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# Networks Consolidation Program

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*The Networks Consolidation Program (NCP) was established by NASA in the fall of 1979 to implement the recommendations of the Networks Planning Working Group, which had been presented at NASA Headquarters in October of that year. The goals of the NCP were defined to include the planning, designing, and implementing of a single network of ground tracking stations.*

*The proposed consolidated network will make use of facilities that are now included in the Goddard Ground Spaceflight Tracking and Data Network as well as the existing JPL Deep Space Network. These facilities will be combined and modified to provide a consolidated network that is capable of supporting the set of planetary and Highly Elliptical Earth Orbiter missions that are planned for the Tracking and Data Relay Satellite System era.*

*This report traces the history of activities and events that led to the decision to consolidate the NASA ground tracking and data networks. It also presents a summary of the management and planning activities that have taken place at the Jet Propulsion Laboratory, Goddard Space Flight Center, and at the NASA Headquarters Office of Space Tracking and Data Systems, with respect to the NCP, from the time of decision in October 1979 to the present.*

## I. Introduction

The Deep Space Network (DSN) provides radio metric data and acquisition support for unmanned spacecraft engaged in the scientific investigation of both the planets and interplanetary space. Communication with and tracking of Earth-orbiting spacecraft have been performed by a world-wide network of ground-based tracking stations known as the Spaceflight Tracking and Data Network (STDN). This network has traditionally handled all Earth orbiters including Highly Elliptical Earth Orbiter (HEEO) and near-Earth missions. The latter class will be serviced by the Tracking and Data Relay Satellite System (TDRSS) when it becomes operational as a part of the STDN early in 1984. The few remaining HEEO missions would be serviced by a portion of the Ground Spaceflight Tracking and Data Network (GSTDN). As shown in Fig. 1, GSTDN stations are located at twelve separated geographical positions. Because of both limited numbers of such future planned missions, and continued high cost of GSTDN maintenance and operations (M&O), a TDRSS era planning study was directed by NASA to identify possible economic alternatives.

The TDRSS was conceived as an alternative means of providing tracking and data relay support for a large class of Earth-orbiting satellies by using a set of satellite relay stations in stationary orbit above Earth's equator. With its two operational satellites (Fig. 1), the TDRSS will provide the potential for near-global, real-time coverage (at least 85 percent of each orbit) for most users. But current and future planned HEEO missions will operate above, or outside of the TDRSS zone of coverage. In many respects, such missions have operational parameters that are similar to those missions that are supported by the DSN. Thus, the question was raised, "was there any combination of GSTDN and DSN that could result in more economical support for those missions that could not be supported by the TDRSS?"

To address this question, NASA Headquarters determined that a study effort should be conducted jointly by its Office of Space Tracking and Data Systems (OSTDS), by the Jet Propulsion Laboratory (JPL), and by the Goddard Space Flight Center (GSFC). Known as the Networks Planning Working Group, the study commenced in May 1979 and concluded in October 1979. The results of the study are summarized here. For more detail, Ref. 1 should be consulted.

## II. Background

The OSTDS Networks Planning Working Group included representatives from OSTDS, GSFC, and JPL in addition to members from the Spanish Instituto Nacional de Tecnica Aerospacial (INTA) and the Australian Department of Science and Environment (DSE).

A Networks Planning Workshop was held on June 11 to 15, 1979, at GSFC. At that time identified options were reviewed, compared, and ranked. Three were selected and presented to NASA's Associate Administrator for OSTDS on June 13, 1979. General encouragement to proceed with the detailing of three primary options was indicated. These options were: (1) the current plans for the DSN and GSTDN (as a baseline), (2) a hybrid network, which would retain the separate identities of the two present networks, but which would provide enhanced cross-sharing of facilities between them, and (3) a single consolidated network, presumably under the management of JPL.

### A. Goals and Objectives

The explicitly stated goal of the 1979 planning effort was to devise a technical and managerial approach that would: (1) provide adequate support for flight projects that cannot be supported by the TDRSS; (2) not preclude other potential NASA missions (e.g., geodynamics); (3) make best use of existing NASA facilities; (4) be consistent with realistic NASA resources; and (5) provide appropriate and useful roles for the several involved organizations, which include NASA Headquarters, GSFC, JPL, INTA, and DSE.

Throughout the planning effort, it was assumed that the TDRSS would provide support for all low Earth-orbiting spacecraft by 1984. GSFC would continue to manage the TDRSS including its associated ground station and control center. Also, any proposed consolidation of the GSTDN and DSN was not to take place until the TRDSS was operational and all GSTDN support of low Earth-orbiting spacecraft was complete. Phasedown of the unneeded GSTDN facilities would also be completed by GSFC before consolidation.

There were two main drivers considered in developing the study. One was economy. The second was the 1986 Voyager encounter at the planet Uranus, as shown in Fig. 3. Enhancement of the X-band telemetry capability, an essential part of the networks' consolidation, would be repaid in additional data from this never-before-explored planet, if the enhancement could be completed before late 1985.

### B. Baseline for Separate Networks

The GSTDN plans for the TDRSS era called for a gradual phasedown of the network, as shown in Fig. 1, with the following exceptions: (1) the GSTDN main sites, consisting of Orroral Valley (ORR), Australia, Goldstone-Mojave (GDS), California, and Madrid (MAD), Spain, are approximately colocated with DSN sites as shown in Fig. 2; (2) stations in Florida (MILA) and Bermuda (BDA), which provide shuttle launch, landing, and range safety support; and (3) the station located at GSFC (ETC) would be dedicated to support of geosynchronous spacecraft.

The baseline plan for the GSTDN also included some automation of the main sites after phasedown was complete. This automation was expected to achieve operational savings in the 1985 to 1987 time period. Also, the baseline plan for the DSN's evolution into the late 80s would result in the Mark IV DSN (1988) configuration. Enhanced navigation, telemetry, and radio science capability were to be concentrated in the Goldstone complex. Overseas tracking would be provided by the present conjoint stations with only minor improvements in their existing capability complement.

### C. A Consolidated Network

In the 1979 study, the Consolidated Network, composed of elements from the present DSN and the GSTDN main sites, showed markedly less cost and more capability than the sum of the separate networks. This option was planned around the then-existing plan for the Mark IV DSN augmented by GSTDN facilities and resources to support the HEEO missions, to enhance the deep space telemetry capability, and to reduce future maintenance and operations costs. Figure 2 is a top-level overview of that Consolidated Network. Each of the complexes contained all of the DSN and GSTDN antennas planned for each locale. The 26-meter antennas were, in all cases, to be expanded to 34-meters for increasing X-band telemetry capability. The enhanced features of the DSN plan for Goldstone were also included. A Signal Processing Center (SPC) would be established at each of the three complexes and provide economies through the concentration of functions, with a corresponding reduction in manpower required by the stations at each complex.

### D. Selection Criteria

The selected approach had to fit within both the projected NASA resources and the institutional capabilities of the "doing" organizations. Also, it needed to be acceptable to the participating organizations. The network life-cycle costs needed to be minimized, subject to a constraint of limited initial funding. Also, the approach would need to make the best use of existing NASA facilities and costs that had already been incurred.

Further, the selected approach was not to inhibit radio astronomy and radio science. If possible, it was not to preclude OSTDS support of future NASA initiatives, such as geodynamics.

### E. Recommendations

On August 1, 1979, the Networks Planning Working Group presented their recommendations at a JPL Formal Review, which included members of the JPL Senior Staff and the Office of Telecommunications and Data Acquisition (TDA) Advisory Council. With their support, the working group concluded the OSTDS review on August 13, 1979, with a series of recommendations. It was suggested that the Networks Consolidation Plan (NCP), as presented, be adopted as a baseline plan for the ground tracking networks and that OSTDS and JPL Program Managers be appointed with responsibility for the networks' consolidation. Work leading to the Mark IV DSN was to be continued insofar as it contributed to the networks' consolidation. The plans to phase down GSTDN support of low Earth orbiters were to be continued.

The working group further recommended that system engineering and management studies should be supported in FY 80 to: detail improvements, such as centralized control and signal processing; prepare a detailed Networks Consolidation Implementation Plan that considers life-cycle costs in view of schedule; integrate network combining with other implementation plans; prepare a Networks Consolidation Management Plan; and prepare a Mission Support Plan for the consolidation period. Design engineering and implementation would begin in FY 81 according to detailed plans developed in FY 80, along with system contracting preparations needed to support the NCP.

## III. Management Planning

Pursuant to these recommendations of the Networks Planning Working Group and the subsequent approval of those recommendations by NASA Headquarters, steps were taken to establish both the NCP and a program management structure. The latter was to include representatives from each of the participating organizations.

By January 1980, an NCP Office was established at JPL in the TDA Office. Simultaneously, program offices were established at GSFC and in the OSTDS. JPL and GSFC management and technical counterparts were identified, and monthly working sessions were initiated.

### A. NCP Flight Mission Set

The JPL Program Manager began discussions with GSFC and OSTDS in February 1980, in an effort to establish a meaningful flight mission set that the Consolidated Network would need to fulfill its support role, and upon which the design of the total network would depend. Figure 3 shows the mission set currently under consideration.

### B. Organization

The NCP is organized within the TDA office in JPL, under the NCP Manager. He directs the accomplishment of the networks' consolidation, together with the OSTDS and GSFC NCP Managers. Additional management support will be provided by the Spanish INTA and Australian DSE agencies. This multiagency organizational structure is depicted in Fig. 4. In addition to these participating organizations, a steering committee and a review board have been formed at JPL to support the NCP Manager. A Planning Team and a System Design Team have been organized to conduct the initial planning and system engineering activities required prior to the detailed design and implementation phase. The Planning Team organization consists of representatives from the key technical divisions within JPL that support the DSN, together with representatives from the organizations in the TDA Office.

The System Design Team also comprises both Technical Division and TDA personnel. Each of several task areas is headed by a Task Leader from a Technical Division with assistance from a Systems Engineer in TDA Engineering (Office 430).

At GSFC, accomplishment of the NCP is supported by the Networks Directorate and the Mission and Data Operations Directorate.

## C. Schedule

The near-term schedule shown in Fig. 5 covers the initial planning phase of NCP activity. This first phase, comprising Program Planning and Systems Engineering, occurs basically in CY 1980. Development of high-level and detailed program plans, performance of special engineering studies, and establishment of a baseline system design are scheduled to be accomplished during this phase.

The overall schedule drivers are: the date on which the TDRSS is declared fully operational (presently estimated to be not later than January 1984), and the Voyager encounter at the planet Uranus beginning in November 1985.

## D. Program Directives

The Networks Consolidation Program directives consist of technical and managerial guidance derived primarily from the OSTDS Networks Planning for the TDRSS Era Study (Ref. 1). Planning assumptions, Consolidated Network design strategy, and technical and managerial option selection criteria have been adopted from this study. They are to be used as the constraints, assumptions, and design strategy to be adhered to in accomplishing the NCP.

The program constraints include the following: the Consolidated Network will not support low Earth-orbital spacecraft, which are by design and policy to be supported exclusively by the TDRSS; the networks' consolidation cannot be completed until the TDRSS is fully operational and GSTDN support of low Earth-orbiting spacecraft is terminated; the consolidation of the networks must be accomplished within a relatively fixed NASA budget; management of the NCP should not preclude provision of tracking services by other host countries or other agencies; and the networks' consolidation is not intended to compensate for the decrease in ground station support of Earth-orbiting spacecraft that will occur because pre-NCP GSTDN stations are being closed. This decrease in ground station support is the result solely of the decision to support such spacecraft by TDRSS and is not related to the networks' consolidation effort.

The program assumptions include the following: TDRSS will be fully operational and providing support for low Earth-orbiting spacecraft not later than January 1984 (GSFC has the management responsibility for TDRSS); phasedown of unneeded GSTDN stations will have been started before the networks are consolidated; equipment from other closed GSTDN stations can be made available for incorporation into the Consolidated Network as the GSTDN is phased down; equipment obtained from GSTDN stations will be configured to make it compatible with the DSN mode of operation; existing staff will be available and can be trained to operate and maintain the developing Consolidated Network, so that additional station and complex personnel will not be needed; and CTA 21 and MIL 71 will continue to exist as functional entities, CTA 21 shall be revised to simulate an SPC and its associated Front End Areas (FEA), and MIL 71 shall be reduced to the configuration that is needed for spacecraft-network compatibility tests and will be activated only when needed for specific flight projects.

The preliminary design strategy is discussed in the baseline system development section later in this article. It is also based upon the following important criteria: the primary means of increasing aperture for enhancing deep-space telemetry reception shall be the arraying of multiple antennas that shall be provided at each of the three complexes; all antennas together with their associated FEA subsystems shall operate in the unattended mode for all normal tracking; signal processing equipment shall be interchangeable between planetary and HEEO spacecraft communications links; design shall plan for a minimum operational lifetime of 10 years; standard data interface protocols and formats that are compatible with TDRSS spacecraft interfaces shall be established; redundancy shall be incorporated only to the extent that it is necessary to provide required schedule and functional availabilities; the Consolidated Network shall provide the same radio science and radio astronomy capabilities that are present in the pre-NCP DSN, i.e., the capabilities that are designated in the Support Instrumentation Requirements Documents (SIRDs) for these activities; consider using turn-key contractors to convert 26-m antennas to 34-m antennas in order to expedite the conversion; economize in the usage of energy from nonrenewable sources by using an energy cost inflation factor that is at least twice that used for other costs when estimating life-cycle costs; accommodate command rates up to at least 1 kbits/s in various modes; and incorporate the ability to detect direct carrier modulation.

## E. Reviews and Reports

NCP reviews are conducted by a Formal Review Board convened by the JPL Assistant Laboratory Director for TDA. NCP status reports are presented periodically at the Director's Report and Discussion (DRD) to acquaint upper levels of JPL management with the NCP. On-going reviews of program directions and progress are conducted by an NCP Steering Committee chaired by the JPL Manager of TDA Special Projects and is composed of JPL experts and external consultants.

Also, two categories of reviews are held at NASA Headquarters to insure that OSTDS Management is kept informed of the status and progress of the program with respect to both budgets and technical matters. First, budgetary reviews are scheduled in six-month intervals as a part of the Work Authorization Document (WAD) review cycle. Second, technical reviews are scheduled on a quarterly basis to provide the OSTDS NCP Manager with a current status report on all aspects of program progress.

Standard NASA/JPL reports are used for program-level reporting and include the Network Management Report (NMR), which is prepared monthly. Also, Implementation Schedule (IMPSKED) Reports are generated quarterly for NASA management, and periodic inputs are provided to the TDA Progress Report.

## IV. System Design Approach

The approach used in designing the system for the networks' consolidation has been one of developing a baseline design that is in conformity with the constraints, assumptions, and design strategy set forth in the Management Plan. Desirable alternatives are then studied to determine their effect on the cost and schedule of the baseline system. Constrained by overall budget effects, the optimum NCP system resulting from this approach will then be selected, developed, and implemented.

### A. Baseline System Development

The baseline system that is being developed for the three complexes (Goldstone, Canberra, and Madrid) includes all of the DSN and GSTDN antennas previously in existence, or planned for in each of those locations. In particular, the GSTDN 9-meter and 26-meter antennas, near each of the DSN complexes in California, Australia, and Spain will become part of the Consolidated Network. These complexes are shown in Fig. 2. Typical DSN and GSTDN stations are shown in Fig. 6 prior to consolidation. The DSN 64-, 34- and 26-meter subnets utilize separate signal processing facilities, generally located at a distance of 5 to 20 km from the Communications Terminal of NASCOM. Also, radio metric signal data, from the GSTDN 9-meter and 26-meter antennas are directed to GSFC via NASCOM.

Figure 7 shows the general complex configuration after the networks' consolidation. A central Signal Processing Center (SPC) will be established at each of the three complexes. Each center provides signal processing and monitor and control facilities for all antennas in the complex, as well as all other functions that are centralized there. The objective of these centers is to provide maintenance and operations cost savings through concentration of functions and a corresponding reduction in manpower. In the Consolidation Network being developed, the front-end area (FEA) of each antenna is to be located at a distance that is less than 1 km from the SPC. This enables RF signal combining, which enhances arraying of multiple antennas. The resulting increase in aperture is useful for improving deep-space telemetry reception. Antenna arraying capability is to be provided at each of the three complexes. Received RF signals are amplified and down converted in the FEA, where all antenna functions are also monitored. Both the 64-meter and the present 34-meter antennas at each complex will be used to track planetary and interplanetary spacecraft. When appropriate, tracking of planetary spacecraft will be augmented by arraying one or more converted DSN or GSTDN 26-meter antennas. An example of this is the planned future support of the Voyager encounter with Uranus. The GSTDN 9-meter antennas are not intended to be used to support planetary and interplanetary missions. However, the GSTDN 26-meter and the present DSN 26-meter DSN antennas will be converted to 34-meter, high-efficiency, S- and X-band listen-only antennas. These antennas will be capable of supporting either deep-space or GSTDN missions.

### B. Special and Alternative Studies

In developing the baseline system, special studies have been conducted in an effort to establish the parametric requirements of the NCP. A special assessment is being made of NCP capability to support HEEO missions in terms of possible special navigation requirements. Additionally, NCP mission support requirements are being analyzed in view of existing mission scheduling resources.

Because of the antenna arraying objective for NCP, certain alternative studies are also being conducted. The results of these studies are necessary to make high-level decisions, including "to move or not to move" certain antennas. Arraying may be enhanced by relocation of some of the antennas within any given complex. Accordingly, cost tradeoffs are being determined for relocation of certain antennas vs possible reconfiguration for remote operation. Also, RFI and performance degradation of antennas colocated in high-density arrangements are under investigation, along with possible weather effects. Microwave link and fiber optic techniques are being considered as a possible means for transmitting received RF data from some of the antenna FEAs to the SPC for possible RF combining. This would further enhance antenna arraying.

### C. Present NCP System

Current study and planning for the Consolidated Network is directed towards selection of a final system design. In general, the configuration has been developing in the direction shown in Fig. 8. The three complexes, Goldstone, Canberra, and Madrid, provide output data from their SPC to the Central Communications Terminal at JPL. There the data is further distributed to the Network Operations Control Center (NOCC), the Mission Control and Computing Center (MCCC), and other Project Operation Control Centers (POCCs).

As shown, the three complexes will have basically the same capability. The Goldstone complex will include the DSN Deep Space Stations (DSSs) 11, 12 and 14, and the GSTDN 9- and 26- (converted to 34-) meter stations. The transmit (XMT) and receive (RCV) capabilities in S-band (S) and X-band (X) are shown in Fig. 8 for the various stations. Also, a microwave relay link connects DSS 12 and the SPC because of their geographic separation. Capabilities at the Australian (Canberra) and Spain (Madrid) complexes are similar. At all three complexes, the GSTDN 9-meter stations have an S-band transmit capability, since these stations will provide for command of HEEO missions. In all Deep Space Stations shown, an objective is to make the FEA (Fig. 7) operate in an unattended environment.

## V. Future Plans

As the system design for the Consolidated Network proceeds, planning for its implementation is also progressing. This includes the important supporting areas of transition and mission support. Planning activity, to date, is reported below. As progress is made, it will be presented in future reports.

### A. Implementation Plan

The NCP Implementation Plan is currently being developed to provide the more detailed technical and managerial approaches to the work that must be performed on the present GSTDN and DSN elements to convert them into the fully operational Consolidated Network.

The plan will provide the processes and approaches to be followed for accomplishing the networks' consolidation during the detailed design, production, installation, and test phases. It will specifically define the constraints on, and assumptions for, NCP implementation, and the interrelationships between participating organizations and program plans. When completed, it will also describe the organizational structure, responsibilities, authorities, and communication interfaces for NCP implementation management. Finally, it will present the orderly sequence of events to be followed at all network facilities and locations for accomplishing implementation of the Consolidated Network. Preliminary planning, to date, is typical of that shown on the target schedule of Fig. 9.

### B. Transition Plan

As an interrelated part of the implementation process, the objective of the Transition Plan is to provide directions for transferring, from GSFC to JPL, the network responsibility for the GSTDN missions to be supported by the Consolidated Network. This change must be accomplished without adversely impacting ongoing flight projects support.

The plan will address three general transition areas including management, operations, and configuration. In the management and operations areas, specific functions to be transferred are being identified. Thereafter, detailed transfer criteria will be developed. Described in detail will be hardware and software elements required from GSFC (if applicable), staffing and budget requirements, and the JPL organization(s) to be responsible after transfer of responsibility from GSFC. In the configuration area, the equipment arrangements that are unique to the transition period will be developed.

### C. Mission Support Plan

Also importantly related to the implementation process is the Mission Support Plan. It will provide the detailed technical and managerial requirements for maintaining adequate support of the flight projects that will be using the Consolidated Network during its transition, implementation, and fully operational stages.

When completely developed, the plan will describe how the DSN will support each of the users of the Consolidated Network. Each mission will be described in terms of the technical characteristics required by NCP planners and designers for network capacity planning and network configuration establishment.

Network user interfaces are being developed as part of the plan. Network scheduling, predicts generation, data delivery, and network operations support will be defined to allow potential users an understanding of the requirements for accessing and obtaining Consolidated Network support.

The Mission Support Plan will specify the user support strategy to be followed during transition to the Consolidated Network. In particular, the specific activities required to demonstrate operational readiness will be delineated in the plan, along with initial planning phase network user interfaces and mission support strategy. The interfaces and commitments specified in the plan will be finalized in the Network Operations Plan (NOP) and Network Support Plan (NSP) prepared for each network user.

# Reference

1. Layland, J. W., *OSTDS Networks Planning for the TDRSS Era*, OSTDS Report, January 1980.

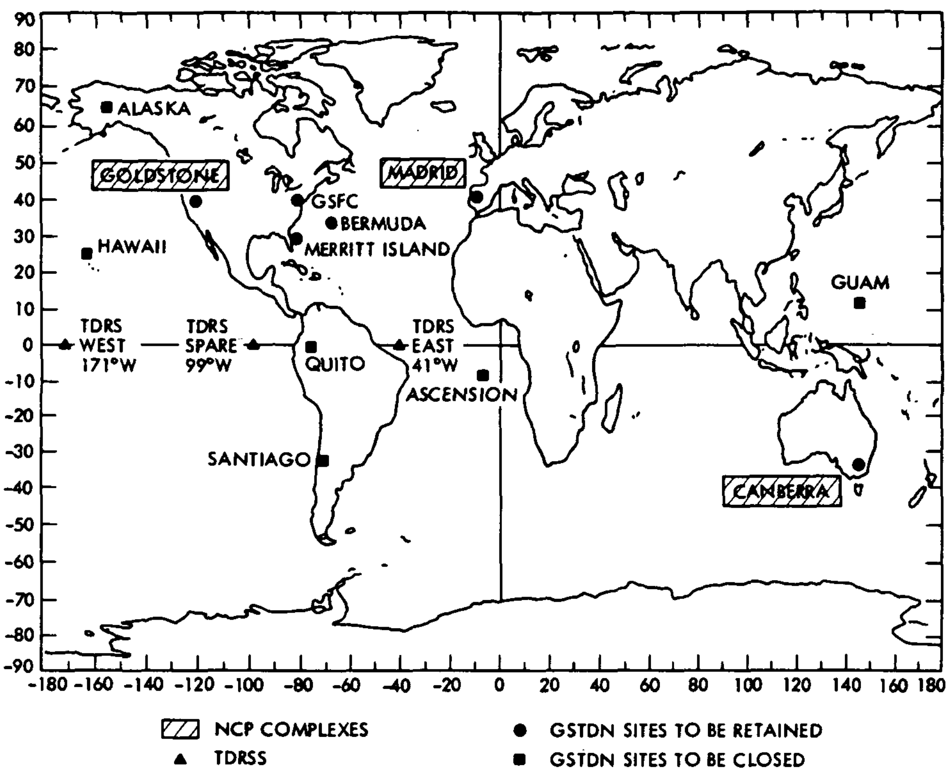


**Fig. 1. Location of NASA ground stations**

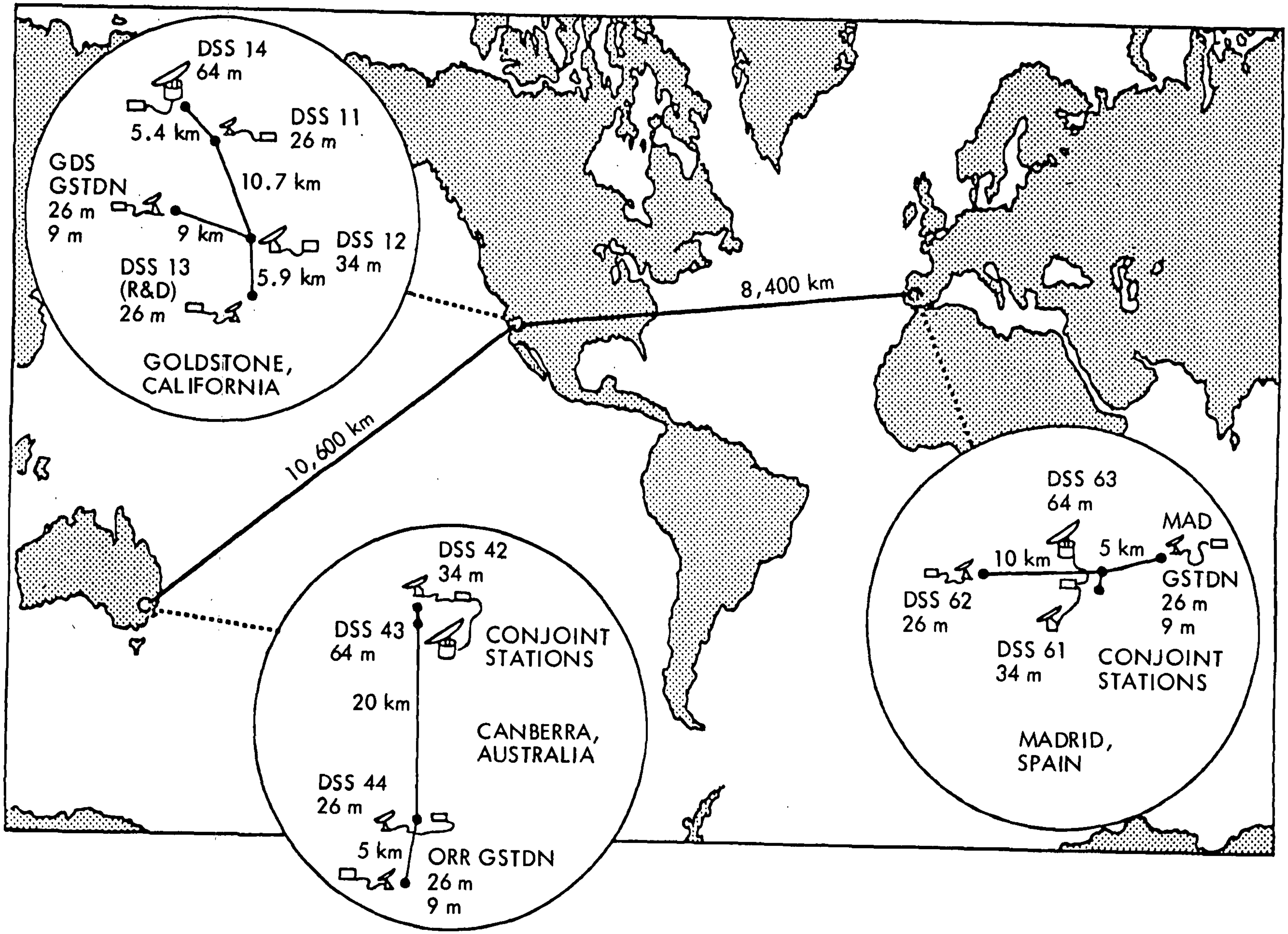


Fig. 2. Deep Space Network complexes

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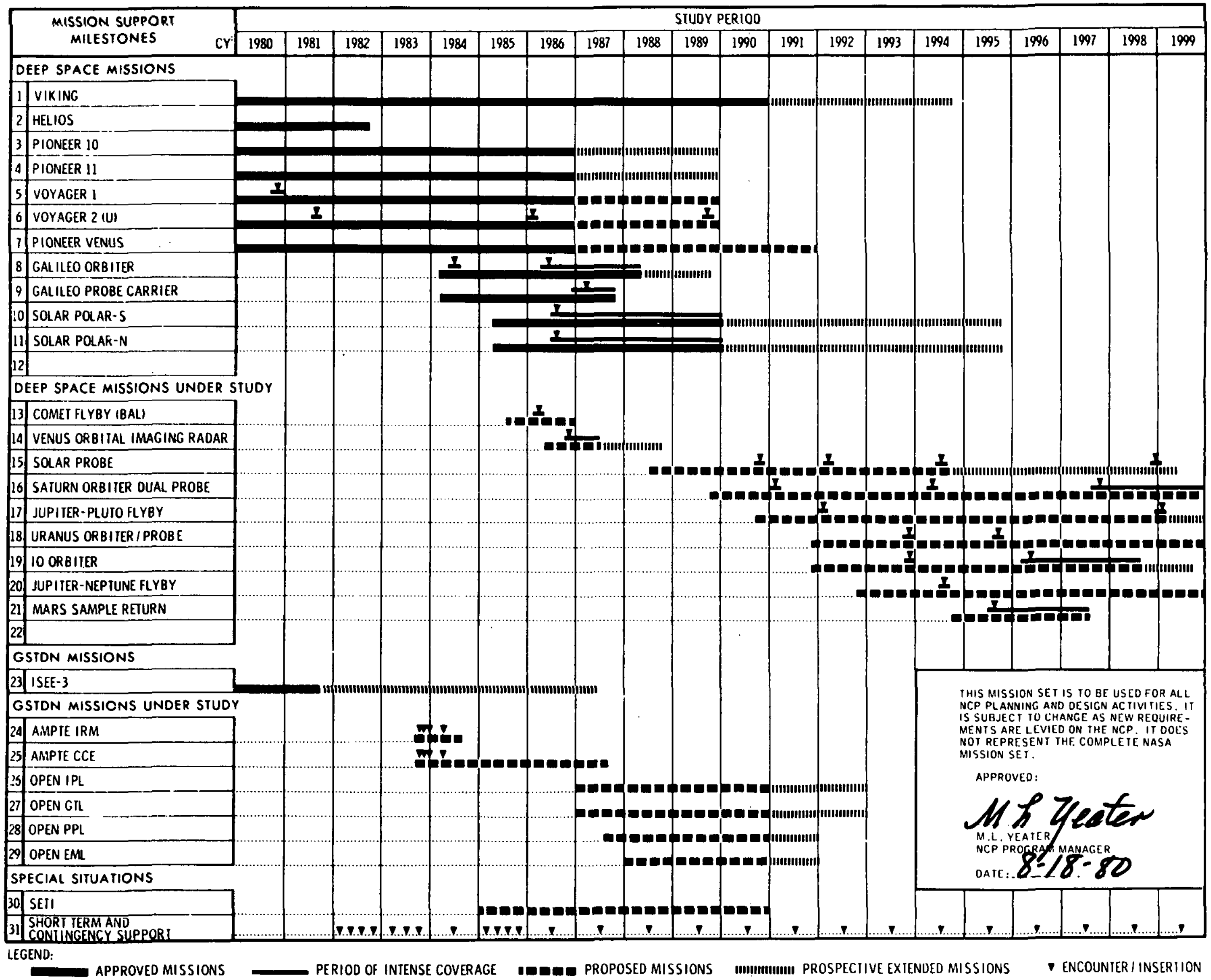


Fig. 3. NCP flight mission set

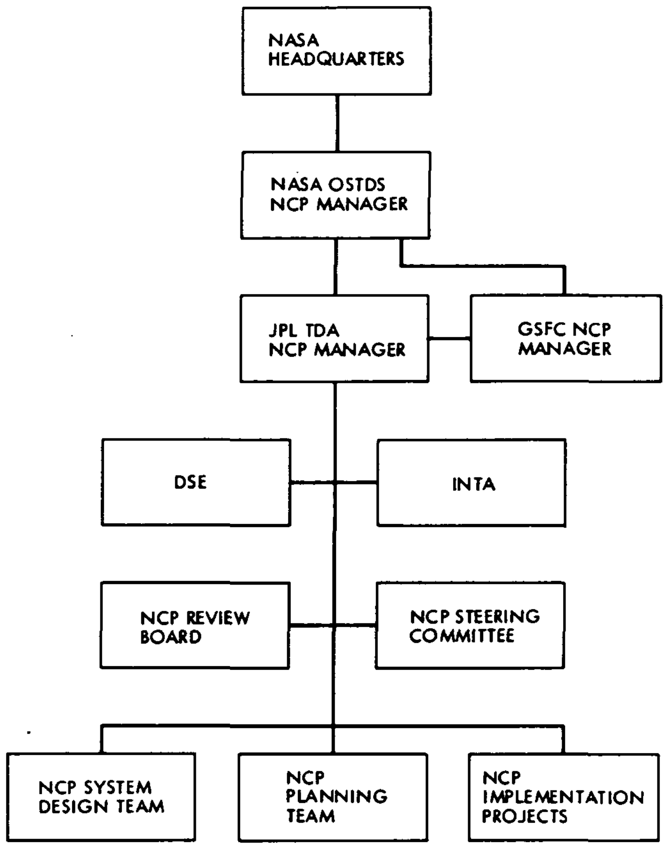


**Fig. 4. NCP organization**

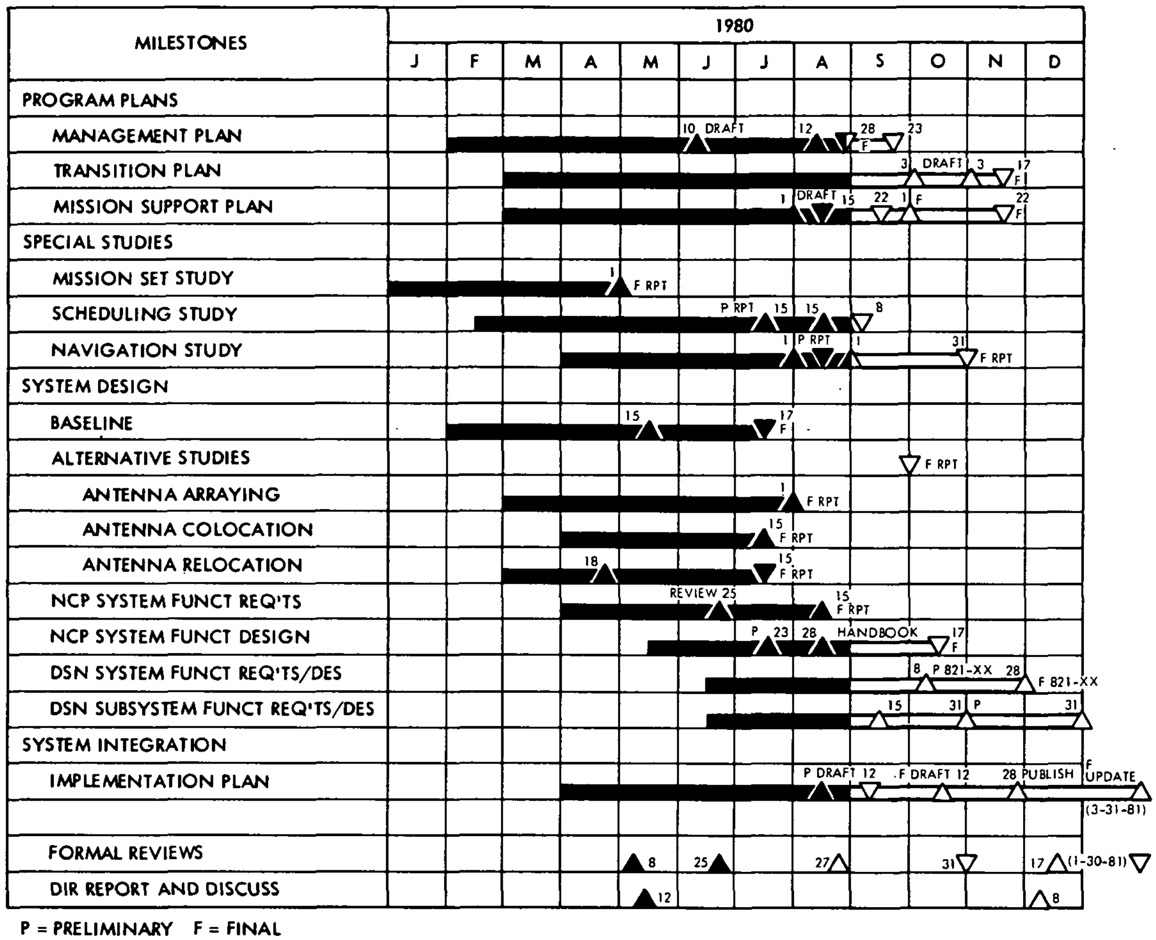


**Fig. 5. Planning and design schedule**

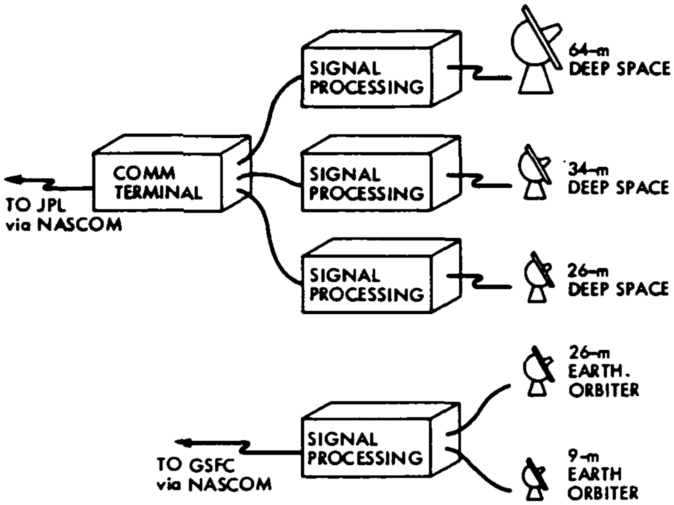


**Fig. 6. Typical complex before the networks' consolidation**

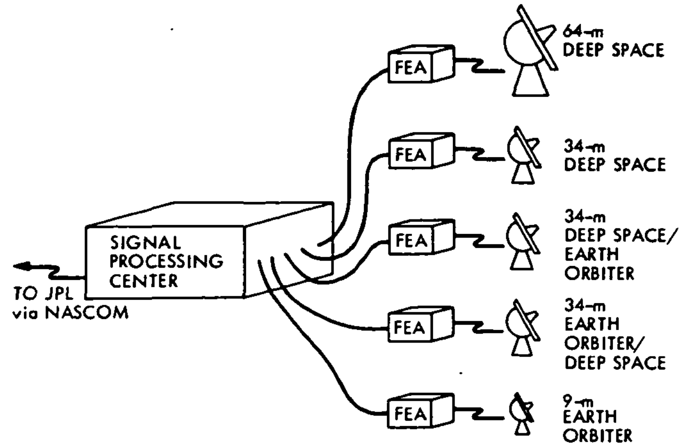


**Fig. 7. Typical complex after the networks' consolidation**

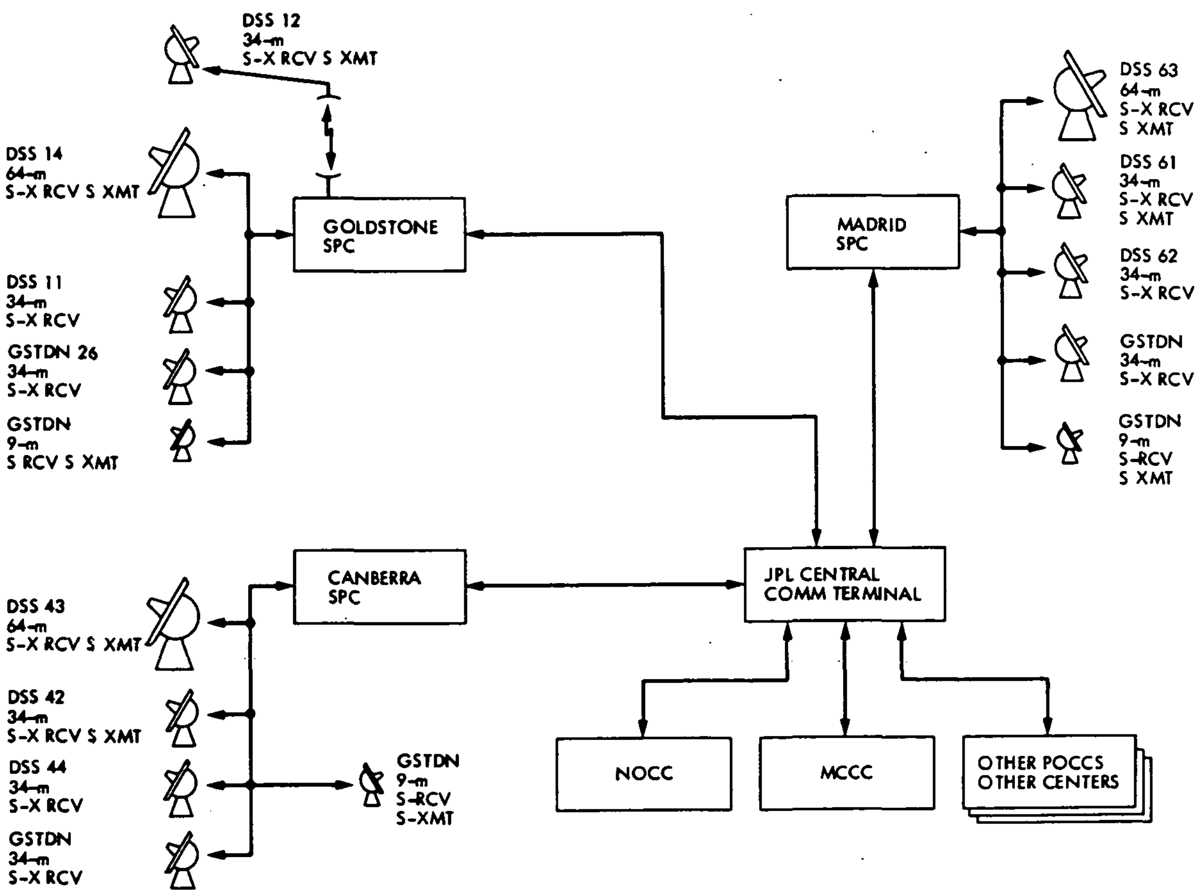


**Fig. 8. Consolidated network configuration**

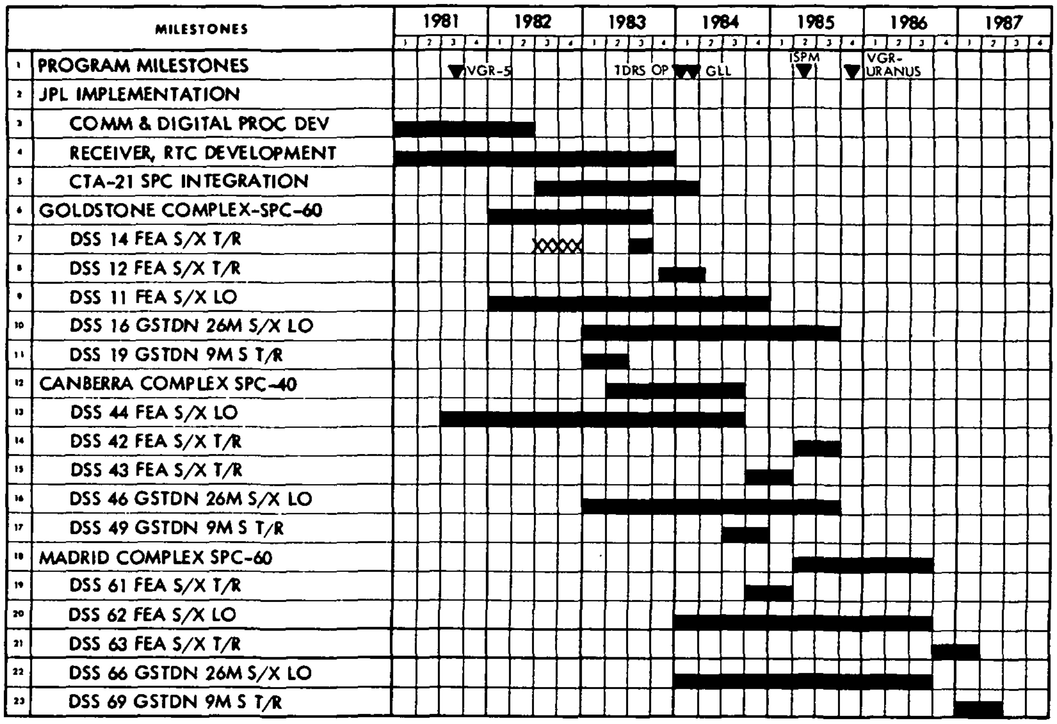


**Fig. 9. Network Implementation Schedule**