Chapter 9

The Deep Space Network as an Organization in Change
IN THE BEGINNING (1958 TO 1963)

Background

Following the ARPA decision to launch several lunar probes by the end of 1958 using the Army JUNO-II launch vehicle, the Army turned to its long-time contractor, JPL, for the payloads and the tracking and data acquisition facilities required for its portion of the new Pioneer Program.\footnote{1}

The flight paths of the lunar probes required a tracking station at Cape Canaveral to cover the launch phase, another in the vicinity of Puerto Rico for the near-Earth phase, and a deep space station in the general vicinity of JPL to track the probe on its way to the Moon. Time was short. There were only eight months to select a site, build an antenna, and set up the requisite receivers, recorders, and communication circuits. Fortunately, the Army owned a considerable amount of property in the Mojave Desert, and it was on this property at Goldstone Dry Lake, about 100 air miles from Los Angeles, that a suitable site for building the deep space antenna was found.

Construction of the site began at Goldstone in June 1958; assembly of the antenna commenced in August; and by December, the antenna, together with electronics, receivers, and communications, was complete. \textit{Pioneer 3} was launched on 6 December 1958. This station, appropriately named Pioneer, was the first station of what was to become the Deep Space Instrumentation Facility (DSIF), and eventually the Deep Space Network (DSN) described in earlier chapters.

As these events began to unfold in 1958, the engineering organization within JPL reflected the technologies that had been appropriate to the missile guidance and telemetry support provided as a contractor to the U.S. Army. The three principal engineering departments were Aerodynamics and Propellants, Design and Power Plants, and Guidance and Electronics. The Guidance and Electronics Department, headed by Robert J. Parks, consisted of three Technical Divisions: Guidance Analysis, led by Clarence R. Gates; Guidance Development, led by Walker E. Giberson; and Guidance Research, led by Eberhardt Rechtin. Rechtin’s Guidance Research Division consisted of an Electronics Research Section under Walter K. Victor and a Guidance Techniques Research Section led by Robertson Stevens.\footnote{2} Design and implementation of the Pioneer DSIF station was carried out under the technical management of engineers from these two sections, with overall responsibility shared by Rechtin, Victor, and Stevens.
In addition to its work for the Army, JPL also supported a substantial aerodynamics research facility known as the Southern California Cooperative Wind Tunnel. This facility was funded and used, on a cooperative basis, by the many aerospace companies flourishing in the southern California region at that time. Although the Wind Tunnel was in no way associated with the DSIF, its Chief of Facilities and Mechanical Equipment would soon play a prominent role in the future history of the DSN. His name was William H. Bayley.

A mechanical engineering graduate (1952) from the University of Southern California (USC) in Los Angeles, Bill Bayley worked on facilities engineering for the Lockheed Aircraft Corporation in Burbank, California, before coming to JPL in 1956 to manage the facilities of the southern California Cooperative Wind Tunnel. At that time, and for several years afterward, this major research facility reflected JPL’s association with Caltech and aeronautical research.

After JPL’s transfer to NASA, Rechtin’s network of tracking stations, communications, and data-processing systems, as well as the staff needed to run it, expanded rapidly. He needed help. The addition of an assistant to interact with NASA on issues of staff and budget and to deal with financial and administrative matters at JPL allowed Rechtin to address the more technical issues associated with the future world network. He turned to Bill Bayley, a perfect choice as it turned out, and made him General Manager in 1960. When Rechtin left JPL in 1967, Bayley assumed Rechtin’s position as Assistant Laboratory Director for Tracking and Data Acquisition, a position he held with distinction until he retired in 1980. During his term of office, the Deep Space Network developed into a major NASA facility of 26-m, 34-m, and 64-m antennas in three countries around the globe. That achievement was due, in no small measure, to his skill in dealing with both NASA Headquarters and JPL and his ability to optimize the relationship between them in the best interests of the DSN.

A pleasant man to talk to and a gentle man to deal with, both at work and outside the work environment, Bill Bayley was popular with his colleagues at JPL and NASA Headquarters, as well as his counterparts at the government agencies in Spain, Australia, and South Africa, on whom NASA depended for support of its tracking stations in those countries. His quiet sense of humor—he was a master of the “bon mot” and “double entendre”—served to enhance his connectivity with the people he met. Bill Bayley introduced “all hands” meetings to the DSN as a way of bringing top management into direct contact with all members of the organization for a frank and open discussion of problems, policies, and procedures. Such meetings, led by Bayley himself, were always
held away from the normal workplace to create a less formal and more productive atmosphere for the free expression of ideas and opinions.

He was a devotee of healthy living and exercise, so it was ironic that Bayley’s untimely death in 1981 was due to a heart-related problem.

The Rechtin Years

In 1958, while the Pioneer antenna was being rushed to completion at Goldstone to meet the deadline for the first Pioneer Lunar Probe launch in December, momentous events were occurring elsewhere in the U.S. space effort. Later that year, Congress passed the National Aeronautics and Space Act to create the National Aeronautics and Space Administration (NASA). President Eisenhower immediately signed the new Act into law, and NASA began operating under the leadership of its first Administrator, T. Keith Glennan, on 1 October 1958. The transfer of JPL from the Army to NASA followed almost immediately. Instead of working under a U.S. Army contract, JPL now worked under a NASA contract. NASA inherited not only JPL’s experienced personnel and its facilities, including Goldstone, but also JPL’s vision of a worldwide tracking network for deep space probes. NASA’s plans for JPL were in keeping with this vision, and there was no interruption to the work in progress as a result of this essentially political change.

However, within NASA and JPL, the change raised serious questions regarding the status of JPL. NASA wanted to operate JPL like other Agency Centers, rather than, as JPL desired, an outside contractor managed by Caltech. Describing this situation, historian Clayton Koppes wrote, “Insider or outsider. Vast amounts of time and energy would be consumed in resolving the question of insider or outsider throughout the next decade.” Despite these internal disturbances, essential work moved rapidly forward.

When the new NASA Headquarters organization first came into being, responsibility for NASA-wide tracking and data acquisition services and facilities rested in Abe Silverstein’s Office of Space Flight Development. Within that office, the position of Assistant Director for Space Flight Operations was filled initially by Edmond C. Buckley.

In this capacity, Buckley interacted directly with JPL on all matters related to NASA policy, guidelines, and budget for the original construction and operation of the DSIF.

Referring to Buckley’s early association with the DSN, historian Cargill Hall said, “A graduate of Rensselaer Polytechnic Institute, personable and articulate, he brought to NASA many years of [NACA] experience in the development of the Wallops Island
Launch Range, where he had been responsible for the development of tracking and instrumentation associated with free flight research.”

Fortunately for the fledgling DSN, Ed Buckley at NASA Headquarters and Eb Rechtin at JPL enjoyed a great deal of mutual respect and worked well together to further their common goal, the establishment of a worldwide network for NASA. Observed Cargill Hall, “No major disagreements (between NASA and JPL) marred the planning and creation of the Deep Space Network.”

Responsibility for tracking and data acquisition in the NASA Office of Space Flight Development at this time is shown in Figure 9-1.

Within a very short time of its transfer to NASA, the organization of JPL was restructured to better meet its new responsibilities in the changing world. No longer was its primary business that of missiles and rockets and the tracking and data acquisition technology to support them as a contractor to the U.S. Army, but lunar and planetary
spacecraft and the technology to support them as a contractor to NASA. Seven new technical divisions and six administrative divisions were created to deal with JPL’s new responsibilities in NASA’s expanding Lunar and Planetary Program. All seven technical divisions were directly responsible to JPL Director William H. Pickering, while the administrative divisions reported to the Assistant Laboratory Director (ALD) of the Business Administration Office, Victor C. Larsen. Amongst the technical divisions, the Telecommunications Division (Division 33), with Rechtin named as Chief and Bayley as Assistant Chief, contained the essential technological expertise that was to become the foundation stone of the emerging worldwide DSIF. In addition to Chief of the Telecommunications Division, Rechtin was also designated as Program Director for the DSIF, an indication of the growing importance of the DSIF in the JPL organization, planning, and budget processes.

The Telecommunications Division, under Rechtin’s leadership, comprised four sections to provide the state-of-the-art technical and operational resources needed to transform the DSIF from a single antenna in California to a worldwide network with tracking stations on three continents. The organization of the DSIF during this period, 1961–62, is shown in Figure 9-2.

Working within this structure, Nicholas A. Renzetti led the engineering, implementation, and operations activity supported by an aggressive and very successful research and
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development program led by Victor, Stevens, and Koukol. In 1961 and 1962, the total engineering and technical staff for both functions totaled about 200 to 250 persons, with a budget of 15 to 20 million dollars. Three years later, reflecting the demands of an expanding network, the staff had increased to 300 to 400, while the budget had increased to 50 to 60 million dollars. In addition to developing the DSIF, these same technical resources were heavily engaged in supporting the first of the NASA lunar and planetary missions, the Rangers and Mariners.

Although the Mariner 2 mission to Venus was very successful and attracted a great deal of scientific attention, the first five Ranger missions were not. In the aftermath of a NASA inquiry into problems with the Ranger program, JPL restructured some parts of its organization that were associated with the lunar and planetary programs. These changes would have a far-reaching effect on the relationship between the organization of the DSIF and that of the flight projects. The JPL structure which followed is shown in Figure 9-3.

Of most significance to the future development of the DSIF was the creation of two new offices headed by assistant laboratory directors who reported directly to the JPL director. These were a Lunar and Planetary (Flight) Projects Office headed by Robert J. Parks and a DSIF Office headed by Rechtin. These two offices would provide the programmatic direction for 1) the Mariner, Surveyor, and remaining Ranger missions and 2) the DSIF, respectively. Technical and administrative support would be provided by the seven technical divisions and the six administrative divisions. Although initially the Technical Divisions were in direct line to the JPL director, an additional Office for Technical Divisions was established within the next year with Fred H. Felberg as ALD. This office coordinated and directed the activities of all seven technical divisions at the program level. With the exception of moving Victor to the Chief position, with Joseph F. Koukol as deputy, the Telecommunications Division remained intact.

JPL had arrived at an organization within which the DSIF, later to become the DSN, would coexist with the flight projects and the technical divisions for the next several decades. As we shall see, fairly major modifications were made from time to time, but with these basic offices in place, the DSN moved rapidly forward to meet the demands for tracking and data acquisition support for the expanding NASA Lunar and Planetary program.

Equally important to the evolution of the DSN in these early years were the changes taking place in the newly formed NASA organization. As William R. Corliss explained,
Rather unexpectedly in the early 1960s, the tracking and data acquisition function was assuming more and more importance in NASA's budget and, consequently, in its organizational structure. Space flight turned out to be not just all launch rockets and spacecraft, it depended very heavily upon ground facilities for testing, launching, and, of course, tracking and communication. The early literature of space flight does not foresee these developments at all. Management practicalities soon forced NASA to recog-

Figure 9-3. JPL organization, 1964.
nize the importance of tracking and data acquisition by placing this function on a par with space science, manned space flight, etc. On 1 November 1961, a new Office of Tracking and Data Acquisition (OTDA) was created at NASA Headquarters. Edmond C. Buckley, who had been in charge of Space Flight Operations, was named director of the new office. In effect, the entire tracking and data acquisition function was elevated a notch in the NASA Headquarters hierarchy.

The new Office of Tracking and Data Acquisition in NASA Headquarters at the end of 1961 is shown in Figure 9-4.

The organization remained in this form until OTDA moved up another step within the NASA hierarchy when the position of Director, previously filled by Ed Buckley, was elevated to Associate Administrator status in 1966. Buckley held that position until he retired in 1968. He was replaced by Gerald M. Truszynski.
Truszynski, a native of Jersey City, New Jersey, came to NASA Headquarters in 1960 from Edwards Air Force Base in California, where he had been chief of the instrumentation division involved in developing tracking systems for jet- and rocket-powered aircraft. A year later, he was named deputy in the Office of Tracking and Data Acquisition and eventually followed Edmond Buckley to become the second Associate Administrator of that office in 1968. In that position, he was responsible, at the NASA Headquarters level, for the planning, development, and operation of global tracking networks, including the DSN, facilities for NASA Communications (NASCOM), and data acquisition and processing for all NASA spaceflight programs. His term of office covered the Mariner and Viking Eras and paralleled the Bayley period in the Tracking and Data Acquisition Office at JPL. This was a period of enormous growth and change in the DSN. It was, perhaps, the period when the Network passed from youth to maturity. Gerry Truszynski and Bill Bayley worked well together as heads of the teams at Headquarters and JPL that brought about those changes.

In addition to his involvement with NASA’s Deep Space Network, Truszynski played a major role in the provision of tracking, data, and supporting services for the Apollo 8 and Apollo 11 lunar missions.

Although the DSIF Office at JPL was not made an official program office until 1963, interactions between it and OTDA had been conducted as if it were. This situation changed in October 1963, when Rechtin’s title was elevated from Program Director for the DSIF to Assistant Laboratory Director for Tracking and Data Acquisition (ALD/TDA) and the former DSIF Office became the official TDA Program Office, a title it retained for the next thirty years. At last, the organization at JPL paralleled that at NASA Headquarters, as far at TDA was concerned. There remained one more event to finish the story of the formation of the modern DSN. That final event occurred in December 1963 with the formal establishment of the Deep Space Network by the JPL director. The historic interoffice Memo 218 that made the announcement, dated 24 December 1963, is reproduced in Figure 9-5.

In addition to the former DSIF, the tracking stations at Goldstone, California; Woomera, Australia; Johannesburg, South Africa; and Cape Canaveral, Florida, the official DSN included the intersite communications now called the Ground Communications Facility (GCF) and the mission-independent portions of the new Space Flight Operations Facility (SFOF) at JPL.
The Deep Space Network as an Organization in Change

JET PROPULSION LABORATORY

To: Senior Staff
    Section Chiefs
    Section Managers

From: W. H. Pickering

Subject: Establishment of the Deep Space Network

Effective immediately, the Deep Space Network is established by combining the Deep Space Instrumentation Facility, Interstation Communications, and the mission-independent portion of the Space Flight Operations Facility. Development and operation of this network is the responsibility of the Assistant Laboratory Director for Tracking and Data Acquisition by extension of the role statement for this Assistant Director (Office of the Director 1020, October 2, 1963).

Funding sources are unchanged for Fiscal 1964 and for the budget submitted by JPL for Fiscal 1965. However, JPL will endeavor to have OTDA and OSSA agree on a single source of funding as quickly as possible.

The interface with mission peculiar facilities and organizations will be worked out between the Assistant Laboratory Director for Tracking and Data Acquisition and the Assistant Laboratory Director for Lunar and Planetary Projects using as a guideline the definition of "mission-independent" as:

1. Required for two or more flight projects.
2. Best handled by JPL and not outside flight project organizations (ARC Pioneer, GSFC-MSFN, LeRe Centaur, etc.).

This change is made in order to accommodate efficiently the increasing number of outside flight projects for which the Jet Propulsion Laboratory has been tasked to supply tracking and data acquisition support. The change should also assist in closer integration of the previously separate facilities.

W. H. Pickering
Director

WHP:me

Figure 9-5. The Deep Space Network established, December 1963.
The events just described were of fundamental importance to the shaping the DSN during its formative stages. These and subsequent events are summarized in the table below:

**Top-Level Management of the DSN at JPL, 1960–97**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event or Head of DSN: Title</th>
<th>Deputy/Program Manager</th>
<th>JPL Director</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>NASA established (October); JPL moves to NASA (December)</td>
<td>Pickering</td>
<td></td>
</tr>
<tr>
<td>1960–62</td>
<td>Rechtin: Chief, Div. 33 and DSIF Director (January 1961)</td>
<td>Bayley</td>
<td>Pickering</td>
</tr>
<tr>
<td>1963</td>
<td>Rechtin: ALD/DSIF (March); Victor: Chief, Div. 33, DSN established (December)</td>
<td>Bayley</td>
<td>Pickering</td>
</tr>
<tr>
<td>1964</td>
<td>Rechtin: ALD/TDAª</td>
<td>Bayley</td>
<td>Pickering</td>
</tr>
<tr>
<td>1967</td>
<td>Bayley: ALD/TDA</td>
<td>Victor</td>
<td>Pickering</td>
</tr>
<tr>
<td>1980</td>
<td>Lyman: ALD/TDA</td>
<td>Johnson*</td>
<td>Murray</td>
</tr>
<tr>
<td>1987</td>
<td>Dumas: ALD/TDA</td>
<td>Johnson</td>
<td>Allen</td>
</tr>
<tr>
<td>1992</td>
<td>Haynes: ALD/TDA</td>
<td>Westmoreland</td>
<td>Stone</td>
</tr>
<tr>
<td>1994</td>
<td>TMOD³ Established</td>
<td>Stone</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>Westmoreland: Director, TMOD (June)</td>
<td>Coffin*</td>
<td>Stone</td>
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<tr>
<td>1997</td>
<td>Squibb: Director, TMOD (June)</td>
<td>Coffin</td>
<td>Stone</td>
</tr>
</tbody>
</table>

1 Telecommunications Division.
2 Assistant Laboratory Director.
3 Tracking and Data Acquisition; changed to Telecommunications and Data Acquisition in 1982 to avoid confusion with NASA’s new Space Network using the Tracking and Data Relay Satellite System (TDRSS), planned for operation the following year.
4 The title of Deputy was superseded by Program Manager in 1980 and again in 1996.
5 Telecommunications and Mission Operations Directorate.
After the DSN was formally established at the end of 1963, the basic organizations involving the DSN at NASA Headquarters and at JPL changed very little until 1994, except for personnel and some vacillation concerning responsibility for the SFOF. Within the DSN organization, however, many changes were made in the interest of improving working relationships with OTDA and with the Flight Projects. The growth and development of the DSN organization during this thirty-year period, 1964–94, is the subject of our next discussion.
THE FORMATIVE YEARS (1964 TO 1994)

A DSN Manager for Flight Projects

Within a few short months of the formalization of the DSN, further changes were made to the organizational structure under which the DSN operated at JPL. A JPL organization chart from 1964 showing the relative positions of the TDA and flight projects offices, including their supporting technical divisions, is reproduced in Figure 9-6. All of the technical divisions were directed by a single ALD, Fred Felberg. A technical staff element was added to the TDA Office, and Richard K. Mallis took over the Communications Engineering and Operations Section formerly managed by Renzetti. Renzetti moved to a Technical Staff position in the TDA Office as the first DSN Manager for the Ranger, Mariner, and Apollo missions. He was soon joined by DSN Managers for the Lunar Orbiter, Surveyor, and Pioneer missions. In the Systems Division, Thomas S. Bilbo replaced Marshall S. Johnson as Chief of Space Flight Operations. Thus, Mallis and Bilbo were independently responsible to their division managers for the operation of the SFOF and the DSN, respectively. They received technical support from other sections within the same divisions, but in a programmatic sense, their authority derived from completely separate sources. The SFOF traced its funding and program direction, via the Lunar and Planetary Projects Office at JPL, to OSSA at NASA Headquarters, while the DSN traced its funding and program direction, via the Tracking and Data Acquisition Office at JPL, to OTDA at NASA Headquarters.

The appearance of the DSN Manager function in the TDA organization needs some explanation at this point, since it became a key factor in determining the future working relationships between the DSN and its client users, the flight projects.

As an inevitable consequence of the creation of separate offices at NASA Headquarters for flight projects and tracking and data acquisition, a separate system of accountability for the resources required by the one to support the other came into being. Based somewhat on a long-existing system used at the military test ranges for receiving and responding to range users’ requirements for instrumentation to cover their tests, the system was introduced to the DSN by a formal NASA Management Instruction (NMI 2310.1) dated March 1965. In this system, flight project requirements for DSN tracking and data acquisition services were identified in a Support Instrumentation Requirements Document (SIRD). Upon receipt of a SIRD, the DSN would respond with a NASA Support Plan that committed its resources as it deemed necessary to meet the requirements in the SIRD. The SIRD and NSP were formal documents signed by
the program managers at OSSA and OTDA, respectively, and were intended to signify approval for the expenditure of the TDA resources involved.

In earlier times, when one or two tracking stations and simple facilities for control of flight operations were all managed more or less by a single entity, verbal agreements or internal memos between participating groups were all that was needed to conduct missions for a single JPL-managed spacecraft. No longer was that the case. By the mid-1960s,
the DSN had expanded to two 26-m Networks and large 64-m antennas were under construction. Spaceflight missions were conducted from a large, completely new facility called the Space Flight Operations Facility (SFOF), and several major, non-JPL projects, including Apollo, were demanding its services.

To deal with this situation, Rechtin assigned a technical staff position to a DSN Manager for each flight project. The DSN manager functioned as single point of contact between his flight project and the DSN, which at that time included the SFOF, for conveying and negotiating requirements and commitments for tracking and data acquisition, mission operations, and data-processing support. The documentation system by which these agreements were consummated was the SIRD and NSP. In actuality, the role of the DSN Manager extended beyond the DSN to include responsibility for negotiating support for his flight project from other entities such as the NASA Communications Division (NASCOM) at GSFC for communications, the Air Force Eastern Test Range (AFETR) for launch support tracking coverage from land stations, Department of Defense (DOD) for ships and aircraft, the Lewis Research Center (LeRC) for launch vehicle data, and so on. Although the DSN manager did not have an inline operational role in flight operations, he was at all times held accountable to the flight project manager for the performance of the DSN in support of mission operations, according to the negotiated agreements.

**The Space Flight Operations Facility**

It had become apparent during the early part of the Ranger Program that the limited facilities available at JPL for conducting flight operations and mission control would not be adequate to support the greatly expanded space programs of the future.

With this in mind, JPL made a recommendation to NASA for the construction of a new building at JPL that would be entirely dedicated to accommodating the personnel, equipment, and facilities needed to manage all of the elements involved in flight operations on a continuous, round-the-clock basis. These elements included the DSIF; ground communications, data processing and display, and mission control, with all the internal communications needed to make them work together. NASA approved the recommendation in mid-1961. Under the aegis of the NASA Office of Space Science and Applications (OSSA), construction of what was called the Space Flight Operations Facility (SFOF) began shortly afterward. The SFOF was completed in October 1963. The IBM 7094 and 7040 computers and 1301 disk files were moved in immediately and began operating just before the launch of the *Mariner 4* mission to Mars in November 1964. Thus,
Mariner 4 was the first flight project to be supported by the new SFOF operating with a combination of real-time and non-real-time computing systems.

In December 1964, however, programmatic responsibility for the SFOF was transferred from OSSA to OTDA on the basis of the interrelated functions of mission control in the SFOF and Network control in the DSN. This responsibility had been anticipated in Pickering’s announcement establishing the DSN in December 1963, and it remained a major element of the DSN for almost the next decade. While the TDA Office assumed programmatic responsibility for the SFOF, its operational and technical support was provided by the Space Flight Operations and Data Systems Sections of the Systems Division 31, in a somewhat analogous way to that in which the Telecommunications Division 33 supported the DSN. (See Figure 9-6.)

The years following the transfer of the SFOF to the DSN were marked by a great increase in the number and complexity of the flight missions that the DSN was called upon to support. Many of these missions were managed by institutions other than JPL. The Lunar Orbiter and Pioneer missions (and, to a lesser extent, the Surveyor and Apollo missions) were typical of this period.

At the same time, the DSN itself was expanding. The second 26-m subnet and the L/S-band conversion were completed in 1965; the first 64-m antenna became operational in 1966; and the multi-mission concept was introduced in 1967.

Toward the end of the 1960s, improvements in communication control, data distribution and display, and computer-based switching of intersite circuits were made in the SFOF. Intersite communications were carried on high-speed and wideband data lines at speeds of 4,800 bps and 50 kbps, respectively, by the DSN Ground Communications Facility, which was also part of the SFOF. Paralleling the increased data-handling capability of the Mark III DSN, the data-handling capability of the SFOF data processors was also expanded by the replacement of the old IBM computers with two IBM 360-75 and two Univac 1108 machines with appropriate interface switches for flexibility and redundancy.

While all of this development was taking place in the DSN, GCF, and SFOF, all three facilities were simultaneously conducting an intense program of lunar and planetary missions operations. The success of all these missions attests to, amongst other things, the adequacy of the organization under which they were performed. With the exception of several personnel changes, notably the resignation of Rechtin and the appointment of Bayley to replace him as ALD/TDA, the organization remained as shown in Figure 9-6.
Nevertheless, despite the apparent suitability of the existing organization to the task it was being called upon to perform, all was not well at the higher levels of management. As William Corliss explains,

The deep space missions of the late 1960s and early 1970s brought with them substantial increases in the SFOF’s data-[ ]processing load. Much of this data processing was strictly scientific and unrelated to DSN operations. Yet, the tracking and data acquisition function was obligated to provide for this computer time without the authority to review requirements. The flight projects were, in essence, requesting and getting large blocks of computer time and were neither financially nor managerially accountable for them. It was a bad managerial situation. NASA Headquarters recognized the situation and, in October 1971, Gerald Truszynski (OTDA) and John Naugle (OSS) reviewed the problem and decided to transfer the SFOF functions from OTDA back to OSSA. In this way the responsibility for review and validation of requirements and the associated costs of scientific data processing would be borne by the flight projects themselves.

The change at Headquarters was immediately reflected at JPL, where responsibility for the SFOF was moved from the TDA Office to a newly created Office of Computing and Information Systems (OCIS). This new organization reported not to OTDA, but to OSS. The transfer became effective in July 1972, and the organization of the technical divisions at JPL which resulted from or gave rise to (depending on the point of view) the separation of the SFOF from the DSN is shown in Figure 9-7.

The Office of Computing and Information Systems, with Allan Finerman as manager, directed the Data Systems Division, which, under the management of Glen E. Lairmore, provided technical support and operational direction for the SFOF and the GCF.

The Telecommunications Division and Mission Analysis Division provided engineering development and navigation-related analysis for the independent DSN.

The TDA Office, under the ALD (Bayley), assigned a manager to each of the three major areas of effort in the Network for which it was responsible. Both implementation of new hardware and software in the Network and Network Operations functions were carried out by Kurt Heftman, the DSN Engineering and Operations manager. Interfaces between the DSN and all flight projects for the negotiation of requirements and commitment of DSN resources were provided by Mission Support Manager Nicholas A. Renzetti and his staff of five DSN managers. The integration of the various elements of
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Figure 9-7. Organization of the technical divisions after the transfer of the SFOF to OCIS, 1972.

the DSN into coherent unified systems was led by John W. Thatcher. The TDA Office also maintained a representative at each overseas site to deal directly with local government officials on matters pertinent to the operation of the tracking stations in their countries. Program Control (budgetary matters) were handled by Wallace P. Spaulding.

Although the separation of the SFOF from the DSN may have appeared to be merely a “paper exercise,” it was not accomplished without considerable disruption to the carefully crafted interface agreements already in place between the DSN and the Pioneer and Viking flight projects.\(^7\);\(^8\) Schedules, interface agreements, and capabilities had been negotiated with various elements of the flight projects and had been formally documented and approved, in accordance with current practices. These schedules, agreements, and capabilities, of course, included the SFOF as well as the DSIF. When the separation took place, new interfaces between the DSN and the flight project, and the DSN and OCIS, had to be developed and documented.
A typical example of the functional interfaces between the DSN and the SFOF after the separation of responsibility is shown in Figure 9-8.

The Viking Mission Control Center (VMCC), which included the SFOF central computing system, the mission support areas, and the Viking mission simulation system, was the joint responsibility of the OCIS and the Viking Mission Operations System. The DSN was responsible for the deep space stations, which included the 64-m and 26-m subnets, and transport of data to and from the VMCC via the high-speed and wide-band data lines of the GCF. Control and monitoring of Network performance and validation of the data streams flowing between the VMCC and the deep space stations was to be accomplished by a separate data-processing capability that would be independent of the mission-related computers in the SFOF. These functions would be accommodated in a new Network Operations Control Center (NOCC), which was being designed at the time (1972).
As the SFOF came into use for multi-mission support in the early 1970s, common terminology was changed to better reflect the way in which the facility was actually being used. The building, JPL Building 230, and its support facilities retained the title SFOF. The SFOF was eventually designated as a Historical Landmark by the U.S. Department of the Interior in 1986. The SFOF housed two facilities that were controlled by the DSN, namely, the GCF (in the basement) and the NOCC (on the first floor). The remainder of the building accommodated the flight controllers and spacecraft analysts for the various flight projects and the data-processing equipment required to support their missions. That ensemble of accommodations and equipment was called the Mission Control and Computing Center (MCCC). It was occupied in turn by one or more Flight Projects for the duration of each mission, after which it was vacated and reconfigured for the next flight project. In some cases, non-JPL flight projects elected to conduct flight operations from Mission Control Centers at their own institutions rather than from the SFOF at JPL.

The first flight project to use the MCCC in this way was Pioneer, managed by the Ames Research Center (ARC) in Moffett Field. Similar arrangements for remote Mission Control Centers came into greater use in later years, as the DSN began supporting greater numbers of non-NASA spacecraft.

The Bayley/Lyman Years

The Tracking and Data Acquisition Office at JPL (Office 400 in the JPL hierarchy) was renamed Telecommunications and Data Acquisition Office and reached maturity under the direction of Bill Bayley over the span of his tenure as ALD between 1967–80. From a relatively small organization of fourteen in 1972 (Figure 9-7), the TDA Office had grown to an organization of seventy-four people, as shown in Figure 9-9, by 1978. Two offices—one for technology development, the other for long-range planning—had been added. Because of the tremendous growth in DSN flight operations and the expansion of the Network needed to meet the increasing number of flight missions, it was necessary to split the former Engineering and Operations Section into separate offices. One of these new offices (430) was managed by Renzetti and focused on developing the engineering systems of the DSN. Interfacing with the flight projects and scheduling antenna time, configuration control, and all other aspects of flight mission support except the actual hands-on operations and maintenance became the responsibility of the DSN Mission Support Office (440), under Spaulding.

In 1980, W. H. Bayley retired and the extant JPL director, Bruce C. Murray, selected Peter T. Lyman to replace Bayley as ALD/TDA. Lyman retained that position until
1987, Bruce Murray was succeeded as JPL Director by Lew Allen (1982), and the TDA Office continued to expand to meet the demands placed upon it by an ever-increasing number of NASA and non-NASA deep space and Earth-orbiter missions, as well as numerous nonflight, scientific programs.

In Figure 9-10, a snapshot of the TDA organization, near the end of the Lyman years in 1986, reveals the extent of the remarkable growth of the organization in that period.

Most noticeable in this organization was the addition of the TDA Science Office (450), created by Lyman in 1983 for the reasons described in the previous chapter. Renzetti managed that new office, which included a Geodynamics program, the SETI program, the Goldstone Solar System Radar program, and several other special research projects.

Paul T. Westmoreland was appointed manager of the TDA Engineering Office (430), which was by then responsible for interagency arraying, compatibility and contingency planning, and implementation of new engineering capability into the Network and GCF, in addition to its ongoing task of DSN System Engineering. The TDA Planning and Technology Development offices appeared under different managers, and they, too, had
expanded in scope. Under the management of Raymond J. Amorose, Office 440 included management responsibility for the large Maintenance and Operations (M&O) Contract, by which an industrial aerospace contractor provided engineering and operations services to the DSN for the Goldstone Complex, the NOCC, and related activities in the Pasadena area. Three DSN engineers managed the M&O contract, the Network Control Center at JPL, and the Complex Control Center at Goldstone. Eight DSN managers attended to the interests of over twenty flight projects that were active in the DSN at that time. Finally, a program manager, chief engineer, and chief technologist provided direct support for the ALD/TDA in establishing budgetary, policy, and long-term development goals.
At this point, a brief digression is in order to explain the organizations by which the three Deep Space Communications Complexes (DSCCs) that composed the DSN were related to the TDA Office.

From the outset, it was never intended that the various stations in the Network would be operated by JPL personnel. In fact, the international agreements that permitted NASA to establish tracking stations on foreign soil stipulated that the facilities would be operated by foreign nationals of the host countries. To this end, comprehensive facilities for technical training in DSN-related technologies were set up at JPL and at Goldstone. At these facilities, visiting foreign national engineers and U.S. national engineers received theoretical and hands-on instruction and training in the hardware and software which they would subsequently be required to operate and maintain at their home sites. In the early life of the DSN (DSIF), when new stations were completed, a few JPL technical personnel remained at the site until the site could sustain continued operations with its own personnel. Later, the sites sent key personnel to the U.S. for training so that upon their return to their home bases, they could implement the new antennas or new capabilities themselves. There was a constant flow of technical personnel between the sites and Goldstone or JPL for this kind of information exchange and dissemination.

In the United States, the staff to operate the tracking stations and DSN-related services at Goldstone and the Network Control Center and Ground Communications Facility at JPL were provided by a technical services contract to NASA/JPL. The Maintenance and Operations (M&O) Contract was managed by Office 440, as discussed above, and through the years passed through the hands of various major U.S. aerospace companies—Bendix Field Engineering Corporation in 1960, Philco-Ford in 1970, and Bendix Field Engineering Corporation in 1978 and 1988. Bendix Field Engineering Corporation became Allied Signal Aerospace in 1992 without interruption to the contract.

Under the direction of JPL personnel, the M&O contractor was responsible to the DSN for the supporting services listed below (in greatly abbreviated form):

1. At JPL:
   a. Operate and maintain the Network Operations Control Center (NOCC), the Ground Communications Facility (GCF), the Compatibility Test Facility (CTA 21), and (occasionally) the DSN Launch Support Test Facility (MIL 71) at Cape Kennedy.
   b. Manage operations support programs such as antenna scheduling, discrepancy reporting, data control, radio frequency interference management, and Network performance evaluation.
c. Provide general support to all Network facilities in the areas of logistics, technical training, documentation, engineering change and configuration control, Network-level maintenance, and sustaining engineering.

d. Provide high-level technical and administrative support for specific tasks in the TDA Office and Telecommunications Division.

2. At the Goldstone Deep Space Communications Complex (GDSCC):
   a. Operate and maintain all of the tracking stations, their intrasite communications, and the research and development facility at the DSS 13 Venus site.
   b. Maintain the established Complex Maintenance Facility, Network Standards Laboratory, and other services.
   c. Maintain all of the buildings, plant equipment, roads, lighting, power, and air-conditioning, as well as fire, food, and security services.

The M&O Contract for Goldstone assigned complete responsibility for running the complex to the contractor, and over the many years of its operation, the GDSCC technical staff were always ready to respond to a call for extra effort, whether it was for an inflight mission, an engineering research and development task, or a DSN science program.

The staff and infrastructure needed to provide engineering and operations support for the Canberra Deep Space Communications Complex (CDSCC) were provided by Australian industry under a contract with the Australian government. However, all costs associated with operation of the CDSCC were borne by NASA under the terms of the intergovernmental agreement. The Complex Director remained an employee of the governmental department (agency) charged with administering the contract on behalf of the Australian government and was responsible to that department head for routine management of the Complex, its staff, and its facilities. On behalf of NASA, the ALD/TDA at JPL was responsible only for providing the operational facilities and directing their use in support of the NASA programs. The ALD/TDA retained a representative resident in Canberra to facilitate the interchange of technical and administrative information between the CDSCC and JPL. He played no part, however, in the direction or operation of the Complex, and the position was abolished in 1985.

International agreements between NASA and the Spanish government for the management, engineering, and operations support for the Madrid Deep Space Communications Complex (MDSCC) were essentially similar to those between NASA and the Australian government for management and operation of CDSCC. There, however, both the director and his staff were employees of a government agency, Instituto Nacional Tecnica Aerospacial.
In both situations, this seemingly awkward organizational arrangement worked well, in general terms. Some initial administrative difficulties were cleared up as time went on, but the technical staffs at both complexes were always prepared (and on many occasions were called upon) to respond unreservedly to the exigencies of deep space mission operations.

The Dumas/Haynes Years

When the position of Deputy to the Director of JPL became vacant at the retirement of Robert Parks in 1987, Lyman was appointed to fill the position, and Larry N. Dumas became ALD/TDA. Apart from the inevitable personnel changes and some structural changes within the five internal offices of the TDA (400) organization, little changed in an organizational sense in the DSN during the Dumas years, 1987 to 1992. More changes in upper management, however, were on the way.

In 1990, Edward C. Stone replaced Allen as director of JPL, and he was joined in 1992 by Dumas as deputy. The then vacant position of ALD/TDA was filled by Norman R. Haynes, who brought Westmoreland from the TDA Engineering Office to become his deputy. The TDA organization had remained essentially unchanged since 1986, and, except for changes in personnel, is well represented by Figure 9-11. This was the final form of the TDA Office. There was no hint of the very dramatic changes that would overtake the entire TDA (400) organization in the next several years.

When Haynes took over the TDA organization in 1992, it was one of several offices headed by an Assistant Laboratory Director (ALD). These offices, under the JPL director, composed the basic structure of the entire JPL organization. When he left in 1996, the JPL structure had been changed to one based upon an ensemble of directorates, each headed by its own director. The directorates were not simply renamed offices, but were restructured to reflect the “policy for change” brought to JPL by the new director, E. C. Stone.

To fully appreciate the latest changes in the TDA organization, it is necessary to understand the organizations at NASA Headquarters and in the MCCC at JPL at that time. Both influenced the shape of the future TDA organization.
Figure 9-11. National Aeronautics and Space Administration, 1991.
By 1991, the organization at NASA Headquarters under Administrator Richard H. Truly included an Office of Space Science and Applications (OSSA, Code S) and an Office of Space Operations (OSO, Code O) as shown in Figure 9-11.

In the context of program direction for users and suppliers of deep space tracking and data-acquisition services, OSSA directed the flight projects (users) and associated ground data-processing facilities (MCCC) while OSO directed the TDA Office and its associated tracking and data-acquisition facilities (DSN).

For clarification, during the period of DSN history reviewed in this book, the NASA office that began as the Office of Tracking and Data Acquisition (OTDA) in 1961 became the Office of Space Tracking and Data Systems (OSTDS) in 1983, the Office of Space Operations (OSO) in 1988, and the Office of Space Communications (OSC) in 1992. During almost that entire period, it was identified as “Code O” and was responsible for programmatic direction of the DSN through the TDA Office at JPL.

The selection in July 1989 of Charles T. Force as Associate Administrator of the Office of Space Operations (OSO) brought immediate changes to the DSN relationship with NASA Headquarters. His highly relevant technical background, considerable experience in tracking-network operations, and strong motivation effectively streamlined the unwieldy, outmoded, and by that time largely irrelevant system of documentation that controlled agreements for providing and expending NASA resources on the DSN antennas. The time span of his position in that office, 1989–96, placed him squarely in the Galileo Era, where he was most effective, at the Headquarters level, during the crises that arose in that period of DSN history.

The funding approved during Force’s tenure enabled the DSN to upgrade the 64-m antennas to 70-m, add more 34-m antennas to the Network, support recovery of the Galileo mission from almost certain failure, introduce multiple antenna arraying on a routine operational basis, move toward K-band operations, and consolidate and upgrade the Signal Processing Centers. Together with the improvements in formal Headquarters documentation, these made an impressive record of achievement that set the stage for the major reorganization that swept through all the NASA Networks in the late 1990s.

Forceful in attitude and spare with words, “Charlie” Force came straight to the point in a discussion, an aspect of his managerial style that appealed to the JPL managers with whom he interacted on DSN-related matters. His full responsibilities included several other NASA Networks in addition to the DSN, and he was seen as fair and impartial.
when at times his decisions regarding the allocation of limited resources were at odds with prevailing opinions at JPL.

Force joined NASA in 1965 as Director of the Guam Tracking Station and, except for returning to industry for a couple of years in the early 1980s, held increasingly responsible positions throughout his career at NASA. A native of Shoals, Indiana, and resident of the state of Maryland, he held a B.S. degree in aeronautical engineering from Purdue University. Force left NASA in 1996 to pursue commercial business interests.

By 1993, the organization at JPL formerly referred to as the MCCC had embraced the concept of multi-mission operations and had evolved into the Multimission Operations Systems Office (440) with the structure shown in Figure 9-12.

Because of its close association with the evolution of the DSN, the path by which the MCCC evolved is of historical interest and is neatly described by Alazard9 as follows:

From the mid-1960s through 1970, the ground data system was comprised of three IBM 7094 computers to support each of the then current (flight) projects. Between 1970 and 1977, the architecture and organization of computing changed and moved toward a multimission orientation. The Mission Control...
and Computing Center (MCCC) was created and data processing was done on IBM 360-75's. The flight projects shared this single system in a multiprocessing mode. Between 1973 and 1981, minicomputers were phased into the MCCC for realtime processing. Mainframe computers were used for processing (flight) project applications programs and data records, i.e. non-realtime processing. These computing capabilities were provided to the flight projects by the Flight Projects Support Office (FPSO). The realtime processors were usually dedicated to a given project while the non-realtime processors were shared.

In an effort to reduce the cost of data processing for flight operations in the mid-1980s, FPSO initiated development of an entirely new facility, called the Space Flight Operations Center (SFOC). The SFOC performed the functions of the MCCC with the newer technology of distributed processing using microcomputers and local area networks in a workstation environment. When it was completed in the early 1990s, existing flight project support was gradually converted from the MCCC to the new system, and new flight projects were adapted to the multimission capabilities and services. In due course the MCCC was phased out and the SFOC became the core of an even more advanced data processing system called the Advanced Multi-Mission Operations System (AMMOS).

The name FPSO was changed to Multimission Operations Systems Office (MOSO) in 1992 to better reflect the multi-mission nature of the organization. MOSO became the overall organization responsible for development, operations, and maintenance of the flight project support capabilities. AMMOS provided the direct operations support functions using the hardware and software of the Multimission Ground Data System (MGDS).

It was the task of MOSO to establish the set of multi-mission data processing capabilities and operational services that supported the flight projects in accomplishing their mission objectives. The AMMOS was the set of hardware and software tools by which this task was accomplished. Defined in this way, the MOSO task closely paralleled the DSN Operations and Mission Support Office (440) task when tracking and data-acquisition services were substituted for data-processing services and the DSN was substituted for AMMOS. The MGDS was the counterpart of the DSN.

The JPL Strategic Plan: 1994

Shortly after the Clinton Administration took office in January 1993, all federal agencies, including NASA, began to feel the effect of a groundswell of change toward a smaller, more efficient, and less costly bureaucracy. A new NASA Administrator, Daniel S. Goldin,
had been appointed early in 1992, and he was quick to respond to the presidential initiative for cost reduction in government agencies. In the course of the changes that followed, the Headquarters organization was significantly reduced in size; many functions were deleted or combined; and a new, streamlined NASA organization emerged. In an environment of economic constraints and redefined national goals, the NASA budget declined in Fiscal Year 1995 for the first time since the end of the Apollo program in the late 1960s. New approaches and revised priorities for the U.S. space program were developed to ensure that space science and technology would continue to advance for the benefit of the nation. All of these factors required NASA and, consequently, JPL to rethink their ways of doing business, adopt new strategies, and create a shared understanding of how to meet customer needs in the new environment.

This state of affairs formed the driver for a Strategic Plan developed for JPL in 1994 by its new director, Edward C. Stone. It defined the set of NASA programs in which

<table>
<thead>
<tr>
<th>NASA SPACE COMMUNICATIONS AND OPERATIONS PROGRAM</th>
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<tr>
<td>• Provide affordable, world-class support to large, complex missions: Ulysses, Galileo, Cassini, and EOS.</td>
</tr>
<tr>
<td>• Advance the state of the art in low-cost support of small and moderate missions.</td>
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<tr>
<td>• Develop the capability to provide Ka-band services for future low-cost missions.</td>
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<tr>
<td>• Upgrade mission operations concepts and support systems to enable simultaneous operation of many missions at significantly reduced unit cost.</td>
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<tr>
<td>• Develop concepts for promising new services such as optical communications and non-DSN tracking terminals.</td>
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<tr>
<td>• Revolutionize ground system designs to reduce complexity and operating costs while emphasizing new technology opportunities and controlled risk.</td>
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<tr>
<td>• Support many more missions in the next five years while reducing DSN tracking operations costs by 50 percent.</td>
</tr>
<tr>
<td>• Advance the state of the art in deep space and near-Earth navigation and communications to meet expected future mission requirements.</td>
</tr>
<tr>
<td>• Seek new concepts for low-cost support of small and moderate missions.</td>
</tr>
<tr>
<td>• Increase the use and scientific impact of the DSN in radio science, astronomy, and planetary radar studies.</td>
</tr>
<tr>
<td>• Lead in developing international science agreements and cross-support systems for an affordable global space exploration program.</td>
</tr>
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Figure 9-13. NASA Space Communications and Operations Program.
JPL would engage to support “NASA’s strategic enterprises and other national needs.” One of these programs was NASA Space Communications and Operations, and because of its importance to the future long-term development of the DSN, it is reproduced in Figure 9-13.

One of the overarching concepts embodied in the newly defined program was the combining of space communications with space operations to create a single entity of reduced complexity with lower operating costs. This was to be achieved without sacrificing performance and was concomitant with a stimulating call to further advance the state of the art in associated technologies.

Birth of the TMOD

The Telecommunications and Mission Operations Directorate (TMOD) was created in 1994 to support the NASA Space Communications and Operations program defined in the Strategic Plan described above. As such, it represented one element of the Laboratory’s overall response to the NASA Strategic Plan.

The transition from the TDA organization to the TMOD organization took place during the latter half of the Haynes years (1994); although there was a considerable disruption of ongoing activities initially, by 1996, when Paul T. Westmoreland assumed the position of Director, the new arrangement had settled down and assumed the form shown in Figure 9-14.

The rearrangement and consolidation of former TDA functions, which is apparent in Figure 9-14, reflected a new and cost-effective approach to complex business management systems made popular at that time (1992–93) by Dr. Michael Hammer, co-author of the book *Reengineering the Corporation.* With institutional encouragement, JPL management personnel at all levels attended Hammer’s courses and returned to JPL to apply the new methodology to the workplace. Early in 1994, the TDA senior staff spent two months developing a process map for the TDA organization. Two of these processes were selected for actual reengineering, and process owners were named. The selected processes and owners were Services Fulfillment (Raymond J. Amorose) and Asset Creation (Edward L. McKinley). Leslie J. Deutsch was assigned to lead the Reengineering Team (RET) for Services Fulfillment—the process deemed most suitable for the first engineering effort. Although the RET was formed initially to reengineer only the TDA organization, the scope of its work was expanded to include the data capture and navigation functions of MOSO when the two organizations were merged to form TMOD.
The RET issued an interim report in September 1994 containing some key items for the future structure of TMOD. Among these were the three Services Fulfillment Processes recommended for reengineering—namely, Data Capture, Activity Planning, and Resources Scheduling, all defined later in this chapter. There was also a proposal that the DSN be changed from an engineering-driven organization, as it had stood in the past, to an operations-driven organization for the future.

The arrangement shown in Figure 9-14 was the first step in the overall reengineering process. Essentially, the former TDA organization was condensed into two offices: one for planning, committing, and allocating DSN resources; the other for DSN operations and system engineering. DSN science and technology were incorporated in the former, DSN development in the latter. In addition to these two offices, the Multimission Ground Systems Office, the project offices of the four inflight missions (Galileo, Space VLBI, Ulysses, and Voyager) and a new business office were added to create TMOD. There could be little doubt that the TMOD was now operations-driven rather than engineering-driven.

Figure 9-14. Telecommunications and Mission Operations Directorate, 1996.

The Deep Space Network as an Organization in Change
While these organizational changes brought the Deep Space Network and the Multimission Ground Data System together under one directorate, they did not effect, alone, the substantial reduction in ground operations costs that was the real objective of the reengineering initiative. DSN operations, now redefined in reengineering terms as the Data Capture Process, still involved a plethora of facilities, starting with the DSCCs, passing through the GCF to the NOCC and to MOSO before eventually delivering the data to the customer. Reduced cost would come from reduction in the size, complexity, redundancy, and performance margin of the infrastructure needed to operate these separate facilities. This, in turn, required a radical change in the way in which future operations were performed, and in the way in which the individual elements of the Data Capture Process would be operated. It was the task of the RET to show how this could be done and to provide a road map for making the transition to the new Data Capture Process.
The Deep Space Network as an Organization in Change

REINVENTING THE FUTURE (1994 INTO THE NEW MILLENIUM)

Reengineering TMOD

The RET completed its redesign of key TMOD subprocesses and submitted its final report to DSN Mission Operations Manager Ray Amorose in March 1995. It succeeded in not only meeting but exceeding its initial cost and efficiency goals of reducing the DSN Operations budget by $9M and doubling the available tracking hours by Fiscal Year 1999. The new designs would cost about $16M to implement and were predicted to result in a cumulative savings to TMOD Services Fulfillment of approximately $35M for the period FY 1996 through FY 2000, as shown in Figure 9-15.

![Figure 9-15. Predicted cost and savings for reengineering TMOD Services Fulfillment Processes.](image)

The three Services Fulfillment Processes include the following:
1. Data Capture—the process that provided the services of telecommunications, target tracking, and data processing to customers.
2. Activity Planning—the process that generated and consolidated the support data that was needed by the Data Capture Process to perform its functions.
3. Scheduling—the process that allocated the resources of the DSN and MGDS for use in the Data Capture Process.
Because the savings to DSN Operations were estimated to be low, the RET elected not to reengineer the Scheduling Process at that time. It was, therefore, only the Data Capture and Activity Planning Processes that, in reengineered form, contributed to the substantial projected cost savings noted above.

By basing its design on standard (rather than customized) services, the new Data Capture Process simplified mission interfaces, increased operational efficiency, and allowed full use of automation to provide these services. At the same time, a “Connection Operator” was made available to provide specially tailored services essential to the customer’s needs. The parts of the NOCC, GCF, and MGDS involved in real-time operations were brought together in a single work area called Central Operations. New, more easily maintained equipment allowed them to be located in a considerably smaller work space with reduced facilities costs.

On the other hand, supporting data such as radio metric predicts, antenna pointing instructions, and schedules for Deep Space Network operations were considered an Activity Planning function and had, in past practice, been generated at the NOCC considerably in advance of the needed time. The inputs were, of necessity, immature, and they invariably led to the generation of many contingency or “just in case” versions, all of which created extra work. In the new, more rapid and efficient “just in time” system, predicts were generated at the site as needed and were based on the most up-to-date requirements and conditions. The resulting system was much more responsive to last-minute changes, more timely, more accurate, and less costly to operate.

Data Capture Process

The new Data Capture Process described above was critically dependent for its implementation on the availability of new hardware and software tools with the requisite capabilities. To a large degree, these were to be provided out of similar studies carried out by the Reengineering Team for the Asset Creation Process, which ran a parallel course to that of Customer Services Fulfillment.

In this context, it was assumed that the operations load on the 26-m/9-m subnetwork would be relieved by the introduction of a subnetwork of small unattended tracking stations to be known as Low-Earth Orbit (LEO) terminals. It was further assumed that updated electronics would allow a large degree of automation for future operation of the 26-m and 9-m antennas and would eliminate the existing need for roving operators (rovers) to configure antenna and microwave equipment in front-end areas (FEAs). At the DSCCs, the already-planned Advanced DSN Monitor and Control (ADMC) sub-
Figure 9-16. Data Capture road map.
system would provide the high degree of automatic features required for the Connection Operations concept. A new “Reliable Data Delivery System” and improved Wide Area Network were already at the advanced design stage and were assumed to be available to meet the proposed transition plan schedule. Finally, it was assumed that technology already developed in MOSO for data processing and management would be extended to incorporate the Data Systems Operations Team (DSOT) as a vital element of the new Data Capture system.

A road map for making the transition to the new Data Capture Process is shown in Figure 9-16.

The dependency on key new implementation described above is shown in the top half of the figure, while the key changes in operations processes are shown in the lower half. The plan attempted to minimize disruption to ongoing operations while it progressed rapidly toward its final realization by 2000. Near-term savings accrued from the early transition to Connection Operation in 1995, collocation of TMOD operations, and reduction in operations documentation.

Activity Plan Process

The two principal functions performed via the Activity Plan process were as follows:

1. Identifying the services to be provided. This was called Service Plan Generation and was based on a schedule showing the TMOD resources required and the time at which they were to be available, as well as a project sequence of events (PSOE) that identified what the customer would be doing during the time allocated in the schedule.

2. Generating the information, internal to the Network, that was required for operating the equipment to provide the needed services. This was called Predicts Generation and was required principally for generation of radio metric or telemetry data. It was based on spacecraft state and ephemeris and station-dependent data such as location, horizon mask, and planetary ephemeris.

At the time that the new Activity Plan Process was being designed, a standard infrastructure for the packaging and manipulation of spacecraft navigation products called the “SPICE” system had been in use for some years at JPL. The SPICE data sets were called kernels and contained the information necessary to assist users in planning and interpreting science observations from spacecraft instruments. For example, the “S” data set contained spacecraft ephemeris data, and the “P” data set contained planetary ephemerides.
In reengineering the Activity Plan Process, the RET extended this idea to create kernels containing spacecraft and planetary ephemerides data, telemetry data, station information, and time and Earth polar motion information needed to compute station locations. The data bases of these kernels would be “shadowed” or automatically updated to the tracking station’s data management system and would therefore be available for use in generating telemetry and/or metric predicts on demand. At the station, computation of predicts could be initiated only minutes before the actual activity was scheduled to take place.

In addition to these innovations, the reengineered Activity Plan Process improved the way in which the customer provided the PSOE by referencing it to a standard catalog of prenegotiated services. The Activity Plan Process would then translate these service requests into the operations procedures necessary to meet them, thereby creating the actual Service Plan.

Although implementation of the new Activity Plan Process began in 1995, it depended on upgraded versions of the data management capability at the stations for full operation. Delay in providing this new capability resulted in a longer term return on the implementation costs than was the case for the Data Capture Process.

At the time of this writing, the implementation plans for the Data Capture and Activity Plan Processes were in progress along the lines discussed above. When fully completed in 1999, the reengineered TMOD Customer Services Fulfillment Process would embody the very best principles of cost-effective, process-based management, rather than the facility-based management and control principles that had been in place for the previous forty years.

Reinventing the Future

After a very short term of one year in office, Westmoreland retired in June 1997, and Gael F. Squibb was appointed director of the Telecommunications and Mission Operations Directorate (TMOD). Squibb was well qualified to guide TMOD into the future. He had served as Manager of Data Services for NASA’s Space Operations Management Office since 1995 and had managed numerous scientific flight projects in thirty years of previous service with JPL.

When Squibb took over TMOD, the reengineering effort was well under way and the DSN and MGDS functions in mission operations had become recognized as contiguous elements of the Customer Services Fulfillment Process. They were, from 1994, still separate offices (940 and 970) of the original TMOD organization. It was time to bring the institutional organization more into line with the concepts of process-based management.
The restructured Telecommunications and Mission Operations Directorate, under the direction of Gael Squibb in 1997, is shown in Figure 9-17.

The former DSN Data Services and Multimission Ground Systems Offices were combined to form the TMOD Operations Office, from which the Customer Services Fulfillment Process, including the allocation of resources, would be managed effectively. To develop the new system engineering functions for this process, a TMOD Engineering Office, which included engineering elements of both the DSN and MGDS, was also created. It would be here that the Asset Creation Process would reside. The enabling technology on which the reengineering teams based their new process-oriented designs was to be provided by the TMOD Technology Office for both the DSN and AMMOS. It was defined as a “Center of Excellence” for telecommunications to focus attention on the particular technology in which the DSN held a unique position in the NASA sphere of influence. The Plans and Commitments Office and flight project offices remained essentially the same.
The Deep Space Network as an Organization in Change

There was another feature of the TMOD organization that, although not apparent on the organization chart, affected the interaction between TMOD and its customers in a significant way—the change in the role of the DSN manager. As mentioned earlier, it was customary for the TDA Office to appoint a representative to work with each flight project in negotiating and using the tracking and data acquisition services that were required for its mission. The title of this position was “Tracking and Data System (TDS) Manager for (Name of Customer).”

Customers included those that used the DSN as a scientific instrument as well as those that used it as a tracking and data acquisition service. The TDS manager helped his designated customers to understand relevant technical and operational aspects of the DSN and acted as an authoritative single point of contact for the customers, dealing with all aspects of the service being provided. But the service rendered extended only to the interface between the DSN and the MGDS. It did not include the processing and management of the data beyond that point, which was, in reengineering terms, “facility-oriented.” When TMOD was reengineered into a “process-oriented” organization, the former TDS manager positions, which were properly resident in the Plans and Commitments Office, were expanded in concept and scope to include the entire Customer Fulfillment Services Process. They became the TMOD version of the “empowered customer service representatives” advocated by Hammer and Champy and were called Telecommunications and Mission Services (TMS) Managers.

The extent to which a single person would be able to discharge this task in a meaningful way at all levels throughout the now extremely complex Services Fulfillment process remained to be seen. Hammer and Champy recognized this problem and observed, “To perform this role—that is, to be able to answer the customer’s questions and solve the customer’s problems—the case manager needs access to all the information systems that the people actually performing the process use and the ability to contact those people with questions and requests for further assistance when necessary.” The TMS managers of the future would need full access to tools and resources such as these to properly carry out their important functions in the new process-oriented TMOD.

“Bridging the Space Frontier”

A few months after taking office, the new director of TMOD issued a statement that presented his goals and vision for the TMOD of the future. It included a plan for their realization and was called “Bridging the Space Frontier.” The plan traced the origin of the powerful forces throughout NASA that had influenced the organizational structure of TMOD and would determine its course for the future. The environment in which
TMOD must plan for the future, said Squibb, “is characterized by three fundamental trends: increasing demand for telecommunication and mission services and technology advancements, highly constrained resources, and organizational change.”

Squibb based his plan on NASA’s response to the National Space Policy, issued from the White House in 1996. The National Space Policy of 1996 directed NASA to focus its research and development efforts in the four principal areas of Space Science, Earth Observation, Human Space Flight, and Space Technologies and Applications. Furthermore, it instructed NASA to “seek to privatize or commercialize its space communications operations no later than 2005” and to “examine with DoD, NOAA[,] and other appropriate federal agencies, the feasibility of consolidating ground facilities and data communications systems that cannot otherwise be provided by the private sector.”

NASA began to address this latter policy by consolidating the management of all its space operations under a new Space Operations Management Office (SOMO), located at the Johnson Space Center in Houston. As the service provider, SOMO was given responsibility for implementing NASA’s space operations and managing the associated space operations work process. The NASA Centers, in support of their respective implementation plans for space operations, were responsible for the execution of the space operations work process.

In his plan, Squibb discussed TMOD’s relationship to SOMO. “Through this cooperative arrangement with SOMO, TMOD (would) oversee operation of the Advanced Multimission Operations System (AMMOS) and the Deep Space Network (DSN). Under SOMO’s leadership, efforts were underway to consolidate and streamline major support contract services.” Transition to a Consolidated Space Operations Contract (CSOC) with a single, ten-year, cost-plus-award-fee contract was expected to begin in Fiscal Year 1998. In the meantime, TMOD worked to understand its future, dramatically different role as a partner with a CSOC contractor, and possibly with other United States or foreign agencies; it also tried to identify any functional activities that would be suitable for commercialization in the immediate future.

JPL’s management responsibilities for the DSN and AMMOS were finally combined under Squibb’s direction in 1996, and TMOD began to operate as a single process-oriented service to its customers. Joe Statman, manager of the TMOD Engineering Office, saw the new way of operating as a challenge to “create one culture—no more separate DSN/AMMOS cultures.” One step remained, however, in the completion of the DSN/AMMOS unification, and that had to do with the still separate sources of programmatic direction at NASA Headquarters.
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Figure 9-18. Organization of the National Aeronautics and Space Administration, 1996. In the new organization, the responsibilities of Code O (the former Office of Space Communications) were distributed among the Centers, the Office of Space Flight, and the Space Operations Management Office (SOMO). It was SOMO that provided programmatic direction for the DSN-related elements of TMOD. Code S, the home of the Space Science Enterprise, continued to provide the source of funding for the MGDS-related elements of TMOD.

The directives of the 1996 National Space Policy, and its focus on NASA research and development efforts, were eventually manifested in the NASA Strategic Plan. This called
for a restructuring of the NASA organization based on four grand “Strategic Enterprises.” The organizational structure took the form shown in Figure 9-18.

Plans held that by Fiscal Year FY 1999, when the Consolidated Space Operations Contract (CSOC) would be in effect, CSOC would have responsibility for both the DSN and AMMOS elements of TMOD. With that final step, the DSN/AMMOS unification would be complete.

NOTE: Each of the four Strategic Enterprises was affiliated with one or more of the NASA Field Centers as shown in the chart. The Space Science Enterprise was affiliated with JPL. However, it was from endeavors in support of the Space Science, Mission to Planet Earth, and Space Flight Enterprises that requirements for the data and mission services that were the prerogative of TMOD would be derived. Two of the four Enterprises were subsequently renamed as their missions were revised. In 1997, the four Enterprises were named Space Science, Mission to Planet Earth, Human Exploration and Development of Space, and Aeronautics and Space Transportation Technology.

TMOD Primary Challenge: 1997

In the 1998 Strategic Plan, NASA established the following near-term, mid-term, and long-term goals for the four Enterprises:

• 1991–2002: Establish a virtual presence throughout the solar system

• 2003–09: Expand the horizons

• 2010–23: Develop the frontiers

Commensurate with these goals, SOMO estimated that the Space Science Enterprise would require data and mission services support for 86 missions through 2004; Mission to Planet Earth would require support for 34 missions; and Human Exploration and Development of Space would require support for 18 missions. A significant number of these missions would involve TMOD and, with more complex investigations and instruments characterizing these missions, would lead to a dramatic increase in the demand for data and mission services over the next several years. This, said Squibb, would take place against an environment of highly constrained, albeit level, budget resources. The situation and the scope of the challenge it presented to TMOD were well illustrated in the graphic shown in the 1997 Space Communications Budget Review and reproduced in Figure 9-19.
As 1997 ended, TMOD was challenged to provide “world-class” data and mission support for an ever-increasing number of missions in the face of the essentially fixed budget shown in the graphic.

To meet this challenge over the following three to five years, Squibb established a set of five goals for TMOD:

• increase data return capacity by a factor of 2.6,

• accomplish a significant portion of TMOD work through interaction with at least 10 strategic partners within five years,

• improve TMOD’s performance by capturing all of the data available from space missions.
• complete the transformation of TMOD into an organization that provides a full Mission Operations Services system, and

• reinvest operations costs savings into technology and development that will yield further cost and performance improvement.

Together with a metric to measure progress and a strategy for action, the goals would form the core of TMOD implementation planning for the years ahead.

With these goals and their enabling technology accomplished, Squibb expected TMOD to not only survive in a realistic new budget environment, but also to move forward, as a vital element of the NASA Strategic Plan, into the new millennium. He put his expectations this way: “In the foreseeable future, the world will witness technological advances that will dwarf those of the past. Before long, our culture will embrace an understanding of the universe that includes, among other things, its origins, evolution and destiny, the distribution and character of planets around the stars, and occurrence or prevalence of life in those environments. I fully expect the people of TMOD to be among the leaders and innovators who will make these things happen.” It was a clear and ringing challenge to the people of the DSN, the engineers and scientists, technicians and administrators, and supervisors and managers at all levels who composed its vital essence. The measure of their response and the record of what they achieved was, of necessity, a task for future historians of NASA’s Deep Space Network.
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Endnotes


