SCaN-MOCS-0001

SPACE COMMUNICATIONS AND NAVIGATION PROGRAM

Space Communications and Navigation (SCaN) Mission Operations and Communications Services (MOCS)

Baseline

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NASA Headquarters
Washington, D. C.

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Space Communications and Navigation (SCaN) Mission Operations and Communications Services (MOCS)

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Preface

This document is under configuration management of the SCaN Program Control Board. This document will be changed by Documentation Change Notice (DCN) or complete revision. Proposed changes to this document must be submitted to the SCaN Configuration Management Office along with supportive material justifying the proposed change. Comments or questions concerning this document and proposed changes shall be addressed to:

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Section 1. Introduction

1.1 Purpose

This document is intended to assist in the preparation of proposals responding to Announcements of Opportunity (AOs) that are issued by National Aeronautics and Space Administration's (NASA) Science Mission Directorate (SMD).

NASA provides many mission operations and communications services relating to the planning and execution of the transport of voice, video, and data for mission support. Costs accrue when using these services and estimates of these costs need to be included in proposals responding to an Announcement of Opportunity (AO). To facilitate proposal preparation, proposers are encouraged to read this document and to contact the individuals named in Section 6. Persons preparing proposals should carefully review this entire document to ensure that the document that they are submitting addresses each applicable item.

It is in the interest of the selected investigation teams to provide information on the communication parameters when submitting a proposal. To that end, while this document provides an initial set of information, additional detail is often referenced; Appendix A contains references and links to websites where further information can be found. Also, Appendix B, Appendix C, and Appendix D provide samples of the information that should be submitted with the proposal. For more details on the requested information, proposers are encouraged to contact the points of contact listed in Section 6.

1.2 Scope

Services and support offered by NASA's Space Communications and Navigation (SCaN) networks are available to all NASA sponsored flight projects and science investigators; the SCaN networks provide standard services to NASA missions – from Hubble Space Telescope to cubesat missions. Other government agencies and commercial flight projects may become eligible for services offered by the SCaN networks through negotiation with NASA Headquarters.

The scope of this document covers the SCaN networks' services that are current at the time of publication. This document will be updated over time, as new services and rates are made available to the public.

1.3 Space Communication and Navigation (SCaN) Network Services Division

NASA's Space Communications and Navigation (SCaN) Program manages and directs the Mission Commitment Office (MCO) and the three tracking networks that provide Tracking, Telemetry, and Command (TT&C) services for different types of missions. Functional responsibilities for MCO and the three networks are shown in Figure 1-1.

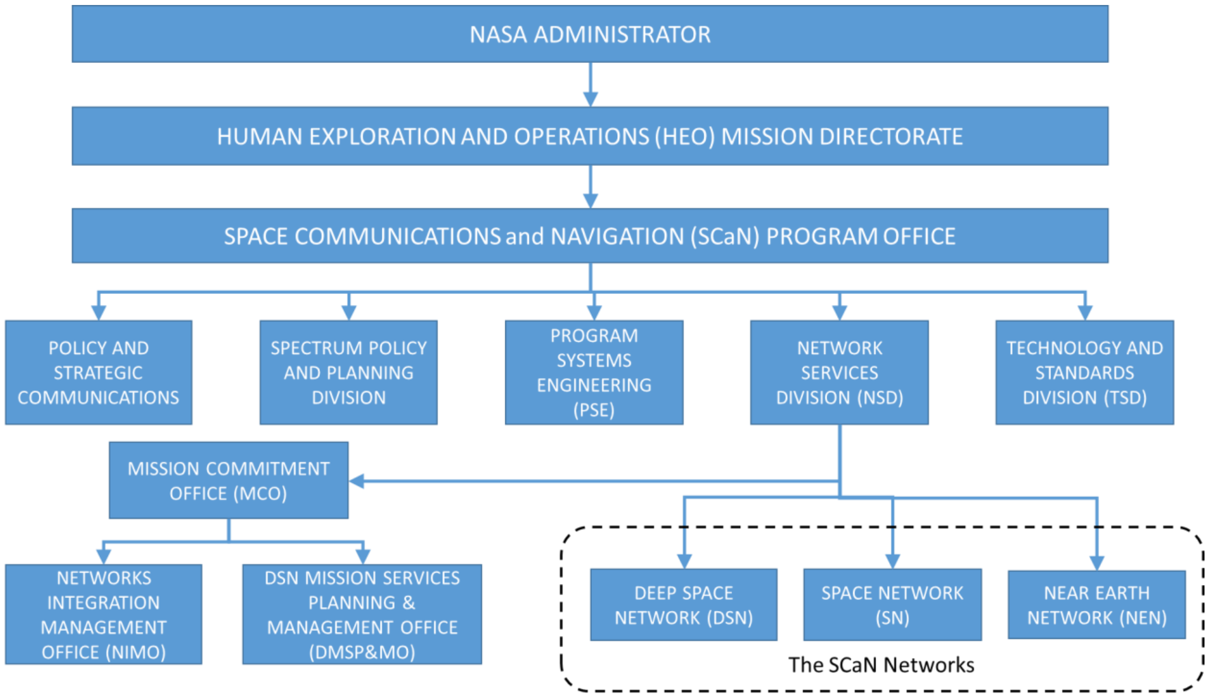


Figure 1-1: Network Functional Responsibility

1.3.1. Mission Commitment Office (MCO)

SCaN utilizes a well-established process to capture and assess user requirements in order to determine how to best support those requirements. The process is collaborative and relies on continuous communication and exchange of information between the customer and SCaN throughout all phases of mission development. It is the responsibility of SCaN's Mission Commitment Office (MCO), along with the Networks Integration and Management Office (NIMO) and the DSN/Mission Services Planning and Management Program (D/MSP&M) Office to facilitate this process on behalf of the SCaN networks.

1.3.2. The SCaN Networks

The SCaN networks – comprised of the Near Earth Network (NEN), the Space Network (SN), and the Deep Space Network (DSN) - provides communications and navigation services over the full operational life cycle of a mission from launch to de-orbit. While missions may have a desire to use specific resources, in accordance with NPD 8074.1 Management and Utilization of NASA's Space Communication and Navigation Infrastructure, the SCaN networks will make the final decision on the provision of its assets.

1.3.2.1. Deep Space Network

The DSN, consisting of ground stations utilizing 34 and 70 meter antennas, is focused on providing precise support to missions operating beyond Geosynchronous Earth Orbit (GEO). Historically, the DSN has supported Lunar, Lagrangian, and planetary missions. The DSN operations are the responsibility of the Jet Propulsion Laboratory (JPL), in Pasadena, CA.

1.3.2.2. Near Earth Network

The NEN, consisting primarily of ground stations with antennas up to 18 meters in diameter, is focused on supporting launch and operational activities in the Low Earth Orbit (LEO) range as well as GEO, Lunar and Earth-Sun Lagrange points. Most NEN antennas slew very quickly enabling the NEN to track Launch vehicles during ascent and high speed low altitude missions with brief visibility windows. The NEN operations are the responsibility of Goddard Space Flight Center (GSFC) in Greenbelt, Maryland.

1.3.2.3. Space Network

The SN, consisting of a constellation of relay satellites in geosynchronous orbit (GEO) pointing towards the Earth and the ground segment that operates the constellation, enables continuous communications services to missions operating in Medium Earth Orbit (MEO) and below, with support provided to Highly Elliptical Orbit (HEO) when the orbit brings the spacecraft within range. The SN has continuous visibility to missions from Launch through LEO operations. NASA’s SN is the responsibility of the GSFC in Greenbelt, Maryland.

Section 2. SCaN Network Policies and Standards

It is NASA policy that space missions receiving funding from NASA comply with all international and United States regulations, standards, and agreements. Such regulations and standards include those promulgated by the:

- International Telecommunications Union (ITU)
- National Telecommunications and Information Agency (NTIA)
- Consultative Committee for Space Data Systems (CCSDS)
- Space Frequency Coordination Group (SFCG)

Information about the ITU and NTIA regulations may be obtained from NASA's Spectrum Management Office by consulting the reference documents listed in Appendix A. Additional information on recommended CCSDS standards applicable to support from the SCaN networks, as well as recommendations of the SFCG, can also be found by consulting the reference documents listed in Appendix A.

2.1 Use of the Electromagnetic Spectrum

Per NASA Policy Directive (NPD) 2570.5E, it is NASA policy that all NASA satellite, airborne, and other missions, whether directly developed and operated by NASA or those supported through contracts or other financial agreements, that require the use of the electromagnetic spectrum shall follow the United States and international spectrum regulatory rules and processes. All uses of the radio frequency spectrum require an authorization either from the National Telecommunications and Information Administration (NTIA) if it is a Federal Government system or a license from the Federal Communications Commission (FCC) if it is a Non-Federal Government system.

The design and operation of radiofrequency communication, navigation, and sensors (i.e., any system that involves the use of the radiofrequency spectrum for transmission, reception, or both) need to consider a variety of factors including spectrum regulations, network services, spaceflight equipment availability, and others depending upon the mission needs. Additional information concerning NASA spectrum policy and processes can be found in NPD 2570.5E and NASA Radio Frequency Spectrum Management Manual (NPR 2570.1C). These requirements and processes apply to electromagnetic spectrum use for radiofrequency (<300 GHz) communication, navigation, radio science, active sensing, and passive sensing.

All missions and projects requiring the use of the electromagnetic spectrum should contact the associated Center/Facility Spectrum Manager (SM) as early in the proposal or mission development process as possible to discuss the electromagnetic spectrum operations concept and the necessary system certification and frequency authorization (licensing) requirements. The current NASA Center Spectrum Managers, NASA National Spectrum Program Manager, and other points of contact are provided on NASA's spectrum website (www.nasa.gov/directorates/heo/scan/spectrum/index.html).

2.2 Bandwidth Efficient Modulation (DSN, NEN, SN)

Missions operating in the 2, 8 and 26 GHz bands, should employ bandwidth efficient modulation methods in conformance with SFCG and CCSDS Recommendations. Spectral Emission Masks for Category A missions (r < 2 x 10^6 km, where “r” is the range from the spacecraft to Earth) are found in the Space Frequency Coordination Group’s (SFCG’s) Handbook, available on the SFCG web site. Specific modulation methods meeting the SFCG mask are enumerated in CCSDS Recommendations 401 for non-deep space and Earth resources missions, respectively.

As a matter of DSN policy, it is recommended that Category B missions (r ≥ 2 x 10^6 km) employ bandwidth efficient modulation whenever operating in the 8400 - 8450 MHz band at symbol rates above 2 megasymbols per second (Msps). CCSDS Recommendation 401 (2.4.17B) B-1 lists acceptable modulation schemes.

2.3 Coding

Most missions employ error detecting/error correcting codes to substantially improve telemetry link performance. Users are reminded that their encoders should conform to the CCSDS Telemetry Channel Coding Blue Book. Acceptable codes include, but are not limited to:

1) Convolutional r = 1/2, k = 7 only;
2) Reed-Solomon 223/255 only;
3) concatenated Convolutional / Reed-Solomon
4) Turbo codes with rates: 1/2, 1/3, 1/4, or1/6, block sizes: 1784, 3568, 7136, and 8920.
5) Low Density Parity Check (LDPC) rate 1/2

DSN will implement LDPC for all frequency bands except Near Earth Ka-band (26 GHz). The SN also supports LDPC.

Proposers are encouraged to contact the representatives listed in section Requesting Mission Commitment Office (MCO) Support 6.1 for the most recent list of acceptable codes.

2.4 Space Link Extension (DSN, NEN, SN)

Missions using DSN and SN services may utilize a standard Space Link Extension (SLE) Services Interface for transferring data to and from DSN or SN sites to control centers on the ground (e.g. Project Operations Control Center (POCC), Mission Operations Center (MOC), etc). Missions using NEN services via WS1 may also utilize SLE.

Seven international space agencies, including: Agenzia Spaziale Italiana (ASI), Centre Nationale d’Etudes Spatiales (CNES), Deutsche Zentrum fur Luft- Und Raumfahrt (DLR), European Space Agency (ESA), Indian Space Research Organization (ISRO), Japanese Aerospace Exploration Agency (JAXA), and NASA, have agreed to implement the SLE Services Interface to achieve full international interoperability. The interface architecture conforms to standards adopted by the CCSDS.

Section 3. Summary of SCaN Network Standard Services

SCaN has developed a set of *Standard Services*; services in this category are inherent to the current functional capabilities of the SCaN networks without modification. There are little-to-no modifications/dependencies on the development of new functions within any of the SCaN networks for standard services. Use of the Standard Services enables more streamlined service evaluation, acquisition, and use (e.g., scheduling). Current Standard Services include end-to-end transport of information between the point of origin (e.g., mission platform(s)) and destination (e.g., mission operations center, university, etc.).

Standard services for Data Transport facilitate the exchange of information between a mission's platform(s) and locations on the earth. Typically, minimal processing is applied to the data - only that which is necessary to communicate with the endpoints (e.g., RF encoding to IP-based transport). Transported data may include voice, video, and/or data. Note that Command and Telemetry data are critical subsets of Forward and Return data transport functions. As services for this type of data deal particularly with the exchange of information to and from a mission's platform(s) for the purposes of monitoring and maintaining control of the platform, this information is typically of higher priority than other categories of data to be transported by the SCaN networks.

This section provides a very brief summary of the standard services that the SCaN networks offer their customers. For additional information on these services, please reference the SCaN Services Catalog (see Appendix A for reference information). Each of the service categories listed in the tables below may contain several services and some of those individual services may require that special arrangements be made with SCaN before they can be provided. Proposers who are interested in services that are not a part of the standard TT&C set should contact the person(s) named in Section 6. for additional information.

3.1 NEN Service Summary

Table 3-1 summarizes the NEN service categories. More detailed information can be found in the SCaN Services Catalog and the NEN User Guide (See Appendix A for references).

Table 3-1: NEN Service Summary

Service Category	Service	Service Type	Brief Description
Data Transport	Forward	Data Stream	Forward: Transmission of voice, video, and/or data, and delivery of telecommands to spacecraft Return: Telemetry voice, video, and/or data capture, decoding and additional value-added data routing.
	Return	Data Stream	
Navigation and Radiometric	Radiometric	Raw Doppler	Measurements and products based on one-way Doppler, two-way Doppler, and range tones; Processing to determine orbital elements for mission platform navigation
	Radiometric	Raw Ranging	
	Radiometric	Tracking Angle Data	

3.2 SN Service Summary

Table 3-2 summarizes the service categories provided by the SN. More detailed information can be found in the SCaN Services Catalog and the SN User Guide (See Appendix A for references).

Table 3-2: SN Service Summary

Service Category	Service	Service Type	Brief Description
Data Transport	Forward	Data Stream	Forward: Transmission of voice, video, and/or data, and delivery of telecommands to spacecraft Return: Telemetry voice, video, and/or data capture, decoding and additional value-added data routing.
	Forward	Forward Communications Link Transmission Unit (FCLTU)	
	Return	Data Stream	
	Return	All Frames	
	Return	Channel Frames	
Navigation and Radiometric	Radiometric	Raw Doppler	Measurements and products based on one-way Doppler, two-way Doppler, and PN ranging; Processing to determine orbital elements for mission platform navigation
	Radiometric	Raw Ranging	
	Radiometric	Tracking Angle Data	

3.3 DSN Service Summary

Table 3-3 summarizes the service categories supported by the DSN. More detailed information can be found in the SCaN Services Catalog and the DSN Service Catalog (see Appendix A for references). See Table 3-3 for a list of standard DSN services included in the *Aperture Fee.*

Table 3-3: DSN Service Summary

Service Category	Service	Service Type	Brief Description
Data Transport	Forward	Forward Communications Link Transmission Unit (FCLTU)	Forward: Transmission of voice, video, and/or data, and delivery of telecommands to spacecraft Return: Telemetry voice, video, and/or data capture, decoding and additional value-added data routing.
	Forward	File	
	Return	All Frames	
	Return	Channel Frames	
	Return	File	
	Return	Packet	
Navigation and Radiometric	Radiometric	Validated Doppler	Measurements and products based on one-way Doppler, two-way Doppler, and range tones; Processing to determine orbital elements for mission platform navigation. Radio interferometric techniques used to determine the plane-of-sky position and velocity of a user mission platform (Delta-DOR).
	Radiometric	Validated Ranging	
	Radiometric	Delta-DOR	
Science	Science	Radio Science	Radio: Open-loop receiver measurements. VLBI: Similar to Radio Science but measures natural phenomena. Wide & narrowband VLBI. Radar: Transmits RF carrier toward user defined target; captures reflected signal.
	Science	VLBI/Radio Astronomy	
	Science	Radar Science	

3.4 MCO Service Summary

Table 3-4 summarizes the services supported by MCO. More detailed information can be found in the SCaN Services Catalog (see Appendix A for reference information).

Table 3-4: MCO Service Summary

Task	Brief Description
Network Loading Assessment and Analysis	Assess User Requirements and Feasibility of Support
Service Level Agreements (DSA/PSLA)	Definition of agreement terms involving SCaN's commitment to missions' space communications services; includes inter-agency, international, commercial, etc. agreements; Definition of the internal agreement terms for utilizing each of the SCaN network's resources for DSN, SN, NEN; Evaluation of mission goals and communication needs; Recommendation for SCaN's network(s) support based on mission's needs and logistics (e.g., orbit, data volume, etc.); Participation during mission concept and definition phases; Documentation of the PSLA / DSA, including collaboration agreements for periodic updates to the PSLA/DSA and Flight Dynamics Facility (FDF) and Advanced Multi-Mission Operations System (AMMOS) support, which is also documented in the PSLA/DSA.
Network Verification Testing	Telecommunications interface design, compatibility testing, Coordination of testing and critical mission event supports, Performance and documentation of the verification tests
Access to Service Management Capabilities	Monitoring of execution and the mission satisfaction metrics, Monitoring of the SCaN network-specific implementation activities to ensure that capabilities will be available to the mission
Readiness Reviews	Compilation of detailed network requirements SCaN services, Assessment of readiness of the SCaN networks to satisfy mission requirements
Network Integration Management	Provide and integrate network services to assure the continued understanding of the mission's requirements, concerns, system performances, etc.
Anomaly Resolution Support	Provide the engineering and operational support necessary to resolve spacecraft/instrument issues
Post Mission Reporting	Reporting on network activity and network status, Review and assessment of the planning and operations activities executed during mission support

3.5 Critical Event Communications

Critical Events are defined as: “spacecraft events that could result in the loss of mission if anomalies occur.” These events include launch, early orbit operations, and those listed as follows:

- Spacecraft separation
- Powered flight
- Critical Maneuvers (e.g., DSMs)
- Orbit insertion
- Entry/Descent/Landing
- Flybys

Any of the networks (NEN, SN or DSN) can provide critical event support - including launch, early orbit and separation - if the launch trajectory permits. However, in cases where there are gaps, another Agency’s Earth station or a small portable station may be required.

Section 4. Support from Non-SCaN Network Service Providers

If needed, the SCaN networks will assist user missions with procuring services from other non-SCaN network entities and partners, including but not limited to other SCaN divisions, other NASA organizations, other government agencies and international and commercial partners. This section discusses the most common external organizations for whom the SCaN networks assist missions with procuring services.

4.1 Spectrum Management

Although the Spectrum Management Office falls under the responsibility of the SCaN Program Office, it is not part of the SCaN networks or MCO (see Figure 1-1). It is NASA policy that any NASA satellite mission, whether directly developed and operated by NASA or those supported through contracts or other financial agreements, that require the use of the electromagnetic spectrum for transmission, reception, or both shall follow the United States spectrum regulatory rules and processes, as well as all applicable international spectrum regulations.

The Center/Facility Spectrum Manager or NASA National Spectrum Program Manager will provide assistance during all phases of a mission or project from conceptual, pre-proposal efforts through formulation and implementation. The Spectrum Manager will support the project at each review in the project life cycle and assist with design and spectrum considerations such as frequency selection, conformance to regulatory constraints and other electromagnetic spectrum parameters. A key element of this support is assisting with or preparing inputs for spectrum certification as early in the acquisition and procurement cycles as possible.

If support from the Spectrum office is required, proposers may either contact their local center Spectrum Manager or the National Spectrum Program Manager directly, or request assistance in coordinating Spectrum support from the SCaN networks by consulting one of the Points of Contact listed in Section 6.

4.2 Communications Service Office (CSO)

The Communications Service Office (CSO) provides Wide Area Network (WAN) and Local Area Network (LAN) voice, video and data services in support of the Agency.

The Corporate Communications Services are managed out of Marshall Space Flight Center (MSFC) and include NASA-wide voice and video teleconferencing, corporate network routed data services as well as Layer 2 Virtual Private Network service. The fundamental function of these services is to provide enterprise level communications services across the Agency.

The Mission Communications Services are managed out of GSFC and include mission routed data services (including IOnet), dedicated mission data services and mission voice services. The fundamental function of these services is in support of spacecraft operations. These include terrestrial transport of spacecraft command, telemetry and tracking data as well as delivery of science data products. The Mission Network must also address risks to the health and safety of human life as well as serious damage or loss of spacecraft. The mission voice services provide order wire and other voice service in support of spacecraft operations.

4.3 Flight Dynamics Facility (FDF)

The Goddard Space Flight Center Flight Dynamics Facility (FDF) provides expertise in navigation analysis and system design, operations planning, trajectory design, orbit determination, network operations support, and critical real-time mission operations. This expertise spans the technical areas of orbit determination and trajectory design for low-Earth, geosynchronous, highly elliptical, lunar, libration-point, heliocentric orbits, other celestial-body centered orbits expendable launch vehicle (ELV) and human spaceflight operations, and support of over 25 on-orbit spacecraft.

FDF evaluates tracking data from the SN, NEN, DSN, and NASA and Department-of-Defense C-band radar sites, and certifies tracking capability for new stations needed for mission support. FDF also participates as end-to-end verification and validation to ensure that FDF products, such as pointing data for the SN and NEN, are received in the proper format. Mission integration is a part of FDF's support of the SCaN networks and its flight project customers. FDF can interface with any of the 3 component networks – NEN, SN or DSN- to support a mission's flight dynamics needs. Products include ephemerides, acquisition data that is used to establish two-way communication with space vehicles, maneuver planning and execution for spacecraft, on-console support for testing and real-time operations, evaluation of ELV performance during ascent utilizing guidance data and other navigation sources, local oscillator frequency analysis for TDRS transponders, orbit event predictions, and calibration of sensors used for tracking spacecraft.

The capabilities of the Goddard FDF include the following:

1) orbit determination in multiple regimes;
2) launch vehicle support including, but not limited to, Atlas V, Delta II, Delta IV, and Sea Launch;
3) launch and early-orbit support utilizing a diversity of networks;
4) tracking performance evaluation of a multitude of ground-based and spaceborne assets;
5) certification of new tracking equipment;
6) mission integration that combines engineering knowledge of the SCaN networks' and the analytical and operation aspects of our flight project customers;
7) FDF provides backup navigation support to the Human Spaceflight Program; and,
8) International Space Station orbit determination and support to all Visiting Vehicles.

4.4 Advanced Multi-Mission Operations System (AMMOS)

Advanced Multi-Mission Operations System (AMMOS) is the responsibility of the Multi-Mission Ground System and Services (MGSS) Program located at the Jet Propulsion Laboratory (JPL). AMMOS consists of a core set of products that can be readily customized to accommodate the specific needs of individual missions. AMMOS provides the elements of a Mission Operations System (MOS) that are common to multiple missions eliminating the need for duplication of development and maintenance of the MOS. Using AMMOS may lower mission cost and risk by providing a mature base for a MOS.

AMMOS comprises multi-mission hardware, software, processes, procedures, and facilities used to implement and operate the Mission Operations System (MOS). Components of the AMMOS include:

- Planning & Sequencing
- Telemetry Processing
- Data Archive
- Navigation, Mission Design, and Solar System Dynamics
- Operations Configuration Management
- Mission Support Facilities
- GDS Integration, Test, Deployment & Support
- Operations Engineering
- Data Relay Coordination for Landed Assets who do not have the direct to earth bandwidth needed to execute the mission

AMMOS supports the entire lifecycle of a flight project or experimental investigation.

4.5 Jet Propulsion Laboratory Mission Design and Navigation

The JPL Mission Design and Navigation Section (MDNAV) provides support in mission design, deep space navigation analysis and operations planning, orbit determination, maneuver design and analysis, critical real-time mission operations, and network operations support. MDNAV typically supports on the order of 25 space missions through all mission phases from pre-project through termination.

The MDNAV charter is to build the maps and tools for interplanetary navigation, design efficient routes for spacecraft to reach any remote Solar System location (including within the Earth-Moon system), and safely pilot spacecraft to their ultimate destination. The overarching themes of this work are science-driven modeling, filtering and optimization, managing trajectory knowledge, control, observability, and uncertainties.

The capabilities of JPL MDNAV include the following:

1) Development and refinement of precision ephemerides for solar system bodies;
2) Trajectory design and optimization satisfying multiple mission constraints;
3) Launch and early-orbit phase operations for missions utilizing the DSN;
4) Orbit determination in multiple regimes;
5) Maneuver design and analysis;
6) Multi-mission flight dynamics software development;
7) Astrodynamics technology research and development; and
8) Certification of new tracking equipment.

Section 5. Network Support Costs

As a matter of policy, NASA includes estimated costs for mission operations and communications services, as well as an assessment of key parameters for mission operations, in the evaluation and selection processes of all Earth-orbiting and deep space missions. NASA is implementing this policy to:

- implement formal NASA-wide full-cost accounting,
- better manage NASA's heavily subscribed communications resources,
- promote tradeoffs between on-board processing and storage vs. communications requirements, and
- encourage hardware and operations system designs minimizing life cycle costs while accomplishing the highest-priority science objectives.

Generally, mission proposals must include non-recurring (i.e., MP&I) and recurring estimates, as well as those for services during launch and operations support. This section explains how to estimate costs for the DSN, NEN, and SN. Cost numbers and equations supplied in this section are for planning purposes only. The calculated estimate of services provided is required to document the full value of the mission and its services. NASA missions that use standard services will not be charged for aperture or per minute fees. However, to ensure accurate application of this information and to validate cost estimates, please contact the appropriate representatives listed in Section 6.

5.1 Non-Recurring Engineering Costs

Non-recurring engineering (NRE) costs cost (e.g., Tracking, Telemetry & Command (TTC), ground communications, Mission Integration Manager) are highly mission-dependent. NRE costs includes any unique equipment that a mission requires as well as its installation and the sustaining engineering of that equipment as well as modifications that JPL / DSN must make to their systems in order to recognize a new mission. It is not possible to provide a simple cost structure such as the one used for the specific stations and/or services. Proposers are advised to contact the point of contacts listed in Section 6. to obtain a cost estimate for their missions.

5.2 Mission Planning and Integration (MP&I)

MP&I is the set of activities performed and coordinated by the Space Communications and Navigation (SCaN) Mission Commitment Office (MCO), NIMO, and DMSP&MO to assure successful provision of NASA's space communications services to evaluate and address mission needs. It includes those tasks that must be executed prior to the operational use of the SCaN networks. Typically, they occur prior to the launch of a space vehicle, although they may occur any time within the life of a mission if changes are needed. Additionally, for longer-duration missions (e.g., interplanetary), an MP&I phase is typically incorporated during the initial Planning activities. MP&I ensures common understanding of the mission services requirements; the abilities of the SCaN networks; and mutual compatibility between the mission (i.e., platform(s), mission operations center(s)) and the SCaN networks. Funding of these efforts is dictated by NASA policies. Because both NASA missions and SCaN are funded through NASA, NASA missions fund SCaN only for the MP&I activities related to the dependencies on their processes/functionality (e.g., planning and development for non-standard services); they are not charged for the SCaN networks' internal management functions related to standard services (e.g., network capacity planning). Conversely, non-NASA missions are responsible for funding all network integration and data services activities in support of their missions, including reimbursement of SCaN costs in support of their MP&I activities. It is not possible to provide a simple cost structure such as the one used for the specific stations and/or services. Proposers are advised to contact the point of contacts listed in Section 6. to obtain a cost estimate for their missions.

5.3 Costs for Using the Near Earth Network and Space Network

The NEN and SN use a standard equation for determining the costs of providing services, per pass for the NEN and per minute for the SN.

For the purpose of initial estimates, the cost of using the NEN's S-band, X- band, and/or Ka-band forward and return services is $490.00 per pass, where one pass is ≤ 30 minutes. Proposers are encouraged to get the most recent rates directly from NEN Website: http://www.nasa.gov/directorates/heo/scan/services/networks/txt_nen.html.

The rates for using the SN are dependent on the service provided. For the purpose of initial estimates, the rates at the writing of this document were as follows:

- Single Access Service (forward/command, return/telemetry, tracking, or any combination of these) - $132.51 per minute.
- Multiple Access Forward Service - $21.41 per minute.
- Multiple Access Return Service - $12.23 per minute.

However, proposers are encouraged to get the most recent rates directly from SN Website: http://www.nasa.gov/directorates/heo/scan/services/networks/txt_sn.html.

5.4 Costs for Using the Deep Space Network

To simplify DSN costing, an algorithm has been developed permitting users to calculate the DSN Aperture Fee and included services. It should be noted that user costs vary with aperture size (e.g. 34 meter vs. 70 meter) and utilization level. DSN service operations and maintenance costs (see Table 5-1) are included in the Aperture Fee (see section 5.4.1).

Table 5-1: Service Types Included in DSN Aperture Fee

Service Category	Service	Service Type / Detail
Data Transport	Forward / Command	Command Radiation Command Delivery
Data Transport	Return / Telemetry	Frame Packet Telemetry File
Navigation and Radiometrics	Tracking	Validated Radiometric Data Delta-DOR Data
Science	Radio Science	Experiment Access Data Acquisition
Science	Radio Astronomy / VLBI	Signal Capturing VLBI Data Acquisition
Science	Radar Science	Experiment Access Data Acquisition

5.4.1. DSN Aperture Fees

The algorithm for computing DSN Aperture Fees embodies incentives to maximize DSN utilization efficiency. It employs weighted hours to determine the cost of DSN support. The Equation 5-1 can be used to calculate the hourly Aperture Fee (AF) for DSN support.

Equation 5-1: DSN Aperture Fee Calculation

AF = RB [AW (0.9 + FC / 10)]

Where:

AF = weighted Aperture Fee per hour of use.

RB = contact dependent hourly rate, adjusted annually

AW = aperture weighting:

= 1.00 for all other 34-meter stations (i.e., 34 BWG and 34 HEF).

= 2.00 for a two 34-meter station array.

= 3.00 for a three 34-meter station array.

= 4.00 for a four 34-meter station array (70-meter equivalent).

= 4.00 for 70-meter stations.

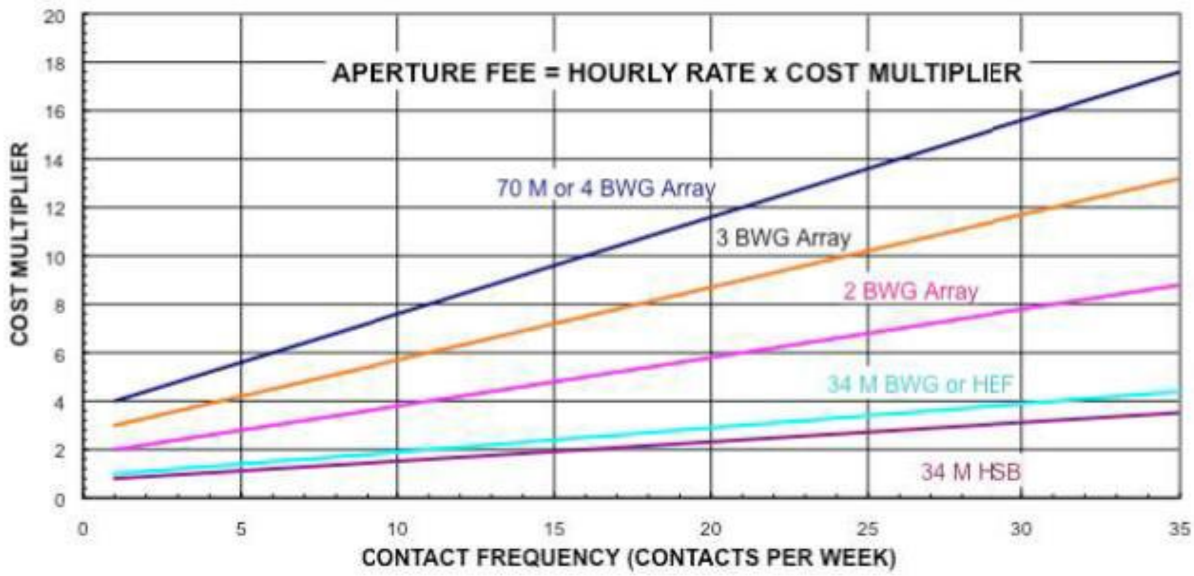
FC = number of station contacts (contacts per calendar week).

The *weighting factor* graph below shows relative antenna costs graphically illustrating how hourly costs vary with station contacts and the relationships between antennas. It demonstrates the benefits of restricting the number of spacecraft-Earth station contacts each week.

For the purpose of initial estimates, the *contact dependent hourly rate (RB)* was $1037 at the time of publication. However, proposers are encouraged to contact DSMP&MO (see section 6.3 for Points of Contact) for the most up to date rate information.

A *station contact, FC,* may be any length but is defined as the lesser of the spacecraft's scheduled pass duration viewperiod, or 12 hours.

For a standard pass, a 45-minute setup and a 15-minute tear-down time must be added to each scheduled pass to obtain the station contact time (other configuration times apply to Beacon Monitoring and Delta-DOR passes – see relevant cost sections below). Note that scheduled pass-lengths should be integer multiples of 1-hour with a maximum of 12 hours per pass.



NOTE: 34m HSB have been replaced with Beam Wave Guides (BWG)

Figure 5-1: Aperture Fee Calculation Chart

Total DSN cost is obtained by partitioning mission support into calendar weeks, grouping weeks having the same requirement in the same year, multiplying by weighted Aperture Fee, and summing these fees over the mission's duration. Aperture Fees include several services in the following categories: command, telemetry, tracking, radio science, radio astronomy, radar science, and services.

5.4.2. DSN Costing Calculations

Calculate DSN costs (Aperture Fee, AF in $/Hr.) by selecting a specific antenna and then determining the number and duration of tracking passes required to satisfy project commanding, telemetry, and navigation for launch, cruise, maneuvers, and science phases. Each tracking pass, except Beacon Mode, DDOR, and a few others must be increased in length by one-hour for re-configuration. Once the pass length and number of passes is determined, multiply the aggregate hours by the hourly Aperture Fee, adjusted to the applicable fiscal year, to compute the mission's cost (in FY Dollars) using Equation 5-1.

A form entitled DSN Mission Support Costs (see Appendix D), can be used to calculate DSN Aperture Fees in real-year or fiscal year Dollars (FY Dollars). An Excel DSN Aperture Fee Tool is available for the preparation of the cost estimates. To obtain a copy, either contact the person named in section 6.3 or the DSN web site (see Appendix A for reference).

5.4.3. DSN Fee Reduction for Utilizing Multiple Spacecraft per Antenna (MSPA)

Some flight programs, such as those surveying Mars, have clustered several spacecraft about a planet/body. It is possible to simultaneously capture telemetry signals from two or perhaps more spacecraft provided that they lie within the beamwidth of the Earth station's antenna.

If this situation applies and the constraints, set forth here and in the DSN Service Catalog, are acceptable, then it may be possible to reduce the Antenna cost by half for spacecraft operating without an uplink in a non-coherent mode. To calculate the cost, first compute the Aperture Fee using Equation 5-1. Thereafter, apply the correction factor according to the formula:

Equation 5-2: Aperture Fee Cost for MSPA

$$AF' = (0.50)\ AF$$

Where: AF' = weighted Aperture Fee per hour of use for spacecraft operating without an uplink in the MSPA mode. (Spacecraft having an uplink when operating in an MSPA mode should use the aperture fee (AF) computed according to Equation 5-2.)

The reduced price, AF', reflects the lack of capability resulting from no uplink communications. It is based upon the loss of commanding and ranging services to the spacecraft operating in a one-way non-coherent mode. If MSPA users agree, all could time-share the uplink and then re-allocate cost savings according to their individually negotiated sharing arrangements. When switching the uplink from one spacecraft to the next, full costs, AF, begin to apply to the new two-way coherent user at the onset of the switching operation.

MSPA exists if, and only if, the same DSN antenna is simultaneously supporting two or more spacecraft without regard to whether an uplink is required by either.

5.4.4. Clustered Spacecraft Aggregated DSN Costing

Occasionally a mission comprises several spacecraft flying in a geometric formation, but with spacing too large to utilize MSPA. Rather than request simultaneous support from several DSN stations, the project may agree to sequentially contact each spacecraft. From a project viewpoint, it is desirable to treat sequential DSN communications with several spacecraft as a single DSN contact for costing purposes. For information on the condition and constraints that allow for Clustered Spacecraft Aggregation, please see the SCaN Services Catalog.

Clustered Spacecraft Aggregated DSN Costs are calculated by:

- Adding a single setup and tear-down time for the aggregated period,
- Including costs for time needed to move from one spacecraft to the next,
- Treating the series of links during a pass as a single contact for the costing algorithm,
- Computing the cost following Equation 5-1 in section 5.4.1.

All missions consisting of a cluster of spacecraft not meeting the above criteria should calculate their costs using Equation 5-1 in Section 5.3.1 treating each sequential communication with a member of the cluster as a separate and individual contact.

5.4.5. Data Relay DSN Costing

Data between a landed object and a DSN station, which is relayed through an orbiting spacecraft, may be unaccompanied or interspersed with data from other sources. At any specific time, a DSN station may be communicating with one or more surface objects.

Proposals for missions employing relays should include their pro-rata share of the DSN station cost. Pass cost can be found by calculating the time required to return the total amount of relayed data, assuming that only this data being transmitted from the orbiting relay element or by assuming 1-hour, whichever is greater. Station configuration times need not be considered. Proposals should state their rationale and assumptions for their computed share of the DSN cost carefully, completely, and in sufficient detail so that evaluators can independently verify the computations.

5.4.6. Delta Differential One-way Range (DDOR) DSN Costing

Under the correct geometric circumstances, Delta Differential One-way Range (DDOR) can result in a net reduction in needed tracks. This is so because adding DDOR passes can reduce the number of contacts needed to collect long data arcs of coherent Doppler and ranging measurements necessary to compute a spacecraft's trajectory. DDOR can also be used as an independent data source to validate orbit solutions. However, two widely separated Earth stations are required simultaneously to view the spacecraft and the natural radio sources.

DSN 34M and 70M stations can be used to collect DDOR data. To calculate a cost for a DDOR pass, users should determine the following:

1) DSN stations desired for the DDOR pass;
2) Amount of DDOR data required to obtain the spacecraft's position;
3) Pass length needed to obtain the data;
4) Setup time of 90-minutes (a 45-minute standard pass setup period for the station plus an additional 45-minutes for DDOR). The tear-down time remains at 15-minutes for each DDOR pass (Note: This is 90-minute setup plus 15-minutes tear-down time for each station in the DDOR array.); and
5) Cost of the pass by summing the cost for the two desired DSN stations plus setup and tear-down times over the length of the pass.

5.4.7. Beacon Tone Monitoring DSN Costing

Beacon Tone Monitoring is a low-cost method for verifying spacecraft health. A spacecraft transmits up to four predetermined tone frequencies (subcarriers) indicating its current condition. Spacecraft must be designed to monitor their subsystems and direct an appropriate tone be transmitted. Beacon Tone Monitoring is particularly useful during long cruise periods when little or no science data is being collected.

Beacon Tone tracks (exclusive of configuration time) are generally short (40 to 60-minutes) and must occur at pre-scheduled times when the spacecraft is in view of a DSN complex. DSN 34M or 70M stations capture tones and project personnel are informed of the frequency received. They, not DSN personnel, must determine the meaning of the received tone.

Because no science or housekeeping data is received, it is possible to reduce the configuration times and hence cost for Beacon Tone Monitoring. Proposers calculating a cost for Beacon tone Monitoring should compute Aperture Fee (AF) for the requested DSN antenna using a setup time of 15-minutes and a tear-down time of 5-minutes (rather than 45-minutes and 15-minutes respectively). The minimum pass length, including configuration times, is 1-hour (40-minute pass plus 20-minutes of setup and tear-down time).

5.4.8. Compatibility Testing DSN Costing

DSN requires pre-launch compatibility testing as a means to eliminate post-launch anomalies and expensive troubleshooting. The DSN maintains two facilities, known as the Development and Test Facility (DTF-21), and the Compatibility Test Trailer (CTT-22). Except for the high power transmitter, antenna, and low noise-receiving amplifier, which are not included, these facilities are configured much like an operational DSN Earth station.

Approximately eighteen months prior to launch, projects should bring their Radio Frequency Subsystems (RFS) to DTF-21 for testing. Testing requires approximately two weeks and includes such items as RF compatibility, data flow tests, and transponder calibration. Additional testing can be arranged by utilizing CTT-22 at the spacecraft manufacturing facility, if required. $45K will be charged to the project for each compatibility test event.

5.5 Critical Event Support Costing

Critical Event support, which can be obtained from one of NASA’s standard networks (DSN, NEN, SN), is computed in the same way as for routine telemetry support. If it is not possible to utilize one of the NASA networks because no station element is in view or they are otherwise unavailable, then estimates will have to be provided by the appropriate network representatives identified above.

Because mission requirements vary over such a broad range, it is not possible to provide a simple means to calculate the cost of telemetry support in the early mission phase. Please see Section 6. for the point of contact who can assist in establishing alternative solutions and/or in costing the required support.

5.6 Non-SCaN Networks Support Costing

Cost for support from non-SCaN networks resources and entities is dependent on the mission needs and the supporting entity to be used. However, if requested, SCaN will integrate the requested support into the overall network plan. SCaN negotiates the costs for using non-SCaN assets on a contractual basis and, therefore, cannot include that information in this document. The SCaN networks have no control over the costs for commercial and / or international service providers. If support is required from outside the SCaN networks, proposers should contact MCO for assistance in determining the potential cost of those services. Please see Section 6. for the appropriate point of contact.

Section 6. Requesting Support from the SCaN Networks

Early planning and coordination between SCaN and its customers is critical to ensuring quality service with minimal complications. Proposers are encouraged to contact SCaN as early in their development process as possible to begin pre-mission planning and analysis activities.

During the concept study phase (Phase-A or Step-2), as the mission's concept is more clearly defined, a Letter of Commitment (LOC) is generated or updated from Step-1. The resulting documentation of services and costs will be captured in the Project Service Level Agreement (PSLA) or DSN Service Agreement (DSA) to be signed by appropriate Project and Network representatives by PDR for the PSLA and CDR for the DSA. The PSLA / DSA will identify all mission operations requirements, including those provided by non-SCaN sources, becoming a source of end-to-end operations information and documenting any cost analyses leading to the selection of non-SCaN services. A Letter of Commitment (LOC) is only done for Step-1 if non- standard services are required. Please reference the AO documentation for a description of Phase –A, Step-1 and Step-2 requirements.

6.1 Requesting Mission Commitment Office (MCO) Support

Missions desiring use of SCaN Services should make contact with the SCaN networks as early in the development process as possible. For missions whose assets will be in deep space, contact the DSN/Mission Services Planning and Management Program (D/MSP&M) Office. Missions whose assets are in LEO should contact the Networks Integration Management Office (NIMO). Missions whose assets are near Earth but beyond LEO may contact either office; the office's first duty will be to help the mission decide which network, or combination of networks, should be used. Missions may also contact the SCaN Mission Commitment Manager for questions related to which network is appropriate.

The NASA Headquarters point of contact for SCaN assets is:

Gary A. Morse
Mission Integration & Commitment Manager
Space Communications and Navigation (SCaN)
NASA Headquarters
Washington D.C 20546
Office: HQ:7J88
Phone: (202) 358-0504
Email: gary.a.morse@nasa.gov

6.2 Process for Requesting NEN or SN Services

At the time when initial science operations concepts are being defined, proposers should contact the person named below for information about NEN and/or SN mission operations services and costs. A representative from the NIMO will assist proposers by providing service and cost information. Further, NIMO aids in documenting initial mission operations requirements in a Networks proposal package.

The NEN and SN point of contact for AOs is the GSFC NIMO:

Scott A. Greatorex, Chief
Networks Integration Management Office, Code 450.1
Exploration and Space Communications Projects Division
Goddard Space Flight Center, Greenbelt, MD 20771
Phone: (301) 286-6354;
FAX:(301) 286-0275
e-mail: Scott.A.Greatorex@nasa.gov

6.3 Process for Requesting DSN Services

Proposers should contact the person(s) named below for information about DSN mission operations services and costs at the time when initial science operations concepts are being defined. A representative will assist proposers by providing information concerning services and costs.

In order to properly estimate and document the requirements for DSN services and support, a minimum lead-time of six weeks must be allowed for the study.

Contact information for the POC, and for his alternate, may also be found on the DSN website at http://deepspace.jpl.nasa.gov/advmiss. The DSN point of contact for DSN services is the DSN/Mission Services Planning and Management Program (D/MSP&M) Office:

Stefan Waldherr
Mission Interface Manager
Jet Propulsion Laboratory
M/S 301-355
4800 Oak Grove Drive
Pasadena, California 91109-8099
Phone: (818) 354-3416
e-mail: stefan.waldherr@jpl.nasa.gov

Appendix A. Reference Documents and Websites

Prospective users of NASA facilities can obtain additional information from the following documents:

1) *Radio Regulations*, International Telecommunications Union, Geneva, Switzerland, Latest Edition.
2) *Manual of Regulations and Procedures for Federal Radio Frequency Management*, National Telecommunication & Information Administration, U.S. Department of Commerce, Washington D.C., Latest Edition. ***Information is available at:*** http://www.ntia.doc.gov/osmhome/redbook/redbook.html
3) Consultative Committee for Space Data Systems (CCSDS). Blue Books published by the CCSDS Secretariat, NASA Headquarters, Washington D. C. 20546. ***Copies of CCSDS Recommendations and Reports are available at:*** http://public.ccsds.org/publications/default.aspx
4) *Space Frequency Coordination Group On-Line Handbook*, ***Recommendations and other technical documents are available at:*** https://www.sfcgonline.org/resources
5) *Management and Utilization of NASA's Space Communication and Navigation Infrastructure,* NPD 8074.1. ***Copies of the document are available at:*** http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPD&c=8074&s=1
6) NIMO Commitments homepage. ***Web site located at:*** http://esc.gsfc.nasa.gov/space-communications/nimo.html
7) DSN Commitments homepage. ***Web site located at:*** http://deepspace.jpl.nasa.gov/advmiss
8) *Space Communications and Navigation Network Service Catalog*, SCaN-SERVICE CATALOG. ***Copies of the document are available at:*** http://esc.gsfc.nasa.gov/space-communications/nimo.html
9) *DSN Service Catalog*, DSN No. 820-100, Rev. F, JPL D-19002, Jet Propulsion Laboratory, ***latest copies available at:*** http://deepspace.jpl.nasa.gov/advmiss
10) *Near Earth Network Users Guide,* Revision 1, 453-NENUG, latest copies available at:http://esc.gsfc.nasa.gov/assets/files/453-UG-002905%282%29.pdf
11) *Space Network Users Guide*, Revision 10, 450-SNUG, latest copies available at: http://esc.gsfc.nasa.gov/assets/files/450-SNUG.pdf
12) Spectrum Management Office homepage. ***Web site located at:*** http://www.nasa.gov/directorates/heo/scan/spectrum/index.html
13) Flight Dynamics Facility (FDF) homepage. ***Web site located at:*** http://fdf.gsfc.nasa.gov/services
14) Communications Service Office (CSO) homepage. ***Web site located at:*** https://cso.nasa.gov/learn
15) AMMOS catalog. ***Web site located at:*** http://ammos.jpl.nasa.gov
16) Spectrum Management Office points of contact. ***Web site located at:*** http://www.nasa.gov/directorates/heo/scan/spectrum/txt_NASA_Spectrum_Personnel.html

17) NPD 2570.5E, NASA Electromagnetic Spectrum Management, 11 July 2011. ***Copies of the document are available at:*** http://nodis3.gsfc.nasa.gov/lib_docs.cfm?range=2
18) NPR 2570.1C, NASA Radio Frequency Spectrum Management Manual, 22 Sep 2014. ***Copies of the document are available at:*** http://nodis3.gsfc.nasa.gov/lib_docs.cfm?range=2

Appendix B. Sample NIMO Questionnaire

Customer Questionnaire

PART A – GENERAL 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 ☐ Implementation ☐ Operations ☐ Extended operations

Expected mission duration: Potential extended operations:

Are you planning on utilizing GSFC Flight Dynamics Facility (FDF) services? ☐ Yes ☐ No ☐ Not sure

Where is the control center?

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

Are you planning on utilizing NASA Integrated Services Network (NISN) Internet Protocol Operational Network (IONet) services? ☐ Yes ☐ No ☐ Not sure

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

What are your expectations for Space Network (SN) and/or Near Earth Network (NEN) services?

Do you require SN or NEN 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 SN or NEN services during powered flight? ☐ Yes ☐ No ☐ Not sure

Do you require SN or NEN 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 SN and NEN services requested, if known (check all that apply):

Service	SN	NEN	Not sure
Telemetry	☐	☐	☐
Tracking*	☐	☐	☐
Science Data	☐	☐	☐
Command	☐	☐	☐
Ranging	☐	☐	☐

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

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

Mark events:

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

Activity	SN	NEN	Not sure
Testing	☐	☐	☐
Launch only	☐	☐	☐
Launch and early orbit**	☐	☐	☐
Please define sub-phases			
Back-up contingency	☐	☐	☐
On-orbit special events	☐	☐	☐
Please define sub-phases			
Nominal operations	☐	☐	☐
End-of-life (EOL)	☐	☐	☐

What are your post launch checkout phase definitions?

(continued on next page)

Customer Questionnaire

Frequency

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

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

What modulation will be used with each band?

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

Data Delivery

Command (R/T forward link) data rates:

Telemetry (R/T return link) data rates:

Science data volume per contact (Mbytes)

Latency (science data delivery) requirements:

Launch-Related Information

Launch site location:

Launch date:

Launch window:

Launch vehicle:

Launch trajectory:

Recycle time for launch scrubs:

Orbit Information

Apogee and perigee, or semi-major axis and eccentricity:

Inclination:

Argument of right ascension:

Nodal crossing type (ascending or descending):

Local time of nodal crossing:

Will there be any transfer orbits?

Repeat cycle, if appropriate:

Spacecraft Services Information

	Space Network (SN)			Near Earth Network (NEN)		
	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:

Appendix C. Sample DSN Communications System Parameter Tables

The requirements in this appendix do not apply to Step-1 proposals. They apply only to the Concept Study Reports (CSRs) that will be prepared by investigations selected at the outcome of Step-1, to conduct Phase A concept studies.

As a minimum, proposals should contain the set of telecommunications parameters shown in Table C-1. While proposers may or may not wish to use a tabular format, the required parameter values should be supplied in a clear, concise, and readily apparent form.

Table C-1: Telecommunications Parameters and Definitions

Parameter	Units	Description
Maximum S/C Distance	Km	Maximum spacecraft-earth station distance during primary mission.
1st Encounter Distance	Km	Maximum spacecraft-earth station distance during first encounter.
2nd Encounter Distance	Km	Maximum spacecraft-earth station distance during second encounter.
Nth Encounter Distance	Km	Maximum spacecraft-earth station distance during Nth encounter.
Uplink Transmitter Power	Watts	Earth Station Transmitter Output.
Uplink Frequency Band	GHz	Proposed earth-to-space frequency band expressed in GHz (2, 7, 34 GHz).
Uplink Command Mod. Index	Rad	Earth Station Uplink Command Modulation Index (Peak Radians)
Uplink Ranging Mod. Index	Rad	Earth Station Uplink Ranging Modulation Index (Peak Radians)
Uplink Transmit Antenna Gain	dBi	Gain (or name) of earth stations transmitting antenna (*e.g.,* 34M BWG).
S/C HGA Receive Gain / Loss	dBi/dB	Gain of spacecraft's high-gain receive antenna / Circuit loss to LNA.
S/C MGA Receive Gain / Loss	dBi/dB	Gain of spacecraft medium-gain receive antenna / Circuit loss to LNA.
S/C LGA Receive Gain / Loss	dBi/dB	Gain of spacecraft low-gain receive antenna / Circuit loss to LNA.
Telecommand Data Rates	b/s	Maximum and Minimum desired telecommand data rate (Max / Min).
Telecommand Bit-Error-Rate	-	Required telecommand Bit-Error-Rate (BER).

Parameter	Units	Description
S/C Receiver Noise Temperature	K	Total spacecraft receiver system noise temperature.
S/C Receiver Bandwidth	Hz	S/C Receiver's phase-locked-loop threshold bandwidth (2 Blo).
Turnaround Ranging	Yes/No	Statement whether turnaround ranging is required.
Required Ranging Accuracy	Meters	Specify project's required range measurement accuracy.
SC Transmitting Power	Watts	S/C Power amplifier output.
Downlink Modulation Format	Name	Format name (*e.g.,* PCM/PM/Bi-phase, PCM/PSK/PM, BPSK, QPSK, etc.).
Downlink Frequency Band	GHz	Proposed space-to-earth frequency band expressed in GHz (2, 8, 26, 32 GHz).
S/C HGA Transmit Gain / Loss	dBi/dB	Gain of spacecraft's high-gain transmit antenna / Circuit loss from PA.
S/C MGA Transmit Gain / Loss	dBi/dB	Gain of spacecraft's medium-gain transmit antenna / Circuit loss from PA.
S/C LGA Transmit Gain / Loss	dBi/dB	Gain of spacecraft's low-gain transmit antenna / Circuit loss from PA.
Downlink Receive Antenna Gain	dBi	Gain (or name) of earth station receiving antenna (*e.g.,* 34M BWG).
Telemetry Data Rates	b/s	Maximum and Minimum desired uncoded telemetry data rates (Max / Min).
Downlink Telemetry Mod Index	Rad	S/C Downlink Telemetry Modulation Index (Peak Radians)
Telemetry Coding & Code Rate	Name & Rate	Telemetry code (*e.g.,* convolutional, Reed-Solomon, concatenated, Turbo etc.).
Telemetry Frame Length	Bits	Total telemetry frame length.
Frame Deletion Rate	Rate	Acceptable Transfer Frame deletion rate from bit errors.
Telemetry Bit-Error-Rate		Telemetry Bit-Error-Rate (BER) required for desired frame deletion rate.
Subcarrier frequency and format	Hz / Sine or Square	Subcarrier frequency used / Sine or Square wave format.
Ground Station Implementation Losses	dB	Total losses including phase jitter, demodulation loss, and waveform distortion.
Downlink Ranging Mod Index	Rad	S/C Downlink Ranging Modulation Index (Peak Radians)
Hot Body Noise	K	The predicted increase from the reference temperature (Tr), resulting from the receiving antenna being directed toward a body having a temperature greater than that of the cold sky reference.

Table C-2 is a sample telecommunications link parameter form containing the necessary parameters. Proposers are requested to include this completed form in their proposals.

Table C-2: Sample Table for Inclusion in Proposal

Parameter	Value	Parameter	Value
Maximum S/C Distance (km)		Turnaround Ranging (Yes/No)	
1st Encounter Distance (km)		Required Ranging Accuracy (m)	
2nd Encounter Distance (km)		S/C Transmitting Power (Watts)	
Nth Encounter Distance (km)		Downlink Modulation Format (Name(s))	
Uplink Transmitter Power (Watts)		Downlink Frequency (GHz)	
Uplink Command Mod. Index (Peak Radians)		S/C Downlink Telemetry Mod Index (Peak Radians)	
Uplink Ranging Mod. Index (Peak Radians)		S/C Downlink Ranging Mod Index (Peak Radians)	
Uplink Frequency (GHz)		S/C HGA Transmit Gain (dBi) / Loss (dB)	
Uplink Transmit Antenna Gain (dBi)		S/C MGA Transmit Gain (dBi) / Loss (dB)	
S/C HGA Receive Gain (dBi) / Loss (dB)		S/C LGA Transmit Gain (dBi) / Loss (dB)	
S/C MGA Receive Gain (dBi) / Loss (dB)		Downlink Receive Antenna Gain (dBi)	
S/C LGA Receive Gain (dBi) / Loss (dB)		Downlink Subcarrier frequency and format	
Telecommand Data Rates (b/s)		Telemetry Data Rates (b/s)	
Telecommand Bit-Error-Rate		Telemetry Coding (Name)	
S/C Receiver Noise Temperature (K)		Telemetry Frame Length	
S/C Receiver Bandwidth (Hz)		Frame Deletion Rate	
Hot Body Noise (K)		Telemetry Bit-Error-Rate	
		Ground Station Implementation Losses (dB)	

Information requested in the Table above should be provided for each link whether Direct-to Earth, Relay, or other (spacecraft separation, LEOP, cruise, EDL, orbit ops).

Link design control tables should be provided for the following conditions as a minimum:

- spacecraft separation,
- emergency mode at maximum distance from Earth, and
- maximum science data rate at maximum distance from Earth.

If a proposal does not contain sufficient information for an evaluator to independently verify that each communication's link operates properly, a negative finding is likely to be made.

Station Requirements by Mission Phase

Proposers should clearly state their Networks support requirements, preferably in a tabular format. For all mission phases (*e.g.,* launch and early orbit operations, cruises, maneuvers, flybys, orbit insertion, orbit operations, data return, etc.) proposals should show the mission's phase, the year in which the services are desired, stations required, pass length, number of passes per day/week, and the duration that these services are required. A sample table containing a few entries for a fictitious planetary mission appears in Table C-3. Proposers are requested to include a completed form showing all major mission phases and the services required in their proposals.

Table C-3: Sample Station Requirements by Mission Phase Table

	Mission Phase	Year of Support	Subnetwork Requested	Hours Per Track	No Tracks Per Week	No. Weeks Required
1	Launch	2012	34BWG	8	21	2
2	Cruise	2012	34BWG	4	2	5
3	Cruise	2012	34BWG	4	2	33
4	TCM-1	2012	34HEF	8	7	2
5	Cruise	2012	34BWG	4	2	2
6	TCM-2	2012	34BWG	8	7	2
7	Planetary Orbit Insertion	2013	34HEF	8	21	3
8	Orbit Operations	2013	70	4	7	12
9	Orbit Operations	2013	70	4	7	37

MSPA User(s) Information (DSN)

Missions planning to employ MSPA can reduce their costs by using shorter track lengths and operating in a non-coherent one-way mode, provided that they do not require an uplink (see section 5.4.3). However, proposers planning to avail themselves of such savings should include a Letter(s) of Agreement from each of the other projects with whom they will be sharing the MSPA capability stating how the uplink services (*e.g.,* commanding, coherent radio metric data capture, etc.) will be shared.

Absent such Letter(s) of Agreement, reviewers will employ their judgment as to whether the proposed MSPA utilization is within "reasonable" levels.

Appendix D. Form for Estimating DSN Mission Support Costs

Prepared By:	
Date Prepared:	
Mission Name:	
Cost Method:	
Fiscal Year:	
User Type	
User Application:	
Launch Year:	

DSN SUPPORT SUMMARY	
Total Station Cost:	
Additional Fees:	
Total DSN Hours:	
Total R-Y Support Cost:	
Total F-Y Support Cost:	

Support Period No #	Support Period Name (description)	Antenna Size (meters)	Service Year (year)	Hours per Track (hours)	No. Tracks per Week (#tracks)	No. Weeks Required (#weeks)	Pre-Post-Config. (hours)	Total Time Reqd. (hours)	Total Cost for period

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Appendix E. Acronym List

AF	Aperture Fee
AF'	Aperture Fee discounted for Multiple Spacecraft per Aperture applications
A_W	Aperture Weighting (For costing DSN stations)
AMMOS	Advanced Multi-Mission Operations System
AO	Announcement of Opportunity
ASI	Agenzia Spaziale Italiana (Italy)
b/s	Bits per second
BWG	Beam Wave Guide (Refers to specific DSN 34M antennas)
Category A	Missions whose distance from Earth is $< 2 \times 10^6$ km.
Category B	Missions whose distance from Earth is $\geq 2 \times 10^6$ km.
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CLTU	Command Link Transmission Unit
CNES	Centre National d'Etudes Spatiales (France)
CSO	Communications Service Office
CSR	Concept Study Report
dB	Decibels
dBi	Decibels (relative to an isotropic radiator)
DCN	Documentation Change Notice
DDOR	Delta Differenced One-way Range
DLR	Deutsche Zentrum fur Luft- Und Raumfahrt (Germany)
D/MSP&MO	DSN Mission Services Planning and Management Office
DSA	Deep Space Network Service Agreement
DSN	Deep Space Network
DTF-21	Development & Test Facility-21 (Compatibility test area located at JPL)
ESA	European Space Agency
F_C	Frequency of Contacts (For costing DSN stations)
FDF	Flight Dynamics Facility
FY	Fiscal Year
GHz	Gigahertz (1×10^9 cycles per second)

GSFC	Goddard Space Flight Center
HEF	High Efficiency (Refers to specific DSN 34M antennas)
HEO	Highly Elliptical Orbit
HEOMD	Human Exploration and Operations Mission Directorate (formerly Space Operations Mission Directorate)
Hr	Hour
HSB	High Speed Beam waveguide (Refers to specific DSN 34M antenna)
Hz	Hertz (cycles per second)
IMT-2000	International Mobile Telephone-2000 (3rd generation mobile telephone system)
ISRO	Indian Space Research Organization
ITU	International Telecommunications Union
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
K	Kilo (1 x 10^{3}) or Kelvin
K_A-Band	Frequency band: Deep Space (Category B) 31.8 - 32.3 GHz downlink Near-Earth (Category A) 25.5 - 27.0 GHZ downlink
Km	Kilometers
LDPC	Low Density Parity Check
LEO	Low Earth Orbit
LEOP	Launch and Early Orbit Phase
LOC	Letter of Commitment
m	Meters
MA	Multi-Access
MD	Maryland (abbreviation)
MEO	Middle Earth Orbit
MGSS	Multiple Ground System and Services
MHz	Megahertz (1 x 10^{6} cycles per second)
MOC	Mission Operations Center
MOCS	Mission Operations and Communications Services
MOS	Mission Operations System
MSPA	Multiple Spacecraft per Aperture
Msps	Megasymbols per second

NASA	National Aeronautics and Space Administration
NEN	Near Earth Network
NIMO	Networks Integration Management Office at GSFC
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NRE	Non-recurring engineering
NTIA	National Telecommunications and Information Administration
PI	Principal Investigator
POCC	Project Operations Control Center
PSLA	Project Service Level Agreement
r	Range (Earth to spacecraft)
R_B	Base Rate (For costing DSN stations)
Rad	Radians
ROM	Rough Order of Magnitude
S/C	Spacecraft
SA	Single Access
SFCG	Space Frequency Coordination Group
SLE	Space Link Extension
SMD	Science Mission Directorate (formerly NASA Headquarters Office of Space Science Code S)
SN	Space Network (TDRS)
STGT	Second TDRSS Ground Terminal
TDRSS	Tracking and Data Relay Satellite System
TMS	Telecommunications and Mission Systems
TT&C	Tracking, Telemetry, and Command
WS1	White Sands 1
WSGT	White Sands Ground Terminal
VLBI	Very Long Baseline Interferometry
X-Band	Frequency band (Space Research Segment): Deep Space (Category B) 7145-7190 MHz uplink, 8400-8450 MHz downlink Near-Earth (Category A) 7190-7235 MHz uplink, 8450-8500 MHz downlink

Document Number

Space Communications and Navigation (SCaN)

Mission Operations and Communications Services (MOCS)