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Abstract
The JPL RAPSO is chartered to divide the limited amount of tracking hours amongst the various missions in as equitable allotment as can be achieved. This paper introduces the concept of the long-range forecasting function, which is performed by the group. This is then used to identify periods of peak oversubscription of resources years before they actually happen, so that proper corrective actions (construction of additional antennas, reduction in support commitment to the impacted projects) can be implemented.

INTRODUCTION TO LONG-RANGE FORECASTING

The Jet Propulsion Laboratory (JPL) Resource Allocation Planning and Scheduling Office (RAPSO) Long-Range Forecasting Process was established to plan and forecast the long-term use of the Deep Space Network's (DSN) antenna resources. The RAPSO Long-Range Process enables the flight projects and other users to coordinate and negotiate their support requirements prior to final submittal to DSN Operations. The process allocates existing and planned network resources in response to a consensus among the users. The goal is to develop a ten-year utilization and capacity projection plan to maximize the return of scientific data.

This Long-Range Resource Allocation Forecasting is based on a mission set composed of approved projects and advanced planning projects. The Resource Analysis Team compiles the User/Mission Planning Set, using National Aeronautics and Space Administration (NASA) guidelines. It also includes the antenna assets, their basic capabilities, and new implementation dates, along with Resource Allocation Review Board (RARB) meeting inputs.

BACKGROUND

Prior to the mid-1980's, simultaneous missions were few in number. Scheduling of all antenna resources was usually conflict-free. The antenna resources could easily meet the demand. During the mid-1980's, the increase in scope and complexity of JPL mission support requirements coupled with improvements and changes in JPL support resources, exceeded the capabilities of the Resource Allocation process. For conflict resolution, JPL create and a process of resource allocation that was controlled by mission requirements and resulted in face-to-face negotiations between the missions to solve scheduling problems.

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In the mid-1990's, the number of missions increased without a corresponding increase in DSN antenna capability. Conversely, older missions extended their operation long beyond the planned end of their prime mission life cycle: Voyager 2 (August 1977); Voyager 1 (September 1977); Galileo (October 1989); Ulysses (October 1990); and Mars Global Surveyor (November 1996).

PURPOSE OF RAPSO LONG-RANGE FORECASTING

RAPSO Long-Range Forecast predicts the allocation of existing and planned DSN network resources. Where high contentions exist, conflicts are identified so the users, the DSN, and the Resource Allocation Review Board (RARB) can take appropriate action.

Mission designers and new projects planning to use network resources, review the semi-annual and special studies to assess resource availability. A user's careful review of the RAPSO Long-Range Forecasting is advantageous before submitting a Project Service Level Agreement (PSLA) and/or modifying their support requirements. The RAPSO Long-Range Forecasts and special studies data which are provided to the Projects and users assist in developing long-range strategies for such endeavors as:

- Early resolution of conflicts for resources
- Network design, implementation, and upgrades
- Mission proposals and design
- Spacecraft design
- Mission event timing and priorities
- Providing a window of opportunity for scheduling major antenna downtime maintenance, modifications, or upgrades

SCOPE OF THE RAPSO LONG-RANGE FORECASTING

The *Long-Range Resource Allocation Plan* forecasts the antenna loading and contention time for a period of ten years (2003-2012). A key aspect of this plan is to identify conflicts in the near-term years (2003-2005), when user requirements are generally better known, and to settle conflicts and optimize use of existing resources through negotiation. *Capacity Projection* (2003-2012) predicts the ability of the DSN to support the projected mission set, and is generated using the baseline missions (ongoing/ planned projects), plus a select group of advanced planning projects (missions) still in the planning stages. These advanced planning requirements are consulted, keeping light of the fact that the Resource Allocation Review Board has not yet considered the contention periods, new user requirements, and availability of ground resources, which may change.

A major goal of the RAPSO Long-Range process is to identify possible problems well in advance and to enable early resolution with the least amount of impact on all concerned, through modification of user requirements and/or antenna resources.

GUIDELINES USED FOR RASPSO LONG-RANGE FORECASTING PROCESS

User/Mission Planning Set

The User/Mission Planning Set is compiled by the Resource Analysis Team and approved by NASA and NASA/JPL's InterPlanetary Network and Information Systems Directorate (IPN-ISD), Deep Space Mission Systems (DSMS) guidelines and various projects/users planning inputs, plus RABB agreements/ recommendations. This mission set is composed of ongoing/planned projects plus advanced planning projects. Only those projects and users included in the User/Mission Planning Set are considered.

Ongoing/Planned Projects

Ongoing missions are those that have launched and are in their prime or extended phases of planning. *Planned missions* are those that are approved missions yet to be launched. Projects/users that use DSN assets as an observational instrument, i.e., Goldstone Solar System Radar (GSSR) and Ground Based Radio Astronomy (GBRA) are included in this latter category, due to the continuing nature of their scientific observational objectives.

Advanced Planning Projects

The advanced planning portion of the DSN User/Mission Planning Set is composed of projects in the proposal or preliminary planning stages. These mission sets are used in creating projected unsupportable time, resource loading, user supportability, and resource capacity projection summaries to determine the ability of the DSN to support the proposed mission. A set is selected, which includes highly probable advanced missions whose characteristics are typical of the expected profile in the out-years, and represent major program thrusts.

Antenna Planned Capabilities

The InterPlanetary Network and Information Systems Directorate (IPN-ISD), Deep Space Mission Systems (DSMS) of the Jet Propulsion Laboratory (JPL) list the latest recommended set of planned capabilities for the DSN stations. The planned set of capabilities is continuously under review for engineering and budgetary considerations.

Additional guidelines

All RARB decisions are factored in the RAPSO Long-Range Forecasting; the first day of the launch window is used as the nominal launch date; and each antenna aperture is capable of providing 168 hours of support per week.

Explanation of Terms Used in RAPSO Long-Range Forecasting

"Resource Loading" - Projected unsupportable time is expressed as low, moderate, severe, or extreme in later sections of this document. Projected unsupportable time is an estimate of the amount of requested time, typically in percentage of requirements or modified requirements, that is unsupportable, based on resource availability, other users' requirements, assumed priorities, and viewperiods. The following percentages apply: Low = <15%; Moderate = 15 to 30%; Severe = 30 to 45%; Extreme = >45%

"Workable" is a term used to express a condition wherein the projected unsupportable time is low. This condition occurs when the general forecasting analysis indicates a low percentage of unsupportable time or when RARB agreements have been made to reduce contention to a workable level. Workable essentially means that experience has shown that the remaining contention may be solved during final schedule preparations and negotiations.

"Capacity Projection" - Capacity is expressed in terms of the total number of schedulable hours available on a network resource. This metric is expressed in terms of the total number of wall clock hours available for a particular site, complex, or subnet for a defined period, minus the total number of hours of planned support for that same period. Routine maintenance activity is included within the calculation of planned hours of support. Utilization is defined as the portion of the total number of available hours for a DSN resource (either a subnet or an individual antenna) that is represented by the number of planned hours (requested minus lost).

METHODOLOGY

The Resource Analysis Team

The Resource Analysis Team consists of expert planners and analysts and is the center of the RAPSO Long-Range Forecasting process. The team operates and maintains the tools necessary for the RAPSO long-range process, and facilitates the negotiation of scores of contention off-line processes. The team members filter requests (interpreting a project's request to be consistent with the scheduling requirements or scaling it back, or changing a request that seems inappropriate). This filtering of requests is based on the experience and knowledge of the team. The team generates the semi-annual JPL DSN RAPSO Long-Range Resource Allocation and Capacity Project Plan, the PSLA reviews, Special Studies, and Resource Allocation Review Board (RARB) semi-annual meetings.

Contention for January 2004

During the month of January 2004, the 70-meter contention for antenna utilization exceeded 25% over the supportable baseline, due mainly to Mars Exploration Rover-A and B performing Mars surface operations.

SOFTWARE TOOLS

Software Improvements - The Resource Analysis Team is transitioning from FASTER to MADB/TIGRAS:

FASTER - Forecasting and Scheduling Tool for Earth-Based Resources is a rule-based tool scheduled on a weekly basis.

MADB - The Mission and Assets Database is a repository of mission and assets information required for the effective allocation of DSN resources.

TIGRAS – TMOD Integrated Ground Resource Allocation Scheduling. Software improvements would include: mediation results into rules; rules into software algorithm; less conflicts for users; more reliability in the final schedule; use output for 34-meter and 70-meter schedule; and replace DSN procedures for building 26-meter schedule.

COMPLEXITY OF LONG-RANGE FORECASTING

JPL manages the worldwide Deep Space Network (DSN), which communicates with spacecraft and conducts scientific investigations from its complexes in Goldstone (in California's Mojave Desert near Barstow); near Madrid, Spain; and near Canberra, Australia. These sites were chosen so that as the Earth orbits the sun, a spacecraft is always in view of at least one of the stations. This is useful in providing continuous coverage for distant spacecraft near the ecliptic plane, where the planets are located. The DSN antennas are linked to a Signal Processing Center computer network at each complex. High-speed and wide-band circuits link the three Signal Processing Centers to the Control Center data systems at JPL.

DSN Antennas

Each DSN Complex consist of at least four deep space stations equipped with ultra sensitive receiving systems and large parabolic dish antennas. These are:

One 34-meter (111-foot) diameter High Efficiency antenna
One 34-meter Beam Waveguide antenna (Three at the Goldstone CA Complex)
One 26-meter (85-foot) antenna
One 70-meter (230-foot) antenna

Overlapping Viewperiods

The majority of DSN-supported missions are traveling in the same general direction away from Earth, causing viewperiods to overlap considerably. Various JPL spacecraft have visited all the planets in our solar system except Pluto. Because of the interest in Mars, many Mars missions are concentrated in one area of the sky with overlapping viewperiods. Another example of overlapping viewperiods are four spacecraft (ACE, Genesis, SOHO, WIND) studying the Sun from nearly the same location, Earth's L1 Libration point.

Trends for the DSN

In the early 1990s NASA recognized the need to revitalize the aging 70-meter antennas, and authorized a twelve 34-meter Project to replace the 34-meter standard antennas, creating more effective backup for the 70-meter antennas. During 1994-1997 the DSN budget was cut from $240 million to $177 million and the 34-meter project was stopped after only five new 34-meter Beam Waveguide antennas were built. In the late 1990s, the number of missions began to increase without a corresponding increase in DSN antenna capability. Because of the present interest in Mars and the many missions being concentrated in that one area of the sky with overlapping viewperiods, an extreme overload is predicted during the month of January 2004, for surface operations support for Mars Exploration Rover-A and Mars Exploration Rover-B, and other scheduled Mars missions.

Discovery Program

The "Faster, Better, Cheaper" concept allowed a large number of smaller missions to be launched or are currently in planning stages. The advent of the Discovery Program has increased the complexity of the RAPSO Process due to the expected short turn-around time. Three missions were successfully launched and attained their major scientific objectives: NEAR (February 1996); Pathfinder (December 1996); Lunar Prospector (January 1998). Five missions still operating, which have either not attained their major scientific objectives or are approved missions yet to be launched include: Stardust (February 1999); Genesis (August 2001); CONTOUR (July 2002); Deep Impact (January 2004); and Messenger (March 2004).

DSN Oversubscription

The DSN is currently supporting 31 projects/users with 8 spacecraft scheduled for launch before July, 2003: Comet Nucleus Tour (July 2002); International Gamma Ray Astrophysics Lab (October 2002); Muses-C (December 2002); Space Infrared Telescope Facility (January 2003); Rosetta (January 2003); Mars Express Orbiter (May 2003); and Mars Exploration Rover-A (May 2003).

Downtime

The DSN is planning major upgrades at each DSN antenna in the next four years requiring downtime on each antenna to range from four to twelve weeks.

RESULTS OF RAPSO LONG-RANGE FORCASTING

The products of the resource allocation process are designed to accommodate the needs of projects throughout their life cycles. The RAPSO process provides information for mission requirements definition, support feasibility, resource allocation, and operations scheduling.

Special Studies

Mission planners may request special studies at any time in order to assess the feasibility of different planning options (such as moving a launch period) or to understand the impact of adding a new mission to the currently understood mission set. Any foreseeable contention is identified in a special study report, along with appropriate statistical analysis and recommendations for alleviating the conflict. The resource allocation process seeks information to produce special studies and identify potential problems as early as possible to form the baseline mission set for the long-range forecast.

DSN to add 34-meter Beam Waveguide Antenna in Madrid, Spain

During 2000 and 2001, the Resource Analysis Team performed several special studies to determine the optimum for new capabilities to the DSN to alleviate the "crunch period" beginning in November 2003. In late 2003 and early 2004, the United States, Europe, and Japan will each have missions arriving at Mars, two other spacecraft will be encountering comets, and a third comet mission will launch. Other missions will have continuing communication needs as well. The Resource Analysis Team concluded that the DSN should be augmented with a new 34-meter antenna (DSS-55) in Spain. NASA approved the recommendation and the new 34-meter antenna at the Madrid complex is due for completion by November 2003. Projections for demands on the Network during the November 2003-February 2004 period indicate the greatest need for increased communications capacity will be at Madrid, as NASA plans to land two rovers on Mars in early 2004. Building a new 34-meter antenna in Madrid would add about 70 hours of spacecraft-tracking time per week during the periods when Mars is in view of Madrid. The Madrid complex's current capacity is 210 hours within Mars viewperiod per week.

20kW X-Band Uplink Capabilities

The Resource Analysis Team also conducted a special study and recommended installing 20kW X-Band Uplink Capabilities at the remaining 34-meter Beam Waveguide antennas (DSS-24, DSS-34, and DSS-54). This upgrade is to be completed by September 01, 2003.

Ground Data System Commitment

The Resource Allocation long-range forecasts play a role in the ground data system commitment process. A project develops its PSLA, to which NASA responds with a NASA Support Plan after the Resource Analysis Team has conducted a special study. The NASA Support Plan is a commitment that the required instrumentation (for example, size, type and frequency of antenna) will be available, as negotiated within the resource allocation process.

THE JPL DSN RAPSO LONG-RANGE ALLOCATION PLAN PLANNING PROCESS

Process Overview

The antenna resource allocation planning process is interactive in nature and begins with user input of generic requirements and major events. Projects submit resource requirements to RAPSO in varying levels of detail up to ten years in advance. From these inputs, a Long Range Resource Allocation Plan is published for user's review. Based on the amount of contention, users may decide to adjust their requirements and timing of events and re-submit their input. The plan is updated with all changes and re-generated.

While the process begins as a forecast, it evolves into an allocation plan that when refined, becomes the basis for operational schedules. Various analyses support the process across a ten-year time frame.

The process must simultaneously address and support all approved projects and the requirements of other users in various phases, including those generating proposals and those generating sequences of mission events.

The process affirms and incorporates the rights and responsibilities of the resource users in establishing priorities, interacting with other users, participating in conflict resolution, and in continually reviewing project requirements. The process is based on user consensus. However, if no resolution of a conflict can be reached in the negotiating process, the contention is appealed to higher management.

The process plans and special studies optimize the use of available DSN resources and strategically plan facility downtime periods. As a minimum, survival support must be guaranteed to spacecraft whose missions have been granted extension beyond their primary objectives.

The key to the success of the process is that the design directly addresses mission events, allows high visibility of problem areas and is highly responsive to changing requirements and constraints. The products of the Resource Allocation Process provide a high-quality, common tool necessary for management of mission design and flight operations.

THE LONG-RANGE RESOURCE ALLOCATION PLAN

The RAPSO Long-Range Allocation Plan provides a vehicle to optimize the use of available resources and to strategically schedule facility downtime periods. As a minimum, survival support must be guaranteed to spacecraft whose missions have been granted extensions beyond their primary objectives. The Plan forecasts antenna loading and contention for a period of ten years. A key aspect of this plan is the identification of conflicts in the three near-term years, when user requirements are generally well known and the only solution is to optimize use of existing resources through negotiation.

The RAPSO Long-Range Allocation Plan process is iterative in nature and begins with user inputs of generic requirements and special events. Projects and users of the DSN submit resource requirements to NASA and JPL management in varying levels of detail up to ten years in advance. A Plan is generated from these inputs for the users' review. Based upon the amount of contention, users may decide to adjust their requirements and timing of events and re-submit their inputs. The plan is updated with all changes and re-generated. The plan provides a forecast for allocation of existing and planned network resources. Where high contention exists, the conflicts are identified so that users, the DSN, and the Resource Allocation Review Board can take appropriate action.

Executive Summary

This section contains the User/Mission Planning Set used in generating the plan. It also describes the resources, including their basic capabilities, as well as dates for implementing new capabilities. Resource charts summarize yearly projected antenna usage by antenna size for 2003 through 2012, as well as monthly charts for 2003 through 2006. Additional User charts show projected user support for years 2003 through 2012, as well as monthly projected usage for 2003 through 2012.

A major goal of the RAPSO Long-Range Allocation Plan is to identify possible problems well in advance in order to enable resolution, through either modification of user requirements or antenna resources, with the least impact to all concerned.

Key to the success of the RAPSO Long-Range Allocation Plan is that it directly addresses mission events, allows high visibility of problem areas, and is highly responsive to changing requirements and constraints. The plan provides a high-quality, common tool necessary for smooth management of mission design and flight operations.

CONCLUSION

Mission planning and management are being optimized using the unique RAPSO Long-Range process planning methodologies at the Jet Propulsion Laboratory. The DSN Process for ground data system resource allocation provides mission planners and managers with long-range visibility into resource loading. Thus, launch dates, mission designs, and spacecraft sequencing can be planned to optimize science return despite limited resources. Periods of resource contention are identified for mission managers in time for them to plan and implement alternatives rather than be forced to react hastily to unforeseen contentions. Conflict resolution is by consensus, and a simple appeal route is provided.

ACKNOWLEDGMENT

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DSN CONFIGURATION

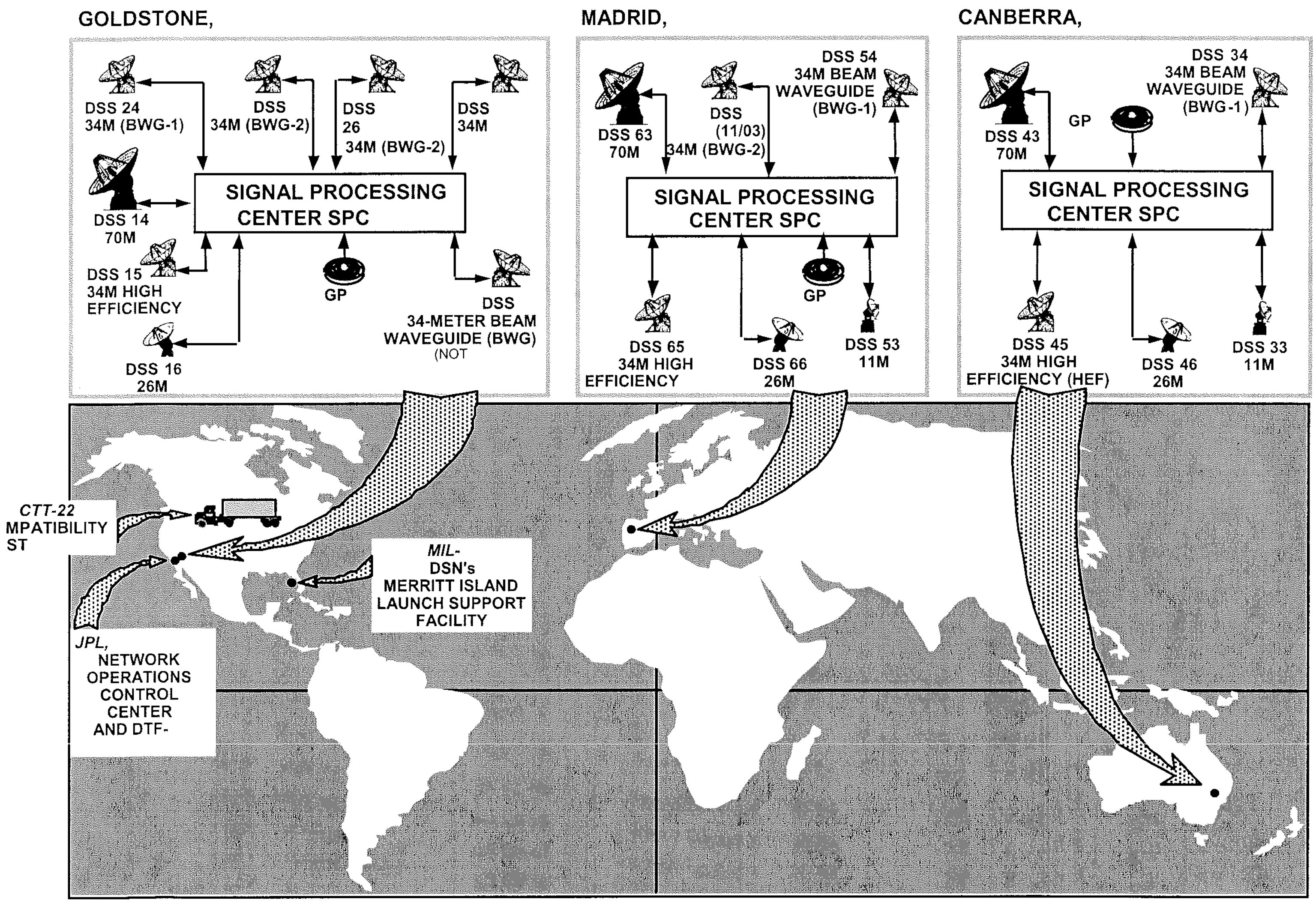

Figure 1 DSN Configuration

IPN-ISD Resource Implementation Planning Matrix

Station	Subnet	Delivery Date	S-Band Down	S-Band Up	X-Band Down	X-Band Up	*20kW X-Band*	Ka-Band Down	Ka-Band Up	*NSP*
DSS-14	70M	XXXX	XXXX	XXXX	XXXX	XXXX	*XXXX*	TBD	N/A	*09/28/02*
DSS-15	34HEF	XXXX	XXXX	N/A	XXXX	XXXX	*XXXX*	TBD	N/A	*05/02/03*
DSS-16	26M	XXXX	XXXX	XXXX	N/A	N/A	*N/A*	N/A	N/A	*N/A*
DSS-24	34B1	XXXX	XXXX	XXXX	XXXX	05/01/03	*12/13/02*	10/01/05	N/A	*12/13/02*
DSS-25	34B2	XXXX	N/A	N/A	XXXX	XXXX	*04/07/03*	XXXX	XXXX	*04/07/03*
DSS-26	34B2	04/02/03	N/A	N/A	04/02/03	04/02/03	*04/02/03*	04/02/03	N/A	*04/02/03*
DSS-27	34HSB	XXXX	XXXX	XXXX	N/A	N/A	*N/A*	N/A	N/A	*N/A*
DSS-34	34B1	XXXX	XXXX	XXXX	XXXX	XXXX	*04/07/03*	01/01/05	N/A	*04/07/03*
DSS-43	70M	XXXX	XXXX	XXXX	XXXX	XXXX	*XXXX*	TBD	N/A	*02/10/03*
DSS-45	34HEF	XXXX	XXXX	N/A	XXXX	XXXX	*XXXX*	TBD	N/A	*11/23/02*
DSS-46	26M	XXXX	XXXX	XXXX	N/A	N/A	*N/A*	N/A	N/A	*N/A*
DSS-54	34B1	XXXX	XXXX	XXXX	XXXX	XXXX	*09/01/03*	08/01/06	N/A	*11/23/02*
DSS-55	34B2	11/01/03	N/A	N/A	11/01/03	11/01/03	*11/01/03*	11/01/03	N/A	*11/01/03*
DSS-63	70M	XXXX	XXXX	XXXX	*XXXX*	XXXX	*XXXX*	TBD	N/A	*04/07/03*
DSS-65	34HEF	XXXX	XXXX	N/A	XXXX	XXXX	*XXXX*	TBD	N/A	*02/10/03*
DSS-66	26M	XXXX	XXXX	XXXX	N/A	N/A	*N/A*	N/A	N/A	*N/A*

XXXX = Capability Currently Exists

N/A = Capability Not Planned

Figure 2 DSN User / Mission Planning Set