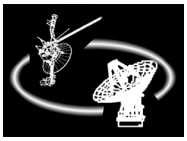

Deep Space Mission System

Deep Space Mission System (DSMS) Services Catalog

Version 7.5

by Wallace S. Tai

DSMS No. **820-100**
DOORS Baseline: **0.9**
Issue Date: May 19, 2003
JPL D-19002

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Section 1
Purpose of the Document

The Deep Space Mission System (DSMS) is a consolidated system of the two JPL multi-mission systems, i.e. the Advanced Multi-Mission Operations System (AMMOS) and Deep Space Network (DSN), providing support to flight projects and science investigations. In general, the DSMS support to its customers can be categorized into 3 types:

(1) mission operations *services,*

(2) *tools* used by customers to operate their missions and to develop their mission operations system (MOS), and

(3) other *engineering support* such as those activities performed to support project mission design, telecommunication link analysis, end-to-end integration and test, etc.

In the past, distinctions between these 3 types of support were rather vague. As NASA moves into an era of full cost accounting, there is an urgent need for the DSMS to be the service providing system to all deep space missions. A clear definition of services and other two types of support is thus needed to delineate mission-specific capabilities (which must be developed or adapted by each flight project) and multi-mission services (which can be more readily available to any flight project), so that not only the most cost effective approach to building a project MOS is possible but also the best performance and cost accountability of service provision can be accomplished.

The DSMS Services Catalog defines standard mission operations services available to customers. Although many of the services defined here are applicable to deep space, Earth orbiting missions, and other mission domains, this service catalog in contents is intended mainly for deep space mission and high Earth orbit mission customers. Its specific usage can be summarized as follows:

(a) It provides a standard taxonomy of mission operations services as a basis for all customers to request support in areas of telecommunications and mission operations from DSMS. This approach differs significantly from the way that support was offered in the past, i.e. the provision of DSN assets (such as antennas) and AMMOS tools as the primary commodities to customers. The service definition is therefore an important input to the development of a service level agreement and other commitment documents between a flight project customer and the service provider.

(b) It provides some service pricing information for pre-project customers to derive life cycle cost estimates for their mission operations systems. This is crucial in an era of full cost accounting, as the mission selection process conducted by the various NASA Enterprises must take into account their expenditure on multi-mission support.

The Services Catalog is not a requirements or design document, nor is it an interface specification. For purpose of defining interfaces between the DSMS and project MOS, the catalog must be applied in conjunction with more detailed information covered in DSMS Telecommunications Link Design Handbook[1], AMMOS capabilities catalog and adaptation guide [4], and others.

It is a DSMS policy that the DSMS Services Catalog shall include only services that are available at the time of the catalog release, or have funded deployment plans and dates.

Throughout this document, the term *service* is applied to mean the mission operations service and the term *customer* refers to a flight project Mission Operations System (MOS) organization or an experiment investigator.

Section 2
Point of Contact and Applicable Documents

The JPL DSMS Plans and Commitments Office will be the point of contact for making commitments to flight project customers on DSMS services, tools, and engineering support. For those services requiring special programmatic arrangement with JPL for subscription as identified in Table 5.1, please contact Dr. Fuk Li at (818) 354-2849. For information about how to contact the DSMS, please access the home page at URL address: http://deepspace.jpl.nasa.gov/advmiss

The custodian of the DSMS Services Catalog is the DSMS System Engineering Manager.

Reference Documents

Throughout this catalog, references to these documents are noted by superscripts corresponding the numbers in parentheses in the following list.

(1) DSMS Telecommunications Link Design Handbook, Document No. 810-5, Rev. E, Jet Propulsion Laboratory, Pasadena, California. URL address: http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/

(2) Telecommunications and Mission Operations Directorate Operations Contingency Plan, Rev. B, Document No. 801-202.

(3) Multimission Ground Data System: Users Overview, D-6057, Rev C, Jet Propulsion Laboratory, Pasadena, California, April 1994.

(4) Advanced Multimission Operations System (AMMOS) Detailed Capabilities Catalog and Adaptation Guide, D-5104, Jet Propulsion Laboratory, Pasadena, California.

(5) Space Flight Operations Center (SFOC) Functional Design Document, D-3752, Jet Propulsion Laboratory, Pasadena, California.

(6) Deep Space Network / Detailed Interface Design, Document No. 820-13, Jet Propulsion Laboratory, Pasadena, California.

(7) Telemetry Channel Coding, CCSDS 101.0-B-5, June 2001.

(8) Packet Telemetry, CCSDS 102.0-B-5, November 2000.

(9) Telecommand, Part 1: Channel Service, CCSDS 201.0-B-3, June 2000.

(10) Time Code Formats, CCSDS 301.0-B-2, April 1990.

(11) Orbit Data Messages. CCSDS 502.0-R-1. Red Book. Issue 1. June 2001.

(12) Space Link Extension Services - Cross Support Reference Model, Part 1: Recommendation for Space Data Systems Standards, CCSDS 910.4-B-1. Blue Book. Issue 1. May 1996.

(13) Space Link Extension - Cross Support Concept Part 1. CCSDS 910.3-G-1. Green Book. May 1995.

(14) Space Link Extension Return All Frames Service, CCSDS 911.1-R-2, Red Book, Issue 2. November 2000.

(15) Space Link Extension Forward CLTU Service, CCSDS 912.1-R-2, Red Book, Issue 2. May 2000.

(16) Space Link Extension Return Virtual Channel Frame Service, CCSDS 911.2-R-1, Red Book, Issue 1.

(17) A Guide to Capabilities Provided by the Office of Space Communications: NASA Office of Space Communications, April 12, 1996.

(18) Packet Telemetry Services, CCSDS 103.0-B-1. Blue Book. Issue 1. May 1996.

(19) Advanced Orbiting Systems, Networks and Data Links: Architectural Specification, CCSDS 701.0-B-2. Blue Book. Issue 2. November 1992.

(20) Lossless Data Compression, CCSDS 121.0-B-1. Blue Book. May 1997.

(21) Radio Frequency and Modulation System, Part 1 - Earth Stations and Spacecraft, CCSDS 401.0-B, June 2001.

(22) CCSDS File Delivery Protocol (CFDP), CCSDS 727.0-R-5. Red Book. Issue 5. August 2001.

Section 3
Definition of DSMS Services

3.1 Standard Service and Tailored Service

Service, in its general sense, is "work done for others." In the context of this document, a service is work performed by the service providing system, i.e. the Deep Space Mission System (DSMS), using one or more tools, facilities, or people, that produces mission and science operations results for a customer. Services may be standard or tailored.

DSMS standard services are those defined in this document, i.e. the DSMS Services Catalog, from which customers can make selection for their needed services to support their missions operations without significant expenditure of non-recurrent engineering to the customers.

A tailored service is one which requires substantial development effort due to the mission-dependent nature of the functions performed by the service or is one requested by customers for functionality different from a corresponding standard service offered in the DSMS Services Catalog. In either case, for fulfilling a tailored service, modification of DSMS capabilities with additional implementation effort will be needed at the cost of the customer.

3.2 Key Attributes of Standard Services

The DSMS standard services have the following key attributes -

(1) Customer Relevance: Services as perceived by the customers must be of value to the customers, packaged at a functional level, and expressed in the customer's terms. In other words, a service must be defined in terms of "what it provides" rather than "how it produces." This implies isolating the lower level of details of the capabilities and activities from the customers while still providing visibility to the customers.

(2) Pick-And-Choose: The services must be selectable by customers. Subscription to a service by a customer should not require buy-in of other services which are not relevant to the customer's needs.

(3) Plug-And-Play: The use of any standard services (as distinguished from the tailored services) must be based on definitions which appear in the DSMS Services Catalog. Once a service, as it exists in the Services Catalog, is subscribed to, it must be readily available for use by the customer. It should not require any implementation effort beyond interface testing, configuration setup, and parameter table updates, by the service provider.

(4) Standard Interfaces: The access to the DSMS services, in terms of control and data interfaces, by the customers will be via standard interfaces. "Standard" interfaces include those formally established by standards organizations (e.g., CCSDS, SFCG, ITU, ISO), those widely applied by the industry as de facto standards, and those defined by DSMS as common

mechanisms to all customers. No additional development effort on the DSMS or the subscriber's system other than that required for conforming to the standard interfaces will be necessary.

(5) Service Control: The customers will be allowed to directly control the service (within the bounds of the system's capabilities and safety criteria).

(6) Interoperability: Services will be standardized, whenever applicable, to enable interoperability with other service providers whenever the same service is requested.

(7) Performance Accountability: Performance of each individual DSMS service subscribed to by a customer will be measurable and reportable.

(8) Cost Accountability: Services will be provided to a customer on a fee schedule basis. This means all standard services will be defined, structured, and priced in such a way that customers' recurrent costs can be visible.

(9) Mission Life Cycle Orientation: Although each service by nature is for supporting the mission operations of flight projects, there are activities which must be conducted by the DSMS during the design, implementation, and integration and test phases of the project in order to make a service available. These activities are inherent part of a service subscribed by the customer. As such, services are not defined according to the mission phases.

Section 4
DSMS as a Service Provision System

4.1 Customer Interface View

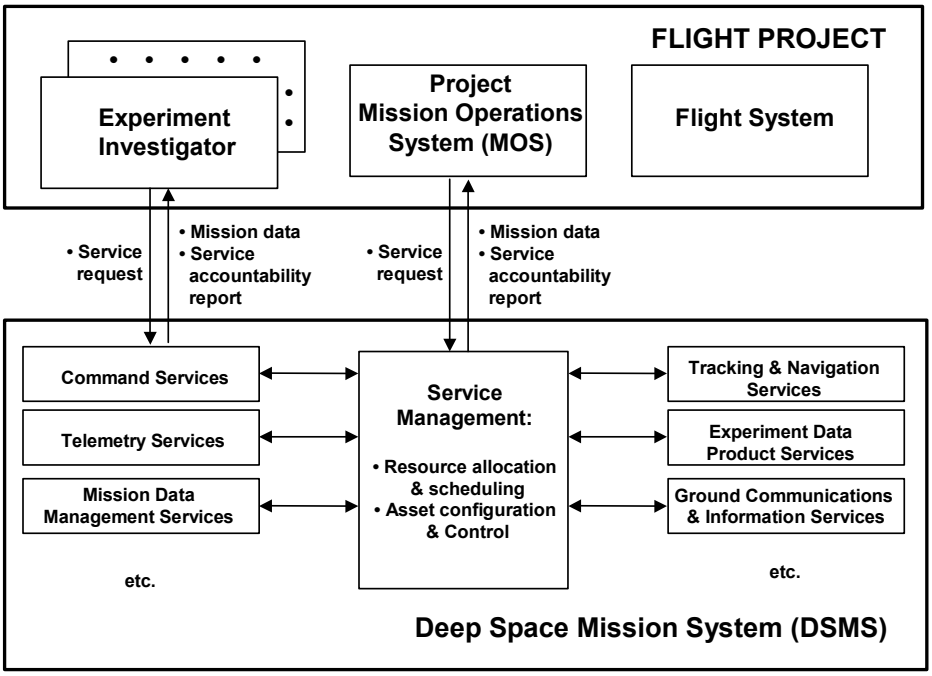
Figure 4.1 depicts the DSMS as a service providing system from the customer interface view. Key characteristics of the system from the customer interface view are as follows:

(1) Service Management function - This is a distributed function with its elements residing at the JPL DSMS Central and 3 Deep Space Communications Complexes (DSCCs). It includes (a) the allocation and scheduling of telecommunications and mission operations resources during service selection, agreement, and negotiation phases, (b) configuring and controlling the DSMS assets at DSMS Central and each DSCCs for service production during service utilization phase, e.g. before, during, and after a pass. With respect to (b), the service management function "monitors" and "controls" the service production and provision process.

(2) Service requests are used by a customer, as a mechanism, to interface with the DSMS for services. Service requests are input to both (a) resource allocation and scheduling, and (b) asset configuration and control, providing a seamless interface to customers for their service need. In fact, the current processes, i.e. long range resource allocation, mid-range scheduling, near-real-time scheduling, and real-time configuration and control, will become a single integrated process.

(3) All services performed by the DSMS will be readily accountable to customers. Service accountability report detailing the quality, quantity, continuity, and latency (QQCL) or other performance metrics about each instance of service will be provided to customers after the fulfillment of the services.

Figure 4.1 DSMS as a Service Providing System: Customer Interface View



4.2 Life Cycle Process View

Figure 4.2 shows the process for customer to interface with DSMS for services over the entire project life cycle.

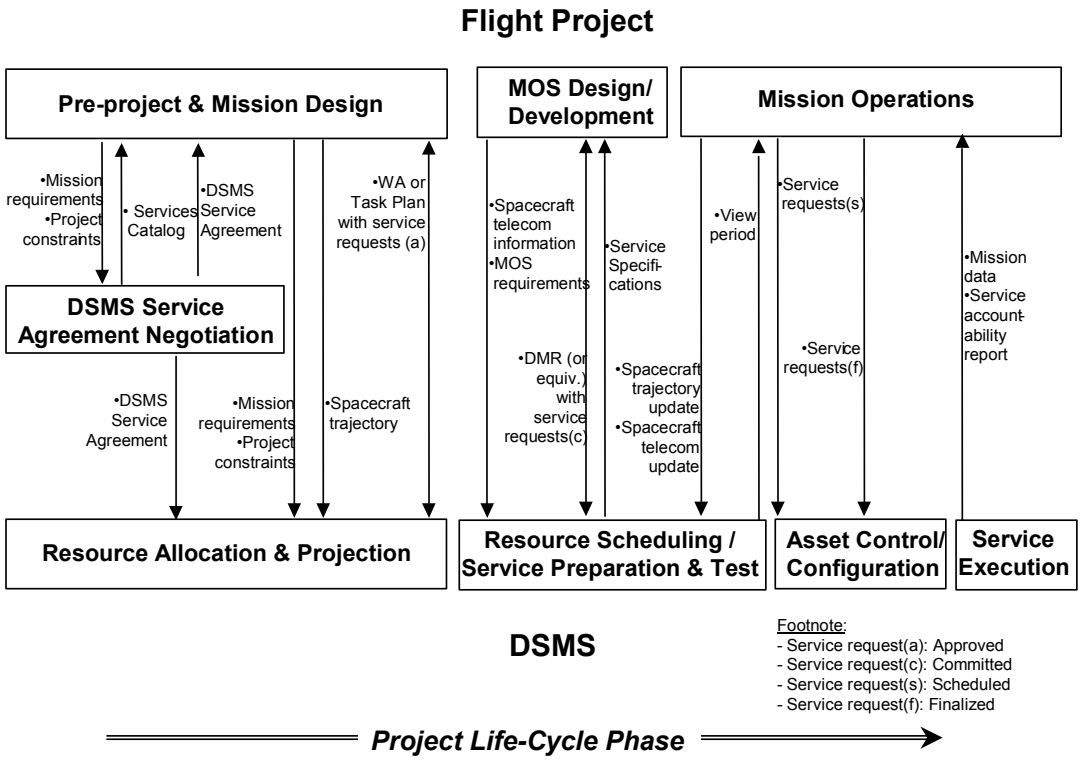


Figure 4.2 Customer Interface for Services: Process Over Project Life Cycle

4.3 Physical Assets View

The DSMS services are visible and meaningful to customer in a functional sense. Many of these services are dependent on the spacecraft/ground links, the key physical assets available through its tracking networks, and the multi-mission data system capabilities. The Deep Space Network (DSN) provides operations support to deep space missions and some Earth orbiting missions. Functions provided by the DSN include tracking, telemetry, command, and ground-based science data acquisition services.

In DSN, there are 3 Deep Space Communications Complexes (DSCCs), located near Goldstone, California; Madrid, Spain; and Canberra, Australia. Each complex has at least a 70-m antenna, a 34-m High Efficiency (HEF) antenna, a 34-m Beam Waveguide (BWG) antenna, and a 26-m antenna. Figure 4.3 gives a summary about the DSN assets and their locations. These stations communicate with and track spacecraft at S- or X-band (in 34-m and 70-m cases both). A few of the 34-m BWG stations are also equipped with Ka-band capability. Table 4-4 contains a summary of the RF capabilities of all the DSN stations.

The specific functions that the DSN performs are:

To acquire telemetry data from spacecraft

To transmit commands to spacecraft

To track spacecraft position and velocity

To perform very-long-baseline interferometry observations

To measure phase and amplitude variations in radio waves for radio science experiments

To gather other science data for ground based experiments

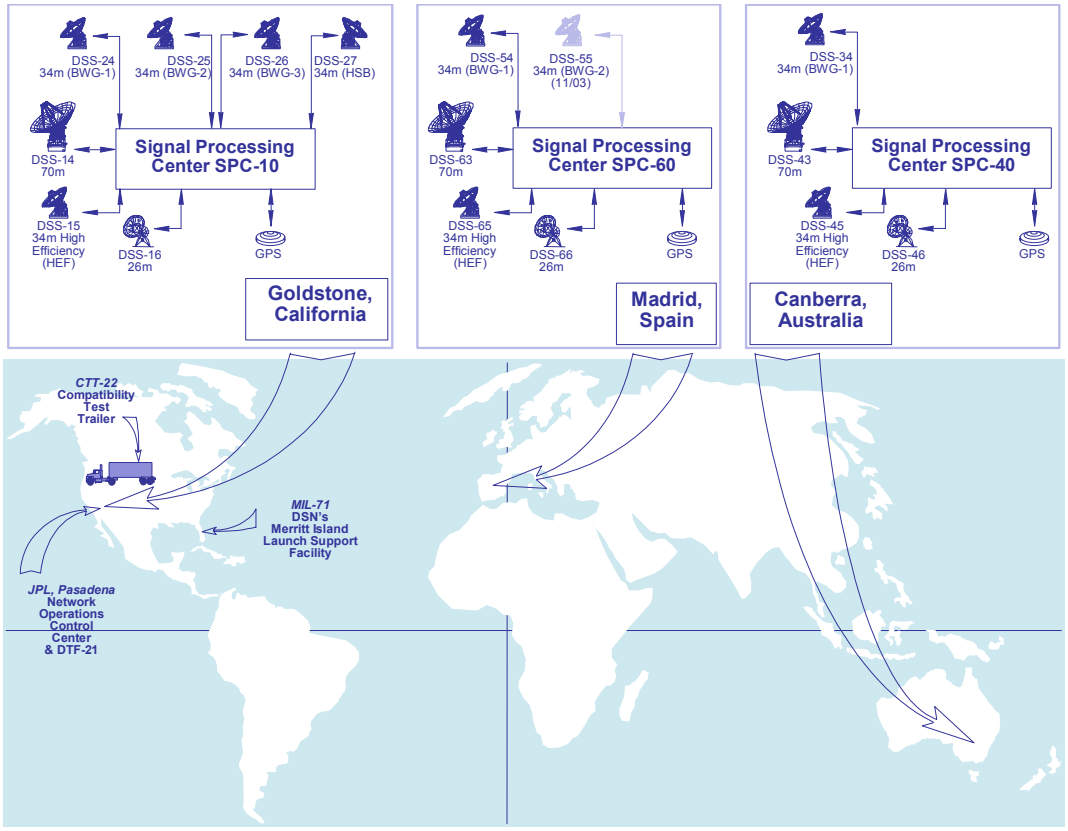


Figure 4.3 DSMS Physical Assets and Locations

Key characteristics of the DSN physical assets are described in the DSMS Telecommunications Link Design Handbook[1].

In addition to the 3 DSCCs, the DSN also includes a Network Operation Control Center (NOCC) in Pasadena, California; various emergency, test, and support facilities; and the people who operate and maintain these.

The AMMOS is made up of a collection of software tools, data processing elements, and the people who operate and maintain these to support flight project mission operations. The components of AMMOS are deployed at various MOS sites including JPL and several contractor facilities.

The combination of the NOCC, AMMOS, and various test and support facilities in Pasadena are referred to as “DSMS Central” in this document.

Table 4.4 DSN Stations and RF Capabilities

Antenna Dia (m)	Type	Location	DSS No.	Date On-Line	S-Band Uplink	S-Band Downlink	GAIN / G/T (Note 2) @ 45 deg (dB)	X-Band Uplink	X-Band Downlink	GAIN / G/T (Note 2) @ 45 deg (dB)	K-Band Uplink	K-Band Downlink	GAIN / G/T (Note 2) @ 45 deg (dB)	Rcvr Type
26	E.O.[1,4]	Goldstone, CA USA	16	Exist.	2025 - 2120[9]	2200 - 2300	52.5 / 31.7	-	8400 - 8500[19]	-	-	-	-	MFR
26	E.O.[1,4]	Canberra, Australia	46	Exist.	2025 - 2120[9]	2200 - 2300	52.5 / 31.9	-	8400 - 8500[19]	-	-	-	-	MFR
26	E.O.[1,4]	Madrid, Spain	66	Exist.	2025 - 2120[9]	2200 - 2300	52.5 / 31.8	-	-	-	-	-	-	MFR
34	BWG-1[1,3]	Goldstone, CA USA	24	Exist.	2025 - 2120[11]	2200 - 2300	56.7 /41.3	7145 - 7190[9] 7190 - 7235[14,20]	8400 - 8500	68.0 / 53.8	-	10/1/05[5,7]	79.0/64.4[18]	Blk. V
34	BWG-1[1,3]	Canberra, Australia	34	Exist.	2025 - 2120[11]	2200 - 2300	56.7 /40.8	7145 - 7190[14, 17] 7190 - 7235[14, 20]	8400 - 8500	68.2 / 52.3	-	1/1/05[5,7]	79.0/64.4[18]	Blk. V
34	BWG-1[1,3]	Madrid, Spain	54	Exist.	2025 - 2120[11]	2200 - 2300	56.7 /41.0	7145 - 7190[14, 17] 7190 - 7235[14, 20]	8400 - 8500	68.2 / 53.1	-	8/1/06[5,7]	79.0/64.4[18]	Blk. V
34	BWG-2[1,3]	Goldstone, CA USA	25	Exist.	-	-	-	7145 - 7190[14]	8400 - 8500	68.3 / 53.1	34200 - 34700[15]	31800 - 32300	79.0 / 64.2	Blk. V
34	BWG-2[1,3]	Madrid, Spain	55	11/1/03[5]	-	-	-	11/1/03[5,6,9,14,20]	11/1/03[5]	68.4/55.8[18]	-	11/1/03[5]	79.0/64.4[18]	Blk. V
34	BWG-3[1,3]	Goldstone, CA USA	26	Exist.	-	-	-	7145 - 7190[9] 7190 - 7235[14,20]	8400 - 8500	68.4/55.8[18]	-	4/2/03[5,7]	79.0/64.4[18]	Blk. V
34	HEF[1,3]	Goldstone, CA USA	15	Exist.	-	2200 - 2300	56.0 / 39.9	7145 - 7190[9]	8400 - 8500[16]	68.2 / 53.5	-	TBD[5,7]	-	Blk. V
34	HEF[1,3]	Canberra, Australia	45	Exist.	-	2200 - 2300	56.0 / 39.8	7145 - 7190[9]	8400 - 8500[16]	68.2 / 53.4	-	TBD[5,7]	-	Blk. V
34	HEF[1,3]	Madrid, Spain	65	Exist.	-	2200 - 2300	56.0 / 39.2	7145 - 7190[9]	8400 - 8500[16]	68.2 / 53.4	-	TBD[5,7]	-	Blk. V
34	HSB[1]	Goldstone, CA USA	27	Exist.	2025 - 2120[10]	2200 - 2300	55.1 / 34.5	-	-	-	-	-	-	MFR
70	D.S.[3]	Goldstone, CA USA	14	Exist.	2110 - 2120[11,12] 2090 - 2094[13]	2270 - 2300	63.3 / 50.8	7145 - 7190[9]	8400 - 8500	74.3 / 62.7	-	TBD[5,7]	-	Blk. V
70	D.S.[3]	Canberra, Australia	43	Exist.	2110 - 2120[11,12] 2090 - 2094[13]	2270 - 2300	63.3 / 50.7	7145 - 7190[9]	8400 - 8500	74.5 / 62.8	-	TBD[5,7]	-	Blk. V
70	D.S.[3]	Madrid, Spain	63	Exist.	2110 - 2120[11,12] 2090 - 2094[13]	2270 - 2300	63.3 / 50.4	7145 - 7190[9]	8400 - 8500	74.3 / 62.3	-	TBD[5,7]	-	Blk. V

NOTES:

1. These stations can be used for Earth Orbiting (Category A) missions.
2. Performance values based on 45 deg. elevation, vacuum conditions and Diplexed (if possible) single band mode.
3. These stations are used for Deep Space (Category B) missions.
4. These 26M stations may be closed in the future if a viable commercial substitute is available.
5. Planned Operational Date.
6. 7145-7235 MHz.
7. 31800-32300 MHz.
8. 34200-34700 MHZ.
9. Transmit power range: 200 W to 20 KW (23 to 43 dBW).
10. Transmit power range: 50 W to 200 W (17 to 23 dBW).
11. Transmit power range: 500 W to 20 KW (27 to 43 dBW).
12. Transmit power range: 5 KW to 400 KW (37 to 56 dBW).
13. Transmit power range: 5 KW to 150 KW (37 to 51.8 dBW).
14. Transmit power range: 200 W to 4 KW (23 to 36 dBW).
15. Transmit power range: 8 W to 800 W (9 to 29 dBW).
16. 8200 - 8600 MHz for VLBI Service.
17. 20 KW transmitter planned.
18. Estimated values.
19. Acquisition Aid
20. Near-Earth spectrum

Section 5
DSMS Standard Services

Table 5.1 contains a list of DSMS Standard Services. Presently there are 11 *service families* (categories) defined. A *service family* is a collection of functionally related *service types*. Each *service family* contains one or more types of service. A *service type* is characterized by the unique function performed and the result produced by that service. Within a *service family*, the various *service types* are distinguished from one another by the level of processing involved, their value-added function, or the type(s) of source data. Numbers in Table 5.1 correspond to the *service descriptions* found in Section 6.

Table 5.1 List of Standard Services (V.20)

1. Command services:	**5. Experiment data product services**:**
• Command radiation service	**• Level 1 processing service****
• Command delivery service	**• Science visualization service****
	• Experiment Product Delivery service**
2. Telemetry services:	
• Bit stream service*	**6. Flight engineering services**:**
• Frame service	**• Telecommunication link analysis service****
• Packet service	**• Spacecraft time correlation service****
• Telemetry channel service**	
• Telemetry file service	**7. Beacon tone service**
3. Mission data management services:	**8. Ground communications services:**
• Short-term data retention service	**• Ground network service**
• Long-term data repository service	**• Data transport service**
4. Tracking & navigation services:	**9. Radio science services:**
• Raw radio metric measurements service*	**• Experiment access service**
• Validated radio metric data service	**• Data acquisition service**
• Delta-DOR service	
• Orbit determination service***	**10. Radio astronomy/VLBI services:**
• Trajectory analysis service***	**• Signal capturing**
• Maneuver planning/design service***	**• VLBI data acquisition**
• Navigation ancillary data service	**• VLBI correlation**
• Ephemerides service	
• Modeling and calibrations service	**11. Radar science services:**
• Gravity modeling**	**• Experiment access service**
• Cartography**	**• Data acquisition service**

Notes:

* Services which are being decommissioned and not available to new missions.

** Services which are not part of the basic TT&C services and, therefore, require additional programmatic arrangement with JPL for subscription.

*** Services which are not part of the basic TT&C services and, therefore, require additional programmatic arrangement with JPL for subscription EXCEPT for LEOP support for DSN tracking purpose.

Section 6
Service Description

Two Command Services, termed *Command Radiation* and *Command Delivery*, are available to transmit data to a spacecraft. Table 6.1 summarizes the characteristics of these two services types. Users of this service should also consult Sections 7.1 and 8.1 to identify alternative configurations and performance characteristics.

6.1 Command Services

The Command Services transmits command data to the spacecraft. By functionality this service family is further divided into command radiation service and command delivery service. Table 6.1 summarizes the various service types and their associated data modes and protocols.

6.1.1 Command Radiation Service

Command Radiation is the more rudimentary of the two services. It can be operated in either a *Stream Mode* or a *File Mode*. In the stream mode, data in the form of Command Link Transmission Units (CLTUs) is received from a Project's MOS and radiated in real-time to a spacecraft as a string of data units. Conversely, in a file mode, a command file is stored at AMMOS or at DSMS Central prior to, or during, a pass and radiated to the spacecraft at a customer-specified time. Both modes ensure timely radiation of command data; however, error-free command delivery to the spacecraft is not guaranteed.

The Command Radiation *Throughput* [6] mode is being decommissioned and is not available to missions launching after April 2002. Beginning in May 2002, the CCSDS Space Link Extension (SLE) CLTU [15] becomes the standard DSMS stream mode for the command radiation service and will be used for the CONTOUR and INTEGRAL missions.

6.1.2 Command Delivery Service

Command Delivery is a more comprehensive service. It accepts command files from a Project's MOS in either real-time or at any point prior to the time designated for radiation. Using the standard CCSDS File Delivery Protocol (CFDP) [22], this service controls command radiation while providing reliable "error-free" delivery of command data to a spacecraft.

CFDP will be operational in August 2003 to support Deep Impact mission launching in 2004.

Table 6.1 Command Services: Service Types, Data Modes, and Protocols

Command Service Type	Data Mode	Protocol & Interface Specification
Command Radiation Service	Stream mode	Throughput: JPL CMD-4-9[6] CCSDS SLE Forward CLTU Service[15]
	File mode	JPL AMMOS SIS[3]
Command Delivery Service	File mode	CCSDS File Delivery Protocol (CFDP)[22]

6.2 Telemetry Services

Telemetry Services acquire, process, store, and deliver telemetry data products to a project MOS. Services are provided at five different levels, selectable by flight projects, and subscription to a higher level automatically provides all lower level services. These are:

1 Bit Stream

2 Frame

3 Packet

4 Channel Data

5 File Level

Users of this service should also consult Sections 7.2 and 8.2 to identify alternative configurations and performance characteristics.

6.2.1 Bit Stream Service

The Bit Stream Service provides a series of data units. Each data unit contains a stream of hard symbols or convolutionally decoded bits, in the order received, with an undetermined starting point, and without value-added processing such as frame decoding. Certain metadata is appended (e.g., received time of a certain bit, spacecraft ID, spacecraft bit rate, SNR, etc.).

Since the status of this product cannot be derived without further processing, the *quality* of this service is not guaranteed. Consequently, this service is available only to legacy missions and is being decommissioned.

6.2.2 Frame Service

Frame Service is available to missions having a supported modulation technique and: 1) a frame structure compliant with the CCSDS *Packet Telemetry* [7, 8, 18] recommendation or 2) a fixed length frame, where each frame is preceded by a CCSDS compliant synchronization marker. Within this service, the following frame output options are available:

6.2.2.1 All Frame Service

All Frame service[14] provides both actual data frames and filler frames

6.2.2.2 Virtual Channel Service

Virtual Channel service[16] provides data frames, i.e., virtual channel data units (VCDUs), selected, subset, and ordered within each virtual channel ID.

6.2.3 Packet Service

The Packet service extracts packets from frames, i.e. virtual channel data units (VCDUs), and delivers them to either project MOS or individual investigator. Compliance by the spacecraft with the CCSDS packet telemetry recommendation[8, 18] is essential to use this service. Two options of packet output are offered to customers:

Extracted packets are ordered by Earth received time.

Extracted packets are ordered by a combination of user specified mission parameters (e.g., application ID, packet generation time, packet sequence number, etc.).

6.2.4 Telemetry Channel Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

Telemetry Channel service extracts all samples of engineering measurements from telemetry packets pursuant to a set of pre-defined decommutation rules or measurement identification numbers. Samples are converted from Data Numbers (DNs) into Engineering Units (EUs).

6.2.5 Telemetry File Service

The Telemetry File Service acquires telemetry data units transmitted by a spacecraft, assembles these data units into individual files, submits the files to a data base, and notifies the MOS and the investigators that the data is available. In essence, this service enables the moving of a file from a spacecraft datastore to a MOS datastore. The CCSDS File Delivery Protocol (CFDP)[22], a content-independent protocol, which requires no knowledge about the information contents being transferred.

The DSMS can operate in either the unacknowledged mode or in one of the acknowledged modes. In an unacknowledged mode data delivery failures are not reported to the spacecraft foreclosing the automatic resending of the missing data. Accordingly, reception of complete files is not guaranteed. Conversely, in an acknowledged mode, the DSMS notifies the spacecraft

of undelivered file segments or ancillary data. Missing items are retransmitted from the spacecraft guaranteeing complete file delivery.

The service provides the following capabilities:

(1) The ability of requesting a listing of the contents of a specified directory in the spacecraft's telemetry store.

(2) The ability of requesting a report of the status of a specified file transmission by the spacecraft.

(3) The ability to request the suspension and resumption of a specified file transmission by the spacecraft.

(4) The ability to initiate the delivery of a file from a spacecraft to a MOS or an investigator.

6.3 Mission Data Management Services

6.3.1 Short-Term Data Retention Service

The short-term data retention service provides reliable distribution of mission data to customers. It includes buffering, staging, and safe-keeping of mission data until custody has been transferred, either via an automated custody transfer protocol or manual acknowledgement. The maximum retention period is for 30 days from data acquisition.

Data types supported by this service include all data directly related to the spacecraft, i.e. command data, telemetry, tracking and navigation data, as well as associated meta-data.

6.3.2 Long-Term Data Repository Service

The long-term data repository service provides life-of-mission storage and retrieval of mission data in support of mission operations. The service includes provision of a catalog of all data in the mission repository. Users may query this catalog for data to be sent to them or re-staged on-line for retrieval. Data can be retrieved by time and data type and provided to the customers either electronically or on physical media.

Data types supported by this service include all data directly related to the spacecraft, i.e. command data, telemetry, tracking and navigation data, as well as associated meta-data.

6.4 Tracking and Navigation Services

6.4.1 Raw Radio Metric Measurement Service

This service provides radio metric observables based on measurement of phase and light time delay of the modulated RF signal acquired by the tracking stations. The data are not validated, except for a limited number of internal data validity flags, e.g. signal in lock, signal-to-noise ratio. The data are available electronically and the format is dependent upon the type of tracking station. All radio metric measurement services are also available as validated data via the Validated Radio Metric Data Service. It is recommended that users utilize the latter service.

6.4.2 Validated Radio Metric Data Service

The formats in which radio metric data is represented include a substantial amount of configuration data necessary for gleaning navigational use from the data. Due to a number of scenarios, this configuration data may be incorrect, rendering the radio metric observables unusable. The Validated Radio Metric Data Service validates incoming data and, when possible, fixes incorrect configuration data and supplies missing data (such as transmitter frequency). Data which can not be validated may be delivered to the customer, but are identified as such. All Doppler, ranging, and angle data are validated, and all data are delivered in the same DSN format, TRK-2-18[6]. It is recommended that all customers use validated data rather than raw data. To receive validated data, the subscriber simply requests the service and the specified data type.

6.4.3 Delta-DOR Service

The differenced differential one-way ranging (delta-DOR) technique provides an observation of the plane-of-the-sky position of a spacecraft, using signals received simultaneously at two or more antennas. In this technique, a spacecraft emits two or more sidetones separated from its carrier by large frequency offset, typically tens of MHz or more. Each of these tones is recorded at two stations simultaneously. Nearly contemporaneously, a quasar is observed with the same pair of stations (this may be done in the pattern quasar-spacecraft-quasar, spacecraft-quasar-spacecraft, quasar-spacecraft_1-spacecraft_2-quasar, etc.). The signals are analyzed afterwards to calculate the delta-DOR observable.

Due to the need for different treatments of systematic error sources depending on details of the observing conditions, the components of the delta-DOR measurement are reported individually along with the aggregated measurement. Specifically, the data provided to the customer is a set of station-differenced phase offsets, differential one-way range, and interstation clock offsets for each source, time, and frequency measured. The data are delivered in the DSN format, 820-13 TRK-2-34 (with a provision of temporary retention to the legacy format of TRK-2-18[6]). Quality assessments are also provided with the data, based on a large number of quality indicators both taken with the data and inferred during signal processing.

To receive validated delta-DOR data, the subscriber negotiates the times of spacecraft and quasar observations, and requests the service. A number of factors must be considered concerning the time and geometry of the session in order to obtain successful results; therefore DSMS provides assistance in the scheduling. The subscriber then arranges that their spacecraft is on earth point, with DOR tones turned on, at the planned time of observation. Important side-effects of the delta-DOR session are: (1) spacecraft telemetry may be degraded when the DOR tones are on, and (2) all other radio services (telemetry, command, radio metrics) will not be available during the quasar observations, because the ground antennas must be pointed away from the spacecraft.

6.4.4 Orbit Determination Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

The DSMS provides to the subscriber an option to request an orbit determination service rather than simply requesting raw radio metric tracking data. With this service the user receives updated trajectory solutions for the subscriber's spacecraft. The subscriber identifies the accuracy to which the spacecraft's trajectory must be known as a function of time. If the accuracy requirement is a prediction requirement, then the customer must also provide information as to how far in advance the trajectory knowledge must be determined. Based on these requirements, the orbit determination service will determine a tracking scenario to meet this request, schedule the needed resources, and process the data to provide the customer with spacecraft trajectory knowledge or prediction to the specified accuracy. Due to the geometry dependencies and scheduling requirements, the accuracy requirements for orbit determination services must be defined three to six months in advance for deep space missions and several weeks in advance for Earth orbiting missions. The customer will receive the spacecraft trajectory at requested times (in NAIF SPK format) and the associated uncertainties. The orbit determination service is offered in a few different ways depending on data types and processing modes. A brief description is as follows.

6.4.4.1 Radio Metric Orbit Determination

The radio metric orbit determination provides the orbit determination for those customers with Earth orbiting or deep space missions who rely exclusively on radio metric observables. It includes launch support and support of transfer phases of missions. Trajectory updates are available at predetermined intervals, but thirty minutes to two hours, at minimum is generally required for the processing of data. The limiting accuracy of this capability is dependent on spacecraft trajectory.

6.4.4.2 Optical Orbit Determination

This capability provides orbit determination services related to the use of optical measurements from an on-board camera. At the request of the customer, it can:

(1) provide a performance analysis for a given on-board image acquisition system,

(2) plan a schedule of observations to meet a customer defined trajectory accuracy either in conjunction with radio metric tracking or with optical data alone, or

(3) process the optical images (telemetered from the spacecraft) either alone or with radio metric data to provide an updated spacecraft trajectory.

As with the other orbit determination capabilities, the user requests a trajectory with a given accuracy over a time interval. The customer must specify if this accuracy requirement is relative to a specified target body (e.g. a planet or an asteroid) or inertial. If a trajectory prediction is required, the customer must specify how far in advance the prediction is required.

6.4.5 Trajectory Analysis Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

This service provides flight path prediction, reconstruction, and/or optimization to service subscribers. Flight path prediction consists of generating a detailed trajectory based upon state vectors, and associated spacecraft maneuver and body force modeling parameters. This allows for the generation of reference trajectories to be used for the tracking and mission predicts. Flight path reconstruction consists of generating a posterior reference trajectory based on orbit determination solutions and force models provided either by the customer or the orbit determination service. The trajectory optimization service will provide an optimized trajectory (from a deterministic delta-V perspective) based either on an approximate trajectory provided by the subscriber or based on a series of trajectory constraints (e.g. flyby conditions, entry conditions, & times).

6.4.6 Maneuver Planning & Design Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

This service provides propulsive maneuver analysis for flight missions and for future mission analysis. Based on a reference trajectory, the subscriber can request injection dispersion and probability of impact analysis for a specified launch vehicle as well as required aim-point biasing to meet planetary quarantine requirements. The subscriber may also request statistical delta-V analysis to characterize propellant needs, based on a trajectory, an expected orbit determination performance, and spacecraft thruster characteristics. This analysis will provide to the customer the optimal placing and sizing of maneuvers as well as estimates of the mission propellant needs. Orbit maintenance maneuver design, or the design of maneuvers required to change the orbit for the next mission phase is also available.

6.4.7 Natural Body Ephemeris Services

Natural Body Ephemeris Services provide ephemerides for all planets, most natural satellites, and several thousand comets and asteroids. The subscriber requests the service by specifying a period of time, the body or bodies of interest, and, if relevant, the desired accuracy of the ephemeris. If an ephemeris is already extant, which covers the desired period to the desired accuracy, it is immediately available. If the ephemeris is not available to the required accuracy, it may be possible to generate an improved ephemeris based on reprocessing of existing data or by acquiring additional data (generally for comets & asteroids). It may require from months to years to acquire the needed data and generate the new ephemeris. If the subscriber wishes, the service includes all of the analysis and scheduling of data acquisition.

6.4.7.1 Planetary Ephemerides

A single planetary ephemeris includes the trajectories (represented as polynomials over arbitrary time intervals) of the Sun, the Earth, the Moon, and 8 planetary system barycenters relative to the solar system barycenter. The accuracies to which each of the planets is known vary from the order 1 km for Venus and Mars, to the order of 10,000 km for Pluto.

6.4.7.2 Satellite Ephemerides

A single satellite ephemeris data set includes the ephemerides of a set of natural satellites and the parent planet relative to the barycenter of the particular planetary system. Satellite ephemerides are based on ground observations, radar measurements, and measurements from previous interplanetary missions.

6.4.7.3 Asteroid & Comet Ephemerides

Ephemerides are available for 14,000 asteroids and comets, including main belt asteroids and many Earth crossing asteroids and comets. An ephemeris can be generated at user request for any one of these bodies.

6.4.8 Modeling & Calibration Services

This service provides the subscriber with calibrations needed to process tracking data to the fullest accuracy possible. Calibrations specifically related to the data acquisition hardware are automatically delivered to subscribers of those data. These calibrations deal with systematic error sources which affect data.

6.4.8.1 Terrestrial Frame Tie

In order to process DSN radio metric data, the subscriber must know the inertial position of the receiver and, if appropriate, the transmitter at the time of the measurement. Although the locations of DSN antennas are known to within centimeters and the baselines between them to

millimeters, the variations in polar motion and the rotation rate of the Earth can move the inertial position by much larger amounts than this. The terrestrial frame time data provides a temporal model for the orientation of the Earth's pole and the spin rate based upon VLBI observations and tracking of GPS satellites. This data provides the subscriber with an instantaneous knowledge of the inertial position of a crust fixed location on the Earth's equator to 30 cm. A posterior knowledge on the order of 1 to 5 cm is available after two to three weeks delay.

6.4.8.2 Transmission Media Calibrations

The transmission media through which the signals pass affects radio signals. The most significant of these are the Earth's troposphere and ionosphere. In order to achieve the data accuracies discussed in the previous sections on data services, it is necessary to calculate adjustments for the delays due to these. The media calibration models are based upon tracking of GPS satellites at two frequencies. The format of these calibrations is a history of zenith delay over a pass and a mapping function to map them to the appropriate altitude.

6.4.9 Gravity Modeling

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

The subscriber to the gravity modeling service can request and immediately receive an existing spherical harmonic gravity model for one of three bodies: Venus (120th degree and order), the Moon (75th degree and order), or Mars (50th degree and order). The subscriber can also request an improved gravity model based on provided tracking data; the improvement in the field will be based upon the accuracy and coverage of the data. The reduction of the tracking data and the generation of the improved gravity model will require some time to process. The amount of time is a function of the density of the data and current state of an existing model and will vary from a few days to a few months.

6.4.10 Cartography

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

The cartography service provides the subscriber with positions of landmarks on a body's surface which can be related to an inertial reference frame. The subscriber can either request the best current knowledge of a landmark based on previous analysis or in some cases, such as Mars landmarks, request an improved location estimate based on reprocessing of extant data. Finally, the customer may provide (or request to have provided from other services) image data and a reference trajectory and have the reference location of a specified landmark determined. The image data must include the inertial pointing of the imager and the time that the image was taken.

6.4.11 Navigation Ancillary Data Service

The Navigation Ancillary Data Service provides reduced and interpreted ancillary dataset to space scientists pertaining to their experiments. These data include spacecraft ephemeris, planetary ephemeris and constants, instrument descriptions, camera pointing, events about spacecraft and instruments, packaged in such a way that they are self-identifiable and correlated to science observations.

6.5 Experiment Data Product Services

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

The Experiment Data Product Services provided by DSMS to flight projects include the generation of a variety of experiment data products from the acquired science instrument data. The processing involved in generating these products applies high degree of multi-instrument capabilities, thus resulting in significant reduction in processing time and cost, and increase in product interpretability to the science team.

6.5.1 Level 1 Processing Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

Level 1 processing applies calibration information and ancillary data to remove the instrument signature from the data. The Level 1 processing service provides products generated in non-real-time after the arrival of the telemetry. Depending on the desires of the science team, the processing includes adding ancillary or correlative data, removal of instrument signature, mathematical transformation of time series data, reformatting of the data, and data quality check.

6.5.2 Science Visualization Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

Science visualization service takes science image data as input to produce still and animated visualizations for the planetary exploration missions, e.g. animated series for flights around Mars, Venus, Miranda, etc. The digital products of science visualization, when incorporated with navigation, ephemeris, or other imagery data, can be used for both science data analysis and science observation planning.

6.5.3 Experiment Product Delivery Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

Experiment product delivery service provides for the recovery of product or file-oriented science data from telemetry; packaging with associated metadata, accounting data, and (optionally) ancillary data; archival and access to the products during the mission; and dissemination of the products to the science community or to an appropriate long-term repository such as the Planetary Data System (PDS). This service requires limited project-specific adaptation in the form of a mapping of ancillary data to product type, retransmission policies, priorities, and dissemination/access policies. "Ancillary data" in this context refers to instrument engineering parameters, spacecraft engineering parameters, data extracted from SPICE (S/C, Planet, Instrument, C-Matrix, Event) files, etc.

6.6 Flight Engineering Services

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

The Flight Engineering Services provide the spacecraft performance analysis, spacecraft and instrument health and safety monitoring, telecommunications link analysis, and spacecraft time correlation. Engineering support to assess spacecraft analysis on-board automation and autonomy design trades vs. requirements will be supported. In addition, Flight Engineering Services provide the engineering and planning required for execution of the real-time and non-real-time mission operations. The Flight Engineering Services also provide a project focal point for operations coordination, initiating commanding, on-line or on-call real-time anomaly response, and operations of non-standard/special circumstances.

6.6.1 Telecommunications Link Analysis Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

Telecommunications Analysis Service provides the means for a flight project customer to plan the communications configuration and capability between a spacecraft and the tracking stations of the Deep Space Network and then to assess the resulting performance against the plans. Planning requires the prediction of signal level, signal-to-noise ratio, and data error rate in terms of link models. Assessment requires the comparison of the values of these quantities as reported in spacecraft telemetry data and station monitor data against the predicted values.

The primary communications links are at any frequency supported by the stations. They include command, telemetry, and radiometric (closed-loop Doppler and turnaround ranging). The telecom analysis service can plan and assess relay links as well as those direct with the DSN.

A flight project can use the telecom analysis service at any time from initial spacecraft and mission design, through the implementation of a flight operations system, and into flight operations when the spacecraft-station communications links are active. It includes the following standard components:

Adaptation of the telecom link prediction and assessment tools. The tools provide a standard prediction, forecasting, and link performance comparison capability.

Set-up of link performance analysis displays involving standard or custom processing of in-flight data for comparison with predictions.

People to operate the tools and so provide pre-defined predictions or communications link analysis reports.

People to participate in the project's flight operations teams as telecom analysts at an agreed upon level of support.

Documentation of the project's telecom plans and support requirements, telecom configuration and performance predictions, and actual telecom performance relative to predictions.

6.6.2 Spacecraft Time Correlation Service

(NOTE: This service is not part of the basic TT&C services and, therefore, requires additional programmatic arrangement with JPL for subscription, prior to inclusion in proposal.)

The DSMS offers a Spacecraft Time Correlation Service which, with a cooperating spacecraft implementation, enables correlation of the time of spacecraft events with Coordinated Universal Time (UTC) and the time these events would be observed on the ground (earth received Time, UTC). Specifically, this service provides:

Validated correlation coefficients to convert spacecraft clock counts into spacecraft event time (UTC) for acquired data.

Predicted correlation coefficients to convert spacecraft clock counts into spacecraft event time (UTC) for future events (e.g., command execution times). This is achieved by modeling and monitoring the spacecraft clock and its drift characteristics.

The corresponding earth received time (UTC) for Validated or Predicted values of spacecraft clock count or spacecraft event time (UTC).

On-board UTC If the spacecraft carries an adjustable clock, DSMS can provide the service of measuring its offset from UTC (as above) and routinely commanding it to drift ahead or behind

to eliminate or reduce the correlation coefficients to acceptable bounds. This enables the customer to use the spacecraft time tags as they appear in the data, without corrections.

To obtain this Service, the spacecraft timing implementation of future missions must:

use CCSDS Source Packets with time tags (in the secondary headers) which are derived from the spacecraft master clock which is being measured as part of this service,

use one of the CCSDS Time Code Formats[10],

use CCSDS Frames,

read the spacecraft clock at the time a specific bit of a telemetry frame leaves the spacecraft, and

report this time, plus the corresponding frame sequence number and Virtual Channel in either a dedicated Time Calibration packet or the Operational Control Field of a related frame.

6.7 Beacon Tone Service

The DSMS provides the Beacon Tone Service for the flight project MOS to monitor the high-level state of the spacecraft according to the beacon tones generated and transmitted by the spacecraft. The DSMS will be capable of acquiring and detecting the 4-tone Beacon Monitoring signals at SNRs down to 5 dB-Hz, with detection times up to 1000 seconds, on the 70-m, 34-m BWG and 34-m HEF stations. The detected tone will be forwarded to the project MOS as a message. However, the interpretation of the detected tone is the responsibility of the MOS. The committed date of this service is 20 June 2003.

For those missions, which have a long ion-powered cruise and confirming progress is needed during periods when the downlink signals drops below threshold for normal telemetry via LGA while on thrust attitude (for example, below a Pt/No of about 18 dB-Hz), the Beacon Tone Service offers a useful mechanism for the MOS to gain a minimum visibility into the health and safety of its spacecraft.

In a sense, the Beacon Tone Service is a special type of telemetry service.

6.8 Ground Communications Services

Ground Communications and Information Services provides a reliable and secure communications infrastructure capability to flight projects.

6.8.1 Ground Network Service

Reliable communications are provided from the stations or JPL to the user's site, and the end-to-end integrity of the network is maintained by DSMS with a 24-hour per day, seven-day per week communications staff. Communication paths for data, voice, and video network between the

mission control center, various PI facilities, various contractor facilities, the launch site, JPL, and DSCC are established via wide area network circuits and/or local area networks.

(1) Wide Area Networks: Ground communication circuits are provided from the antenna stations or JPL, to the user's site. DSMS orders the wide area network services from the NASA Integrated Service Network (NISN) Program. In turn, NISN orders domestic services through the General Service Administration's FTS 2000 contract (i.e., AT&T), and arranges special contracts for international circuits. Circuits that are used to carry spacecraft data are usually ordered with carrier guarantees for 20-minutes-to-isolate problems, and two-hour-to-restore.

Dedicated channels from the antenna stations through JPL can often be provisioned by multiplexing channels through a shared NISN circuit.

(2) Local Area Networks: Local area networks are installed and maintained by the DSMS network engineers. The most common LAN technology is Ethernet (10 Mbps, 100 Mbps, or Gigabits), which are used to form the backbone networks for high-speed access among various locations.

(3) Data Networks: Data networks are based on the Internet Protocol (IP). Among hosts at a particular site, Ethernet hubs and virtual LAN technology are used for ground communication. IP routers are used to transmit data traffic across a path of dissimilar networks. Routers and hubs may be installed and configured by the DSMS network engineers.

(4) Voice and Facsimile (Fax): DSMS supports dedicated voice loops for real-time communications between project operations centers (POCs) and antenna station operations. Compressed voice technology (from normal 64 kbps, down to 12 kbps) is usually used for these communications.

Fax transmission occurs over the same voice paths.

(5) Remote Communications Terminal (RCT): DSMS may provide a dedicated terminal for a user's site that includes circuit-termination equipment, voice interface equipment, a router, and remote testing equipment. The RCT may be configured for unattended operations.

6.8.2 Data Transport Service

At the DSN antenna stations, the station communications processor (SCP) receives all data generated by the digital receiver and telemetry processor. It may pass the data directly to the Project MOS and/or PI's sites as a low-latency UDP (User Datagram Protocol) stream or forward the stream to a reliable network service (RNS) that guarantees no lost IP packets. The RNS delivery service has several user options that are described below.

Low-Latency Service: The low-latency service is used to feed a real-time stream of spacecraft data to the user in the shortest possible time. This service is similar to the (now obsolete) NASCOM 4800-bit switched service. No error recovery is made; data packets that may be damaged by noise in the ground communications circuit are simply discarded. This is a legacy capability and is no longer offered to new missions.

Reliable Network Services:

Timely Service - Timely Service transmits a reliable real time stream to the user, but if the stream is delayed due to ground network congestion, any data older than 10 seconds is discarded. A simultaneous stream (complete) is forwarded to a data repository for later delivery. This makes it possible for the user to keep abreast of activity on the spacecraft, and have confidence that the data is complete within the specified time limits.

Complete Service - The Complete Service is used for most stream data. Congestion in the ground network may cause delays, but all the data will be delivered in the stream, and a simultaneous stream (complete) is forwarded to a data repository for later delivery. Delivery is guaranteed within 5 minutes.

Off-Line Service - All RNS data is stored for later, off-line, delivery. Delivery is accomplished using the File Transfer Protocol (FTP). After prior registration with the operations Communications Chief, the data may be delivered by FTP (1) automatically, (2) on command by the Communications Chief, or (3) on command by the user using a Web interface.

6.9 Radio Science Services

DSN Radio Science Services are provided to scientists to enable them to use of the Deep Space Network for direct scientific observations. The services deliver measurements of the spacecraft downlink signal from either open-loop or closed-loop receivers. Data from the open-loop receiver are digital recordings of the baseband signal derived from the received spacecraft signal at S, X, or Ka-band. Closed-loop data are measurements of the Doppler frequency and spacecraft range (see the Tracking Navigation Service description for more details).

The Radio Science Services are further divided into two types of service based on the level of operational activities involved:

Level 1 - Experiment Access. The first level of service is aimed at users with expertise in the DSN science capabilities and provides them with access to the equipment and technical assistance, including operations support and scientific collaboration when appropriate, to perform their experiments. In some cases access can be via remote operations terminals or onsite.

Level 2 - Data Acquisition. The second level of service provides raw measurements and ancillary data from observations. DSMS provides scheduling, experiment design, instrument operations, and data delivery based on agreements negotiated prior to the observations.

Key performance characteristics of radio science services in metrics such as frequency stability, phase noise, and amplitude stability, are described in Module 209, Open-Loop Radio Science, of Document 810-005, DSMS Telecommunication Link Design Handbook.

6.10 Radio Astronomy/VLBI Services

The Radio Astronomy/VLBI Services uses the DSN's large gain, low system noise temperature, and tracking stations to make observations of RF emitting astronomical sources. The Radio Astronomy capabilities are intimately related to the DSMS's R&D programs in science and technology. For observations within standard DSN communications bands, users are provided conditioned IF signals. These IF signals can then become input to either DSMS supplied special purpose receiving and data acquisition equipment being used for R&D or user supplied equipment. For observations outside the standard communications bands, investigators can use special purpose R&D microwave and receiving equipment, when available.

Radio Astronomers using DSN antennas as part of a network in Very Long Baseline Interferometry (VLBI) observations receive digitized and formatted samples of an open-loop signal on VLBA (Very Long Baseline Array) compatible tapes. VLBI observations are supported using a standard Mark IV VLBI data acquisition system. Correlation of VLBI data from up to four antennas is also available.

The Radio Astronomy/VLBI Services can be categorized into the following three types of services:

6.10.1 Signal Capturing Service

The Signal Capture service provides antenna pointing, radio frequency output, and/ or output at an intermediate frequency (downconverted from RF) for observations of natural radio emitters. R&D equipment or user supplied equipment, external to this service, is used to complete signal processing and data acquisition. Amplification and downconversion of signals is available at "standard" DSN communications frequencies defined in Document 810-005, DSMS Telecommunication Link Design Handbook. Use of special-purpose R&D equipment for observations at other frequencies and bands may be negotiated through the DSN Science Office.

6.10.2 VLBI Data Acquisition Service

The VLBI Data Acquisition service includes signal capture and utilizes the Mark IV VLBI Field System for data acquisition and recording. The Mark IV system, including the Mark IV data format, is a standard used at radio observatories throughout the world and is described in the reference document listed above in "applicable documents." This service includes delivery of data tapes to a user-designated correlator.

6.10.3 VLBI Data Correlation Service

The VLBI Data Correlation service provides the capability to cross correlate up to 4 data streams in the Mark IV format. Correlation is provided using the JPL VLBI Correlator, located in Pasadena, California.

Key performance characteristics of VLBI services in terms of accuracy of VLBI measurements are described in Module 210, Narrow Channel Bandwidth VLBI and Module 211, Wide Channel Bandwidth VLBI, of Document 810-005, DSMS Telecommunication Link Design Handbook.

Within the DSN downlink frequencies, the service provides conditioned IF distribution from S, X and Ka Band DSN radio frequency subsystems to special purpose receiving and data analysis subsystems. The latter are operated and maintained by various R&D engineering groups that differ among the three Deep Space Communication Complexes (DSCCs).

The service also provides monitor and control interfaces to DSN operational subsystems (e.g., antenna pointing, receivers, FTS) via Radar and Radio Astronomy special purpose control subsystems.

6.11 Radar Science Services

DSN Radar Science Services are provided to scientists to enable them to use of the Deep Space Network for direct scientific observations. The Radar Service provides observations from the Goldstone Solar System Radar (GSSR), a dual wavelength (3.5 cm and 12.5 cm), multi-aperture, high power, simultaneous dual polarization reception (RCP and LCP), radar. The GSSR can be operated in continuous wave or binary phase coded modes. Interferometric observations using up to four DSN receiving antennas are possible as are bi-static observations with the radar at the Arecibo Observatory or the Greenbank Telescope.

It is the only fully steerable planetary radar system in the world. This characteristic makes it extremely valuable for observations of Near-Earth asteroids and comets which typically encounter the Earth at a wide variety of declinations.

The Radar Science Services are further divided into two types of service based on the level of operational activities involved:

Level 1 - Experiment Access. The first level of service is aimed at users with expertise in the DSN science capabilities and provides them with access to the equipment and technical assistance, including operations support and scientific collaboration when appropriate, to perform their experiments. In some cases access can be via remote operations terminals or onsite.

Level 2 - Data Acquisition. The second level of service provides raw measurements and ancillary data from observations. DSMS provides scheduling, experiment design, instrument operations, and data delivery based on agreements negotiated prior to the observations.

The modes of operation of the GSSR fall into three broad categories, all at both 3.5-cm and 12.5-cm:

6.11.1 Continuous Wave (CW) Modes

There are three CW modes, each with different hardware subsystems (Normally both circular polarizations are received in CW observations.):

a) Narrow bandwidth. This mode is offered for targets whose received bandwidth spreading is no more than 40 kHz.

b) Medium bandwidth. This mode is offered for targets whose received bandwidth spreading is no more than 8 MHz.

c) Wide bandwidth. This mode is offered for targets whose received bandwidth spreading is no more than 40 MHz.

6.11.2 Binary Phase Coded (BPC) Modes

The possible modes provided are divided by received polarization diversity and the number of stations receiving. The transmitter subsystem can supply either right OR left circular polarization signals in the BPC mode. The receivers at DSS-14 and DSS-13 can be configured for both or either circular polarization. DSS-15 and DSS-25 can only receive a single polarization, with RCP or LCP at the experimenter's choice.

6.11.3 Interferometric Observations Modes

The GSSR can utilize the following baselines at the Goldstone Deep Space Communications Complex: DSS-14 to DSS-13, DSS-13 to DSS-25, DSS-13 to DSS-15, DSS-15 to DSS-25, and DSS-14 to DSS-25. The DSS-14 to DSS-15 baseline is too short for any practical application. In addition, the GSSR can transmit a CW signal designed to be used for direct imaging in both polarizations at the Very Large Array (VLA) of the National Radio Astronomy Observatories (NRAO, Socorro, NM) and the Very Large Baseline Array (data processing at the NRAO correlator in this case only, also in Socorro).

6.12 Service Management

Service Management is a special category of functions that must be performed by the customer and DSMS cooperatively to ensure that instances of services are properly planned and executed. It provides operational support to customers in preparation for the services they need, for controlling the production and provision of services, and for providing the visibility and accountability of DSMS service systems [Ref. to "CCSDS Space Link Extension - Cross Support Reference Model].

It includes

(1) planning, scheduling, and allocating DSMS resources required for fulfilling the services,

(2) controlling and configuring DSMS assets required for providing the services, and

(3) service execution reporting.

The service management functions typically performed by a customer and their respective interfaces are summarized as follows:

(1) Generating predicted spacecraft trajectory – via interface conforming to the CCSDS Orbit Data Messages standard[11] or SPK.

(2) Making schedule request - via interface conforming to the Schedule Request, OPS-6-12 document[6] or its variations.

(3) Providing spacecraft telecommunication events and link characteristics – via interface conforming to the Keyword Files, OPS-6-13 document[6] or its variations.

Section 7
Alternative Configurations

DSMS facilities can be configured in different ways to better suit a user's requirements. This section provides a short description of possible configurations for the named services.

7.1 Command Configurations

The DSMS provides two command configurations. These are: Low Rate Command and Medium Rate Command.

7.1.1 Low Rate Command

Low Rate Command has been the typical configuration used for years. Command data units received by the DSMS from the Project's MOS are Phase Shift Key (PSK) modulated on a 16 KHz sine wave subcarrier such that the subcarrier is fully suppressed. This PSK modulated subcarrier is then modulated on an Earth station's RF carrier so as to leave a residual (ruminant) carrier component. Data rates from 7 1/2 bps to 4 Kbps can be radiated. Low Rate Commands comply with CCSDS Recommendation 401 (2.2.2) B-1. (Note: 1 Kbps in this context means 1,000 bps.)

7.1.2 Medium Rate Command

Command data units received by the DSMS from the Project's MOS are Bi-Phase (Bi-() modulated on an Earth station's RF carrier so as to leave a residual (ruminant) carrier component. Initially, data rates from 8 Kbps to 128 Kbps can be transmitted; however, the system will be upgraded to cover the proper range up to 256 Kbps when the need arises. Medium Rate Commands comply with CCSDS Recommendation 401 (2.2.7) B-1. (Note: 1 Kbps in this context means 1,000 bps.)

7.2 Telemetry Configurations

DSMS signal capture efficiency is influenced by several factors including: station-operating mode (diplexed v. non-diplexed), aperture size, operating frequency, and various station configurations. In addition to the standard one-station configuration, there are other alternatives. This section describes some additional capabilities.

7.2.1 Multiple Spacecraft Per Aperture (MSPA)

Multiple Spacecraft Per Aperture (MSPA) is a special configuration wherein multiple receivers are connected to a single DSN antenna permitting the simultaneous reception of signals from two

or more spacecraft. MSPA makes more efficient use of DSN facilities by enabling simultaneous data capture services to several spacecraft, provided that they are all within the Earth station's beamwidth. MSPA is not a service; it is a capability for resolving some schedule conflicts.

Presently, the DSN can receive signals from two spacecraft simultaneously in a 2-MSPA configuration. By the conclusion of 2005, there are plans to support up to four spacecraft simultaneously in a 4-MSPA configuration.

MSPA design limits unlink transmissions to a single spacecraft at a time. Thus, only one spacecraft can operate in a two-way coherent mode, all others must be one-way non-coherent.

Only the spacecraft having the uplink can be commanded. However, MSPA users can agree to share the uplink, switching during the pass. Approximately 30-minutes are required to reconfigure the uplink to operate with a different spacecraft.

There are certain requirements for users to avail themselves of MSPA. First, all spacecraft must lie within the beamwidth of the requested DSN station. Second, all spacecraft must operate on different uplink and downlink frequencies. Third, commands can only be sent to the spacecraft having the uplink. Fourth, high quality (2-way) radio metric data can only be obtained from the spacecraft operating in the coherent mode.

7.2.2 Antenna Arraying

Antenna Arraying is another special configuration wherein the signals from two or more DSN antennas are combined to create the performance of an antenna larger than either. Combining is done at an intermediate frequency (i.f.) resulting in improved performance of both the carrier and data channels. Arraying 34M antennas with a 70M station improves the performance of the 70M station. When operating in the 8 GHz band, approximately five 34M stations are required in an array configuration to equal the performance of a 70M station. Like MSPA, arraying is a capability, not a service.

7.2.3 Site Diversity

Site diversity is a special configuration in which multiple sites are scheduled to improve the certainty of achieving the desired service availability. This can be done deterministically (sites are scheduled without reference to equipment or weather conditions), or adaptively (sites are scheduled on short notice only when needed). The ability to use such techniques depends strongly on the customer's ability to adapt, the availability of resources, and/or the ability to find other customers who are willing to make arrangements to relinquish their resources on short notice.

Section 8
Performance Characteristics

The service paradigm demands performance accountability for the services rendered. Where data delivery is involved, accountability requires a measure of the quantity, quality, continuity, and latency of the data delivered. This section addresses those subjects.

$$Q_{TY} = \frac{\text{Number of } \textit{acceptable} \text{ data units delivered}}{\text{Number of } \textit{acceptable} \text{ data units input to the service}}$$

8.1 Command Service Performance

8.1.1 Quantity

Quantity is defined as the volume of "acceptable" data units delivered by the service.

$$Q_{LTY} = \frac{\text{Number of data units correctly delivered}}{\text{Total number of data units sent over a properly operating RF link}}$$

Note: The number of acceptable data units used to compute QTY are based upon the number of complete and error-free data units either delivered or expected during the service time in which the performance of the RF link is equal to or better than that specified for the pass. Quantity is the primary measure of completeness.

For the command system, a data unit is a Frame, Packet, CLTU, or File, depending upon the type of service.

8.1.2 Quality

Quality is defined as the "error rate" for the delivered data units over the end-to-end path.

Data unit error rate depends upon whether or not coding is used and, if so, which particular scheme is employed.

Currently, commands are typically encoded by the Project's MOS with a BCH code providing a two error detection, one error correction capability. In the future more sophisticated codes, such as those used for telemetry, may become available.

8.1.3 Continuity

Continuity is defined as the number of gaps in the set of data units delivered to a customer during a scheduled pass. A gap is defined as the loss of one or more consecutive data units. *Continuity* is distinguished from *Quality* in that the former counts the number of gaps (holes) in the data set during a scheduled pass while the latter measures the percentage of the total number of data units returned to a customer during the same scheduled pass.

For the *Command Radiation Service*, gaps are not an issue when operating in the File Mode because all of the data is received by the DSMS prior to radiation. Likewise, gaps do not occur in the *Command Delivery Service* because complete, error-free delivery of all commands is guaranteed.

8.1.4 Latency

Latency is defined as the time delay between a data unit's transmission from a specified point and its delivery to another point where it becomes accessible to a customer.

For commands, the point of transmission is the Project MOS and the delivery is the beginning of actual command radiation by the DSMS. *Latency* includes delays in the communications system from the Project MOS to the DSMS and delays occurring within the DSMS until the command is actually radiated.

Command Radiation Service times can be specified and have accuracies of 0.1 seconds or (8 bit-times, whichever is greater. Latency is the sum of the delays specified above plus the radiation timing accuracies.

For the *Command Delivery Service* latency times are the sum of the delays specified above for the *Command Radiation Service* plus the time required to actually delivery of the command to the designated spacecraft.

8.2 Telemetry Service Performance

8.2.1 Quantity

Quantity is as defined in Section 8.1.1 above for command. For telemetry, *data units* are Frames, Packets, and Files. The DSMS routinely achieves 95% delivery during the life of mission; however, up to 98% is achievable (but not guaranteed) if special arrangements are made. These values are derived from an assessed probability of unrecoverable data loss based upon "system availability" statistics from the DSMS telemetry system. It must also be noted that use of acknowledged Telemetry File service will significantly improve the percentage of original data delivered.

Users of any frequency band will experience some outages due to adverse weather conditions. The extent of outages depends strongly on the user's assumptions about weather when

configuring their spacecraft, and the application of data management techniques such as CFDP. Users are advised to design their data return strategy to be tolerant of weather caused data delays or gaps. The peak data quantity at S-, X-, and Ka-band is currently believed to result from assuming approximately 98th, 95th, and 90th percentile weather respectively when using long term statistical averages. Thus the user should design the data return strategy such that planned re-transmission of 2%, 5%, or 10% is acceptable. However the role of climatic fluctuation is not yet fully understood, so some consideration should be given to the possibility that weather will be significantly better or worse than the historical averages. For optimal link utilization at Ka-band users should plan on near real-time (RTLT) data rate adjustments based on weather conditions.

8.2.2 Quality

Quality is as defined in Section 8.1.2 above for command. Telemetry *data units* typically use an error-detecting error-correcting code such as: Reed Solomon, convolutional, turbo, or some combination of these. Assuming a frame (or packet) length of approximately 10,000 bits, and a convolutional (r = 1/2, k = 7) code concatenated with a Reed-Solomon (223/255) block code the:

Frame Rejection Rate $\leq 10^{-6}$ at an $E_b/N_0 = 2.8$ dB (Bit-Error-Rate $\leq 10^{-8}$).

While a rate = $^1/3$ turbo code having a frame size of 8920 bits has a:

Frame Rejection Rate $\leq 10^{-4}$ at an $E_b/N_0 = 0.4$ dB (Bit-Error-Rate $\leq 10^{-7}$).

However, a rate = 1/6 turbo code with a block size of only 1784 bits provides a:

Frame Rejection Rate $\leq 10^{-5}$ at an $E_b/N_0 = 0.4$ dB (Bit-Error-Rate $\leq 8 \times 10^{-7}$).

Therefore, users should take care to determine their acceptable frame rejection rate and thereafter carefully select a coding scheme to provide the required performance.

Undetected error rate, introduced by ground equipment is less than 4×10^{-12}.

8.2.3 Continuity

Continuity is as defined in Section 8.1.3 above for command. Data units are Frames or Packets depending upon the subscribed service type.

For a frame (or packet) length of approximately 10,000 bits, the DSN routinely provides a gap rate less than or equal to 8 in 10,000 frames (or packets), for a frame (or packet) length of 10,000 bits provided:

1. The E_b/N_0 is sufficient for a Frame Error Rate $\leq 1 \times 10^{-5}$ at all times during the pass.
2. There are no spacecraft anomalies throughout the pass.
3. The telemetry data rate does not change during the pass necessitating reacquisition.
4. No RFI events occur during the pass.

To obtain higher levels of continuity, special human intensive efforts are required during the pass. Potential users are advised to design their mission data return strategy to be tolerant of occasional gaps. A gap-rate of 8/10,000 frames (or packets) as described above should be expected as the nominal condition.

8.2.4 Latency

Latency is as defined in Section 8.1.4 above for command. For telemetry, three grades of delivery can be selected, subject to availability of adequate ground communications bandwidth.

Grade-1: (Timely Delivery) in which correct data units are delivered in order, without duplication, but with potential omissions resulting from excessive transmission latency, are provided with a typical latency of seconds. This grade is used along with Off-Line Delivery to retrieve omitted data.

Grade-2: (Complete Delivery) in which: all data, in correct order, without omission or duplication, are provided with a typical latency ≤ 5 minutes.

Grade-3: (*Off-Line Delivery*) is primarily used for data recall. It is also used for post-pass delivery to those customers whose receiving system is not *on-line* during the pass. Typical latencies can be hours.

All three grades use the reliable communication protocol, i.e., TCP, as underlying interface method. The difference is that the *timely delivery* allows for the controlled discarding of telemetry frames at the application layer if it is not possible to deliver those frames within a certain amount of time after they are acquired from the space link (e.g., because of communications service backlog).

8.2.5 Telemetry Data Acquisition - Throughput

Depending on the link performance, coding scheme, modulation method, and other factors, the DSN is presently capable of acquiring telemetry data at the maximum throughput of 2.2 Mbps and the minimum throughput of 10 bps (uncoded). By 2005, the maximum throughput for telemetry data acquisition will be increased to 4 Mbps for Reed-Solomon encoded data using convolution code (7, 1/2).

8.3 Tracking Service Performance

8.3.1 Doppler Data

Doppler data are the measure of the cumulative number of cycles of a spacecraft's carrier frequency received during a user specified count interval. The exact precision to which these measurements can be made is a function of received signal strength and station electronics, but is a small fraction of a cycle. Raw Doppler data is generated at the tracking station and delivered via DSN interface TRK-2-34[6], for 34m and 70m stations and in format TRK-2-30[6] for 26 m antennas. In order to acquire Doppler data, the user must provide a reference trajectory, and information concerning the spacecraft's RF system to DSMS to allow for the generation of pointing and frequency predictions.

The user specified count interval can vary from 0.1 sec to 10 minutes, with count times of 10 to 60 seconds being typical. The average rate-of-change of the cycle count over the count interval expresses a measurement of the average velocity of the spacecraft in the line between the antenna and the spacecraft. The accuracy of Doppler data is quoted in terms of how accurate this velocity measurement is over a 60 second count. The accuracy of data improves as the square root of the count interval.

(1) Noncoherent Doppler Data

Noncoherent data (also known as one-way data) is data received from a spacecraft where the downlink carrier frequency is not based on an uplink signal. The ability of the tracking station to measure the phase of the received signal is the same for non-coherent versus coherent data types, however the uncertainty in the value of the reference frequency used to generate the carrier is generally the dominant error source.

(2) Coherent Doppler Data

Coherent Doppler data is that received from a spacecraft where the reference frequency of the received carrier signal was based on a transmitted uplink signal from the Earth. This is commonly known as two-way data, when the receiving and transmitting ground stations are the same, and three-way data, when the transmitting and receiving stations are different. Since the frequency of the original source signal is known, this error source does not affect data accuracy. The accuracy of this data is a function primarily of the carrier frequency, but is affected by transmission media effects.

S-band: S-band (2.2 GHz) data is available from 26m, 70m, and some 34m antennas. The one-sigma accuracy of S-band data is approximately 1 mm/s for a 60 second count interval after being calibrated for transmission media effects. The dominant systematic error which can affect S-band tracking data is ionospheric transmission delays. When the spacecraft is located angularly close to the Sun, with Earth-spacecraft-Sun (EPS) angles of less than 10 degrees, degradation of the data accuracy will occur. S-band data is generally unusable for EPS angles less than 5 degrees.

X-band: X-band (8.4 GHz) data is available from 34m and 70m antennas. X-band data provides substantially better accuracy than S-band. The one-sigma accuracy of a 60 second X-band Doppler measurement is approximately 0.1 mm/s. X-band data is less sensitive to ionospheric media delays but more sensitive to weather effects. X-band data is subject to degradation at EPS angles of less than 5 degrees, but is still usable with accuracies of 1 to 5 mm/s at EPS angles of 1 degree.

Ka-band: Doppler accuracy at Ka-band is mostly affected by the Earth-spacecraft-Sun angle, and for X-band uplink/Ka-band downlink mode the one sigma accuracy is near that as described in X-band uplink/X-band downlink.

8.3.2 Ranging Data

Ranging data measures the time that it takes a series of signals superimposed upon the uplink carrier frequency to reach the spacecraft, be retransmitted, and then received at an Earth station (round-trip-light-time, RTLT). As such, all DSN ranging systems are intrinsically coherent.

The user of ranging data service must define two of three required parameters: the desired accuracy, the desired range measurement ambiguity, and the maximum observation time. These along with the knowledge of the received ranging power-to-noise ratio will allow for the configuration of the ranging system.

(1) Sequential Ranging

The 26m, 34m, and 70m subnets utilize a sequential ranging technique. For strong signals the technique can provide measurements of the range to the spacecraft to 1 meter accuracy with X-band uplink and Ka-band downlink, 1 meter accuracy with X-band uplink and downlink, and to 2 meters accuracy with S-band uplink and downlink. However, data accuracy is a function of signal strength and for ranging data via a spacecraft low gain antenna at typical deep space ranges, the data accuracy may be degraded to as much as 1 km.

The sequential ranging technique modulates a series of codes upon the radio signal to the spacecraft. The first of these, the "clock code," defines the resolution or accuracy that the ranging measurement will have. However, the observation from the clock code is ambiguous as it only identifies the fractional part of the clock code period comprising the RTLT, there are an unknown additional integer number of clock periods composing the RTLT. The DSMS then sequentially modulates a decreasing series of lower frequency codes upon the signal in order to resolve the ambiguity in the range measurement, by increasing the period of the ranging code.

The maximum range ambiguity possible in the DSMS is approximately 152,000 km, however ambiguities of 1,190 km and 2,380 km are more commonly used.

The accuracy of a ranging observation is a function of the received power-to-noise ratio in the ranging signal. Greater accuracy can be achieved by observing the "clock code" signal for a longer period of time. For lower power-to-noise ratios it also takes longer to resolve each of the ambiguity resolution codes. Consequently, for a given power-to-noise ratio, a desired accuracy and a desired ambiguity will result in a required observation time. For practical purposes the maximum value for this observation time is 30 minutes. In the event that the desired accuracy and desired ambiguity result in a required observation time greater than 30 minutes, either a change in the ambiguity or the accuracy will be required. DSN Document 810-5, Module 203[6] provides a detailed description and the formula used in calculating the accuracies.

(2) 26m Ranging

In addition to the sequential technique, the 26m subnet also supports a second order ranging system which is a hybrid system combining a harmonic side tone ranging system with a binary encoded ambiguity resolving code. This system operates only at S-band and provides a measurement accuracy varying from 1 to 10 meters for Earth orbiting spacecraft. The ambiguity of the measurement is 644,000 km. DSN document 810-5, Module 204 provides a detailed description of the ranging system.

8.3.3 Angle Data

The DSN 26m subnet has the capability to provide closed loop pointing to a spacecraft being tracked and to report the resulting azimuth and elevation of the antenna. This angle data which is primarily used to support low Earth orbiters and for launch support is accurate to approximately 0.02 degrees. Angle data does not require a coherent signal, but is only available at S-band. A customer wishing to receive raw angle data service would receive the data via DSN interface TRK-2-30.

8.3.4 Delta DOR Data

Assume of sufficient signal detection (The delta-DOR measurements are expected to have the following accuracy:

(1) 0.3 m at S-band, assuming a minimum 7 MHz DOR tones separation

(2) 0.04 m at X-band, assuming a minimum 20 MHz DOR tones separation

(3) 0.04 m at Ka-band, assuming a minimum 80 MHz DOR tones separation

The above values further assume a condition of sufficient signal detection and minimal interference, e.g., a received tone voltage signal-to-noise ratio of 5 or greater in 1.0 second of integration time, for spacecraft/Sun separation angle of at least 5 degrees and quasar/Sun separation angle of at least 15 degrees.

8.3.5 Latency of Validated Radio Metric Data Service

At the present, the Validated Radio Metric Data Service routinely provides data products with a 24-hour turn-around time. For supporting time-critical mission events, a delay of 30 minutes to 1 hour in delivery of data can be achieved.

8.4 Navigation Orbit Determination Service Performance

The performance of the radio metric orbit determination is described in terms of an Earth-centered Earth Equatorial Radial-Transverse-Normal coordinate system. Accuracy is principally a function of the amount of tracking, Earth relative geometry, and data types utilized. The following captures the typical one sigma capability:

(1) Coherent Doppler only, spacecraft geocentric declination greater than 10 degrees --

Range: 10 km

Transverse & Normal: 250 meters for every 1,000,000 km from the Earth (e.g. 37.5 km at 150 million km geocentric range)

(2) Coherent Doppler only, spacecraft geocentric declination less than 10 degrees --

Range: 10 km

Transverse & Normal: 500 meters for every 1,000,000 km from the Earth (e.g. 75 km at 150 million km geocentric range)

(3) Coherent Doppler and Ranging, spacecraft geocentric declination greater than 10 degrees --

Range: <1 km

Transverse & Normal: 100 meters for every 1,000,000 km from the Earth (e.g. 15 km at 150 million km geocentric range)

(4) Coherent Doppler and Ranging, spacecraft geocentric declination less than 10 degrees --

Range: <1 km

Transverse & Normal: 150 meters for every 1,000,000 km from the Earth (e.g. 22.5 km at 150 million km geocentric range)

Section 9
Description of Tool Delivery Process

In addition to providing services, the DSMS can provide an extensive set of tools, i.e. software or hardware system components that are intended to be operated by end-users that are intended to be operated by end-users rather than by DSMS personnel as part of providing a service (see the next section for more on "what is a tool"). Customers can use these tools for integration and testing, for developing their mission operations system (MOS), and for operating their missions. DSMS-provided tools can be integrated with the customer's custom or commercial-off-the-shelf systems to augment their functionality. A special tool, the core ground data system (GDS), can be used as the basis upon which to build a complete, mission-specific GDS. Many of the tools can (or must) be adapted to meet a mission's unique requirements. In most cases, adaptation can be done either by the DSMS tool providers or by the customers themselves.

Figure 9.1 illustrates the customer interfaces for the acquisition and support of DSMS tools as a function of project life-cycle phase. In this diagram, boxes represent activities performed by the customer (top) or DSMS (bottom). The arrows represent the exchange of artifacts or information.

Note: For purposes of this catalog, the Mission Management Office (MMO) is considered to act on behalf of the flight project, and no distinction is drawn regarding their respective roles.

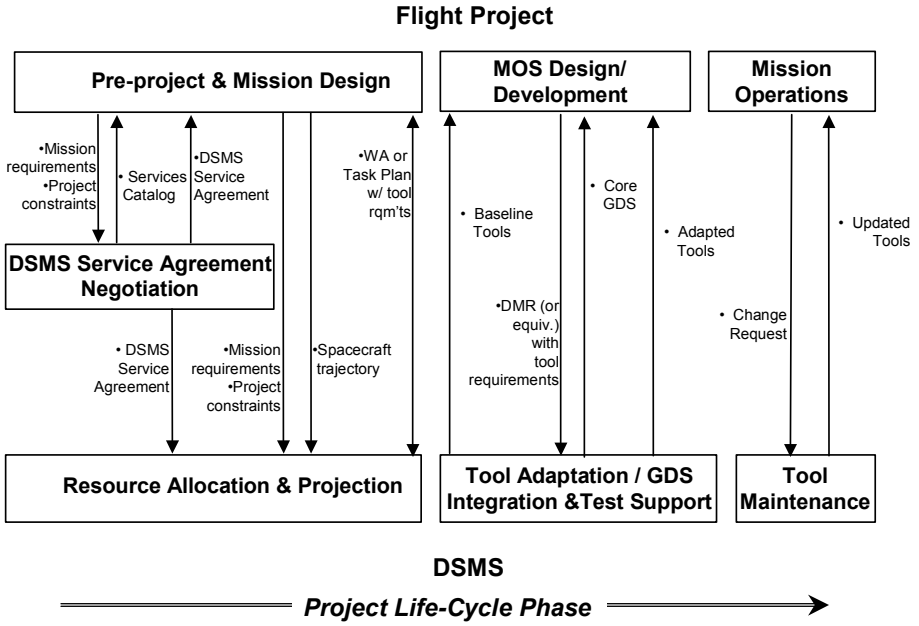


Figure 9.1 Customer Interface for Tools: Process Over the Project Life Cycle

9.1 Learning About DSMS Tools

Section 10 of this Catalog provides an overview of the tools provided by DSMS. The individual tools and tool-kits are listed and described in Appendix B, "DSMS End-User Tools". The customer is advised to contact DSMS personnel as described in section 2 for more detailed information about specific tools.

9.2 Acquiring DSMS Tools

DSMS tools are not included within the scope of the basic TT&C services. As a consequence, **customers are required to make a programmatic arrangement with JPL for obtaining any of these tools**. That programmatic arrangement should include notation in the service agreement between the customer and DSMS that the tool is needed and will be supplied, as well as the support and delivery options selected (see below).

-- JPL flight projects may acquire tools and tool support through the same process used for tailored services. See section 12, "Pricing of Services". If funding is needed for DSMS

adaptations or support at JPL, then appropriate JPL Work Agreements and accounts must be established.

-- For customers other than JPL flight projects, a government-use license for limited use of selected tools may be obtainable through the JPL cognizant procurement officer. If funding is needed for DSMS adaptations or support at non-JPL centers, then a Task Plan must be executed between the DSMS Program Office and the Project's Program Office to specify the work and enable transfer of those funds via the JPL Contracts Management Office.

9.3 Support and Delivery Options

There are three options for tools:

(1) DSMS delivers a Core Ground Data System (GDS) to the customer to use as the basis for developing a mission-specific GDS. The Core GDS is described in section 10 (it is the last entry). In this option DSMS will adapt the provided tools to the particular mission, integrate them with each other and the underlying platform, and configure them to interact with the set of DSMS services selected by the project.

(2) DSMS supplies tools that have been adapted to meet the customer requirements. Adaptation refers to the tailoring of a tool to reflect the specifics of a given mission, typically through augmenting the tool with mission-specific parameters, models, etc. In this option, the customer is responsible for integrating the tools into their system and for configuring them to interact with the selected DSMS services.

(3) DSMS provides the baseline tool in its unadapted, multimission form. In this option, the customer is responsible for adaptation or other customization, for integrating the tools into their system, and for configuring them to interact with the selected DSMS services. This option is not available for all tools.

Each of these options includes:

-- Verification to a level commensurate with the option;

-- Documentation of the basic tool and of any adaptation or customization that are provided;

-- Delivery from a reliable, configuration-managed DSMS repository (except where otherwise noted);

DSMS will provide maintenance of the tool over the life of the mission as negotiated. This typically includes bug fixes, periodic upgrades, and incorporation of change requests. Different levels of maintenance are available. In addition, support levels for configuration and integration are also subject to negotiation, up to and including responsibility for integration and verification of the entire GDS.

9.4 Supported Platforms

In general, the DSMS end-user tools are supported for a limited and evolving set of computing platforms. Customers are encouraged to inquire about the network, computer types, and operating system versions that will be supported during the relevant period so as to avoid incompatibilities. The majority of the tools support a common configuration of computing and communications hardware, operating system, and third party software known as the "AMMOS standard workstation". This is an evolving standard which is periodically updated via a process that invites customer participation. Tools which require other platforms are noted in Appendix B. In addition, some of the tools support additional configurations, which are also noted.

Section 10
Overview of DSMS Tools

As described in the previous section, the tools provided by the DSMS are system components that are intended to be operated by end-users rather than by DSMS personnel as part of providing a service. "End-users" in this instance refers to flight project or experiment personnel such as members of Mission Operations System (MOS) teams or science teams. Although the majority of the tools provided by DSMS take the form of ground software, a limited set of tools in the form of flight software components or special-purpose hardware are provided as well. Tools are provided over the entire spectrum of mission applications: from observation planning through scheduling, sequencing, prediction, mission control, monitoring, to analysis of engineering and science data.

Note: Procedures as tools may be addressed in a subsequent update to this Catalog.

Note that a given component may have multiple uses, being used both by end-users and by DSMS operations personnel in providing service. Such dual-use components are considered to be DSMS end-user tools and are included here.

It is common for a service implementation to provide a user interface, application program interface, or client which works in concert with a server or other centrally operated component. In that case, only the portion that is operated by the end-user is considered to be an end-user tool. Further, cases where a service is accessed via a standard, widely available package such as a web-browser or electronic mail client are not considered "DSMS end-user tools".

See section 9 for information on obtaining DSMS end-user tools.

In this catalog, tools are categorized according to the principle class of information upon which they operate. This is intended to provide convenient, consistent groupings and prevent confusion between tools with similar-sounding functionality but very different uses. Tools that convert from one form of information to another are categorized according to the source information. The categories are:

Activity Plan Tools
Catalog Tools
Command Tools
Computing Environment Tools
Experiment Product Tools
File Transport Tools
Navigation Tools
S/C Data Tools
S/C Model Tools
Schedule Tools
Sequence Tools
Simulation Tools
Telemetry Transport Tools
Test Tools
Time Tools
Integrated Data System

The remainder of this section further defines these categories and gives an overview of the tools in each. A more detailed list of the tools is provided in tabular form in Appendix B "DSMS End-User Tools". The table presented there is organized using the same categories in the same order as appear below.

Note on terminology: The systems which encompass the DSMS-provided tools have been identified differently at different times. In some cases these terms persist in document titles, tool names etc.

Space Flight Operations Center (SFOC)

Multimission Ground Data System (MGDS)

Advanced Multi-Mission Operations System (AMMOS)

10.1 Activity Plan Tools

Activity plan tools are used to compose, manipulate, format, and view plans for mission, spacecraft, and instrument activities.

10.1.1 Activity Plan Generation Tool

The Activity Plan Generation (APGEN) tool is used to plan overall mission scenarios and observation sequences, and to create schedules for communication, spacecraft, and instrument activities. It enables a user to interactively add and modify activities within the plan, visually depicts the overall plan, forecasts performance and resource usage, and evaluates them against defined constraints. In addition to its internal capabilities for modeling various aspects of S/C behavior, it includes defined interfaces for incorporating results of external models. Further, it can serve as a planning and modeling engine to support external activity planning and visualization packages.

10.1.2 Science Observation Planning Tools

Tools for science observation planning aid experimenters in identifying and analyzing observational opportunities that meet specific science objectives. They provide capabilities for specifying criteria, displaying time windows that meet those criteria, and visually depicting position and pointing relationships. The tools also aid in designing the observation, model the relevant S/C activities, and check constraints.

10.2 Catalog Tools

Catalog tools are used to browse, publish data to, and select and access data from catalogs. This category also includes tools for disseminating data from catalog-like repositories.

10.2.1 Catalog User I/F Clients

Catalog clients provide both graphical and command-line user interfaces for querying and updating cataloged data, thereby supporting both interactive and automated access. Programmable subscription capabilities are also available to automatically deliver selected classes of data as it arrives. The clients are compatible with the full range of open and managed access modes supported by the Mission Data Management Services. Application programming interfaces (API's) are provided to permit direct integration of the data management and catalog functions into other applications.

10.2.2 Meta-data Utilities

Utilities are available for creating, modifying, and removing meta-data associated with cataloged files, specifically Standard Formatted Data Unit (SFDU) “K-Headers” ("K-Headers" are described in the AMMOS User's Guide, Vol.02 "Working with File Data", MGSO0088-00-11-02).

10.2.3 File Exchange Utilities

Utilities are provided to aid users in synchronizing the contents of various types of repositories by managing and transferring files between them, including catalogs maintained via the Distributed Object Manager (DOM), the Central Data Base (CDB), and Multimission Image Processing System (MIPS).

10.2.4 Service Management Data Access User I/F Client

DSMS provides a user-interface client that enables users to access an archive of the support products (e.g. predicts, schedules) that are generated and used by the Service Preparation System in managing the execution of DSMS services.

10.3 Command Tools

Command tools are used to compose, manipulate, format, and view spacecraft or instrument commands.

10.3.1 Command Translation Toolkits

The Command Translation Subsystem (CTS) is used in defining and translating spacecraft commands. It includes utilities for editing Command Definition Language files, compiling command translation tables, and generating a command dictionary. It also includes libraries for accessing command files.

10.3.2 Command Control Toolkit

The command control toolkit includes tools to create, edit, and validate mnemonic command files, translate them into spacecraft command message files, and reformat them into Command Link Transmission Units (CLTU's) for radiation to the spacecraft. It also includes tools to initiate, control and monitor the transfer of command data to the DSCC's for radiation, and to control access to command capabilities. The Command Control toolkit provides interacts with Command Radiation Service and Command Delivery Service via the CCSDS Space Link Extension (SLE) protocol.

10.3.3 Command View Tool

The command view tool provides a "read-only" capability to monitor a command session and to view command-related monitor data.

10.3.4 Automated Command Tracking Tool

The Automated Command Tracking (ACT) tool manages and tracks command files and automatically facilitates the command review and approval process. It includes functions to support electronic review and approval of command loads using secure means for user authentication.

10.4 Computing Environment Tools

Computing environment tools are used to manipulate or view aspects of the network or workstation computing and communications environment.

10.4.1 General Utilities & Shells

A number of utilities are available to aid the user in viewing and manipulating the workstation environment itself. In addition, user interface shells are provided that can be configured to provide convenient access to the DSMS and custom tools available on the workstation.

10.4.2 Support Tools

Two subsystems are supplied that are required in order to support various DSMS-provided tools. The Data Transport Subsystem (DTS) provides standard communications, logical name service, and broadcast service. The System subsystem (SYS) includes many of the tables and configuration files used by various DSMS tools.

10.5 Experiment Product Tools

Experiment product tools are used to format, aggregate, visualize, or transform science data products.

10.5.1 Video Image Toolkit

The Video Image Communication and Retrieval (VICAR) toolkit is an integrated suite of tools used to process image, spectral, radar, time series, and other experiment data forms. These tools may be invoked via a user interface which provides command line, GUI, and on-screen visual programming supported by extensive on-line help. The entire suite of tools may be used in a highly interactive data exploratory mode or programmed for automated processing of large data volumes. Extensive user documentation is available. VICAR incorporates science data processing tools, science data visualization tools, cartographic tools, and instrument development tools.

Science data processing tools are used to produce "level 1A&B" products generated in non-real-time after the creation of the raw level zero data products. This processing may include merging of telemetry data received from multiple sources into the best available set of data, removal of instrument signature, mathematical transformation of time series data, and data quality checks. Higher level processing may include true color reconstruction from multiple exposures, cartographic projections and generation of large image mosaics.

Science data visualization tools are used to convert the science data products into forms that can be displayed or printed for visual interpretation. This may include animation sequences, mathematical transformation of time series data, visualization products portraying data from multiple instruments, and visualization products of multispectral data. Other tools are available to perform "data mining" operations, scanning large volumes of data for particular signatures or artifacts.

Cartographic tools can be used to support precise cartographic projections, derive elevation maps from stereo/SAR imagery, Cartographic projections for bodies other than the Earth including irregular bodies.

Instrument development tools provide support for instrument calibration analysis as well as for selection, development, and end-to-end simulation of science data compression algorithms.

10.5.2 Batch Image Production Tool

The Multiple Recorder Production System (MRPS) tool enables users to conveniently produce batches of images.

10.6 File Transport Tools

File transport tools are used to access, manipulate, and view S/C file or product data in transit at the transport or network protocol layers.

10.6.1 CFDP User Interface Tools

CCSDS File Delivery Protocol (CFDP) user interface tools provide access to the ground CFDP handler. These tools enable users to select files for transmission, monitor a CFDP session, and receive notifications and reports. The CFDP User Interface interacts with Telemetry File Service and Command Delivery Service.

10.6.2 On-Board CFDP Handler

This tool implements the CCSDS File Delivery Protocol (CFDP) onboard the spacecraft. CFDP provides reliable file transfer over space links using common flight and ground software.

10.7 Navigation Tools

Tools in the navigation category are used to compose, manipulate, format, view, and analyze navigation data. Functionally, these tools can be further divided into tools used for the production and dissemination of ancillary or reference information related to navigation, tools used for mission analysis and design, and tools used for navigation per se' in a flight operations environment.

10.7.1 SPICE Ancillary Data Toolkit

The Spacecraft, Planet, Instrument, C-Matrix, Events (SPICE) toolkit permits creation of reduced and interpreted ancillary datasets which may include spacecraft ephemerides, planetary ephemerides and constants, instrument descriptions, camera pointing, and events about spacecraft and instruments. The output from these tools may be used to annotate observations or otherwise record mission analyses, events and processing states. Packaged as an integrated toolset, the SPICE tools have been used by many flight projects and PIs in a variety of different science domains.

10.7.2 Generic SPICE Kernels

DSMS provides reference data sets containing ancillary navigation data that are generic in the sense that they are not specific to a given mission. Three separate sets of ephemerides (accurate position and velocity histories for selected bodies within the solar system) are provided: planetary bodies, natural satellites, and small bodies (e.g. comets and asteroids). See also Natural Body Ephemeris Services regarding generation of ephemerides for specific requests. In addition, data sets containing planetary constants and leap seconds are similarly provided. These data sets may be accessed or manipulated via the SPICE toolkit (see above).

10.7.3 Mission Analysis Software

Mission analysis software is used in the design, analysis, and visualization of spacecraft trajectories and related data. Several different types of tools are provided:

-- Applications: these provide end-to-end execution of specific tasks or functions in mission analysis and design;

-- Utilities: these perform more basic mission analysis and design functions than do applications. They are intended to be combined and re-used in multiple ways;

-- Libraries: these provide similar types of functionality to utilities, but in a form suitable for integration into custom applications or utilities;

-- Environments: these provide a user interface (interactive or scripted) integrated with basic mission analysis functionality

10.7.4 Precision Trajectory & Orbit Determination Tools

The Double-Precision Trajectory (DPTRAJ) and Orbit Determination (ODP) program sets provide high-precision flight path information in flight operations. The two work in concert, using dynamic models to compute the predicted flight path based on actual forces operating on the spacecraft, then comparing these with observed data using a parameter estimation model to improve knowledge of the flight path.

10.7.5 Maneuver Computation & Evaluation Tools

The Maneuver Analysis Program Set (MOPS) is used to compute high precision trajectory correction maneuvers during flight operations, based on targeting requirements and constraints, ephemerides for spacecraft, target, and other bodies, and spacecraft performance history.

10.7.6 Next Generation Navigation Tools

The Mission-analysis, Operations, and Navigation Toolkit Environment (MONTE) is an integrated, combination toolkit and environment for planning and designing S/C trajectories, estimating and controlling the actual trajectories, maintaining and disseminating flight path knowledge, and providing information for solar system bodies such as planetary orbits, pole orientations and rotation rates, etc. MONTE is intended to replace the navigation and trajectory analysis software systems currently in use.

10.7.7 Radiometric Data Processing Tools

The Automated Radiometric Data Validation and Real-time Correction (ARDVARC) software provides validation and correction of radio metric tracking data, export of validated observables to real-time and off-line orbit determination software, real-time monitoring and analysis of radio

metric data residuals, and real-time monitor of the tracking of a spacecraft across all DSN stations (e.g. what stations are tracking a spacecraft at any particular time).

10.7.8 Gravity Modeling Tools

The Gravity Modeling Subsystem provides high precision models of the gravity fields of planets, satellites, asteroids, and comets.

10.7.9 Navigation Utilities & Libraries

Software in the form of various utility programs and libraries can be used to read and write data in various navigation-supported formats, convert among those formats, manipulate the data, and perform coordinate transformations and rotations, and perform matrix or vector computations.

10.8 Spacecraft Data Tools

Spacecraft data tools are used to manipulate, condition, filter, view, or analyze engineering data from spacecraft and instruments, as well as related data such as ground system or space environment data that pertains directly to spacecraft behavior or performance. This includes both predicted data (whether generated by a model or simulator) and actual data.

10.8.1 Data Monitor and Display

Data Monitor & Display (DMD) provides routine processing, display, and format conversion of spacecraft engineering telemetry and selected ground system monitor data to aid in assessing the health and safety of the spacecraft. Although designed for near-real-time operation, it can also be used retrospectively. Included in this toolkit are utilities for managing channel conversion algorithms and parameters as well as alarm conditions. Also included is a user-configurable alarm notification capability.

10.8.2 Miscellaneous S/C Data Utilities

DSMS provides a number of supplementary utilities for querying, viewing, and manipulating spacecraft engineering or science telemetry. Generally, these work in conjunction with the processing capabilities of Data Monitor & Display (DMD).

10.9 Spacecraft Model Tools

Spacecraft model tools are used to model various aspects of spacecraft behavior and performance. This category also includes tools that are used to compose, manipulate, format, view, and apply such models.

10.9.1 DARTS/DSHELL S/C Dynamics Tool

DARTS/DSHELL provides a toolkit for the high-fidelity simulation and modeling of spacecraft. The DARTS component is a high performance computational engine for flexible multibody dynamics. It is based on Spatial Operator Algebra, a mathematical approach for modeling the dynamical behavior of complex, articulated collections of bodies interacting with each other in free-space or in contact with the environment. The DSHELL component integrates the DARTS S/C dynamics simulator and a library of hardware models (for actuators, sensors and motors) into an integrated simulation environment that can interface with flight software and hardware in numerous configurations to meet real-time and non real-time S/C simulation needs.

10.9.2 Telecommunications Link Analysis Tools

The telecommunications analysis tools generate link design control tables showing the uplink and downlink telecommunications performance. They take into account the configuration and characteristics of the spacecraft telecommunication subsystem, the selected capabilities and configuration of DSN tracking stations, trajectory geometry, etc. for estimating future uplink and downlink signal strength, signal-to-noise ratios (SNR), best lock frequency, Doppler frequency offsets, etc. Outputs are provided in file, graphical , and tabular formats as a function of time. These predictive tools may also assist customers in specifying the spacecraft telecommunication system parameters during the mission design phase. Both interactive and batch (command line) versions are available.

10.10 Schedule Tools

Schedule tools are used to compose, manipulate, format, and view schedules of spacecraft and ground system activity.

10.10.1 Common Allocation Scheduling Tools

The Common Allocation Scheduling Tools (CAST) are used to generate various schedule views and other products that assist users in negotiating ground station coverage.

10.10.2 Scheduling Utilities

Various scheduling utilities are provided to produce human-readable schedules from sequence products, peruse available view periods, and perform general project planning and scheduling.

10.11 Sequence Tools

Sequence tools are used to compose, manipulate, format, and view spacecraft sequences.

10.11.1 Sequence Generation Toolkit

Sequence generation tools provide sequence generation, validation, and review capabilities for standard mission commanding scenarios. The inputs to these tools are the mission and observation plans, current spacecraft state, allocations of tracking passes, and associated viewperiod, lighttime, and other predicts. Output of these tools are validated command sequences suitable for uplink to the spacecraft, an integrated schedule of spacecraft and ground data system events, and other information used to predict and validate spacecraft operation. Virtual Machine Language (VML) is supported.

10.11.2 Automated Sequence Processing Tool

The automated sequence processor can be used to quickly and reliably perform the steps involved in integrating sequence requests, validating the resulting sequence, and generating the required command products.

10.11.3 On-board Virtual Machine Language Tool

The on-board Virtual Machine Language (VML) provides a standard implementation of a sequence engine. In addition to having the capability of causing activities to occur at specified absolute or relative times, the virtual machine approach incorporates the ability for time-tagged instructions capable to invoke functions. A virtual machine simulates a generic processor, memory locations, and registers: the basics of any computing environment. The On-board VM is based on the same sequence engine as the Off-line VM simulation tool, and is compatible with output from the Sequence Generation tools.

10.12 Simulation Tools

Simulation tools are used to emulate aspects of flight software or sequence execution. This category includes tools that aid in setting up the simulation as well as reporting results.

10.12.1 Off-Line Virtual Machine Simulation Tool

The Off-line Virtual Machine (OLVM) is an emulator that incorporates the same virtual machine sequence engine as On-Board VM (see above), and adds to it a graphical user interface, test controls and other capabilities needed to make a usable simulator.

10.13 Telemetry Transport Tools

Telemetry transport tools are used to access, manipulate, extract, and view spacecraft telemetry in transit at the transport or network protocol layers. This category includes tools for dealing with telemetry in Standard Formatted Data Unit (SFDU) format, as well as selected monitor and Quality, Quantity, and Continuity (QQC) data. Many of the tools in this category interact with

the Telemetry Delivery Subsystem, which is a specialized database management system for telemetry data used in providing Mission Data Management services.

10.13.1 Telemetry Output Tools

Tools are provided to enable users to query for telemetry frames and for packets derived from spacecraft telemetry, monitor data, or Quality, Quantity, & Continuity (QQC) data. Tools with both graphical and command line user interfaces are available. These tools interact with the repository maintained as part of the Telemetry Frame Service and Telemetry Packet Service.

10.13.2 Telemetry Transport Utilities

Various utilities are provided to monitor the flow of telemetry through the ground system, identify data outages, peruse and identify available data, manipulate data in Standard Formatted Data Unit (SFDU) form, and convert data between various file formats (e.g. bytestream and spooler formats, which are binary file formats used to represent telemetry data).

10.13.3 Common Data Access Toolkit

The Common Data Access subsystem comprises an application programming interface (API) for reading and writing files containing data in Standard Formatted Data Unit (SFDU) format. It supports both bytestream and spooler file formats. CDA is not actually a tool or tool-kit, but is used by various other telemetry transport tools and therefore must be part of the end-user's workstation environment.

10.13.4 Workstation Decommutation Toolkit

A toolkit is provided which can be used in lieu of Telemetry Channel Service to perform the functions of decommutation and channelization. Tools are included to aid in composing, compiling, and managing decommutation maps.

10.14 Test Tools

Test tools are used to generate spacecraft or instrument test data, to conduct tests of spacecraft or instrument behavior, and to present or record results.

10.14.1 Test Telemetry and Command Subsystem

The Test Telemetry and Command Subsystem (TTACS) is a tool that supports flight system development and test by mimicking the relevant portions of the ground data system to allow data to flow to and from the spacecraft without a complete set of operational interfaces and DSN facilities. It is available in two different forms:

First, the TTACS Core provides serial telemetry and command interfaces between the spacecraft GSE and specially configured command and telemetry software resident at the various workstations. It includes a high-speed serial device for the interface with spacecraft ground support equipment; the Test Telemetry Interface (TTI) software that receives and processes the telemetry data from the test spacecraft hardware and transmit it to the other GDS components in the testbed environment; and the Test Command Interface (TCI) software that processes command files from the GDS components into blocks of command bits and delivers them to the test spacecraft hardware.

The second form of the test tool is the adapted TTACS. It is essentially a miniature version of its counterparts in the operational system with a configuration that supports the development and test of the spacecraft and MOS. Varying from project to project, it can be configured to include, in addition to the TTACS Core, a certain number of parallel telemetry streams, a limited number of data rates, a few workstations, data management capabilities, a GSE interface, instrument bench checkout equipment connections, etc. A final configuration of the TTACS is used to support the pre-launch system tests.

10.14.2 Test Execution Tool

The spacecraft Test Execution Control Tool (TECT) provides test control scripting for engineering subsystem, instrument, and integrated spacecraft testing. Capabilities include closed-loop command control for ground support equipment (GSE), simulators, or S/C subsystems; real-time command control with closed-loop telemetry feedback; automated regression testing; and capture and archival of test procedures and results.

10.15 Time Tools

Time tools are used to convert, present, or operate on time in various formats.

10.15.1 SC Clock Coefficient Tools

In lieu of Spacecraft Time Correlation Service, DSMS can provide the basic tool used to determine the correlation coefficients for converting between S/C clock counts and S/C event time. Note that the same caveats that apply to the service apply to effective use of the tool.

10.15.2 Time Format Utilities

DSMS provides a number of utilities to convert times between various formats or references and to display times.

10.16 Integrated Data System

This category consists of integrated collections of tools from the preceding categories which can serve as a basis for development of a custom system.

10.16.1 Core Ground Data System

The core ground data system (CGDS) is an integrated, turnkey system supplied by DSMS. The customer then builds on this system in order to create a mission-specific GDS. The CGDS includes computer platforms along with the requisite network support and an integrated suite of the tools described above in this section. Adaptation of any part of the CGDS for mission-specific needs can be provided by DSMS personnel or flight project itself. On-going maintenance of the CGDS during the project life cycle will also be available. The CGDS has the following properties:

-- The components (computer H/W, network, software tools) have been integrated with each other and configured to support the customer's operational needs;

-- The CGDS exhibits a high degree of generic behavior, other than the specifics of the adaptations;

-- Interfaces to the DSN service interfaces have been configured (mission services typically require adaptation and therefore frequently cannot be pre-configured);

-- The CGDS can be configured for test and early ATLO, as well as for operations;

Section 11
Engineering Support Activities

DSMS engineering personnel will be available to support customers in conducting pre-project studies, mission design, development of data systems, and/or the operations of missions. In general, these are level-of-effort support activities. The scope of each engineering support activity will have to be assessed on a case-by-case basis.

11.1 Support to Systems Engineering

DSMS engineering personnel can provide systems engineering support to missions to assist them in defining an end-to-end telecommunications and mission operations system architecture, defining operations concepts, identifying system solutions, and defining interfaces.

11.2 Support to Advance Mission Planning

DSMS engineering personnel provides engineering support to the planners of future missions in identifying and verifying their requirements for DSMS services, proposing or assessing telecommunication design for ensuring its compatibility with DSN, and analyzing optimal tracking and data acquisition approach.

11.3 Support to Configuration Management

Support can be provided to customer in the configuration management (CM) of the MOS and GDS. This includes giving assistance and advices to customer in establishing CM tools, data bases, and procedures, so that the flight project can have an operational CM system without having to develop its own system from scratch.

11.4 Support to Emergency Mission Operations Center

For a customer subscribing to the use of the Emergency Control Center (ECC) provided by the DSMS, engineering support will be provided to the contingency flight team in getting the data system, e.g. work stations, tools, and network connections, into operable state. (Note: The ECC is a scale-down version of the mission operations center. One of its purposes is to allow the customer to resume its flight operations in the event of a natural disaster or other catastrophic event which disables certain facilities of a mission operations center.)

11.5 Support to End-To-End Integration and Test

During spacecraft development phase, DSMS engineering personnel participate in the integration and test activities involving the DSMS-provided mission operations services. Support to testing

the end-to-end telecommunications link and characterizing spacecraft telecommunications subsystem prior to launch and during flight operations can also be provided.

11.6 Support to RF Compatibility Test

Before launch, RF compatibility test equipment will be available for customer to validate the RF interface compatibility between the spacecraft and DSN. The compatibility test equipment emulates the data modulation/demodulation capabilities and provides an RF link between the user spacecraft and tracking stations.

11.7 Support to Telecommunications Design

The telecommunications design can be conducted during mission design phase to help a customer achieve a flight segment telecommunications design which is compatible with the space-ground link and capabilities of DSN tracking stations, and will achieve the desired level of performance. Design issues, potential deficiencies and possible trade-offs are identified through these analyses. In general, the support is dependent on project phases:

(a) Phase A (Preliminary Design): Initial telecommunications link design includes trial selection of transponder or transceiver, power amplifier, antenna type, data rate determination, and channel coding schemes. The purpose is to assess feasibility and derive initial cost estimates. Also, basic tracking support issues are identified, e.g. required DSN capabilities, tracking schedule, navigation data types, and mission unique features.

(b) Phase B (Detailed Design): Detailed design includes final selection of spacecraft telecommunications components, transponders, power amplifier, antenna patterns, trajectory geometry, function cross strapping, and redundancy management. Link losses based on spacecraft dimensions and coax or waveguide selections are included with ground antenna G/T curves, spacecraft pointing models, Doppler and Doppler rates, for all link functions, i.e. telemetry, command, ranging, and radio science if present.

(c) Phase C/D (Implementation, Integration, and Test): All of the design work of Phase B is maintained with measurements of actual flight hardware performance. Performance estimates are adjusted by changes in values from their earlier estimates, as well as by reductions in uncertainties allowed by measured versus estimated values. Discrepancies are analyzed for their effects and corrective actions. Mission operations adaptations are completed, sequences are built for testing on the spacecraft and for use in flight. Compatibility with the DSN is proven by test, and end-to-end tests from mission operations system to spacecraft.

11.8 Spectrum and Frequency Management

The DSMS Program Office is responsible to NASA and the international Space Frequency Coordination Group (SFCG) in managing deep space spectrum and frequency resources. In that capacity, the DSMS engineering personnel helps the customer license the use of the RF spectrum, performs conflict analysis, makes frequency allocation and interference

avoidance/mitigation recommendation, and handles the licensing process with other government agencies.

11.9 System Administration

The DSMS system administrators install and configure mission-related workstations, routers, and firewalls. This may include both MOS software and third-party software installation.

11.10 Security Engineering

The DSMS Security Engineer arranges all interconnections between the (closed) Flight Operations Network and the (open) Internet. The primary path is through the DSMS Firewall. Security engineering support may be provided to the requesting Flight Project. This includes preliminary design and cost estimates for end-to-end network security.

11.11 Spacecraft Search

In time of severe spacecraft anomaly causing the loss of communications with the ground, the DSMS can provide equipment, e.g., high-power transmitter and high-sensitivity receiver, as well as personnel support to s flight projects for re-establishing contact with the spacecraft.

The ability to search for a lost spacecraft depends on the number of places that need to be searched, and on the signal level. There can be several dimensions in the search region: frequency, frequency rate, direction (ephemeris) and perhaps time, if the signal may be time varying. The difficulty of the search, or the time required for the search, increases approximately proportionally to the size of the search region, and inversely with assumed minimum possible SNR.

One dimensional searches, such as just over frequency, are fairly easy, as are two-dimensional searches over limited regions, such as over small uncertainties in frequency and frequency rate or space. Large two dimensional searches are very difficult, but can be done with the custom capabilities.

The Spacecraft Search capabilities offered are further divided into 6 types of services according to the techniques, complexity, and expertise involved in service provision: Frequency and Time Searches, Spatial Search, Frequency Rate Search, Extreme Weak Signal Search, Wideband Spatial Searches, and Extremely Weak Signals with Frequency and Frequency Rate Uncertainty.

Section 12
Pricing of Services

As NASA moves to a full cost accounting model, it is important that the pro-rata share of each service's cost be determined and budgeted by each mission. This section provides some pricing information intended to assist customer in estimating the DSMS service costs.

12.1 DSN Utilization Cost for TT&C Services

The DSN utilization cost is an essential portion of the total MOS cost for a mission. It can be computed from an "aperture fees"-based empirical algorithm described in this section. The algorithm was established by the NASA Headquarters more than 10 years ago and has been maintained by NASA official authority since then.

The DSN utilization cost covers the subscription fees for the following DSMS standard services:

(1) Command Services

(2) Telemetry Services (except Telemetry Channel Service)

(3) Tracking Services, i.e. Radio Metric Data Services (both raw and validated)

(4) Ground Communications Services (except dedicated circuit and LAN provision)

(5) DSN Science Services, i.e. Radio Science, Radio Astronomy/VLBI, and Radar Science Services

(6) Beacon Tone Service

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.

$$AF = R_B [A_W (0.9 + F_C / 10)]$$

where:

- AF = weighted *Aperture Fee* per hour of use.
- R_B = base hourly rate = $767.00/hr in FY 2002 dollars).
- A_W = aperture weighting:
  - = 0.8 for 26-meter stations.
  - = 1.0 for 34-meter stations.
  - = 4.0 for 70-meter stations.
- F_C = number of station contacts, (contacts per calendar week).

The weighting factor graph in Figure 10.1 shows relative antenna costs. A station contact may be any length but is defined as the lesser of the spacecraft's view period or 12 hours. Total DSN cost is obtained by partitioning mission into calendar weeks and summing the Aperture Fees. This total cost can be obtained by grouping weeks having the same requirement, multiplying by Aperture Fee, and summing over the mission's duration. An Excel spreadsheet is available at the Homepage [TBD] to help customers establish the DSN cost estimate for their missions.

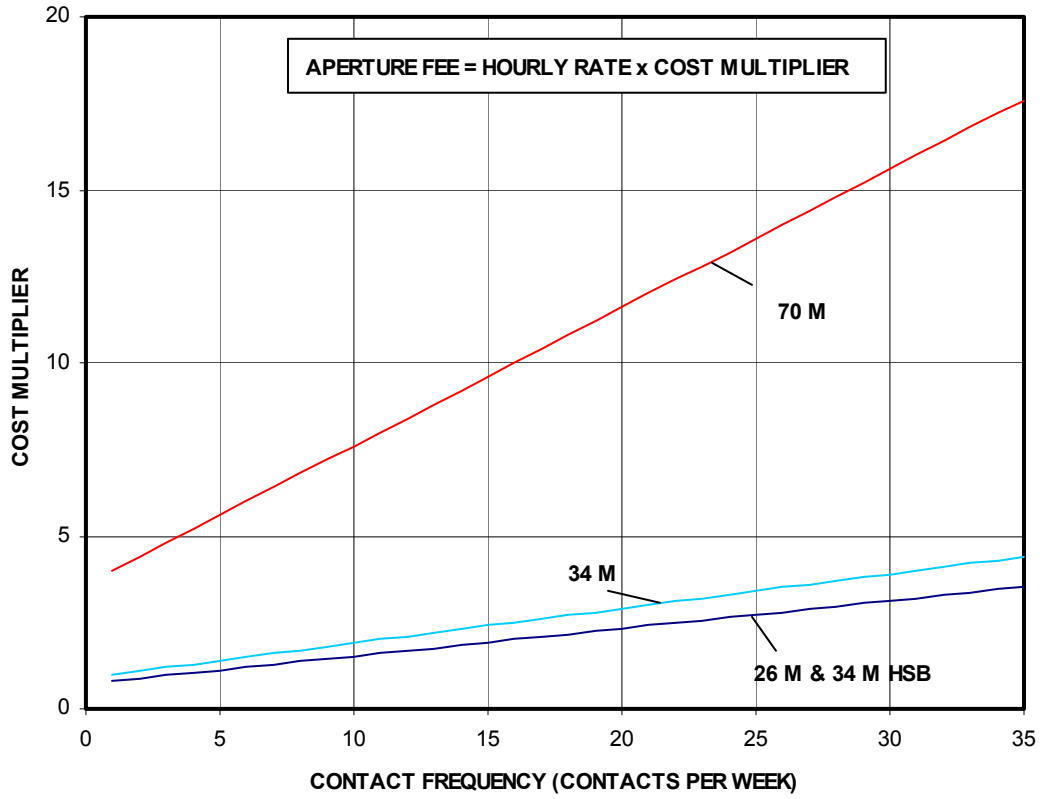


Figure 10.1 Aperture Weighting Factors and Cost

For each station contact, i.e., a tracking pass, there is the need for calibrating and testing the configured equipment prior to the supported event. The time period for such activity is known as the pre-calibration time. Similarly, there is the need for configuration reset after a supported event. The time taken for the latter is known as the post-calibration time. Both pre-calibration and post-calibration times are part of the aperture time cost-attributable to customer. For a regular station contact, the pre-calibration time is 45 minutes and the post-calibration time is 15

minutes. For a station contact providing only Beacon tone service, however, they are 15 minutes and 5 minutes, respectively.

12.2 Policies on Non-recurring Costs of Services

A few policies have been established to guide the determination of non-recurring costs associated with services. In general, non-recurring costs are negotiated by the customer and DSMS personnel based on the project requirements, scope of the adaptation, and agreed levels of customer support. Recurring costs are derived from standard tables such as the DSN aperture fee base rate, operational network rates, and wide area network circuit fees.

12.2.1 Performance-based Non-recurring Costs

Subscribers to standards services requiring better performance than provided by the standard services will be charged non-recurring costs. Examples include:

- Continuity requirement (for telemetry services) better than 8 gaps in 10,000 packets
- Completeness requirement (for telemetry services) better than 95% during mission life

12.2.2 Content-Independent Services

Subscribers to standard services which are content-independent generally have no non-recurring cost to begin use of the service. This reflects the plug and play and standard interface attributes discussed above. In these cases adaptation includes establishing labels, parameters, addresses, and other selections that are bounded by the normal scope of that standard service. Examples of services supplied at a simple recurring cost are:

- Command Radiation/Delivery
- Telemetry Frame, File services
- Radiometric data services
- Beacon Tone
- DSN Science services

12.2.3 Content-Dependent Services

Subscribers to tailored services, or to standard services which have significant content dependence, can expect a non-recurring cost to make the necessary adaptations. Examples of services which typically have non-recurring cost are:

- Mission Data Management

- Navigation (OD, Trajectory, Maneuver, etc.)
- Experiment data products
- Flight Engineering

12.3 Fee for Other Services

For cost estimate regarding other types of services as well as all the DSMS-provided tools and engineering support, a “grass-root” design-based costing exercise is highly recommended. For missions in conceptual design and planning phases, typically, this is conducted by an engineering team organized by the DSMS Program Office, at a nominal expense to the customer. Customers are advised to contact the DSMS Program Office (see Section 2 of this document for Point of Contact) for details.

Section 13 Appendix A
Acronyms and Abbreviations

AMMOS	Advanced Multi-Mission Operations System
APGEN	Activity Plan Generation program set
API	Application Program Interface
ARDVARC	Automated Radiometric Data Validation and Real-time Correction
ARQ	Automatic Retransmission Request
BCE	Bench Checkout Equipment
BWG	Beam Waveguide
CCSDS	Consultative Committee for Space Data Systems
CDA	Common Data Access subsystem
CDE	Consolidated Development Environment
CFDP	CCSDS File Delivery Protocol
CGDS	Core Ground Data System
CLTU	Command Link Transmission Units
DARTS	a S/C dynamics simulator (actual acronym expansion unknown)
DFS	Distributed File System
DMD	Data Monitor and Display
DN	Data Numbers
DPTRAJ	Double-Precision TRAJectory program set
DSCC	Deep Space Communications Complexes
DSHELL	DARTS Shell

DSMS	Deep Space Mission System
DSN	Deep Space Network
EPS	Earth-Spacecraft-Sun
ERT	Earth Receive Time
EU	Engineering Units
FTS	Frequency and Timing Subsystem
GDS	Ground Data Systems
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GUI	Graphic User Interface
HEF	High Efficiency
ICC	Integrated Computer Complex
ICT	Integer Cosine Transform
IGSE	Instrument Ground Support Equipment
ISO	International Organization for Standards
ITU	International Telecommunication Union
JPEG	Joint Photographic Engineering Group
K-Header	That part of the K-header SFDU that holds the keyword=value fields (hence, K-object) that describe the SFDU through attributes like mission, spacecraft, data type, producer, and so forth. Also called K-object or catalog header.
MADB	Missions & Assets Data Base
MOS	Mission Operations System
MRPS	Multiple Recorder Production System
MSM	Mission Service Manager

MSPA	Multiple Spacecraft Per Aperture
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NISN	NASA Integrated Service Network
NSSDC	NASA Space Science Data Center
OD	Orbit Determination
ODP	Orbit Determination Program
ODRC	Operations Data Reduction Complex
OLVM	Off-Line Virtual Machine
PCD	Project Commitment Document
PDS	Planetary Data System
POCC	Payload Operations Control Center
PSLA	Project Service Level Agreement
QQC	Quality, Quantity, and Continuity
QQCL	Quality, Quantity, Continuity and Latency
RF	Radio Frequency
RMDC	Radio Metric Data Conditioning Service
RSS	Radio Science Services
RTLT	Round-Trip-Light-Time
SAR	Synthetic Aperture Radar
SCPS	Space Communications Protocols Standard
SFCG	Space Frequency Coordination Group
SFDU	Standard Formatted Data Unit
SLA	Service Level Agreement
SLE	Space Link Extension

SNR	Signal-to-Noise Ratio
SOMO	Space Operations Management Office
SPICES	Spacecraft Planetary Instrument Camera Event
SRA	Sequential Ranging Assembly
TDM	Time Division Multiplexed
TDRS	Tracking and Data Relay Satellites
TECT	Test Execution Control Tool
TMO	Telecommunications & Mission Operations
TMS	Telecommunications & Mission Services Manager
TT&C	Tracking, Telemetry, and Command
TTACS	Test Telemetry & Command Subsystem
TTI	Test Telemetry Interface
UTC	Coordinated Universal Time
UDP	User Datagram Protocol
VCDU	Virtual Channel Data Units
VLBI	Very Long Baseline Interferometry
VM	Virtual Machine
VML	Virtual Machine Language

Section 14 Appendix B
List of End-user Tools

This is a table listing the individual tools and tool-kits by category. The table gives the common name, description, type, source, configuration identification, and status for each entry.

Note: Versions of this table that are sorted can also be made available. In particular, a version that is sorted by source can be handy for review purposes

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		1 About DSMS End-User Tools				
		DSMS end-user tools are data system components that are intended to be operated by end-users rather than by DSMS operations personnel as part of a DSMS service. "End-users" in this instance refers to flight project or experiment personnel such as members of Mission Operations System (MOS) teams or science teams. DSMS end-user tools typically must be integrated into the project's ground data system or flight system. They often must be adapted to the particular flight project or experiment.				
		See sections 9 and 10 of the DSMS Services Catalog for more on the general characteristics and availability of DSMS end-user tools.				
		See the notes following the table for an explanation of the column entries.				
		2 List of Tools				
		2.1 Activity Plan				
Activity	APGEN	Activity Plan Generator-- Resource-based,	Exe;	MS&A	502.102	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
Plan		interactive activity plan generator for mission planning and sequencing. Enables automatic scheduling and modeling of activities and resources. Requires mission-specific adaptation. -- (All adaptations currently being done by projects and Mission Management Office.) Platforms: AMMOS standard workstation;	Adpt			
Activity Plan	SEQ_POINTER	Planetary Observation Instrument Targeting Tool-- Enables a user to design remote sensing sequences for execution on a S/C. Calculates and checks pointing design and constraints. Currently used by Cassini only. Platforms: AMMOS standard workstation;	Exe; Adpt	MS&A	502.202	IMP
Activity Plan	SOA	Science Opportunity Analyzer-- Enables scientists to interactively select, visualize, and design observations for S/C instruments. Typically adapted for a particular flight project, but core multi-mission capability can be used directly. -- Cassini; Platforms: AMMOS standard workstation;	Exe; Adpt	MS&A	502.101	IMP
		2.2 Catalog				
Catalog	"Kwik" SFDU toolkit	Collection of utilities for handling K-header type SFDU files (Standard Formatted Data Unit). K-Headers are typically used to represent the meta-data used by catalogs in performance of	Exe	TlcmS	SSS 224.3 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Mission Data Management services. Includes: -- kwikkat: Create and modify SFDU catalog header template files for use with kwikwrap. -- kwikunwrap: Strip the SFDU catalog headers from a file and save either or both the original data file and the catalog header file. -- kwikval: Validate the format of a K-Header SFDU file, according to the mission policy table. -- kwikwrap: Combines a catalog header file with a data file to create a K-header type SFDU. -- sfdugui: Graphical user interface providing access to kwikkat, kwikunwrap, kwikval, and kwikwrap. Platforms: AMMOS standard workstation;				
Catalog	cdb_fti	Command line or interactive client interface for the Central Data Base (CDB) file transfer system, that moves, transfers, and deletes files to and from the CDB. Used in conjunction with Mission Data Management service. Platforms: AMMOS standard workstation;	Exe	TlcmS	DOM 224.1 P	IMP
Catalog	DOM Clients - "C"	"C" versions of applications for interacting with catalogs managedy by the Distributed Object Manager (DOM, aka Darkstar). DOM is a specialized database management system used in providing	Exe	TlcmS	DOM 224.1 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Mission Data Management services. It is designed to organize files or other data objects and associate user-definable meta-data with them. The user-operated clients include: -- cat_delete: Remove a file or other object from the catalog; -- catedit: Graphical user I/F for modifying and maintaining the catalog; -- cat_getfile: retrieve a particular file from the catalog; -- catnav: Graphical user I/F for navigating the catalog and accessing non-telemetry files or objects. -- catpub, cat_publish: Applications for publishing new file or other objects to the catalog; -- cat_replace: replace a file or other object with a successor version; See also entry under DOM Clients - Java. Platforms: AMMOS standard workstation;				
Catalog	DOM Clients - Java	Java versions of applications for interacting with catalogs managed by the Distributed Object Manager (DOM, aka Darkstar). DOM is a specialized database management system used in providing Mission Data Management services. It is designed to organize files or other data objects and associate user-definable meta-data with them. The user-operated clients include:	Exe	TlcmS	DOM 224.1 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		-- jcat_delete: Remove a file or other object from the catalog; -- jcatedit: Graphical user I/F for modifying and maintaining the catalog. -- jcat_getfile: retrieve a particular file from the catalog; -- jcatnav: Graphical user I/F for navigating the catalog and accessing non-telemetry files or objects. -- jcatpub, jcat_publish: Applications for publishing new files or other objects to the catalog. -- jcat_replace: replace a file or other object with a successor version. See also entry under DOM Clients - "C" Platforms: AMMOS standard workstation;				
Catalog	FEI/Database View	Multimission Image Processing System (MIPS) File Exchange Interface Client--Client portion of system used to manage and transfer files, especially large image files. Includes both basic file manipulation functions (get, add, replace, etc.) and subscription capability based on file type. Deployment of FEI servers at customer sites is also supported on a case-by-case basis. This typically requires engineering support from SIS. Also distributed as part of VICAR (see entry in Experiment Product category). Platforms: Special - direct inquiries to SIS;	Lib	SIS	601.601	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
Catalog	SPS Archive Client	DSMS provides a user-interface client that enables users to access an archive of the support products (e.g. predicts, schedules) that are generated and used by the Service Preparation System in managing the execution of DSMS services. This allows users to participate in post-mortem investigations of discrepant service results, particularly when it is unclear whether the problem originates on the S/C or the ground. The client interface would be a supplement to the standard service management interface. While the design has not yet been finalized, it is most likely that this will take the form of a Web Services application program I/F. Platforms: <<TBD>>	Lib	M&CS	<tbd>	Com
		2.3 Command				
Command	ACT	Automated Command Tracker client--Tracks execution of processes through a well-defined procedure. Includes mission-specific Electronic Command Request Forms. There are both multi-platform, graphical user I/F and Unix command-line user I/F versions of the client. Requires mission-specific adaptation. Platforms: AMMOS standard workstation;	Exe; Adpt; DS	TlcmS	OAS 223.5 P	IMP
Command	cmdview	Standalone graphical utility that allows monitoring of a command session and	Exe	TlcmS	CMD 222.1 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		viewing of command-related monitor data without enabling any write or control access to command functions or data. Platforms: AMMOS standard workstation;				
Command	Command Control Toolkit	Application software that enables customers to prepare command files, stage them to or from a Project Master Directory (PMD), control their transfer to DSSC's for radiation to the S/C, and monitor a command session. Also provides client-side access control to these functions. Includes: -- cmdcontrol: Command Control graphical user interface; -- acmd_crs: Command Radiation Service processor-- accepts & process directives from Command Control GUI, establishes and maintains connection with DSCC; -- acmd_pmdsd: Project Master Directory (PMD) interface client; -- acmd_cmdbsd: Command Broadcast services; Broadcasts command session data; -- Command File Utilities: Utilities to generate command files from mnemonic input or sequence command packet files;, update command files; and validate file headers; -- acmd_db: catalog interface client for command (I/F to DOM, the catalog	Exe, Lib	TlcmS	CMD 222.1 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		manager used for Mission Data Management services); -- acmd_mdrsd: Command Mission Data Reader; Routes monitor and command session data to Command Control and Command View. -- acmd_tcwrap: wrap a command packet file to produce an SCMF (S/C Command Message Format) file. In addition to this toolkit, a Command Control Workstation requires the Command Translation Subsystem (CTS - see below) as well as the Data Transport Subsystem (DTS)Logical Name and Broadcast servers (see entry in Comp Env category). Platforms: AMMOS standard workstation;				
Command	Command Control Toolkit (Old)	Software for Command workstation prior to deployment of Command Replacement; Provides similar functions;	Exe,Lib	TlcmS	CMD 222.1 P	Dcm
Command	CTS	Command Translation Subsystem-- Set of global libraries and executables used for defining and translating S/C commands. Includes: -- cmd_xlt: Wraps command translation tables w/ Standard Formatted Data Unit (SFDU) headers; -- cmd_procxlt: Processes wrapped command translation tables; -- cdbg: Command Definition Language	Exe; Lib	MS&A	CTS 502.503	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Compiler. Note: These may be delivered with Telecom Services software in cases where there is no MS&A delivery. Platforms: AMMOS standard workstation;				
		2.4 Comp Env				
Comp Env	cdaerr	Translates an error number generated by the Common Data Access (CDA) subsystem into a meaningful error message. See listing for CDA in the Telem Transport category. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Comp Env	DTS	Data Transport Subsystem-- Provides communications services for various tools and services provided by Teleom Services. Although not directly accessed by end-users, DTS is required by other selected tools in this list. It must be installed as part of the end-user's workstation environment. It is therefore listed here for completeness. In particular, the Logical Name Server (LNS) and Broadcast Server (BCS) processes must be running on a user's workstation in order to access selected DSMS services. <<TBD - Identify specific tools & services that require DTS>> Platforms: AMMOS standard workstation;	Exe; Lib	TlcmS	DTS 221.2	IMP
Comp Env	dtserr	Translates an error number generated by the Data Transport Subsystem (DTS) into	Exe	TlcmS	OAS 223.5 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		a meaningful error message. Platforms: AMMOS standard workstation;				
Comp Env	oelcal	General-use, X-Motif graphical calendar tool. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Comp Env	oelshell	Perl shell script that calls specific graphical interface tools. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Comp Env	printshell	Graphical user interface shell for specifying parameters when printing a file. Platforms: AMMOS standard workstation;	Exe	TlcmS	CMD 222.1 P	IMP
Comp Env	sfocversion	Displays the version of DSMS-provided software currently installed on a workstation. This tool is delivered in source form only, and must be built at installation time by the system administrator. Platforms: AMMOS standard workstation;	Exe	TlcmS	SYS 221.4 P	IMP
Comp Env	submitshell	Graphical user interface shell for setting up one or more processes to run at a future time. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Comp Env	SYS	System Support Subsystem-- Delivery mechanism for tables and configuration files used by various DSMS-provided software. Although not directly accessed by end-users, SYS is required by other selected tools on this list. It must be installed as part of the end-user's workstation environment. It is therefore listed here for completeness.	Exe;Lib; DS	TlcmS	SYS 221.4	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Platforms: AMMOS standard workstation; <<TBD- Refine which portions of subsystem are tools, and which are required by tools.>>				
Comp Env	wdump	Prints any X window raster image to a laser printer. Platforms: AMMOS standard workstation;	Exe	TlcmS	WSE 221.5 P	IMP
Comp Env	xpstat	Graphs virtual memory usage on the workstation. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
		2.5 Experiment Product				
Experiment Product	MRPS	Multiple Recorder Production System--Enables user to print batches of images. Platforms: Special - direct inquiries to SIS;	Exe	SIS	601.9	IMP
Experiment Product	VICAR	Video Image Communication And Retrieval-- A general-purpose suite of ~600 individual programs and routines for digital image processing. Includes the VICAR executive which is accessed via TCL (Transportable Applications Executive Control Language) directives and forms the interface between the user, the library of application programs and procedures, and the computer's operating system. Extensive user documentation is available. Platforms: Special - direct inquiries to SIS;	Exe; Lib	SIS	601.2 P; 601.201; 601.3; 601.4; 601.601; 601.704; 601.801; 601.802; 601.8 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		2.6 File Transport				
File Transport	CFDP User I/F	User interface for interacting with the CCSDS File Delivery Protocol (CFDP) service Includes: -- cfdpui: Enables user to select files for transmission to a S/C; -- cfdpview: Standalone utility that allows monitoring of a CFDP session, i.e. viewing status of files being transmitted or received. Platforms: AMMOS standard workstation;	Exe	TlcmS	CFDP 221.6 P	Com
File Transport	On-board CFDP	Version of CCSDS File Delivery Protocol (CFDP) handler intended for use onboard a spacecraft. Provides reliable file transfer over space links. Uses source code in common with ground CFDP implementation (which is part of the Telemetry File and Command Delivery services). Platforms: AMMOS standard workstation;	Exe	TlcmS	CFDP 221.6 P	Com
		2.7 Navigation Data				
Navigation Data	ARDVARC	Automated Radiometric Data Validation and Real-time Correction-- processes tracking data from a DSN data feed (via multiplex or from a file) to produce Doppler, range, ramps information. Inlcudes -- ARDVARC: Command-line user	Exe	T&NS	514.2	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		interface; -- XARDVARC: Graphical user interface; -- Netardvarc: stand-alone shell that can be used to remotely send commands to an ardvarc process; -- various utilities; Requires mission-specific adaptation. Platforms: Special - direct inquiries to T&NS;				
Navigation Data	ARTSN	Automated Real-Time Spacecraft Navigation-- prototype software suite which autonomously processes radiometric tracking data for orbit determination. Integrates S/C state vectors and dynamic partial derivatives; calculates computed observable and partial derivatives; estimates selected parameters along with their uncertainties; maps S/C states and uncertainties to other epochs. ARTSN can be used either in a stand-alone configuration or with a remote shell. Either configuration can be used both for real-time or off-line processing. No longer supported.	Exe	T&NS	???	Dcm
Navigation Data	AUTONAV	Software for on-board optical navigation. Discontinued.	Exe	T&NS	515.2	DCM
Navigation Data	DPTRAJ	Double-Precision Trajectory-- creates a spacecraft ephemeris using a dynamic model to compute a flight path based on the actual forces operating on the S/C. Requires mission specific adaptation.	Exe	T&NS	514.2	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Platforms: Special - direct inquiries to T&NS;				
Navigation Data	Gravity Modeling Subsystem	High precision modeling of the gravity fields of planets, satellites, asteroids, and comets. No mission-specific adaptation required. Platforms: Special - direct inquiries to T&NS;	DS	T&NS	517	IMP
Navigation Data	MAS Applications	Mission Analysis Software applications-- a suite of programs which execute tasks end-to-end in the design, analysis, and visualization of trajectories and related data. Includes: -- Atmospheric Entry & Powered Landing (AEPL): Provides medium precision propagation of spacecraft aerobraking or entry trajectories. [FORTRAN '95; Sun, HP, & Linux] -- Computer Algorithm Trajectory Optimization Tool (CATO): Medium precision trajectory optimization and searches; [FORTRAN'95; Sun, HP, Linux, & SGI] -- EVENTS: Determine times of geometrical and physical events; [FORTRAN'77; Sun, HP] -- GALLOP: Fast, low-precision parametric optimization of low-thrust trajectories [FORTRAN'95; Sun & Linux] -- GRIST: Trajectory propagation via	Exe	T&NS	503.1	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		numerical integration; [FORTRAN'95, Sun, HP & Linux] -- MIDAS: low-to-moderate precision, high-thrust trajectory optimization [FORTRAN'77; Sun, HP, & SGI] -- MYSTIC: High precision, low-thrust trajectory optimization for multiple-body missions, including departure and arrival spiral trajectories and low-thrust heliocentric cruise under influence of multiple gravitating bodies [FORTRAN'95; Sun & Linux] -- POHOP: High precision (integrated) long-term trajectory [FORTRAN'77; Sun, HP & Linux]; -- POLOP: Low precision, long-term trajectory propagation [FORTRAN'77; Sun, HP & Linux]; -- SEPTOP: Creation of medium fidelity, primer-vector-based, optimal, low-thrust trajectories [FORTRAN'77; HP & SGI] -- STOUR: Trajectory propagation via conics; No adaptation required. Platforms: Special - direct inquiries to T&NS;				
Navigation Data	MAS Environments	Mission Analysis Software environments--collections of functional components with an associated user interface that assist in the design, analysis, and visualization of trajectories and related data.	Exe	T&NS	503.1	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Includes: -- Librations Tool (LTOOL): Environment for scripted astrodynamics modeling, particularly if libration-point/three-body trajectories [C++, Python; Sun & Linux]; -- Quick: Environment for Interpreted astrodynamics mathematical programming and scripting of multiple applications [FORTRAN'77; Sun, HP, SGI, & Linux]; No adaptation required. Platforms: Special - direct inquiries to T&NS;				
Navigation Data	MAS Libraries	Multi-mission Analysis Subsystem Libraries-- collections of library routines for the design, analysis, and visualization of trajectories and related data.. Includes: -- MASL Plot Library: graphing/plotting subroutines [FORTRAN'77; Sun, HP, SGI, & Linux]; -- MASL SPICE Library: variant on NAIF SPICE that "wraps" MASL Vector entry point calls [FORTRAN'77; Sun, HP, SGI, & Linux] -- MASL Vector: algorithms for linear algebra, quaternion math, orbit propagation, orbit geometry, orbit targeting, and natural body description. [FORTRAN'77; Sun, HP, SGI, & Linux]; No adaptation required; Platforms: Special - direct inquiries to	Lib	T&NS	503.2	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		T&NS;				
Navigation Data	MAS Utilities	Mission Analysis Software utilities-- a collection of programs which can be combined and re-used in multiple ways in the design, analysis, and visualization of trajectories and related data. Includes: -- BPLOT: Creates contour plots in B-plane [FORTRAN'77; Sun, HP, SGI, Linux]; -- Fast Flight: Trajectory visualization via animation [FORTAN'77; Sun, HP, & SGI]; -- GPOST: Tabulates trajectory data and find events on trajectories [FORTRAN'77; Sun, HP, SGI, & Linux]; -- GTRACK: Generates & displays S/C ground tracks [FORTRAN'77; Sun, HP, SGI, & Linux]; -- Kingsland Plot Tool (KPLOT): Visually depicts trajectories via x-y plots or movies [FORTRAN'77; Sun, HP, SGI, & Linux]; -- OSMEAN: Converts between osculating and mean orbit elements [FORTAN'77; Sun, HP, & Linux]; -- Scan: Generates beam tracks and swaths [FORTRAN'77; Sun, HP, SGI, & Linux]; -- Xcontour: Generates contour plots of launch vs arrival date via a GUI [FORTRAN'77; Sun, HP, SGI, & Linux]; No adaptation required.	Exe	T&NS	503.1	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Platforms: Special - direct inquiries to T&NS;				
Navigation Data	MONTE	Mission Analysis, Operations, and Navigation Tool-kit Environment-- a single, integrated tool-kit for planning and designing S/C trajectories; estimating and controlling the actual S/C trajectory throughout the mission; maintaining and disseminating knowledge of the S/C trajectory; and providing information for solar system bodies such as planetary orbits, pole orientations and rotation rates, etc. Requires mission-specific adaptation. Platforms: Special - direct inquiries to T&NS;	Exe; Lib;	T&NS	<tbd>	Com
Navigation Data	MOPS	Maneuver Operation Program set-- Computes and evaluates high precision trajectory correction maneuvers. Requires mission-specific adaptation. Platforms: Special - direct inquiries to T&NS;	Exe; Lib; DS	T&NS	514.4	IMP
Navigation Data	Nav Lib	Navigation Software Libraries- Consolidated library of routines used for navigation. Includes ephemeris readers, matrix and vector routines, nav I/O, portable namelist library, rotations, time and coordinate transformations, and others. No adaptation required. Platforms: Special - direct inquiries to T&NS;	Lib	T&NS	514.6	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
Navigation Data	Nav Utilities	A collection of utility programs that manipulate or extract information from Double Precision Trajectory (DPTRAJ) and Orbit Determination Program (ODP) file types, or otherwise support the use of those programs. No adaptation required. Platforms: Special - direct inquiries to T&NS;	Exe	T&NS	514.5	IMP
Navigation Data	ODP	Orbit Determination Program-- Applies an observation model to fight path information to compute observations received; computes partials of observables with respect to modeled parameters; uses a parameter estimation model to compare and improve the knowledge of the dynamic and observation models. Requires mission-specific adaptation. Platforms: Special - direct inquiries to T&NS;	Exe	T&NS	514.1	IMP
Navigation Data	SPICE Kernel Production Tools	Programs used to produce SPICE (Spacecraft, Planet, Instrument, C-Matrix, Events) kernel files. Requires minimal mission-specific adaptation for full functionality. Platforms: Special - direct inquiries to T&NS;	Exe	T&NS	???	IMP
Navigation Data	SPICE Kernels (Generic) - Misc	Supplemental reference information for use with ephemerides and other navigation data. Includes:	DS	T&NS	???	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		-- Planetary Constants Kernel (PCK); -- Leapseconds Kernel (LSK) No adaptation required. Platforms: AMMOS standard workstation; Additional platforms - direct inquiries to T&NS;				
Navigation Data	SPICE Kernels (Generic)--Satellite Ephemeris	Accurate position and velocity histories (ephemerides) for the natural satellites within the solar system. Available in two formats: NAVIO and SPICE. No adaptation required. *<<tbd - does 820-061 id cover both formats?>>* Platforms: AMMOS standard workstation; Additional platforms - direct inquiries to T&NS;	DS	T&NS	511.2	IMP
Navigation Data	SPICE Kernels (Generic)--Planetary Ephemeris	Accurate position and velocity histories (ephemerides) for planetary bodies within the solar system. Available in two formats: NAVIO and SPICE. No adaptation required. *<<tbd - does 820-061 id cover both formats?>>* Platforms: AMMOS standard workstation; Additional platforms - direct inquiries to T&NS;	DS	T&NS	511.1	IMP
Navigation Data	SPICE Kernels (Generic)--Small Bodies Ephemeris	Accurate position and velocity histories (ephemerides) for small bodies within the solar system (e.g. comets and asteroids).	DS	T&NS	511.3	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Available in two formats: NAVIO and SPICE. No adaptation required. *<<tbd - does 820-061 id cover both formats?>>* Platforms: AMMOS standard workstation; Additional platforms - direct inquiries to T&NS;				
Navigation Data	SPICE Toolkit	Spacecraft, Planet, Instrument, C-Matrix, Events Toolkit (aka Navigation Ancillary Information Facility or NAIF Toolkit)-- A portable ANSI FORTRAN 77 or ANSI C toolkit that contains subroutines for retrieving data from each of the SPICE kernels, plus a wide assortment of geometry, math, and utility modules useful in computing instrument observation geometry parameters derived from those kernel data. Examples of the computations available with SPICE are range, optic axis intercept latitude and longitude, and phase, incidence, and emission angles. The Toolkit also includes utility and demonstration programs, and is accompanied by extensive user-focused documentation. Requires mission-specific adaptation for full functionality, however some core portions can be used directly. Platforms: AMMOS standard workstation; Additional platforms - direct inquiries to	Exe; Lib	T&NS	516	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		T&NS;				
Navigation Data	Stripper	(aka RMD Stripper)-- Produces Tracking Data Files (TDFs) and Orbit Data Files (ODFs) for use with other Navigation System software. Can be used in either interactive or batch modes. No adaptation required. Platforms: Special (VAX 8530). Direct inquiries to T&NS;	Exe	T&NS	244.101	IMP
		2.8 S/C Data				
S/C Data	argosplot	Real-time and non-real-time plotting and printing program for reviewing data files stored in Encapsulated Comma Separated Values (ECSV) Format. Based on the X-Windows application programming interface (API). Note: ECSV is a text format used for data exchange among Telecom Services tools. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
S/C Data	comboshell	One of three query2plot graphical user interface shells. Processes TOT query inputs and parameter value language (PVL) files and file inputs. (See entry for query2plot in this category and entry for TOT in Telem Transport catagory). Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	Dcm
S/C Data	DMD	Data Monitor and Display Subsystem--Processes and displays real-time telemetry, monitor, and Quality, Quantity, & Continuity (QQC) data in a variety of	Exe	TlcmS	DMD 223.6 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		formats. Includes -- Channel Conversion Language (CCL) utilities (createccl, dmdccl, binary_load). -- Automated Alarm Notification (AAN). Provides an automatically generated message upon receipt of data meeting user-specified conditions. This can be provided as a service, but can also be configured by end-users. Platforms: AMMOS standard workstation;				
S/C Data	ecdr_dump	Collects and dumps statistics on files that contain Expanded Channelized Data Records (ECDRs). Note: ECDR is a binary format used for data exchange among Telecom Services tools. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
S/C Data	ECSV Shell	Aka ecsvview-- One of three query2plot graphical user interface shells. Reads any Encapsulated Comma Separated Values (ECSV) file and shows its channelized records. Note: ECSV is a text format used for data exchange among Telecom Services tools. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
S/C Data	ecsvmerge	Merges files in Encapsulated Comma Separated Values (ECSV) format. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
S/C Data	GPLOT	Generates plots, including comparative plots, of S/C data from a source in any of	Exe	TlcmS	DMD 223.6 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		three forms: Encapsulated Comma Separated Values (ECSV) format, columnar text, or manually entered analytic functions. Note: ECSV is a text format used for data exchange among Telecom Services tools. Platforms: AMMOS standard workstation;				
S/C Data	NOCC RT	DSN Network Operations Control Center Real-Time Display-- Workstation configured to enable user to select and view NOCC monitor data in near-real-time.	H/W; Exe	M&CS	308.106; 308.115; 308.201; 308.202	Dcm
S/C Data	oplot	Graphical tool for building telemetry data plots using files generated with ecsv2plot (see query2plot). Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
S/C Data	query2plot	Retrieves channelized data from the project database (maintained as part of Mission Data Management services), passes it through DMD, converts the output binary data to Encapsulated Comma Separated Values (ECSV) format, generates statistics and channel-tabular listings, and generates plots with oplot. See entry for DMD in this category. Includes: -- killquery2plot: used to kill any running query2plot processes; -- vgr_query2plot: Voyager-specific Perl script for query2plot; Requires mission-specific adaptation.	Exe; Adpt	TlcmS	MCA 223.4 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Note: ECSV is a text format used for data exchange among Telecom Services tools. Platforms: AMMOS standard workstation;				
S/C Data	queryshell	One of three query2plot graphical user interface shells. Processes TOT query inputs and parameter value language files. See entry for query2plot in this category. See entry for TOT in Telem Transport category. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
		2.9 S/C Model				
S/C Model	DARTS/DSHELL	A S/C simulation environment for closed-loop, destop/non-real-time as well as real-time, hardware-in-the-loop simulations. DSHELL simulations can be used for algorithm development, testing and verification of flight software and hardware, and for sequence verification during mission operations. Requires mission-specific adaptation. Currently used by Cassini, ST-6, Starlight, MTP and others. DARTS/DSHELL is delivered and supported informally. Configuration management consists of periodic "snapshots". There is a modest amount of on-line documentation. MS&A considers this to be more appropriate to its nature as a continuously evolving, R&D-type effort than are the standard DSMS approaches.	Exe; Adpt	MS&A	n/a	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Platforms: AMMOS standard workstation;				
S/C Model	TFP/UTP	Telecom Forecaster-Predictor / Unified Telecom Predictor-- Model performance of the S/C-to-ground station telecommunications links based on specified conditions, equipment, and configuration. TFP is an application with a graphical user I/F and is intended for interactive analysis. UTP utilizes the same engine and models but has a control interface designed for batch execution. Both versions incorporate models of DSN performance that are based on 810-5, DSMS Telecommunication Link Design Handbook. Requires mission-specific adaptation. Platforms: AMMOS standard workstation;	Exe; Adpt;	MS&A	504.101	IMP
S/C Model	TFP Generic Model	Telecom Forecaster/Predictor Generic Model Tool-- Provides a simple S/C model for use with the TFP (see entry for TFP/UTP). This model can be specified with few parameters, and can be used in early mission design before detailed S/C model data is available. The fidelity of the common ground models is the same as those used in TFP/UTP. Platforms: AMMOS standard workstation;	Exe	MS&A	504.102	IMP
		2.10 Schedule				
Schedule	CAST	Common Allocation Scheduling Tools-- Generates products that assist schedule	Exe	MS&A	502.103	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		engineers in the process of negotiating DSN ground station coverage. Platforms: AMMOS standard workstation;				
Schedule	dsnsedt	Part of the Sequence of Events Generation Subsystem. Displays, edits, and prints a timeline image of the DSN allocation and viewperiod files. Requires minimal mission-specific adaptation. Superceded by CASTEDT (which is part of CAST, see entry in this category).	Exe; Adpt	MS&A	CAST 502.103 P	Dcm
Schedule	RSFOS	Re-Engineered Space Flight Operations Schedules Software-- Translates output files from other schedule and sequence tools into human-readable spacecraft operations schedules. No adaptation required, Platforms: AMMOS standard workstation;	Exe	MS&A	502.204	IMP
Schedule	sfosedt	Displays, edits, and prints the Space Flight Operations Schedule timeline. Cassini only.	Exe	MS&A	502.204 P	Dcm
Schedule	Viewperiod Generator Client	Generate and peruse viewperiods based on user-provided ephemeris. Note: This capability will be offered both as a service (accessible via a standard web browser) and via a web services application program I/F intended for integration into end-user applications. The latter is the "tool" form. Platforms: <<TBD>>	Lib	M&CS	311.201 P	Com
Schedule	xopps	General project planning and scheduling	Exe	TlcmS	MCA 223.4 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		tool that uses Motif graphical user interface. Platforms: AMMOS standard workstation;				
		2.11 Sequence				
Sequence	ASP	Automatic Sequence Processor-- A set of scripts which can be configured to automatically initiate activity integration, sequence generation and validation, and command product generation, significantly reducing execution time, manual effort, and human error. Requires mission-specific adaptation. Currently adapted for: -- MGS; Stardust; Odyssey; Genesis; SIRTF; Deep Impact; Configuration management and delivery for ASP are done using an alternative scheme that MS&A considers to be more appropriate to its relationship with operational procedures than are the standard DSMS approaches. Platforms: AMMOS standard workstation;	Exe; Adpt	MS&A	n/a	IMP
Sequence	FDSASM	Voyager Flight Data System (FDS) Assembler Tool	Exe	MS&A	502.504	Dcm
Sequence	On-board VM	Virtual Machine Language (VML) Flight Component - flight software sequence engine intended for use on-board a spacecraft. Capable of initiating activities conditionally or invoking functions in addition to initiating activities at specified	Exe; Lib;	MS&A	502.701	Com

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		absolute or relative times. Based on same sequence engine as Off-Line Virtual Machine (OVLM) simulator. Currently used (or planned for use) by SIRTF; Odyssey; MRO; Genesis; Stardust. Requires mission-specific adaptation to define commands. Platform: Flight computer integrated into S/C; Contact MS&A for specifics.				
Sequence	SEG	Sequence of Events Generation. Cassini only.	Exe	MS&A	502.201	Dcm
Sequence	SEQ_ADAPT	Sequence Adapter-- Assists a user in adapting project-specific information into a form that can be read by SEQ_GEN in order to perform sequence integration, generation, and validation. Normally used internally by MS&A. However, it is also delivered and used as a tool by flight projects which are adapting Seq_Gen themselves (e.g. Cassini, Odyssey, Stardust, Genesis, SIRTF). Can also be used to make a preliminary adaptation for use in ATLO. No adaptation required. Platforms: AMMOS standard workstation;	Exe	MS&A	502.501	IMP
Sequence	SEQ_GEN	Sequence Generator-- Enables a user to create, merge, edit, print, expand, and check sequence activity requests. Expands sequence requests into one or more lower-level sequence activities, commands, or notes. Can validate that sequence activity	Exe; Lib; Adpt	MS&A	502.203	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		request parameter values are of a specified type, within a specified range, and satisfy constraints governing relationships among parameters. Can verify that a sequence is consistent with flight rules, mission rules, and availability of S/C and ground resources. Requires mission-specific adaptation. -- MGS; Stardust; Odyssey; Genesis; SIRTF; MER; Deep Impact; Platforms: AMMOS standard workstation;				
Sequence	SEQ_REVIEW	Sequence Review Tool-- Facilitates user review of various files associated with S/C sequences. Enables user to modify the appearance of the file (e.g. suppress unwanted information, reformat columns, compute derived quantities). Includes library of pre-generated file descriptors. Typically adapted for a particular flight project, but core multi-mission capability can be used directly. -- MGS; Stardust; Odyssey; Genesis; SIRTF; MER; Deep Impact; Platforms: AMMOS standard workstation;	Exe; DS	MS&A	502.506	IMP
Sequence	SEQTRAN	Sequence Translation/Macro Assembler Tool-- MGS and Cassini only.	Exe	MS&A	502.301	Dcm
Sequence	SLINC	Spacecraft Language Interpreter and Collector (aka STS)-- Translates from the S/C Sequence File format output by SEQ_GEN into Command Packet File	Exe; Adpt	MS&A	502.302	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		(CPF) format suitable for radiation to a S/C. Also translates from a binary UNIX file format into CPF. Requires mission-specific adaptation in the form of configuration files. -- Stardust; Odyssey; Genesis; SIRTF; Deep Impact; Platforms: AMMOS standard workstation;				
Sequence	VMLCOMP	Virtual Machine Language Compiler-- Works in conjunction with SLINC to compile a converted S/C Sequence File into a Virtual Machine Language binary file. No adaptation required. Platforms: AMMOS standard workstation;	Exe	MS&A	502.303	IMP
		2.12 Simulation				
Simulation	HSS-CAS	High Speed Spacecraft Simulation-- Cassini version. Bit-level emulator for simulating flight software and sequence execution. Cassini only. Platforms: Special - Direct inquiries to MS&A;	Adpt	MS&A	502.401	IMP
Simulation	OLVM	Offline Virtual Machine language Engine-- A ground system-deployed instance of the flight sequence machine (see entry for On-board VM in Sequence category). Can be used to simulate the actions of the on-board-deployed machines at speeds up to 100 times real-time.	Exe	MS&A	502.601	Com

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Requires mission-specific adaptation. Platforms: AMMOS standard workstation;				
		2.13 Telem Transport				
Telem Transport	allbc2	Monitors telemetry broadcast channels produced by Telemetry Services and displays information about the last received records on each channel. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Telem Transport	bcui	Graphical user interface for bcwatch, which reports data outages in broadcast circuits. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Telem Transport	bcwatch	Monitors broadcast circuits used in providing Telemetry Services for outages in data channels. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Telem Transport	browser	Command-line application that selects and displays telemetry Standard Formatted Data Units (SFDUs). Includes the Template Editor (TED), a graphical user interface for editing browser dump templates Platforms: AMMOS standard workstation;	Exe	TlcmS	WSE 221.5 P	IMP
Telem Transport	CDA	Common Data Access Subsystem--Provides application programming interface for local and networked Standard Formatted Data Unit (SFDU) file I/O. Supports both spooler and standard UNIX bytestream file types. Although not directly accessed by end-users, CDA is	Exe; Lib	TlcmS	CDA 221.1	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		required by other selected tools in this list. It must be installed as part of the end-user's workstation environment. It is therefore listed here for completeness. Note: Spooler and bytestream refer to file formats used for telemetry data as an output of Telemetry Services and by tools provided by Telecom Services. Platforms: AMMOS standard workstation;				
Telem Transport	chdocp	"All-purpose" utility for capturing data from one of the telemetry data sources and outputting it in any of the formats used by Telecom Services tools. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Telem Transport	sfducheck	Validates the structure of all Standard Formatted Data Units (SFDUs) found in a wrapping spooler, bytestream file, or broadcast channel. Note: Spooler and bytestream refer to file formats used for telemetry data as an output of Telemetry Services and by tools provided by Telecom Services. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Telem Transport	sfducount	Counts SFDU records found in a wrapping spooler, bytestream file, or broadcast channel. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Telem Transport	splcatalog	Displays a summary of the data in one or more specified telemetry SFDU files. Platforms: AMMOS standard workstation;	Exe	TlcmS	CDA 221.1 P	IMP
Telem	Spooler Toolkit	A collection of utilities for manipulating,	Exe	TlcmS	CDA 221.1 P;	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
Transport		converting, and viewing "spooler files", an older binary file format used for Standard Formatted Data Units (SFDUs), which has now been largely supplanted by "bytestream" SFDU files. Includes: -- bctospl: Captures data from a real-time Data Transport Subsystem (DTS) broadcast circuit and stores it in a wrapping spooler. -- byttospl: Copies a bytestream file with SFDUs to a wrapping spooler file. -- splcopy: Copies data between SFDU files or spoolers. -- splcreat: Creates a wrapping spooler file. -- spltobyt: Copies an wrapping spooler file containing SFDUs to a bytestream file. -- xbctospl: Captures data from a broadcast channel into a wrapping spooler file. Similar to bctospl, but with expanded options. Platforms: AMMOS standard workstation;			OAS 223.5 P	
Telem Transport	tds_viewer	Stand-alone viewer for Telemetry Delivery Subsystem (TDS) catalog server for catalog information sent through Data Transport Subsystem virtual circuits. TDS is a specialized database management system for telemetry data used in performing Mission Data Management services. Also, see entry for DTS in this	Exe	TlcmS	TDS 223.3 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		category. Platforms: AMMOS standard workstation;				
Telem Transport	TOT	Mission-specific Telemetry Output Tools-- Graphical user interface for querying the telemetry database for telemetry minor frames and packets derived from spacecraft telemetry, DSN monitor data, or TIS QQC data. Requires mission-specific adaptation. -- ctot: Cassini Telemetry Output Tool. -- dtot: ??? Telemetry Output Tool. -- gtot: Galileo Telemetry Output Tool. -- ltot: ??? Telemetry Output Tool. -- mtot: ??? Telemetry Output Tool. -- M01tot Mars'01 Telemetry Output Tool. -- mipstot MIPS Telemetry Output Tool. -- stftot SIRTF Telemetry Output Tool. -- stot ??? Telemetry Output Tool. -- utot: Ulysses Telemetry Output Tool. (not to be confused with uTot, the old alias for micro-Tot (aka mTot). -- vtot: Voyager Telemetry Output Tool. Also includes: -- mtot: MicroTelemetry Output Tool (formerly uTot). Sends a query to the Telemetry Delivery Subsystem (TDS) query server, retrieves the data stream and sends it through a virtual circuit. Platforms: AMMOS standard workstation;	Exe; Adpt	TlcmS	TDS 223.3 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
Telem Transport	uTotFile	Sends a query to the Telemetry Delivery Subsystem (TDS) query server, retrieves the data stream and writes it to a bytestream file. TDS is a specialized database management system for telemetry data used in performing Mission Data Management services. Platforms: AMMOS standard workstation;	Exe	TlcmS	TDS 223.3 P	IMP
Telem Transport	Workstation Decommutation	Toolkit for decommutating and channelizing raw telemetry minor frames and packets (in lieu of Telemetry Channel Service, i.e. processing by the Telemetry Input Subsystem /TIS). Includes -- mc: Compiles or translates a decom map written in Data Monitor & Display Language (DMDL); -- mapex: Performs the decommutation and channelization; -- mg: Translates an ASCII table into a DMDL decom map. -- mi: Installs a binary decom map into a database. Requires mission-specific adaptation. -- Cassini; Deep Impact; DS1; Galileo; Genesis; Mars01; Mars98; MER; MGS; Multi-Mission Test; MUDSO; Stardust; SEA; SLE; SIRTF; Ulysses; Voyager; Platforms: AMMOS standard workstation;	Exe; Adpt	TlcmS	TIS	IMP
Telem Transport	xvgrgap_log	Displays and logs data outages on a graphical interface for Voyager project data.	Exe	TlcmS	MCA 223.4 P	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Platforms: AMMOS standard workstation;				
		2.14 Test				
Test	Test Execution Control Tool (TECT)	Graphical user interface that allows tester to regulate the execution of a script file in a testbed environment. Currently used by Seawinds and SIRTF. Platforms: AMMOS standard workstation;	Exe	TlcmS	<tbd>	Com
Test	TTACS	Test Telemetry and Command Subsystem-- Allows data to flow to and from spacecraft test hardware without requiring the normal operational interfaces. Typically adapted for a specific mission, but core, multi-mission capability can be used directly. Platforms: AMMOS standard workstation;	Exe; H/W	TlcmS	various	IMP
		2.15 Time				
Time	fixtime	Converts a simple time to a standard time format used by DSMS tools and services. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Time	hexstrtotime	Converts a hexadecimal time string to a standard time format used by DSMS tools and services. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
Time	mclk	Creates a display of mission clocks based on parameters in a selected file. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Time	SCEGEN	Spacecraft Event Time Generation Program-- Application which is used to determine correlation co-efficients for	Exe	MS&A	504.201	IMP

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		converting between S/C clock counts and S/C event time. Platforms: <<TBD>>				
Time	timecalc	Graphical tool that performs general time calculations using a variety of formats and converts S/C Event Time (SCET) to S/C Clock counts (SCLK) and vice versa. Platforms: AMMOS standard workstation;	Exe	TlcmS	MCA 223.4 P	IMP
Time	timetohexstr	Converts a standard time format used by DSMS tools and services to a 12-digit hexadecimal time string. Platforms: AMMOS standard workstation;	Exe	TlcmS	OAS 223.5 P	IMP
		2.16 Int Data Sys				
Int Data Sys	Core GDS	Core Ground Data System-- An integrated, turnkey system for customers to build on in creating a mission specific ground data system. Includes computer platforms and an integrated suite of the other tools listed.	Exe; Lib; DS; Adpt; H/W	DSMS	n/a	IMP
		3 References				
		-- AMMOS User Guides, various numbers, versions, and dates; as found on-line at URL "http://div390-www.jpl.nasa.gov/usrguide/";				
		-- DSMS Subsystem, Configuration Item and Responsibility Definitions, 820-061, dated 9 Aug'02;				
		-- Deep Space Mission System				

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Requirements & Design, 820-001, Rev. A, dated 9 May'02.				
		-- Encapsulated Comma Separated Values (ECSV) File Format for Telemetry Services, 820-13 0160-Telecomm, M. Levesque, dated 30 Sep 2000.				
		4 Notes				
		4.1 Category Tools are categorized according to the principle class of information upon which they operate. Tools that convert from one form of information to another are categorized according to the source information. The categories are presented in the same order in the table as in the body of the Catalog.				
		4.2 Tool Types DSMS end-user tools are classified into the following types. A given tool (or tool kit) may contain components of several types:				
		-- Executables (Exe) Software programs or scripts that can be run independently;				
		-- Libraries (Lib) Software subroutines or other code fragments that must be embedded in a custom program or script in order to function effectively;				

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		-- Data Sets (DS) Reference data in software form, typically tables. Data set "tools" are distinguished from operational data in that they change infrequently and are delivered via the DSMS delivery process and managed under DSMS development configuration management rather than a project's operational configuration management.				
		-- Adaptations (Adpt) Software that extends or customizes a multi-mission deliverable for a particular project or experiment. Typically an adaptation comprises a model of some facet of S/C behavior. Adaptations are usually tables or scripts in a specialized "little language", but may also take other forms such as libraries, scripts, or executables. There is some overlap between the adaptation and data set categories. Components falling in that overlap are classified as "Adaptations".				
		-- Procedures (Proc) Documented, human-executed procedures intended for operational use. *Procedures will be addressed in a future revision of this table*.				
		-- Hardware (H/W) Computer or communications hardware. While in principle the general workstations and communications gear that DSMS provides				

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		to flight projects could be classified here, there appears to be no practical advantage in doing so. This type is intended to apply to more specialized equipment or specific configurations.				
		4.3 Sources Unless otherwise noted, sources are service/system areas within DSMS. The following service/system areas do not provide any end-user tools: Antenna, Microwave, and CoF (947); Network Infrastructure Services (949);				
		4.4 ID ID is the tool's subsystem, major assembly, or assembly number as assigned by DSMS Subsystem, Configuration Item and Responsibility Definitions, 820-061. A suffix of "P" indicates that the listed tool is only part of the configuration item identified.				
		4.5 Commitment Status				
		Com (Committed); IMP (Implemented or Implemented w/ Idiosyncrasies); Dcm (Decommitted); With the exception of the				

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		first two, these are the same as the commitment status values defined in Deep Space Mission System Requirements & Design, 820-001. Additional categories of ??? (Unconfirmed); Obs (Obsolete); Fut (Future, Unfunded); were used in preparation but do not appear in the final table.				
		Future, Unfunded: This means that the requirement is planned to be met upon implementation and transfer to operation, but that there is no committed date for implementation. If a date appears in "Commitment Date", it is a goal for implementation.. Committed, Qualifications: This means the plan is to implement the requirement with 'minor changes'; where the mapping is not exact. See requirement Object Text for details or references. For example, implementation of turbo codes to a specific CCSDS standard. Committed: This means that the requirement will be met upon implementation and transfer to operation. Each such requirement should have a commitment date documented in another attribute called "Commitment Date."				

Category	Common Name	820-100 DSMS Services Catalog Appendix - DSMS End-User Tools	Type	Source	ID	Status
		Implemented, Idiosyncrasies: This means the capability has been implemented, but the requirement is not met completely or in all instances. See requirement Object Text for details or references. Implemented: This means that the requirement has been met and that there is a commitment to continue to meet the requirement. Decommitted: This means that the requirement is no longer offered for new missions. However, it may be retained for some legacy missions -- see requirement Object Text for details. If a date appears in "Commitment Date", it is the date at which the capability will be terminated for all customers.				