NASA's Mission Operations and Communications Services

This Description applies to proposals in response to NASA's Announcement of Opportunity for

DISCOVERY 2010

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1.0 INTRODUCTION

This document is intended to assist in the preparation of proposals responding to the 2009 Announcement of Opportunity (AO), which is issued by NASA's Science Mission Directorate.

NASA provides many operations and communications services for mission support. Costs accrue when using these services and estimates of these costs need to be included in proposals responding to the AO. To facilitate proposal preparation, proposers are encouraged to read this document and to contact the individuals named in Section 1.3 below.

1.1 Costing Policy

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. The Science Mission Directorate (SMD) 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.

1.2 Choice of Service Providers

NASA Procedural Requirements (NPR 7120.5D) require all programs/projects to develop requirements for space operations services provided by NASA facilities during mission formulation. Such services include communications, tracking, mission operations, navigation, and data processing. NPR 7120.5D requires projects to use NASA services unless a more cost-effective life cycle can be found and demonstrated in the proposal.

Programs/projects are free to propose procurement of services from sources other than NASA. Projects should conduct trade studies comparing the use of NASA-provided services with any proposed alternatives. NASA-initiated projects (e.g., missions in the SMD Strategic Plan) should conduct these studies in Phase A. Competitively selected projects (SMD PI class missions) may, at their option, conduct such studies in Phase A or Phase B.

Generally, NASA provided services should be employed whenever they meet mission objectives and have a life-cycle cost to the project and/or to the SMD, which is less than or equal to any of the proposed alternatives. Contact persons listed in Section 1.3.1.3 or 1.3.2.2 for assistance in identifying appropriate service, prices, and cost trades.

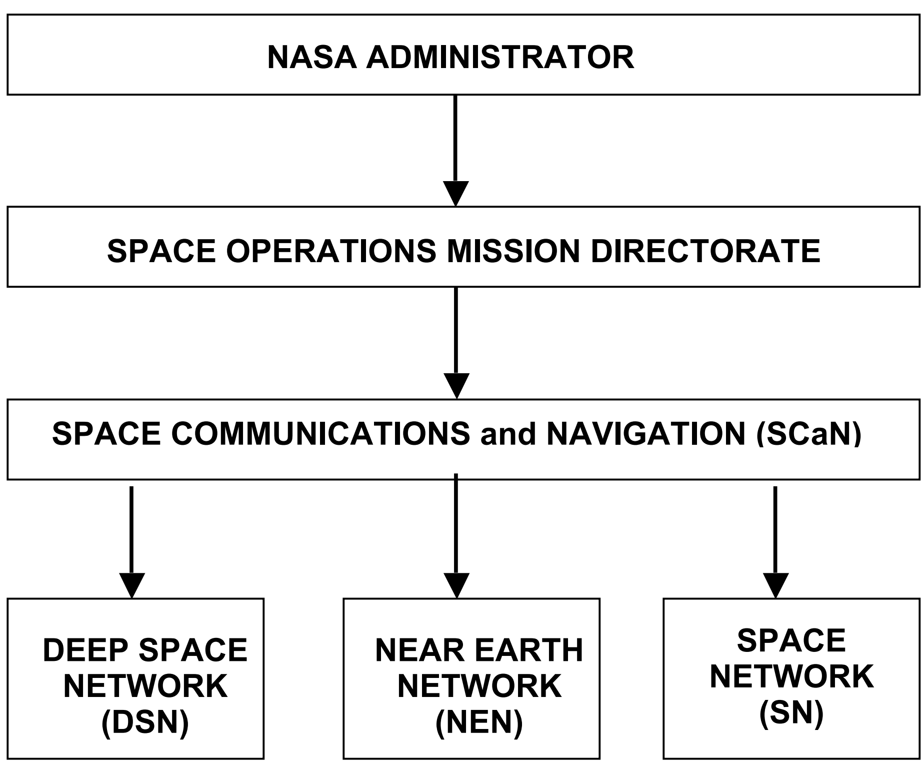
Where the SMD finds that the proposed project or PI approach does not result in the lowest life-cycle cost, the SMD may direct the project or PI to modify their approach. If utilizing NASA provided support services increases the project / PI costs, but reduces the cost to the SMD, any funding impacts to the project / PI will be resolved by the SMD.

If a trend towards project / PI-unique solutions appears to reduce individual mission cost but increases the total cost to NASA by not utilizing shared services and facilities, any resolution using the appropriate NASA-wide services strategy will be implemented in a manner in which the SMD shares in the cost savings.

1.3 NASA's Tracking Networks

The NASA Space Communications and Navigation (SCaN) Office manages and directs three tracking networks to provide services for different types of missions. Several past proposals have included Earth orbiting vehicles for which either NASA's Near Earth Network (NEN) or Space Network (SN) would be more suitable than the Deep Space Network (DSN). For that reason, and to avoid early obsolescence of this document, a short description of each has been included. Functional responsibilities for NASA's three networks are shown in Figure 1-1. The SCaN Office has the overall responsibility to be the arbiter of mission requirements versus the establishment of network tracking and navigation assets. While missions may have a desire for specific NASA facilities the SCaN Office will make the final decision on the provision of network assets.

Figure 1-1: NASA Network Functional Responsibility



1.3.1 Interplanetary Network Directorate

The Interplanetary Network Directorate (IND) comprises the Deep Space Network (DSN) and the Multi-Mission Ground Systems and Services Program Office (MGSS) organization located at the Jet Propulsion Laboratory (JPL). MGSS manages the Advanced Multimission Operations System (AMMOS). IND provides the operations and engineering of the DSN and provides the technical expertise needed for flight projects to use the DSN. This expertise includes communications formats, antenna capabilities and performance limits, scheduling, loading and other operations considerations, and in particular, maintaining the cost algorithm for use of the DSN. The AMMOS develops, maintains, and employs a set of tools and services, including spacecraft navigation, for working with the DSN. Most spacecraft operating in deep space ($r \geq 2 \times 10^6$ km, Category B missions) will require services from the DSN.

1.3.1.1 DSN Services

Capabilities have moved from a facilities-based services model to one based upon standard services. Detailed descriptions of these standard services can be found in the Deep Space Network (DSN) *Services Catalog* (Reference 6). These services enable both Earth orbiting and deep space science missions. Table 1-1 lists the DSN Service categories found in Reference 6. Each of the Service categories named in Table 1-1 may contain several services. Some of those individual services may require that special arrangements be made with JPL 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 1.3.1.3 for additional information. See Table 2-1 for a list of standard DSN services included in the *Aperture Fee.*

Table 1-1: DSN Service Categories

Service Category [1]	Brief Description of Service's Content
Some services in the categories below are not a part of the basic TT&C set and require additional programmatic arrangements with JPL.	
Command Services	RF modulation, transmission, and delivery of telecommands to spacecraft.
Telemetry Services	Telemetry data capture and additional value-added data routing and processing.
Tracking Services	Radio metric data capture (Doppler and range), Delta-DOR Service
Calibration and Modeling Services	Platform and media calibration services
Radio Science Services	Closed-loop (S/C Doppler & range), or open-loop receiver measurements.
Radio Astronomy / VLBI Services	Similar to Radio Science but measures natural phenomena. Wide & narrowband VLBI.
Radar Science Services	Transmits RF carrier toward user defined target; captures reflected signal.
Engineering Support Services	System engineering, advanced mission planning, emergency mission operations center support, RF compatibility test support, mission system test support, spectrum and frequency management support, and spacecraft search services.

Notes:
1. See DSN Services Catalog (Reference 6) for details of services contained in these categories.

1.3.1.2 AMMOS Services

The Advanced Multimission Operations System (AMMOS) enables Principal Investigators to directly, immediately, flexibly and seamlessly interact with their instruments and their data from wherever they are located. The enabling tools, personnel, and infrastructure will be transparent to the user.

The AMMOS provides Flight Missions with a standard end-to-end information system that dramatically reduces Project design effort (flight and ground) and resulting cost by providing an adaptable architecture and by fully exploiting the emerging DSN communications capabilities.

Projects can choose the multi-mission elements as well as project-specific adaptations for their mission operations and ground data systems for their particular mission. The cost of adapting and maintaining the tools and creating a project's mission operations system are charged to the benefiting mission, MGSS may pay for some or all of the development. Adaptation to a project's needs takes much less time than would be required for the development of the mission operations system by individual projects (weeks or months compared with years), and projects enjoy greater reliability by using modern and proven tools.

1.3.1.3 Process for Requesting DSN/AMMOS Services

Proposers should contact the person(s) named below for information about DSN/AMMOS 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. Further, they will assist in documenting initial requirements and estimates for DSN/AMMOS services/tools in the form of a letter of commitment.

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

During the concept study phase (Phase-A or Step-2), as the mission's concept is more clearly defined, requirements in the letter will be revised. The resulting documentation of services and costs will be captured in the DSN Service Agreement (DSA) to be signed by appropriate Project and Network representatives by CDR. The DSA will identify all mission services, including those provided by non-DSN sources, becoming a source of end-to-end operations information and documenting any cost analyses leading to the selection of non-IND services.

The NASA Headquarters point of contact for SCaN assets is:

> Pete Vrotsos
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> NASA Headquarters
> M/S 7L73
> Washington, D. C. 20546-0001

Phone: (202) 358-1329; FAX: (202) 358-2830
e-mail: pete.vrotsos@nasa.gov

The IND point of contact for DSN services is the Systems Engineering and Commitments Office:

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Phone: (818) 354-3416; FAX: (818) 354-7498
e-mail: stefan.waldherr@jpl.nasa.gov

For assistance with AMMOS tools and services, contact the MGSS Program Commitments Engineer (Organization 930):

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1.3.2 Near Earth Network

The Near Earth Network (NEN) operations are the responsibility of Goddard Space Flight Center (GSFC) in Greenbelt, Maryland under the auspices of the Space Operations Mission Directorate (see Figure 1-1 above). The NEN currently provides Earth services from ground stations located in the United States at: Poker Flat, Fairbanks, and North Pole, Alaska; Merritt Island, Florida, Wallops Island, Virginia; Los Cruces, New Mexico; as well as in McMurdo, Antarctica; Santiago, Chile; and Svalbard, Norway. Other commercial/foreign Earth stations may be obtained by the NENS in response to customer requirements. Generally, these stations support non-deep space (Category A) missions in the 2 and 8 GHz bands; however, several are capable of receiving signals from deep space (Category B) missions as well. Table 1-2 shows several of the service categories.

1.3.2.1 NEN Services

NEN service categories are similar to those of the DSN listed above in Table 1-1, but include several *value added* services. Additionally, several design services are available to assist mission planners in their conceptual design phase. Table 1-2 summarizes the NEN services.

Table 1-2: NEN / SN Service Categories

NEN / SN Service Category	Brief Description
Commanding	RF modulation, transmission, and delivery of telecommands to spacecraft.
Telemetry	Telemetry data capture, decoding, and additional value-added data routing.
Tracking	Radio metric data capture (range, Doppler, and angles).
Mission Planning	Communications design, orbital modeling, scheduling, resource planning.
Flight Operations	Planning, controlling, and monitoring of operational spacecraft.
Flight Dynamics	Design spacecraft trajectory, predict and control of operational spacecraft.
Science Data Processing	Processing of science data, generate data products, analysis of data.
Consulting and Training	Anomaly resolution, troubleshooting, consulting.
Range Support	Control center, range communications, meteorology, launch imagery.
System Performance & Test	Telecommunications interface design, compatibility testing.
System Procedure Develop	Develop detailed processes & procedures for S/C operations.
Special Operations	Non-routine flight ops. Including: anomalies, contingencies & emergencies.

1.3.2.2 Process for Requesting NEN and SN Services

At the time when initial science operations concepts are being defined, proposers should contact the person named below for information about NEN mission operations services and costs. A representative assists proposers by providing service and cost information. Further, the Networks Integration Management Office (NIMO) aids in documenting initial mission operations requirements in a preliminary Project Support Level Agreement (PSLA).

During the study phase, as the mission's concept is more clearly defined, requirements in the preliminary PSLA are revised. The resulting documentation of services and costs become the PSLA to be signed by appropriate Project and Network representatives.

The NASA Headquarters points of contact for SCaN assets are:

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e-mail: pete.vrotsos@nasa.gov

The GSFC point of contact for NEN and SN services is the GSFC Networks Integration Management Office (NIMO):

Scott A. Greatorex
Chief, Networks Integration Management Office
Space Communications Program
Goddard Space Flight Center
Code 450.1
Greenbelt, Maryland 20771

Phone: (301) 286-8422; FAX: (301) 286-0275
e-mail: Scott.A.Greatorex@nasa.gov

1.3.3 Space Network

NASA's Space Network (SN) is the responsibility of the Space Operations Mission Directorate (SOMD). The SOMD is accountable for NASA's Tracking and Data Relay Satellite System (TDRSS). TDRSS operates in the 2, 13-15 and the 26 GHz band.

1.3.3.1 Space Network Services

NASA's Space Network (SN) consists of seven geosynchronous satellites. Satellite control and data capture facilities are located in: Guam (GRGT), Goddard Space Flight Center in Greenbelt, MD and White Sands, New Mexico (STGT and WSGT).

Second generation Tracking and Data Relay Satellites (TDRS) offer enhanced Multiple Access (MA) capability and higher data rates on the S-band (6 Mbps) and K_A-band (800 Mbps) Single Access (SA) channels.

SN service categories follow those for the NEN outlined above in Section 1.3.2.1 and readers should refer to Table 1-2 for the list of services.

1.3.3.2 Process for Requesting SN Services

At the time when initial science operations concepts are being defined, proposers should contact the person named in Section 1.3.2.2 above for information about SN mission operations services and costs. A representative will assist proposers by providing service and cost information. Further, the NIMO aids in documenting initial mission operations requirements in a preliminary Project Service Level Agreement (PSLA).

During the study phase, as the mission's concept is more clearly defined, requirements in the preliminary PSLA are revised. The resulting documentation of services and costs become the PSLA to be signed by appropriate Project and Network representatives.

1.3.4 Very Long Baseline Array (VLBA)

The VLBA is a system of ten radio-telescope antennas, each with a dish 25 meters (82 feet) in diameter. Located from Mauna Kea on the Big Island of Hawaii to St. Croix in the U.S. Virgin

Islands these stations are primarily used for astronomical radio observations. Other station locations include: Brewster, Washington, Owens Valley, California, Pie Town, New Mexico, Kitt Peak, Arizona, Los Alamos, New Mexico, Ft. Davis, Texas, North Liberty, Iowa, and Hancock, New Hampshire. . In an agreement with NASA they can be used for spacecraft navigation purposes. In 2011 these facilities can be used at X-band and by 2016 used at 32 GHz Ka-band for mission navigation. The current estimated cost for using the VLBA is $1700 per hour.

1.4 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 at the Glenn Research Center or by consulting References 1 and 2. Recommended CCSDS standards applicable to DSN, Near Earth Network, or TDRSS support can be found in Reference 3, the CCSDS home page. Recommendations of the SFCG are available in Reference 4.

1.5 Policies

Capabilities described below result in the more efficient use of NASA's facilities. Where it is determined not to use an item, the proposal should include the rationale for its omission. Explanations are particularly important in Concept Study Report (CSR). Networks to which each item is applicable are noted following the subsection's title.

In addition to providing the operations and communications services costs as required by Section 1.1 and complying with the standards listed in Section 1.4 above, there are other NASA policies affecting proposal content. Proposers should carefully consider each item below.

1.5.1 Space Link Extension (DSN, NEN, SN)

Project Operation Control Centers (POCCs) using DSN and SN services should use a standard *Space Link Extension* (SLE) *Services Interface* for transferring data to and from DSN or SN sites. This interface is designed to provide international control center–network interoperability and reduce mission risk by facilitating the rapid substitution of a different earth station, not necessarily only NASA's, in the event of a ground station anomaly. The SLE Services interface will require POCCs to directly access DSN stations for the following services: Command Link Transmission Unit (CLTU), Return All Frames (RAF), Return Channel Frames (RCF), and CCSDS File Delivery Protocol (CFDP).

Seven international space agencies, including: ASI, CNES, DLR, ESA, ISRO, JAXA, and NASA, have agreed to implement the SLE Services Interface to achieve full international interoperability. Interface architecture conforms to standards adopted by the CCSDS (Reference 3).

1.5.2 X-Band and K_A-Band Communications (DSN, NEN, SN)

Category B ($r \geq 2 \times 10^{6}$ km) missions operating in a *Space Research* should be designed to communicate in either the 7/8 GHz or 7/32 GHz bands. Ever increasing congestion and the addition of allocations for incompatible services (e.g., IMT-2000) have restricted future operations in the 2 GHz deep space band. Accordingly, the Science Mission Directorate is recommending that use of the 2 GHz deep space band be limited to radio science and in-situ communications. Deep space missions having high data rates should operate in K_A-Band (31.8 - 32.3 GHz space-to-earth) or, if using the 8400-8450 MHz band, they should comply with SFCG Recommendations regarding bandwidth-efficient modulation. Approved methods for bandwidth efficient modulation can be found in Reference 3.

Category A ($r < 2 \times 10^{6}$ km) missions also have an allocation for the *Space Research* service in the 7190 - 7235 MHz (Earth-to-space) and 8450 - 8500 MHz (space-to-Earth) bands. Because of the congestion in the 2 GHz band from ever increasing use, proposers are encouraged to use the 7/8 GHz bands whenever possible. Missions operating in either the 2 or 7/8 GHz bands should comply with the spectrum emissions mask in the SFCG Handbook (Reference 4). Approved methods for bandwidth efficient modulation can be found in Reference 3.

Category A Missions with high data/symbol rates planning to operate in the 8 GHz *Earth Exploration Satellite* (EES) (8025 - 8400 MHz) should investigate capabilities in the 26 GHz band. Missions utilizing the EES service tend to have very high data/symbol rates and all missions planning to operate in the 8 GHz band should comply with the spectrum emissions mask in the SFCG Handbook (Reference 4). Approved methods for bandwidth efficient modulation can be found in Reference 3.

An allocation for the *Space Research* service has been approved for the 25.5 - 27.0 GHz band (a.k.a. 26 GHz band). High data rate near-Earth space science missions, requiring bandwidths in excess of 10 MHz, should be designed to operate in this 26 GHz band.

The Space Communications and Navigation Office is highly recommending, while polices are being worked, that all missions launching in 2016 and beyond should use Ka-band. For Deep Space missions the spectrum combination would be X and Ka (32 GHz) and for Near Earth S and Ka (26 GHz).

1.5.3 Bandwidth Efficient Modulation (DSN, NEN, SN)

Missions operating in the 2 and 8 GHz bands (see Section 1.5.2), should employ bandwidth efficient modulation methods in conformance with SFCG and CCSDS Recommendations. Spectral Emission Masks for Category-A missions are found in the Space Frequency Coordination Group's (SFCG's) Handbook, available on the SFCG web site (Reference 4). Specific modulation methods meeting the SFCG mask are enumerated in CCSDS

Recommendations 401 (2.4.17A) B-1, and 401 (2.4.18) B-1 for non-deep space and Earth resources missions respectively (Reference 3).

As a matter of IND policy, it is recommended that Category B missions employ bandwidth efficient modulation whenever operating in the 8400 - 8450 MHz band at symbol rates above 2 Msps. CCSDS Recommendation 401 (2.4.17B) B-1 lists acceptable modulation schemes.

1.5.4 CCSDS File Delivery Protocol (DSN, NEN, SN)

To improve station usage efficiency as well as reduce mission risk and costs, all DSN users shall employ the CCSDS File Delivery Protocol (CFDP), to transfer data files to and from a spacecraft. CFDP operates over a unitdata transfer ("UT-layer") protocol stack, which affects the exchange of CFDP protocol data units over radio or optical transmission media. Candidate UT-layer protocol stacks include, but are not limited to, the CCSDS conventional packet telecommand, packet telemetry, Advanced Orbiting System (AOS) or Proximity-1 space links. CFDP enables the automatic transfer of a complete set of specified files and associated information from one storage location to another replacing an expensive labor-intensive manual method. It can transfer a file from a source point to a destination site using an Automatic Repeat Queuing (ARQ) protocol. In this acknowledged mode, the receiver notifies the transmitter of any undelivered file segments or ancillary data so that the missing elements can be retransmitted guaranteeing delivery. An unacknowledged mode is also permitted. CFDP information can be found in the CCSDS File Delivery Protocol Blue Book available under the Advanced Orbiting Systems category on the CCSDS web site (Reference 3).

1.5.5 Delay-Tolerant Networking [DTN] (DSN)

In order to further automate space mission operations and thus increase performance while reducing cost, NASA is committed to a rapid evolution towards an internetworked model of space communications. The basis of the new techniques is the Delay and Disruption Tolerant Networking (DTN) protocol suite that is being developed by the DTN Research Group of the Internet Research Task Force (Ref. DTN-1) and is described in Ref. DTN-2. In particular, the DTN Bundle Protocol (RFC 5050, Ref. DTN-3) and the Licklider Transmission Protocol (RFC 5326, Ref. DTN- 4) form the basis for space internetworking. All DSN users are strongly encouraged to operate CFDP in Class 1 (Core procedures, Unacknowledged mode) using the services of the Bundle Protocol (BP) and the Licklider Transmission Protocol (LTP) as the UT-layer protocol stack to provide routing and reliability. In this configuration, CFDP files or file segments will be carried by the BP using the services of the LTP across each space link. The LTP service data units may be placed in CCSDS Packets prior to transmission across the space link or (preferably) by using the CCSDS Encapsulation Protocol (Ref. DTN-5). The DTN protocol suite is currently being standardized by CCSDS and information can be found in Ref. DTN-6. A space qualified implementation of DTN – the "Interplanetary Overlay Network" (ION) is available for free download at Ref. DTN-7.

References to DTN:

(DTN-1) http://www.dtnrg.org/wiki/Docs
(DTN-2) IETF RFC 4838, Delay-Tolerant Network Architecture, V. Cerf et al., April 2007
(DTN-3) K. Scott, and S. Burleigh, Bundle Protocol Specification, IETF RFC 5050, November 2007.

(DTN-4) M. Ramadas et al., Licklider Transmission Protocol - Specification, IETF RFC 5326, September 2008.
(DTN-5) CCSDS 133.1-B-2, Encapsulation Service. Blue Book. Issue 2. October 2009.
(DTN-6) http://cwe.ccsds.org/sis/default.aspx#_SIS-DTN
(DTN-7) https://ion.ocp.ohiou.edu/index.php

The capabilities provided by DTN are only meaningful to those missions requiring typical networking capabilities, i.e., network addressing, routing, Quality of Service (QoS) management, etc. Missions relying only on a single point-to-point direct space-Earth link do not have such needs. In addition, the DSN is currently not funded, nor has a baseline plan to implement this capability.

1.5.6 Multiple Spacecraft Per Antenna (DSN)

Where a multiplicity of spacecraft lie within the beamwidth of a single DSN antenna, it may be possible to capture data from two or more spacecraft simultaneously using the Multiple Spacecraft Per Aperture (MSPA) system. MSPA decreases DSN loading and will save the project's money (see Section 2.1.3).

There are a few constraints. First, only a single uplink frequency can be transmitted. Generally, this means that only one spacecraft at a time can operate in a two-way coherent mode, while the remainder must be in a one-way (i.e., non-coherent) mode. Second, multiple-independent receivers are required at the Earth station. This sets a practical limit of two spacecraft that can be served simultaneously. Third, ranging and two-way coherent Doppler data can only be obtained from the single spacecraft operating in a two-way coherent mode.

Approximately 30-minutes are required to transfer two-way coherent operations from one spacecraft to another irrespective of whether or not the spacecraft, which will be in the two-way coherent mode, is currently part of the MSPA cluster. When switching the uplink from one spacecraft to the next, full *Aperture Fee (AF)* costs apply to the new two-way coherent user at the onset of the switching operation. Transfers of two-way coherent operations require:

1) Tuning the uplink of the spacecraft in a two-way coherent mode to its rest frequency,
2) Setting the station uplink frequency to the next spacecraft's and acquiring the uplink,
3) Reconfiguring the command subsystem (if required) for the next spacecraft,
4) Reconfiguring ranging (if required) for the next spacecraft,
5) Reconfiguring the Monitor and Control subsystem,
6) Relocking the Earth station's receiver and telemetry processor following the switch.

For a Project to avail itself of the MSPA savings, the following conditions must apply:

1) All spacecraft must lie within the beamwidth of the requested antenna.
    a. Projects must accept reduced link performance from imperfect pointing.
2) Spacecraft downlinks must operate on different frequencies.
3) Only one spacecraft at a time can operate with an uplink in a coherent mode.
    a. Commands can only be sent to the spacecraft receiving an uplink.
    b. Ranging & coherent Doppler are available from the spacecraft in a 2-way mode.
    c. Remaining spacecraft transmit 1-way downlinks with telemetry only.

1.5.7 Delta Differenced One-Way Range (DSN)

Delta Differenced One-Way Range (DDOR) can be used in conjunction with Ranging and Doppler data to:

1) Increase spacecraft targeting accuracy (when used with range and Doppler data).
2) Improve mission reliability (when used with range and Doppler data).
3) Reduce tracking time (if pass duration is driven by tracking data capture).

Projects should investigate whether this data type offers sufficient improvement in one or more of the above parameters to justify the cost in terms of spacecraft implementation, operational complexity, and Earth station scheduling. Under the proper conditions, (DDOR) can offer significant benefits including a reduced mission cost.

For (DDOR) to be usable:

1) The spacecraft must transmit two tones (the greater the frequency separation the better).
2) Two DSN Earth stations must observe the spacecraft and natural radio sources.

1.5.8 Relayed Data (DSN)

Some missions may propose dropping probes, landers, or even rovers to explore the atmosphere and/or surface of a planet/body. Others may insert orbiters around the same body. The result can be a multiplicity of spacecraft on or around a planet/body. While Mars has been the recent focus, it is foreseeable that other planets or objects in space could be of equal interest in the future.

Where several spacecraft are relatively close together and positioned far from the Earth, it makes sense to send data to and from small vehicles via a relay (Proximity Link). Typically, this has been an orbiting spacecraft carrying a special transceiver operating at UHF frequencies. Relaying data from surface objects can save money and reduce size and power requirements of landed equipment. Proposals for landed objects in the vicinity of an orbiting spacecraft should consider whether a data relay makes sense for their application. Some *Announcements of Opportunity* (AOs) have required orbiting spacecraft with certain characteristics to carry Proximity Link hardware. A specific relay link design [Proximity Link] has been adopted by the CCSDS and its specifications can be found in Reference 3.

1.5.9 Coding

Most missions employ error detecting – error correcting codes to substantially improve telemetry link performance. DSN users are reminded that their encoders should conform to the *CCSDS Telemetry Channel Coding* Blue Book (CCSDS 231.0-B-1, September 2003. Acceptable codes include: 1) Convolutional r = 1/2, k = 7 only; 2) Reed-Solomon 223/255 only; 3) concatenated Convolutional / Reed-Solomon and 4) Turbo codes with rates: 1/2, 1/3, 1/4, or 1/6, block sizes: 1784, 3568, 7136, and 8920.

1.5.10 Critical Event Communications

The appendix in the Announcement of Opportunity (AO) requires telemetry services during all *Critical Events,* per NPR 8705.4 Appendix B. *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
- Orbit insertion
- Powered flight
- Entry/Descent/Landing
- Critical Maneuvers (e.g., DSMs)
- Flybys

An Earth station is normally required during launch, early orbit and separation. It could be one of the DSN or NEN Earth stations 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. The costs for *Critical Event* support must be included in the proposal. For information about costing this support, see Section 2.4.

2.0 NETWORK SERVICES COSTS

Generally, mission proposals must include both launch and communications/navigation costs. This section explains how to obtain costs for the DSN, NEN, SN, and AMMOS.

2.1 Costs for Using the Deep Space Network

Proposed Category B missions operate in deep space and frequently have lower signal levels and restricted communications bandwidths, as compared to missions orbiting close to Earth. In developing their mission concept, proposers should perform trade-offs among the elements of the end-to-end data system. The elements include instrument format design, flight data system, the space communications features, and the several elements of the ground data system. The integrated contact time and the contact frequency of the spacecraft with the DSN are typically important parameters in these trade studies. To simplify DSN costing, an algorithm has been developed permitting users to calculate the *DSN Aperture Fee* and included services.

The DSN consists of control, communications, test facilities at JPL, and Earth station complexes located near Goldstone, California; Canberra, Australia; and Madrid, Spain. The DSN provides communications services between spacecraft and Earth station complexes together with the ground communications among the complexes and the DSN control center located at JPL in Pasadena, California.

Testing to establish compatibility between the spacecraft's Radio Frequency Subsystem (RFS) and DSN stations is available at the JPL Development Test Facility (DTF-21) or by using the Compatibility Test Trailer (CTT-22) at a remote site. RFS compatibility testing is highly recommended and should be completed about eighteen months prior to launch.

DSN 34-meter, and 70-meter diameter antennas operating in the 2, 7, 8, 26, and 32 GHz bands provide radio frequency communications. User costs vary with aperture size and utilization level. Generally, DSN services are included in the *Aperture Fee* (see Equation 2-1 below).

2.1.1 DSN Aperture Fees

Cost numbers supplied in this Section are for planning purposes only. To ensure accurate application of this information and to validate cost estimates please contact the DSN representative listed in Section 1.3.1.2. IND personnel should always be consulted to validate these costs in the CSR.

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 following equation can be used to calculate the *hourly Aperture Fee* (AF) for DSN support.

$$AF = R_B\,[A_W\,(0.9 + F_C\ /\ 10)] \qquad (2\text{-}1)$$

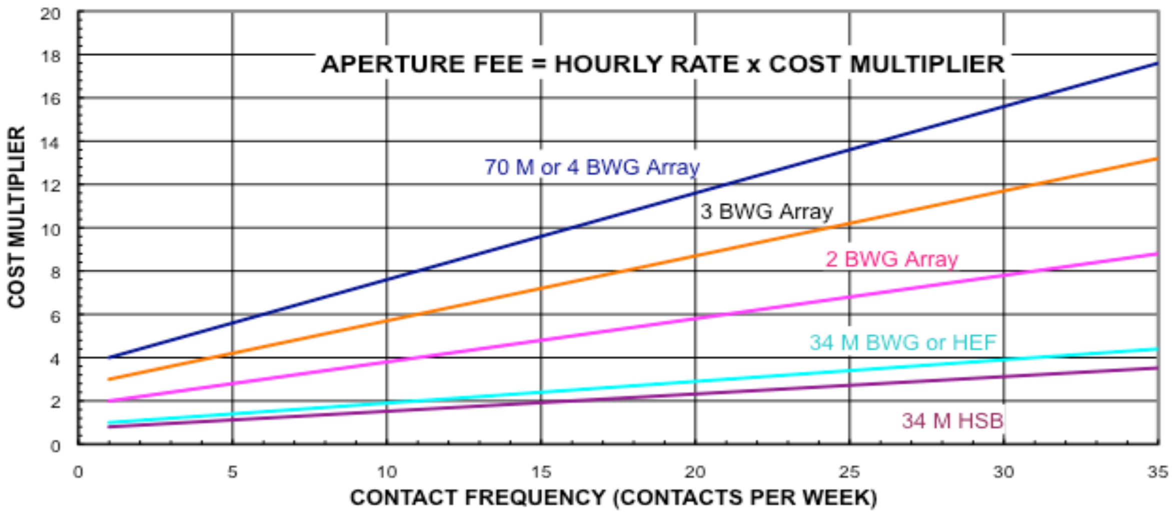
Where:

AF = weighted *Aperture Fee* per hour of use.
R_B = contact dependent hourly rate, adjusted annually ($1057/hr. for FY09)
A_W = aperture weighting:
= 0.80 for 34-meter High-Speed Beam Waveguide (HSB) station.
= 1.00 for a single 34-meter station (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.
F_C = 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.

A *station contact, F_C,* 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 teardown 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.



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, routine compatibility testing, and the DSN Commitments Engineer and services.

2.1.2 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 (2-1).

A form entitled *DSN Mission Support Costs*, Table 2-2, can be used to calculate DSN *Aperture Fees* in real-year or fiscal year Dollars. An Excel 2000 personal computer program is available for the preparation of the cost estimates. To obtain a copy, either contact the person named in Section 1.3.1.2 or the DSN web site (Reference 5).

New to the DSN Aperture Fee Tool is the cost for multiple 34M antennas in an array configuration (e.g., two 34Ms, three 34Ms, and 4 34Ms).

2.1.2.1 Included Services

Several value added services are available from the DSN and are included in the *Aperture Fee*. Table 2-1 names those services. For additional details, consult Reference 6.

Table 2-1: Services Included in DSN Aperture Fee

Service	Service
Command 1. Command Radiation 2. Command Delivery	**Radio Science** 1. Experiment Access 2. Data Acquisition
Telemetry 1. Frame 2. Packet 3. Telemetry File	**Radio Astronomy / VLBI** 1. Signal Capturing 2. VLBI Data Acquisition
Tracking 1. Validated Radio Metric Data 2. Delta-DOR Data	**Radar Science** 1. Experiment Access 2. Data Acquisition
Calibration and Modeling 1. Platform Calibration 2. Media Calibration	

Table 2-2: 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		Antenna	Service	Hours per	No. Tracks	No. Weeks	Pre-, Post-	Total	Total Cost
No #	Name (description)	Size (meters)	Year (year)	Track (hours)	per Week (# tracks)	Required (# weeks)	Config. (hours)	Time Reqd. (hours)	for period

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2.1.3 Multiple Spacecraft Per Antenna DSN Costing - DSN Fee Reduction

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 Section 1.5.5, 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 2-1 above. Thereafter, apply the correction factor according to the formula:

$$AF' = (0.50)\ AF \qquad (2\text{-}2)$$

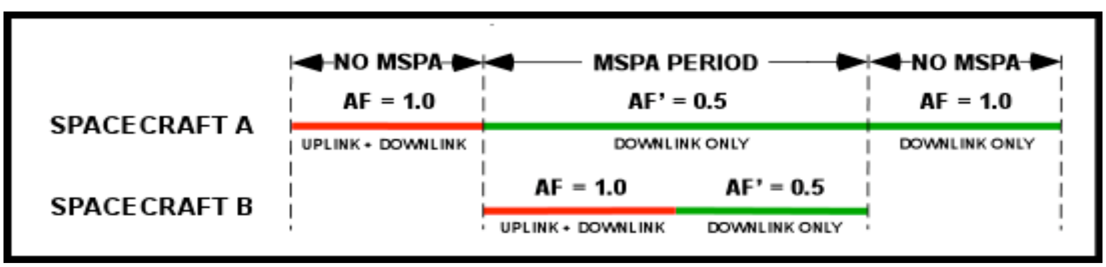
Where: AF' = weighted *Aperture Fee* per hour of use for spacecraft operating without an uplink in the MSPA mode. (Spacecraft having an uplink when operating in an MSPA mode should use the aperture fee (AF) computed according to equation 2-1.)

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.

Note: 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.

Some examples may prove helpful. If a single DSN antenna is capturing telemetry from two spacecraft simultaneously, one with an uplink and the other in a one-way mode, the one with the uplink is at full cost (*AF*) [equation 2-1] while the other without the uplink calculates its cost at *AF' = 0.5 AF*. Where neither of the two spacecraft has an uplink, then each pays an *Aperture Fee' (AF')* of 0.5 *AF*. **If the pass of one spacecraft begins before the other, or lasts beyond another, then there is no MSPA and that user is charged the full *Aperture Fee, AF* irrespective of whether there is an uplink.** Figure 2-1 may help to clarify the rules.

Figure 2-1: MSPA Aperture Fee



Note: Proposals employing the MSPA reduced-cost algorithm should also include Letter(s) of Agreement from the other simultaneous MSPA users stating the relevant conditions including how the uplink will be shared (see Section 3.3).

2.1.4 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. This section outlines the conditions when aggregation is permitted.

DSN *station configuration* is a key element in establishing the continuous nature of a contact. If a new configuration is required for each spacecraft in the cluster, then support of several spacecraft assumes the character of individual contacts arranged in a sequential order. Conversely, if everything at a DSN station, except the direction in which the antenna is pointing remains fixed when transitioning to a different spacecraft, the essential character is one of a single contact.

Station configuration involves loading predicts containing: transmit and receive frequencies, Doppler frequency estimates, spacecraft identification numbers, data routing information, measuring station ranging delay, etc. These may be unnecessary when the several spacecraft:

- Operate on the same frequency and polarization,
- Require identical data routing, and
- Do not use ranging.

For missions consisting of a multiplicity of spacecraft, each of which receives commands and/or transmits telemetry sequentially to and from a single DSN Earth station in a series of contiguous communications, then aggregation of individual pass times into a single contact may be reasonable.

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 the spacecraft 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 2-1 in Section 2.1.1.

All missions consisting of a cluster of spacecraft not meeting the above criteria should calculate their costs using equation 2-1 in Section 2.1.1 treating each sequential communication with a member of the cluster as a separate and individual contact.

2.1.5 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.

2.1.6 DDOR DSN Costing

Under the correct geometric circumstances, Delta Differential One-way Range (DDOR) can result in a net reduction in needed tracks (see Section 1.5.6). 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: 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. Use of the VLBA resources may reduce navigation costs.

2.1.7 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 teardown 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).

2.1.8 Compatibility Testing DSN Costing

DSN encourages 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 a 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.

Because IND believes that this testing materially improves the likelihood of mission success, no charge is made for the use of the DFT-21 facility for a single set of compatibility tests. Rather, it is included in the hourly-dependent rate, R_B, used in Equation 2-1. For the use of the CTT-22 facility the only charge is to cover the travel and per-diem costs of the DSN personnel and the transportation cost of moving the test trailer to the user facility.

2.2 Advanced Multi-Mission Operations System Costing

The Advanced Multi-Mission Operations System (AMMOS) offers a selection of tools for mission planning, spacecraft control, data reduction, spacecraft engineering analysis, and navigation. Proposals should identify required AMMOS tools where necessary. For information and/or cost of these tools, contact the person named in Section 1.3.1.3.

AMMOS tools include telecommand encapsulation and protocol verification, mission analysis software, spacecraft monitoring programs, and data analysis software. See Reference 7 for the latest service descriptions in the AMMOS catalog.

Because each mission is unique, and mission specific adaptation of these tools is needed, it is difficult to provide *a priori* tool prices. Generally, AMMOS personnel need to confer with project personnel to determine specific tool requirements. Thereafter, it should be possible to quote a price for the product. If a tool's specification is completed by the end of Phase B, then work can commence at the start of Phase C/D so that the tool will be available at launch.

2.3 Near Earth Network and Space Network Costing

NEN and SN services are highly mission dependent. Therefore, it is not possible to provide a simple cost structure such as the one used for DSN stations. Proposers are advised to contact the GSFC NIMO listed in Section 1.3.2.2 above to obtain a cost estimate for their mission.

For the proposes of initial rough estimates, the following rate may be used for NEN S-band, X-band, and/or Ka-band service:

- $495.00 per NEN pass (one pass is <= 30 minutes).

The standard rates for using the SN:

- Single Access Service-Forward command, return telemetry, or tracking, or any combination of these, the rate is $131.00 per minute
- Multiple Access Forward Service - $29.00 per minute
- Multiple Access Return Service - $14.00 per minute.

2.4 Critical Event Support Costing

If *Critical Event* support can be obtained from one of NASA's standard networks (DSN, NEN, SN) then calculating costs is relatively simple. Costs are computed in the same way as for routine telemetry support. If it is not possible to use one of the NASA networks because no station element is in view or they are otherwise unavailable, then the task of computing *Critical Event* support becomes somewhat more complex.

For the launch, early orbit, and separation phases, it may be possible to use the SN although a small Earth station is generally sufficient. Several possibilities exist. First, it may be possible to arrange with another space agency for use of their station provided that it has a reasonable view period. Second, commercial stations may exist that would be able to provide the needed support. Third, it may be possible to contract for use of an existing, or alternatively construct, a small transportable station, which can be placed in a location with a suitable view period.

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 for this early mission phase. For assistance in establishing alternative solutions and/or in costing the required support, please contact the person named in Section 1.3.1.2 if the proposed mission utilizes DSN support or the person named in Section 1.3.2.2 if the proposed mission uses either NEN or SN support.

3.0 Proposal And Concept Study Information

3.0.1 Step 1 Proposals

The requirements in sections 3.1, 3.2, and 3.3 of this document do <u>not</u> apply to Step 1 proposals (Requirement B-35, in Appendix B of the AO, defines the corresponding requirements for Step 1 proposals). They apply to the Concept Study Reports (CSRs) that investigations selected at the outcome of Step 1, to conduct Phase A concept studies, will prepare.

3.0.2 Concept Study Reports

It is in the interest of the selected investigation teams to provide the information required in the following tables and sections. Absent this information, evaluators are forced to estimate the values of missing parameters from assumptions based on their knowledge, experience, and judgment. Conservative estimates by evaluators may hurt an investigation's prospects for down-selection and the subsequent phases of mission development and flight operation.

3.1 Communications System Parameters

As a minimum, proposals should contain the set of telecommunications parameters shown in Table 3-1. 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 3-2 is a sample telecommunications link parameter form containing the necessary parameters but using roughly 1/3 of a page. Proposers are requested to include this completed form in their proposals.

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.

3.2 Station Requirements by Mission Phase

Proposers should clearly state their DSN 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, station required, pass length in hours, number of passes each week, and the number of weeks that this services are required. A sample table containing a few entries for a fictitious planetary mission appears in Table 3-3. Proposers are requested to include a completed form showing all major mission phases and the services required in their proposals.

3.3 MSPA User(s) Information

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 2.1.2). 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.

Table 3-1: 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).
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-ϕ, 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.

3.4 Other Information

The previous sections (1 and 2) set forth requirements for proposal content. Persons preparing proposals should carefully review all three sections to ensure that the document that they are submitting addresses each applicable item. This is particularly important in step two proposals.

Table 3-2: 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).

Table 3-3: 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
7	Orbit Operations	2013	70	4	7	12
8	Orbit Operations	2013	70	4	7	37

4.0 REFERENCES

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 Telecommunications & 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. *Handbook of the Space Frequency Coordination Group*, ESA Frequency Manager and SFCG Secretariat, European Space Agency Headquarters, 8-10 Rue Mario Nikis, 75738 Paris, France. ***Copies of the document are available at:*** http://www.sfcgonline.org/

5. *DSN Commitments*. ***Web site located at:*** http://deepspace.jpl.nasa.gov/advmiss

6. *DSN Service Catalog*, DSN No. 820-100, JPL D-19002, Jet Propulsion Laboratory, ***latest copies available at:*** http://deepspace.jpl.nasa.gov/advmiss

7. *AMMOS Tools and Services Catalog,* ***latest copies available at:*** http://ammos.jpl.nasa.gov/AMMOS_Catalog

5.0 GLOSSARY

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
ARQ	Automatic Repeat Queuing
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
CDR	Critical Design Review
CE	Commitments Engineer
CTT	Compatibility Test Trailer
CFDP	CCSDS File Delivery Protocol
CLTU	Command Link Transmission Unit
CNES	Centre National d'Etudes Spatiales (France)
CSR	Concept Study Report
dB	Decibels
dBi	Decibels (relative to an isotropic radiator)
DDOR	Delta Differenced One-way Range
DLR	Deutsche Zentrum fur Luft- Und Raumfahrt (Germany)
DSA	Deep Space Network Service Agreement
DSN	NASA's Deep Space Network
DTF-21	Development Test Facility-21 (Compatibility test area located at JPL)
EES	Earth Exploration Satellite (A communications service designated by the ITU)
ESA	European Space Agency
F_C	Frequency of Contacts (For costing DSN stations)
FY	Fiscal Year
GHz	Gigahertz (1×10^9 cycles per second)
NEN	NASA's Near Earth Network
GRGT	Guam Remote Ground Terminal
GSFC	Goddard Space Flight Center
HEF	High Efficiency (Refers to specific DSN 34M antennas)
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)
IND	Interplanetary Network Directorate (JPL Program Office)
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
LEOP	Launch and Early Orbit Phase
M	Meters
MA	Multi-Access
MD	Maryland (abbreviation)
MHz	Megahertz (1 x 10^6 cycles per second)
MSPA	Multiple Spacecraft per Aperture
NASA	National Aeronautics and Space Administration
NEN	Near Earth Network
NIMO	Networks Integration Management Office at GSFC
NPR	NASA Procedural Requirements
NTIA	National Telecommunications and Information Administration
PI	Principal Investigator
POCC	Project Operations Control Center
PSLA	Project Service Level Agreement
r	Range (Earth to spacecraft)
RAF	Return All Frames
R_B	Base Rate (For costing DSN stations)
RCF	Return Channel Frames
RFS	Radio Frequency Subsystem
SA	Single Access
SCaN	Space Communications and Navigation
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 (TDRSS)
SOMD	Space Operations Mission Directorate (formerly NASA Headquarters Office of Space Flight Code M)
STGT	Second TDRSS Ground Terminal
TDRSS	Tracking and Data Relay Satellite System
TT&C	Tracking, Telemetry, and Command
VLBA	Very Long Baseline Array
WSGT	White Sands Ground Terminal
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