Planning, Operation and External Communications of the Andover Earth Station

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This paper relates some of the considerations in the planning of the Andover, Maine, earth station. It describes the station layout, the operating plan and the Long Lines interconnections. Power facilities, air conditioning, heating and dehumidification arrangements are also covered.

I. INTRODUCTION

The purpose of this paper is to describe the layout, operation, and external communications links of the Andover, Maine, earth station. This station was designed to provide the terminal facilities required for communications via artificial earth satellites. Complete facilities for orbit determination, tracking, and broadband microwave communications were included in order to obtain data which would be useful in the evaluation of designs for future operational systems. Experimental verification of the feasibility of communicating via satellites was, however, the primary goal.

In this paper, various aspects of the Andover station are described in detail under the following headings: II. Site Planning, III. Operating Plan, IV. Power Facilities, V. Air Conditioning and Heating, VI. External Communications Requirements, and VII. Experimental Demonstrations

II. SITE PLANNING

The Andover ground station is situated in a 1000-acre tract surrounded by mountains. The site is nearly ideal since the mountains are high enough to protect against interference from overland microwave systems but low enough to permit proper operation when the satellite is near the horizon.

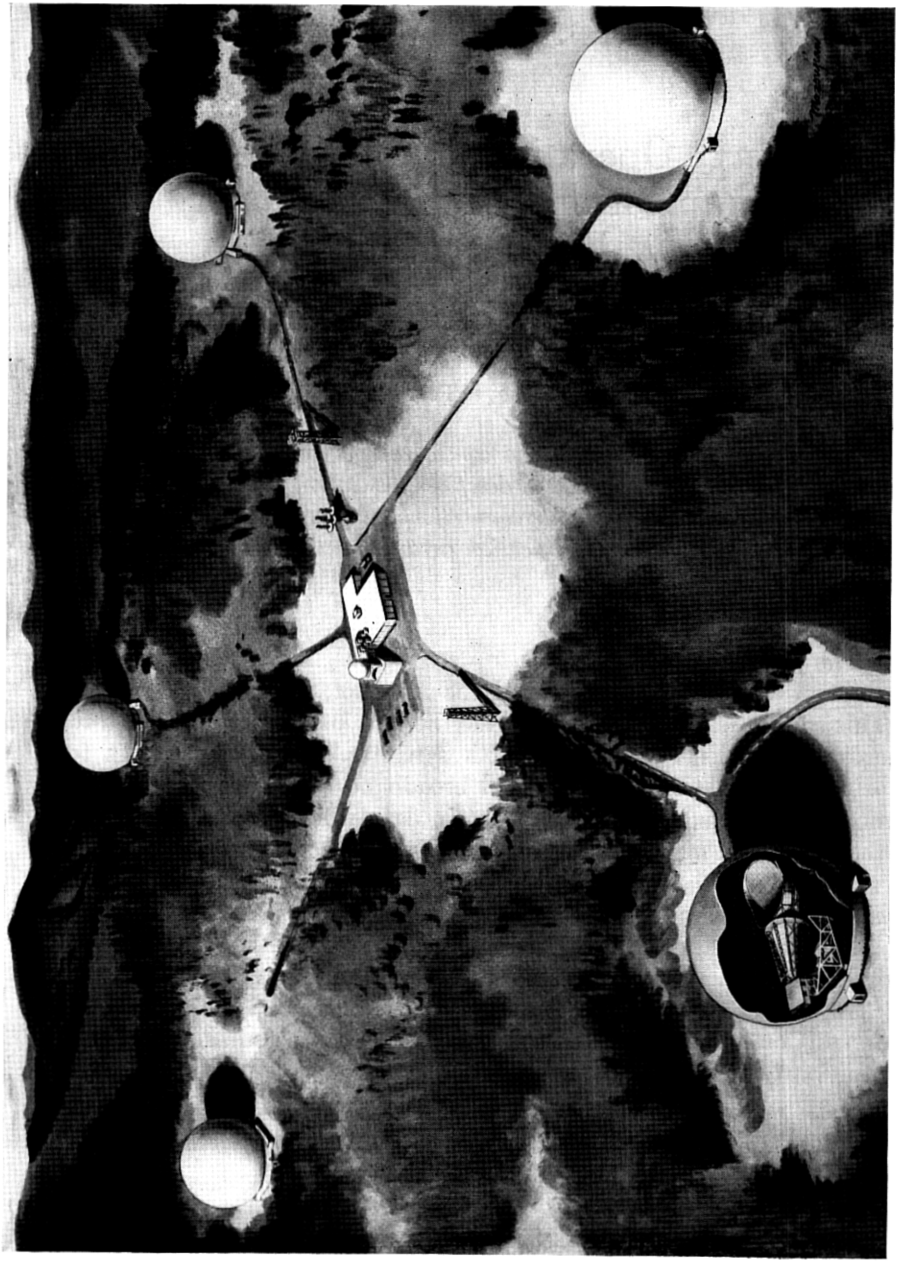


Fig. 1 — Site plan for Andover

Aerial surveys of the site were used to assist in locating the control building, antennas and boresight towers. Anticipating the possibility of more extensive experimentation or of eventual commercial systems, a sufficiently large site was obtained such that a control building could be located on relatively high ground, surrounded by five horn antennas. One possible commercial system would require a multiplicity of satellites and a minimum of two antennas at each terminal for efficient operation. One antenna at each terminal point would follow a satellite as long as that satellite is mutually visible. As the end of a period of mutual visibility is approached, continuity of service could be provided by switching to a second, or handover, antenna which would be tracking another satellite in the early part of its period of mutual visibility. A third antenna might be provided as an active spare. On this basis, it was estimated that five antennas would be sufficient to provide three broadband radio channels, with one antenna always available for handover and another as a spare.

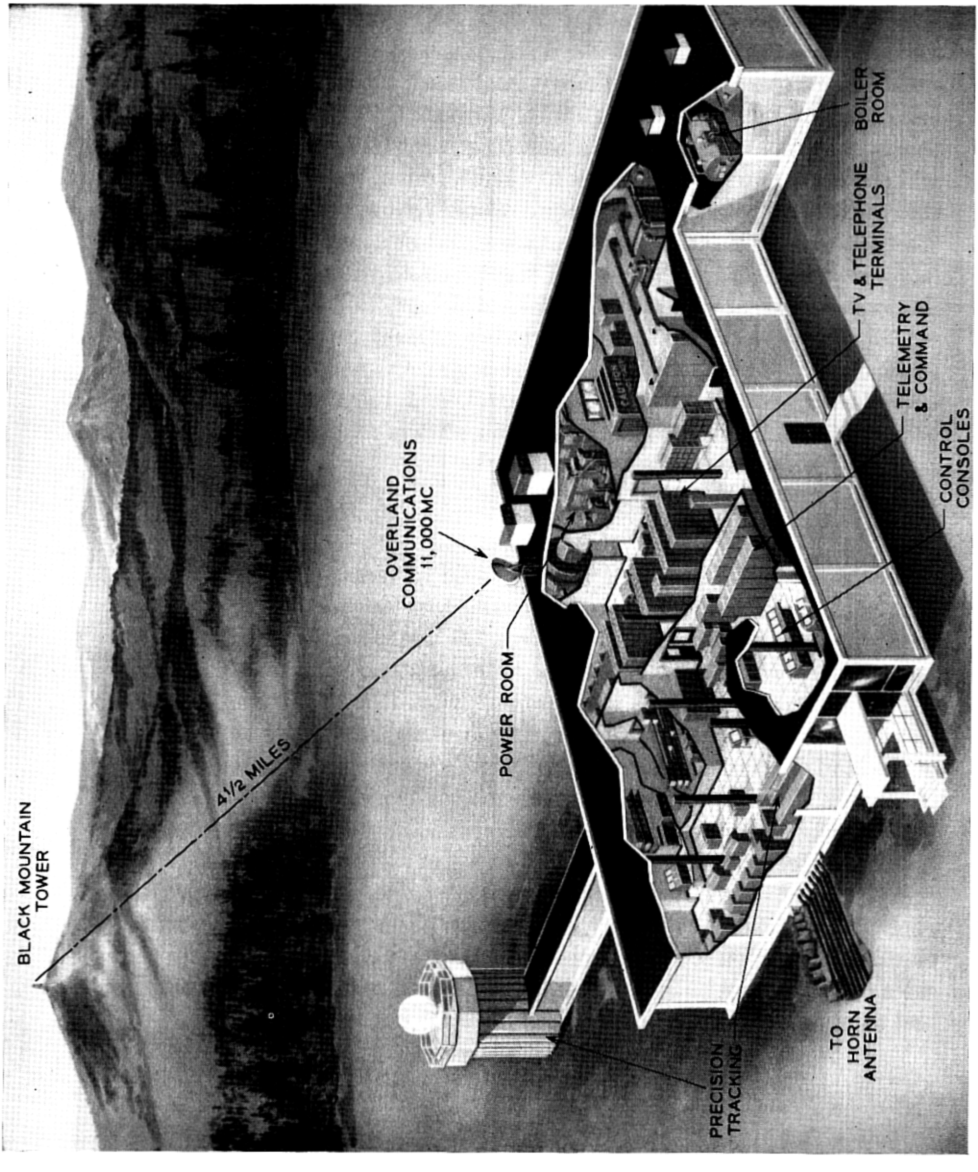
2.1 *Antenna Spacings*

On the Andover site, five antennas could be located, as shown in Fig. 1, in such a manner as to prevent masking of the microwave signals by each other at elevation angles above 7.5 degrees. The most practical arrangement would be to cluster the antennas about the control building. At the potential locations the antennas would be at varying distances from the control building and from each other because of the contours of the land. The antenna location for the Telstar experiment was selected because of its proximity to the approach highway.

Trees were cleared to avoid interference at low angles. For the same reason the commercial power line was placed underground as it approached the control building. Masking of the precision tracker and command tracker antennas by the control building was avoided by elevating them on concrete pedestals and locating them at opposite sides of the control building so that their beams would clear the building and each other for elevation angles above 7.5 degrees.

2.2 *Control Building*

A cutaway view of the control building and its facilities is shown in Fig. 2. The building is a windowless one-story structure, and it may be considered as being made up of three areas. One area contains the heating, power and utility equipment, not only for the control building itself but also for the horn antenna and its radome. Another area contains


BLACK MOUNTAIN TOWER
4½ MILES
OVERLAND COMMUNICATIONS 11,000 MC
POWER ROOM
BOILER ROOM
TV & TELEPHONE TERMINALS
TELEMETRY & COMMAND
CONTROL CONSOLES
TO HORN ANTENNA
PRECISION TRACKING

the telephone terminal equipment, microwave terminal, television operating center and distributing frames. Most of the equipment in this area is made up of standard Bell System items.

The third area contains equipment quite special for the Telstar project. This consists of the ground station control and other consoles, antenna pointing equipment, computers, precision tracker, command, telemetry and sundry testing equipment.

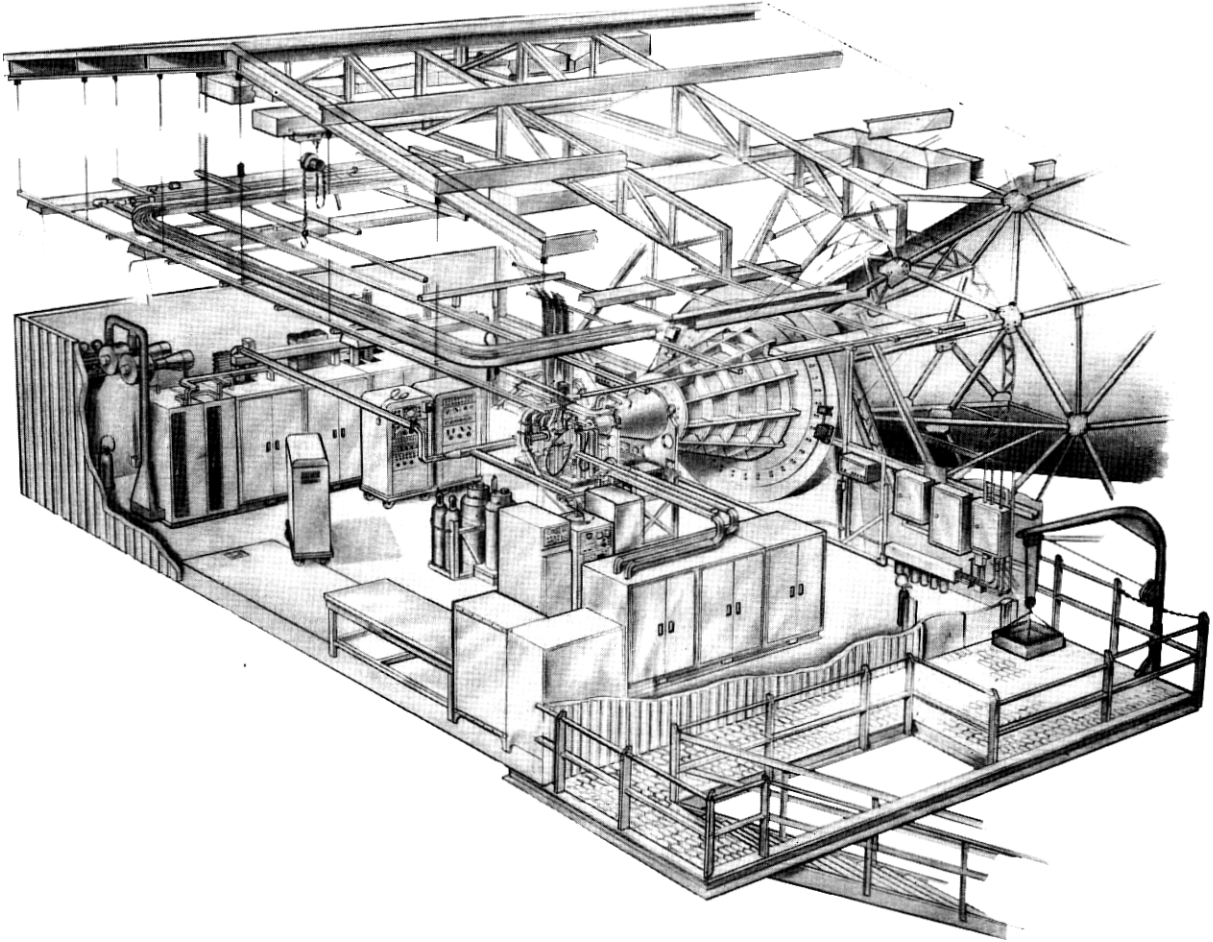
2.3 *Main Antenna Building*

It was considered desirable to concentrate as much of the transmission and antenna guidance equipment as possible in the control building. This would obviate dispersal of maintenance personnel and equipment. However, to avoid expenditure of considerable development time, it was necessary to locate much of this equipment on the horn-reflector antenna structure or in the utility building at the periphery of its radome. The horn antenna structure design included two rooms for equipment and personnel. One room, located at and behind the apex of the horn feed, is called the "upper" room. The other room, located on the floor of the azimuth near the pintle area, is called the "lower" room. The apportionment of equipment among the utility building and the lower and upper rooms of the rotating antenna structure was given serious consideration. In order to achieve optimum servo performance it was essential that the nonstructural weight on the movable structure be minimized. It was not only the weight of the equipment that had to be considered, but also the flooring and housing for it. Furthermore, of the equipment that was to be placed on the antenna structure, as much as possible was located in the lower room close to the center of rotation. Figs. 3 and 4 show the arrangement of equipment in the upper and lower rooms, respectively.

In the interest of weight saving, the cabinets, unit frameworks and overhead cable rack and framing supports were made of aluminum. Closed cabinets permitted the use of local air cooling as required. The air for cooling equipment in some of the cabinets is provided from outside the room and is exhausted outside the room through a closed system over a chilled water heat exchanger. In other cabinets where the heat generated is moderate, room air is used for cooling.

2.4 *Slip Ring Assembly*

Electrical connections between the equipment on the moving part of the antenna and the remainder of the system are made through slip



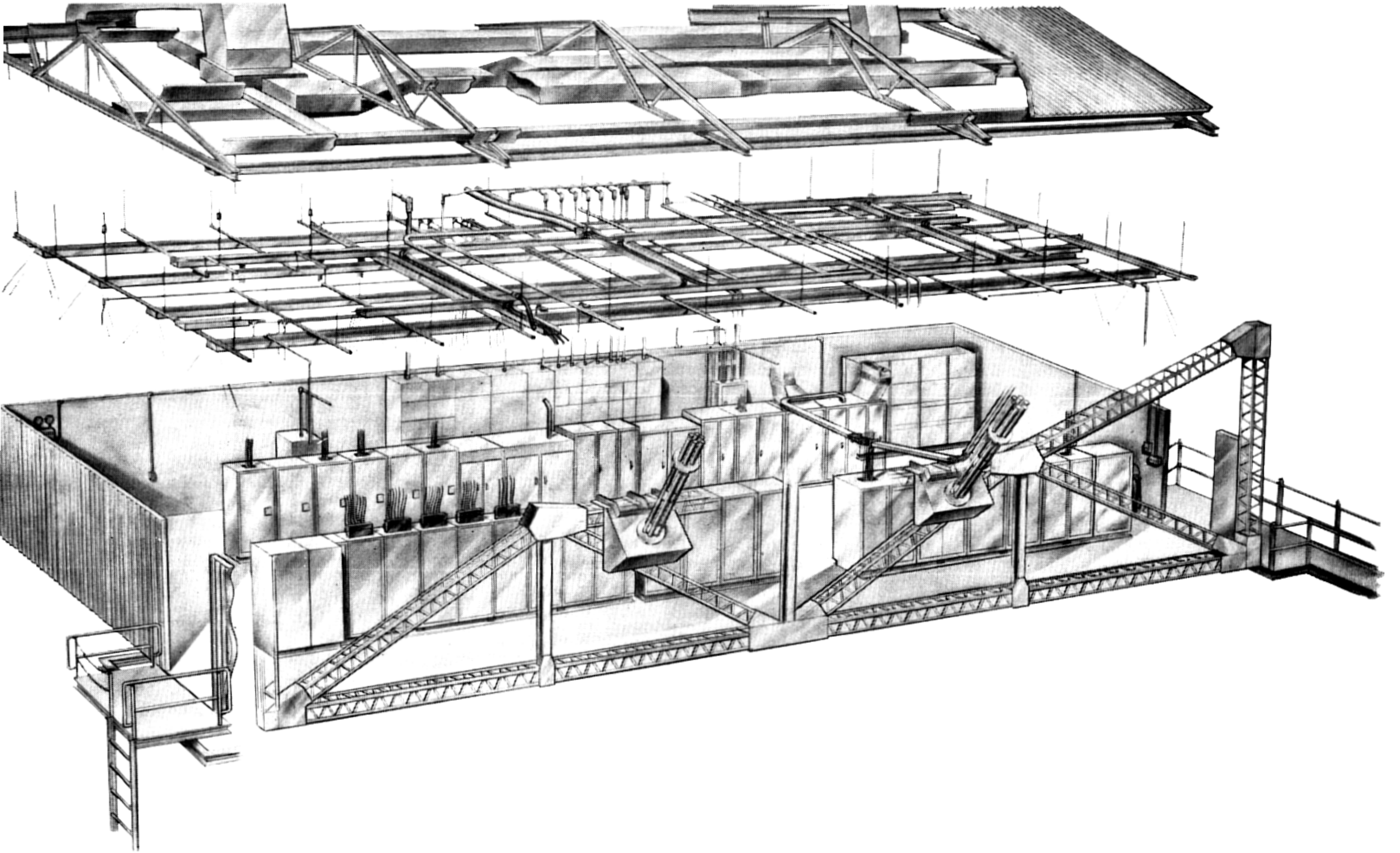


Fig. 4 — Lower room of antenna structure.

rings. A slip ring assembly previously designed for another project was modified to satisfy the requirements of the Telstar installation. The previous design was for 12 power rings, 300 general-purpose rings and seven unbalanced video circuits. The modifications permitted 28 power rings, 246 general-purpose rings and three balanced video circuits of very good quality.

The bulk of the power requirements for the rotating structure are satisfied by 340 KVA 440-volts 3-phase 60-cycles. It was deemed desirable to bring 440 volts instead of lower voltages into the rotating structure in order to minimize the current requirements for the slip rings. Where 208/120-volt power is needed, this is obtained from transformers on the antenna structure.

It is now believed that a cable-wrap system would be more practical than a slip ring assembly. The slip ring assembly would be essential for an antenna that has to revolve continually but is not of great value for a communications satellite ground station antenna that requires only a partial revolution for any one pass. With a cable-wrap system a fair amount of equipment would be eliminated.

III. OPERATING PLAN

An early step in system planning for the Andover ground station was the development of an operating philosophy. Analytic studies were made to determine the sequence of activities that could occur during the interval commencing with preparation for a satellite pass and ending with release of all systems at the termination of a mission. From these studies, operator decision points were defined and assigned as functional responsibilities at logical operator positions. Control and display requirements were then established and incorporated in the design of operating consoles. Also, an operations plan was prepared to set forth the specific procedures that would be used when operating various systems in concert. Training exercises and evaluation tests were carried out for the system as a whole to: (a) calibrate the interconnecting equipments, (b) determine system response times and other necessary operations data, (c) verify operations procedures, and (d) develop an efficient operator team. The last step in operations "prove-in" came through the experience obtained once the Telstar satellite was in orbit.

3.1 *Concept of Operations*

Centralized control was considered essential for coordinated operations involving many interrelated but independent subsystems—particularly in view of the experimental nature of the project, the time constraints imposed upon design and installation, and the objective of insuring highest probability of success. Of secondary importance, but still significant, was a desire to minimize manpower requirements once standardized routines were validated.

The central control functions for ground operations very naturally group into two areas of responsibility: (*i*) satellite acquisition and tracking, and (*ii*) broadband experimental communication. The purpose of the first area is to establish and maintain a usable broadband communication path, while that of the latter is to carry out the various transmission experiments and obtain resulting test data. The two areas are assigned, respectively, to a ground station controller and a communications controller. Over-all supervision of operations during a mission is accomplished by a mission director or by one of the two controllers, dependent upon the complexity of the scheduled experiments and degree of external coordination required. Operating positions for the two controllers are adjacent to each other, with the director's monitoring position located behind the controllers as shown in Fig. 5.

The ground station controller has specific responsibility for:

1. Coordinating the pre-mission calibration and testing activities.
2. Verifying operability of the tracking and command complex before each pass.
3. Locating the satellite.
4. Activating the satellite in an appropriate sequence.
5. Positioning the horn-reflector communication antenna to excite the satellite repeater with broadband signals from the ground, and to receive its 4-kmc signal outputs.
6. Keeping the horn-reflector antenna properly positioned throughout the satellite pass so that experiments can be conducted.
7. Deactivating the satellite functions in an appropriate sequence before the satellite goes outside of command coverage.

The communications controller has specific responsibility for:

1. Calibrating the communication transmitter and receiver systems before and after each pass.
2. Setting up and verifying readiness of all scheduled communications experiments.
3. Carrying out such experiments and coordinating with external participating sites so that valid useful data are obtained.

Assisting the controllers are operators at a few vital equipment positions. Their duties are: (*i*) to monitor the performance of a subsystem or major equipment group, (*ii*) to make operating adjustments or con-

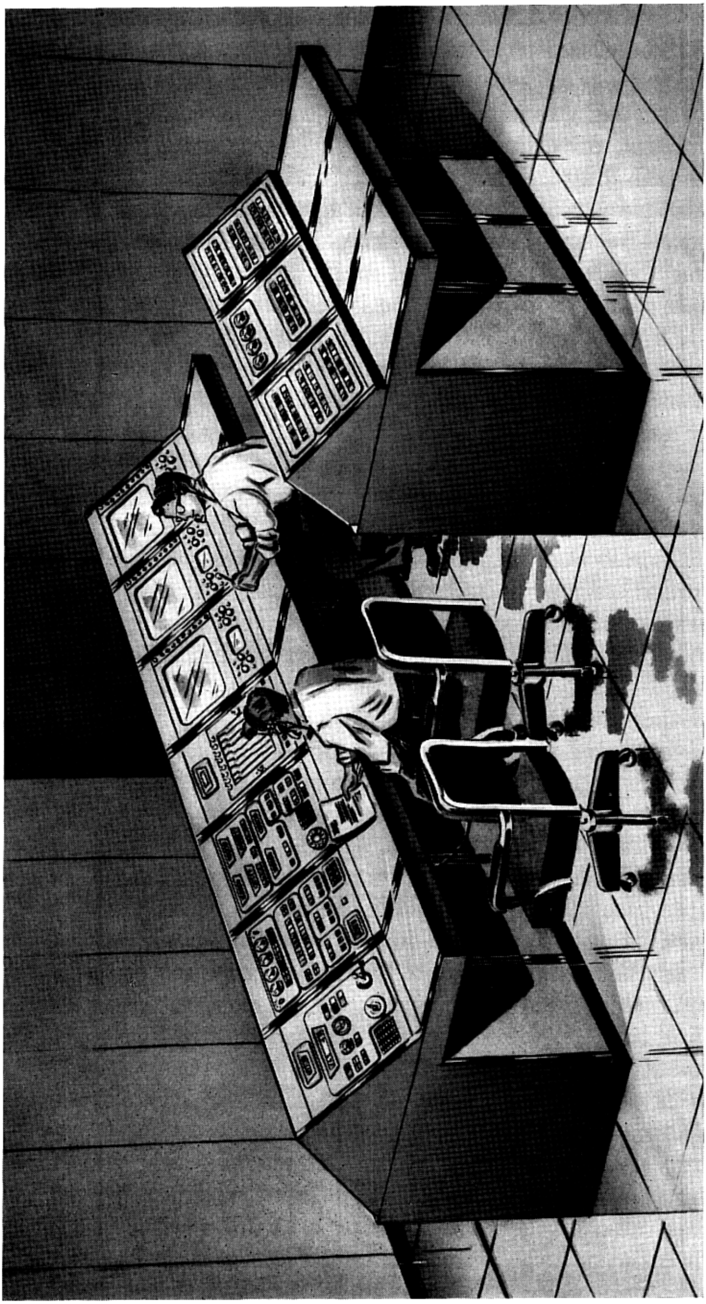


Fig. 5 — Director and control consoles.

TABLE I — BASIC OPERATIONS MANNING

Mission Operator Designation	Operator Position
Director	Director console
Ground controller	Ground station control console
Communication controller	Communication console
Command operator	Command encoder cabinet
Command track (1)	Command tracker equipment
Data operator	Tape switching console
ACE	Antenna digital control group
SERVO (2)	Antenna servo group
VAT	(Vernier) autotrack equipment
Receiver	4-kmc receiver equipment
Transmitter	6-kmc transmitter equipment
Test operator	Communications test center
TEG (3)	Track digital control group
Precision track (4)	Precision tracker console
Recorder (5)	Intercom and video recorders
Satellite (6)	Telemetry equipment bay

Notes:
(1) Manned only for initial operations, usually covered by command operator.
(2) Manned separately when needed, otherwise covered by ACE.
(3) Manned only when ranging data are scheduled.
(4) Manned separately when needed for orbit determination data.
(5) Manned only when video recordings are scheduled.
(6) Manned during first weeks of operation, for real-time assessment of satellite operating performance.

figuration changes when directed, and/or (*iii*) to perform manual control actions assigned to the local position. Table I presents the positional manning that was used during the first three weeks of operation after launching of the Telstar satellite. As indicated on the table, several of the positions are not manned during normal, routine missions.

Fig. 6 shows the basic control configuration of the ground station and the primary flow of status and control signals during a satellite pass. Briefly stated, normal operations proceed according to the general plan outlined below, assuming that the horn-reflector, command tracker and precision tracker antennas are all active. The plan is simplified for approximately 50 per cent of the passes by the deletion of the precision tracker and associated track digital control group when data for orbit determination are not required.

All systems are activated, tested and calibrated individually; they are then turned over to the two controllers who establish the integrated configuration and verify its operability by use of the satellite replica located on the test tower several miles from the station. The mission tape, with the pointing ephemeris and related data for the satellite pass, includes a set pattern of pointing and ranging data necessary for dynamic verification using the test tower. This tape is generated and

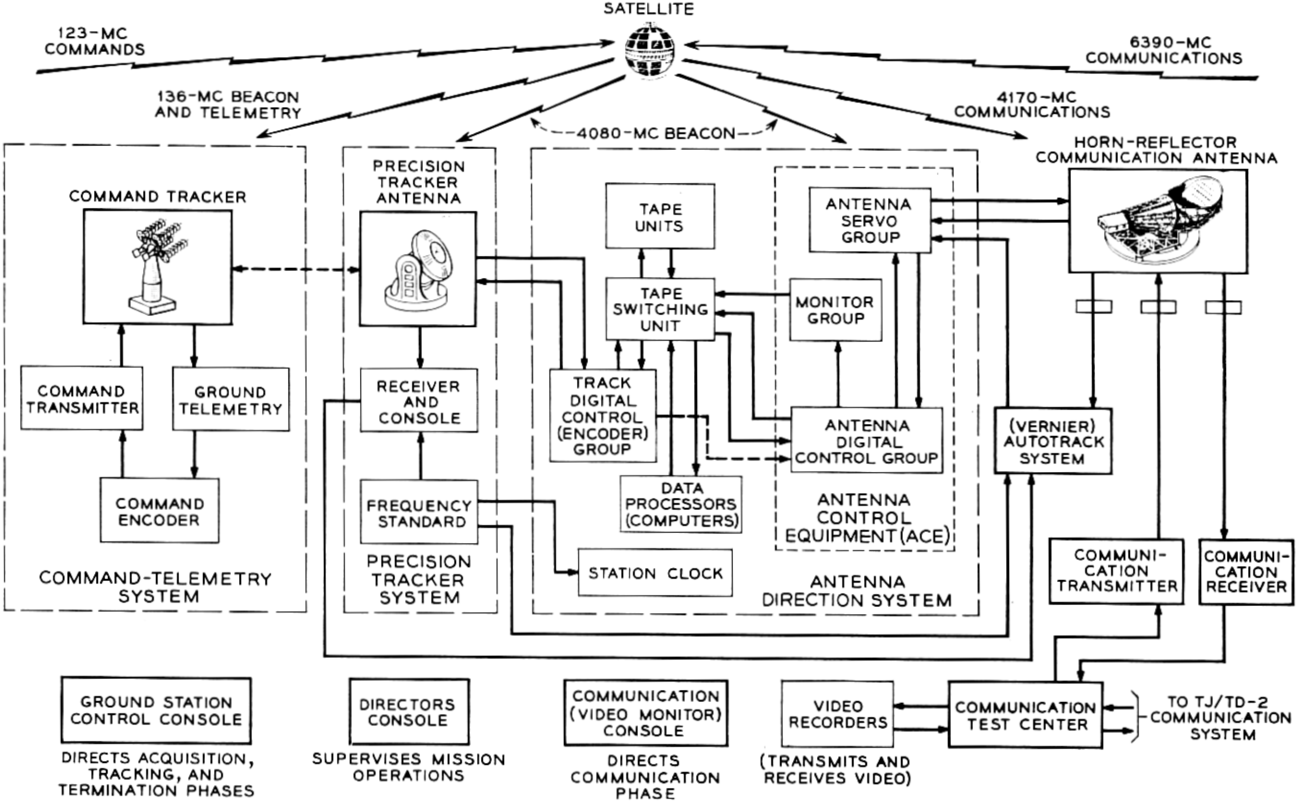


Fig. 6 — Basic control configuration.

checked by one of the local computers prior to the system testing interval. Concurrent with generating the tape data points, the computer produces a print-out of information about the pass for use by the operators; this print-out includes, among other things, pointing angles and rates for every whole minute during the passage. The print-out provides the operations team with a convenient reference for anticipating actions that will be necessary during the pass; it also serves as a back-up, for manually positioning any of the antennas to acquire the satellite, in case of loss of the automatic pointing data coming from the mission tape or other antennas.

Upon completion of the verification tests, and several minutes prior to expected satellite rise time, all three antennas are positioned to the angles for expected acquisition, using the mission tape as a common pointing source. When the command tracker begins receiving 136-mc beacon signals from the satellite and obtains a frequency phase-lock, its autotracking mode is selected. As soon as the strength of the received signal permits, commands are transmitted in a prescribed sequence to energize operating circuits in the satellite that activate telemetry and later turn on the broadband repeater. During this interval of several minutes, all vital conditions for safe operation of the satellite are verified by the received telemetry data. The mission tape keeps the horn-reflector communication antenna and the precision tracker pointed toward the satellite as it rises, or, optionally, the precision tracker can be slaved to the command tracker if desired.

As soon as the satellite repeater is ON, its 4080-mc beacon signal is radiated. At that time, both the autotrack system (sometimes referred to as vernier autotrack or VAT) and the precision tracker commence frequency search and obtain phase-lock for tracking. Concurrently, the communication transmitter may radiate 6390-mc carrier at normal power, and the broadband FM signals from the satellite repeater will usually be detected through the communication receiver, confirming satisfactory pointing by the horn-reflector antenna. When phase-lock is established, the autotrack system outputs are inserted into the tracking loop for the main antenna; similarly, the precision tracker begins autotracking. If difficulties are experienced in acquisition by either antenna, outputs from the other system may be used to assist in completing the process.

When the autotrack system error loop has been completed and the signal strengths in the 6390-mc and 4170-mc paths have been confirmed to be at expected levels, the communications controller uses the link for scheduled experimental transmissions. At a predetermined time during satellite descent, or if a critical condition should occur in its operation, the ground station controller sends a sequence of commands that shut down the satellite repeater and restore other operating circuits to their secured state. Tracking is terminated at this time, and any necessary post-mission calibration data are obtained prior to release of the ground systems.

3.2 *Operational Performance*

The first several days of operation after the Telstar satellite launching established that command tracking acquisition normally can be accomplished slightly before the satellite rises to the optical horizon, that command of the satellite is reliable as soon as the acquisition is completed, and that usable telemetry data can be obtained before 5 degrees elevation except in the presence of severe noise from electrical storms or man-made interference. Acquisition by the horn-reflector antenna was found to be considerably more rapid than had been anticipated, usually being completed in less than ten seconds after full activation of the satellite repeater. Similarly, precision tracker acquisition was usually swift and was no problem. Some of the contingency capabilities that had been provided in the tracking systems were therefore of lesser importance than had been expected. These capabilities did give a great deal of flexibility for handling any troubles that might arise, and for probing for the marginal performance limits of tracking — quite appropriate characteristics for an experimental facility. During the first three weeks after the launch, all possible acquisition and tracking modes and configurations were attempted and all were successful. This even extended to slaving the horn-reflector antenna to the command tracker for acquisition. Of particular interest was the capability for manual acquisition by the horn-reflector antenna — that is, manually positioning to angles in advance of the satellite along its expected path and then achieving a full autotrack state during the interval that the satellite moved through the 0.22-degree beamwidth of the antenna's main receiving lobe. It was found that this technique could be used even at high elevation angles: At a satellite angular rate of movement of 0.3 degree/sec or less, the acquisition was relatively easy; at an angular rate of 0.45 degree/sec the acquisition required good operators, particularly at the autotrack position, but could be effected. Also of interest was the capability for minimizing disruptions of the communications link when the satellite passed very close to the site's zenith. By alert operation at the ground station control console, the link outage could be kept to within 10 seconds of the calculated interval for azimuth slew at the maximum rate of 1.5 degrees/sec. Finally, horn-reflector antenna tracking up to elevation angles of 85 degrees was eminently satisfactory: The autotrack system nearly always held the pointing to within 0.005 degree of its null when its servo-loop was closed, or with the autotrack loop open the indicated pointing error could be kept under 0.01 degree by manually inserted offsets. Even with the autotrack system outputs turned off, a usable communications link could be maintained by keeping the 4170-mc received carrier AGC maximized through manual offset insertions, admittedly an arduous monitoring task for the ground station controller.

3.3 *Console Design Considerations*

3.3.1 *Ground Station Control Console (GSCC)*

An important objective in designing the operating position for the ground station controller was to achieve a minimum over-all manpower requirement for supervision, operation and maintenance at the ground station; consequently, design philosophy was based on performing as much of the acquisition and tracking control from this one console as was practical. This meant that the ground station control console or GSCC would interconnect with nearly all systems on the station (see Fig. 7). At the same time, the experimental nature of the project dictated that the design be flexible enough to accommodate development changes. Therefore, displays and controls were organized so that console activities could be handled by a single operator or apportioned between two, or even three, operators if necessary during training and early experiments. Also, features were included in the mechanical and wiring design so that functional changes could be made quickly after the console was installed, with minimum interference to its operational use.

Controls for the entire tracking and command complex were provided in the GSCC except for the precision tracker, data processors and their associated equipments. These were excluded for three reasons:

1. The primary real-time tracking complex does not require control changes involving these subsystems during normal operations.

2. If operating controls for these subsystems were included, the GSCC size and complexity would be such that a single operator, or possibly even two operators, might not handle the work load.

3. The excluded subsystem might be used for other operations during certain active passes in which they were not a part of the real-time horn-reflector antenna pointing complex. In particular, the data processors would be used for data reduction or generation of future predictions,

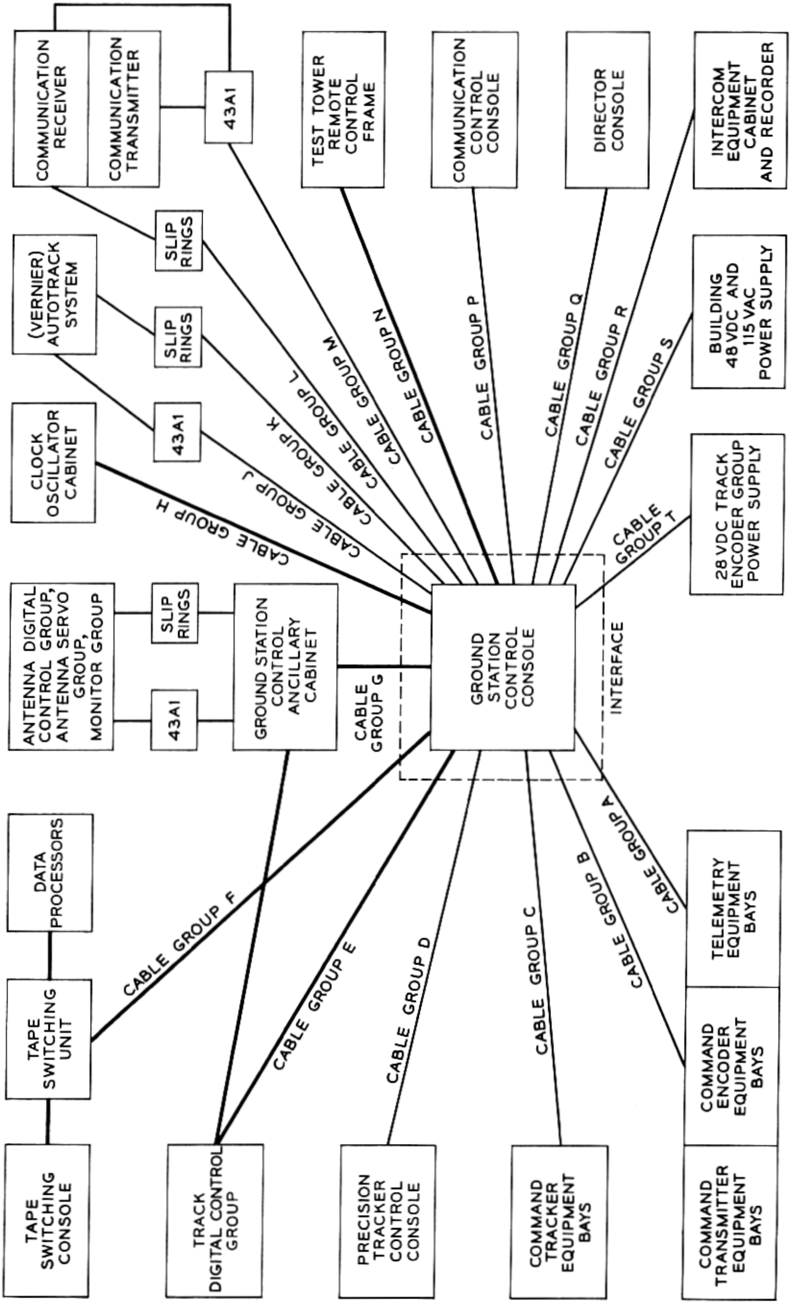


Fig. 7 — Connections to ground station control console (GSCC).

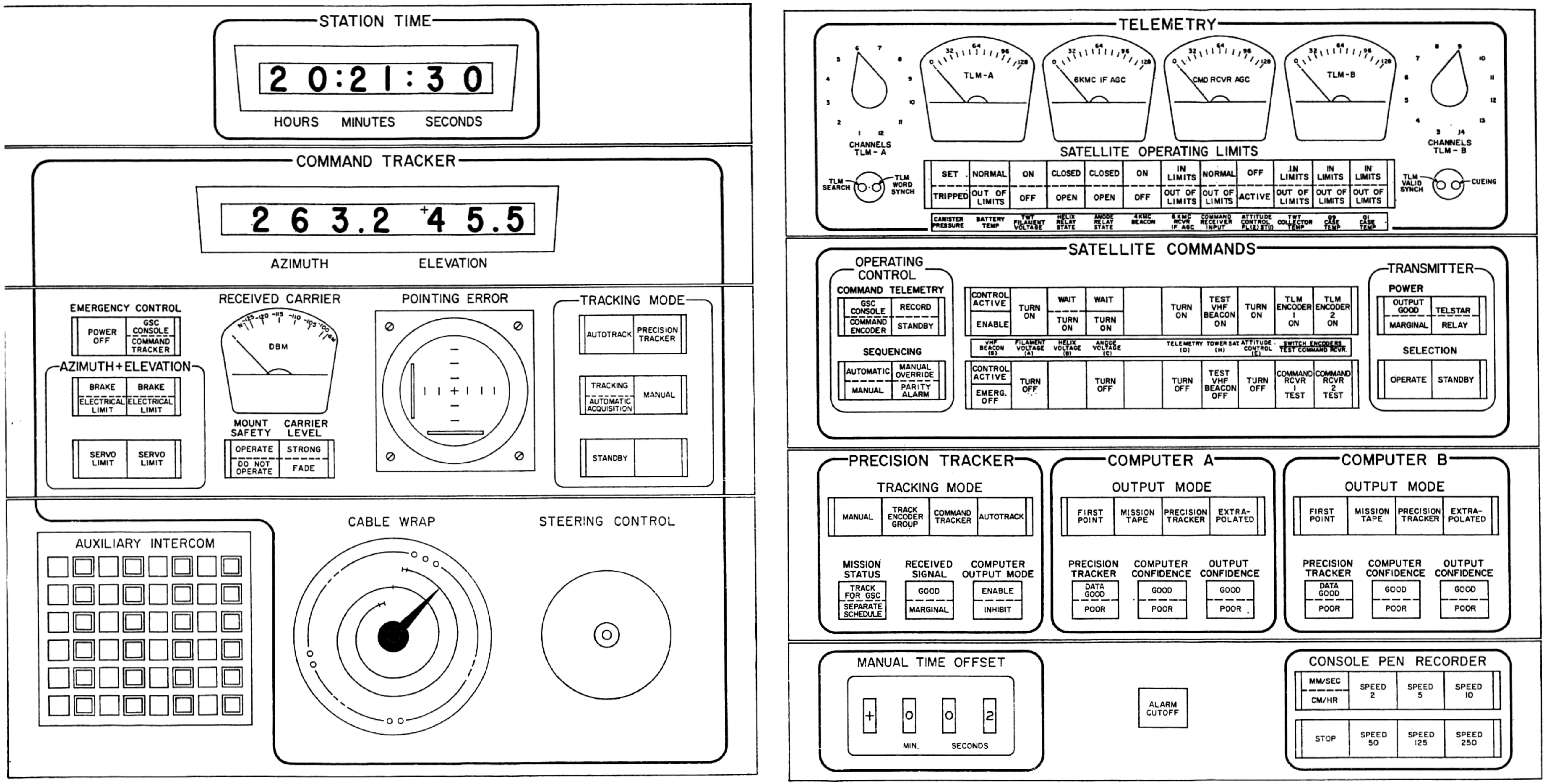
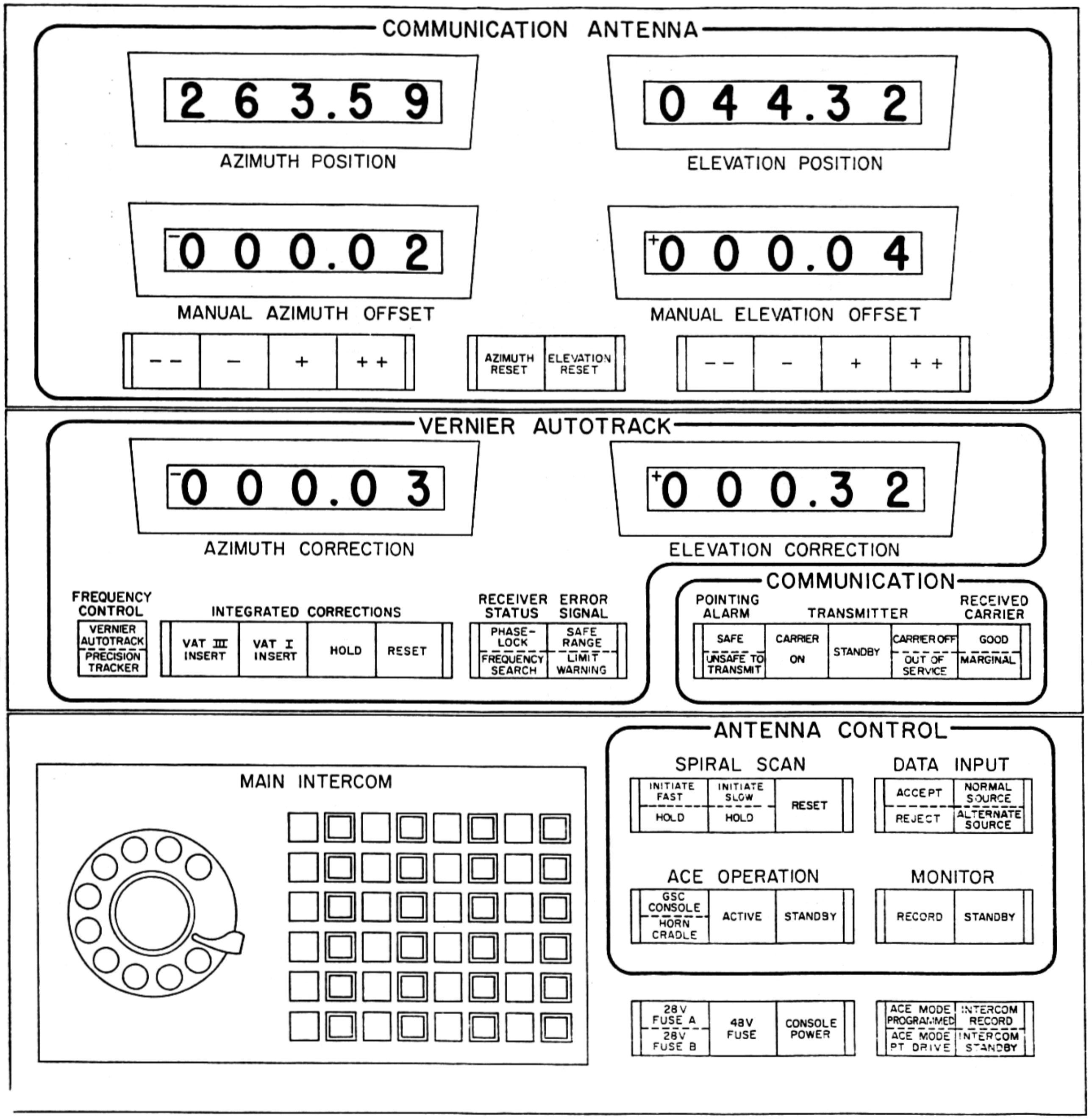
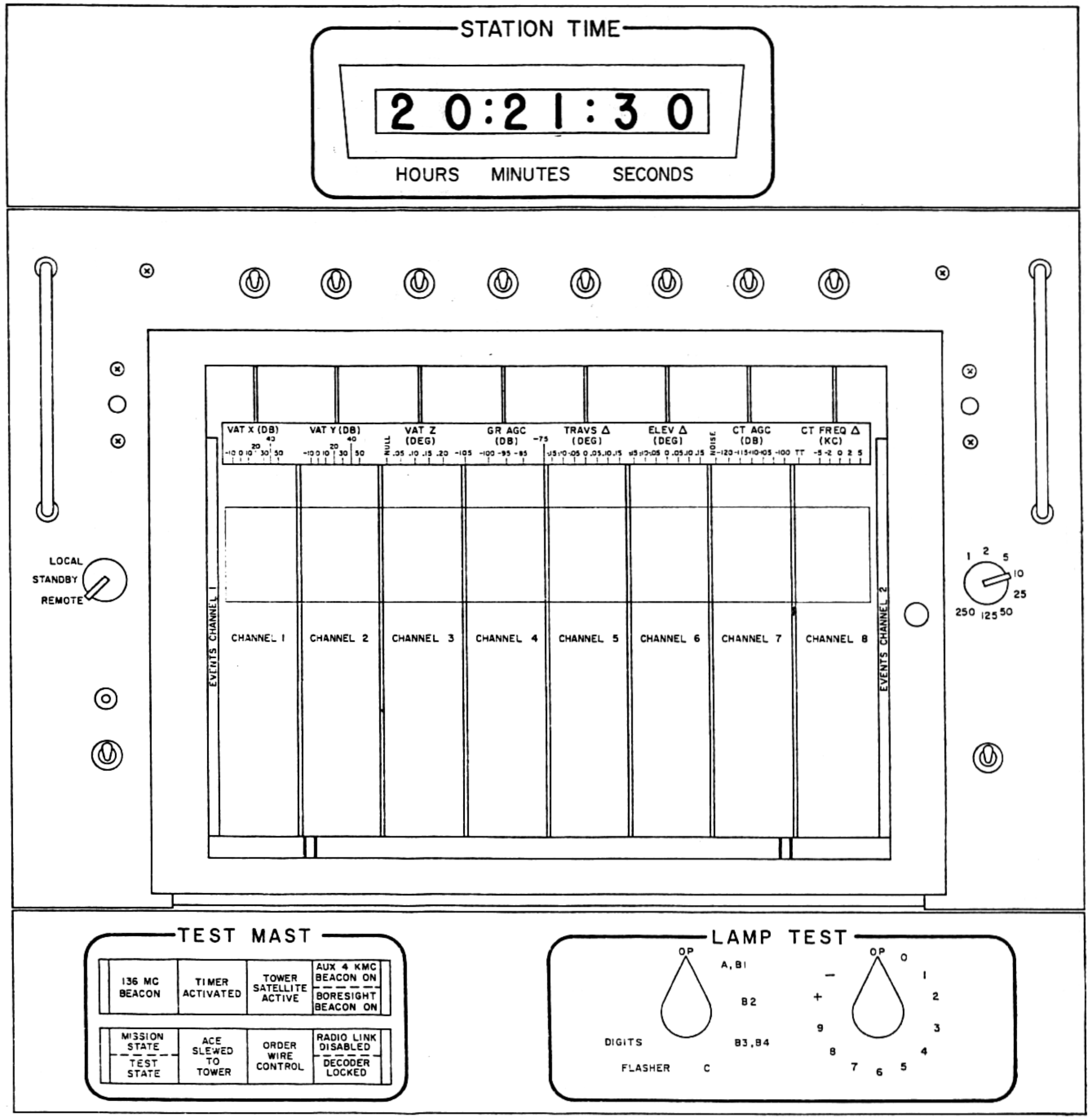


Fig. 8 (This page and overleaf)—Front panel layout of ground station control console.


COMMUNICATION ANTENNA
2 6 3.5 9
AZIMUTH POSITION
0 4 4.3 2
ELEVATION POSITION
-0 0 0.0 2
MANUAL AZIMUTH OFFSET
+0 0 0.0 4
MANUAL ELEVATION OFFSET
-- - + ++
AZIMUTH RESET
ELEVATION RESET
-- - + ++
VERNIER AUTOTRACK
-0 0 0.0 3
AZIMUTH CORRECTION
+0 0 0.3 2
ELEVATION CORRECTION
FREQUENCY CONTROL
VERNIER AUTOTRACK
PRECISION TRACKER
INTEGRATED CORRECTIONS
VAT III INSERT
VAT I INSERT
HOLD
RESET
RECEIVER STATUS
PHASE-LOCK
FREQUENCY SEARCH
ERROR SIGNAL
SAFE RANGE
LIMIT WARNING
COMMUNICATION
POINTING ALARM
SAFE
UNSAFE TO TRANSMIT
TRANSMITTER
CARRIER ON
STANDBY
CARRIER OFF
OUT OF SERVICE
RECEIVED CARRIER
GOOD
MARGINAL
ANTENNA CONTROL
SPIRAL SCAN
INITIATE FAST
HOLD
INITIATE SLOW
HOLD
RESET
DATA INPUT
ACCEPT
REJECT
NORMAL SOURCE
ALTERNATE SOURCE
ACE OPERATION
GSC CONSOLE
HORN CRADLE
ACTIVE
STANDBY
MONITOR
RECORD
STANDBY
MAIN INTERCOM
28V FUSE A
28V FUSE B
48V FUSE
CONSOLE POWER
ACE MODE PROGRAMMED
ACE MODE PT DRIVE
INTERCOM RECORD
INTERCOM STANDBY


STATION TIME
2 0:2 1:3 0
HOURS
MINUTES
SECONDS
LOCAL
STANDBY
REMOTE
VAT X (DB)
-10 0 10 20 30 40 50
VAT Y (DB)
-10 0 10 20 30 40 50
NULL
VAT Z (DEG)
.05 .10 .15 .20
GR AGC (DB)
-105 -100 -95 -85 -75
TRAVS Δ (DEG)
.15 .10 .05 0 .05 .10 .15
ELEV Δ (DEG)
.15 .10 .05 0 .05 .10 .15
NOISE
CT AGC (DB)
-120 -115 -110 -105 -100 TT
CT FREQ Δ (KC)
-5 -2 0 2 5
EVENTS CHANNEL 1
CHANNEL 1
CHANNEL 2
CHANNEL 3
CHANNEL 4
CHANNEL 5
CHANNEL 6
CHANNEL 7
CHANNEL 8
EVENTS CHANNEL 2
1 2 5 10 25 50 125 250
TEST MAST
136 MC BEACON
TIMER ACTIVATED
TOWER SATELLITE ACTIVE
AUX 4 KMC BEACON ON
BORESIGHT BEACON ON
MISSION STATE
TEST STATE
ACE SLEWED TO TOWER
ORDER WIRE CONTROL
RADIO LINK DISABLED
DECODER LOCKED
LAMP TEST
OP
A, B1
B2
B3, B4
C
DIGITS
FLASHER
OP
0 1 2 3 4 5 6 7 8 9
-
+

and the precision tracker might eventually be used for concurrent tracking of a second satellite.

Several of the GSCC controls and displays were included to allow full manual operation if required or desired during early experiments. In some instances, this capability was essentially a back-up for a mechanized feature or a hedge against operating problems that could but probably wouldn't arise; in others, it was an interim measure used for operations procedures that might eventually be automated after experience was gained with the first satellite. Thus, it was anticipated that the console and the operator's job would simplify as the system evolved after first experiments.

Fig. 8 shows the front panel layout of the console. Controls and displays were arranged in logical functional groupings and were located in the general order that the groupings are needed during acquisition and tracking; thus, operator activities start from the left and proceed to the right, going from top to bottom of each section. In so far as was practicable, the usual human engineering rules of uniformity, legibility, compatibility and operability were followed in the over-all design.

Components for display of magnitude quantities were selected on the basis of the dimensionality of the quantity and total range or precision required. Unidimensional quantities were presented on meter movements if no better than 2 per cent of full-scale accuracy was required; when greater precision was needed for such quantities, co-planar, projection-type decimal-digital displays were used. Important quantities whose history of variation over an interval of time was significant were presented on an eight-channel strip chart recorder in the section furthest to the right.

The digital nature of a substantial portion of the circuits in the tracking systems required that magnitude controls be in a digital form. An exception to this was the manual pointing control for the command tracker, which was in analog form. For uniformity in control and display configurations, magnitude inputs were decimal-digital wherever practicable. For quantities whose rate of change had to be limited, control from the GSCC was effected through increase/decrease switches associated with a decimal-digital display feeding back the present magnitude of the quantity stored in the associated subsystem.

Self-illuminated placard displays were used for binary event and for status information displays. Labels were engraved directly on the placards so that they would be visible even when the placard was dark. If a display was associated with a binary control function, the control and status displays were combined in a single pushbutton placard assembly.

This afforded visual confirmation by illumination of the control when an action was effected. All status indicators were arranged to be lighted by contact closures at the applicable system so that only confirmed status would be displayed. Wherever possible, a satisfactory condition would be shown by positive information (a lighted indicator), rather than by the lack of a warning signal.

Color coding for indicators was assigned on the following bases:

1. *White* was used for display of active equipment status or to confirm the execution of a simple, mutually exclusive GSCC command.

2. *Green* was used to signify that operation is normal and within limits or, on a control, that a binary command which is necessary in the acquisition-tracking process has been executed by the interconnected subsystem.

3. *Amber* was used to indicate that a function necessary to the acquisition-tracking process remains to be executed or requires attention by the controller. When flashing, the amber indicator was to denote a mild warning that a function of some urgency requires attention.

4. *Red*, when steady, was used to warn the operator that a control action is prohibited or that a vital function is in an unsatisfactory, nearly critical condition. Flashing red was reserved for emergency and alarm situations that required immediate action by the controller. Flashing red indicators were arranged also to trigger an audible alarm and to remain ON until acknowledged by the controller. When warranted, steady red controls were provided automatic interlocks to prevent effecting the prohibited action until the improper status had been cleared.

The color-coded status displays were selected so that they (*i*) prevented overlooking any essential steps in the acquisition, activation and tracking processes and (*ii*) gave the ground station controller confirmation at a glance (only green and white displays showing) that all conditions were normal once the communications link was established. This made it possible for the controller to direct primary attention during transmission experiments to the recorded traces on the strip chart or to specific satellite operating parameters.

Operational experience, after the Telstar launch, confirmed that for normal passes all necessary ground station controller responsibilities could be carried out by a single competent operator at the GSCC. Two operators could adequately handle the position under even the most unusual command or tracking experiments that were scheduled. It was also demonstrated that the position could be shared by three operators in a quite satisfactory manner, which was very convenient for collecting specific data on tracking performance during early operations and for training new controllers.

3.3.2 *Communication and Director Consoles*

In conducting transmission experiments via the satellite, it is necessary that close coordination be maintained with the ground controller and with participating external stations while concurrently monitoring the test signals sent and received. The communication console was therefore located adjacent to the GSCC so that key displays could be shared and critical interactions could be accomplished expeditiously and efficiently. A separate test center was provided as well, instrumented essentially as both a television operating center and a toll test board. Duplicate facilities were provided so that either the communication console or the test center could control, through a video and an audio crossbar switch, the connection of baseband inputs to the communication transmitter and outputs from the communication receiver.

For dynamic evaluation of the working outputs at the video switch, the communication console was instrumented with three commercial-type picture and waveform video monitors. One of these displays the selected outputs for transmission on the satellite up-path, another the received picture on the satellite down-path, and the third any available picture input such as that received over land-line circuits from the Holmdel station. For control of the video, a pushbutton matrix was installed on the console whereby any one of 10 transmission and test input signal channels may be applied to any one of 10 output channels. Associated audio, where applicable, was made available to the operator's headphones via a separate group of 10 pushbuttons on the console. In addition, several auxiliary control and status features were provided, such as those for interposition and external communication and those for selecting between the three available video standards for display generation.

The director console was designed to give a general view of the progress of operations and to provide flexibility in communicating with external participating stations prior to, during, and upon completion of a mutual experiment. For convenience, many of the individual status displays at the GSCC were provided to the director console in multiple. The only controls provided to this position were those associated with the intercom system and a mission time counter. This counter provided a display of time relative to the expected rise of the satellite, in minutes, from up to 99 minutes before the epoch until 99 minutes after the epoch had occurred. This display was used by the controllers and operators as the main reference for cueing during operations in that it was a more convenient display for the purpose than conventional station time.

The consoles for the controllers and the director were each provided with direct access to the voice telephone circuits interconnecting external participating stations for operational coordination purposes. Also, the consoles were given access to the local PBX, intercom and paging systems. This arrangement allowed nearly complete freedom among the three positions for exercising supervisory responsibilities and for preventing overloads or coordination delays. The local intercom was designed to include two conference loops with appearances at all operating positions, and four maintenance loops with appearances at certain operating and related maintenance points. The conference loops were engineered for monitoring by each operator at all times desired, with freedom to talk simultaneously over this or another selected circuit. During operational missions, one conference loop is normally monitored by all operators as the primary coordination channel, and the other is used to handle any lengthy interchanges that may become necessary between two or three positions during the mission. Standardized station designations, push-to-talk, and a modest set of rules are imposed as circuit discipline for the conference loops.

IV. POWER FACILITIES

The Andover earth station, fully equipped with several communication systems, would require about 1000 kw of 60-cycle alternating current to energize rectifiers in the technical equipment and loads such as motors, lights and other utilities. Present load at the station is about one half the anticipated maximum load. There are two sources of this current. One source is commercial service from the local public utility company. The second source is a self-contained prime power plant equipped with diesel engine-generator sets.

The earth station loads are divided into the categories of technical loads and utility loads. Among the technical loads, examples include power for electronic equipment: rectifiers for tracking equipment, antenna control equipment, computers, receivers, transmitters, video monitors, tape recorders, and 60-cycle servomechanisms; and for primary essential services: motors for the main antenna drive, motor generators for 400-cycle servomechanisms, compressors for the maser cryostat, air conditioning and lighting for movable rooms on the main antenna structure, and blowers for equipment cabinets. Among the utility loads, examples include power for various secondary essential services: lighting circuits and convenience outlets in the control building and for stationary rooms in the main radome, motors and controls for building heating and air conditioning equipment, blowers for pressurizing the main radome (see below), and dc power plants with battery stand-by for alarms and carrier telephone facilities.

The general plan for distribution of current to these loads is shown in Fig. 9. The service reliability criterion influenced greatly the choice of power switching circuits, the choice of the engines, the plant operating procedures, and the switchgear operating sequences.

The Andover plant is presently operated as a hybrid prime power installation with commercial service used for both the technical and utility busses during stand-by periods. During an experiment, even a brief interruption on the technical bus is unacceptable. A short interruption on the utility bus is undesirable, but tolerable.

The power-plan circuit in Fig. 9 is shown in the normal operating condition which obtains during a satellite communications experiment. Generators A and B are in parallel, delivering energy through the generator circuit breakers A and B, and the tie breaker AB to the technical bus. The utility bus is energized from the commercial service through circuit breaker K1B. When an interruption occurs in the commercial service, breaker K1B is opened and breaker 2B is closed, so that the engines feed both busses. If one engine fails during normal operations, the other engine can carry the load on the technical bus. If an engine

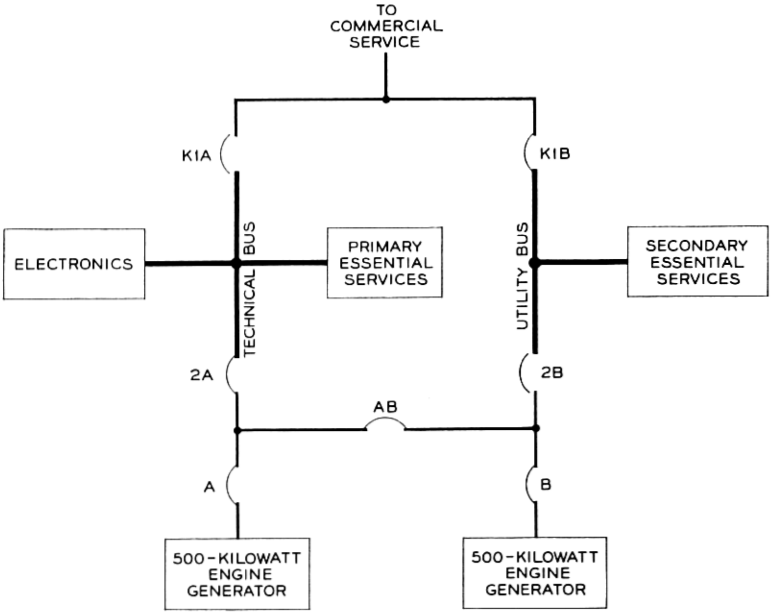


Fig. 9 — General plan for distribution of power.

fails during a commercial failure, the remaining engine will carry the entire load on the technical bus plus part of the load on the utility bus.

The engine-generators are rated at 500 kilowatts, 900 rpm, and are of the type procured by the Bell System for stand-by service in central and toll offices. The choice of this particular machine was dictated primarily by load demand, although a single larger engine could have been used to carry the total station load. The use of two 500-kilowatt machines gives greater flexibility for growth, and for higher reliability than would be obtainable with a single machine. Also, a considerable backlog of experience has been built up with this particular set, and its proven performance in other prime power applications makes it a preferred choice.

An axiom derived from Bell System power plant experience is that the probability of occurrence of operator error is highest during the first few minutes of an emergency such as a power failure. Therefore, power plant operator procedures are arranged so that most failures of the types expected to be encountered do not require immediate action on the part of the operator. Thus, if commercial service fails, the operator is relieved of pressure to restore utility bus voltage by the fact that immediate restoration is not necessary, by definition, on the utility bus. Similarly, if one of the engines fails, the operator is relieved from pressure by the fact that one engine can carry the technical bus load indefinitely. Of course, engine circuit breakers are depended upon to clear overloads due to faults or current reversals.

It will be noted that the blowers for pressurizing the main radome are fed from the utility bus. This is the one load on the utility bus for which a power failure of a few minutes duration could be a hazard. Consequently, the motor control center for the blowers can be energized from a small 30-kilowatt, automatic-start diesel generator, located at the radome, as well as from the utility bus. This arrangement gives protection against failure of the utility bus or any of the switchgear associated with the bus, for more than a few minutes.

The reliability features in the power system have proved to be well worth-while. Operating records show that there were six interruptions in the commercial service in 1962, four of which occurred after the Telstar satellite was launched. One of these interruptions caused a loss of system power long enough to disturb seriously a communications experiment. In addition, there have been partial and full power failures due to operator errors and training sequences, but these failures were anticipated as an unescapable part of the installation and familiarization program. Analysis of the causes of these failures has confirmed the soundness of the plan to minimize pressure on the operator during an emergency.

V. AIR CONDITIONING AND HEATING

The Andover site, located in a remote section of Maine, experiences some of the most severe environmental conditions in the United States. In order to communicate with a satellite orbiting in space, precise control of the 380-ton antenna[1] is essential at all times. To reduce mechanical deviations which might be expected from snow, ice, wind and large fluctuations in temperature, the entire antenna is housed in a large air-inflated plastic radome. The inside of the radome requires heating to prevent the accumulation of ice and snow on the outside surface of the radome. It also requires dehumidification to avoid damage to equipment through rain, fog or condensation within the radome.

In addition to the radome, the two rooms which house transmitting, receiving and tracking equipment are part of the rotating antenna structure and require heating and cooling for both equipment and personnel.

Heating and cooling for the utility building adjacent to the radome foundation and the control building presented no unusual problems and will not be discussed in this paper.

5.1 *Radome Heating and Deicing*

The use of a protective radome created a number of engineering problems. Controlled heating of the inside air is needed to prevent ice and snow accumulation on the radome which might impair system transmission. The heating system must be capable of maintaining temperatures suitable for both personnel and equipment.

Fig. 10 is a schematic diagram of the closed hot water system used to heat the utility building and to heat and deice the radome. This system originates at the control building where two oil-fired boilers, each with an output rating of 10 million BTU per hour, supply 200°-225°F hot water. The complete output of these boilers is not used at the radome, however, since some 4 million BTU per hour are used at the control building itself. The hot water is piped one quarter mile underground to the radome and utility building where it is distributed by branch piping to the heating coil, room space heaters, and the radome heating-deicing units. The discharge water from these units is directed into return water lines which eventually return the water to the boilers for reheating.

Radome heating and deicing represent two different heat problems.

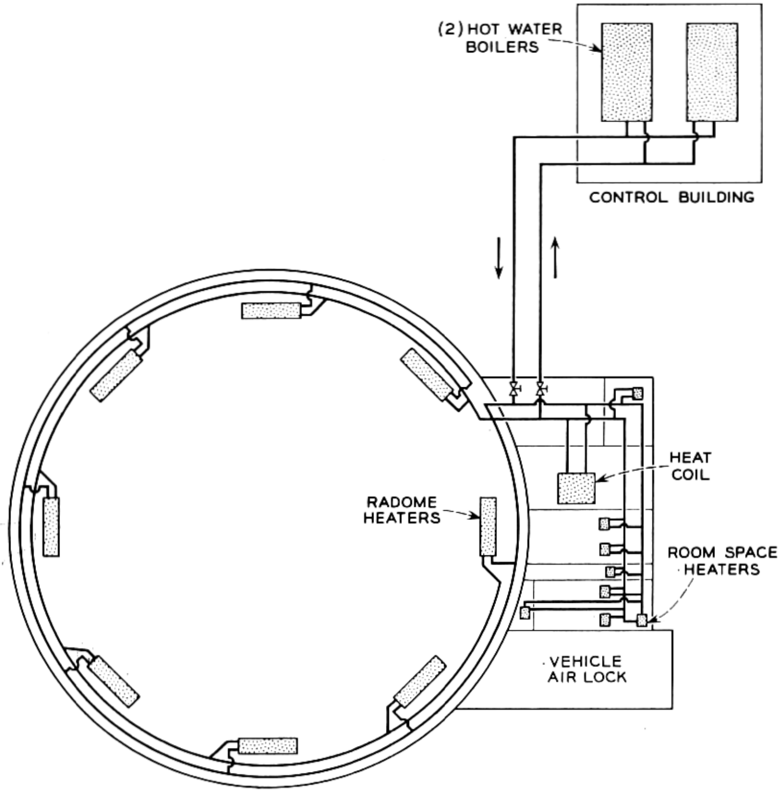


Fig. 10 — Schematic diagram of closed hot water system.

For interior heating it is desirable to direct the bulk of the heat near the equipment and working areas and to minimize heat losses through the plastic type radome. For snow melting and deicing, heat concentration should be at the top and sides of the radome with a maximum heat flow through the radome material being desirable.

In order to design an adequate heating-deicing system for the radome, it was necessary to calculate heating requirements for both heating and deicing. Calculations indicate that 13,551,000 BTU/hr is required for radome heating and that 10,250,000 BTU/hr is required to melt the snow and any ice film on the outside surface. Therefore, radome heating determines the maximum amount of heat to be supplied to the radome.

Although heating is the governing criterion in determining the amount of heat to be supplied to the radome, the distribution of heat is another problem. The air temperature in the upper portion of the radome must be 107°F to melt snow, and an air temperature of 62°F is required to keep water from freezing on the lower portion. To accomplish this heat distribution, eight radome deicers spaced 45 degrees apart discharge warm air into a plenum chamber through a transition section and into flexible plastic wall ducts. Tap-off ducts, with damper-controlled flow, were designed for scrubbing the lower radome wall. Eight circular plastic ducts were provided; four were designed to extend 50 feet above the radome heaters and four designed to extend eighty feet. The duct openings are directed to provide a scrubbing action over the inner radome surface.

5.2 *Radome Dehumidification*

In addition to radome heating, another problem encountered in using a protective enclosure was radome dehumidification. Provisions for this had to be made in order to avoid damage to equipment through rain, fog or flooding of the concrete base by condensation. Condensation occurs when saturated air is cooled. During the cooling process, the heat losses of the saturated air represent the sum of sensible heat of air and the latent heat of the condensed water.

Considering the radome conditions, if it is assumed that the outside dry bulb temperature is less than the inside dew point temperature, the following conditions can occur:

1. When the inner radome surface temperature is greater than the inside dew point temperature, no condensation will occur.
2. When the inner radome surface temperature is less than the inside dew point temperature, condensation will occur on the radome skin.
3. When the inside dry bulb temperature is equal to the inside dew point temperature, the air will be saturated and condensation in the form of fog or rain will occur within the radome.

In order to prevent the formation of condensation within the radome enclosure, it is necessary to keep the dew point temperature lower than the dry bulb temperature. This can be accomplished by using a dehumidifying coil. The coil can be placed in the incoming air stream and by circulating cold water through the coil, most of the moisture contained in the incoming air can be condensed out. With a chilled water system supplying 40°F water, incoming air can easily be cooled to 45°F. 38.7 tons of refrigeration are required to maintain the proper conditions during the summer.

For winter operation, a thermostatically controlled heat coil, located on the input side of the dehumidifying coil, is used to heat incoming air above freezing. The heat coil selected is a 2-row Aerofin Coil having the required heat capacity when circulating 13 GPM of 225°F water.

5.3 *Temperature Control in the Equipment Rooms*

The two house-sized rooms, built as part of the rotating structure, require heating and cooling for both equipment and personnel. The upper room, measuring approximately 26 feet by 34 feet by 9 feet high at the walls, is located about 60 feet above the radome floor. This room contains the radio transmitting and receiving equipment. The lower room, located about 10 feet above the floor of the radome, is approximately 24 feet by 68 feet by 9 feet high at the walls. This room contains the antenna drive and control equipment and the power distribution equipment.

Electronic equipment, transistorized and otherwise, operates very efficiently in a stabilized ambient of 60° to 85°F with a relatively low humidity; the majority of people are comfortable at 70°F and approximately 50 per cent relative humidity. Fortunately, these conditions are not contradictory, and the latter condition was established as the ambient design condition inside both rooms on the antenna structure.

Chilled air is transmitted through a system of ducts for both equipment and personnel cooling. The duct system is split into two parts, one for distributing chilled air to plenum chambers running under each row of equipment cabinets for equipment cooling, and the second for supplying chilled air to outlets in the head space of the room for personnel cooling. Resistance heaters in the personnel supply ducts permit the use of these ducts for heating purposes. Air-handling units mounted beneath the floor of each room, upper and lower, contain the blowers and chilled water cooling units required to supply chilled air to the duct systems.

A source of chilled water was required for the air-handling units and for the water-cooled traveling-wave tube in the transmitter for the Telstar satellite, and also for the klystron used in the transmitter used for experiments with the Relay satellite.

5.3.1. *Equipment Cooling and Personnel Air Conditioning*

The first step in the solution of the equipment cooling and personnel air conditioning problem was to determine the expected climatic conditions from synoptic meteorological records. Expected heat loads and their distribution were established and were categorized as to whether they were sensible or latent. Finally, it was necessary to determine the most efficient means to dissipate the heat, i.e., by forced cooled air or chilled water, and whether the equipment and personnel cooling systems should be in series, parallel or a combination of both.

Investigation indicated that one of the following three systems for providing over-all cooling and heating would be feasible.

1. A chilled water system for water cooling plus radome air-cooled, self-contained air conditioning units for forced air cooling plus electrical resistance heating.
2. A chilled water system for water cooling plus chilled water air handling units for air cooling plus electrical resistance heating.
3. A chilled water system for water cooling plus water-cooled, self-contained air conditioning units for air cooling plus electrical resistance heating.

Using as an evaluation criterion the basic philosophy of requiring (*i*) the least weight on the rotating structure, (*ii*) the least power required, and (*iii*) the least expense from the standpoint of maintenance as well as first cost, system No. 2 was selected for the Telstar project.

To insure that the heat-transfer surfaces of the traveling-wave tube in the 6-kmc transmitter[2] did not suffer degradation from contamination, the water used in the chilled water system had to be very pure. Copper piping, which has a tendency to kill bacteria and does not add impurities such as rust to the water, was selected for use in the chilled water system. To further insure that the water passing over these heat transfer surfaces was pure, all minerals found in ordinary drinking water in the form of ions and cations had to be removed. This was accomplished by installing a deionizer with a bed of nuclear grade resin in series with a microfilter. The microfilter is capable of removing particles as small as 1 micron. The water obtained by using the copper piping, the microfilter and the deionizer is purer and cleaner than normal drinking water and has an electrical resistance of between 12 and 20 million ohm-centimeters.

Specifying the size and physical requirements of the equipment to be designed or modified requires that a summation of the heat gains and losses be determined for all equipment and personnel locations. Using established design criteria, the heat gains and losses had to be correlated with the existing outside ambient conditions for Andover, as well as for the predicted inside ambient radome conditions. After accumulating this information, a heat balance was made to determine the amount of refrigeration required in the summer and the heating required in conjunction with cooling during the winter. The requirements for refrigeration are summarized in Table II.

TABLE II — REFRIGERATION AND CHILLED WATER FOR UPPER AND LOWER ROOMS

	Gal/min Water	Tons
Lower room		
Air handler	35	25.2
Klystron for Project Relay	25	11.44
Upper room		
Air handler	24	17
TWT tube	25	7.10
	109	60.74
Dehumidification	60	38
Total	169	98.74

Air handlers having the following characteristics based on the use of 42°F cooling water were selected:

	Lower Room	*Upper Room*
Cooling capacity	25.2 tons	17 tons
Quantity chilled water required	25 gal/min	24 gal/min
Air temperature drop	20°F	20°F
Air flow capacity	14,000 CF/M	10,000 CF/M

5.3.2 *Refrigeration System*

To insure reliability in this system, multiple smaller-sized refrigeration components are used instead of one large unit. The main components of the water system are two chillers, each having four compressors, two centrifugal water pumps, four condensers, a deionizing unit, two air handlers, four receivers, and a dehumidifying coil. The majority of these components are installed in the utility rooms at the base of the radome, external to the pressurized area.

The refrigeration system uses four refrigeration circuits. If one circuit fails, maintenance can be completed without affecting the other three circuits. Each refrigeration circuit consists of two compressors, one air-cooled condenser, a liquid freon receiver, and associated refrigerant valves. The nominal capacity of the four circuits is 100 tons of refrigeration.

Integral with each refrigeration circuit is an air-cooled condenser located on the roof of the utility building. Again reliability was a contributing factor in the selection of this type condenser. The severe winter conditions in the Andover area made it necessary to pick a unit with simple controls requiring a minimum of maintenance. The air-cooled condenser is preferred over the evaporative type of condenser or cooling tower because air instead of water is used to dissipate heat.

5.3.3 *Chilled Water System*

The requirement for reliability indicated the need for more than one high-pressure pump for circulating chilled water. Failure of the operating pump requires that the standby pump must start automatically and immediately. As a result, the pumps were supplied with automatic backflow check valves at the supply end of each pump. This insured no loss of pressure due to flow through the idle pump but of course increased the flow pressure on the output of the other pump. The requirement that the traveling-wave tube, inherently a high-flow resistance device, be used in parallel with a low-flow resistance unit such as an air handler, required special valves in conjunction with regular valves, which increased the over-all flow resistance of the system.

Two high-pressure pumps, each having a flow capacity of 230 gallons per minute when pumping against a head pressure of 231 feet of water (93 psi), were installed. The chilled water flow path starts at the operating pump and passes through the two chillers operating in parallel. These chillers cool the return water to 40°F. The water is then forced through a 4-inch, cork-insulated copper pipe. At the center of the antenna, the pipe size is reduced to 2 inches prior to passing through the rotary joint. (Water flowing from a stationary component onto a rotating structure, such as the antenna, requires a leakproof rotary joint, illustrated in Fig. 11.) The chilled water then passes through one cavity of the rotary joint onto the antenna, where it is diverted to several branches of fiberglass insulated pipe which carry it to the upper and lower rooms. At these rooms the chilled water is distributed to the TWT, klystron tube and air-handling units.

The requirement for very pure water also dictated that the chilled water system be a closed one. Therefore, the return water passes through the second cavity of the rotary joint and back to the pumps. A portion of the chilled water is used to dehumidify the air used to inflate the radome.

The selection of a deionizer was based upon an established standard that a deionizer have sufficient capacity to handle at least one per cent per minute of the total gallonage in the system. A deionizer with a capacity of 6 to 20 gallons per minute was selected.

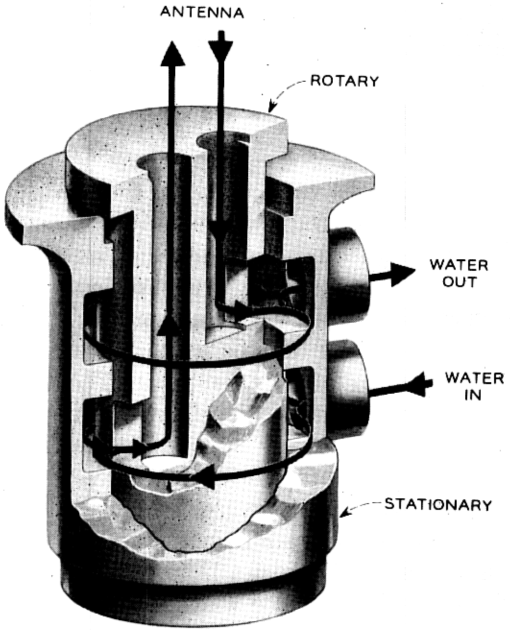


Fig. 11 — Rotary joint for chilled water system.

5.3.4 *Heating of Equipment and Personnel Areas*

To establish a stabilized air conditioned area for personnel in both the upper and lower room requires that heat be added when the radome temperature is between 40° and 50°F. Since both the rooms are on the rotating structure, a great advantage can be derived in using an electrical resistance type of heat, as no storage tanks are required and the heat is "clean." Assuming that the radome temperature surrounding the lower equipment rooms is 45° and knowing that the personnel area is to be maintained at 70°F, there will be a loss of heat from the room to the radome. Part of this heat loss is offset by warm air discharged from the equipment and by heat radiated from the lights and personnel. Additional heat, however, must be added to the air being supplied directly to the personnel area in order to maintain the desired 70°F room temperature. A summary of the heat losses indicates that 19.7 kw is required in the lower room and 15 kw is required in the upper room to maintain design temperature of 70°F.

5.3.5 *Duct and Control System for Equipment Rooms*

The duct system used for both upper and lower rooms is made of aluminum. In these rooms, it was desirable to keep background noise levels as low as possible. In order to achieve this with the air flow required, the ducts had to be not only thermally insulated but also insulated acoustically with all ninety-degree duct turns vaned. This was accomplished by using a 1-inch fiberglass thermal insulation in conjunction with a simulated horse hair acoustical absorbing material, both of which were attached to the inside of the ducts. Control of the air distribution was accomplished by using strategically located manual dampers, along with adjustable air diffusers and registers. Due to the limited space available in both the upper and lower equipment rooms, the associated air handlers were suspended in a centrally located area under each room. This also helped to reduce the noise level inside the rooms. A system of catwalks and platforms provides access to the air handlers for maintenance purposes. Transmission of vibration to the antenna structure and rooms was reduced by mounting the air handler units on vibration isolators. To further reduce noise and vibration transmission through the ducts, canvas boots were used to attach both supply and return ducts to the air-handling units.

The duct system was designed so that the air handler associated with a specific room cools both the personnel area and equipment. This meant that the unit had a common return and supply duct. The supply duct was branched under the room floor to feed cool air to distribution ducts and equipment plenum chambers running under each row of equipment cabinets.

The personnel area branch duct feeds a portion of the cooled air to the distribution duct system located in the head space of the rooms. The temperature of all cool air leaving the air conditioning unit is controlled by a by-pass damper box. This box is located on the return side of the air handler and is controlled by a thermostat in the supply duct in front of the unit. This adjustable thermostat, usually set for 60°F air, modulates the flow of air across the cooling coil of the unit. If the outgoing air is too warm, the dampers direct more return air across the coil; if the air is too cold, most of the air by-passes the cooling coil.

The air temperature in the personnel space is controlled by a thermostat. This instrument is located in the personnel return air duct in the room just prior to the point where the equipment and personnel return air ducts combine into a common return duct. The thermostat controls the resistance heaters, which can add heat in increments of 2.5 kw in the upper room and 3.3 kw in the lower room up to totals of 15 kw and 20 kw, respectively.

VI. EXTERNAL COMMUNICATIONS REQUIREMENTS

An extensive communications network involving some 86 circuits was provided between the Andover earth station and various U. S. and European locations by the Long Lines Department of the American Telephone and Telegraph Company. Its purpose is to provide operations control and coordination, tracking and telemetry data exchange, and interconnection for remotely originated tests and demonstrations. The facilities used include voice, teletypewriter, data and video channels.

Access by the Andover station to the nationwide radio relay network was attained by the construction of four links of microwave radio relay between Andover and Portland, Maine. In addition, a 150-pair cable was placed between Andover and Rumford, Maine, where it connected with existing cable facilities.

On July 10, 1962, all connecting circuits with Andover were involved in the initial tests and demonstrations. For the first four months after launch, these facilities were used regularly for nearly 400 demonstrations and remote tests.

6.1 *Support Communications*

Control and information circuits were provided to coordinate station operations and to exchange tracking and telemetry data between Andover and other Bell Laboratories, NASA, A.T.&T. Co., and overseas locations. Figs. 12 and 13 show these circuits, consisting of 7 full-period voice circuits, 5 order wires, 3 DATA-PHONE and 5 teletypewriter circuits.

The voice circuits interconnect Andover with the several Bell Laboratories locations in New Jersey and at Cape Canaveral, as well as with the French and British earth stations at Pleumeur-Bodou and Goonhilly. The order wires interconnect with A.T.&T. Co. Long Lines Department plant operating centers for the coordination of carrier telephone, radio relay and television channel usage to and from Andover.

DATA-PHONE circuits between Andover and the Murray Hill and Whippany Laboratories and the French station were established to transmit antenna pointing data to Andover and Pleumeur-Bodou and to return satellite telemetry information from Andover. These circuits transmit digital data at 1200 bits per second between commercial magnetic tape data terminals.

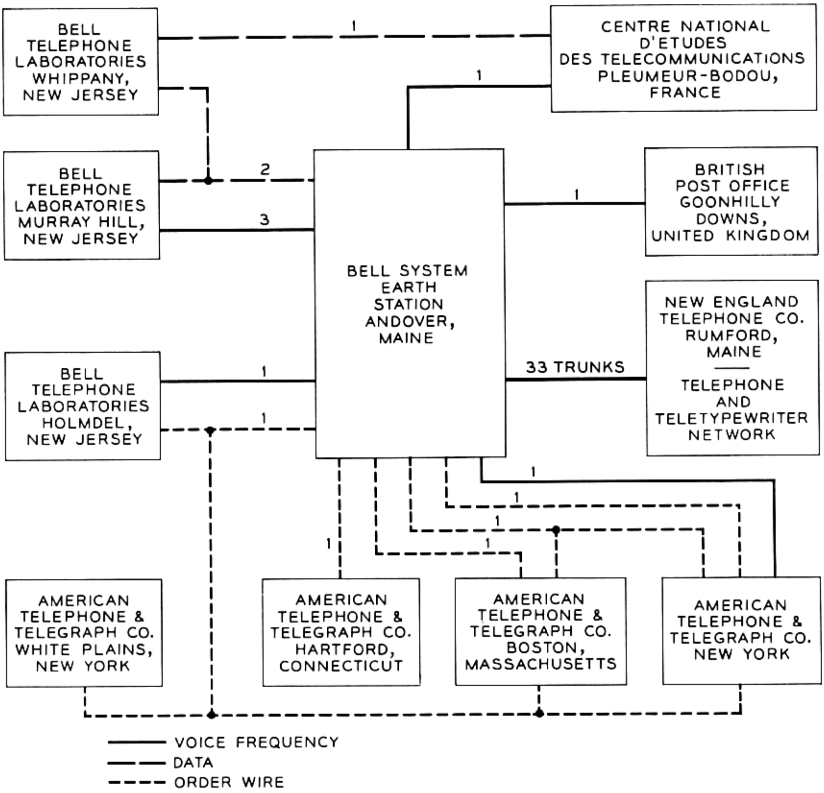


Fig. 12 — Voice-frequency, data and order wire connections with Andover.

Teletypewriter circuits to carry scheduling information, operations messages, orbital tracking data and administrative traffic were installed between the Andover station and NASA Goddard Space Flight Center, Bell Laboratories computing center and operations offices in New Jersey, and the British and French stations.

As shown in Fig. 12, local trunks from the Andover station interconnect with the message telephone network at Rumford, Maine. These serve the local administrative needs of the station and include 10 inward and 10 outward dial trunks through the station PBX, a TWX trunk, 2 public coin box lines and 10 miscellaneous local trunks.

The basic test and demonstration network, consisting of 24 voice-grade channels, 2 telephoto circuits and 2 video channels in each direction, is shown in Fig. 14. These facilities were used for demonstrations

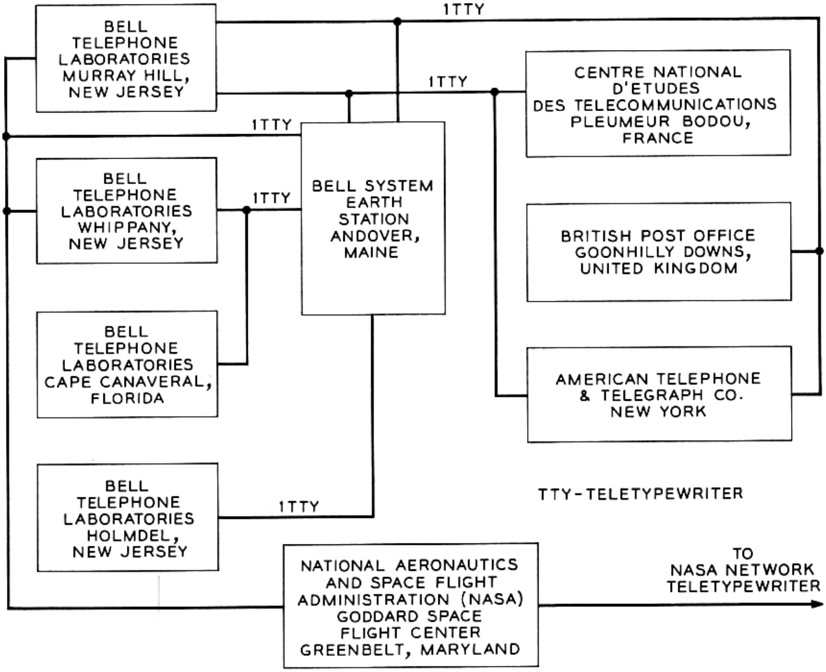


Fig. 13 — Teletypewriter connections with Andover.

and for conducting data transmission tests at the A.T.&T. Co. Long Lines Department headquarters in New York City. In addition, a pair of video channels and a telephoto circuit were provided from the Bell Laboratories Holmdel, New Jersey, receiving station to New York for test and demonstration use.

6.2 *Radio Relay and Cable Access Links*

New broadband facilities were required to link the Andover station with the existing Bell System radio relay network to handle video and multiplex telephone channels. The nearest junction point was Portland, Maine, approximately 90 miles south of Andover. Microwave radio relay links of TD2 (4 kmc) and TJ (11 kmc) were constructed in tandem between Portland and Andover. Since the satellite-to-ground signal is at 4170 mc and the ground-to-satellite signal is at 6390 mc, it was decided not to employ either TD2 (4 kmc) or TH (6 kmc) systems for the first external microwave links out of Andover. Therefore, a TJ (11 kmc)

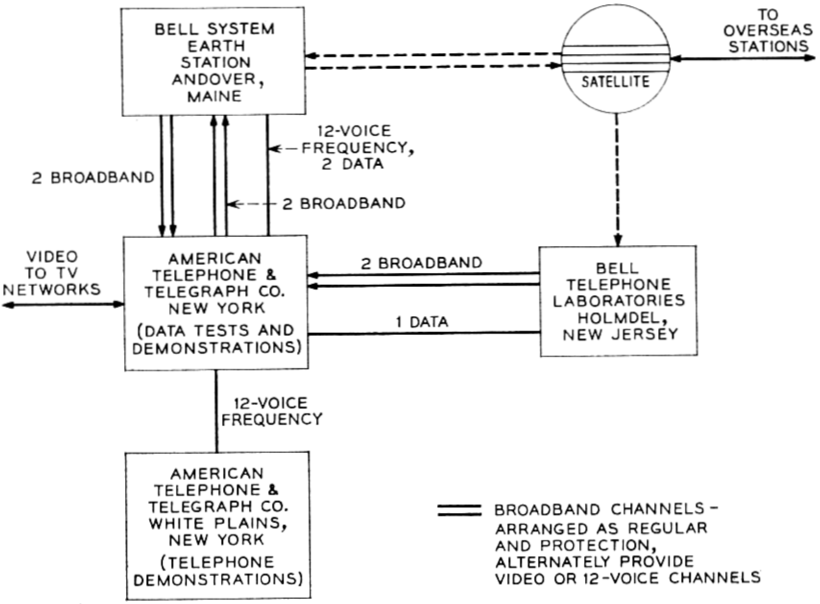


Fig. 14 — Test and demonstration network.

system was selected for the first two links. A coaxial cable system would have been free of interference but was economically impractical because of the mountainous terrain. The first microwave repeater station was located 4.5 miles south of the Andover station atop Black Mountain, on the rim of the "Andover bowl." Beyond the second link a TD2 system was used. The combination of the ring of mountains forming the bowl, the physical distance, and the bearing of the paths reduce to inconsequential levels any stray signals between the repeater stations and the Andover site. From this point to Portland, Maine, where connection was made to the existing TD2 microwave network, normal engineering criteria were used. The over-all route is shown in Fig. 15.

Two radio channels, one regular and one protection in each direction, were provided between Andover and Portland. They were each equipped to handle a 4-mc video signal with the corresponding audio signal provided by a diplexing arrangement using a subcarrier inserted above the video band. Channelizing equipment to permit transmission of 12 two-way telephone circuits instead of the video signals was also installed.

In addition to wideband facilities, voice-frequency cable circuits were provided to handle the support communications requirements. Sixty-one

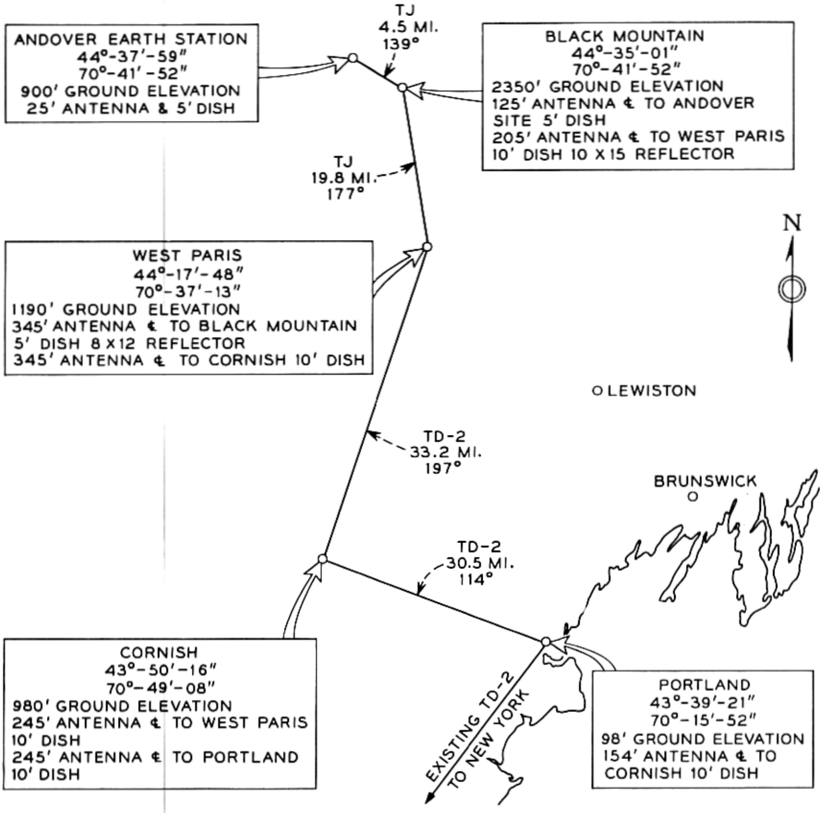


Fig. 15 — Overland route to Portland.

pairs of a 150-pair 19-gauge cable, planned to serve the area north of Rumford, Maine, were extended into the Andover site by the New England Telephone and Telegraph Company. Voice-frequency circuits over this cable were interconnected at Rumford with existing ON carrier circuits to Portland. Later, the ON carrier system was extended directly to Andover to provide 24 direct Andover-Portland circuits.

VII. EXPERIMENTAL DEMONSTRATIONS

Eight special networks were established for the first demonstrations on July 10, 1962, using the support communication facilities shown in Fig. 14.

A closed-circuit video network was established between Andover, Boston, New York, Holmdel and Washington. The pickup equipment located at Andover and Washington was provided by Theatre Network Television, Inc., monitors provided in the Andover, Boston, Washington and New York areas made it possible for several thousand people to view the closed-circuit program. In addition, a feed was provided from Andover to New York to feed the program to the ABC, CBS, and NBC television networks.

Vice President Lyndon B. Johnson and Mr. F. R. Kappel, Chairman of the Board of the A.T.&T. Co., spoke between Washington and Andover on the first telephone call using the Telstar satellite. Mr. Kappel spoke via the satellite and the diplexed audio channel. Special program facilities were used to transmit Vice President Johnson's voice to Andover.

Special facsimile, data and telephone circuits also were established for the several initial transmissions. The first facsimile test, a picture of the Telstar satellite, was transmitted during the latter portion of the first usable pass (during the 6th orbit) from the auditorium of the Long Lines

TABLE III — SUMMARY OF *Telstar* DEMONSTRATIONS AND TESTS: July 10, 1962, to November 22, 1962

Telephone calls		117
Black-and-white TV (to and from Europe) including simultaneous 2-way TV, Andover/France		42
Color TV		5
Facsimile		9
International carriers (6)		126
Telegraph	68	
Data	26	
Facsimile	31	
Telephone	1	
Data		66
42,000 bits/sec (52,000 wpm)	1	
62,500 char/sec computer to computer	1	
875,000 bits/sec (1.4 million wpm)	1	
1,000 wpm—punched tape	3	
Data speed—magnetic tape (1,200 bits/sec)	1	
1,000 wpm—teletypesetter	3	
Clock synchronization to UK	3	
66 wpm—teletypewriter to UK	9	
EKG—recording over DATA-PHONE	1	
Other data tests	43	
Business machine manufacturers (11)		14
Radio broadcast programs		6
Satellite light-route equipment tests and demonstrations—Holmdel/Andover and Holmdel/Holmdel		5
Total		390

headquarters building in New York via the satellite to press locations in New York, Andover, Holmdel and Washington. A press release was prepared on punched paper tape and transmitted at 1050 words per minute during the second usable pass (the 7th orbit) from the visitors' building at Andover via the satellite to the Long Lines headquarters in New York using Bell System DATA-PHONE sets. The message was converted to page copy by a tape reader and printer in New York. Six telephone channels were also established via the satellite during this pass, including circuits connecting via the regular message telephone network to points throughout the United States. Calls were made by government and Bell System officials and members of the press.

Between July 10, 1962, and November 22, 1962, some 390 demonstrations and tests were conducted using the connecting communications facilities to Andover. A summary of the demonstrations is shown in Table III.

VIII. ACKNOWLEDGMENTS

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