NASA's Mission Operations
and Communications Services

This Description applies only to proposals in response to
NASA's Announcement of Opportunity for Small Explorers (SMEX)
and Missions of Opportunity

AO 03-OSS-02

February 2003
1.0 INTRODUCTION

This document is intended to assist in the preparation of proposals in response to an Announcement of Opportunity (AO) issued by NASA's Office of Space Science (OSS) for Small Explorers (SMEX) and Missions of Opportunity. NASA has extensive institutional resources that provide communications services to NASA missions. These services transmit flight data between spacecraft and ground terminals and between the terminals and mission-related data centers.

The use of these services may incur costs to the user and estimates for these costs need to be included in proposals submitted under this AO. To facilitate proposal preparation, proposers are to read this appendix and contact the individuals named in Section 2.3 and 2.4.2 below.

1.1 Costing Policy

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

- in anticipation of formal NASA-wide full-cost accounting,
- to better manage our currently oversubscribed communications resources,
- to encourage tradeoffs between on-board processing and storage vs. communications requirements, and
- to encourage proposers to design hardware and operations systems which minimize life cycle costs while accomplishing the highest-priority science objectives.

1.2 Choice of Service Providers

NPG 7120.5B (Sections 2.1.5d and 3.1.5c) require all programs/projects to develop requirements during mission formulation for space operations services provided by NASA facilities. Such services include communications, tracking, mission operations, navigation, and data processing. NPG 7120.5B requires projects to use NASA services unless a more cost-effective life cycle can be found and demonstrated in the proposal.

Proposers are free to use all, some, or none of the NASA-provided services referenced below. Regardless of this choice, the proposal must include a rationale for the level of communications services proposed, the basis for costs of communications services, key communications parameters, and a rationale and cost basis for mission operations services. Required services should be identified irrespective of the provider. As a matter of policy, proposers should be prepared during the definition phase to support tradeoff studies on the use of NASA-provided services versus proposed alternatives. Contact with NASA is encouraged early in the proposal development process to help the project converge on the best approach.

If OSS finds that the proposed project or PI approach does not result in the lowest life-cycle cost, the Enterprise 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 OSS, any funding impacts to the project / PI will be resolved.

1.3 NASA's Mission Operation Services

NASA can provide mission operations services through Goddard Space Flight Center or through the Jet Propulsion Laboratory. Mission operation services at GSFC are discussed in the GSFC Services document located in the Explorer Program Library for this AO. Mission operation services at JPL are discussed in Section 2.4.
2.0 NASA’s Communications Services

NASA operates four networks for supplying space communications services. These networks are the Deep Space Network (DSN), the Ground Network (GN), the Space Network (SN), and the NASA Integrated Services Network (NISN). The GN and SN support the near-Earth and high-Earth orbiting missions. The DSN supports planetary and heliospheric missions, those operating at the Lagrangian points (L1 and L2) and the highly-elliptical Earth-orbiting missions. NISN operates NASA’s wide area network (WAN) and provides for communications circuits from NASA centers to several universities and research centers. Each network has a technical interface for developing new requirements.

2.1 Ground Network Services

GN operations are the responsibility of Goddard Space Flight Center (GSFC) under the auspices of the Office of Earth Science. The GN has Earth stations located in the United States at: Poker Flats, Alaska; Merritt Island, Florida; Wallops Island, Virginia; as well as in Antarctica, Chile, and Norway. Generally, these stations support non-deep space missions in the 2 and 8 GHz bands; however, several are capable of receiving signals from deep space missions as well. Earth station antennas range in size from 2.4 to 18 meters in diameter. Table 1-1 shows several of the service categories.

<table>
<thead>
<tr>
<th>GN Service Category</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commanding</td>
<td>RF modulation, transmission, and delivery of telecommands to spacecraft.</td>
</tr>
<tr>
<td>Telemetry</td>
<td>Telemetry data capture, decoding, and additional value-added data routing.</td>
</tr>
<tr>
<td>Tracking</td>
<td>Radio metric data capture (range, Doppler, and angles).</td>
</tr>
<tr>
<td>Mission Planning</td>
<td>Communications design, orbital modeling, scheduling, resource planning.</td>
</tr>
<tr>
<td>Flight Operations</td>
<td>Planning, controlling, and monitoring of operational spacecraft.</td>
</tr>
<tr>
<td>Flight Dynamics</td>
<td>Design spacecraft trajectory, predict and control of operational spacecraft.</td>
</tr>
<tr>
<td>Science Data Processing</td>
<td>Processing of science data, generate data products, analysis of data.</td>
</tr>
<tr>
<td>Consulting and Training</td>
<td>Anomaly resolution, troubleshooting, consulting.</td>
</tr>
<tr>
<td>Range Support</td>
<td>Control center, range communications, meteorology, launch imagery.</td>
</tr>
</tbody>
</table>

2.2 Space Network Services

NASA’s Space Network (SN) consists of seven geosynchronous satellites located at: 275° W, 174° W, 171.3° W, 171.1° W, 49° W, 47° W, and 41° W. Satellite control and data capture facilities are located in: Guam (GRGT), GSFC, and White Sands, New Mexico (STGT and WSGT).

Second generation Tracking and Data Relay Satellites (TDRSs) 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. The services listed in Table 1-1 are also available to SN users.
2.3 Process for Requesting GN or SN Services

Proposers should contact the person named below for information about GN or SN 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 mission operations requirements in a preliminary Project Service Level Agreement (PSLA). During the study phase, as the proposer’s mission concept becomes more clearly defined, the requirements in the preliminary PSLA will be clarified. The resulting documentation of services and costs will become the PSLA to be signed by appropriate Project and Network representatives.

The primary GN and SN point of contact for this AO is the GSFC Customer Commitment Manager (see also Reference 6):

Jon Z. Walker  
Deputy Program Manager, Customer Commitment Office  
Goddard Space Flight Center  
Code 451  
Greenbelt, Maryland 20771  
Phone: (301) 286-7795  
FAX: (301) 286-0275  
e-mail: Jon.Z.Walker@nasa.gov

2.4 The Deep Space Network

The Interplanetary Network Directorate (IND) comprises the Deep Space Mission System (DSMS) and the Institutional Computing and Information Services (ICIS) organization located at the Jet Propulsion Laboratory (JPL). DSMS is the executive agent for 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 employing the DSN. In addition, the DSMS develops, maintains and employs a set of tools and services known as the Advanced Multi-Mission Operations System (AMMOS) for working with the DSN.

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.

2.4.1 DSMS Services

DSMS has moved from a facilities-based support approach to one based upon standard services. Standard services are described in the DSMS Services Catalog (Reference 5). These services support both Earth orbiting and deep space science missions. Table 1-2
summarizes DSMS service categories. Each of the Service Categories named in Table 1-2 may contain several services. Proposers interested in services having the word *Call for Information* in the rightmost column of Table 1-2 should contact the person named in Section 2.4.2 for additional requirements. A description of all services can be found in the DSMS Services Catalog (Reference 5).

### Table 1-2: DSMS Service Categories

<table>
<thead>
<tr>
<th>Service Category</th>
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<tr>
<td>Command</td>
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<tr>
<td>Telemetry</td>
<td>Telemetry data capture and additional value-added data routing and processing.</td>
</tr>
<tr>
<td>Mission Data Management</td>
<td>Data buffering, staging, short and long term storage.</td>
</tr>
<tr>
<td>Tracking and Navigation</td>
<td>Radio metric data capture, LEOP trajectory, ephemerides, and modeling.</td>
</tr>
<tr>
<td>Experiment Data Products</td>
<td>Higher level data processing providing photo and science visualization products.</td>
</tr>
<tr>
<td>Flight Engineering</td>
<td>Spacecraft link performance, analysis, and prediction (<em>Call for Information</em>).</td>
</tr>
<tr>
<td>Beacon Tone</td>
<td>Monitors subcarrier frequencies transmitted by S/C depending on S/C’s health.</td>
</tr>
<tr>
<td>Ground Communications</td>
<td>Data, voice, and video communications network services.</td>
</tr>
<tr>
<td>Radio Science</td>
<td>S/C Doppler, range, and open-loop receiver measurements at 2, 8, and 32 GHz</td>
</tr>
</tbody>
</table>

#### 2.4.2 Process for Requesting DSMS Services

Proposers should contact the person named below for information about DSMS mission operations services and costs at the time when initial science operations concepts are being defined. A DSMS representative will assist proposers by providing information concerning services and costs. Further, they will assist in documenting initial DSMS requirements in a *preliminary* Project Service Level Agreement (PSLA). During the study phase, as the proposer’s mission concept becomes more clearly defined, the requirements in the preliminary PSLA will be clarified. The resulting documentation of services and costs will become the PSLA to be signed by appropriate Project and Network representatives. PSLA’s identify all mission operations requirements, including those provided by non-DSMS sources, in order to provide a source of end-to-end operations information and to document any cost analyses leading to the selection of non-DSMS services.

The primary DSMS point of contact for this AO is the Plans and Commitments Office Manager (Organization 920):

Richard B. Miller  
Manager, DSMS Plans and Commitments, Office 920  
Jet Propulsion Laboratory  
M/S 303-402  
4800 Oak Grove Drive  
Pasadena, California 91109  
Phone: (818) 354-1515  
FAX: (818) 393-1692  
e-mail: richard.b.miller@jpl.nasa.gov
2.5 NASA Integrated Services Network (NISN)

The mission of the NISN is to provide cost-effective wide area network telecommunications services for transmission of data, video and voice for all NASA Enterprises, Programs and Centers, utilizing commercial capability wherever possible. NISN services can be used to provide data links between NASA centers and project operations sites that may be located away from a NASA center. These circuits may be for routine operations or may be temporary for support of integration and test activities or launch activities.

For more information, contact the customer commitment representatives listed in Section 2.3 or 2.4.2 above. Also contact NISN directly; see: http://www.nisn.nasa.gov/.

2.6 Communications 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:

- 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 can be obtained from the NASA Management Office at the Glenn Research Center or by consulting References 1 and 2. Recommended standards applicable to DSN, Ground Network, or Space Network (TDRSS) support can be obtained from Reference 3, the CCSDS home page. Recommendations of the SFCG are available in Reference 4.

Capabilities described below result in the more efficient use of NASA’s facilities. Proposers should carefully consider each item below. Networks to which each item is applicable are noted following the subsection’s title.

2.6.1 Space Link Extension (DSN, GN, SN)

Project Operation Control Centers (POCCs) using DSN and SN services should utilize 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 failure. In 2005 and beyond, 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). Proposers interested in SN or Gn services should contact the person named in Section 2.3.

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

2.6.2 X-Band and $K_a$-Band Communications (DSN, GN, SN)

Category A ($r < 2 \times 10^6$ km) missions 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 resulting 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 ($r < 2 \times 10^6$ km) with high data/symbol rates planning to operate in the 8 GHz Earth Exploration Satellite (EES) service (8025-8400 MHz), should investigate SN capabilities in the 26 GHz band. Missions utilizing the EES service tend to have very high data/symbol rates and those 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.

Category B ($r \geq 2 \times 10^6$ km) missions operating in a Space Research allocation launching after 2002 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 made future operations in the 2 GHz deep space band impractical and therefore, risky and unwise. Accordingly, the Office of Space Science is recommending against the use of the 2 GHz band for future Category B missions. 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 must utilize bandwidth-efficient modulation (see Section 1.5.3 and Reference 4). Approved methods for bandwidth efficient modulation can be found in Reference 3.

Additionally, a new allocation for the Space Research service is being requested in the 25.5 – 27.0 GHz band (a.k.a. 26 GHz band) at the World Radio Conference (WRC) in 2003. If this new allocation is adopted at WRC 03, high data rate space science missions, requiring bandwidths in excess of 10 MHz, should be designed to operate in the 26 GHz band.

2.6.3 Bandwidth Efficient Modulation (DSN, GN, SN)

When operating in the 2 and 8 GHz bands, Category A and B missions should employ bandwidth efficient modulation methods in conformance with SFCG Recommendations. Category B missions should employ bandwidth efficient modulation whenever they operate in the 8400-8450 MHz band. A Spectral Emissions Mask can be 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 Recommendations 401 (2.4.17A) B-1, 401 (2.4.17B) B-1; and 401 (2.4.18) B-1 for non-deep space, deep space, and Earth resources missions respectively. For CCSDS modulation Recommendations consult Reference 3.

2.6.4 CCSDS File Delivery Protocol (DSN, GN, SN)
To improve station utilization efficiency as well as reduce mission risk and costs, all DSN users should employ the CCSDS File Delivery Protocol (CFDP), to transfer data to and from a spacecraft. CFDP operates over a CCSDS conventional packet telecommand, packet telemetry, or an Advanced Orbiting System (AOS) Path service link. 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 operates by copying a file from a source point to a destination site using an Automatic Repeat Queuing (ARQ) protocol. In an 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 Red Book available on the CCSDS web site (Reference 3).
3.0 NETWORK SUPPORT COSTS

Generally, mission proposals must include both launch and support costs. This section explains how to obtain costs for the GN, SN, NISN, DSN, and AMMOS.

3.1 Costs for the Ground Network and Space Network

GN and SN services are highly mission dependent. Therefore, it is not possible to provide a simple cost structure such as the one used for DSMS stations. Proposers are advised to contact the GSFC Customer Commitment Office listed in Section 2.3 above to obtain a cost estimate for their mission.

3.2 Costs for Using the Deep Space Network

DSN 26-meter, 34-meter, and 70-meter diameter antennas operating in the 2, 7, 8, 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).

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

\[
AF = R_B \left[ A_W \left(0.9 + \frac{F_C}{10}\right)\right]
\]

where:
- \(AF\) = weighted Aperture Fee per hour of use.
- \(R_B\) = contact dependent hourly rate, adjusted annually ($842/hr. for FY02).
- \(A_W\) = aperture weighting:
  - 0.80 for 26-meter or 34-meter High-Speed Beam Waveguide (HSB) stations.
  - 1.00 for all other 34-meter stations (i.e., 34 BWG and 34 HEF).
  - 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. It graphically illustrates the cost relationships between antennas and demonstrates the benefits of restricting the number of spacecraft-Earth station contacts each week.

A station contact may be any length but is defined as the lesser of the spacecraft’s viewperiod, the scheduled pass duration plus calibration times, or 12 hours. For a standard pass, a 45-minute pre-calibration and a 15-minute post-calibration time must be added to each scheduled pass.
pass to obtain the *station contact* time (other calibration times apply to Beacon Monitoring and Delta-DOR passes). Note that scheduled pass-lengths should be integer multiples of 1-hour.

Total DSN cost is obtained by partitioning mission support into calendar weeks and summing the *Aperture Fees*. This total cost can be obtained by grouping weeks having the same requirement in the same year, multiplying by weighted *Aperture Fee*, and summing over the mission’s duration. *Aperture Fees* include several services in the following categories: command, telemetry, tracking and navigation, radio science, radio astronomy, radar science, and routine compatibility testing.

3.2.2 DSN Compatibility Testing Costing

DSMS encourages pre-launch compatibility testing as a means to eliminate post launch anomalies and expensive troubleshooting. DSMS maintains a facility known as the Development Test Facility (DTF-21) in Pasadena, California. Except for the high power transmitter, antenna, and low noise-receiving amplifier, which are not included, DTF-21 is 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.

Because DSMS believes that this testing materially improves the likelihood of mission success, no charge is made for the use of these facilities for a single set of compatibility tests. Rather, it is included in the hourly-dependent rate, $R_B$, used in Equation 2-1.

3.2.3 Costs for the Advanced Multi-Mission Operations System

Advanced Multi-Mission Operations System (AMMOS) elements are located at JPL; however, specific subsystems may also be placed at user sites. AMMOS offers a selection of services and tools for spacecraft command and control, data reduction and analysis, and navigation.
DSMS services are integrated, and certain DSN services may be a prerequisite to obtaining AMMOS value-added services. Proposals should identify required AMMOS services. For information about these services see Reference 5. Cost estimates for AMMOS services can be obtained by contacting the person named in Section 1.4.2.

In addition to its standard services, AMMOS can provide users with specific software tools. Such tools include telecommand encapsulation and protocol verification, mission analysis software, spacecraft monitoring programs, and data analysis software.

Because each mission is unique, it is difficult to provide \textit{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.

### 3.3 PROPOSAL INFORMATION

Evaluation requires an independent assessment of systems proposed in response to the AO to verify the claims made. Absent the necessary information, evaluators are compelled to \textit{assume} values for missing parameters based upon their knowledge and experience. Conservative assumptions by an evaluator can work to the detriment of proposers. Accordingly, proposers are encouraged to provide sufficient information so that evaluators can make the necessary calculations. The points of contact for the NASA network listed above will supply proposers with the lists of mission parameters and other items needed for proposal evaluation.

Any further questions concerning NASA communications services should be directed to the technical points-of-contact listed in paragraph 6.1.2 of this AO.
4.0  REFERENCE DOCUMENTS

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


6. *GSFC services for space communications* are described at the following web site: http://msp.gsfc.nasa.gov/mainindex.htm