TMOD PLANS & COMMITMENTS
OFFICE 920
FUTURE MISSIONS PLANNING OFFICE

TMOD's MISSION OPERATIONS AND COMMUNICATIONS SERVICES

(A HANDBOOK FOR PREPARING PROPOSALS)

MARCH 2000

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1.0 INTRODUCTION

This document is intended to assist in the preparation of proposals in response to Announcements of Opportunity (AO) issued by NASA. To facilitate proposal preparation, services are described and costs are tabulated for the facilities operated by two organizations: the Telecommunications and Mission Operations Directorate (TMOD) at the Jet Propulsion Laboratory (JPL) and for the Goddard Space Flight Center (GSFC) under the Consolidated Space Operations Contract (CSOC). This description includes Earth stations, the Tracking and Data Relay Satellite System (TDRSS), and mission control centers. By providing this summary information, it is hoped that the task of proposal preparation will be materially simplified.

1.1 Costing Policy

As a matter of policy, NASA requires that proposals include costs for mission operations and communications services irrespective of the organization providing those services. The Office of Space Science (Code S), working with the Office of Space Flight (Code M), the Space Operations Management Office (SOMO), Lockheed-Martin Inc., and JPL are implementing this policy:

- in compliance with formal NASA-wide full-cost accounting procedures,
- to better manage NASA's currently oversubscribed communications resources,
- to encourage tradeoffs between on-board processing/storage and. 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 Responsible Organizations

The Space Operations Management Office (SOMO) at the Johnson Space Center is responsible for the functional management of most NASA space operations facilities. SOMO is also responsible for managing NASA's space operations systems, including the Deep Space Network's (DSN's) United States facilities, other NASA Ground Network (GN) stations, the Tracking and Data Relay Satellite System (TDRSS), the NASA Information Services Network (NISN), and mission and science operations systems associated with NASA centers.

JPL's TMOD is responsible for managing the DSN's international facilities and all services provided by the Advanced Multi-Mission Operations System (AMMOS). Because of TMOD's broad responsibilities, both AMMOS and the DSN have been aggregated under the TMOD's Deep Space Mission System (DSMS). However, to minimize confusion, the individual component names of AMMOS and DSN will be used throughout this document.

1.3 Choice of Service Providers

Proposers are free to use all, some, or none of the NASA-provided services described below. Regardless of their choice, the proposal must include a rationale for the level of communications and mission services proposed and the costs of these services. Key communications and mission services parameters are listed below.

NASA-provided communications and operations services are expected to be the most cost-effective services available, (i.e., cost and performance competitive with any services obtained from non-NASA providers). During the proposal evaluation process, the Office of Space Science and SOMO will review each proposal's performance and cost requirements, and assess the proposed implementation from mission-specific as well as NASA-wide perspectives.

1.4 Further Information

For information about SOMO's mission operations and communications service plans, contact:

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SOMO Mission Services Manager
Code 720
Goddard Space Flight Center
Greenbelt MD 20771

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For information about the DSN's international sites and TMOD Mission Services contact:

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FAX: (818) 393-1692
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1.5 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 NASA's Spectrum Management Office at the Lewis Research Center or by consulting References 1 and 2. Recommended CCSDS standards applicable to DSN, Ground Network (GN), or TDRSS support can be obtained from Reference 3, the CCSDS home page. Recommendations of the SFCG are available in Reference 4.

1.6 Selection of Services

A SOMO Service Catalog (Reference 5) has been assembled, permitting users to select combinations of services ranging from full mission operations to basic telecommand and telemetry. Proposals should specify which services and tools they require from the list of standard services found in Sections 2 and 3. However, some services require other services as a prerequisite (e.g., telemetry frame service is a prerequisite for the packet extraction service).

1.7 SOMO Service Categories

SOMO has moved from a facilities-based support approach to one based upon standard services. Standard services are described in the *SOMO Services Catalog* (Reference 5). These services support both Earth orbiting and deep space science missions. Table 1-1 summarizes SOMO service categories.

Table 1-1: SOMO Service Categories

SOMO Service Category	Brief Description
Command	RF modulation, transmission, and delivery of telecommands to spacecraft.
Telemetry	Telemetry data capture and additional value-added data routing and processing.
Mission Data Management	Data buffering, staging, storing, and archiving.
Experiment Data Products	Higher level data processing providing photo and science visualization products.
Tracking and Navigation	Radio metric data capture and generation of high order navigation products.
Telecom Analysis	Spacecraft link performance, analysis, and prediction.
S/C Time Correlation	Monitors spacecraft clock drift and correlates time to a standard time reference.
Mission Control	Monitors spacecraft health and safety and sends corrective commands.
Instrument Control	Monitors specific spacecraft instruments, sends corrective commands.
Flight Engineering	Performance analysis and anomaly detection of instrument and S/C systems.
Radio Science	S/C Doppler, range, and open-loop receiver measurements at 2, 8, and 32 GHz.
VLBI	Capture of narrowband or wideband very long baseline interferometric data.
Radio Astronomy	Similar to Radio Science except measures natural phenomena.
Service Management	Planning, scheduling controlling, configuring and accounting of system resources.
Mission Planning	Trajectory and mission design, launch analysis, science instrument planning.
Sequence Engineering	Uplink process and sequence design, S/C operations schedule, event prediction.
Ground Communications	Data, voice, and video communications network services.

1.8 Changes from Previous Version

This version of TMOD's Mission Operations and Communications Services document has been updated and contains the most recent services and pricing information. Prices for TMOD Earth stations and AMMOS services reflect values effective on 1 March 2000.

2.0 TMOD SERVICES, SUPPORT AND TOOLS

The Telecommunications and Mission Operations Directorate (TMOD), located at the Jet Propulsion Laboratory (JPL), is the program office responsible for operating the Deep Space Network (DSN) and the Advanced Multi-Mission Operations System (AMMOS). AMMOS and DSN facilities have been aggregated under the title of the Deep Space Mission System (DSMS). The DSN comprises a multiplicity of Earth stations and associated operating systems while AMMOS provides many mission related tools and services for: control, monitoring, orbit determination, data analysis, etc. These facilities are available for supporting Earth orbiting and deep space missions.

2.1 Deep Space Network

The DSN consists of control, communications, and test facilities at JPL, and Earth station complexes located near Goldstone, California; Canberra, Australia; and Madrid, Spain. Reference 5 contains a description as well as the specific characteristics of these stations.

The DSN provides communications services between spacecraft and Earth station complexes together with the ground communications among the complexes and the control center. Control for the network is 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 Development Test Facility (DTF-21) at JPL in Pasadena or by using the Compatibility Test Trailer (CTT) at a remote site. RFS compatibility testing is highly recommended and should be completed at least 18 months prior to launch.

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 (see equation 2-1). Generally, DSN services are included in the *Aperture Fee* (see Form 2-1 below). DSN 11-meter stations are designed for Very Long Baseline Interferometry (VLBI) missions and operate at 7, 8, and 15 GHz. Because of their limited capability, 11-meter stations are priced at a flat rate.

<u>As a minimum, proposals should contain the set of telecommunications parameters in Table 2-1 and a list of required services taken from Table 2-3.</u> While Proposers may or may not wish to use a tabular format, the required parameter values and service names should be supplied in a clear, concise, and readily apparent form. Table 2-2 is an example of a communications parameter table containing 20 parameter values in only 1/3 of a page.

2.2 Advanced Multi-Mission Operations System

Main AMMOS elements are located at JPL; however, specific subsystems may also be placed at user sites. AMMOS offers users a selection of services for spacecraft command and control, data reduction and analysis, and navigation. TMOD services are integrated, and certain DSN services may be a prerequisite to obtaining AMMOS value-added services. Proposals should identify specific services (whether obtained from AMMOS or other sources) listed in Table 2-3 required for mission support and the costs for each service over the life of the mission.

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.

A list of available tools can be found in Table 2-5. Fees for AMMOS services and tools will vary with project requirements and costs must be based upon a user's needs. The information in Tables 2-3, 2-4, and 2-5 below may be used to generate rough estimates of AMMOS costs.

Table 2-1: Required Telecommunications Parameters and Definitions

Parameter	Units	Description
Maximum S/C Distance	Km	Maximum spacecraft-earth station distance during primary mission.
Encounter 1 Distance	Km	Maximum spacecraft-earth station distance during first encounter.
Encounter 2 Distance	Km	Maximum spacecraft-earth station distance during second encounter.
Encounter N 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.
Uplink Transmitting Antenna	DBi	Gain (or name) of earth stations transmitting antenna (e.g., 34M BWG).
S/C Receiving Antenna Gains	DBi	Gains of all spacecraft receiving antennas.
Telecommand Data Rate	b/s	Maximum desired telecommand data rate.
Telecommand Bit-Error-Rate	-	Required telecommand Bit-Error-Rate (BER).
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.
SC Transmitting Power	Watts	S/C Power amplifier Output.
Downlink Modulation Format	Name	Format name (e.g., PCM/PM/Bi-Ù, PCM/PSK/PM, BPSK, QPSK, etc.).
Downlink Frequency Band	GHz	Proposed space-to-earth frequency band expressed in GHz.
S/C Transmitting Antenna	DBi	Gains of all spacecraft transmitting antennas.
Downlink Receiving Antenna	DBi	Gain (or name) of earth station receiving antenna (e.g., 34M BWG) .
Telemetry Data Rate	b/s	Maximum desired telemetry data rate.
Telemetry Coding	Name	Telemetry code (e.g., convolutional, Reed-Solomon, concatenated, etc.).
Telemetry Bit-Error-Rate	-	Required telemetry Bit-Error-Rate (BER).

Table 2-2: Sample Table for Inclusion in Proposal

Parameter	Value	Parameter	Value
Maximum S/C Distance (km)		S/C Receiver Bandwidth (Hz)	
Encounter 1 Distance (km)		Turnaround Ranging (Yes/No)	
Encounter 2 Distance (km)		S/C Transmitting Power (Watts)	
Encounter N Distance (km)		Downlink Modulation Format (Name(s))	
Uplink Transmitter Power (Watts)		Downlink Frequency Band (GHz)	
Uplink Frequency Band (GHz)		S/C Transmitting Antenna Gains (dBi)	
Uplink Transmitting Antenna Gains (dBi)		Downlink Receiving Antenna Gain (dBi)	
S/C Receiving Antenna Gains (dBi)		Telemetry Data Rate (b/s)	
Telecommand Data Rate (b/s)		Error Detecting-Correcting Code (Name)	
Telecommand Bit-Error-Rate		Telemetry Bit-Error-Rate	

2.3 TMOD Services

TMOD offers an integrated set of AMMOS and DSN services. A detailed description of these services and their deliverables can be found in Reference 6 and 7. A service list and summary description appear in Table 2-3 below. Users can select only those services needed to support their project. However, some services require others to obtain or condition data before they are available.

Table 2-3: Standard TMOD Services

Service Types	Brief Description
Command:	
Command Radiation	RF modulates and transmits CLTUs to user spacecraft.
End-to-End Command Delivery[1]	Error-free delivery of command files to spacecraft using COP-1 protocol (at 26M only).
Telemetry:	
Frame	Provides frame reconstruction and routing options for CCSDS compliant formats.
Packet	Extracts packets from frames by earth received time or sequence number.
Channel	Extracts data samples from packets based upon pre-established criteria.
Data Set	Provides Level-O products for selected instruments and observation cycles.
Mission Data Management:	
Short Term Data Retention	Data buffering and staging (up to 1-week) to ensure delivery.
Long Term Data Repository	Data storage and retrieval for life-of-mission.
Archive Product Preparation	Prepares data products for long-term data archival.
Experiment Data Products	
Level 1 Processing	Generates Level-1 experiment data.
Higher Level Processing	Generates Level-2 (or higher level) data products.
Photo Product	Provides photoproduct enhancement and annotation at any level.
Sense of Active Presence	Adapt commercial technologies to man-machine interface for improved operations.
Science Visualization	Science data visualization and animation using navigation, ephemeris, CAD, and remotely sensed data/imagery. 3D science data rendering and animation. Sense of Active Presence – virtual reality based on telemetry, science data, models, etc.
Archive Product Design	Interface with cognizant personnel of selected archive to define/design product.
Product Distribution	Distribution of data and science products, based on published/subscribed paradigm.
Compression Engineering	Design/select compression/decompression algorithms for specific instruments.
Tracking and Navigation	
Radio Metric Measurement	Provides raw, uncalibrated radio metric observables.
Validated Radio Metric Data	Validated, calibrated, radio metric data.
Orbit Determination	State vectors representing a solution obtained from conditioned data.
Trajectory Analysis	Flight path prediction, reconstruction, or optimization.
Maneuver Plan/Design	Provides maneuver analysis and design required for project planning.
Ancillary Data	S/C and planetary ephemeris and constants and instrument operational information.
Ephemerides	Ephemerides for planets, planetary satellites, comets and asteroids.
Modeling & Calibration	Provides terrestrial frame and transmission media calibration data.
Gravity Modeling	Harmonic gravity models for Moon, Mars, and Venus.
Cartography	Cartographic anchor points on surface of specific bodies.
Flight Engineering	
Spacecraft Health/Safety Monitor	Monitoring of spacecraft health based on project provided limits automated alarms.
Spacecraft Performance Analysis[2]	Provides system level performance analysis of spacecraft.
Telecom. Link Analysis	Planning, prediction, and performance analysis of S/C telecommunications link.
Spacecraft Time Correlation	Monitors S/C clock drift and correlates S/C time to a standard time reference.
Instrument Health/Safety Monitor	Provides instrument performance monitoring based on project provided limits.
Sequence Engineering[2]	Design, development, and execution of uplink process.
Science Observation Planning	Design and integration of target observations producing conflict-free timeline.
Radio Science	
Baseband Measurements	Transmission S-, X-, and K_A-bands, open and closed loop signal capture.
Power Spectrum Display	Capture and partitioning of received signal into frequency bins containing amplitude.
VLBI	
Narrowband Measurements	Signal delay to 2 or more antennas based on narrowband signal.
Wideband Measurements	Signal delay to 2 or more antennas based on wideband signal.
Radio Astronomy	
Radio Astronomy in DSN Bands	I.F. signal distribution at 2, 8, and 32 GHz to special purpose equipment.
Radio Astronomy at Special Freqs.	I.F. signal distribution at special frequencies from 70-meter R & D cone.
Radar Science	
Continuous Wave	Transmission & reception of reflected continuous wave (CW) signal.
Binary Phase Coded	Transmission & reception of reflected CW signal modulated with binary sequence.
Interferometric Observations	Transmission & reception of reflected CW signal at multiple sites.
Ground Communications	
Ground Network	Provides data, voice, and video communications network services.
Data Transport	Low-latency UDP or Reliable Network Service (RNS) guaranteeing no lost packets.
Collaborative	Distributed file or computing services or videoconferencing between specific sites.

NOTES:

1. This service is not currently available but will be provided for missions launching in 2002.
2. This service is not currently available but will be provided for missions launching in 2003.

2.4 Service Costs

Caveat:
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 a TMOD representative listed in Section 2.8. Upon request, TMOD will provide a cost estimate and letter of commitment. TMOD costs in Phase 2 proposals should always be validated by TMOD.

As NASA moves toward full cost accounting, it is important that proposals identify the pro-rata share of each service's cost. Users are free to select only those services that they require, but they also have the burden of estimating the costs for each of those services. The following information is intended to assist in estimating those costs.

2.4.1 DSN Antenna 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.

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

where:

AF = weighted *Aperture Fee* per hour of use.

R_B = contact dependent hourly rate, adjusted annually ($607/hr. for FY00).

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., 34BWG and 34 HEF).

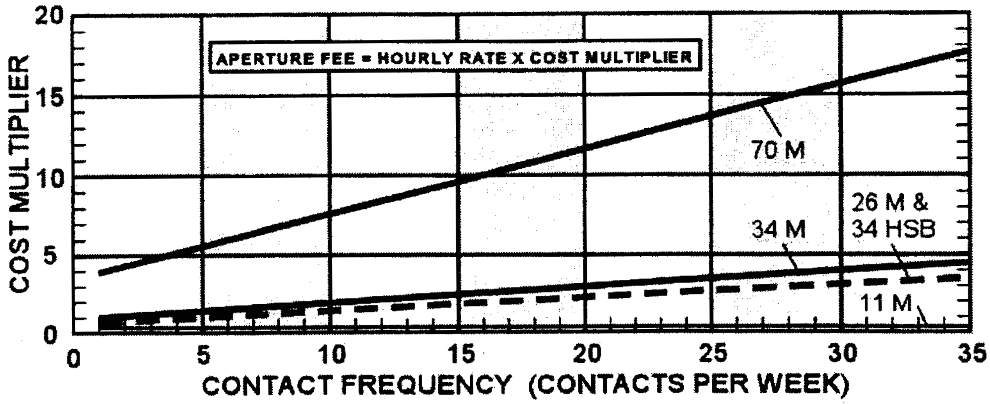
= 4.00 for 70-meter stations.

F_C = number of station contacts, (contacts per calendar week).

The *weighting factor* graph (Figure 2-1) 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. A 45-minute precalibration and a 15-minute post calibration time must be added to each scheduled pass to obtain the *station contact* time.

Figure 2-1: Aperture Weighting Factors



Total DSN cost is obtained by partitioning mission into calendar weeks and summing the *Aperture Fees*. This total cost can be computed by grouping weeks having the same requirement in the same year, multiplying by weighted *Aperture Fee*, and summing over the mission's duration.

11-meter stations are designed to support Very Long Baseline Interferometry (VLBI) missions and have a very limited capability. VLBI missions are characterized by high data rates and nearly continuous Earth station support requirements. Therefore, the 11-meter station is charged at a flat rate of $0.2R_B$ irrespective of the number of hours that they are used each week.

A table entitled Form 2-1: *DSN Mission Support Costs*, can be used to calculate DSN *Aperture Fees*, and is on the following page. A personal computer program, running under Excel 2000, is available from the persons listed in Section 2.8 to compute the fee.

2.4.2 Multiple Spacecraft Supported by a Single Antenna - Fee Reduction

Some programs, such as Mars, cluster a multiplicity of spacecraft in a single location. It may be possible to simultaneously capture telemetry signals from two or more spacecraft provided that they lie within the beamwidth of a single Earth station's antenna.

There are a few constraints. First, only one uplink frequency can be transmitted. In most cases, this means that only one spacecraft in the cluster can operate in the two-way coherent mode. The remainder must be in a one-way mode. Second, multiple, independent receivers are required at the Earth station. This sets a practical limit on the number of spacecraft that can be served simultaneously to 4. Third, ranging and two-way coherent Doppler data can only be obtained from the single spacecraft in a two-way mode.

If this situation applies and the constraints are acceptable, then it may be possible to reduce the Antenna cost for all spacecraft operating in this mode. To calculate the cost, first compute the *Aperture Fee* using equation 2-1 above. Thereafter, apply the correction factor according to the formula:

$$AF' = (0.75)\, AF \qquad (2\text{-}2)$$

where:

AF' = weighted *Aperture Fee* per hour of use when 2 or more spacecraft simultaneously share the same antenna.

The reduced price, AF', reflects the reduced capability available as a result of sharing. It assumes that the uplink and ranging capabilities will rotate through all spacecraft on a substantially equal basis.

2.4.3 Compatibility Testing Cost

TMOD encourages prelaunch compatibility testing as a means to eliminate post launch anomalies and expensive troubleshooting. TMOD maintains a facility known as the Development Test Facility (DTF-21) in Pasadena, California as well as a Compatibility Test Trailer (CTT). Except for not including a high power transmitter and a low noise-receiving amplifier, DTF-21 and the CTT are configured much like an operational DSN Earth station.

Form 2-1: DSN Mission Support Costs

Mission Name:	
Program Name:	
Launch Year:	
User Type:	
Prepared By:	
Date Prepared:	

DSN SUPPORT SUMMARY	
Total Station Cost:	
TMS / NOPE Cost:	No Add'l. Chg.
Additional Fees:	
Total DSN Hours:	
Total Support Cost:	

	Mission Phase (name)	Antenna Size (meters)	Service Year (year)	Hours per Track (hours)	No. Tracks per Week (# tracks)	No. Weeks Required (# weeks)	Total Pre-Cal. (hours)	Total Post-Cal. (hours)	Total Time Reqd. (hours)	Total Cost for period (real-year $)
1										
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INSTRUCTIONS FOR COMPLETING TABLE **(Make Entries only in Blue or Red Cells)**

1. Complete summary table in upper left hand corner of page.
   a. Specify *Launch Year* using 4-digits (e.g., 2003, 2015, 2022, etc.)
   b. Specify *User Type* using exactly one of the following: Gov (if NASA), Gov-Reimb, Non-Gov-Reimb, VLBI, Radio Astronomy, Radar.
2. In the main table above, complete each line exactly as follows:
   a. Specify the *Antenna Type* as: 11, 26, 34BWG, 34HEF, 34HSB, or 70. Only one *Antenna Type* is permitted on each line.
   b. Enter only one, or part of one, *Service Year* (e.g., 2003). Use consecutive lines for different years, or the same year if multiple antennas are needed.
      1) Several lines can be used for one year representing multiple mission phases, each with differing support requirements.
   c. Each line can have only one set of support level values (i.e., *Hours per Track*, *No. Tracks per Week*, *No. Weeks Reqd.*).
      1) Use consecutive lines where concurrent support by an additional antenna is required and to augment coverage during critical periods.
3. *Hours per Track* is the actual time used for sending or receiving data, Pre-Cal. and Post-Cal. times are added automatically - do not include these times.
4. All costs are computed in real-year dollars using NASA's official inflation index.
   a. TMS Manager, CSR, and Compatibility Testing costs are included in the *Total Support Cost* found in the table in the upper right hand corner.
   b. Total DSN Hours are those spent in transmitting or capturing data plus Pre-Calibration and Post-Calibration times.

Approximately 18 months prior to launch, projects should to bring their Radio Frequency Subsystems (RFS) to DTF-21 (or use the CTT) for testing. Testing requires approximately two weeks and includes such items as RF compatibility, data flow tests, and transponder calibration.

Because TMOD believes that this testing materially improves the likelihood of 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.

2.4.4 AMMOS Fees

TMOD has moved to a service based architecture. Only services required for support of each mission need be selected, minimizing the operations support costs for each project.

> **Note: Proposals should identify each specific service required for support of that project together with the number of units of that service required during the operational**

Computing AMMOS services fees is more complex than DSN costs because each mission's requirements depend upon its specific objectives. Nevertheless, it is possible to estimate costs for some services. AMMOS service costs, C_S, comprise two components:

$$C_S = C_M + C_O \qquad (2\text{-}3)$$

where:

C_M = Phase A and Phase C/D costs for hardware and software modifications.

C_O = Phase E mission operations costs for each service.

C_M represents a setup effort for preparing the AMMOS system to perform the service during the mission's operational phase. Setup costs include both labor and hardware components. Labor costs are expressed in *Work Months* (WM) corresponding to the effort of one person, possessing the requisite skill level, working for one month. Hardware costs are expressed in FY00 dollars. Preparation costs, C_M, should be shown during the 2-3 year period before launch.

C_O is the incremental effort needed to perform the named service throughout the mission's operational phase (Phase E). Generally, C_O represents a labor cost. In Table 2-4, costs are expressed in FY98 dollars and should be adjusted to FY00 where \$14.5K ≈ 1 WM. C_O represents the service cost during the specified time interval, or the cost for the named capability. C_O appears as a Phase E service cost during each year that the service is provided.

Since the previous publication of this document, work has continued to refine service costs. Fees in Table 2-4 are based upon the most recent information and can be used as a guideline in proposal preparation. In an effort to simplify the process, costs are shown for the service category. Specific services in that category will be provided for that cost (e.g., a *Packet Service* is provided for the telemetry charge even though the *Frame Service* is required before packets can be extracted). AMMOS costs are separate and distinct from the aperture fees for DSN stations described above in Section 2.4.1.

Table 2-4: Standard TMOD Mission Services and Support

Service Name	DSN Costs	Typical AMMOS Costs			
	Post-Launch	Pre-Launch		Post-Launch	
	Services In Aperture Fee	Work Force (*Work Months*)	Hardware (*FY98 $*)[5]	Work Force (*Work Months*)	Support Cost (*FY98 $*)[5]
Command:	Aperture Fee	9	$20K	0.5/Month	$100/Up-link Hour
Telemetry:	Aperture Fee	12	$40K	1.0/Month	$40/Dn-link Hour
Mission Data Management:	Aperture Fee	16/Mission +	-	0.2/Month +	-
Short Term Data Retention	-	0	$40K + $1K/10 GB	0.5/Month	$7K/Month
Long Term Data Repository	-	1/Instrument	$40K + $1K/10 GB	0.1/Month	$7K/Month
Archive Product Preparation	-	4/Instrument	$40K + $1K/10 GB	0.2/Inst./Month	$2.5K/Inst./Month
Experiment Data Products:					
Level 1 Processing (Std. Inst.)	Aperture Fee	8/Instrument[1]	$25K	0.2/Month	-
Higher Level Processing	-	Min. 6/Instrument	$50K	0.4/Inst./Month	-
Photo Products	-	2/Instrument	$2.5K	0.1/Month	Media Cost
Sense of Active Presence	-	Min. 4/Instrument	Min. 10K	0.1/Inst./Month	-
Science Visualization	-	2/Visualization	$5K	0.1/Inst./Month	-
Product Distribution	-	0.5/Product	$5K	0.1/Inst./Month	-
Archive Product Design	-	3/Instrument	-	-	-
Archive Product Production	-	1/Inst. (Cal. Data)	-	0.2/Inst./Month	-
Compression Engineering	-	2/New Inst. Type	-	-	-
Tracking and Navigation:[2]					
Radio Metric Measurement	Aperture Fee	-	-	-	-
Validated Radio Metric Data	Aperture Fee	-	-	-	-
Orbit Determination	-	See	See	See	See
Trajectory Analysis	-	Reference	Reference	Reference	Reference
Maneuver Plan/Design	-	7	7	7	7
Ancillary Data	-		-		
Ephemerides	-		-		
Modeling & Calibration	-		-		
Gravity Modeling	-		-		
Cartography	-		-		
Flight Engineering:					
S/C Health/Safety Monitor	-	10	$50K	0.6/Month	-
S/C Performance Analysis	-	Call for Info.	Call for Price	Call for Info.	Call for Price
Telecom. Link Analysis	-	29	$50K	0.6/Month	-
S/C Time Correlation	-	5	$25K	0.1/Month	-
Inst. Health/Safety Monitor	-	15/Instrument	$50K	0.4/Inst./Month	-
Sequence Engineering:	-	Call for Info.	Call for Price	Call for Info.	Call for Price
Science Observation Plan:					
In-Situ Instrument Observe	-	10/Instrument	$15K	1/Inst/Month	-
Remote Sensing Instrument	-	2/Instrument	$15K	0.4/Inst./Month	-
Radio Science:	Aperture Fee	-	-	-	-
VLBI:	Aperture Fee	-	-	-	-
Radio Astronomy:	Aperture Fee[3]	-	-	-	-
Radar Science:	Aperture Fee[3]	-	-	-	-
Ground Communications:					
Data Communications	Aperture Fee[3]	-	-	-	-
Voice Communications	-	-	-	-	-
Video Communications	-	-	-	-	-
Data Transport	-	-	-	-	-
Collaborative	-	-	-	-	-

Notes:

1. **Antenna Fee = Service included in fee calculated from Section 2.4.1; 1 *Work Month (WM)* = 14.5K in FY 00 dollars;**
2. **Labor for standard instrument. Labor for more complex instruments will be a minimum of 14 Work Months.**
3. **Aperture costs only representative, for accurate costing please refer to equation in Reference 7.**
4. **Additional costs may accrue if new or special equipment is required to make the necessary measurements.**
5. **Costs contained in these columns are specified in FY 98 dollars and must be inflated to an appropriate year.**

2.4.5 Cost Calculation

Total TMOD service cost is obtained by summing the DSN and AMMOS fees. DSN cost (*Aperture Fee, AF in $/Hr.*) is calculated by selecting a specific antenna and then determining the number and duration of tracking passes required to satisfy project navigation and science objectives. Each tracking pass must be increased in length by one-hour for calibrations. Once the pass length and number of passes is determined, multiply the aggregate hours by the hourly *Aperture Fee* computed using equation (2-1). A reduced cost is available when two or more spacecraft simultaneously share the same antenna (equation 2-2).

Total AMMOS costs are the sum of all service setup and incremental fees and depend upon the number and duration of the services required. Projects must first identify the specific AMMOS services that they need. They also need to determine the number of years, and fractions thereof, that these services will be required during the operational phase. Total Phase E cost for all services is calculated by multiplying the incremental fee for each service, found in the rightmost column of Table 2-4, by the total time that service is required and then summing over the set of services. Total Phase C/D expenses are labor plus hardware setup costs for each service summed over the set of services. Phase C/D costs should be distributed over a 2-3 period prior to launch.

AMMOS labor costs are stated in *Work-Months* to insulate the data from inflation factors. Users need only multiply the total number of *Work-Months* required for each service by the value for the year specified in the AO. For FY00, a burdened *Work-Month* is approximately $14.5K. Hardware and Phase E costs are shown in FY00 dollars and will need to be adjusted in order to be applicable to a different year.

2.5 AMMOS Tools and Costs

In addition to services, AMMOS can also provide users with tools needed to operate their mission. Tools are distinguished from services in that the former are software and hardware elements created for or adapted to a specific mission whereas the latter are those activities defined in Table 2-3 above. Tools are transferred to the flight project for operation by their personnel during the mission. Table 2-5 lists some AMMOS provided tools and includes a short description.

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

2.6 Ground Communications Costs

TMOD's Ground Communications Facility (GCF) provides data lines between the several DSN complexes and JPL. NASA's Integrated Services Network (NISN) maintains communications lines among NASA centers and to institutions such as the European Space Agency's control center, ESOC, in Darmstadt, Germany.

Table 2-5: TMOD Provided Mission Operations Tools [1]

TOOL NAME	TOOL FUNCTION
Command	
Command Delivery	Command data encapsulation and uplink protocols conforming to CCSDS.
Automated Command Tracker	Automated command file tracking, review, and approval process.
Telemetry	Turnkey telemetry system dedicated to acquisition, processing, monitoring, storage, and distribution of telemetry data (up to level-0), including CCSDS frame, packet, and channel services.
Mission Analysis	
Telecommunications Analysis	Monitor and predict the uplink and downlink telecommunications performance.
S/C Performance Analysis	Analysis capability for spacecraft and science instrument performance and health based upon telemetry data acquired from the various subsystems.
Mission Data Management	
Data Management	Data catalog, query, access, and data storage capabilities.
Data Products	Tools to create data products containing engineering and science data sets and to record them on a variety of magnetic and optical media.
Experiment Product	
Science Data Processing	Generates level 1A&B and higher level products from level-0 data.
Cartographic	Tools to support precise cartographic projections and elevation maps.
Science Data Visualization	Converts science data products for display or printing for visual interpretation.
Science product Delivery	Track and deliver file products to distributed Investigator sites.
Photo Product	Creation of photo products with visual enhancement and annotation.
Navigation	
Ancillary Data	Software supporting radiometric data conditioning, orbit determination, trajectory analysis, and maneuver planning and verification.
Mission Control	Displays engineering telemetry data to monitor spacecraft health and safety.
Instrument Control	Displays engineering telemetry data to monitor instrument health and safety.
Planning and Scheduling	
Sequence Planning	Provides sequence generation, validation, and review capabilities for standard mission commanding scenarios.
Test and Simulation	
Data Simulation Test	Generation of test data, i.e. simulated RF signals, spacecraft telemetry frames and packets, science data frames, and other data artifacts.
Spacecraft Simulation Test	Simulates spacecraft's behavior in response to control and external events.
Ground Data System	Both a full Test Telemetry and Command Subsystem (TTACS) and a miniature version of the entire GDS for support and development and test of spacecraft MOS.
Integrated Ground Data System	Provides turnkey system including computer platforms and a complete suite of tools adapted for mission specific needs.
Instrument Development	
Ground Support Equipment	Instrument Ground Support Equipment (IGSE) and environment software.
Flight Software Development	Tools and development environment for instrument software.
Instrument Modeling	Provides mathematical models of remote sensing instruments.
Calibration / Decalibration	Software supporting calibration analysis for science instruments.
Data Compression / Decompression	Selection and development of science data compression algorithms including end-to-end data system simulation – photon to final science product.

NOTE: 1. Contact TMOD service representative for Tool pricing information.

If service is required to a facility not now connected to the GCF or NISN, additional lines must be procured. Under full cost accounting, such additional common carrier fees must be acknowledged by the requesting project. In calculating line costs, users should determine the monthly cost, for a line of the needed capacity, from NISN's gateway at MSFC to the desired location. That cost should be multiplied by the number of months that the special service is required. TMOD personnel can assist in obtaining costs.

2.7 TMOD Requirements

The *Standard Services* architecture is intended to improve the efficiency of TMOD's operations and hence, to lower mission support costs to all of TMOD's customers. However, this architecture does impose a few constraints upon the users of TMOD's facilities.

2.7.1 Use of Standards

Missions seeking TMOD support must comply with international and United States regulations, standards and agreements. Such regulations, standards, and agreements include those published by the:

- International Telecommunications Union (ITU) (Reference 1)
- National Telecommunications and Information Agency (NTIA) (Reference 2)
- Consultative Committee for Space Data Systems (CCSDS) (Reference 3)
- Space Frequency Coordination Group (SFCG) (Reference 4)

2.7.2 TMOD Services Interface

Institutions wishing to transfer data to or from TMOD facilities should utilize a standard *Space Link Extension* (SLE) *Services Interface.* The interface's architecture is based upon internationally adopted standards promulgated by the CCSDS. It will become operational on or before 1 October 2001 and missions launching after that date should plan to use this system. Additional information can be obtained by contacting the persons listed in Section 2.8.

2.7.3 X-Band and k_A-Band Communications

Projects operating in a *Space Research* allocation, which launch after 2003, should be designed to communicate in either the 7/8 GHz or 7/32 GHz bands. Both deep space and near Earth allocations exist in the 7/8 GHz band and should be used by future missions. Ever increasing congestion and the addition of allocations for incompatible services (e.g., IMT-2000) have made future operations in the 2 GHz band uncertain and, therefore, risky.

2.7.4 Use the Smallest Aperture and the Lowest Uplink Power Possible

Designing a spacecraft to use the smallest DSN antenna possible increases the flexibility of TMOD's Scheduling function by permitting support of the mission with larger apertures if the requested station is unavailable. This maximizes the probability that the project will receive its requested coverage. Likewise, for missions requiring DSN 34M stations transmitting uplinks in the 7 GHz uplink band, designing the spacecraft to operate with a transmitter power $\leq$ 4 KW permits the use of either the DSN's 34M BWG or 34M HEF stations.

2.7.5 Use of File Delivery Protocols

Users should take advantage of the enhanced efficiency and operability facilitated by the use of the CCSDS emerging standards as well. The CCSDS Proximity-1 Space Link Protocol (currently in Red book form) provides in-situ users with standard formats, procedures, and qualities of services for bi-directional data transfer. The CCSDS File Transfer Protocol (CFDP) can be layered on top of Proximity-1 to provide both bi-directional file and message transfer between in-situ users as well as deep space – Earth transfers. Reference 8 describes to protocol and can be viewed on the CCSDS home page: http://www.ccsds.org/red_books.html.

2.8 Assistance with Mission Design

Prospective TMOD service users can obtain additional information about TMOD's services and capabilities by consulting Reference 6 below or by contacting the Future Missions Planning Office in TMOD's Plans and Commitments Office. TMOD's Future Missions Planning personnel can assist individuals preparing proposals by: identifying future capabilities and services, preparing a preliminary communications link analysis, describing TMOD requirements placed on users of its facilities, and assisting in the preparation of cost estimates for TMOD services. For such support please contact one of the persons listed below:

Warren L. Martin Manager, TMOD Future Missions Planning Office Jet Propulsion Laboratory 4800 Oak Grove Drive M/S 303-402 Pasadena, CA 91109 Phone: (818) 354-5635 FAX (818) 393-1692 e-mail: warren.l.martin@jpl.nasa.gov	Greg J. Kazz Systems Engineer, TMOD Future Missions Planning Office Jet Propulsion Laboratory 4800 Oak Grove Drive M/S 303-402 Pasadena, CA 91109 Phone: (818) 393-6529 FAX (818) 393-1692 e-mail: greg.j.kazz@jpl.nasa.gov	Edward Luers Systems Engineer TMOD Future Missions Planning Office Jet Propulsion Laboratory 4800 Oak Grove Drive M/S 303-402 Pasadena, CA 91109 Phone: (818) 354-8206 FAX (818) 393-1692 e-mail: edward.b.luers@jpl.nasa.gov

3.0 GODDARD SPACE FLIGHT CENTER SERVICES

In the past, the Goddard Space Flight Center (GSFC) was responsible for operating the Ground Network, and the Tracking and Data Relay Satellite System (TDRSS), and for providing mission operations and ground data system services. Generally, these services were for the support of Earth orbiting missions. SOMO and the Consolidated Space Operations Contract (CSOC) have now assumed these responsibilities.

3.1 Ground Network

Some information about the stations in NASA's Ground Network can be obtained at: http://www.wff.nasa.gov/~code452/. At this writing, the author is not aware of a publicly available CSOC Services Catalog. Some information may be gleaned from the old SOMO "Services Catalog", dated 1997. However, extreme caution should be exercised when using this document. Although it too is becoming dated, the best source for technical information about these Earth stations can most likely be found in CCSDS 411.0-G-3: Radio Frequency and Modulation -- Part 1: Earth Stations. Green Book. Issue 3. May 1997, which is available at: http://www.ccsds.org/green_books.html. The best course is to contact one of the persons named in Section 3.3.

3.2 Tracking and Data Relay Satellite System

Fortunately, the situation appears different for TDRSS. Current information is available at the GSFC web site at: http://www530.gsfc.nasa.gov/tdrss/. While some TDRSS services are listed on the web site, a service breakdown, equivalent to Table 2-3 above, was not found. For more information, contact the persons listed in Section 3.3 below.

3.3 SOMO Contact Information

The primary point of contact for the AO is the SOMO Lead Center Missions Services manager (CMSM). Please contact one of the persons listed below:

Jon Walker GSFC Center Mission Services Manager Code 450 Goddard Space Flight Center Greenbelt MD 20771 Phone: (301) 286-7795 e-mail: jon.walker@gsfc.nasa.gov	John Dalton SOMO Mission Services Manager Code 720 Goddard Space Flight Center Greenbelt, MD 20771 Phone: (301) 286-7213 FAX (301) 286-1765 e-mail: john.dalton@gsfc.nasa.gov

4.0 GLOSSARY

AF	Aperture Fee
AMMOS	Advanced Multi-Mission Operations System (located at JPL)
AO	Announcement of Opportunity
b/s	Bits per Second
CCSDS	Consultative Committee for Space Data System
CFDP	CCSDS File Delivery Protocol
CLTU	Command Link Transmission Unit
CMSM	Center Mission Services Manager
CSOC	Consolidated Space Operations Contract
CSR	CSOC Service Representative
CTT	Compatibility Test Trailer (contact TMOD)
dB	Decibels
dBi	Decibels relative to an isotropic radiator
DSMS	Deep Space Mission System
DSN	Deep Space Network
DTF-21	Design-Test Facility-21 (21 indicates a U.S. Location)
ESOC	European Space Operations Center (Control Center of European Space Agency)
FY	Fiscal Year
GCF	Ground Communications Facility
GHz	Giga-Hertz (1 x 10^9 Hertz)
GN	Ground Network
GSFC	Goddard Space Flight Center
Hz	Hertz (cycles per second)
ITU	International Telecommunications Union
JPL	Jet Propulsions Laboratory
K	1000 ($K = Thousands of Dollars)
Km	Kilometer
NASA	National Aeronautics and Space Administration
NISN	NASA Information Services Network
NTIA	National Telecommunications and Information Administration
RF	Radio Frequency
RFS	Radio Frequency Subsystem
SFCG	Space Frequency Coordination Group
SLE	Space Link Extension
SOMO	Space Operations Management Office
TDRSS	Tracking and Data Relay Satellite System
TMOD	Telecommunications and Mission Operations Directorate
TMS	Tracking and Mission Services [Manager]
VLBI	Very Long Baseline Interferometery
W	Watts
WM	Work-Months

5.0 REFERENCE DOCUMENTS

Prospective users of SOMO 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.gov/osmhome/redbook/ch10.pdf

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 are available at:*** http://www.ccsds.org/blue_books.html

4. *Handbook of the Space Frequency Coordination Group*, SFCG Secretariat, Frequency Management Office, European Space Agency, 8-10 Rue Mario Nikis, 75738 Paris, France, Latest Update. **Recommendations and Resolutions can be obtained at:** http://sfcg.lerc.nasa.gov/

5. *Services Catalog,* NASA Space Operations Management Office, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration, Code TA, 2101 NASA Road 1, Houston, Texas 77058.
Copies of the document are available at: http://www.jsc.nasa.gov/somo/products.htm

6. *AMMOS and DSN Support of Earth Orbiting and Deep Space Missions*, Document D-13973, Telecommunications and Mission Operations Directorate, Jet Propulsion Laboratory, Pasadena, California, **Latest Edition**. ***Copies of the document are available at:*** http://deepspace1.jpl.nasa.gov/advmiss

7. *Telecommunications and Mission Operations Directorate Services Catalog*, Organization 920, Jet Propulsion Laboratory, Pasadena, California, V 6.0 (or later edition), September 1998. ***Copies are available at:*** http://jpl-madb/srp/catalogHTML/CATALOG-FS.htm

8. *CCSDS File Delivery Protocol, Part 1: Introduction and Overview*, **Red Books can be viewed at**: ftp://tgannett.gsfc.nasa.gov/pub/ccsds//p1f/CFDP/

9. *NASA/GSFC/WFF Ground Network Resources*.
Copies of the document are available at: http://somo.gsfc.nasa.gov/msm/wff.htm

10. *Space Network Users' Guide*, **Latest Edition**.
Copies of the document are available at: http://www530.gsfc.nasa.gov/tdrss/