26-Meter S-X Conversion Project

V. B. Lobb
DSN Engineering Section

The 26-meter S-X Conversion Project provides for the conversion of an existing 26-meter S-band subnet to a 34-meter S- and X-band subnet. The subnet chosen for conversion consists of the following stations: DSS 12 near Barstow, DSS 44 in Australia, and DSS 62 in Spain. The Conversion Project has evolved from its formative stages, where many options were considered and alternates chosen, to its present status. The main Subsystems effected by this project are the Antenna Mechanical, Antenna Microwave, and Receiver-Exciter. In addition to these, there are many project-related electronic equipments that have been added to the existing station equipment. Functional Requirements and Design Response Reviews were held. The major subsystems are essentially through the design stage with the Antenna Mechanical Subsystem completed through detail design with procurement in process.

I. Introduction

The objective of the 26-meter S-X Conversion Project is to add an X-band (8.44-GHz) receive capability to the existing 26-meter antenna S-band (2.1 to 2.3-GHz) stations and increase the station's gain capability by increasing the antenna aperture from 26-meters to 34-meters. The X-band receive capability is needed to provide adequate data returns from the outer planets and improve immunity from the increasing incidences of radio frequency interference that have been occurring at S-band. The aperture increase from the 26-meter antenna to a 34-meter antenna was to increase the antenna gain, and hence its usefulness to the MJS'77 Mission and other outer planet missions, and to enhance this subnet's offloading capability of the 64-meter subnet during cruise modes.

The selection of the subnet to be converted was made on the basis of the constraints of "shared equipment" and "single point of failure". This selection process led to a subnet of stations that were not conjoint stations. The S-X conversion schedule for the selected subnet is as follows: DSS 12 (Goldstone) shall be completed by 1 December 1978, DSS 44 (Australia) shall be completed by 1 April 1980, and DSS 62 (Spain) shall be completed by 1 October 1980.

The main modifications occur in the Antenna Mechanical, Microwave and Receiver-Exciter Subsystems with other project-related station electronics to be added. These modifications are shown in Table 1 and are described in further detail in the following text.

II. Background of the 26-meter S-X Conversion Project

The project's formative stage started in an exploratory discussion held on 14 January 1975, between representatives of the Telecommunications Science and Engineering Division and TDA Engineering Office personnel. This meeting outlined the following early project assumptions for preliminary estimates as to the project's cost:

(1) Use of a Block IV receiver.

(2) Use of a Coherent Reference Generator Assembly.

(3) An enlarged primary reflector with shaping.

(4) S-X simultaneous operation (2-way S-band; coherent X-band downlink).

(5) Microwave hydrogen frequency reference from DSS 14 to DSS 12.

(6) The S-X 26-meter subnetwork is comprised of stations 12, 42, and 61.

(7) No X-band uplink.

(8) Planetary ranging to be included.

A 26-meter upgrade study team was formed on 29 April 1975 for the purpose of preparing budget guidelines and a detailed Implementation Plan, including the cost and schedule for an August 1975 OTDA and JPL-TDA Budget Review.

Four meetings were held with members of the study team reporting work progress and action items. The net result of this study was an Implementation Plan for $7.4 million for hardware that concerned three major Subsystems (Antenna Mechanical, Antenna Microwave, and Receiver-Exciter). It did not include station electronic equipment. In addition to this basic plan, there were three main options proposed. These options were an aperture increase, shaping, and a 65-kW S-band transmitter, which had a total cost of $3.5 million.

A meeting was held on 27 August 1975 after the plan was presented to OTDA for the purpose of reviewing the configuration and costs for a "baseline system" (a bare minimum requirement program). This meeting and subsequent study by team members resulted in many options and alternates being evaluated and either selected or rejected. At this stage the required station electronic equipments were added.

After this study effort was completed and the November 1975 OTDA Review meeting was held, the following decisions were made in December 1975:

(1) Recommended stations were DSS 12, DSS 44, and DSS 62.

(2) Authorized immediate initiation of design for DSS 12.

(3) The described antenna diameter is to be 34-meter. The 34-meter design will be reviewed prior to proceeding with the hardware.

(4) Schedule to be per Fig. 1.

(5) Defer all performance enhancement options.

(6) Baseline implementation to be per Table 2.

The site selection factors, as differentials, are shown in Table 3 with indicated selected stations.

The main options that were deferred were the 65-kW S-band transmitter and antnenna shaping. The baseline concept included the use of existing S-band microwave components such as switches, diplexers, filters, and maser. The use of the existing Block III Receiver-Exciter Subsystem modified to receive X-band was selected. The deferred options were as follows:

(1) Electric drives for the antenna.

(2) Antenna thermally painted.

(3) Facility modifications at DSS 13 for cone assembly testing.

(4) Increased S-band doppler frequency range.

(5) 3-Hz loop for the Receiver-Exciter Subsystem.

(6) Remote control for S-X and S-S translators.

(7) Remote control for S-band polarization.

Thus the 26-meter S-X Conversion Project was initiated with the start of design of hardware for DSS 12 and the Project budgeted in the FY-76 WAD. Using the previous work of the study team, the assigned personnel from the Telecommunications Science and Engineering Division and the TDA Engineering Office embarked on the development of a Data System Development Plan (DSDP) for the Project, which was completed and published on 1 July 1976.

III. Project Description

The addition of X-band receive capability to stations involves the following changes: a dual S- and X-band reflex microwave feed; the addition of an X-band maser; the addition of an X- to S-band down converter and X-band test translator for use with the existing Block III Receiver-Exciter Subsystem; the addition of an X-band harmonic filter to the existing S-band transmitter to prevent internal station interference. The microwave components will be housed in a new dual cone shell, which will support the reflex feed reflectors.

Within the station control room, the new X-band receive capability requires the addition of a second string of doppler extractors (for X-band) and two ranging channels, one for S-band and the other for X-band. Having this dual S- and X-band doppler and range (radio metric data) capability requires the introduction of cesium frequency standards and a minicoherent reference generator to provide the long-term frequency stability required to navigate spacecraft to outer planets. The X-band radio metric data needs to be processed in real-time and recorded. This will be provided by the addition of a Planetary Ranging Assembly, communication buffer, coded multiplexer, and dual high-rate, high-density tape recorders. The above functions are shown on a functional block diagram, Fig. 2.

The aperture increase from 26-meters to 34-meters requires extensive changes to the structure. These changes, along with changes to the shaft angle encoders and servo electronics, are shown on Fig. 3.

The DSS 44 station (originally a part of the STDN) is an X-Y antenna configuration, but the modifications still apply except for those associated with raising the antenna. Instead of raising the antenna structure, the topography is such that benching out of the hillside adjacent to the antenna foundation will allow for the necessary sky coverage.

IV. Project Status

The Project was organized with both a Programmatic Manager and Project Manager appointed to manage the S-X conversion task effective 1 October 1976. The Project Manager, representing the TDA Engineering Office, interfaces with the Telecommunications Science and Engineering and the Applied Mechanics Divisions in the implementation of the S-X conversion task through the TDA Division representatives. The interface to Operations Division 37 is through an appointed engineer. The interface with OTDA and TDA is through the Programmatic Manager.

Following the official appointment of the managers for this task, a Management Plan for the 26-meter S-X Conversion Project was prepared. This Plan was then approved by all the above mentioned Divisions and Office Managers, and was released on 1 December 1976.

This Management Plan covers the implementation of the 26-meter S-X Conversion Project. It defines the management approach and the project staffing, scheduling, and work description, which form the basis of an interorganizational agreement for project implementation.

In response to a request by the Project Manager, the JPL Quality Assurance Office published a Quality Assurance Management Plan for the Project on 15 January 1977. This plan covered the implementation of JPL quality assurance activities in support of the project. Its purpose was to define the quality assurance management approach, work description, and staffing in accordance with the Project hardware requirements and schedules.

The progress made from the official project start date of 1 October 1976 to present follows:

A. Station DSS 12

1. Antenna Mechanical Subsystem. The design and detailing of the antenna mechanical components (excluding servo and control hardware) was completed. The S-X reflectors and the dual cone shell fixed price contract was awarded to Capital Westward Inc. of Los Angeles and was within 5% of the budgeted funds. The quadripod and subreflector bid packages were sent to four vendors with the award expected by 1 April 1977. The reflector backup structure extension bid package was sent to vendors with the award expected by 15 March 1977. Raising hardware for the antenna is being fabricated at Goldstone and is 40% completed. Fabrication of metal forms, coring of holes into the existing foundation, and grouting of rebar ties for the 3-meter concrete pedestals into the existing foundation is in process with completion expected by 1 April 1977.

2. Servo and Control. The servo-pointing effort has been primarily in evaluating existing drive and pointing capabilities, and completing an electric drive option study.

The subreflector position controls computer program and operating requirements have been defined.

The angle encoder study for life-cycle cost on 18 bits versus 20 bits was completed with the 18-bit encoder being selected. Encoder prototype hardware was installed and tested on the antenna at the DSS 13 station.

3. **Antenna Microwave Subsystem.** The radio frequency instrumentation design was completed. The monitor receiver prototype test was completed. All long-lead items are in procurement with cryogenic accessory instrumentation procurement initiated.

Design of the Microwave Cone Assembly, which has been designated the SXD (S-band, X-band, Dual) cone assembly, was completed. The integration of maser and receiver components into this design has started. All long-lead components and materials are in procurement with some X-band feed parts in fabrication.

The X-band maser housing design was completed. Fabrication of maser parts and superconducting magnet was completed.

The microwave switch control configuration design is 50% complete.

4. **Receiver-Exciter Subsystem.** The engineering model for new module types has been completed, including breadboard testing and complete design documentation. The new module types are the frequency shifter, doppler mixer, doppler reference, frequency distribution, and frequency multiplier.

The new converter and translator assemblies for the engineering model are in the assembly stage with completion expected 1 March 1977. The modified control room cabinets for the exciter and control are in the manufacturing stage with modifications to be completed by 1 May 1977. Manufacturing of the same modules for operational equipment is 25% complete.

5. **Other Project-Related Electronics.** The design of the minicoherence reference generator has been started and is 15% complete. The coded multiplexer and GCF wideband NASCOM terminal has been rescheduled to suit a change in funding. The system cable design has been initiated by starting the detailed Subsystems Functional Block Diagram and the initial data base listing of system cables.

B. Stations DSS 44 and DSS 62

1. **Antenna Mechanical.** The design analysis of the reflector backup extension for DSS 44 is completed with member sizes determined. The analysis of the lower wheel and pedestal is in progress. The design layouts of the backup structure extension is in process with fabrication detail drawings to be started by the vendor on 21 February 1977.

All the design and detail drawings for DSS 62 are the same as those for DSS 12, except those for the pedestal and foundation interface hardware. These design drawings are 70% complete.

2. **Antenna Microwave and Receiver-Exciter.** The design and documentation of the Antenna Microwave and Receiver-Exciter modifications for DSS 44 and DSS 62 are essentially the same as those for DSS 12, hence the drawings for DSS 12 will be applicable to DSS 44 and DSS 62. However, the Antenna Microwave Subsytem will require some additional minor design and documentation to fit DSS 44 since the electronic room is a different size and in a different location on the antenna.

C. Transfer Plan

A Transfer Plan has been written and covers the transfer of the hardware and software to operations of the 26-meter S-X Conversion Project. The purpose of the plan was to establish guidelines and dates of milestones for hardware and software, documentation, spares, testing, etc., so that operations receives adequate support on a definite schedule to accept transfer of the S-X conversion equipment. The plan's hard objective is the transfer of all the hardware prior to shipment unless specifically directed otherwise by the Program Office. The Transfer Plan will be issued on 1 May 1977.

D. Project Schedule and Resources

The overall project schedule, as currently planned and in process, is shown on Fig. 4. The progress made is shown by the black shading and is effective as of 1 April 1977. The detail schedule of the individual hardware components is shown on Fig. 5, and again progress can be checked by the indicated shading for an effective date of 1 April 1977. The resource plan for the project for hardware is shown in Table 4 for an effective date of 1 October 1976, which was the official project start date.

Table 1. New or modified station equipment

Electronics		Antenna mechanical
Microwave Dual S-X reflex feed X-band maser Remote calibration	Tracking Planetary Ranging Assembly S- and X-band range demodulators	Extend diameter to 34 meters; Raise pedestal height 3 meters (10 ft)
Receiver-exciter X-to-S down converter X-band test translator X-band doppler extractor	Telemetry Wideband communications buffer and I/V converter High-rate tape recorders	Replace quadripod and subreflector
Transmitter X-band harmonic filter	GCF JPL Wideband Assembly NASCOM Wideband Assembly Interface to GHS for monitoring	Add dual cone shell and S-X reflectors
DIS (monitor) interface frequency and timing Cesium frequency standard Minicoherent reference generator S-X UPS/FTS Assembly Interface FTS to mini-CRG and cesium frequency standard		Reinforce structure and add counterweight mods
		Angle encoder replacement
		APS replacement servo electronics

Table 2. Cost[a] summary of baseline items

Item	12	DSS 44 and 62	Total base
Antenna mechanical	867	1624	2491
Microwave	606	1146	1752
Antenna feed	93	–	93
XMTR/harm filter	75	70	145
Receiver/Exciter Assembly	635	650	1285
Ranging demodulator	44	177	221
Planetary ranging	–	105	105
Intrasite frequency distribution	277	–	277
Wideband data	98	174	272
Welding	91	179	270
Angle encoders	41	–	41
Extension to 34 m	507	752	1259
Cesium standard	–	50	50
Equipment total	3334	4927	8261

[a]Costs are in $k.

Table 3. Site selection factors (differential only)

Service to flight projects	Goldstone DSS 11	Goldstone DSS 12	Australia DSS 42	Australia DSS 44	Spain DSS 61	Spain DSS 62
Eliminate OPS schedule constraints	0	0	$1903k (6 my/y × 10 y)	0	0	0
Eliminate shared equipment constraints	0	0				0
Implementation	0	0	$909k		$909k	0
Maintenance (personnel)			638k (2 my/y × 10 y)		1160k (3 my/y × 10 y)	0
Eliminate single-point failure by adding control room facility	0	0	560k	0	560k	0
Implementation costs:						
Antenna	$200k	0	0	$91k	0	$50k
Equipment	0	0	0	98k	0	98k
NASCOM	0	0	0	96k	0	96k
Sites selected		X		X		X

Table 4. Equipment funding[a] summary (3 stations)

Task 59 equipment	DSS 12	DSS 44 and 62	Total
Antenna mechanical (C of F)		993	993
Antenna mechanical (R&D)	1531	1842	3373
Microwave	652	1165	1817
Antenna feed	71	–	71
FTS-UPS Equipment	50	94	144
XMTR/harmonic filter	59	70	129
Receiver/exciter	749	675	1424
Ranging demodulator	44	177	221
Planetary ranging	–	105	105
Minicoherence reference generator	104	180	284
Recording (TPA/GCF)	41	82	123
Wideband data	67	85	152
Cesium standard	73	152	225
Total	3441	5620	9061

[a]WAD A, $k obligation. 1 OCT 76

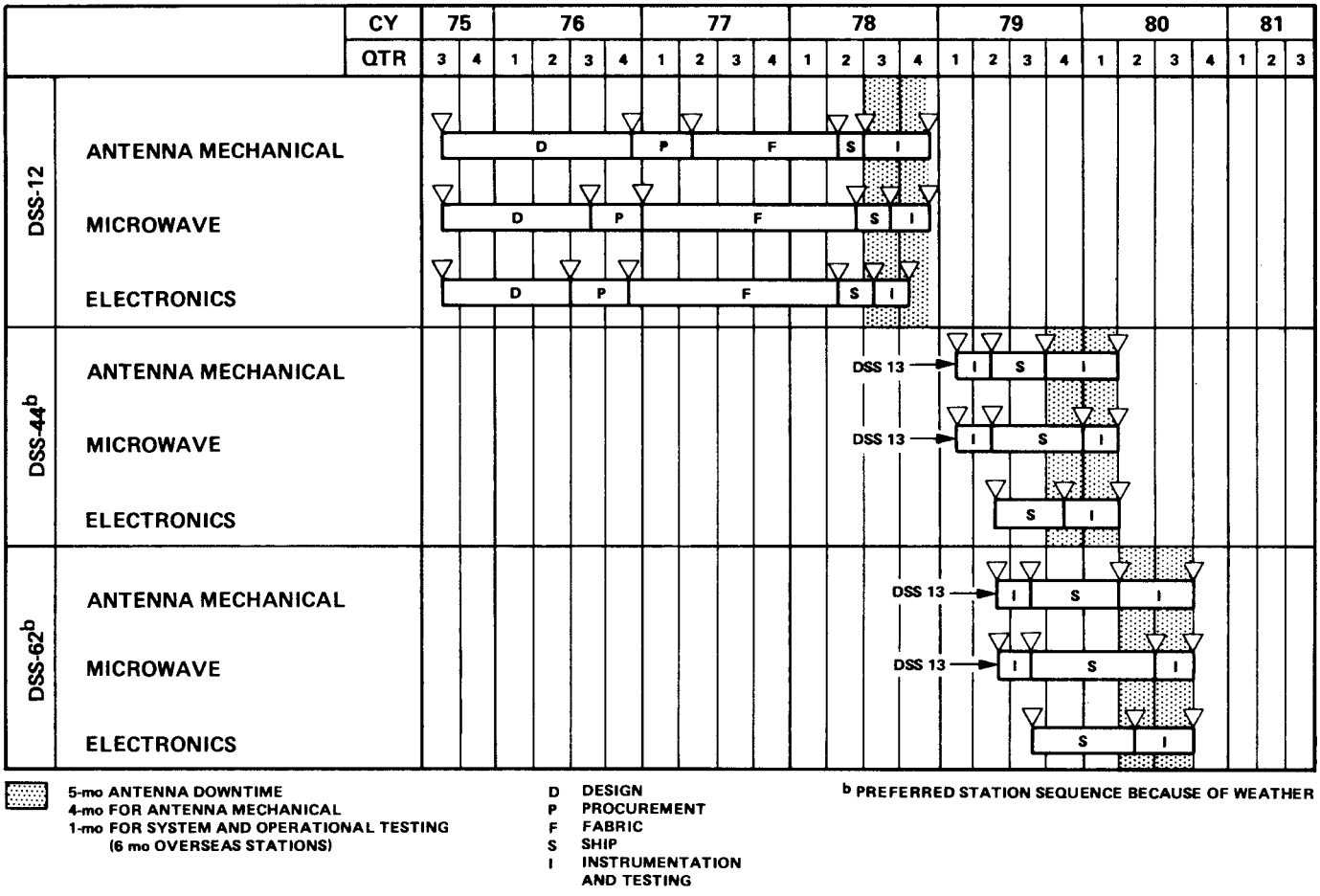

Fig. 1. Preliminary 26-meter S-X conversion schedule

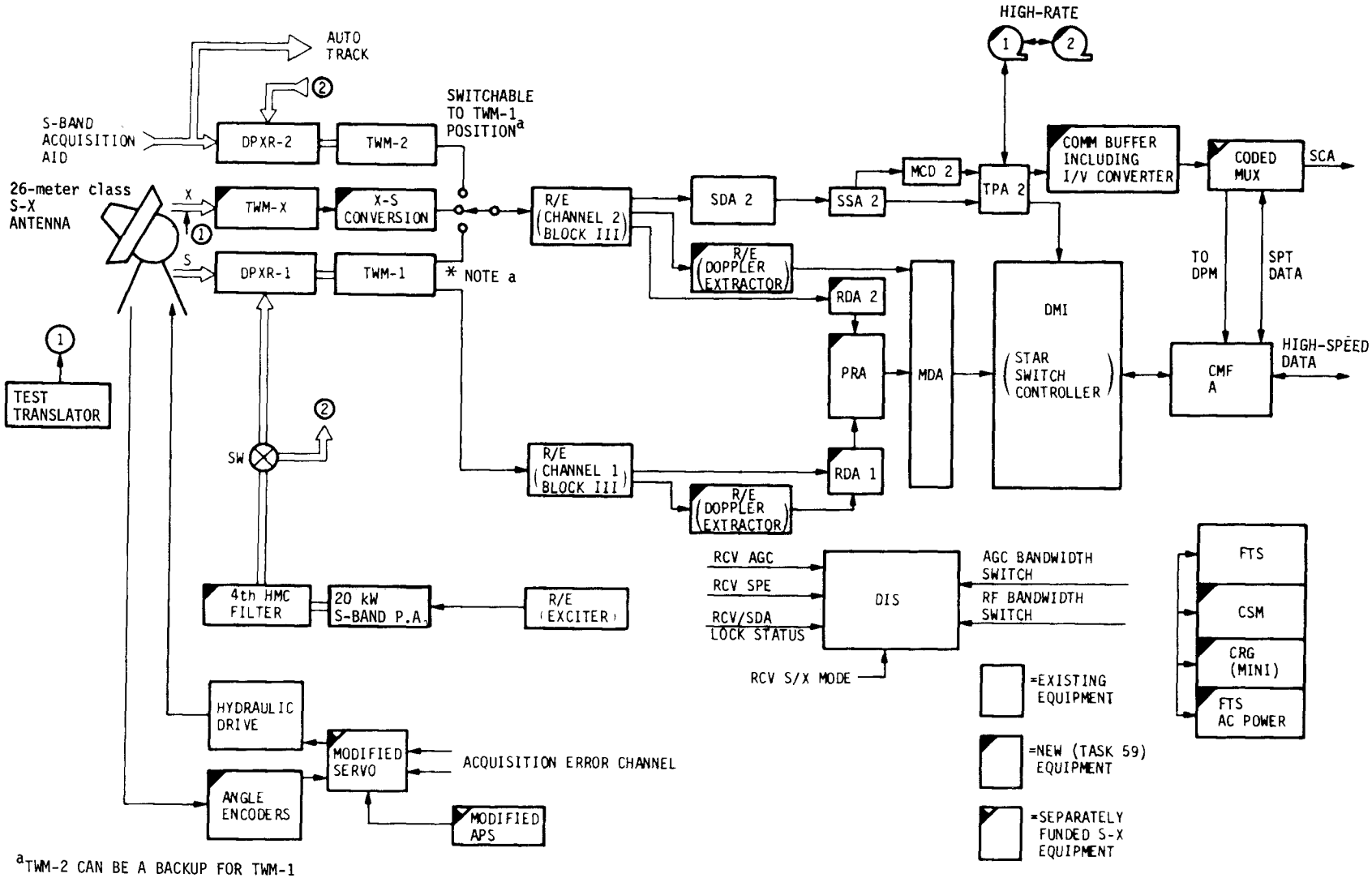

Fig. 2. 26-meter S-X Conversion Project — functional block diagram

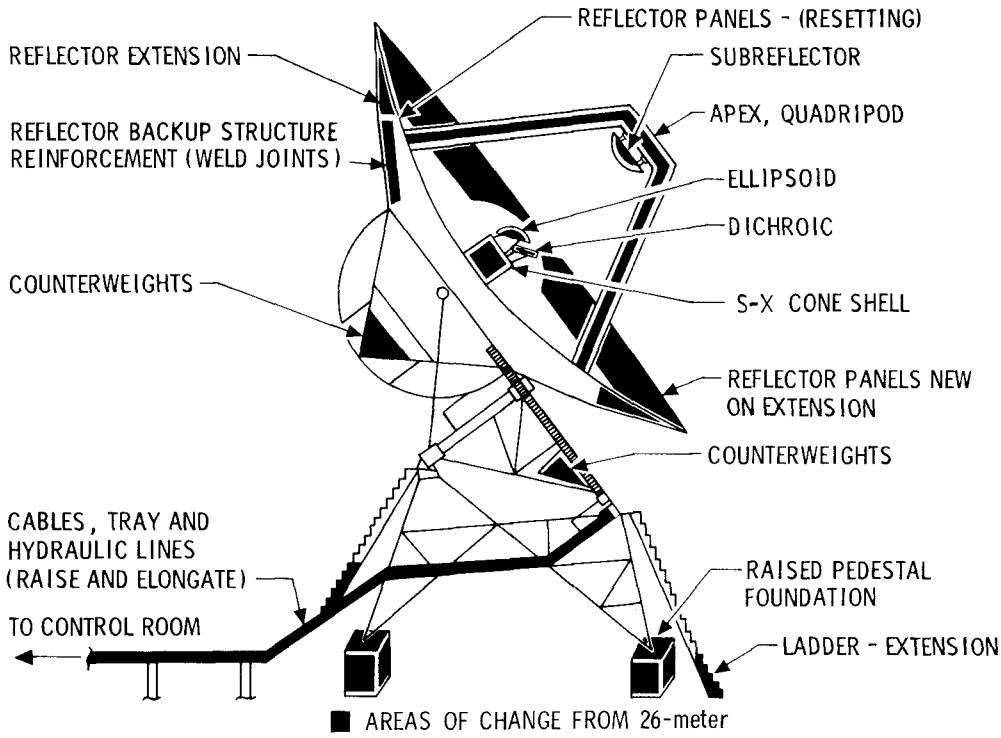

Fig. 3. Structural changes to Antenna Mechanical Subsystem for extension to 34 meters

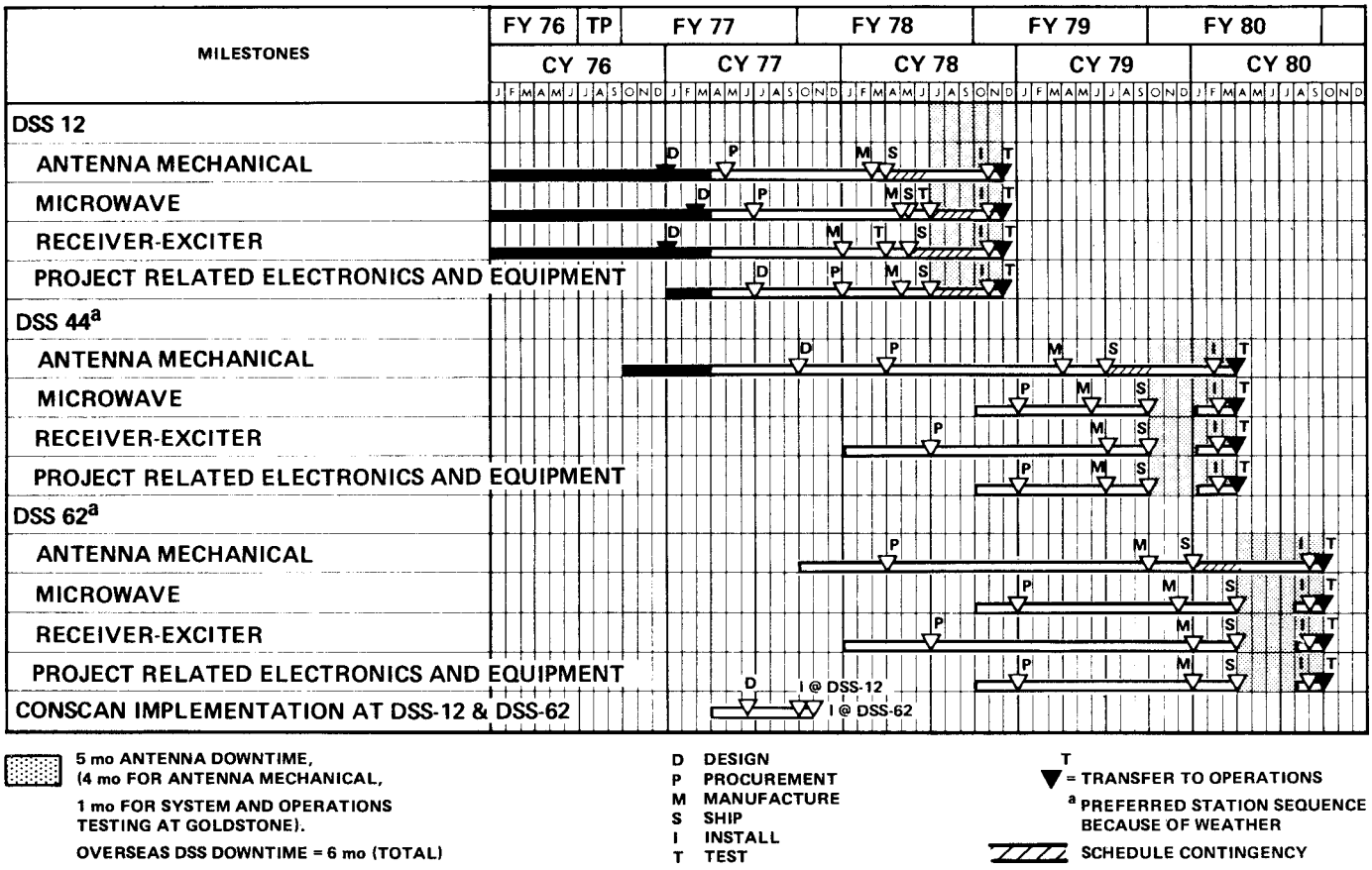

Fig. 4. 26-meter S-X Conversion Schedule

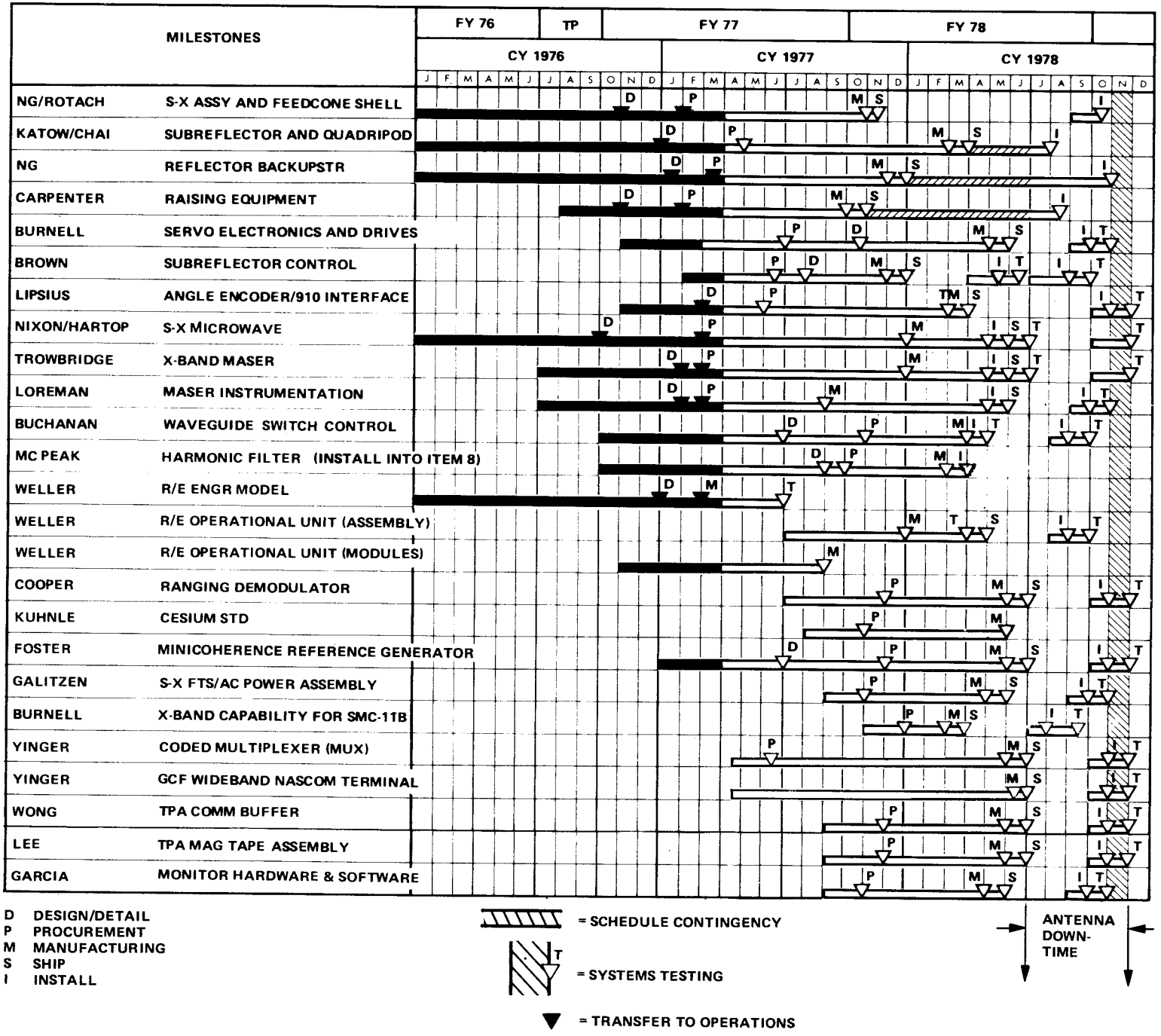

Fig. 5. 26-meter S-X conversion DSS 12 overall schedule