TT & C SYSTEM FOR AT&T TELSTAR 3

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ABSTRACT

The first of three TELSTAR 3 satellites will be launched in mid 1983. Prior to this time, a Telemetry Tracking and Control system will have been installed to track and command the satellites during transfer orbit and will continue these tasks when each satellite is in it's working orbit. This system consists of the Satellite Control Center (SCC) and the Primary Satellite Control Earth Station (PSCES), co-located at Hawley, Pennsylvania. In the event of unforeseen circumstances, the alternate satellite control center and earth station at Three Peaks, California, would be capable of performing the on-station Telemetry, Tracking, and Command operations for all three TELSTAR 3 satellites. Each location has redundant computer systems which are capable of all telemetry and command processing for three spacecraft. Only the Hawley site has the capability for tracking during transfer orbit by using the 13 meter full-motion antenna. This 13 meter antenna also houses the computer-controlled test equipment that will perform initial in-orbit testing of all three satellites, as well as normal testing throughout the life of the satellites. During transfer orbit, remote tracking station services will be provided by stations which are not part of the AT&T system. Data collected by the remote stations will then be sent to the SCC at Hawley for use in determining attitude and orbit. The second and third launches are scheduled for Mid 1984 and 1985, respectively.

INTRODUCTION

The TELSTAR 3 TT & C System is the latest system that has been evolving since INTELSAT IV ground control equipment began controlling the first INTELSAT IV launch in January, 1971. Later versions were used for the following programs. The Anik A program in November, 1972 used a small minicomputer for telemetry and command processing. The WESTAR launch in April, 1974 used a more sophisticated TT & C system utilizing CRT/keyboard control of the spacecraft with overhead displays of spacecraft status. The PALAPA system used the same type of system as WESTAR for launches in July, 1976 and March, 1977. The second generation WESTAR will utilize an up-dated TT & C system for the up-coming WESTAR IV launch in February, 1982. This

TT & C system will utilize two PDP-11/70 computers to accomplish telemetry and command processing, transfer orbit calculations, and attitude/orbit determinations. The PALAPA B system will use a TT & C system which is essentially identical to the latest WESTAR system. The TELSTAR 3 TT & C system is an outgrowth of the WESTAR/PALAPA systems to include a back-up location and to also include computer-controlled test equipment to accomplish in-orbit testing.

SATELLITE CONTROL FACILITIES (SCF)

The Satellite Control Facilities consist of the Satellite Control Center (SCC) and Primary Satellite Control Earth Station (PSCES) located at Hawley, PA; and the Alternate Satellite Control Center (ASCC) and Alternate Satellite Control Earth Station (ASCES) located at Three Peaks, CA.

The SCC at Hawley is a fully integrated, centralized center with processing, display, and storage of telemetry; command and ranging capability; and full support of mission operations, including 13 meter antenna pointing and tracking interfaces during transfer orbit and while on station. A redundant PDP 11/70 computer is used.

The ASCC at Three Peaks is used to maintain control and operation of up to three satellites in orbit in the event of failure of the equipment of facilities located at Hawley. The limited capabilities provided include commanding, ranging, and telemetry display of up to three satellites on station at a small operator’s console and on-station orbital analysis on the redundant PDP 11/44 computers. Dial up telemetry is provided between the two SCCs.

The PSCES consists of r.f. equipment installed in three existing 30 meter antennas and a 13 meter fully steerable, high slew rate telemetry, tracking, and command (TT & C) antenna. The following functions will be served by the 13 meter antenna at the PSCES:

- Transfer orbit TTAC and ranging.
- Backup geostationary orbit TTAC and ranging.
- Satellite test capability across the full 500 MHz receive and transmit bandwidths of the 6/4 GHz transponders.

Uplink, downlink, and translation functions for telemetry, command, and ranging are supplied as modifications to the existing antenna systems. The PSCES equipment interfaces with the SCC at intermediate frequency for both up and down link functions.

The ASCES consists of r.f. equipment installed in two existing 30 meter antennas and one existing 12 meter antenna. Uplink, downlink, and translation functions for telemetry, command, and ranging are supplied as modifications to the existing antenna systems. The ASCES equipment interfaces with the ASCC at intermediate frequency for the up and down link functions.

DESIGN OBJECTIVES

The major SCF design objectives are to:

- Maximize the use of existing AT&T facilities by co-locating the two SCESs with communications earth stations at Hawley, PA and Three Peaks, CA.
- Centralize control of satellite operations at the SCC which is co-located with the primary SCES at Hawley, PA.
- Provide detailed displays, short and long term analysis, and computational capabilities at the SCC. Limited display and computational capability at the ASCES augments overall system reliability.
- Centralize manual and computer controlled commanding at the SCC.
- Locate the Master Control Center (MCC) at the SCC for transfer orbit and drift orbit operations. The MCC will receive telemetry, angle tracking, and ranging data from the SCES and remote tracking sites. These data shall be analyzed at the MCC to determine optimal maneuvers for satellite control.

FUNCTIONAL REQUIREMENTS

The functions performed by the SCF can be broadly divided into the following categories:

- Telemetry data will be received and processed on a continuous basis for determining the satellite operational status.
- Commands will be transmitted to the satellite for operating mode changes and attitude and orbital corrections.
- Ranging and angle tracking will be performed for satellite orbit determination.
- Orbital analysis will be performed to determine the necessary attitude correction and stationkeeping maneuvers.
- In-orbit satellite testing will be performed for communication and housekeeping systems from the PSCES.
- The SCC will control all activities associated with launch, transfer orbit, and on-station operations.
- Normally all the above functions will be performed at the Hawley SCC/PSCES.

Figure 2 shows an overview of the SCF in an on-station configuration.

SATELLITE CONTROL CENTER OVERVIEW

The Satellite Control Center (SCC) equipment consists of computers, peripherals, test equipment, recorders, modems, and other commercial hardware that are integrated with the system software to perform the following satellite control functions:

- Determining spacecraft health via telemetry processing.
- Determining spacecraft position from ranging and spacecraft sensor data.
- Calculating new orbital parameters with DEC 11/70 computers.
- Commanding spacecraft jet firings and satellite configuration with synchronous and nonsynchronous commands.
- Recording and maintaining accurate records with event times.
- Maintaining station configuration.

As shown on the SCF overview drawing (Figure 2), the Hawley Station spacecraft health is determined by processing the three sets of telemetry data (three satellites) that are input into the DEC 11/70 data processors, converted to engineering units, and compared to limits, and then displayed to the various operators for analysis. If an out-of-limit condition exists, an alarm is sounded.

Spacecraft orbital and attitude position is determined by using the range data periodically computed with the range tone processor and the decoded PCM stream sensor data; range and sensor data are then used by the DEC 11/70 orbital software.

The operator starts the command sequences at the appropriate time by interacting with the computer that automatically controls the command generator.

For historical considerations as well as for analysis, many of the signals are recorded and hardcopied on line printers or plotters, analog tape recorders, disk files, and strip chart recorders. Typical hardcopy data includes alarms, commands, and operator displays.

A centrally located status and control panel gives the operator the capability to monitor the station configuration as well as to change this configuration if a unit should fail.

In contrast to the Hawley station, the Three Peaks station can only process three spacecraft telemetry streams and has a limited number of monitor/record units and operator positions. There are no offsite capabilities for monitoring satellite control activities at Three Peaks and data processing capabilities are slower, but more than adequate, by using the DEC 11/44 instead of the DEC 11/70 computers.

70 MHZ INTERFACES

The downlink interface block diagrams that show the interrelationship of antennas, downconverters, and telemetry receivers for the Hawley SCC and Primary Satellite Control Earth Station (PSCES) and for the Three Peaks SCC and Alternate Satellite Control Earth Station (ASCES) are provided in Figures 3 and 4, respectively. The interrelationships of antennas, FM modulators, and upconverters are presented in the respective uplink block diagrams (Figures 5 And 6) for the Hawley SCC/PSCES and Three Peaks ASCC/ASCES.

SCC FLOOR PLAN

The Hawley SCC consists of three rooms that contain master control, computer, and orbital analysis equipment. A layout of the SCC is shown in Figure 7.

The master control room contains the operator consoles with three overhead graphic display CRTs, teletypes, and line printers. Space is also provided for a desk and for the operations manager’s office. The 12 SCC equipment racks are 7 feet in height and form one wall of the control room with only the operating face of the racks exposed. The rear portions of the racks extend into the computer room; a false wall between the top of the racks and the ceiling separates the two rooms, isolating the master control room from rack equipment noise and heat load.

The computer room contains two DEC PDP 11/70 computer mainframes and DECwriter communication terminals, digital tape recorders, and four disk drives. Space is also provided for storage of computer associated spares and supplies.

The orbital analysis room contains most of the computer input/output (I/O) equipment. Included are three VT-100 CRT/keyboards, two graphic terminals, and two P-600 printer plotters. A large worktable is provided in the center of the room for examination of I/O unit hardcopy data.

All of the rooms are provided with a computer type false floor. The floor provides space for air conditioning, instrument interconnect wiring, and a.c. power raceways. The modular nature of the floor panels provides easy access to wiring and ducts, and permits ready relocation of equipment, if desired.

HAWLEY TELEMETRY SUBSYSTEM

The Hawley telemetry subsystem consists of the downlink interface panel, receiver input select, telemetry receivers, receiver output select, PSK demodulators, PCM decommutators, FM data detectors, downlink data select telemetry data preprocessors, and the telemetry and command simulator.

The inputs to the telemetry subsystem are at 70 MHz from three beacon down-converters. A single input is received from each of the four antennas (three 30 meter and one 13 meter). The subsystem is capable of processing three of the four 70 MHz inputs, i.e., telemetry data may be processed simultaneously from three satellites. The four 70 MHz inputs are connected into the subsystem through the downlink interface panel.

Each 70 MHz input actually consists of a summed pair of beacon IF signals near 70 MHz. One of the pair is always the common beacon frequency for all satellites. The other is the beacon frequency that is unique to each satellite.

Up to three of the four 70 MHz inputs may be selected by the receiver input select with each output directed to a different pair of telemetry receivers; each pair of receivers has a common input.

Each telemetry receiver is a 6-channel device capable of selecting one of the four beacon IF frequencies listed above. Once a pair of receivers is connected to a specific antenna, each receiver may be tuned to one of the two beacons arriving from the specific satellite at which the antenna is pointed. In this manner, telemetry may be received from any satellite through any antenna using any of the three available receiver pairs. As a backup, a seventh receiver may be switched in to replace any of the other six.

Each receiver output is at baseband and, depending upon satellite configuration, will be one of the following:

32 kHz	PSK/PCM telemetry
28 kHz	FSK ranging tones
14 kHz	FM real time telemetry

The receiver output select directs the baseband signal to the appropriate processing equipment.

PSK/PCM TELEMETRY

When a satellite beacon is transmitting PCM telemetry, the receiver output select must be set to direct the receiver output to a PSK demodulator. There is one PSK demodulator for each receiver on a one-to-one basis. That is, no crossstrapping exists between receivers and PSK demodulators. The PSK demodulator is connected directly to a specific PCM decommutator. The output of the PSK demodulator is NRZ/PCM at 1 kbps. The PCM decommutator first conditions the data stream with a bit synchronizer, establishes data synchronization, and finally outputs 8-bit serial word parallel data along with word count and other synchronizing information.

There are six sets of PSK demodulator/PCM decommutators to provide the capability of simultaneously processing both PCM streams from three satellites. For backup, a seventh PSK demodulator/PCM decommutator may be switched in to replace any of the other six. This backup capability is independent of that for the receivers.

The downlink data select directs the PCM decommutator output to the synchronous command generators and the computer subsystem. Each of the command generators receives an independently selected PCM decommutator output. Each of the computers receives all six PCM decommutator outputs at all times. Two data preprocessors, crossstrapped into both computers, assist in organizing telemetry data input.

Each PCM decommutator has front panel capability to select one word of telemetry for numerical display. A built in digital-to-analog converter provides a 0 to 5 volt representation of the selected word. This voltage is made available on the data patch panel.

FSK RANGING TONES

When a satellite beacon is transmitting ranging tones, or when ranging tones are being repeated by the test loop translator during calibration, the receiver output select must be set to direct the receiver output to a range tone processor. There are two range tone processors, each of which receives an independently selected receiver output.

FM REAL TIME TELEMETRY

When a satellite beacon is transmitting real time telemetry, the receiver output select must be set to direct the receiver output to an FM data detector. There is one FM data detector for each pair of receivers. The FMDD detects satellite sensor pulses for strip chart presentation and for use by the synchronous command generator.

There are three FM data detectors to provide the capability of simultaneously processing real time telemetry from three satellites. For backup, a fourth FMDD may be switched in to replace any of the other three.

The downlink data select directs the FM data detector output to the synchronous command generators. Each of the command generators receives an independently selected FMDD output, however, the switching logic is arranged so that a command generator must receive both PCM and FM data from the same satellite.

All switching by the receiver input select, receiver output select, and downlink data select is coordinated by the telemetry subsystem status and control panel. This panel also monitors the LOCK/UNLOCK status of all receivers, PSK demodulators, bit synchronizers, and PCM decommutators. In addition, receiver frequency selection is controlled and monitored by the telemetry subsystem status and control panel.

Finally, the telemetry and command (T & C) simulator provides limited simulation of both 70 MHz and baseband inputs for SCC checkout. Only PCM and FM telemetry are provided. The simulator decodes commands for the purpose of providing simulated command register contents on PCM telemetry.

THREE PEAKS TELEMETRY SUBSYSTEM

The Three Peaks telemetry subsystem components are each identical to their counterparts in the Hawley telemetry subsystem, however, Three Peaks differs from Hawley in flexibility, redundancy, and the amount of equipment required.

The Three Peaks telemetry subsystem characteristics that differ from the Hawley subsystem are as follows:

- Only three 70 MHz inputs
- No receiver input select (each receiver is dedicated to a specific antenna)
- Only one receiver per antenna (only one telemetry beacon per satellite may be received at a time, unless two antennas are pointed at the same satellite)
- One on-the-shelf spare receiver
- One on-the-shelf spare PSK demodulator
- One on-the-shelf spare PCM decommutator
- One FM data detector dedicated to each of two synchronous command generators
- Both FMDDs receive a common input selected from one of three receivers
- Both command generators receive a common input selected from one of three PCM decommutators
- The T & C simulator 70 MHz output is manually patched into a receiver input in place of the nornal 70 MHz source
- The T & C simulator baseband output is manually patched into a PSK demodulator or FM data detector input in place of the receiver output.

HAWLEY COMMAND AND RANGING SUBSYSTEM

The Hawley command and ranging subsystem consists of the synchronous command generators, range tone processors, uplink data select, command/ranging FM modulators, and uplink interface panel.

Normally the synchronous command generators and range tone processors operate under computer control, however, each has the capability of being operated manually. Each command generator and range tone processor interfaces with both computers. The on-line computer has control and receives status. The operator interface for computer controlled commanding and ranging can be through any one of three operator console CRT/ keyboards. Only one CRT/ keyboard can have control of commanding/ranging at one time.

Each synchronous command generator receives PCM data from an independently selected PCM decommutator. The PCM data provides satellite command register contents for command verification and satellite attitude data processor measurements for synchronizing execute pulses to satellite spin rate. An alternate method of synchronizing execute pulses utilizes real time telemetry pulses from an FM data detector.

The two synchronous command generators and two range tone processors together provide four signal sources. The uplink data select provides the capability to select any two signal sources to modulate any two satellite uplinks simultaneously. All switching by the uplink data select is coordinated by the telemetry subsystem status and control panel to ensure that both the uplink and downlink relevant to a selected signal source belong to the same satellite.

Each FM modulator is connected directly to a command upconverter through the uplink interface panel at 70 MHz. Four FM modulator/command upconverters are associated with the three 30 meter antennas and two are associated with the 13 meter antenna. Each of the first three FM modulator/command upconverters is connected to a specific 30 meter antenna. The fourth may be switched in to replace any of the first three. The last two FM modulator/command upconverters act as a redundant pair for the 13 meter antenna. Selection of the spare FM modulator/command upconverter path for the 30 meter antennas and the redundant path for the 13 meter antenna is coordinated by the command/ranging subsystem status and control panel.

THREE PEAKS COMMAND AND RANGING SUBSYSTEM

The Three Peaks command and ranging subsystem consists of the same basic hardware as at Hawley, however, there are only two FM modulator/command upconverters at Three Peaks.

At Three Peaks only one signal source may be selected to modulate one satellite uplink at a time. The synchronous command generators, range tone processors, and FM modulator/command upconverters are connected in redundant pairs. Redundancy switching and choice of commanding or ranging are accomplished by the uplink data select under control of the status and control panel.

RANGING PHILOSOPHY

Ranging to the TELSTAR 3 spacecraft is performed during both transfer orbit operations and for all on station operations.

The ranging system uses low frequency tones (28,000 to 31,500 Hz) looped through the spacecraft by the command and telemetry links as a means of determining range. A device called the range tone processor (RTP) generates the tones at the earth station for transmission and receives the tones after they are looped through the spacecraft. The phase difference as measured by the RTP between the transmitted and received tones can be directly related to range.

The Hughes range tone processor is operated under the control of a PDP 11/70 computer. This computer controls the generation of the tones and the timing of the major steps in the ranging sequence and performs the necessary processing to convert phase measurements into spacecraft range.

RANGING REQUIREMENTS

The functional requirements of the ranging link are listed below; range tone frequencies have been selected that conform with these requirements:

- Resolve initial range ambiguities
- Operate with maximum range rate experienced during transfer orbit
- One sigma phase delay measurement error at highest tone caused by all range tone processor time varying sources (phase jitter, thermal noise, and quantization error) must give a corresponding range uncertainty of ±15 meters RMS for on-station measurements
- Operate (range) through the spacecraft command receiver and telemetry transmitter

SYNCHRONOUS COMMAND GENERATOR

The command generator formats operator requests into a command sequence compatible with the command system of the spacecraft and transmits these formatted commands to the spacecraft as a series of tone bursts of different frequencies for the 1 and 0 bits which the spacecraft command decoder will reconstruct into the proper command. This command can then be executed by the command generator by sending a third tone, the execute tone. The timing of the execute tone will directly control the execution of the command by the spacecraft. The synchronous command generator can synchronize the execution of the commands with either real time signals from the spacecraft or by reconstructing spacecraft spin timing from PCM data. The execution can then be started at an operator selected position in the spin cycle of the spacecraft. Operator inputs to the command generator can be from the front panel in the manual mode or from the computer in the CPU mode. For command verification, the command generator receives the word identified output of a PCM frame synchronizer. By monitoring several words in each minor frame, it can display the relevant command verification data.

MANUAL OPERATION

The manual operating mode of the synchronous command generator allows the operator to set up and control the transmission and execution of commands via the front panel.

If the manual key-switch is placed in the manual position, the front panel keys and switches will be enabled for operator entry and the indicators and displays will show the data as it is entered. The computer cannot make any parameter changes in the manual mode, but it can read the status of any parameter. In addiiton, whenever a parameter is entered in the manual mode, the unit will send a flag to the minicomputer and the special status word will be available on the status lines to advise the minicomputer as to which parameter was changed.

HAWLEY SCC COMPUTER SUBSYSTEM

The Hawley SCC computer subsystem consists of the DEC PDP 11/70s and peripherals, and a switching unit called the computer I/O select. The computer I/O select unit provides the following three basic functions:

- The unit permits the CRT/keyboard, graphics displays, teletypes, and DEC writers to be switched from one CPU to the other. This switching is controlled by the SCC status and control panel or by a remote control in the analysis room to provide the required computer CPU redundancy.
- The unit is the computer interface for the 30 meter antenna system azimuth and elevation data input.
- The unit is the computer interface for the 13 meter antenna system azimuth and elevation data input and output.

DEC CPU AND PERIPHERALS

The display and I/O devices as well as antenna data input/output interface with one of the two CPUs. The CPU selected is controlled by the computer I/O select unit. This switching implementation gives full CPU redundancy to the display and I/O devices. The SCE hardware has redundant interfaces with both CPUs. This means that either CPU has the capability to receive and process telemetry, command, ranging, time of day, or other required information. As stated earlier there are two CPUs for the normal SCC computer functions that form the redundant system. With each of these CPUs is a magnetic tape recorder which is used for telemetry archiving. These recorders are dedicated to their assigned CPUs, therefore there is no switching or crossstrapping capability, but with the two recorders there is redundancy. In addition to the two CPUs, there are four disk drives. These disk drives are all dual port models that enable each disk drive to be connected to both CPUs. Because the system and software architecture is based on two disks per system, the system is provided with added flexibility as well as redundancy.

THREE PEAKS ASCC COMPUTER SUBSYSTEM

Operationally, the Three Peaks computer subsystem is basically the same as the Hawley subsystem although Three Peaks has less capability with a lesser number of equipment units and the use of a different model CPU. The equipment differences are listed below:

THREE PEAKS, CA	HAWLEY, PA
CPU PDP 11/44	CPU PDP 11/70
Disk R W M-02	Disk R W A-03
Time source (1)	Time source (2)
Remote control (none)	Remote control (1)

COMPUTER SUBSYSTEM OVERVIEW

Full redundancy is achieved for both spacecraft control and orbital operations. During normal in-orbit operation, each computer is capable of handling the folowing computer operations associated with the spacecraft:

- Spacecraft stationkeeping
- Spacecraft attitude correction
- Spacecraft health maintenance
- Prime station for in-orbit testing
- Eclipse and sun/moon interference prediction
- Processing and evaluation of spacecraft telemetry
- Processing of tracking and ranging data for orbit determination
- Display of command status and telemetry information
- Initiation and verification of commands
- Monitoring of all antenna positions and control of the 13 meter antenna for the program track mode
- Monitoring of spacecraft status and health and triggering of alarms for out-of-tolerance conditions

- Time tagging and recording of telemetry
- Calculation of spacecraft orbit from tracking and ranging data
- Antenna pointing data and sun/moon interference prediction

During the transfer orbit, the computers are capable of supporting the following transfer orbit computer functions without the use of any additional computers:

- orbit determination
- Attitudeldetermination and control
- Subsystem monitoring and control
- Transfer orbit maneuvers and control
- Apogee motor firing
- Drift orbit maneuvers and control
- Attitude positioning in final synchronous orbit
- 13 meter antenna pointing information

Each computer will have access via switch selection to both the ranging system and the two telemetry and two prime command chains. Both computers will also have access to either the operator console or the orbital operations set of display devices through switch selection. This switching system provides a means for recovery from equipment failure with a minimum of downtime and reconfiguration.

13 METER ANTENNA SYSTEM

The 13 meter antenna is required for primary support of telemetry, tracking and command and ranging operations for three TELSTAR 3 satellites during transfer orbit and backup operations for on-station (stationary orbit) support. Additionally, the 13 meter antenna provides an on-station satellite test capability.

The antenna subsystem consists of a 13 meter cassegrain antenna mounted on a full tracking elevation-over-azimuth pedestal. The pedestal is installed atop a reinforced concrete foundation which is configured to include a base structure providing a room for the servo electronics, high power amplifiers, up and downconverters and test equipment, all mounted in standard type racks. A weather tight enclosure is provided in the hub area which contains the LNAs and assorted equipment.

The reflector is made of shaped aluminum sheet panels mounted on a steel truss back structure. Panels are individually aligned during installation to provide an accurate parabolic surface. A view of the antenna is shown in Figure 8.

FUNCTIONAL REQUIREMENTS

Functional requirements for the 13 meter TT & C antenna system are as follows:

- Automatic tracking of any one of four downlink beacon frequencies phase modulated with telemetry or range data. This capability shall be provided for both transfer and stationary orbit.
- Provide both vertical and horizontal receive capability. Automatic tracking selectable for either polarization.
- Frequency reuse through linear vertical and horizontal polarizations.
- Provide automatic/manual polarization tracking with transmit polarizers slaved to receive polarizers.
- Provide manual (handcrank) slew capability.
- Provide computer program track mode and accept computer generated scan routines.
- Provide standby mode (brakes on, independent axis control).
- Provide vertical, horizontal, and circular polarization for transmit capability.
- Provide three part independent control deicing capability.
- Provide automatic transmit inhibit below 5° elevation.
- Provide a remote control capability for AZ/EL control at the antenna pedestal.

3 kW HIGH POWER AMPLIFIER (HPA) ASSEMBLY, EQUIPMENT DEFINITION

The C band HPA assembly is required for transmission of command, range and communications data to three TELSTAR 3 satellites in either synchronous or transfer orbit. The C band HPA assembly will operate in such a manner that one HPA is primary and in the active transmitting mode. The remaining two HPAs will be available for transfer to the active mode in the event of a primary failure. The HPA assembly includes one high powered switchbank and three C band HPAs. The switchbank will be capable of switching either of the standby HPAs to the active mode in the event of a primary failure. The HPA assembly will accept transfer commands from the status and control panel and will return configuration status. The assembly will accept a modulated carrier from either command or communication upconverters for amplification and transmission to the satellite. Each HPA will interface with a separate and independent remote control panel. A functional block diagram of the assembly is shown in Figure 9.

HPA PERFORMANCE REQUIREMENTS

Each HPA is designed to accept the derived and modulated carrier for amplification and transmission to the referenced satellite. Each HPA has the following major characteristics:

Output frequency range	5.925 to 6.425 HGz
Output power level	3.0 kW, minimum
Input carrier frequency range	5.925 to 6.425 GHz
Input carrier level	-10 dBm ± 0.5 dB
Output VSWR	1.2:1, maximum
Tuneability	Tuneability over 12 channels within the specified output frequency range (remote and local capability)
Output signal bandwidth	40 MHz minimum around center frequency (f_o) of each channel at the -1 dB bandwidth
Output spectral noise density in 5.925 - 6.425 GHz band	≤ -60 dBw/4KHz
HPA RF output adjustment	≥ 20 dB range below maximum output carrier level
Cooling	Forced Air
Prime power	120 VAC, 60 Hz, 3 phase

AGILE UPCONVERTERS/DOWNCONVERTERS

The agile upconverter is required to receive a 70 MHz carrier and upconvert to within the 5.925 to 6.425 GHz band for purposes of communication testing with any one of three TELSTAR 3 satellites in synchronous orbit. Likewise the agile downconverter is required to receive and downconvert frequencies within the 3.7 to 4.2 GHz band. The agile upconverters and downconverters are integral parts of the automatic computer controlled satellite test capability.

These units contain all front panel controls and indicators necessary for operational evaluation and will interface with the status and control panels for remote control and status functions and with the HPIB bus for frequency control from the HP 9826 Calculator.

COMMAND UPCONVERTER

The command upconverter performs these coincident uplink operational functions:

- Translates the 70 MHz, FM modulated command/ranging signal up to the desired command carrier frequency (low-band or high-band).
- The spacecraft omni antenna accepts the low-band signal and the spacecraft reflector accepts the high-band signal.
- Provides the low frequency linear sweep modulation on the output carrier about the nominal output frequency. (Nominally plus and minus 1.5 MHz)
- When ranging or commanding is not being accomplished, the command upconverter provides a ground-based beacon for the spacecraft antenna to track.

AUTOMATIC TEST SYSTEM (ATS) CONCEPT

The Hewlett Packard HPIB bus is IEEE 488 compatible and is used at the remote locations to interface with the system test equipment and with the frequency control of the agile up and down converters. A pair of HP 37203 HPIB bus extenders are used to extend the bus over the approximately 600 foot wiring path between the pedestal base and the SCC console. Data is transmitted both ways over a single coaxial line between the units at a rate up to 40 K bytes/second. At the SCC end, the bus interfaces with the HP 9826 desktop calculator, HP 9872C 8-color Vector plotter, and HP 9876A thermal printer. The calculator is provided with a real time clock option to permit HPIB bus management and with an HP 9875A calculator I/O extender to permit the additional interfaces which are required for the calculator.

The computer system interfaces with the calculator over a two-way EIA RS 232 serial link to receive test data and to send calculator instructions.

Test access has been provided in the antenna system for injection of automatic test signals into the LNA inputs, and for injection of test loop translator signals into the LNA inputs, and for injection of test loop translator signals into the LNA inputs direct as well as through couplers. Agile downconverters are provided with test output ports for use by the ATS. Test signals can be injected at IF on the uplink.

Test programs are composed at the Calculator and loaded into its disk storage. These programs are then transferred to the computer for storage where they may subsequently be called up by acronym from the computer keyboard. When called, the program is transferred back into the calculator memory and execution of the test begins. The calculator controls the setup of the remote test equipment via the HPIB bus. For some tests, interaction between the calculator and the console operator will be required via the console keyboard and display. Test data from the test instrumentation is processed by the calculator and output to the printer and plotter as required. Test data is also output to the computer and provision is made for archiving the test data on disk for subsequent review, comparison, and trend analysis.

PSCES 30 METER ANTENNA TELEMETRY AND COMMAND (T & Q

As a part of the PSCES installation at Hawley, the three existing 30 meter antennas will be equipped with IF/RF inputs/outputs and equipment that, in conjunction with the SCC, will enable performing of command, telemetry, and ranging functions on any of the on station satellites (satellites at 87°, 95°, and 128°, West longitude). The antenna systems provide the normal communications mode functions using new and/or existing equipment. The principal new building blocks provided for these functions are as follows:

Uplink
- Command upconverters (4)
- High power amplifier (HPA) chains (4)
- High power switching

Downlink
- Telemetry downconverters (6)

Both Links
- Test loop translators (3)
- Status and control panel (1)

Three 70 MHz (plus one redundant) inputs are received from the SCC and accepted by the command upconverters for RF transmission to the satellites. The signal is processed to provide a sawtooth satellite antenna tracking reference and is upconverted to one of the two command/ranging frequencies.

The output of the command upconverter is divided in a 3 dB hybrid and used to drive two nominal 400 Watt HPAs. The amplifier outputs are amplitude and phase combined by using a second 3 dB hybrid and provide a 650 Watt output for a particular uplink.

The 650 Watt HPA output enters a waveguide switch where it normally passes through to a second switch (these and all other switches are controlled from the SCC console's 30 meter status and control panel). The waveguide switch is used to insert a redundant command upconverter/HPA chain into any of the three uplink chains, as required. The redundant chain is normally terminated in a high power load. When the redundant chain is used, the replaced chain is terminated into the same load.

DOWNLINK

The downlink signal is obtained from the normal output of the vertical or horizontal receive port of the antenna feed through two 16 port power dividers in the existing communications equipment room. The outputs of these dividers are used to drive new and redundant downconverters.

The fixed frequency downconverter 70 MHz outputs are routed to the SCC telemetry IF input. This provides redundant downconverters since both telemetry signals will appear on a single 70 MHz output.

CONCLUSION

Reliability, flexibility, and redundancy are key factors in the design of the AT&T TELSTAR 3 satellite control network. This is evidenced by examining the redundant systems at Hawley which are further backed-up by the ASCC and ASCES located at Three Peaks, CA. This design should provide AT&T the equipment and facilities to control and test the TELSTAR 3 satellites over the 10 year design life of the satellites.

ACKNOWLEDGMENT

This paper is based upon requirements set forth by AT&T Long Lines and Bell Telephone Laboratories. Special recognition should be given to efforts of personnel in the Satellite Ground Equipment Division of Hughes Aircraft Co. for their design contributions.

TABLE I
SCES PERFORMANCE SPECIFICATIONS

Antenna type	Parabolic, Cassegrain subsystem
Antenna mount	EL over AZ
Aperture size	13 meter, nominal
Gain-to-system temperature ratio G/Ts	$\geq$ 33.1 + 20 Log $\frac{F}{4}$ dB/° K
Transmit gain	$\geq$ 56 + 20 Log $\frac{F}{6}$ dBi
Transmit/receive capability	Simultaneous
Polarization, transmit	Vertical, horizontal, and circular (RCP/LCP)
Polarization, receive	Vertical and horizontal

Polarization discrimination	≥ 35 dB
Polarization tracking	Automatic and manual, transmit slaved t receive
Bandwidth, transmit	5.925 to 6.425 GHz
Bandwidth, receive	3.7 to 4.2 GHz
Beamwidth, transmit	≤ 0.27°
Beamwidth, receive	≤ 0.40°
Axial ration (Circular)	≤ 1.4:1
Sidelobe levels (transmit/receive)	Compliant to FCC rules and regulations
Power handling (transmit)	≥ 6.0 KW, continuous duty, 24 hours/day
Transmit/receive isolation	Consistent with G/Ts requirements
VSWR (transmit/receive)	1.2:1 maximum
Autotracking mode	Psuedo-monopulse
Autotracking accuracy (Geostationary)	≤ 0.008°, rms
Autotracking accuracy (transfer)	≤ 0.01° rms
Program track mode	Computer control
Program tracking accuracy (Geostationary)	≤ 0.04°, rms
Program pointing accuracy (transfer)	≤ 0.10°, rms
Manual slew mode	Console and pedestal remote control box
AZ/EL pointing resolution	≤ 0.01°
Manual movement with loss of prime power	Manual hand cranks on each axis
Standby mode (independent axis control)	Brakes on
Antenna velocity requirements	1 deg./sec.
Antenna acceleration requirements	1.0 deg./sec.^{2}

Antenna Travel	
Azimuth	± 160°
Elevation	0 to 92°
Antenna limits (AZ/EL)	Servo, electrical and mechanical limits
Brake capacity	Hold in any position in 200 Km/H
Wind loads:	
Antenna operational	
Steady state	Up to 100 Km/H
Gusting	Up to 140 Km/H
Antenna stowed	
Steady state	200 Km/H
Covered with 25 mm layer of ice	100 Km/H
Deicing system (three independent subsystems):	
Feed	Heaters
Subreflector	Heaters
Reflector (three independent sectors)	Heaters
Controls/status	Remotely located
Operation	Remote manual

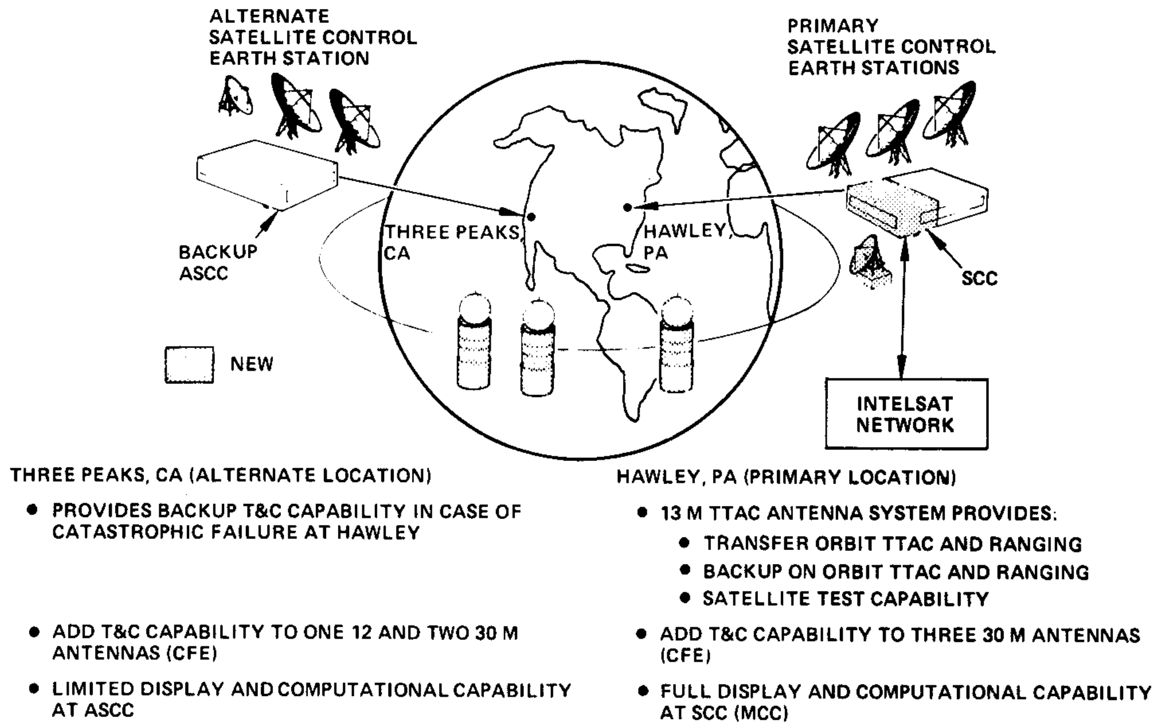

Figure 1 - SATELLITE CONTROL FACILITIES (SCF)

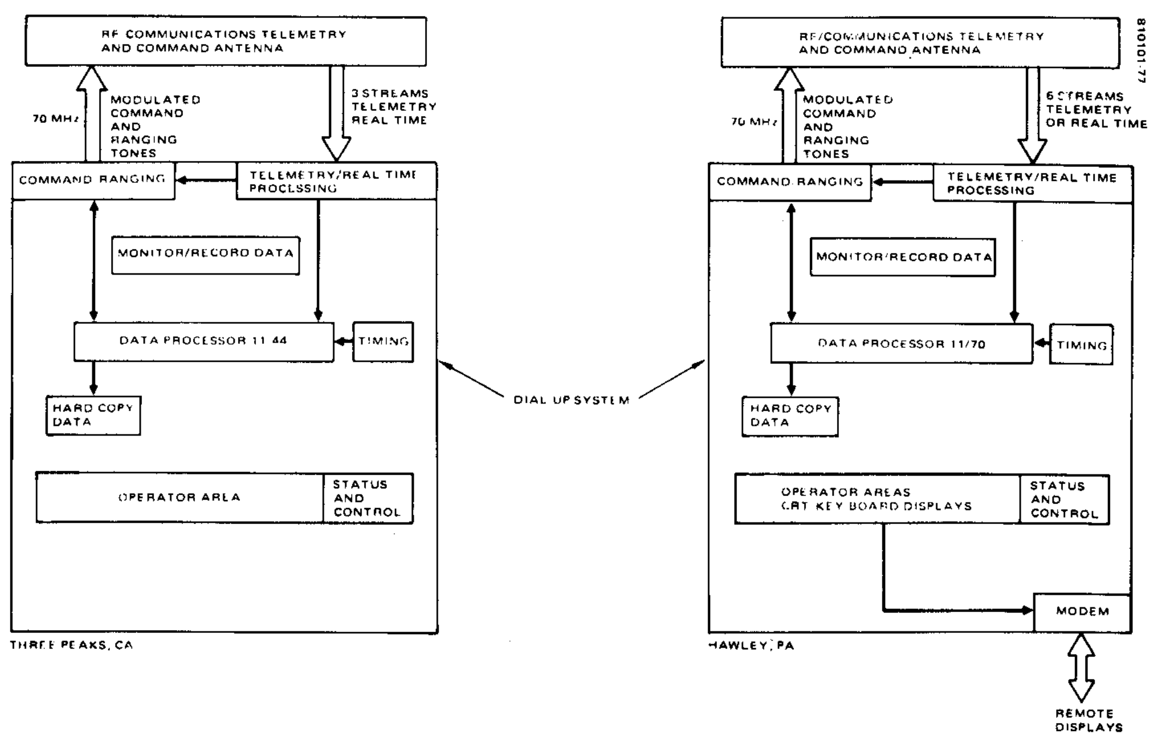

Figure 2 - AT&T SATELLITE CONTROL FACILITIES OVERVIEW BLOCK DIAGRAM

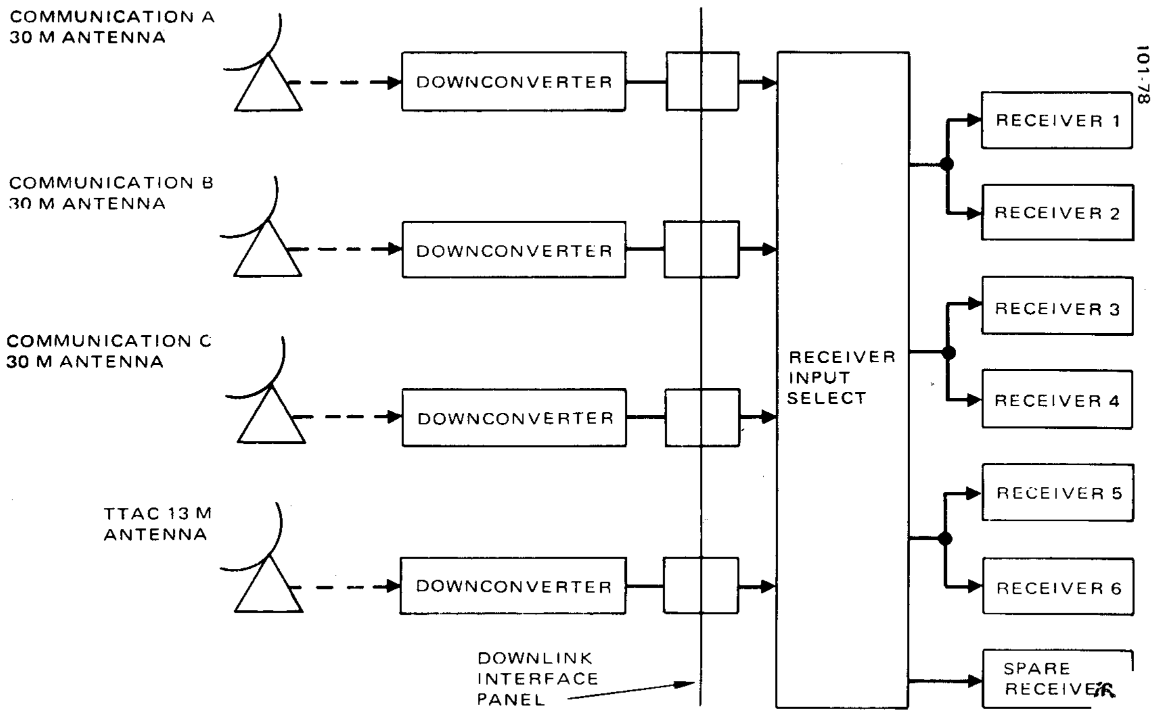

Figure 3 - HAWLEY SCC/PSCES DOWNLINK INTERFACES

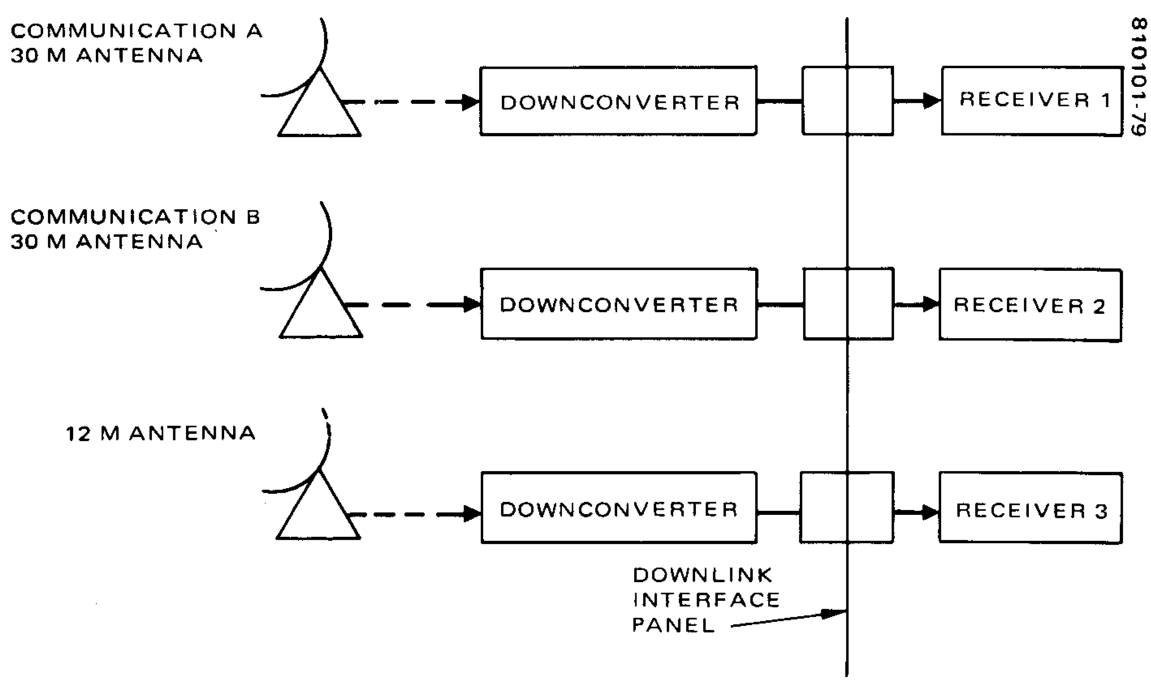

Figure 4 - THREE PEAKS ASCC/ASCES DOWNLINK INTERFACES

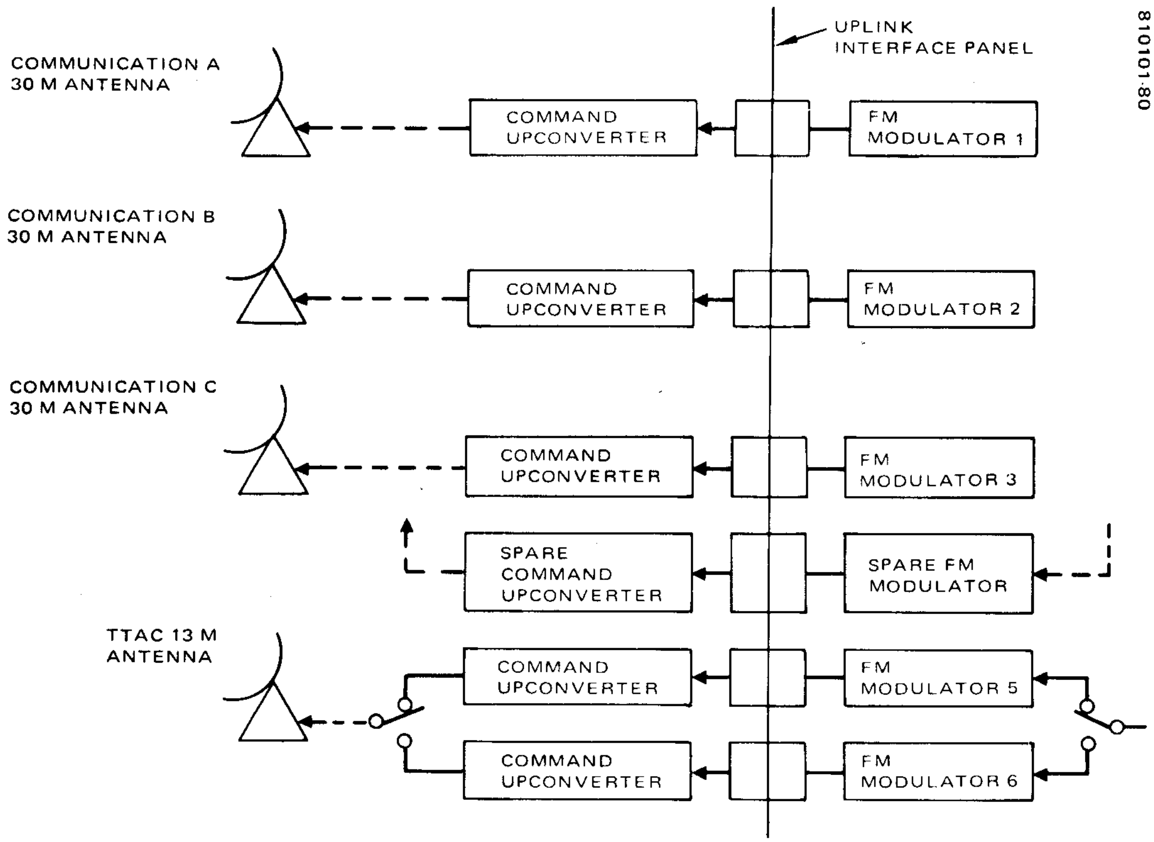

Figure 5 - HAWLEY SCC/PSCES UPLINK INTERFACES

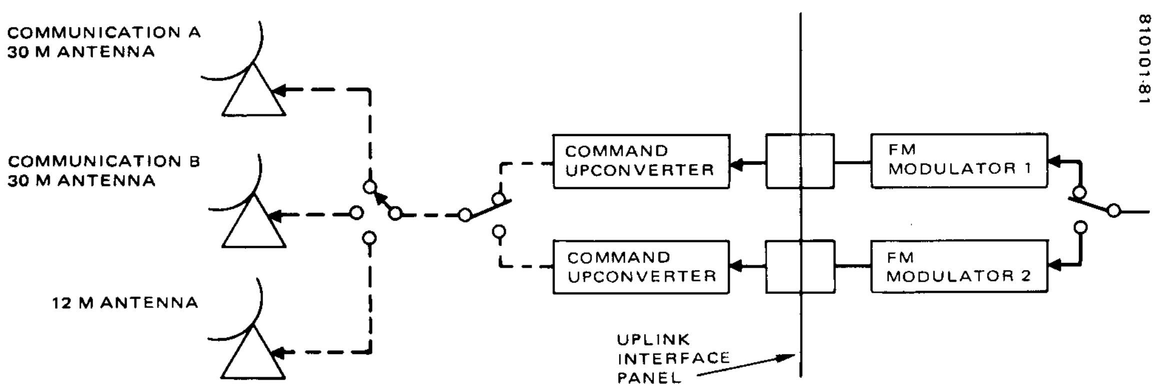

Figure 6 - THREE PEAKS ASCC/ASCES UPLINK INTERFACES

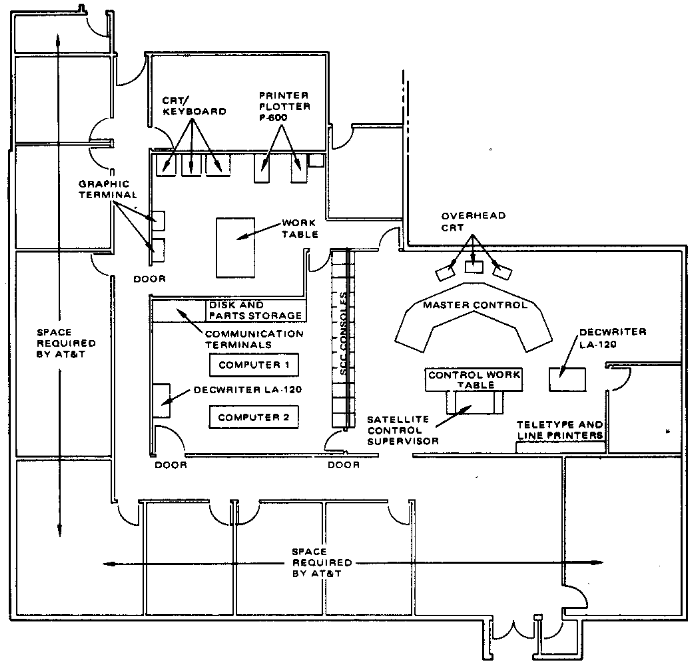

Figure 7 - SCC FLOOR PLAN

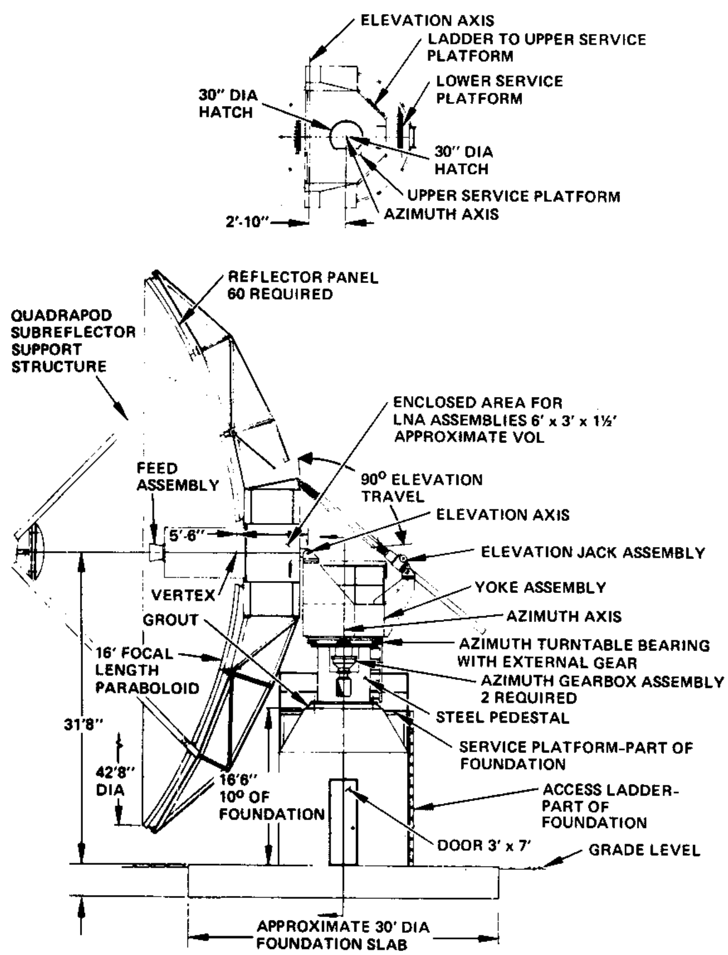

Figure 8 - 13 M ANTENNA (SIDE VIEW)

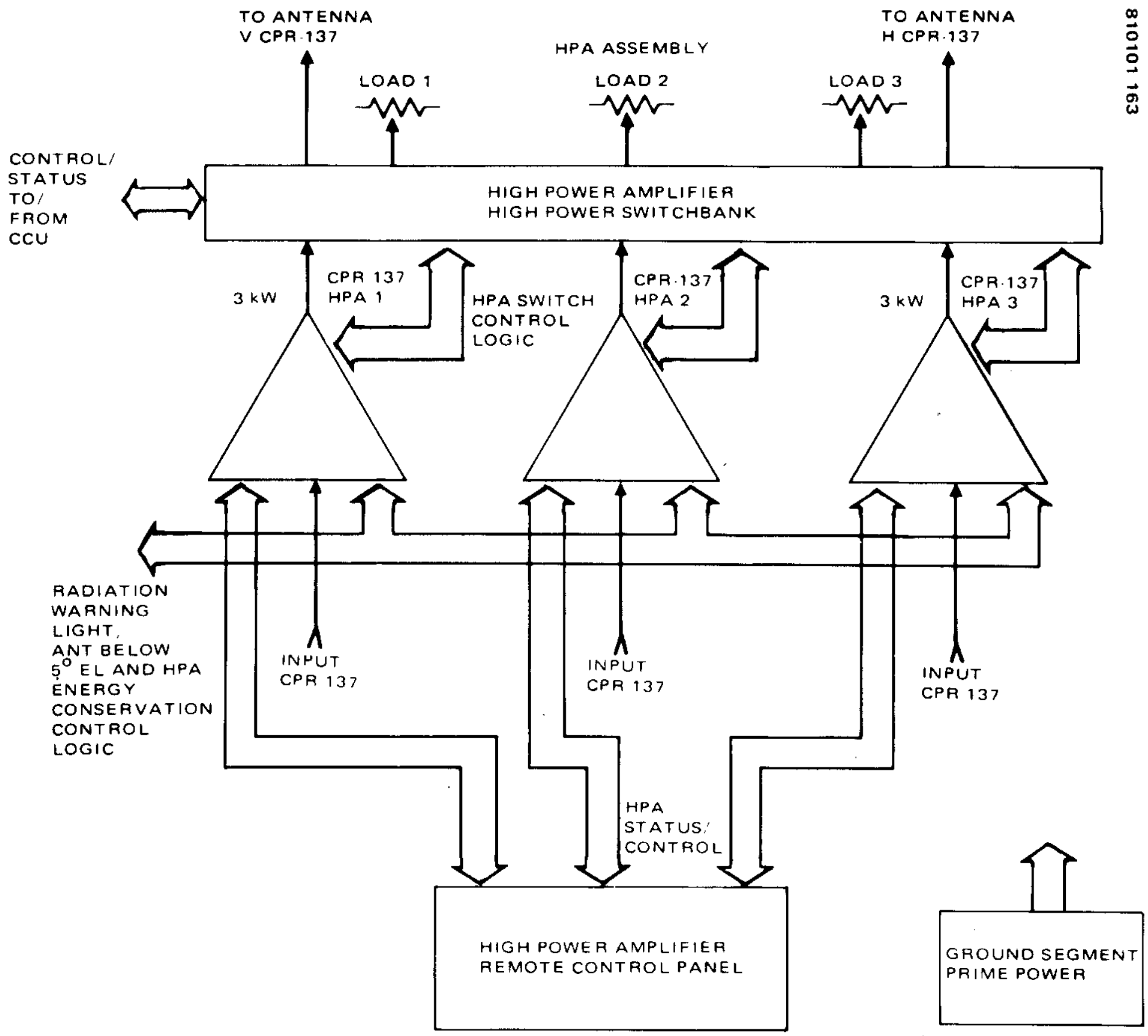

Figure 9 - HPA FUNCTIONAL BLOCK DIAGRAM