka-Band conference paper [5].

3.2. Applied Physics Lab Wideband Flight Demonstration

Building on the success of the ground demonstrations, NASA selected APL to continue to prepare for, and execute a flight demonstration project. The Polylingual Experimental Terminal (PExT) will demonstrate the feasibility of seamless on-orbit user roaming across multiple commercial relay services. 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 TDRSS. The purpose of the PExT mission is to gather operational data in addition to user experience and bring those lessons to the broader NASA community. However, the terminal development and planning represents an investment in risk reduction activities as NASA introduces commercial SATCOM and is intended to quickly expand enabling capabilities rather than to test a complete set of desired capabilities for all missions.

The APL team plans to demonstrate contact, link management, and forward/return link data flow through TDRS and three commercial relay services to a payload operations center. The intention is to establish backwards compatibility to TDRS over the KaSA Forward / Return, and DVB-S2 services with O3b mPOWER, Inmarsat-Global Xpress and Telesat BlackJack. However, planned service demonstrations may change in response to emerging engineering opportunities over the course of the development. This approach not only demonstrates broad network diversity and compatibility, it will also provide end-to-end operational data from communicating with constellations in different orbits, coverage areas, and latencies. The terminal will operate at a range of symbol rates and link performance parameters on-orbit and utilize the space relay services to demonstrate the following day in the life mission scenarios: self-pointing, long-term schedule execution, intra-network link handoff, inter-network link handoff, waveform adaptation and reloading, command stack protection (crypto), and link fault recovery. The objective 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 and constraints on each network so that users can make informed decisions.

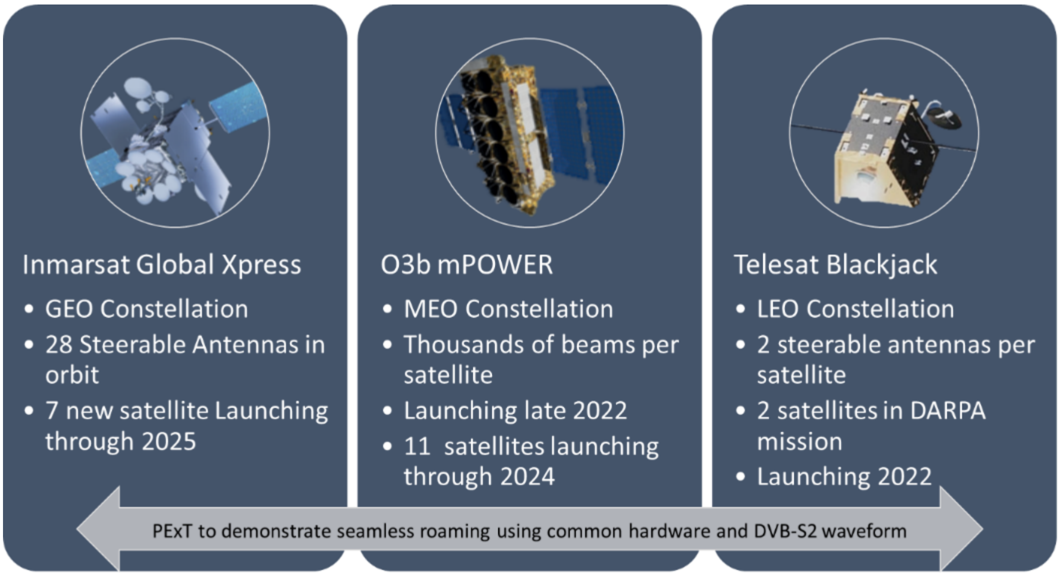

Figure 1: Commercial SATCOM Providers for PExT

APL is targeting development of an RF frontend capable of interfacing across multiple Ka-band space assets (commercial, government and military) operating within a 25.25 GHz – 31 GHz (Return) and 17.7 GHz – 23.55GHz (Forward) frequency assignment (shown in Figure 2). PExT will be required to support autonomous network management of multiple space assets, such as seamless handover. The terminal will be reprogrammable with the capability of reconfiguration in flight to support communication with future space data networks. Interfacing with multiple networks presents an inherent security challenge and consequently the team will incorporate the cryptography necessary to support connection with specified networks and protection of mission command stack per NASA Space System Protection Standard (NASA-STD-1006).

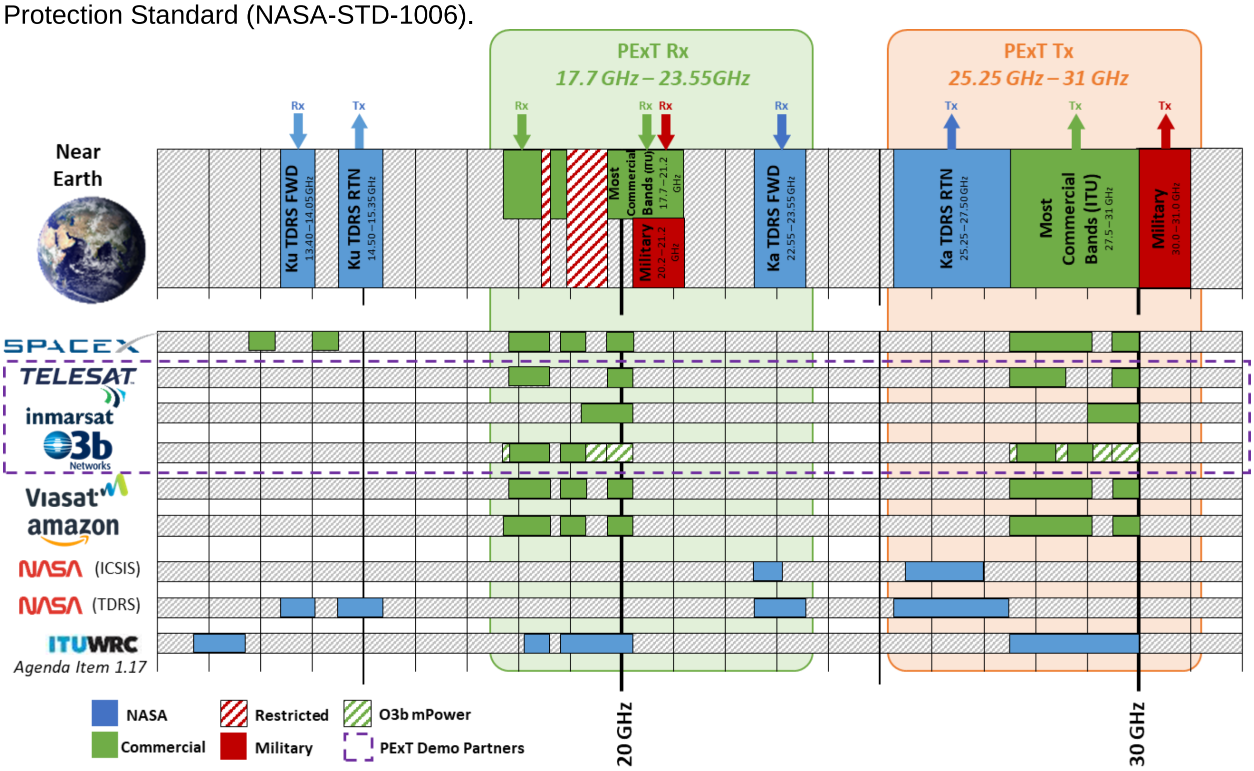

Figure 2: Spectrum Usage by NASA's Commercial Partners and NASA Systems

The terminal flight demonstration configuration is depicted in Figure 3 and a conceptual image of the completed PExT payload is shown in Figure 4. Maximizing the use of commercial off the shelf (COTS) products is intended to reduce cost and create a path to commercialization. Necessary revisions to some of these components are being made to ensure that the functions specific to the PExT requirements are met.

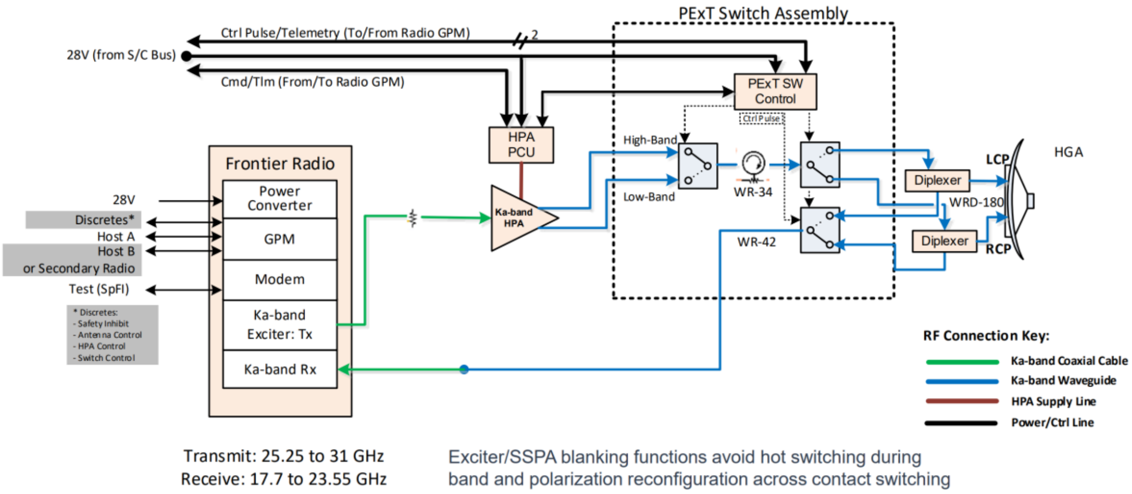

Figure 3: PExT Block Diagram

The design will leverage the APL Frontier Radio to take full advantage of flexible software defined components with the goal of building in interoperable functionality. Antenna sizing will likely vary based on mission needs for the operational terminal, however, for the demonstration the mission will be using a body mounted 0.6-meter antenna. The PExT payload is being designed for integration onto a commercial SmallSat bus which will not include a propulsion system.

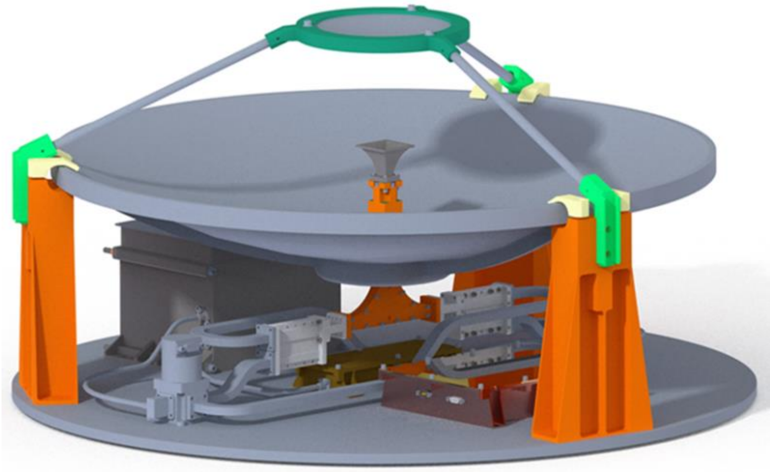

Figure 4:Terminal Design

The demonstration will be executed in the following phases: flight demo development, flight demo integration and testing, spacecraft integration and testing along with launch activities, and flight demo operations. The team is currently executing activities in the flight demo development phase which is focused on design and component development activities, evaluation of relay service options and bus provider selection. The on-orbit demonstration will occur over the six months following launch with an anticipated launch date in Q2 of calendar year 2024.

4. Emerging Opportunities and Challenges

The demonstration efforts across wideband and commercial SATCOM represent significant progress toward the future of the communications services for NASA missions. These activities will be used not only to build a functional understanding of available service offerings but also to create the practical approach for use of those services by science and exploration mission users. As the transition into an interoperable network of multiple service providers occurs, several key opportunities and challenges have emerged. Addressing each of these opportunities and challenges will allow NASA to smoothly transition users within the desired timeline.

4.1. Mission Engagement and Transition

During the space relay service demonstrations, NASA will facilitate engagement with the mission community to socialize capabilities and identify opportunities for early transition. Progress will be shared to encourage opportunities for mission insight into and feedback on the demonstrations, and eventually to gauge interest in early adoption of commercial SATCOM services. CSP will also include the mission community formally via quarterly Stakeholder Reviews. Engagement with individual missions will be driven in part by the assessment of the TDRS constellation fly-out and associated mission impact analyses led by Goddard Space Flight Center. A successful increase in commercial services will only be achieved if mission teams – principal investigators, engineers, and mission designers – have an awareness of the communications network resource evolution in progress.

4.2. Wideband Terminal Path to Commercialization

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 potential synergy / overlap between PExT demonstration participants (Telesat, Inmarsat, and SES O3b) and the CSP demonstration awardees is notable. As the CSP partners have initiated preparations for their demonstrations, several have reached out to APL on potential use of either the entire multilingual terminal or the Frontier Radio as part of their demonstrations. The flexibility of the terminal and its components is already being recognized by industry and the interest across a variety of SATCOM vendors underscores the potential of interoperable user terminals. The radio and payload are both planned for transition to commercial production and eventually, the goal is to reach a point where commercially provided multi-lingual terminals are cataloged and available the same way TDRS-compatible terminals are today. The process to transfer the Frontier radio to commercial use has already begun with licensing from among a number of interested commercial entities. Other known commercial industry development efforts include wideband capable SSPAs which could be integrated into future terminal designs. 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.

4.3. Shared Vision with Other Government Agencies

NASA is not alone in recognizing the advantages and potential of the flourishing commercial market in space. Other Government Agencies have expressed interest in various aspects of the NASA commercialization efforts and/or are pursuing similar efforts. For example, the DoD is also working toward a hybrid architecture that enables international, commercial and DoD SATCOM services to be managed as a single enterprise. This highlights a technical need for a flexible terminal that will enable user to access multiple disparate networks and seamlessly roam between networks [6]. The rationale, performance parameters, and timing for delivery for a wideband capable terminal are remarkably similar between NASA and the DoD. In addition, the Defense Innovation Unit (DIU) will participate as a stakeholder for the CSP SATCOM capability development and demonstrations.

4.4. Spectrum

A key aspect of enabling commercial communications services across the agency will depend on securing additional spectrum allocations for commercial space relay services. 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 for FSS and/or MSS for commercial SATCOM providers must be on an experimental and non-interference basis (NIB). 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. In 2019, NASA supported the U.S. proposal for the inclusion of agenda items (AIs) for the World Radiocommunication Conference in 2023 (WRC-23) and started the process of preparing for additional AIs for 2027 (WRC-27). The objective of these spectrum regulatory engagement activities is aimed at augmenting existing space-Earth and inter-satellite frequency allocations available for space systems, both government and commercial.

4.5. Standards and Interoperability

Interoperability within the civil community has been achieved by leveraging Consultative Committee for Space Data Systems (CCSDS) standards. However, CCSDS standards should not be levied on the commercial community. 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. In some cases, previous commercial industry standards, such as DVB-S2, are applicable and already in use in space-to-ground communications. A notable example of the success of standards-based interoperability can be found in the terrestrial wireless telecommunications industry. NASA intends to leverage as much of this success and experience as possible, migrating terrestrial capability to the space user environment. An initial step toward this goal is to engage with industry to begin the process. The 3rd Generation Partnership Project (3GPP) is an umbrella organization known for the development and maintenance of mobile telecommunications standards. NASA is exploring the applicability of 3GPP standards in the Earth proximity region and on the lunar surface. Initially, NASA joined 3GPP as a provisional (observer) participant in 2020 but transitioned to being an official member organization in 2021.

The telecommunications industry has invested in developing efficient, low-SWaP, reliable telecommunications base transceiver stations (BTS) and user equipment (UE) giving NASA an opportunity to adapt or adopt commercial practices where possible. 3GPP has defined an interface between 5G UE and 5G Non-Terrestrial Networks (NTN) within the near-earth region and the market is moving toward greater NTN usage and integration. One example is the recent T-Mobile announcement of plans for SpaceX Starlink broadband satellites to introduce connectivity beyond the reach of current ground infrastructure. Therefore, in the 3GPP forum, NASA is planning to advocate for the study of the use case where the UE is in space. Potential NASA applications for space users include: (1) Scientific experiments in orbit, (2) proximity communications with astronauts performing Extravehicular Activities (EVA) in orbit, (3) proximity communications for formation-flying spacecraft, and (4) monitoring of space-based autonomous systems [7]. Including space users in the 5G NTN architecture will provide the industry with opportunities to grow and build on an existing strong terrestrial user base.

In parallel with the focused 3GPP engagement involving Near Earth use cases, NASA is broadening the standards conversation. A Space Communications Consortium is being formed by CSP with collaboration from interested parties such as Seamless Air Alliance. This group is intended to provide an agnostic view of solutions to improve telecommunication in space across all collaborators (commercial, government, and etc.).

5. Summary and Future Work

The NASA network transition hinges on the successful completion of all the demonstration activities and associated enabling developments, opportunities, and regulatory changes. Anticipating the end of these development and demonstration activities, SCaN is studying and planning the future management and operation of commercials services. The demonstration timelines indicate capabilities and services will be ready for operations in the 2030 timeframe as shown in Figure 5.

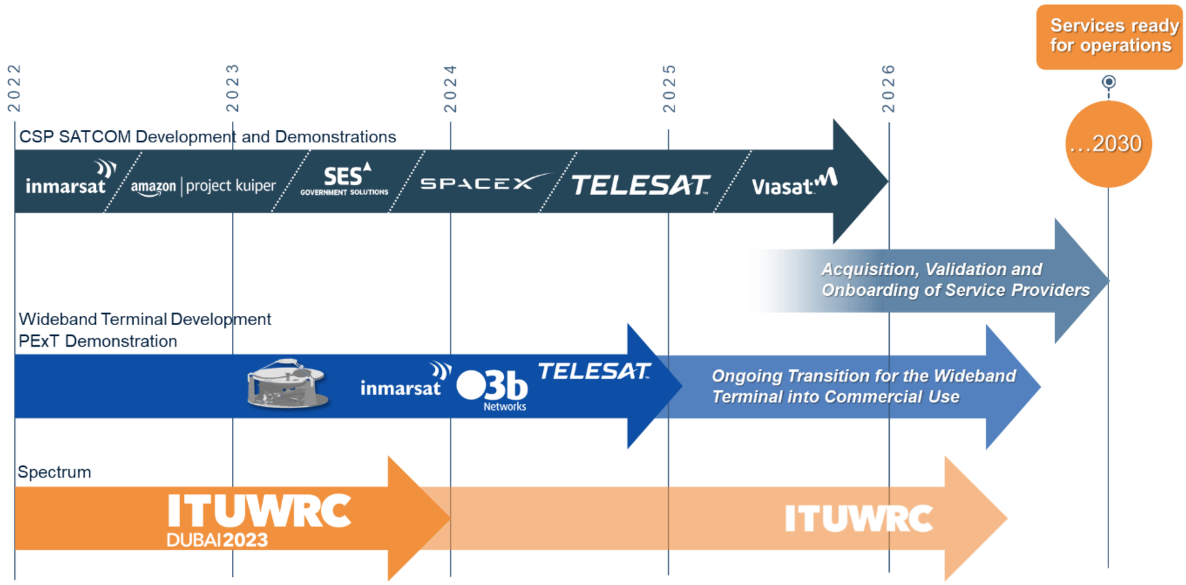

Figure 5: Schedule for NASA's Commercial Service Transition

The results of the SATCOM demonstrations will inform the viability of transitioning commercial relay capabilities to operational status. Additional rounds of demonstrations and capability development activities will be undertaken as needed to ensure that all services meet mission needs. Similarly, evaluation and transition of enabling technologies to commercial providers will be needed beginning with a fully operational wideband payload. Demonstrated services and technologies will be migrated into the NSN service catalogue for operational use. However, in order to increase adoption of commercial services missions will need to be fully informed regarding available network resources. Outreach to inform potential users of new services and capabilities has already begun and will continue as the set of commercial services available to missions evolves.

Beyond the near Earth commercial service infusion activities, SCaN seeks to promote an interoperable, scalable, feature-appropriate solution for Artemis and future lunar surface communication and navigation users. These efforts are aimed toward beginning the transition of new technology into future operational architecture. The Lunar surface communications use case is an ideal application for 3GPP technology given that lunar surface-to-surface communications is analogous to the terrestrial use case but with the UE on the Moon. In 2020, a demonstration was awarded to Nokia to integrate 4G/LTE network assets for lunar surface communications between the lunar lander and a lunar rover. The objective of this demonstration is to verify the 4G/LTE network performance in two main scenarios: for short-range (~100-300m) and for long-range (up to 2 km) surface communications. Upon completion of the Nokia demonstration, SCaN will advance a 5G solution due to its operational advantages over 4G/LTE. To allow full implementation of a 3GPP solution for lunar surface communications, SCaN will need to secure the required spectrum allocations and address any other challenges as they arise.

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