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Goddard Space Flight Center
Greenbelt, Maryland

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Near Space Network User's Guide

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Preface

This document is under the configuration management of the Near Space Network Configuration Control Board (NSN CCB).

Changes to this document require prior approval of the applicable CCB Chairperson or designee. Proposed changes shall be submitted to the NSN Project Manager along with supportive material justifying the proposed change.

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1 INTRODUCTION

1.1 Purpose

This document provides user mission project personnel with an understanding of the Near Space Network (NSN) architecture, the services provided, the interfaces between the user mission systems and the NSN, and the Mission Services Integration process. This document includes the catalog of services available to missions which can be used in preliminary planning.

1.2 Scope

Detailed planning should be undertaken only in coordination with the NSN through the Advanced Planning and Mission Service Integration teams. The Near Space Network User's Guide (NSN-UG) will not provide a complete technical read-out of all NSN assets, since the commercial providers supporting the NSN will operate a dynamic set of ground stations and other capabilities. The NSN-UG is intended to be a stable document, capturing the fundamental services provided to missions. Lower-level detail documents such as the NSN Brochure are included as references and the NSN personnel are available to respond to user queries.

Integration with other providers within the network, such as the Flight Dynamics Facility (FDF), Space Link Providers (SLP) and Data Transport Providers (DTP), is described in this NSN-UG. Mission Users will not have to seek separate guidance on how space links are provided, or how data will be delivered through a commercial cloud which connects to the user operation center. The NSN Project provides a one-stop-shop for Communication & Navigation (C&N) services and is prepared to answer any questions or concerns for Near Earth Communication & Navigation mission design.

The baseline NSN-UG will include capabilities for the initial implementation of NexTEra, the NSN's virtual network management system, and the associated NSN architecture. As new capabilities are included, these capabilities will be added to future revisions of the User's Guide.

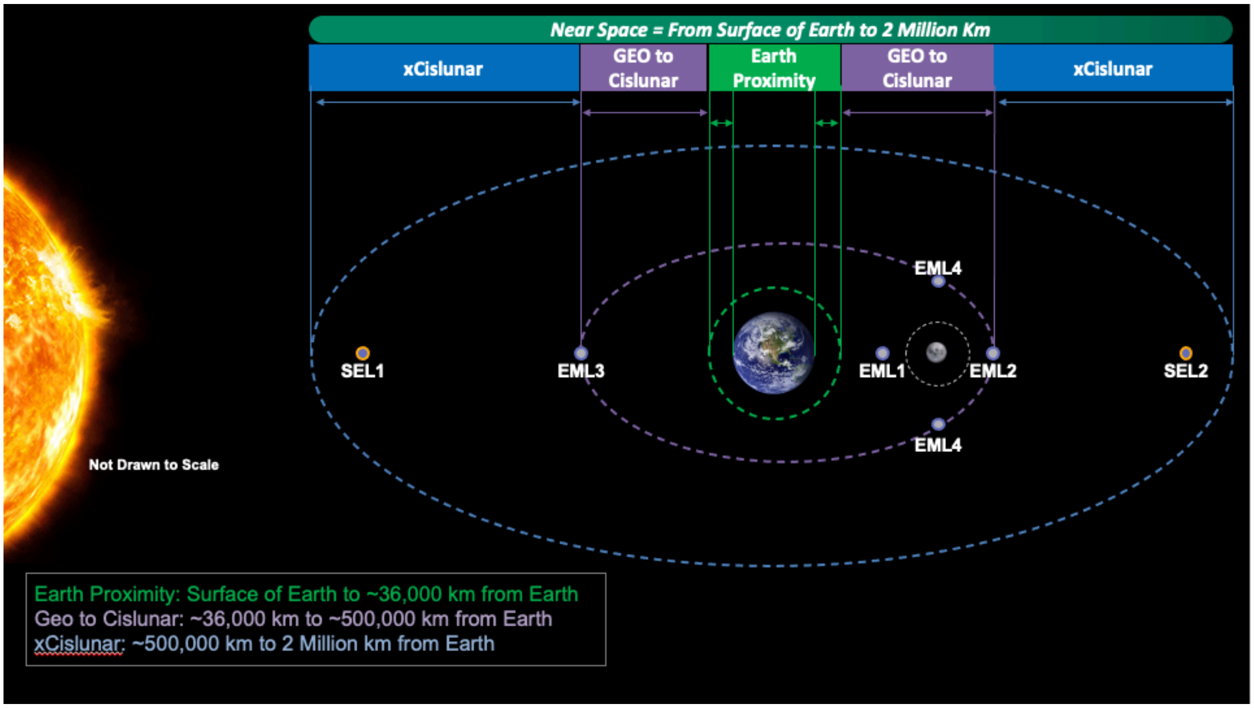

Figure 1. Definition of "Near Space"

This document covers the services and capabilities provided by the Space Communications and Navigation (SCaN) Program in the Near Space region, defined as the region of space that includes coverage up to 2 million kilometers from Earth, as shown in Figure 1. Operations further than this limit are considered Deep Space. Provision of services in Deep Space is arranged by the Customer Interface Management Office (CIMO) at the Jet Propulsion Laboratory (JPL). Where technically feasible, the NSN and CIMO will work together for cross-support of missions that operate in both regions.

Services and support offered by NASA's SCaN networks are available to all NASA sponsored flight projects and science investigators. Other United States (US) government agencies and commercial flight projects may become eligible for services offered by the SCaN networks through negotiation with NASA Headquarters. This document will be updated over time as new services and capabilities are made available to the public.

1.3 Related Documentation

1.3.1 Applicable Documents

NPD 8074.1	NASA Policy Directive (NPD) Management and Utilization of NASA's Space Communication and Navigation Infrastructure
NPR 2570.1	NASA Procedural Requirement (NPR) NASA Radio Frequency (RF) Spectrum Management Manual,
NPD 2570.E	NASA Electromagnetic Spectrum Management

NTIA REDBOOK-MANUAL	NTIA Manual of Regulations and Procedure for Federal Radio Frequency Management (Redbook)

1.3.2 Reference Documents

Document Number	Document Title
457-BROC-0001	Near Space Network Brochure
457-TOOL-0008	Customer Questionnaire (new customer questionnaire)
457-TOOL-0017	Letter of Intent
N/A	Letter of Acknowledgement
SCaN-MOCS-0001 (or 0002)	Mission Operations and Communications Services (MOCS)
CCSDS 130.12-G-1	Consultative Committee for Space Data Systems (CCSDS) Protocols Over DVB-S2 – Summary of Definition, Implementation, and Performance (Green Book)
CCSDS 141.0-B-1	Optical Communications Physical Layer Recommended Standard (Blue Book)
CCSDS 414.1-B-2	Pseudo-Noise (PN) Ranging Systems Recommended Standard (Blue Book)

1.3.3 Reference Web Sites

Website Name	Website Uniform Resource Locator (URL)
NSN Service Inquiry Form	http://go.nasa.gov/NSNServiceInquiry
Space Communications and Navigation (SCaN)	https://www.nasa.gov/scan
Exploration and Space Communications Project (ESC)	https://esc.gsfc.nasa.gov/
CCSDS Website	https://public.ccsds.org/default.aspx
Marshall Space Flight Center (MSFC)/ Communications Service Office (CSO) Home Page	https://cso.nasa.gov/
Exploration and Space Communications (ESC) Online Library Repository (internal access)	https://ipdtdms.gsfc.nasa.gov
Goddard Commercial Cloud	https://itcd.gsfc.nasa.gov/cloud-computing

2 NEAR SPACE NETWORK OVERVIEW

2.1 NSN Customers / Users

User missions include launch vehicles, robotic/uncrewed missions, and crewed missions in the Near Space region, defined as the Earth's surface to the moon and beyond up to a distance of 2 million km away from the Earth. The mission customers are primarily NASA missions, but services can be extended to other US government programs, international partners and even commercial enterprise, if the proper agreements are negotiated with NASA.

2.2 Space Communications and Navigation Program Overview

NASA's Space Communications and Navigation (SCaN) Program is an organization within the NASA's Space Operations Mission Directorate (SOMD). SCaN serves as the Program Office for all of NASA's space communications and navigation activities and is responsible for operations, maintenance and sustainment of the ground and space-based facilities, equipment and services provided by the Near Space Network (NSN) and Deep Space Network (DSN). NASA's SCaN networks provide space communications and navigation services anywhere in the solar system over the full operational life cycle of a mission from launch to end of life and/or deorbit.

For missions that require Near Space services before reaching a Deep Space destination, or for missions that operate in regions where using both networks can be advantageous, such as at the moon or Sun-Earth Lagrange point 1 (SE-L1) and Sun-Earth Lagrange point 2 (SE-L2), separate mission integration processes will be required for each network. However, SCaN personnel have a long history of working together across networks and the NSN and DSN will coordinate to support missions that utilize both networks. This coordination includes sharing of operational planning, finding common interfaces, and sharing results of any testing.

The DSN consists of ground stations utilizing very large aperture (34- and 70-meter) antennas and is focused on providing support to missions operating beyond Geostationary Orbit (GEO). The DSN primarily supports planetary missions and missions beyond 2 million km from Earth, which region is referred to as Category B – Deep Space. The DSN facilities are strategically located in three geographic locations: (1) Goldstone, California, (2) Madrid, Spain, and (3) Canberra, Australia. These facilities together provide near-full-time coverage of deep space mission trajectories. The NSN is the primary service provider in Near Space so that the more expensive DSN assets are free to provide C&N services for deep space missions. This document describes SCaN's Near Space Network services, managed out of NASA's Goddard Space Flight Center (GSFC) and provided via a blend of both commercial providers and government-owned systems. This document does not cover DSN beyond the high-level description provided here.

DSN management and operations are the responsibility of the Jet Propulsion Laboratory (JPL) located in Pasadena, California. Further description of the DSN services and capabilities are not included in this document. For more information or to procure DSN services, refer to the DSN User's Guide and contact SCaN's Mission Commitment Office (MCO).

2.3 NSN Project Overview

In order to take advantage of the growing commercial capabilities in space communication and navigation, NASA developed the concept of the Near Space Network as an interconnected system with contributions from many US government, international partners, and commercial organizations. Just like the ubiquitous terrestrial 'Internet', there is no single organization that controls every element of the network. The NSN Project was formulated to work with User Mission projects to develop Communications and Navigation (C&N) requirements and then orchestrate delivery of those services across the network to the User Mission.

Therefore, there are two distinct definitions for the NSN. One refers to the Network as a system and the other for the NASA Project that orchestrates delivery of services from the system.

The Near Space Network is the collection of interconnected network systems and communication links that provides C&N services to launch vehicles, robotics, and human spaceflight missions in the near space region through a robust blend of government and commercial services throughout their entire mission lifecycle.

The NSN Project is the single focal point for fulfilling the customer missions' scheduling and data transport needs through an orchestrated mix of government and commercial service providers. The NSN Project leverages a broad spectrum of capabilities available through government and commercial link providers and negotiates with providers on behalf of all missions to lower costs.

2.4 NSN Network Architecture

The NSN provides Direct-To-Earth (DTE) services via a global system of commercial and NASA-owned ground stations that provide line-of-sight communications and tracking services to missions ranging from low-Earth orbit and extending to Sun-Earth Lagrange Points 1 and 2. ACCESS manages all GOCO assets utilized by the NSN, including DTE assets at White Sands, Wallops and McMurdo. Note that the NSN uses DTE for both forward and return services, while the DSN use the term DTE for return services and Direct From Earth (DFE) for forward services.

The NSN also coordinates delivery of Space Relay (SR) services from a Government-Owned and Contractor-Operated (GOCO) system managed by SCaN's ACCESS Project. This system consists of a space segment of six operational Tracking and Data Relay Satellites (TDRS) and a ground segment of facilities at White Sands, Guam, Australia and Blossom Point. This system was formerly referred to as the 'Space Network' but is now referred to as the 'Space Relay' system. Currently, the GOCO system managed by ACCESS is the only system supplying SR services for the NSN, and therefore the terms are largely synonymous. When commercial SR providers are brought into the network, this naming convention will be reconsidered.

Figure 2 shows the NSN Project context.

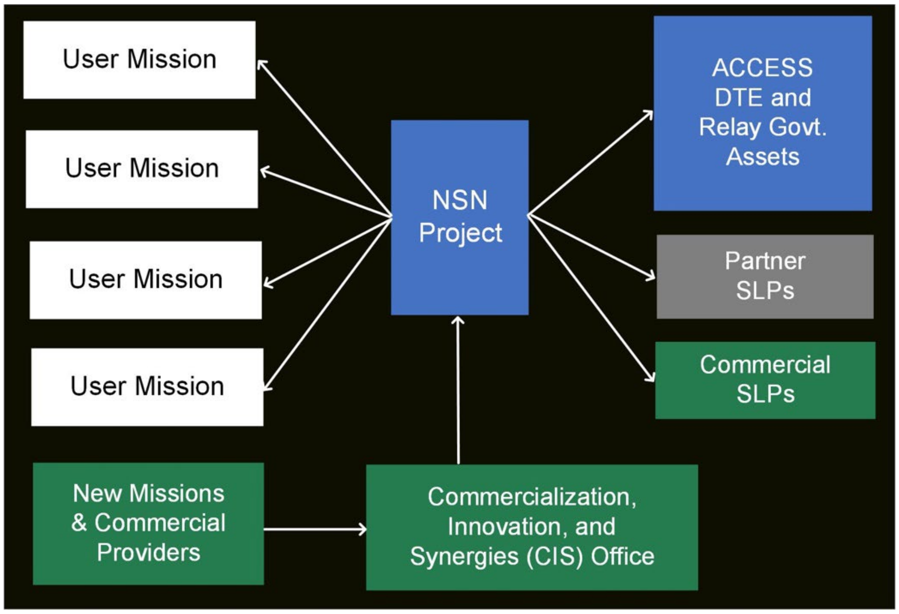

Figure 2. NSN Project Context

2.4.1 Space Link Provider (SLP)

The term ***Space Link Provider (SLP)*** refers to systems that receive and transmit the electromagnetic signals from the edge of the network to mission platforms. ACCESS is a Government-Owned Contractor-Operated (GOCO) SLP. Kongsberg Satellite Services (KSAT), and Swedish Space Corporation (SSC) are current commercial SLPs for the NSN. International and University organizations can also supply SLP services to the NSN through partner agreements.

NSN project coordinates with the SLPs for delivery of services from the Mission User perspective. Mission User services will be delivered by multiple providers and will likely change over the course of the mission lifetime. The NSN will negotiate, schedule and orchestrate operational services from providers on behalf of mission user.

2.4.2 Data Transport Providers (DTPs)

Data Transport Provider is the generic term for organizations that move data through a ground network or provide data processing services. Like the SLPs, all DTPs are operated independently from the NSN Project. The NSN Project coordinates with the DTPs for delivery of services that meet the Mission User requirements. Delivery of DTP services is controlled through interface requirements documents between the NSN Project and the DTP. Mission User services will be delivered by multiple providers and will likely change over the course of the mission lifetime.

The ground network that has historically provided DTP services is the NASA Communications (NASCOM) network. NASCOM provides mission-critical terrestrial voice, video, and data services in support of NASA and its missions. The mission communications services of the NASCOM network are managed out of GSFC and include routed mission data services, dedicated mission data services and mission voice services, including access to cloud computing services.

Cloud service providers are also considered DTPs because the access points for Space Link Providers and Mission Operations Centers can be in different regions of the world, with the cloud provider responsible for transport between regions. The Mission Cloud Platform (MCP) is able to provide support to NSN missions in setting up a commercial cloud presence and ensuring IT security compliance. The Goddard Commercial Cloud Team is addressing cloud computing requirements collectively and developing a menu of shareable, consumable cloud services that mission project managers and other stakeholders across the Center can choose from to meet their needs without having to become cloud experts themselves.

2.4.3 Flight Dynamics Facility (FDF)

The FDF provides expertise in mission and navigation analysis, trajectory design, maneuver planning, operations planning, orbit determination, network operations support, and critical real-time mission operations. FDF provides real-time orbit determination, network acquisition data updates, orbit insertion performance analysis, and validation of mission Global Positioning System (GPS) solutions. The FDF processes measurement data from the SCaN networks and provides missions with a complete orbit determination solution in one or more of various ephemeris formats.

2.4.4 NexTEra

The NSN Project is developing the NexTEra system to be a centralized orchestration system to autonomously coordinate delivery of services from the supporting elements in order to meet mission user requirements. NexTEra is defined as the abstraction layer between the User Missions and the SLP nodes that orchestrates across many network elements by providing service management, network monitoring and control, service execution, and data transport services. Figure 3 provides a graphical presentation of how NexTEra integrates with the mission users, the supporting elements, and the other elements of the NSN Project such as the operators, Project management, and the Near Space Operations Control Center (NSOCC). NexTEra also facilitates the delivery of timing and tracking services provided by the FDF.

NexTEra is derived from the combination of three words: Nexus, Terra, Astra; meaning to state “Connecting Earth to Stars”.

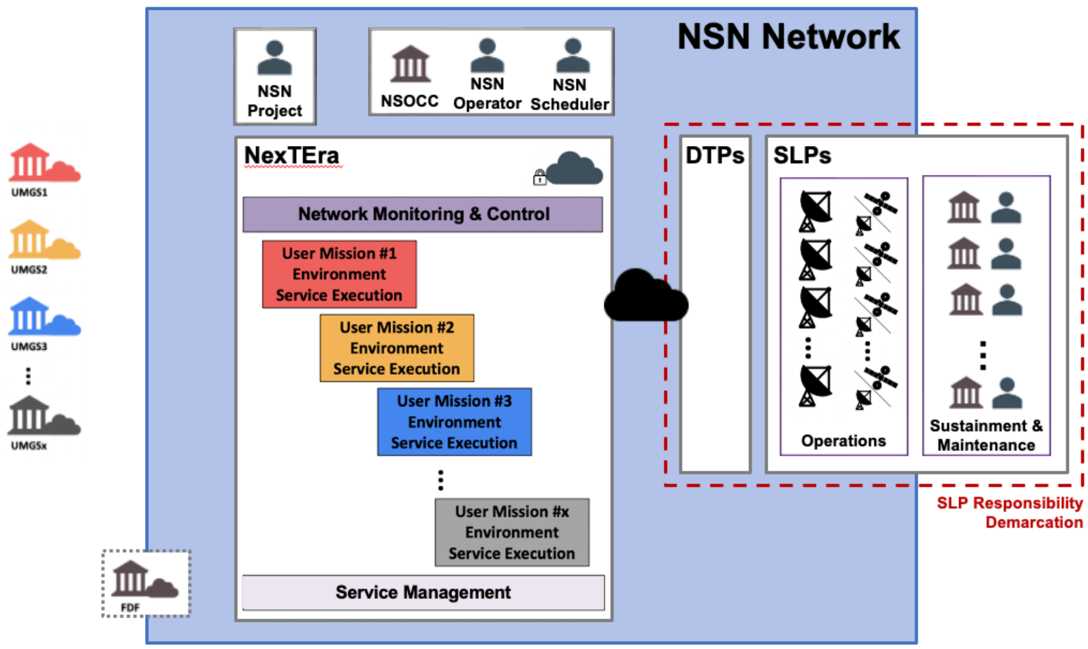

Figure 3. NSN Architecture

3 NEAR SPACE NETWORK SERVICES

3.1 NSN Services Overview

NSN orchestrates communications services, Position Navigation and Timing (PNT) services, space links, and data transports for users as a single, end-to-end network. The NSN leverages a broad spectrum of capabilities available through government and commercial link providers and negotiates with providers on behalf of all missions to lower costs.

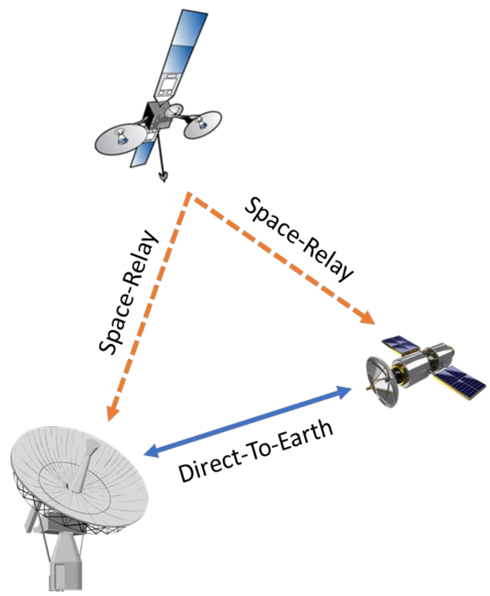

Figure 4. The NSN provides Space Relay and Direct-to-Earth Service

NSN services can be split into two broad categories based on the geometric configuration of elements of the integrated system as shown in Figure 4. The configuration consisting of just two nodes, the user mission platform in space and the link provider station on the ground, is called Direct-to-Earth (DTE). Availability of these services is limited by the terrestrial body (Earth or Moon) blocking visibility between the space platform and the ground station. To overcome this blockage, relay spacecraft can be inserted between the ground station and the user space platform. This geometric configuration is known as a Space-Relay (SR) service.

DTE services:

- Especially effective for missions needing frequent, short-duration contacts with high data throughput
- Longer latency durations between contacts due to orbital dynamics and station visibility
- For LEO users, requires significantly less power to achieve equivalent performance levels than SR services
- Support from low-Earth altitudes to lunar distances and beyond.
- The NSN currently utilizes a mix of GOCO and commercial DTE providers and is working to increase the balance toward more commercial providers.

SR services:

- Especially useful for missions needing continuous coverage, low latencies, and coverage of launch, critical events or emergencies
- Provides continuous or low-latency communications and tracking services
- Requires additional power from the user space platform to achieve performance levels equivalent to DTE Service
- Currently supports only the Earth Proximity region
- Currently, ACCESS is the sole provider of NSN Space Relay services. Efforts are underway to develop a commercial SR capability, and commercial providers are anticipated to onboard into the network during the late 2020's timeframe.

The NSN supports a variety of Near Space missions with reliable service, extensive coverage and expanding solutions for high data rates. The NSN Network Map in Figure 5 shows the distribution of the network assets (both NASA-owned, commercial- and university-partner) currently available for mission support.

The following sections describe the general types of services that are offered by the NSN. Specifics of the services offered are maintained in the NSN Brochure, available from the NSN Project at the link provided here.

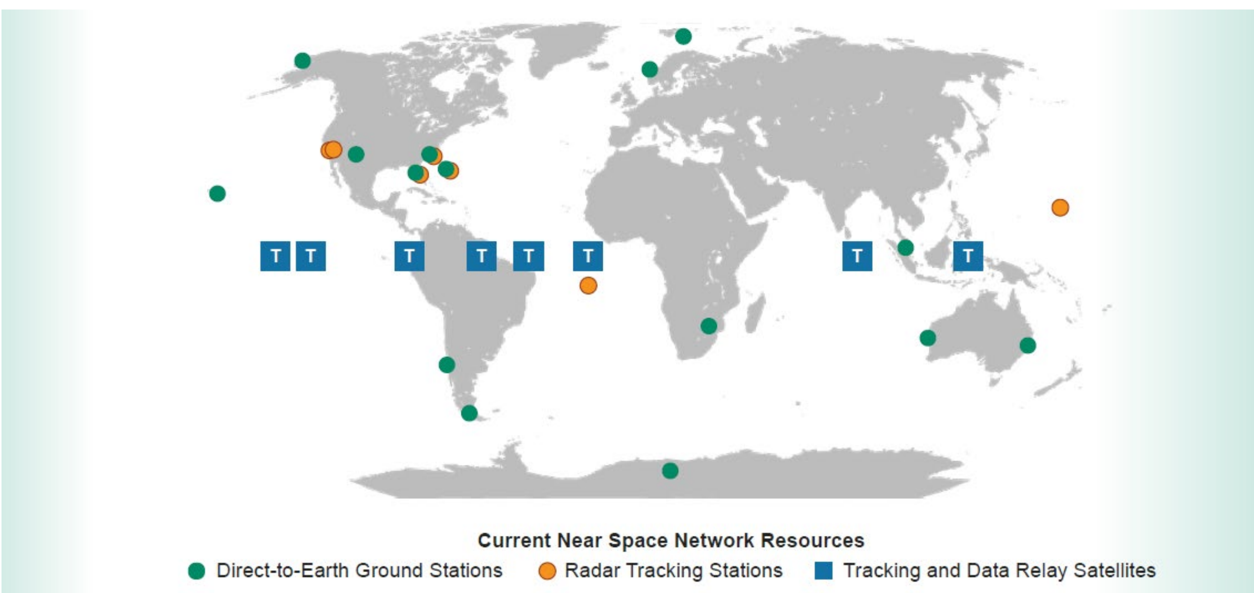

Figure 5. NSN Network Map

3.1.1 Forward Data Delivery

The NSN's Forward Data Delivery services facilitate transmission of the data received from the User Mission ground system to the User Mission platform. Data transmitted typically includes commands, sequence loads, and flight software loads, but may also include any other types of data elements. Human Space Flight (HSF) missions will include voice and video within forward data services.

3.1.2 Return Data Delivery

The NSN's Return Data Delivery services facilitate acquisition of the data transmitted by the User Mission platform over the space link and delivery to the User Mission ground system locations. There are many types of return data including navigation messages, tracking data, spacecraft telemetry, science data, voice and video. In terms of network operations, the main characteristics for return data are data volume and latency. One general category of return data is low-volume and low-latency data, commonly lumped into the category of 'telemetry'. The other main category is 'science data', which typically has high data volume but more lenient latency requirements. There will also be exceptions to these general categories that require special treatment, such as priority video files from HSF missions that are high-volume but still desire low-latency.

3.1.2.1 Space Internetworking

Space Internetworking Services provide end-to-end networking services. The protocol suites that fulfill this service are either Delay-Disruption Tolerant Networking (DTN) or the Transmission Control and Internet Protocol (TCP/IP). Path characteristics determine which protocol should be implemented and used.

The DTN protocol suite is suited for environments where the end-to-end data path has high levels of delay and/or inconsistent connectivity. While the use of TCP/IP is appropriate for end-to-end data paths that are persistently connected and have short delays.

3.1.3 Radiometric Data Delivery

The NSN's Radiometric Data Delivery Services provide radiometric observables (e.g., range, Doppler, angular position) from which the position and velocity of the User Mission platform can be derived. Observables could be measured in the RF, as currently done at S-band, X-band, and Ka-band, or at optical frequencies in the future.

3.2 NexTEra Data and Navigation Standards

The NSN Project is striving to develop common interfaces between the supporting elements of the NSN and the user ground facilities, which are generically referred to by the name User Mission Operations Center (UMOC). Figure 6 below shows the overview of NexTEra interfaces. The specific standards for each of these interfaces can also be found in the NSN Brochure.

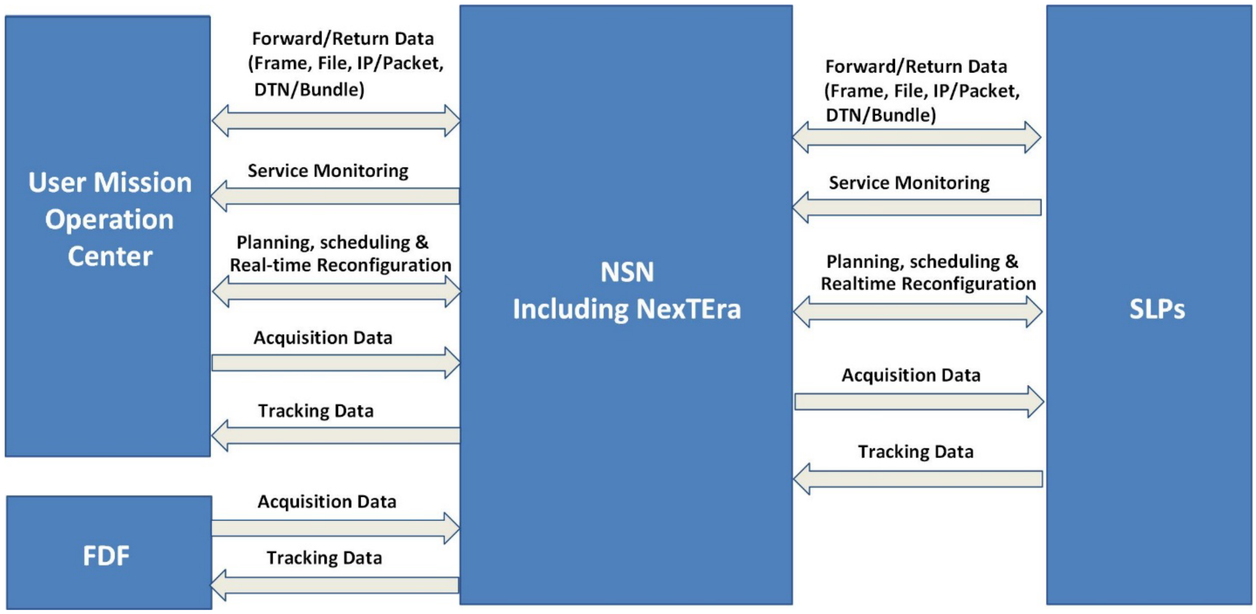

Figure 6. NexTEra Interface Overview

3.3 Mission Specific Capability Development

The NSN Project has developed a suite of services designed to cover the expected needs of the majority of user missions. Throughout the process of understanding mission needs and defining service requirements, NSN personnel will assist in utilizing existing capabilities in order to minimize the financial burden on the User Mission Project.

NASA missions are very unique, and inevitably there will be user missions with unique C&N needs. Once a unique capability is identified for a mission, the NSN will work with the User Mission Project to define the necessary capability. Once defined, the NSN Provider Onboarding group will engage to determine if the mission service is available in commercial industry. If available, the NSN Project will perform the contract actions necessary to obtain the services on behalf of the user. If the mission-unique services are not available commercially, the NSN has a Capability Development Group that can provide new services to the missions.

In either case, the NSN Project will develop a cost and schedule necessary to achieve the unique mission service. The necessary additional resources will be included in the agreement between the User Mission Project and the NSN Project.

3.4 Future Capabilities (Committed)

Committed Capabilities are those capabilities which do not currently exist but have SCaN Program level commitment to fully implement in time to meet the operational date of the anchor user. The anchor user is the first mission that defined a new capability and jointly arranged for the implementation of that new capability to support the mission.

Below are the current capabilities under development and expected to be operational in time to support launch of the of the anchor users.

3.4.1 Lunar Exploration Ground Sites (LEGS) 18-meter Subnet

The future Lunar Exploration Ground Sites (LEGS) subnet will utilize 18-meter class antennas to improve coverage and data rates for compatible users in cislunar, L1 and L2 regimes by providing dual-band (X- and Ka-) forward and return services, and the ability to support Pseudo-Noise (PN) ranging via X-band. This capability will be in place to support Gateway operations.

3.4.2 Antenna for Roman Mission Support (ARMS)

The ACCESS Project will modify the existing White Sands 1 (WS1) S/Ka-band antenna at NASA's White Sands Complex in order to provide increased communications capability for missions at Sun-Earth Lagrange points 1 and 2. This capability will be in place to support the Roman mission.

3.4.3 Lunar Relay Constellation

SCaN's Lunar Relay Constellation will implement communications relay, PNT, and Space Weather broadcast services via S-/X-/Ka-band systems on lunar orbiting spacecraft providing support to mission users in lunar proximity. These lunar relay spacecraft are required for support of the Human Landing System mission.

3.4.4 NexTEra

The NexTEra system described in Section 2.4 is a new capability that is required for operation of the LEGS and ARMS systems and is therefore required to be operational prior to Roman and Gateway missions. NexTEra will be incorporated into other new missions and existing legacy missions as determined jointly by the NSN Project, supporting elements, and mission users.

3.5 Future Capabilities (Development)

The NSN is constantly looking at ways to improve the flexibility and robustness of the network, including ensuring diversity in providers, increasing the number of standard services offered, and providing an open architecture to which missions and providers can easily interface to support robust communication services to all locations within the Near Space region.

The mission integration process, as described in Section 4, is in place to identify any new capabilities needed to satisfy mission-unique requirements or interfaces that may be required to fully support specific missions. At a higher level, the Commercialization, Innovation and Synergy (CIS) team engages with the broader mission user community and industry to determine new technologies that would improve the overall network capabilities, thereby improving the services available to NASA missions. When CIS identifies a beneficial capability, a roadmap is developed to plan out the steps to make the new capability available. Then, a team is formed with key industry, user and SCaN stakeholders to make the plan a reality.

The following capabilities have been identified as likely new additions to the NSN but are not currently guaranteed to be available for mission service. Once the concepts are better defined and developed, they may be moved to the ‘committed category’ and assigned as requirements for future missions. Until that step is undertaken, user missions should not expect to use these services.

3.5.1.1 LunaNet

LunaNet is a flexible lunar communications and navigation architecture that will provide lunar missions with access to robust network services similar to those on Earth, allowing data transfer between any LunaNet user. The LunaNet architecture is based on linked network assets, or nodes, capable of providing a combination of three standard services.

1. Network Services: Data transfer services capable of moving data between nodes and to the end user. These services will incorporate innovations like Delay/Disruption Tolerant Networking, User Initiated Services (UIS) and other advanced high-rate communications systems.
2. Positioning, Navigation and Timing Services: Services for positioning and velocity determination, as well as time synchronization. This includes search and rescue location services for astronauts.
3. Science Utilization Services: Services providing situational alerts and science measurements for human and asset safety and protection in cislunar space.

The architecture will be provided by a combination of NASA and others in industry, academia and the international community. This collaborative approach will allow LunaNet to develop in a manner analogous to the development of the internet on Earth.

3.5.1.2 Low-cost and streamlined Support for SmallSats

Small satellite (SmallSat) missions (including CubeSats) often have limited budgets and more aggressive schedules. Current C&N services and mission integration processes were initially developed to suit traditional large NASA missions. By altering network capabilities and processes, or by developing standardized options for reduced service levels, many of these SmallSat missions can be supported at levels consistent with their lower budget and higher risk posture. Low cost and streamlined support for SmallSat community would include:

- Expanded commercial services providers
- Streamlined Mission, Planning and Integration (MP&I) processes
- Cataloged standard flight components to minimize or eliminate compatibility testing requirements
- Elimination of current frequency assignment barriers via a new approach for SmallSat missions

3.5.1.3 Responsive Network Services

Responsive Network Services initiative will target network modernization and upgrades that provide improvements to service access and scheduling. Users will benefit from:

- Reduction in wait time or latency between space mission data generation and transmission
- Reduction of scheduling operations and system limitations
- User-initiated communication service scheduling via autonomous software on ground systems or on-board the spacecraft
- Introduction of network broadcasts and cross-mission dissemination of telemetry, command, navigation information, and spacecraft and network health information for individual or distributed space mission coordination and strategic operations

3.5.1.4 Unified Space Data Link Protocol (USLP)

NSN is considering incorporating the CCSDS specified Unified Space Data Link Protocol (USLP) for use by space missions. USLP is a Data Link Layer protocol designed to provide enhanced efficiency of data transfer of space applications data of various types and characteristics over space links.

3.5.1.5 Variable / Adaptive Rates

The current capability of the network is limited to scheduling passes with pre-defined rates. With a Variable / Adaptive Rate capability, a single pass (contact event) can be broken up into smaller segments with rates based on predicted performance. A true variable / adaptive capability has not yet been implemented in the NSN. The satellite communication standard called Digital Video Broadcasting—Satellite—Second Generation (DVB-S2) can provide variable or adaptive data rates, codec rates and Phase Shift Keying (PSK) modulation orders to achieve power and bandwidth efficiencies. The DVB-S2 standard proposes advanced modulation techniques (e.g., 8PSK, 16APSK, and 32APSK) and a wide range of coding rates (from 1/4 to 9/10) with near-Shannon coding schemes (Low-Density Parity Check [LDPC] codes). This high number of modulation and coding schemes, combined with variable or adaptive coding and modulation, allows a wide range of possibilities to satisfy specific mission constraints and enhance data throughput. The NSN currently can use DVB-S2 in a scheduled manner. Full adaptive capability will provide enhanced data throughput and improved reliability to missions.

3.5.1.6 Optical Communications

Optical communications, also known as laser communications, offer higher data rates while requiring less space, weight, and power burden on the spacecraft. Implementations of optical communications in the NSN is expected to be able to support 5 Gbps data rate in the near-future, and higher rates on the order of ≥100 Gbps are also envisioned. Future optical communications will also support increased tracking ability through optimetrics, which provide very precise measurements of range and Doppler.

The Lunar Laser Communications Demonstration (LLCD) has previously demonstrated a 622 Mbps optical return link from Lunar orbit. The Laser Communications Relay Demonstration (LCRD) has demonstrated a geostationary relay capability for optical communications, relaying data between ground stations in Hawaii and California. The Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal (ILLUMA-T) will communicate high-rate data over optical from the International Space Station (ISS) to the ground through LCRD. The Orion Artemis-2 Optical Communications System (O2O) is being developed by NASA's GSFC in partnership with the Massachusetts Institute of Technology's Lincoln Lab and will implement bi-directional optical communications with the manned Orion spacecraft as part of the Artemis II mission. The Laser-Enhanced Mission Communications Navigation and Operational Services (LEMNOS) Pipeline project office at GSFC is overseeing the O2O project. LEMNOS is tasked with leading the advancement and implementation of optical communications systems and technologies for NASA missions. The LLCD, LCRD, O2O, and ILLUMA-T projects are the vital first steps toward operational NASA missions having access to optical communications and tracking services.

4 MISSION PLANNING & INTEGRATION (MP&I)

4.1 Introduction

The NSN implements a well-established process to capture and assess user requirements and determine how to best support those requirements. The process is collaborative and relies on continuous communication and exchange of information between the customer and NSN throughout all phases of mission development. It is the responsibility of the NSN Advanced Planning team together with the Mission Services Integration (MSI) team to facilitate this process for the NSN.

The NSN has established a process to support a customer through each phase starting in Pre-Formulation and going through Formulation and Implementation. To the greatest extent possible, the NSN processes and schedules are synchronized with project lifecycle milestones. Figure 7 provides a high-level breakout of key NSN activities that are carried out across the mission's project lifecycle. The following sections describe the NSN integration activities, and the inputs required from the mission during each mission lifecycle phase.

NASA's unique missions usually benefit from the full integration process, starting in Pre-Phase A and working extensively with the Advanced Planning team through several cycles of analyses and iteration before proceeding into implementation and operation. If a mission does not engage the NSN during Pre-Phase A, the full Advanced Planning process described in section 4.2 below will be executed for those missions who wait to engage the NSN until the Phase A Formulation work. Missions that do not contact the NSN for planning & analysis until Phase B or later may go through an abbreviated advanced planning process. In this case, analysis will be performed (but may be limited) to verify NSN support is feasible, a Cost Estimate (section 4.2.3.5) will be generated, the Spectrum Allocation process (section 4.2.4) will be initiated, and the mission will proceed directly to the process described in section 4.4.

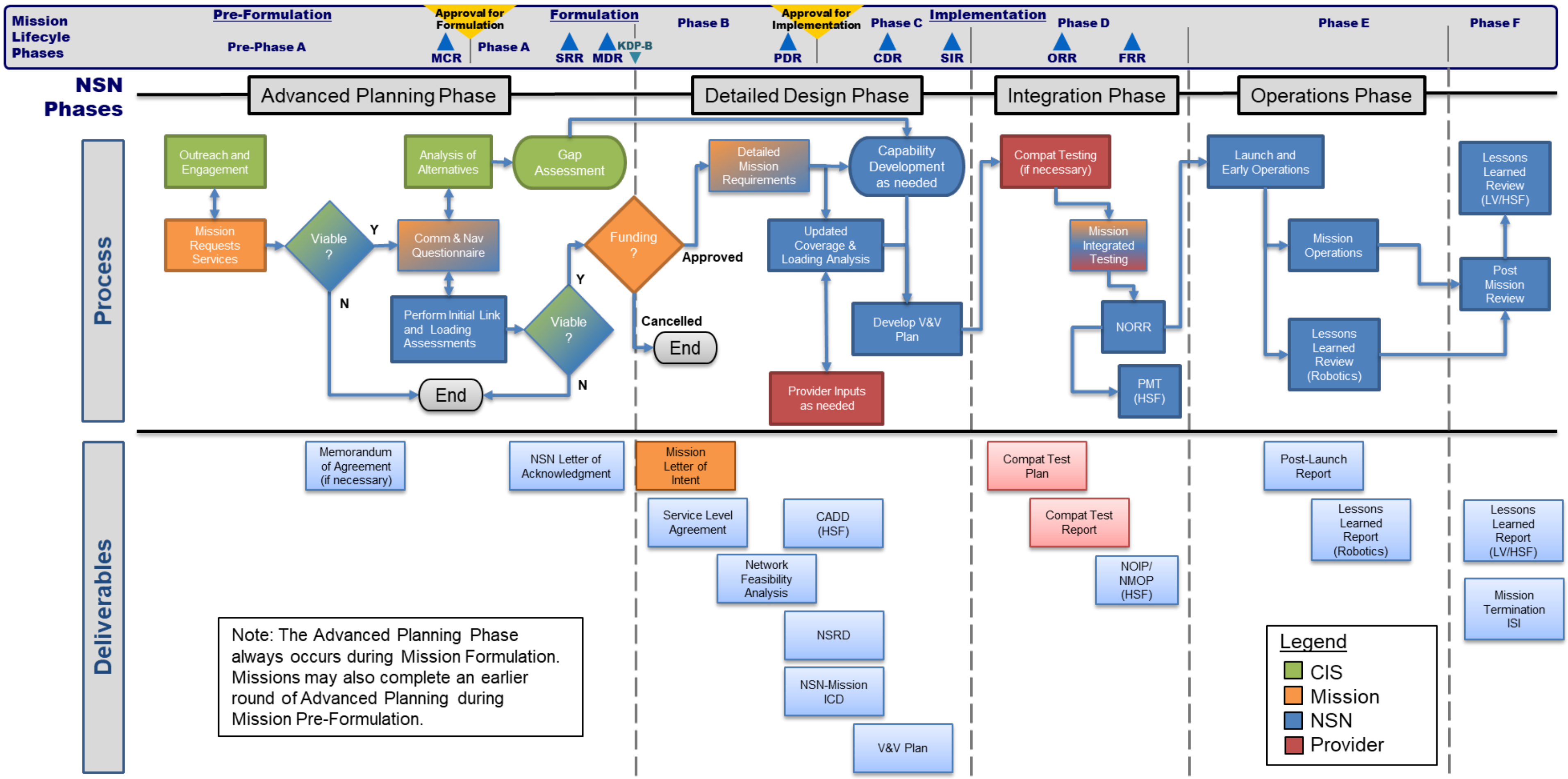

Figure 7. NSN Mission Planning and Integration Process

4.2 Customer Pre-Phase A (Concept Studies)

4.2.1 NSN Advanced Planning Introduction

The Pre-Phase A and Phase A phases are referred to as "pre-formulation" phases within the practice of NASA Systems Engineering. The NSN tasks and interactions with potential customers in these phases are conducted by the NSN Advanced Planning team. A process called "mission engagement" has been implemented by the NSN to screen and track new mission interactions and to foster increased and consistent communications with new missions.

4.2.2 Mission Engagement

Initial inquiries for NSN services will be directed to the Mission Engagement Working Group (MEWG). The MEWG is the single entry-point through which potential missions ("customers") seeking NSN communications and navigation services make initial contact. The NSN and the Commercialization, Innovation and Synergy (CIS) Office participate collaboratively in the MEWG to engage with potential NSN customers and service providers and evaluate the viability of obtaining or providing NSN services.

The principal purpose of the MEWG is to record, categorize, coordinate, and ensure appropriate actions are assigned with respect to initial customer contacts. The MEWG is responsible for ensuring the initial customer request contains sufficient information for the MEWG to "screen" the request. The MEWG's scope involves a screening of the potential customer. The MEWG will assess the customer entity and confirm viability if the following three criteria are met:

1) NSN support is permissible. This criterion is met if:
    - The customer mission is sponsored by NASA
    - Or the customer is non-NASA, however one of the following conditions are met:
        - The customer is a foreign entity that it is not involved with a prohibited foreign entity and an international agreement is documented at the NASA HQs level.
        - The customer is a commercial entity that has demonstrated their mission requires services that are not available from any non-government service provider, and therefore only GOCO assets will enable their mission. The customer must demonstrate with appropriate supporting artifacts that this is the case.
        - The customer is a NASA partner, such as a University partner or a NASA funded space research lab, and a Space Act Agreement (SAA) is in place or in work.
        - The customer is a US government agency, and an Interagency Agreement (IAA) is applicable and in place.
2) NSN support is technically feasible
    - The User Mission operating regime falls within the defined Near Space domain (≤ 2,000,000km from Earth), and
    - Applicable NSN capabilities are expected to exist at the time of the mission.

3) Funding is available.

   - Funding can be in progress, e.g., for NASA mission proposals

     - Note 1: SCaN covers the cost of initial discussions and "advanced planning" with new customers in pre-formulation for NASA-sponsored missions. NSN mission services integration including planning, service level agreements, integration and testing, can only begin once the customer is fully funded through formulation and implementation and funding is transferred from the project to cover NSN implementation tasks.

     - Note 2: The NSN cannot make support commitments based on projected future capabilities (e.g., future networks, station locations, etc.), but can only make commitments to new customer missions based on what is available today and what future or developmental capabilities are fully funded through development and operations. If applicable NSN capabilities are not expected to exist to meet the mission requirements, the NSN and CIS will discuss network upgrades, development of new capabilities, and/or onboarding of new service providers in order to provide the mission support required. The costs for implementation of new NSN capabilities to meet the customer's requirements will be customer funded.

If the screening process of a network service request results in rejection, the MEWG will communicate the reasons and recommend possible remediation strategies to the inquiring project team. The MEWG will ensure feedback to the customer is focused, clear, timely and responsive. The MEWG is intended to simplify the interactions between a customer's initial contact with the NSN and minimize the number of points of contacts a customer has to maintain.

After consideration of a customer request, and if the project passes the screening criteria, the MEWG transfers the customer mission request to the NSN for advanced planning. The Advanced Planning team will provide customer interaction and feedback as the NSN progresses towards definition and implementation of a mission support concept. The NSN Advanced Planning Lead brings in the Human Space Flight (HSF)/Lunar or Launch Vehicles (LV)/Robotics Network Directors as appropriate to interact with customers beginning from the initial inquiry / request for services.

4.2.3 NSN Advanced Planning Process

NSN Advanced Planning is the established process for planning and estimating NSN services. This process begins after successful MEWG disposition of the initial request for support. The NSN advanced planning process begins by gathering additional customer information, planning mission services, and verifying the NSN's ability to meet a new customer's requirements. Once initial analysis is completed which shows the feasibility of providing a particular set of customer-requested services, the NSN can then provide preliminary cost estimates. If applicable, the NSN will also provide a formal "Letter of Acknowledgment" to the customer which documents the NSN's proposed plan to provide the necessary mission services as understood by the NSN, considering current and projected network capabilities and scheduling (i.e., network loading). Figure 8 illustrates the NSN Advanced Planning Process which is described in further detail below.

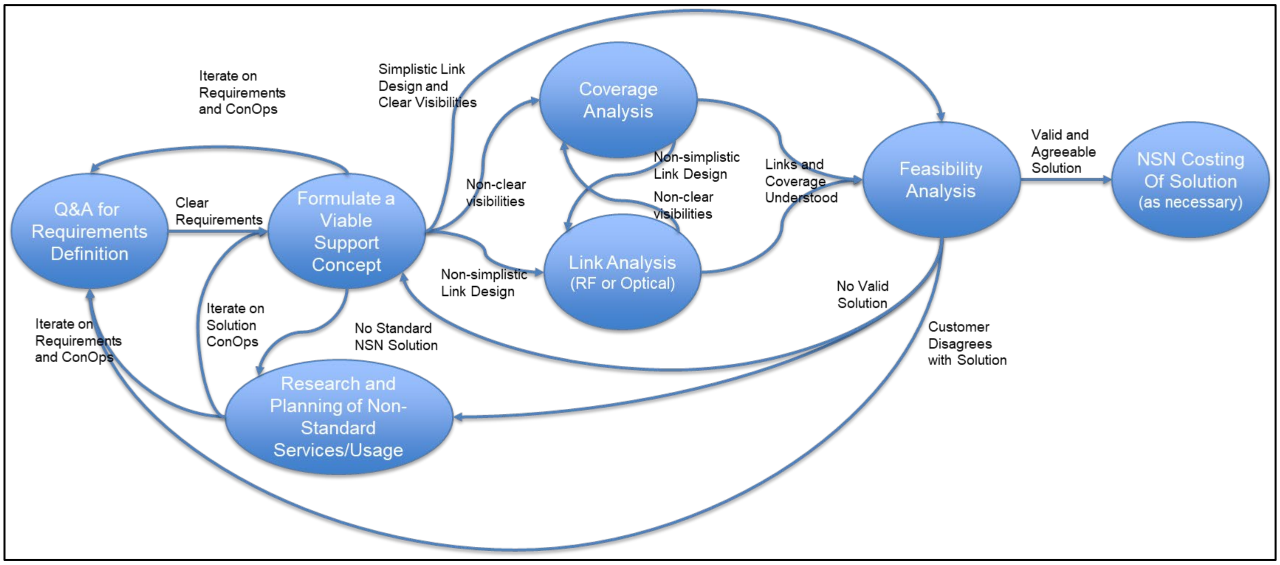

Figure 8. NSN Advanced Planning Process

Note, the NSN has a dedicated Advanced Planning team for customer missions that supports missions in the pre-formulation phases (Pre-Phase A and Phase A) and a separate Mission Integration team which supports missions in the Formulation and Implementation phases (Phase B-D). For HSF customers, the Mission Integration team is involved from the development of the customer questionnaire responses throughout the life of the NSN support activities. The HSF Network Director, or the assigned Mission Manager, facilitates discussions, questions, identification of assumptions, and overall coordination from cradle-to-grave to provide customer continuity.

The NSN adheres to this advanced planning process for all new missions. If and when a customer requests NSN services later in the mission development process, outside of the mission's Pre-Phase A or Phase A mission phase, or under emergency / critical constraints, the NSN advanced planning process is still used. Timelines can be expedited under special circumstances.

For recurring missions, both HSF and LVs, where the mission interfaces and services are unchanged from previously implemented mission services, the advanced planning process can be streamlined or bypassed entirely.

4.2.3.1 Initial Q&A

NSN Questionnaire: The NSN begins the Advanced Planning process by gathering information from the customer in technical interchanges. This includes programmatic information, design details, timelines, communications needs, tracking and/or navigation needs, and any already available communications signal design information. The NSN maintains a questionnaire form in order to facilitate the transfer of this information from the mission to the NSN Advanced Planning team. This information is applicable to short and intermediate duration robotic missions, mission projects/programs in long-duration robotics missions such as Hubble, and vehicles for launch services and/or human space flight support.

Below is a high-level listing of the information requested in the NSN questionnaire, which the NSN needs to know to begin developing the customer's communications and navigation design solution.

Operational Parameters:

- Mission information:
    - Customer Mission Type:
    - Science Type (if applicable): Tech Demo or Science Category
    - Launch Date:
    - Operational Timeline:
- Operating region (LEO, GEO, HEO, Lunar, Lagrangian, Ascent)
- Orbit details
- Applicable Design constraints (Budget constraints, Size, Weight/Mass and Power limitations)

Requirements/Needs:

- Communications requirements and constraints:
    - Link services: DTE uplink/downlink, SR forward/return
    - Data Rates or Data Volumes (e.g., volume per day)
    - Latency (minimum or maximum time between contacts)
    - Duty Cycle (contact separation times)
    - Applicable operational constraints (scheduling flexibility)
- Position, Navigation, and Timing (PNT) requirements
    - Position, velocity, and timing (PVT) and convergence time requirements
    - PVT messages required (content, duty cycle)
    - Predictive capability (computation)
    - Tracking needs (e.g., is ranging required?)
    - FDF requirements (e.g., Are FDF services required for orbit determination?)
- Cloud connection information:
    - Cloud-based mission environment data processing and storage requirements
    - Data protection requirements

The above listing is the high-level listing of information the NSN needs to begin to formulate a viable support concept. The NSN also works to verify the candidate support concepts by analysis and to aid the customer in developing their solutions. To do this, there is additional data needed to evaluate available NSN coverage, link closure, and available network capacity. Some of the additional mission design parameters that are needed by the NSN are listed in the following sections. For a full listing of the information that the NSN advanced planning and mission integration teams will request, see the NSN Questionnaire in Appendix A.

4.2.3.2 Development of NSN Support Concept

The NSN works collaboratively with its potential mission customers to help design a communications and navigation support concept. New NSN customers can initiate the design process with a range of requirements and mission design maturity ranging from well-defined requirements with a clear or simplistic support concept to loosely defined service requirements with complex preliminary mission design concepts. When the mission requirements are not mature or are not simplistic, the NSN will work together with the mission to formulate a viable mission support concept. The NSN will facilitate this process using information given in the NSN customer questionnaire, along with customer collaboration via email and technical meetings.

Once the NSN and customer have agreed to a viable support concept for NSN mission services, along with any necessary assumptions for the mission communications and navigation design details, the advanced planning process moves into the analysis window to verify the feasibility of the planned NSN services and assess impacts to the network and the other NSN missions.

4.2.3.3 NSN Analyses to verify mission support

The Advanced Planning team documents the customer requirements for NSN services and performs analyses to verify the NSN's ability to support the customer's requirements and communications configurations. These analyses will also allow NSN to ensure that sufficient network resources are available to provide the requested new customer services, while identifying and minimizing impacts to the NSN's service commitments made to its existing and future users.

The analyses performed in the NSN advanced planning process are preliminary and will need to be reassessed as the mission concept and communications requirements mature through the NSN implementation process (including documentation, integration, and testing) up to and through Launch and Operations.

Link Analyses

The NSN communications analysis team provides communications signal design and technical mission communications design support via communications link analysis. Communications Link Analysis is used to help design a flight segment telecommunications solution which is compatible with the NSN and will achieve the desired level of communications and tracking performance. Link Analysis and signal design expertise is provided to missions from Advanced Planning Phases (Pre-Phase A and Phase A) through implementation and testing phases (Phases B-D) to the Network Operational Readiness Review (NORR), as well as through Launch, Operations, Extended Operations (LEOP) and End-of-Life (EOL) (Phase E). The NSN's communications analysis team provides the signal design assessment and link margin analysis which are the only analysis products that can be used as the basis for providing commitment of NSN services to new missions. The communications analysis team also supports the NSN the new provider analyses, new capability analyses, as well as network architecture trade studies.

The NSN provides the official signal design assessment and link margin analysis which is used for commitment of NSN services to new missions as well as for definition of mission interfaces in the

RF Interface Control Document (RFICD) portion of the Mission Interface Description Document (MIDD). As the mission design matures, updates to link analyses will be made and results will be reflected in an updated MIDD.

The NSN communications analysis team will need additional customer provided information to perform the RF Link Analysis. The NSN will need (at a minimum):

- Link Type: Ground-Space, Space-Ground, Space-Space
- NSN Service Type: Direct to Earth (DTE) or Space Relay (SR)
    - For SR: Single Access (SA) or Multiple Access (MA)
    - Tracking needs (e.g., is Ranging required?)
- Frequency(ies)
- Spacecraft EIRP & G/T (including pointing losses, passive loss/line loss, antenna axial ratio, and receiver noise figure, etc.)
- Definition of Orbit/Trajectory: Maximum Slant Range (Or Maximum Altitude and Minimum Elevation Angle)
- Communications Schemes (Modulation, Coding, BER, and polarization)
- Data Rates (can be mission provided or calculated by the NSN)

The NSN can make a number of recommendations and assumptions to help design and guide the communications signal when mission data is not available, when the provided information is not satisfactory, or when the mission does not have a signal design preference. This listing is a high-level description of the basic information the NSN will need to understand to help design and assess the communications solution. For a full listing of the information that the NSN communications analysis team will request, see the NSN Questionnaire in Appendix A.

Coverage and Feasibility Analyses

The NSN's Network Loading and Modeling (NLM) team performs feasibility analyses for new mission customers and supports new service provider assessments to ensure sufficient network services and resources are available to make and keep service commitments to current and future NSN mission customers.

NLM performs three types of analyses: coverage, loading, and feasibility. The Coverage Analysis assesses the geometric line-of-sight visibility between users and network assets. A Loading Analysis is used to evaluate the network's ability to meet all customer commitments as overall network parameters change, such as architecture changes, additions of new service providers, and changes to the availabilities of the NSN stations. The Network Feasibility Analysis (NFA) incorporates both coverage (geometric line-of-sight visibility) and network loading (resource sharing capability) and is used to assess the network's ability to support a specific mission customer's needs given orbit dynamics, network loading constraints and established mission priority levels.

It is important to understand the differences between the NFA and the Loading Analyses. "Feasibility" is focused on the ability of the network to meet a specific mission's requirements.

"Loading" refers to an assessment of the network's ability to meet all of its customer commitments, as is performed annually for Planning, Programming, Budgeting and Execution.

An NFA is performed for each new mission before the NSN can commit to providing mission services. Typical information needed for analysis includes the mission description (e.g., projected mission timeline, orbit, and science type) and communications requirements (radio frequencies, data rates, signal design, contact frequency and latency). The NFA helps to ensure that the user's required level of NSN services is appropriate, and that the NSN can commit to providing those services given its various other customer mission commitments. As the mission design matures through planning and into implementation, updated NFAs may be required to ensure accurate and cost-effective mission scheduling results.

<u>Note on NFAs for HSF customers</u>: HSF missions are always at the highest priority for nominal operations scheduling. However, a feasibility analysis is still required by SCAN for HSF customer missions in order to assess impacts to other users of the NSN.

The NSN NLM team will need additional customer provided information to perform the necessary Coverage and Feasibility Analyses. To facilitate these analyses, the NSN will need (at a minimum):

- Mission Timeline (Launch Date, LEOP and Operations timeframes)
- Orbit Profile
  - Keplerian elements, a state vector, TLE, IIRV, or a mission provided Ephemeris file.
  - For highly dynamic orbits or for LEOP and critical event coverage, the NSN will require a mission provided Ephemeris file.
  - For constellations, the NSN will need to understand the orbit phasing/spacing.
- Interfaces (e.g., compatibilities, frequency bands, communications schemes, maximum rates, maximum distances, etc., some of which will come from the communications link analysis results, and some of which can be assumed in the advanced planning phases)
- Contact time requested (or data volume required and an associated data transfer rate)
- Latency constraints (i.e., minimum/maximum contact separations)
- Any on-board spacecraft field of view constraints (masking)
- Ranging requirements (Ranging methodology and accuracy needed, and whether science data is to be included in the TLM return link)
- Any other mission constraints effecting available communication time periods, view angles, interferences, etc.

4.2.3.4 Non-standard services and new capabilities

If it is determined that the NSN is unable to provide the required mission services, the NSN will investigate options for alternative services solutions to include non-standard services. This may be accomplished by adding new technologies, capabilities, and capacities within the current set of NSN commercial service link providers, by adding new service providers, or by internal development of new capabilities as part of NSN's government owned service providers.

The costs for setup or development of non-standard services will be negotiated with the mission. In many cases, the mission will be responsible for funding the non-standard services, but in some cases, as in the case where many other customer missions would benefit from the new capability, the cost to develop and/or provide the capabilities may be shared between missions and/or NSN.

4.2.3.5 Cost Estimation

The NSN provides cost estimation of NSN services for missions in pre-formulation when requested by the mission. Refer to section 7.2 for more details.

4.2.3.6 Letter of Acknowledgement

The NSN provides a letter of acknowledgment to provide NSN services as applicable upon request. The letter states that the NSN has performed assessment and analysis and the letter includes the outcome of the determination as to what services the NSN can provide. The letter typically is included in the customer's proposal package to accompany the NSN services descriptions and associated cost figures.

4.2.3.7 Additional HSF Considerations

The NSN understands that HSF customers expect a significantly high level of insight into the operations of their supporting elements. To meet this need, the NSN employs the HSF Mission Integration (MI) team to support HSF customers beginning in the advanced planning phase. The HSF MI team is embedded in the customer process from the start, aiding the development of the questionnaire, and continues to add another layer of insight and understanding throughout the Advanced Planning and Mission Integration process all the way through closing of final mission documentation.

There are often many iterations of designs, features, constraints, etc. for HSF missions that require detailed review, monitoring, and communication from the NSN. The HSF MI team provides the necessary high-level of agility and responsiveness to the NSN's HSF customers. This high level of service can be made available to other missions (non-HSF) at an increased cost.

4.2.4 Spectrum Management Services

The GSFC NSN Spectrum Management Office (SMO) is the responsible authority for all NASA Goddard missions transmitting or receiving RF spectrum to obtain the required equipment certification and frequency authorization from the national licensing authority. The office provides support for spectrum considerations such as frequency selection, conformance to regulatory constraints and assessment of other electromagnetic spectrum parameters and is described in Table 1. Missions are advised to contact the GSFC NSN Spectrum Management Office and NSN Advanced Planning Group early in the project formulation in order to understand spectrum policy and available network resource impacts and to avoid significant delays in many areas. All spacecraft communication links with the NSN as well as other ground networks must be coordinated, licensed, and internationally registered prior to operation. Federal missions are prohibited from purchasing communications hardware until the Spectrum approval cycle is in progress. Additional services performed by the GSFC NSN Spectrum Management includes Global Spacecraft Identification (GSCID) code assignment, Pseudo Noise (PN) Code assignment, etc.

Table 1. Spectrum Authorization Process

Step	Description	When
Initial contact	The project must contact the SMO of the NASA Center responsible for the mission. SMO will determine eligibility for use of spectrum and advise as appropriate to meet data/operational requirements of the mission. NSN Advanced Planning team will advise all available network resources and perform optimization for the mission. SMO will also determine the appropriate process (Federal or commercial) to be utilized to obtain authorizations.	As soon as a need for RF operation is identified. Concepts should be discussed prior to submission of proposal to insure that planned spectrum usage is even possible. Initial contact is mandatory for all projects, reference NPD 2570.5 and NPR 2570.1.
Frequency Selection	SMO will perform analyses to identify initial frequency candidates and any applicable interference mitigation methods.	Once project is funded and the technical information needed for the studies is provided by the project, but no later than 2.5 years before launch.
Frequency Coordination	SMO initializes coordination with other users of the spectrum (agencies or administrations) both domestically and internationally	Once frequency pairs are identified, but no later than 2 years before launch. This process can take a year or more depending upon the spectrum usage required.
NTIA System Certification Stage 2	SMO prepares and submits a request for system certification Stage 2 approval to the NTIA for preliminary domestic approval.	Once the information needed for the filing is provided by the project, but no later than 2 years before launch (parallel with frequency selection and coordination). This approval process can require 6 months to a year, depending upon the system.
ITU Filing	NASA HQs International Spectrum Office submits filing to the International Telecommunication Union (ITU) for international approval.	Once SMO submits a copy of the NTIA Stage 2 filing and selected frequencies have been pre-coordinated.
NTIA Stage 4	SMO prepares and submits a request for equipment certification Stage 4 (final) approval to NTIA. No spacecraft can be launched or obtain a license to operate RF equipment until the system has been certified.	After the project provides final measured technical data demonstrating compliance with all technical requirements such as the NTIA and Space Frequency Coordination Group (SFCG) emission masks, harmonic and spurious attenuation, antenna gain and pattern, etc. Ideally, 1.5 years before launch but no later than 1 year before launch.
Radio Frequency Authorization (RFAs) (Licenses)	SMO submits RFA requests to NTIA Frequency Assignment Subcommittee (FAS). Subcommittee to obtain the authority to radiate at the space station and associated earth stations on specific frequencies and at specific locations.	No earlier than six months before launch

The spectrum authorization process can take over 1 year to complete from beginning to finish. Projects are encouraged to engage with GSFC NSN SMO and NSN Advanced Planning Group to ensure spectrum authorization and any applicable interference mitigation methods will be completed in time. Any changes in project technical parameters/requirements such as earth station list should be communicated to the SMO as soon as possible to avoid lengthy delays.

For planning purposes, the spectrum authorization process can also be overlayed over typical NASA project plan shown in Figure 9.

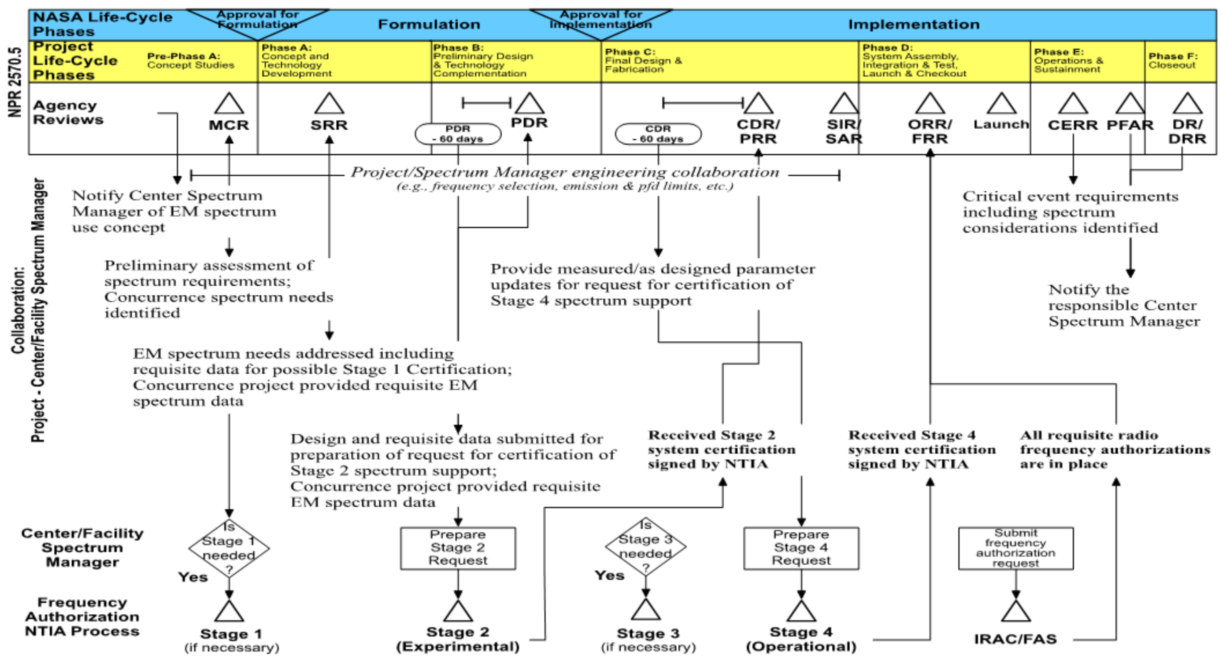

Figure 9. Spectrum Authorization Process

The GSFC NSN Spectrum Manager (SM) will perform the following functions related to project support:

1) Provides internal and external coordination of RF spectrum requirements at GSFC facilities, and for activities to be managed or conducted by GSFC directorates, offices, programs, missions and projects at other locations.
2) Works with projects, programs, and mission directorates to ensure that the communications and RF spectrum requirements for future GSFC missions and science programs are identified as early as possible.
3) Reviews and takes actions to see that all RF equipment utilized by GSFC and by any party or activity within GSFC is legally authorized for usage.
4) Facilitates the certification and licensing of GSFC RF equipment by coordinating, as needed, with other organizations, by making frequency selections, by evaluating RF equipment against applicable national and international requirements, by performing RF analyses of planned and existing operations and by completing and submitting certification

and authorization requests. Reports GSFC RF equipment operating outside the United States and Possessions to the offices of the NASA Director of Spectrum Policy and Planning.
5) Reviews GSFC frequency authorizations at prescribed intervals, to determine if renewal or deletion is required.
6) Assigns TDRS PN and CCSDS GSCID codes.
7) GSFC NSN SM assists other Center/Facility SMs in investigating incidences of RF interference that may occur in the 2025-2110 MHz and 2200-2290 MHz bands.

The project formulation manager, project manager, program managers, when responsible for the development, procurement, or use of RF equipment, shall ensure the following efforts are accomplished:

- Contact GSFC SM early in the formulation phase of the project, or pre-development process of the product, to convey the nature of RF spectrum usage or support requirements and obtain spectrum guidance on proper frequency bands and, where appropriate, maximum allowable bandwidths and effective isotropic radiated power levels.
- Contact GSFC SM to obtain guidance as soon as practicable following approval and/or funding of missions, projects, programs or other activities.
- Only obligate funds for formal engineering (as determined by the Center Director), development and testing, or procurement of operational Electromagnetic (EM)-radiating or receiving devices after the spectrum certification has been approved by the NTIA and the approval is provided to the appropriate program office and SM. The SM may determine that certification is not required.
- Provide sufficient data, on a timely basis as required by GSFC SM, concerning equipment design, operational specifications, and program or mission operations to enable the GSFC SM to perform the following required work.
- When hosting another agency, administration or non-government entity's RF equipment, experiments, or payloads on a GSFC spacecraft, aircraft, balloon or other vehicle (i.e., where GSFC provides the vehicle platform but does not control/or own the RF equipment), provide a copy of the entity's RF license or complete technical specifications for each RF device or instrument to the GSFC SM for review and approval prior to agreement to include such equipment on the flight manifest.
- Designate an operational point-of-contact to handle on-going authorization or operational coordination issues, and to identify updates or modifications relevant to authorizations as part of the five-year review process.

Pre-Phase A milestones includes:

- Letter of Acknowledgement including Link Analysis, NFA and cost estimate

4.3 Customer Phase A (Concept and Technology Development)

NSN support during a Mission's Phase A is very similar to the Pre-Phase A support described in section 4.2. In both Phase A and in Pre-Phase A, the NSN supports advanced planning of communications and navigation mission support services, including support concept development, analysis, documentation of analysis results and cost estimation for NSN services (as requested).

If a mission has already worked with the NSN during Pre-Phase A and is returning to the NSN with updated mission information, objectives, or service needs, the NSN advanced planning activities which were completed in Pre-Phase A are repeated and refined during Phase A. For those missions that did not previously work with the, the NSN advanced planning team will work with the new customer to complete the advanced planning process described in the previous section (Pre-Phase A) for the first time. Cost estimation will be performed for new missions (assuming that a viable mission support concept has been verified by analysis), or an update to a previous cost estimate will be generated to reflect changes to mission requirements, requested services and/or updates to the NSN network (i.e., service provider changes, network updates, new capabilities, etc.).

The NSN will support mission Systems Requirements Review (SRR) and/or Mission Design Review (MDR) as requested, however the costs associated with this support will be charged to the customer.

Phase A milestones includes:

- Letter of Acknowledgement including Link Analysis, NFA and cost estimate

4.4 Customer Phase B (Preliminary Design and Technology Completion)

At the beginning of Mission Phase B, most missions will have completed the initial collaborative service planning efforts with the NSN Advanced Planning team. Depending on timing as well as potential customer requirement changes since initial advanced planning was performed in the Pre-formulation phases, an updated Cost Estimate may need to be generated.
However, some missions may have their first contact with the NSN during this detailed design phase, in which case the advanced planning team will facilitate the initial customer coordination and the customer mission may go through an abbreviated advanced planning process. In this case, analysis will still be performed, but may be limited, in order to verify NSN support is feasible, then a Cost Estimate (section 4.2.3.5) and a Letter of Intent will be generated.

4.4.1 Letter of Intent (LOI)

For missions that are selected and/or funded and are ready to begin the NSN integration process (for NASA missions, that is, they have moved into mission Phase B or are ready to move into Phase B), the NSN drafts a 457-TOOL-0017, *Letter of Intent,* to accompany the NSN Cost Estimate. This letter states the mission's intention to proceed ahead with the technical description of the support and the estimated costs as described in the NSN Cost Estimate, as well as the project's ability and intent to transfer funds to the NSN in order to fund the NSN to begin mission integration activities. When a mission is ready to move ahead with NSN services based on the Pre-planning analysis and the Cost Estimate provided to the mission, the mission will be required to sign and return the Letter of Intent to the NSN. (An authorized NSN Project representative will sign the letter and return a copy to the mission.)
Once this letter is completed and signed by both parties, funding is required to be transferred from the customer to the NSN. At this point, the interaction between the mission and the NSN Project transitions from the Advanced Planning team to the Mission Services Integration (MSI) Group. The integration process proceeds beginning with development of service level agreements,

requirements documentation, updating analyses, developing test and operations plans, performing testing and reviews, and finally transitioning to operations.

4.4.2 Beginning the Integration Process

The NSN Integration Process generally begins about 1 year to 6 months before mission Preliminary Design Review (PDR). The NSN's typical integration process for new space vehicle customers takes about 36 months to complete. In accordance with lower-costs and a higher risk-tolerance for CubeSat missions, this timeline is compressed to about 24 months.

The NSN MSI team will begin the integration process after the Letter of Intent is signed and funding is transferred to the NSN. Once the LOI is signed and initial funding is transferred to the NSN, all NSN support including mission service coordination from this point forward is led by the Mission Services Integration (MSI) Group.

The first items the integration team will begin to work are (1) documentation of the support agreements and (2) documentation of the space link interfaces formerly contained in the Radio Frequency Interface Control Document (RFICD). Coordination between the mission customers, the NSN, and the NSN service providers will involve the mission and supporting network elements in regularly scheduled Network Engineering Working Group (NEWG) meetings led by the assigned NSN Mission Manager. These working group meetings will be conducted for the duration of the mission integration process timeline.

The majority of the mission specific information is documented in the Mission Interface Definition Document (MIDD). This document was created to consolidate all mission information which was previously contained in the Service Level Agreement (SLA), Network Service Requirements Document (NSRD), Radio Frequency Interface Control Document (RFICD) and Ground Interface Control Document (Ground ICD) or equivalent. The MIDD is approved iteratively, meaning a revision of the document will be signed each time a significant section of the document is completed. For convenience, these sections of the MIDD can still be referenced based on the content completed during a particular timeframe. For example, the SLA can be used to refer to the MIDD approved through the NSN Configuration Control Board (CCB) after agreements have been resolved and documented in section 2 of the MIDD. In that document, sections to be written on requirements and the ground interface will likely remain blank.

During Phase B, customers can expect to develop SLAs derived from previously-provided information in the NSN Questionnaire as well as additional discussions and design activities; initial versions of RFICDs and MOC ICDs; an initial NSRD; and updated loading and coverage analyses. Note, HSF missions may use a Program Requirements Document (PRD) in place of, or along with, the SLA.

NSN activity in Phase B builds on the information gathered and discussed in previous phases to develop requirements for customer support. The standard procedure is for the Network to work with customers to identify network interfaces. In addition, interfaces to the MOC are also developed; this tends to aid in the development of integrated and/or complementary operational procedures.

As a general guideline, Phase B completion correlates with closeout of vehicle/mission PDR activities. Upon coordination between the Project and the Network, coordination activities may be adjusted to most efficiently support the Project's needs in accordance with Network's constraints, such as being able to develop appropriate mission support requirements with sufficient time for Network elements to confirm the ability to support.

Phase B milestones includes:

- Documenting SLAs in the MIDD

4.5 Customer Phase C (Final Design and Fabrication)

Phase C further refines and solidifies the interactions and dependencies between the vehicle and the Network. The baseline version of the RF ICD is completed during this phase based on vehicle CDR development and is updated as necessary based on the results of compatibility testing between the vehicle and the Network. Desired Network features and operational activities are defined, and Network verification and validation testing begins based on final NSRD and loading assessment(s).

The NSN supports the customer mission Critical Design Review (CDR), but support may be limited or negated for CubeSat customers.

Phase C milestones include:

- Definition of the Concept of Operations (CONOPS) Architecture or Design Document (CADD) for HSF missions
- Documenting network service requirements in the MIDD
- Approval of the detailed network requirements at the NRR
- Risk mitigation testing
- Documenting the baseline RF ICD in the MIDD
- Start of the Network verification and validation activities

4.6 Customer Phase D (System Assembly, Integration and Test, Launch)

Phase D completes the initial Network verification activities and begins the mission-specific activities for the first vehicle mission. For HSF missions and LV missions, the first mission may be pre-operational (e.g., demonstration mission) or an operational mission. The level of detail and scrutiny on a first mission tends to be more intensive, but the activities themselves are consistent with future missions for the same vehicle. New missions and SLPs will conduct end-to-end testing with NexTEra to confirm that the agreed to services are functioning in accordance with the signed agreements, permissions established, environments configured, performance achieved, etc. and provide a test report to support the NORR. Missions and SLPs will support this end-to-end testing as required to satisfy the requirements of the NSRD/MIDD.
Human Space Flight vehicles and Launch vehicles have iterative missions using the vehicle model for which the Phase B/C requirements and operational procedures were defined, verified, and validated. As part of the verification, the Network executes a compatibility test to confirm Network-to-vehicle communications compatibility; often, especially for first missions, the Network will also participate in joint and/or simulation tests to coordinate operations (e.g., in service confirmation changes).

The Network mission readiness preparations culminate in a NORR in which NSN presents information relative to the Network's readiness to support of the mission from the concept of operations to the understanding of contingency support, including:

- Mission Concept of Operations
- Communications Concept of Operations, including critical comms
- Schedule and cadence of activities to the mission start
- Vehicle interface characteristics and expectations
- Applicable flight rules
- Requirements, including verification and validation
- Operational support postures
- Risks and Issues
- Network's recommendation of the readiness of the vehicle/Project
- Network's readiness to support the mission

This review is one of the most inclusive checkpoints for confirming the Network's mission support status.

After the NORR, the Network moves towards the operational support phase. If the NORR is conducted with sufficient time remaining before the mission launch date, operational documentation is developed prior to, and released in, a Pre-Mission Telecon (PMT) for HSF missions or a Pre-Launch Tag-Up (PLT) for Robotics missions where all parties involved in operations confirm that they are ready to support the upcoming mission. Products due at the PMT include Network Mission Operations Plan, Network procedures, Network troubleshooting documents, and "counts" (e.g., launch count, undock count, etc.). PMTs typically occur between 3 and 7 days before a mission begins. This is sufficiently close to the mission to be assured of support with enough time to investigate and address any Network issues. For LV missions, the NORR is performed two weeks prior to launch to ensure the network is ready to support the required services.

At L-30 days for HSF missions and L-10 days for LV/Robotics missions, a mission status Interim Support Instruction (ISI) is delivered to the network teams and mission POCs, this ISI notifies the network elements and supporting facilities that they are on mission status (i.e., providing the team a heads-up that pre-launch activities are about to commence).

Specific activities performed during Phase D include:

- Conduct RF Compatibility Test
- Finalizing the RF ICD in the MIDD
- Performing the Dynamic Link Analysis (if applicable)
- Performing the Orbit Dynamics Analysis (if applicable)
- Developing and presenting the NORR
- Conduct PMT/PLT
- Generating operational documentation such as Network Mission Operations Plan (NMOP), Network Operations Integration Procedures (NOIPs), Briefing Messages (BMs), ISIs, etc.
- Delivery of mission status ISI

5 OPERATIONS MAINTENANCE & SUSTAINMENT (OM&S) (CUSTOMER PHASE E)

5.1 Nominal Operations

The NSN Mission Manager (MM) is the primary point of contact for the LV, Robotics, and HSF missions for the life of the mission, including during the NSN Integration Phase, Launch, Nominal Operations, and end of mission (EOM). A Networks Operations Manager (NOM) is also assigned to Robotics and LV operational user missions to assist the mission during Operations. The NOM provides scheduling assistance including insights and training for customers to generate and submit schedule requests. HSF mission customers perform direct scheduling. The NSN currently provides scheduling services to existing missions through the Near Earth Network Schedule System (NENSS). This scheduling function is being replaced by NexTEra, the NSN's virtual network management system, and the associated NSN architecture. Service scheduling typically occurs on a weekly basis. However, short-notice or time-sensitive services can be scheduled in mission critical situations or emergencies on a best-effort basis. In order to best meet mission needs, schedule requests can be made for specific times or be generic/flexible in order to allow scheduling flexibility.

For certain Robotic missions, proficiency contacts are required to be scheduled during any month where no other services are scheduled. The proficiency support is required to ensure the service is operating as expected when needed. The proficiency contacts will be applied toward satisfying the daily contact time requirement. If proficiency contacts are not conducted on a regular basis as prescribed, then the NSN cannot assure that contingency services will be provided when needed. Additionally, all such contacts will be deemed engineering contacts until any/all issues encountered are resolved.

Specific activities performed during Phase E include:
- Execution of ISIs, BMs (including NOIPs, launch count)
- For HSF missions, post-dock review and pre-departure telecon as required
- Scheduled contacts
- Proficiency contacts

5.1.1 NexTEra Services Management

Per the SCaN Service model, Service Management includes:

- Service Planning includes activities to negotiate service agreements with user missions, plan and allocate comm and nav resources based on requirements, perform RF link analyses, and assess impact of proposed commitment. See section 4 for a complete description.
- Service Scheduling: Described below in section 5.1.1.1
- Service Accountability Reporting includes activities to report on the quality and quantity of service provision.

5.1.1.1 NexTEra Service Scheduling

NSN missions can fall into two categories in terms of scheduling, generic and specific. A generically scheduled mission is one that has provided NSN contact/scheduling requirements and guidelines and depends on the NSN to develop a proposed schedule. A specifically scheduled mission is one that provides the NSN with the specific windows of when they desire services.

Missions will follow a multi-period scheduling timeline that includes four periods: Open, Schedule, Buffer, and Active.

- Open Period: The time period when missions can submit specific pass requests (i.e., specifically scheduled missions) for the upcoming Active Period.
- Schedule Period: The time period when the NSN develops a complete proposed schedule for all missions based on provider availability, mission view periods, mission priority, specific mission requests, mission scheduling profiles, and NSN policies. Once developed, the proposed schedule will be provided to each Service Provider and each mission for review. The Service Providers will temporarily hold their assets based on the proposed schedule for the duration of the schedule period. The missions will review the proposed schedule and either accept as is or modify and then accept. At the end of this period all agreed-to passes will be booked resulting in an established schedule.
- Buffer Period: The time period when missions are allowed to request any changes to the established schedule for the upcoming Active Period. All changes/additions would be based on open availability (i.e., the Mission Priority List does not apply during this period), unless it is an Absolute Priority instance (e.g., spacecraft emergency). Changes may be subject to additional charges depending on the SLA and provider agreements.
- Active Period (formerly Real-time Week): The time period when the schedule, developed and refined over the last three periods, is being executed (where missions are pointing their spacecrafts at the scheduled ground stations).

Figure 10 presents the four periods in a simplified timeline view. The greyed-out text shows mapping to the NENSS Timeline for comparison purposes only.

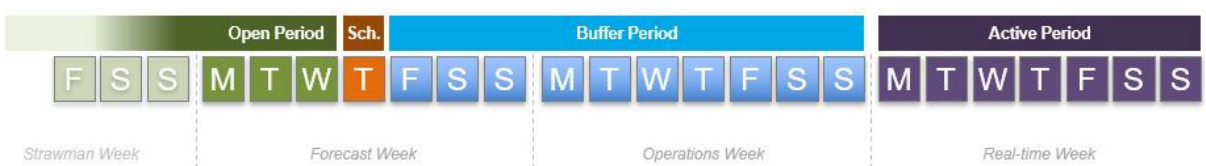

Figure 10. Simplified Scheduling Timeline View with Distinct Periods

A generically scheduled mission has no required actions during Monday through Wednesday of the Open Period, formerly part of the Forecast Week; however, the mission could log in and review their mission profiles, submit a change request to the Schedule Analyst, etc.

For specifically scheduled missions, the mission will log onto NexTEra anytime between Monday and Wednesday of the Open Period to provide their specific requested times to be scheduled for the upcoming Active Period. The mission will see a Gannt chart-like view within NexTEra, showing all line-of-sight visibilities to assets within the NSN (not based on specific asset availability, just views) broken out by the pre-established Service Configuration (e.g., Transmit/Receive (TR) Codes). The views will be based on the composite view of all compatible assets for each configuration code. The mission will select the visibility windows they prefer to be scheduled, when finished selecting all passes for the upcoming Active Period; the user will submit their request for schedule deconfliction prior to the end of the Open Period.

Missions can request assistance from NSN Schedule Analysts to resolve scheduling by accessing the scheduling help function within NexTEra.

5.1.1.2 NexTEra Service Accountability Reporting

During NSN mission support, NexTEra collects status parameters from each site providing communications services from the sites' monitor and control (M&C) system (e.g., hardware control (HWCTRL) for NSN-owned sites and Alaska Satellite Facility (ASF) and stores the data in a secure repository for retrieval by or distribution to the appropriate users. NSN then distributes the data to the authorized mission destinations (e.g., cloud-based mission repository, MOC, SOC, etc.). NexTEra provides the ability to generate ground station status parameter reports tailored to missions and operators. Such reports could include, for example, information regarding antenna position (e.g., azimuth, elevation), frequency-specific data (e.g., signal strength, Eb/N0), forward error correction (e.g., type, error counts), etc.

5.1.2 NexTEra Service Execution

NexTEra provides space communication to missions through the creation and maintenance of Mission Environments. A Mission Environment is a virtual logical space dedicated for a specific mission, securely separated from other missions in which all mission related functions and requirements are being deployed.

- Data handling, processing, and distribution
- Forward and Return Data Transport
- Peering access to all SLPs
- Translation layers (mission-specific or SLP specifics).

NexTEra provides the necessary translation layer needed for conversions between customer facility (MOC and SOC) protocols and SLPs at the same or lower layer of protocol interface to support transport of forward (FWD) and return (RTN) data. From a mission's viewpoint, each mission environment appears as a dedicated network of ground stations and tools, fulfilling the mission's needs as documented in SLAs and mission-specific ICDs.

5.2 Contingency Operations & Emergency Services

5.2.1 Contingency Operations

The Contingency Action Plan (CAP) is invoked in the event of a mission declared contingency. In addition, if the Network determines that significant off-nominal activities are occurring, but no spacecraft contingency is declared, the Network will invoke off-nominal procedures to gather and evaluate detailed Network performance data. This off-nominal procedure set is based on the CAP.

5.2.2 Emergency Services

Emergency service occurs when a MOC declares a customer platform emergency.

For DTE services, the request for emergency services will be sent to the NexTEra scheduling system. Within 30 minutes of receiving a request for emergency services, the NexTEra scheduling system will assign the mission that has declared an emergency a higher priority and initiate a new Schedule Period. NSN will develop an updated complete schedule based on provider availability, mission view periods, mission priority, specific mission requests, mission scheduling profiles, and NSN policies. Schedule Analysists will assist with any resulting support changes, as needed.

For SR services provided by TDRSS, the legacy process will continue. The Mission Operations Control Center (MOCC) requests emergency support by notifying the Network Control Center Data System (NCCDS) of the nature of the declared emergency, desired start time, services required, and expected duration of the support. Customer platform emergency requests for support are submitted as Schedule Add Requests with the customer priority set to 1 to indicate that the request is for emergency support. If the start time is less than 10 minutes away, manual intervention by the NCCDS operator will be necessary. The procedure for processing the customer platform emergency request is similar to the regular scheduling process except for any unresolvable scheduling conflict. If the scheduling request is rejected, the message from the NCCDS notifies the NCCDS Scheduling Operator (SO) of the details of the conflict. The NCCDS SO attempts to resolve the conflict by individual discussions with each impacted MOCC to determine if its scheduled service support period can be terminated or delayed. If these conflict resolution discussions are not successful, the NCCDS makes the scheduling decisions. When necessary, the NCCDS SO deletes conflicting events. This results in Schedule Result Messages being transmitted to the impacted MOC to notify them of the deletions. The NCCDS SO also informs the MOC initiating the customer platform emergency request of appropriate details of the conflict resolution. Based upon the information supplied to that MOC by the NCCDS SO, it prepares and transmits a new Schedule Add Request to the NCCDS for processing. However, if the changes are relatively simple, the NCCDS SO may edit the request rather than requiring the MOCC to submit a new request. If the scheduling request causes no conflict, the NCCDS automatically approves it, generates a Schedule Order (SHO). The NCCDS also generates and transmits a Schedule Result Message to the MOC.

For HSF customers, the NMOP shall guide the customer on how to obtain services during emergencies.

5.3 Extended Missions

Extended missions are those that have enduring mission capability beyond their original planned end-of-life and have obtained approval to extend operations. Ongoing network support (e.g., operations, scheduling, etc.) is routinely provided to extended missions. The customer should coordinate with their assigned Mission Manager to extend mission network support beyond the initial planned duration of flight. The MIDD and/or other service agreements with the customer will be reviewed and updated as necessary, and future network loading projections and customer funding profiles will be assessed and updated accordingly. Specific activities performed during this phase include:

- Update service dates in documentation such as the SLA, SARD, MIDD, etc.

6 END OF MISSION (EOM) (PHASE F)

In-flight performance is monitored, and a post-mission review conducted to evaluate the Network's performance for each mission. At defined completion points, a Post Mission Report[1] (PMR) is developed, reviewed, and released. For HSF this is typically at completion of the mission (e.g., return to Earth, destructive reentry); for Robotics this is often at the completion of Launch and Early Orbit Phase (LEOP); and for Launch Vehicles this is after completion of launch vehicle use (e.g., post-ascent, return to Earth, etc.). PMRs include a recap of the Network's expectations of the mission, along with summary of actual mission support, identification of differences and Network anomalies, along with Lessons Learned (LL) and follow-up actions.

Once mission support is completed, the MM works with the NOM or NetOps to generate an ISI stating the mission has termination, this ISI releases the network elements and support facilities from mission support.

Customers should coordinate with their assigned MM to plan for end of mission (EOM) activities as soon as a mission end interval has been identified. The MM will work with the customer to ensure NSN communication and navigation services can fully support the customer EOM plan.

Upon completion of EOM activities, the NSN financial team will coordinate with the customer to close out accounts, and the MM will archive the mission network documentation. Specific activities performed during Phase F include:

- PMR/LLs
- Mission Termination ISI

[1] The Post Mission Report may take the form of a Post-Mission Review baseline package and/or a Lessons Learned package, as agreed upon by the Project and the Network.

7 FUNDING

7.1 Agreements

NASA utilizes partnerships in support of the Agency's missions and programs. Agreements are required to accomplish stated objectives of a joint undertaking whenever Goddard Space Flight Center (GSFC) or Space Communications and Navigation Program (SCaN) commits resources to a non-NASA entity. Resources include personnel, funding, services, equipment, expertise, information, or facilities. According to Federal Acquisition Regulation (FAR) guidance, agreements are also required if NASA is buying civil servant support from another Government entity. When NASA buys services from another Government Agency, these actions are processed by Center Procurement Offices under the Economy Act. The agreement process is documented in 457-WI-1050.1.1, the Network Services Agreements Process.

7.2 Cost Estimation

Agreements between SMD and SCaN have provided that NASA/SCaN will fund nominal operational services (per pass and/or per minute costs not including "critical events") and a portion of the pre-launch planning and integration activities for NASA missions. The remaining portions of pre-launch mission planning and integration activities are funded by the mission. NSN cost estimates for NASA missions will typically include the Mission funded portions but will not show the SCaN funded portions of the total costs of NSN services.

For reimbursable missions (Non-NASA missions), the mission will need to fund all NSN activities, including both the pre-launch activities and the operational services. The NSN cost estimates for reimbursable missions will include all NSN costs as mission funded.

7.3 Funding Transfers

Once a mission/customer is ready to proceed to procure NSN services and begin the mission integration process, transfer of the required funds to the NSN is necessary to give authorization to the integration team to begin planning, integration, and testing activities. NSN support typically needs to begin 18-24 months (at a minimum) to 3-5 years (nominal) prior to the anticipated launch date. Funding is expected to be transferred to the NSN 30 days before the NSN support is to begin. Furthermore, a minimum of three months of funding needs to be always available to the NSN. Notice of available funding can come in email form from the mission to the NSN Business Office, to include Fund, WBS, Cost Center, and mission financial Point of Contact (POC). If funding is coming from another Center, a Center-to-Center funding transfer must be completed before NSN can begin work. An email confirming the funding transfer has been completed should be sent to the NSN Business Office notifying the NSN that the funding is available. The relevant NSN Business Office POCs will be identified in the NSN Cost Estimate. For non-NASA customers, the funding is sent to the NASA Shared Services Center (NSSC) upon a signed agreement.

The NSN cannot begin supporting the required mission services as described to the NSN and as outlined in the NSN cost estimate (i.e., developing SLAs, interface documentation, test plans, etc.) until a Customer Letter of Acknowledgement is signed and funding is provided. Once funding is provided to the NSN team, a MM is assigned to be the primary technical POC for the mission/customer and NSN mission integration activities can proceed, beginning with development of the SLA.

Appendix A NSN Customer Questionnaire

PART A – MISSION INFORMATION

Project full name: Acronym or short title:

Person Submitting Questionnaire: Date:

Title: e-mail address: Telephone:

Project purpose (25 words or less):

Sponsoring organization type: NASA Center Sponsoring org. name:

Current project phase: ☐ Formulation (Phase A-B) ☐ Implementation (Phase C-D) ☐ Operations (Phase E) ☐ Extended operations (Phase E extension)

Expected prime mission duration: Potential extended operations:

Are you planning on utilizing NASA navigation services? ☐ Yes, JPL-NAV ☐ Yes, FDF ☐No ☐ Not sure

Where is the mission operations control center?

Where will the science data be delivered (facility and location)?

What are your plans for Terrestrial Communications for Telemetry, Tracking, and Commanding with NSN?
☐ NASCOM ☐ Cloud Interface ☐ Other ☐ Not sure

Will you require mission voice services? ☐ Yes ☐ No ☐ Not sure

Do you require NSN services during launch and early orbit when the S/C may still be connected to the launch vehicle? ☐ Yes ☐ No ☐ Not sure

Do you require NSN or DSN services during powered flight? ☐ Yes ☐ No ☐ Not sure

Do you require NSN or DSN services immediately following separation when the spacecraft is not at its nominal attitude or not under its final attitude control (i.e., tumbling/rotating)? ☐ Yes ☐ No ☐ Not sure

Are there other assets providing services? ☐ Yes ☐ No ☐ Not sure

If yes, which assets?

Points of Contact	**Name**	**Phone**	**Email**
Project Manager			
Project networks services			
Financial point-of-contact			
Radio frequency engineer			

Types of SCaN Network services requested, if known (check all that apply):

Service	SR	DTE	DSN
Telemetry	☐	☐	☐
Tracking*	☐	☐	☐
Science Data	☐	☐	☐
Command	☐	☐	☐
Radio Science	☐	☐	☐

*Do you need 1-way or 2-way Doppler during launch & early orbit and/or during on-orbit ops?
☐ Yes ☐ No ☐ Not sure

Activities for which services are requested, if known (check all that apply):

Activity	SR	DTE	DSN
Testing	☐	☐	☐
Launch only	☐	☐	☐
Launch and Phase E Support	☐	☐	☐
Please define mission phases			
Backup Contingency	☐	☐	☐
Pre-Launch Non-Recurring Engineering	☐	☐	☐
Post Launch special events	☐	☐	☐
Please list mission phases			
Nominal operations	☐	☐	☐
Special Support Requirements	☐	☐	☐

End-of-life (EOL)/Mission(DSN)	☐	☐	☐

* If 2-way Doppler is needed, is Ranging data needed?
☐ Yes ☐ No ☐ Not sure

*Are there specific critical events that require mandatory coverage?
☐ Yes ☐ No ☐ Not sure

Critical events:

List critical support requirements

Launch-Related Information

Launch site location:
Launch date:
Launch window:
Launch period: to

Launch vehicle:
Name of Primary Payload:
Launch trajectory:
Recycle time for launch scrubs:

Orbit Information

Apogee and perigee, or semi-major axis and eccentricity for earth orbiting missions:

Inclination for earth orbiting missions:

Argument of right ascension:

Nodal crossing type (ascending or descending) for earth orbiting missions:

Local time of nodal crossing for earth orbiting missions:

Will there be any transfer orbits?

Repeat cycle, if appropriate:

For non-earth orbiting missions, describe destination (example L1, L2, Lunar Orbit, Mars orbit, Mercury flyby):

PART B – ADDITIONAL INFORMATION

What organization is obtaining spectrum and frequency authorizations?

If applicable, provide NTIA/FCC Spectrum Certification number and Radio Frequency Authorization (RFA) number.

———

What organization will do acquisition data (ephemeris) generation?

Are there applicable CCSDS standards? ☐ Yes ☐ No Which version?

COP-1? ☐ Yes ☐ No Will VCIDs will be utilized?

COP-2? ☐ Yes ☐ No

Has NASA determined if this mission is a reimbursable? ☐ Yes ☐ No
If yes, provide NASA Point of Contact:

Any additional information or special requests you would like to add?

PART C1 – NSN SERVICES INFORMATION

Frequency

Frequency band to be used: ☐ Ku ☐ Ka ☐ S ☐ X ☐ Other

Will simultaneous receipt (return link) of two bands be required? ☐ Yes ☐ No

What modulation will be used with each band on return link (deg or rad/sin or square)?

What modulation will be used with each band on forward link (deg or rad/sin or square)?

For SR service : ☐ SA ☐ MA ☐ SMA ☐ DAS

Data Delivery (see part D1 for DSN)

Command (R/T forward link) data rates in sps:

Telemetry (R/T return link) data rates in sps:

Science data volume per contact (Mbytes)

Latency (science data delivery) requirements:

PART C1 – NSN SERVICES INFORMATION CONTINUED

Spacecraft Services Information

	Near Space Network/SR			Near Space Network/DTE		
	Min	Avg	Max	Min	Avg	Max
Desired number of contacts per day:						
Average length of each contact:						
Are there required min./max. separation times between contacts for telemetry and command?						

Other constraints:

Other special considerations:

PART C2 – NSN RADIO FREQUENCY (RF) INFORMATION FOR LINK ANALYSES

Uplink/Forward Link Information (for each link)

Service Description:

Frequency:

Polarization:

Data Modulation Information:

Description: (Note: If there are multiple channels, please provide the details for each channel; for example, if the signal includes both a channel on the baseband carrier and includes a channel on the subcarrier which modulates the carrier, please describe each channel individually. If the signal is a single data source and separated into channels, please describe (or provide a block diagram) how this signal is separated, including single data rate and separate channel rates and any requirements to recombine the channels into a single data stream.)

Modulation Type: Modulation Index (if not PSK):

Sub-carrier Modulation Frequency (if applicable):

Data rate prior to any coding (should include CCSDS overhead):

Data format: Symbol rate prior to any convolutional coding:

Symbol rate after all coding: Symbol format:

PN spreading rate constraints (if applicable):

Required BER: Receiver implementation loss:

Required acquisition performance:

Other links, modes, playbacks?

DTE-Ranging Modulation Information (if applicable):

Description: Highest tone/code frequency:

Highest tone/code modulation index:

Lower tone/code modulation index (if applicable):

Receive Vehicle RF Information:

Description:

Receive antenna gain Information (include gain characteristics, polarization, and beam-width and axial ratio associated with gain):

Passive loss from antenna to receiver:

Noise figure of receiver and/or system noise temperature at receiver:

Downlink/Return Link Information (for each link):

Service description:

Frequency (include description on coherent and non-coherent operations as applicable):

Data Modulation Information:

Description: (Note: If there are multiple channels, please provide the details for each channel; for example, if the signal includes both a channel on the baseband carrier and includes a channel on the subcarrier which modulates the carrier, please describe each channel individually. If the signal is a single data source and separated into channels, please describe (or provide a block diagram) how this signal is separated, including single data rate and separate channel rates and any requirements to recombine the channels into a single data stream.)

Modulation type:

Modulation index (if not PSK):

Subcarrier modulation frequency (if applicable):

Data rate prior to any coding (should include CCSDS overhead):

Data format:

Symbol rate prior to any convolutional coding:

Type of coding :

Symbol rate after all coding:

Symbol format:

PN spreading rate (if applicable):

Required BER:

DTE Ranging modulation information (if applicable):

Description:

Turnaround Modulation Index for a single uplink tone:

Accuracy Requirements:

Transmit vehicle RF information:

Description:

Transmitter power:

Passive loss from transmitter to antenna input:

Transmit antenna gain Information (include gain characteristics and beamwidth and axial ratio associated with gain & polarization):

Tracking Information (excludes ranging, which was discussed earlier):

Description:

Doppler Requirements: ☐ 1-way ☐ 2-way ☐ Differenced One-Way

Doppler Accuracy Required:

Point-of-Contact for RF Link Analyses Questions (name, phone, email):

PART C3 – NEXTERA DTE DATA DISTRIBUTION INFORMATION (TBD)

Data Volume per Pass

AOS Frame Size   CRC? ☐ Yes ☐ No

VC Separation? ☐ Yes ☐ No   If Yes, VC List:

Latency Requirement: Data File naming convention:

Delivery Protocol (SFTP, CFDP, SCP):

SFTP End Point Retrieval? ☐ Yes ☐ No   If No, Self Service retrieval? ☐ Yes ☐ No

PART C4 – NEXTERA SR DATA DISTRIBUTION INFORMATION (TBD)

SR Gateway Encapsulation Format:

Space Link Extension ☐   **LEO-T** ☐   **IPDU** ☐

Encapsulation Format General Information:

Frame Sync Enabled? ☐ Yes ☐ No

Frame Sync Pattern xxxxxxxx   **Frame Length** ####

Location ☐ First ☐ Last   **Size in Bits (default is 32)** ##

Slip Size ##   **Search Frames** #

Lock Frames #   **Check Frames** #

Automatic Polarity Control Enabled? ☐ Yes ☐ No

NOTE: A detailed questionnaire for selected encapsulation format will be sent to project.

PART D1 – DSN SERVICES INFORMATION OVERVIEW

Frequency

Frequency band to be used: (Near Earth or Deep Space) ☐ Ka ☐ S ☐ X

Will simultaneous receipt of two bands on return link be required? ☐ Yes ☐ No

Data Delivery

Command (R/T forward link) data rates in bps:

Telemetry (R/T return link) data rates in bps:

Science data volume per contact (Mbytes) in bps:

Latency (science data delivery) requirements:

Delay Tolerant Networking (DTN) requirements:

CFDP service requirements and type:

Spacecraft Services Information

Required number of passes per mission phase, e.g. - LEOP, Cruise, orbit insertion, etc., use the DSN RF Aperture Fee tool located at https://dse.jpl.nasa.gov/ext/

Any 70-meter requirements, if yes give description:	Yes	No	
Any high-power uplink requirements above 20kw, if yes give frequency band:	Yes	No	
Are there any special tracking pass requirements: e.g. – DDOR passes per week in what mission phase, MSPA, Relay, Array, Beacon . If yes put it in the DSN RF Aperture Fee tool.	Yes	No	
Is DSN Direct from Earth (DFE) service required (telemetry, command) for a rover or lander? If yes, what is the minimum horizon elevation (when pointed to earth) for the lander or rover?:	Yes	No	
Will the mission operate at a low Sun Earth Probe (SEP) angle (other than inferior or superior conjunction? If yes, what is the minimum SEP angle?:	Yes	No	

Other constraints:

Other special considerations :

PART D2 – DSN RADIO FREQUENCY (RF) INFORMATION

Uplink/Forward Link Information (for each link)

Service Description: Command

Frequency:

Polarization:

Minimum EIRP required:

SLE FCLTU: PLOP 1 PLOP-2

Modulation Type: Modulation Index: Sine Square

Sub-carrier Modulation Frequency (if applicable): 8Khz 16Khz

Bit rate in bps:

Modulation format: NRZ-L,M,S Bi-Phase L

Manchester M,S

CLTU Frame Length:

Ranging Modulation Information (if applicable):

Type :

Sequential

PN – regenerative

PN – non-regenerative

Highest Clock:

Lower Clock:

Spacecraft Receive G/T Information:

Description:

Receive antenna gain Information (include gain characteristics, polarization, and beam-width and axial ratio associated with gain):

Passive loss from antenna to receiver:

Noise figure of receiver and/or system noise temperature at receiver:

Downlink/Return Link Information:

Service description:

Frequency (include description on coherent and non-coherent operations as applicable):

Data Modulation Information:

Description: The DSN supports multiple polarizations and modulations schemas. Describe each frequency downlink channel if more than more for an off-nominal configuration, e.g. – LCP and RCP combined for S or X-band, LCP only for Ka-band.

Modulation type:

Modulation index:

Subcarrier modulation frequency (if applicable):

Telemetry bit rates including headers (all) in bps:

Data format:

Type of coding, e.g. – Turbo, LDPC, Reed-Solomon, Convolutional:

Spacecraft RF information:

Description:

Transmitter power:

Minimum G/T required at the ground antenna:

Tracking Information (excludes ranging, which was discussed earlier):

Description:

Doppler Requirements: ☐ 1-way ☐ 2-way

Point-of-Contact for RF Link Analyses Questions (name, phone, email):

PART D3 – DSN COMMUNICATIONS WAN/LAN INFORMATION

Data Volume per Pass MBs/GBs

Latency Requirement for Science and Engineering data, Specify each VC separately:

VC0 =

VC1 =

Etc.

Timely = within 10 second

Complete = Streaming service that commences during the tracking

Offline = normally post-pass with latency commensurate with data volume and data circuit capacity

457-TOOL-0008 (8/21) Baseline

Appendix B Letter of Acknowledgement

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

DATE

Reply to Attn of: 457

PI
Mailing Address
City, State Zip

Subject: Proposal entitled STRIVE

Ref: AO Year and Name (Acronym)
AO Number: XXX dated TBD

The Goddard Space Flight Center Near Space Network (NSN) project is pleased to support you and your team on the NAME mission.

The Near Space Network has reviewed the network communications services that are required by your mission and has determined that we are capable of delivering the needed capacity and required capabilities to support the NAME mission. The preliminary cost estimate, cost breakdown and technical assessment for the NAME mission is contained in the attachment. We are committed to the services that have been estimated for you. However, please note that NSN services are shared with many other missions and binding commitments will only be made upon completion of an up-to-date resource accommodation analysis that indicates continued availability, which will typically be performed at the time of your Systems Requirements Review.

The communications services planning estimate you have received reflects the degree of accuracy appropriate for your mission design at this proposal phase. Those estimates will likely change in the later mission development phases, due to refinements of your mission communications requirements and your spacecraft design. If your mission is selected, NSN will revisit the planning estimate and will work with you to update the services design and operations support estimates.

NSN looks forward to working with you again in Phase A/B.

Sincerely,

Vir Thanvi
Project Manager, Near Space Network
Exploration and Space Communications Division

Attachment:
Mission Cost Estimate .pptx

Appendix C Letter of Intent

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

Reply to Attn of: NASA Near Space Network, Code 457

SUBJECT: Customer Letter of Intent for [PROJECT/MISSION NAME]

I, the undersigned, as an authorized representative of the [PROJECT/MISSION NAME] project, do convey the project's intent to proceed with obtaining the NASA Near Space Network's (NSN) communication and/or navigation services, as described to the NSN and as documented in the NSN Cost Estimate entitled [NAME OF COST ESTIMATE PPT PACKAGE] submitted to the project on [DATE of COST ESTIMATE SUBMISSION].

I hereby consent to the estimated costs described in the NSN cost estimate and do convey both the project's full intention and ability to transfer the necessary funds to the NSN 30 days before the NSN support is to begin. Based on the anticipated launch date of [ENTER LAUNCH DATE], I understand NSN support needs to begin by [ENTER DATE NSN NEEDS TO BEGIN WORK TO MEET REQUIREMENTS], therefore funding will be provided by [ENTER DATE OF 30 DAYS BEFORE THE WORK STARTS]. I understand a minimum of three months of funding needs to be always available to the NSN.

If the mission requirements change or the launch date changes, upon notification the NSN will provide an updated cost estimate and new letter of intent to be signed.

I understand the NSN will not begin supporting the required mission services as described to the NSN and as outlined in the NSN Cost Estimate (i.e., developing service level agreements, interface documentation, test plans, etc.) until this Letter of Intent is signed and funding is provided.

Signature of [PROJECT MISSION] representative:	Signature of NSN representative:
X________________________________	X________________________________

457-TOOL-0017 (07/22) DCN 001

Appendix D Abbreviations and Acronyms

APSK	Amplitude and Phase Shift Keying
ACCESS	Advanced Communications Capabilities for Exploration and Science Systems
ARMS	Antenna for Roman Mission Support
ASF	Alaska Satellite Facility
AWS	Amazon Web Service
BDS	Bermuda Station
BER	Bit Error Rate
BFS	Best Frame Select
BM	Briefing Messages
BPSK	Binary Phase Shift Keying
C&N	Communications and Navigation
CAP	Contingency Action Plan
CCB	Change Control Board
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFDP	CCSDS File Delivery Protocol
CIMO	Customer Interface Management Office
CIS	Commercialization, Innovation and Synergy
CLASS	Communications Link Analysis and Simulation System
CLTU	Command Link Transmission Unit
CMO	Configuration Management Office
CONOPS	Concept of Operations
CP	Communications Program
CSLP	Commercial Service Link Provider
CSP	Commercial Service Provider
CSO	Communications Service Office
DCN	Document Change Notice
DFE	Direct From Earth
DR	Design Review
DSN	Deep Space Network
DTE	Direct to Earth
DTG	Direct to ground
DTN	Delay/Disruption Tolerant Networking
DTP	Data Transport Provider
DVB-S2	Digital Video Broadcasting - Satellite - Second Generation

EIRP	Effective Isotropic Radiated Power
EM	Electromagnetic
EOL	End Of Life
EOM	End of Mission
ESC	Exploration and Space Communications
FAS	Frequency Assignment Subcommittee
FDF	Flight Dynamics Facility
FRR	Flight Readiness Review
FWD	Forward
G/T	Gain over Temperature
GCC	Goddard Commercial Cloud
GEO	Geostationary Orbit
GOCO	Government-owned, Commercially-operated
Gbps	Gigabytes Per Second
GPS	Global Positioning System
GRGT	Guam Remote Ground Terminal
GSFC	Goddard Space Flight Center
GSID	Global Spacecraft Identification
HEO	Highly-Elliptical Orbit
HEOMD	Human Exploration and Operations Mission Directorate
HSF	Human Space Flight
HLS	Human Landing Systems
HWCTRL	Hardware Control
IIA	Interagency Agreement
IIRV	Improved Inter-Range Vector
ILLUMA-T	Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal
IONet	Internet Protocol Operational Network
IP	Internet Protocol
IRIG	Inter-Range Instrumentation Group
ISI	Interim Support Instruction
ISS	International Space Station
ITAR	International Trade in Arms Regulation
ITU	International Telecommunication Union
JPL	Jet Propulsion Laboratory
KSAT	Kongsberg Satellite Services
KSC	Kennedy Space Center
KUS	Kennedy Uplink Station
L3VPN	Level 3 Virtual Private Network
LEOP	Launch and Early Orbit Phase

LL	Lessons Learned
LEOP	Launch and Early Orbit Phase
LV	Launch Vehicle
LCRD	Laser Communications Relay Demonstration
LCS	Launch Communications Stations
LDPC	Low-Density Parity Check
LEMNOS	Laser-Enhanced Mission Communications Navigation and Operational Services
LEO	Low Earth Orbit
LEGS	Lunar Exploration Ground Sites
LLCD	Lunar Laser Communications Demonstration
MA	Multiple Access
MAF	Multiple Access Forward
MAR	Multiple Access Return
MCO	Mission Commitment Office
MCR	Mission Concept Review
MCP	Mission Cloud Platform
MDR	Mission Design Review
MEO	Mid-Earth Orbit
MEWG	Mission Engagement Working Group
MIDD	Mission Interface Definition Document
MM	Mission Manager
MOC	Mission Operations Center
MOCS	Mission Operations and Communications Services
MOCC	Mission Operations Control Center
MORR/ORR	(Mission) Operations Readiness Review
MP&I	Mission Planning and Integration
MSFC	Marshall Space Flight Center
MSI	Mission Services Integration
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
NaTS	Network and Telecommunications Services
NCCDS	Network Control Center Data System
NDOSL	NASA Directory of Station Locations
NE	Network Engineer
NEN	Near Earth Network
NENSS	Near Earth Network Scheduling System
NFA	Network Feasibility Analysis
NIKA	NEN Initiative for Ka-band Advancement
NIMO	Networks Integration and Management Office

NLM	Network Loading & Modeling
NMOP	Network Mission Operations Plan
NOIP	Network Operations Integration Procedure
NOM	Networks Operations Manager
NPD	NASA Policy Directive
NPR	NASA Procedural Requirement
NRD	Networks Requirements Document
NRR	Networks Requirements Review
NSN	Near Space Network
NSN-UG	Near Space Network User's Guide
NSSC	NASA Shared Services Center
NSOCC	Near Space Operations Control Center
NTIA	National Telecommunications and Information Administration
O2O	Orion Artemis-II Optical Communications System
ORR	Operational Readiness Review
PDL	Ponce de Leon
PDR	Preliminary Design Review
PLAR	Post-Launch Assessment Review
PLT	Pre-Launch Tag-up
PMR	Post Mission Report
PMT	Pre-Mission Telecon
PN	Pseudo Noise
PNT	Position, Navigation and Timing
POC	Point of contact
PSK	Phase Shift Keying
PVT	Position, Verification and Timing
Q/GSCID	
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RFA	Radio Frequency Authorization
RFA	Request For Action
RFCTP	Radio Frequency Compatibility Test Plan
RFCTR	Radio Frequency Compatibility Test Report
RF ICD	Radio Frequency Interface Control Document
RTN	Return
SA	Single Access
SAA	Space Act Agreement
SBU	Sensitive But Unclassified
SCaN	Space Communication and Navigation

SEP	Sun Earth Probe
SFCG	Space Frequency Coordination Group
SHO	Schedule Order
SFTP	Secure File Transfer Protocol
SLA/PSLA	(Project) Service Level Agreement
SLE	Space Link Extension
SLP	Space Link Provider
SmallSat	Small Satellites
SMO	Spectrum Management Office
SN	Space Network
SO	Scheduling Operator
SOC	Science Operation Center
SOMD	Space Operations Mission Directorate
SR	Space Relay
SRR	System Requirements Review
SSC	Swedish Space Corporation
SE-L1	Sun-Earth Lagrange point 1
SE-L2	Sun-Earth Lagrange point 2
TBD	To be determined
TBR	To be revised
TBS	To be scheduled
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TDRS	Tracking and Data Relay Satellites
TDRSS	Tracking and Data Relay Satellite System
TLE	Two-Line Element
TR	Transmit/Receive
UDP	User Datagram Protocol
UG	User's Guide
UIS	User Initiated Services
UMOC	User Mission Operations Center
URL	Uniform Resource Locator
US	United States
USLP	Unified Space Data Link Protocol
USLP	Unified Space Data Link Protocol
VCDU	Virtual channel data units
WFF	Wallops Flight Facility
WS1	White Sands 1 (Antenna)
WSC	White Sands Complex
ZOE	Zone of exclusion