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TOS MISSION OPERATIONS PLAN FOR WTR LAUNCHES

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TOS
MISSION OPERATIONS PLAN
FOR WTR LAUNCHES

August 1966

Approved by:

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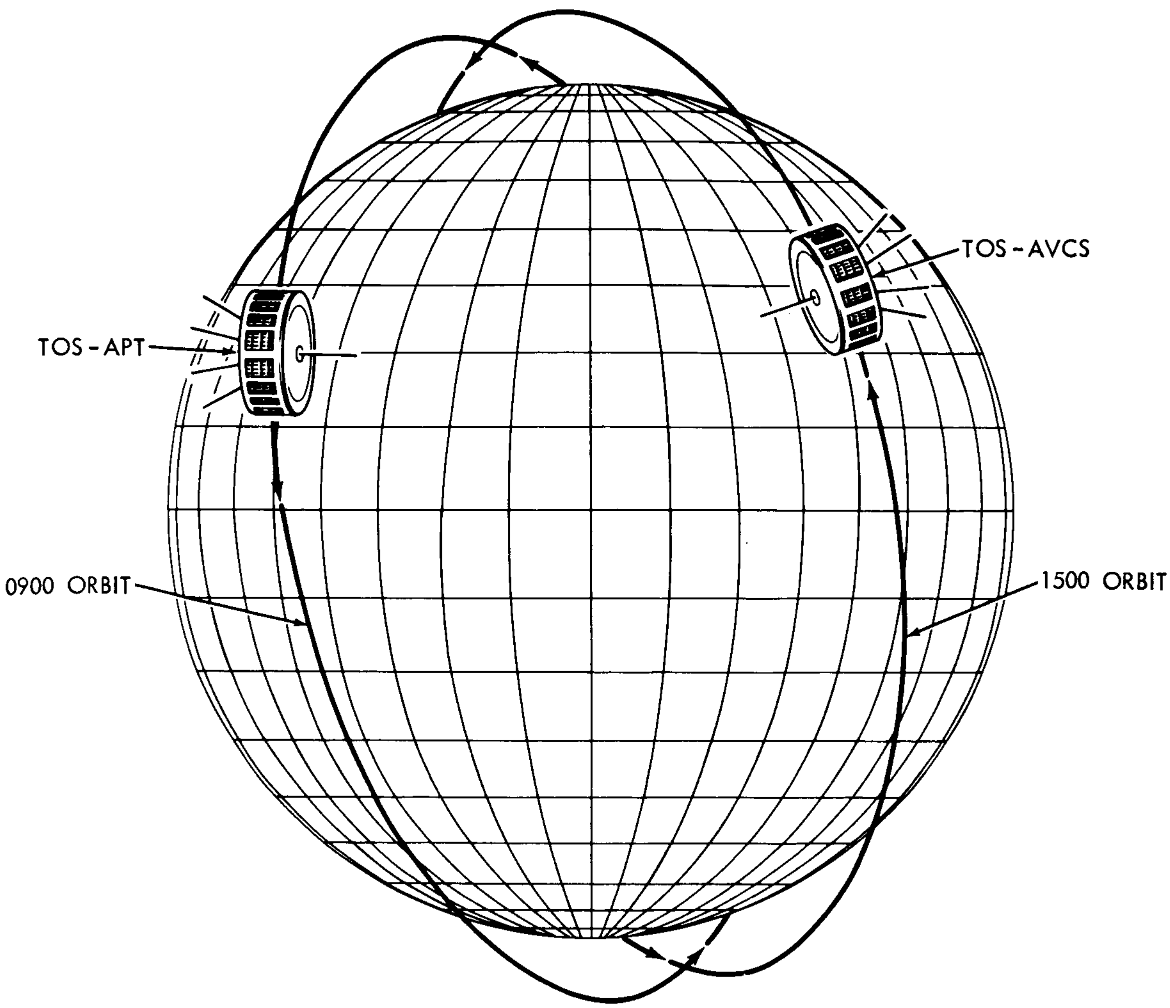
Memo for: Distribution

This is the TOS Mission Operations Plan for WTR launches.

Please remove the original TOS Mission Operations Plan from the binder and discard it except for: (1) the index tabs, (2) Figure III-6, Subsatellite Track, page III-20, which are to be used for the WTR Mission Operations Plan.

A completely revised Mission Operations Plan will be issued for ETR launches.

Any changes or additions to this plan should be directed to the attention of the TOS Project Manager.



Frontispiece — Artist's Concept of TOS

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ABBREVIATIONS

A-1 time - alarm 1, initial spacecraft command

AADPS - automatic attitude determination program system

AHS - attitude horizon sensor

A&E - architect and engineer services

AFSSD - Air Force Space Systems Division

APT - automatic picture transmission

AT&T - American Telephone and Telegraph

ATMAPW - attitude map for wheel spacecraft

ATW - Air Test Wing

AVCS - advanced vidicon camera subsystem

CDA - Command and Data Acquisition

CDAXYZ - CDA tracking tapes

CDC-160 - Control Data Corporation computer

CDU - command distribution unit

C of F - construction of facilities

CONFLK - satellite conflict list (TOS-TIROS)

CORFOR - conversion routine for orbital elements

COSSAK - consolidated station satellite acquisition conflicts

D days - calendar days before launch

DAC - Douglas Aircraft Company, Inc.

DAPAF - Data Processing and Analysis Facility, NESC

DOC - Department of Commerce

DOD - Department of Defense

DSAI - digital solar aspect indicator

DSDP - Data System Development Plan

DTO - Detailed Test Objectives document

EPHEM - satellite subpoint data

ESSA - Environmental Science Services Administration

ETR - Eastern Test Range

GFOM - TOSCOM TTY address for GILMOR NESC facility

GILMOR - identification of CDA station at Gilmore Creek, Alaska

GHNJ - RCA-AED TTY address

GMOR - NASCOM TTY address for GILMOR

GMT - Greenwich Mean Time, also Zulu or UT

GOFF - TOSCOM TTY address for Offutt

GOPS - OPSCON TTY address

GOSI - TTY address for TIROS/TEC

GNET - NETCON TTY address

GPUT - GSFC computer TTY address

GSFC   Goddard Space Flight Center

GTEC - TOSCOM TTY address for TEC

GTOS - NASCOM TTY address for TOC

HCI - horizon crossing indicator

IRFNA - inhibited red fuming nitric acid

IRIG - interrange instrumentation group

KSC - Kennedy Space Center

LATOC - satellite look angles (antenna pointing angles)

LOS - loss of signal

MDC - Mission Director Center, WTR

MCR - Mission Control Room, GSFC

M&O - maintenance and operation

MASC - magnetic attitude spin coil

MBC - magnetic bias coil

MECO - main engine cutoff

MGAPW-ASP - magnetic attitude prediction, wheel - attitude smoothing program

MIG - miniature integrating gyro

NASA - National Aeronautics and Space Administration

NASCOM - NASA communications network

NASCOP - NASA communications operating procedures

NE&O - Network Engineering and Operations Division, GSFC

NESC - National Environmental Satellite Center, Suitland, Md.

NETCON - Network Control, GSFC

NORAD - North Atlantic Air Defense Command

NWRC - National Weather Records Center, Asheville, N.C.

OFFUTT - Offutt Air Force Base, Neb., station identification

OIS - Operational Intercom System, ETR

OPSCON - operations control, GSFC

OSO - Operational Satellites Office, GSFC

PDP - Project Development Plan

PMP - Program Management Plan

POP - Program Obligation Plan

PRD - Program Requirements Document

QOMAC - quarter-orbit magnetic attitude control

R&D - research and development

RCA-AED - Radio Corporation of America, Astro Electronics Division

RCAHNJ - identification of RCA CDA and APT station

RCAS - RCA Service Company

SAO - Smithsonian Astrophysical Observatory

SCAMA - switching, conferencing, and monitoring arrangement

SECO - sustainer engine cutoff

SS&SA - Space Sciences and Satellite Applications

SSOD - TTY address for NESC Operations Division

STADAN - Space Tracking and Data-Acquisition Network

STADEE - status data extraction evaluation and reduction

STOC - TTY address for TOC

T&DS - Tracking and Data Systems Directorate, GSFC

TAD - thrust-augmented Delta

TAT - thrust-augmented Thor

TEC - TOS Evaluation Center, GSFC

TID - Technical Information Division, GSFC

TIROS - Television Infrared Observation Satellite

TOC - TOS Operational Center, NESC

TOS - Tiros Operational System

TOSCOM - TOS communications network, operated by NESC

TTCC - TIROS Technical Control Center, GSFC

TTY - teletype

UDMH - unsymmetrical dimethyl-hydrazine

ULASKA - NASA R&D station at Gilmore Creek, used as GILMOR backup

ULO - Unmanned Launch Operations

UT - Universal Time, GMT

VAFB - Vandenberg Air Force Base

WALOMS - identification of Wallops Station, Va., NESC facility

WOMS - TOSCOM TTY address for WALOMS

WMO - World Meteorological Organization

WMSAD - world map and station acquisition data

WTR - Western Test Range

ZULU - Greenwich Mean Time or UT

PART I

TOS PROGRAM SUMMARY

The TIROS Operational System (TOS) is a joint effort of NASA and the Environmental Science Services Administration (ESSA). NASA's Goddard Space Flight Center (GSFC) is responsible for design and development of the spacecraft, vehicle, and ground systems, for launch operations, for initial spacecraft checkout in orbit, for spacecraft evaluation, and for interferometer tracking. ESSA is responsible for the operational phase of each spacecraft, including determination of need for replacement; for operation of the CDA stations and ESSA communication lines; and for acquiring, handling, and processing spacecraft-acquired data. ESSA is responsible for all funding and for overall system evaluation and management.

This Mission Operations Plan describes the execution of NASA responsibilities and the necessary interfaces with ESSA. The ESSA plan for its TOS activities will be published separately by ESSA.

To meet ESSA's requirements for obtaining meteorological data from the entire globe on a daily basis, TOS will have two operational spacecraft in circular 750-nm sun-synchronous, near-polar orbits, with launches at intervals of approximately 3 months. The orbit will be 78.84 degrees retrograde with an orbital period of 113.5 minutes. The spacecraft will be spin-stabilized and magnetically torqued to a wheel attitude, so that the spin axis will be normal to the plane of the orbit and the radially mounted cameras will view the earth once each spacecraft revolution. The orbital plane will precess easterly about 1 degree a day at the same rate as the earth-sun line.

The first TOS spacecraft, weighing about 285 lbs., carried two automatic picture transmission (APT) cameras and was launched on February 28, 1966, into an 0900 hour (descending node) orbit. The second spacecraft, weighing about 316 lbs., will have two advanced vidicon camera systems (AVCS) and an infrared (IR) system and will be launched into a 1500 hour (ascending node) orbit. The 750-nm altitude allows full global coverage with one camera; therefore, two cameras provide full system redundancy.

The first launch was from the Eastern Test Range (ETR); the second and following launches will be from the Western Test Range (WTR). The launch vehicle is the Improved Delta, DSV-3E.

Based conservatively upon the average lifetime of the TIROS spacecraft, the life expectancy of TOS spacecraft is 6 months, with a minimum of 3 months. Therefore, alternate configurations of the TOS spacecraft (APT, AVCS, APT, AVCS) will be made available by the contractor every 3 months. The objective, however, is to launch a replacement spacecraft within approximately a month after ESSA's decision to launch.

The spacecraft will be commanded and meteorological and spacecraft data will be acquired by Command and Data Acquisition (CDA) stations in Fairbanks, Alaska (GILMOR), and Wallops Station, Va. (WALOMS). The combination of WALOMS and GILMOR provides complete global coverage each day. All spacecraft data will be sent by data link and teletype to ESSA's National Environmental Satellite Center (NESC) at Suitland, Md., for engineering evaluation and for analysis and dissemination of meteorological data to the meteorological community. Data will also be sent to GSFC for spacecraft checkout and evaluation. Meteorological data, spacecraft attitude data, and time will be transmitted to the Global Weather Center, Offutt Air Force Base, Omaha, Neb.

The spacecraft will be tracked by the NASA Space Tracking and Data Acquisition Network (STADAN) operated by GSFC Network and Engineering (NE&O) Division. Tracking information will be used by the GSFC Data Systems Division (DSD) for orbital determination during the early orbit phase and for orbital refinement; orbital data will be sent to STADAN via the NASA Communications (NASCOM) facilities.

DATA SHEET

TOS APT

Spacecraft Characteristics

Size:	Right circular cylinder 42 inches diameter, 22.5 inches high	
Weight:		285 lb
Orbit:	Altitude:	750 nm circular
	Inclination:	101.16 (78.84 retrograde)
	Sun-synchronous	0900 descending node
	Period:	113.5 min
Spin axis orientation:		Normal to orbit plane
Spin period:		5.5 sec (10.9 rpm)
Camera pointing accuracy:		Camera optical axis collinear with local vertical to within one degree. Time of shutter action known to within one second.

Picture Characteristics

Camera lens effective field of view 89° across flats

Resolution: 2 nm per TV line at picture center, not worse than 5 nm at 65° zenith angle

Coverage:
800 TV lines per picture
Square picture 1700 nm on a side 4 or 8 pictures per orbit
352-second interval between pictures
30% picture overlap along track
Pictures from successive orbits contiguous at equator

Video Data Characteristics

208 seconds per frame including start and phasing signals

4 lines per second

Video bandwidth: 1600 cps

Video AM subcarrier: 2400 cps

Transmission to ground in real time

Transmitter: Frequency modulated
Power out: 5 watts

Carrier Frequency: 137.500 Mc ± 0.005%
Deviation: ± 10 kc max
Transmission bandwidth: 30 kc
Min. spacecraft antenna gain: -4 db

Other Spacecraft Subsystem Characteristics

Command:	AM transmission: 148 Mc band Digital data: FSK subcarrier Receiver sensitivity: -107 dbm Spacecraft antenna gain: -4 db Number of commands: 66
Telemetry:	Telemetry/beacon transmitter phase modulated Power out: 0.250 watt Carrier frequency: 136.770 Mc ± 0.005% Subcarriers: IRIG 7, 8, 9 Transmission bandwidth: 20 kc Min. spacecraft antenna gain: -5 db Housekeeping points monitored: 74
Spacecraft power:	Voltage: -24.5 volt regulated bus Nominal power available from spacecraft array at bus: 53 watts
Standby:	9 watts
Peak:	55 watts (not including shutter pulse)
Average:	28 watts over an orbit (8 pictures)

DATA SHEET

TOS AVCS

Spacecraft Characteristics

Size:	Right circular cylinder 42 inches diameter, 22.5 inches high	
Weight:		325 lb
Orbit:	Altitude:	750 nm circular
	Inclination:	101.16 (78.84 retrograde)
	Sun-synchronous (near-polar):	1500 ascending node
	Period:	113.5 min
Spin axis orientation:		Normal to orbit plane
Spin period:		6.5 sec. (9.25 rpm)
Camera pointing accuracy:		Camera optical axis collinear with local vertical to within one degree. Time of shutter action known to within one second.

Picture Characteristics

Camera lens effective field of view 89° across flats

Resolution: 2 nm per TV line at picture center, not worse than 5 nm at 65° zenith angle

Coverage:
833 TV lines per picture
6 or 12 pictures per orbit, 1700 nm on a side
260 second interval between pictures
50% overlap along track
Pictures from successive orbits contiguous at the equator

Video Data Characteristics

6.75 seconds per frame, including sync
133.3 lines per second
Video bandwidth: 60 kc
Video FM subcarrier: 96 kc
Deviation: ±24 kc
Flutter and wow correction signal: 9.6 kc

Data Storage: 36 pictures per tape recorder, maximum (up to 3 orbits)

Data Playback:
Playback time: 10 seconds per stored TV picture
Transmitter: Frequency modulated
Power out: 5 watts
Carrier frequency: 235.000 Mc ± 0.005%

	Deviation: ±125.0 kc Transmission bandwidth: 500 kc Min. spacecraft ant. gain: -5 db

<u>Other Spacecraft Subsystem Characteristics</u>

Command:	AM transmission: 148 Mc band Digital data: FSK subcarrier Receiver sensitivity: -107 dbm Spacecraft antenna gain: -4 db Number of commands: 66
Telemetry:	Telemetry/beacon transmitter phase modulated Power out: 0.250 watt Carrier frequency: 136.770 Mc ± 0.005% Subcarriers: IRIG 7, 8, 9 Transmission bandwidth: 20 kc Min. spacecraft antenna gain: -5 db Housekeeping points monitored: 74
Spacecraft power:	Voltage: -24.5 volt regulated bus Nominal power available from spacecraft array at bus: 53 watts
Standby:	9 watts
Peak:	52 watts (not including shutter pulse)
Average:	20 watts per orbit (12 pictures and heat budget data)
IR Subsystem:	Heat budget of earth

PART II

TOS SYSTEM OPERATIONAL PLAN

1. TOC AND TEC RESPONSIBILITIES AND COORDINATION

The NESC TOS Operations Center (TOC) and the GSFC TOS Evaluation Center (TEC) are focal points for different aspects of TOS. TEC is responsible for the checkout and evaluation of newly launched spacecraft. TEC may also be requested by TOC to take control of ailing spacecraft and may resume control of spacecraft which TOC considers no longer operational.

TOC is responsible for spacecraft operation after successful completion of checkout and for operation of the CDA stations and ESSA communications equipment and links. The complementary functions of the two centers require coordination of their operations and a reliable mutual reporting system.

An outline of TOC and TEC responsibilities and TOC/TEC interfaces are given here; detailed responsibilities are described in Parts III and V.

1.1 TOC RESPONSIBILITIES

TOC, the central operations control center for TOS, is an element of the Satellite Operations Division at NESC. TOC equipment and layout are described in Appendix F. TOC will be responsible for operational control of the entire system, on a 24-hour-a-day, 7-day-a-week basis. Specifically, TOC will:

- Monitor launch and checkout operations
- Provide technical control of TOS operation
- Originate command programs for operational spacecraft
- Receive from TEC prelaunch mission simulation requests or command programs for newly launched spacecraft
- Formulate CDA station operating schedules
- Transmit operating schedules and all spacecraft command programs to the CDA stations
- Receive, technically evaluate, and disseminate all engineering data from TOS
- Evaluate meteorological data from an engineering viewpoint
- Control the TOS communications network (TOSCOM)
- Collect messages, data, analyses, and reports generated in the normal operation of TOS, and make available to TEC such information as required, including:

    Complete monitor files of teletype messages and other system instructions

    Beacon and events data stripcharts and tape recordings

Engineering and attitude data analyses

CDA station reports regarding performance, problems, repairs, and modifications

TOSCOM reports

1.2 TEC RESPONSIBILITIES

TEC, operated by the TOS project, is located at GSFC with the TIROS Technical Control Center (TTCC) in Building 14; TEC equipment and layout are described in Appendix F. Under the direction of the TEC Manager, TEC is responsible for prelaunch, launch, and checkout of each spacecraft. The launch and checkout operation will be accomplished by the GSFC/TEC staff, supplemented by one key TOC individual per shift and by the TOS evaluation team.

System performance will be evaluated by the TOS Evaluation Engineer, assisted by two evaluation engineers and a data clerk.

1.2.1 PRELAUNCH OPERATIONS

Before each launch TEC will conduct engineering tests to check the CDA stations, simulated command programs, a 5-day activation plan, and a coordinated readiness countdown, as detailed elsewhere in this plan.

1.2.2 LAUNCH, INITIAL MANEUVER, AND CHECKOUT

TEC will operate as the spacecraft control center for the checkout of each new TOS as described in Part III. Specifically, TEC will:

1.2.2.1 Assess and evaluate TOS performance on a realtime basis.

1.2.2.2 Direct to the appropriate system manager or the Project Manager all information or summary of data relative to the malfunction or nonroutine operation of the system.

1.2.2.3 Determine the spacecraft attitude from V-head horizon sensor data and the digital solar aspect indicator (DSAI).

1.2.2.4 Coordinate with TOC a long-term schedule of station readouts based on operation of spacecraft in orbit. This schedule will be used as a guide for CDA station operations.

1.2.2.5 Prepare and transmit to TOC a weekly prediction of all possible CDA satellite contacts.

1.2.2.6 Originate and transmit to TOC the specific command programs and station interrogation schedules for daily operations, based on:

- Analyses of predictions processed from the computing center as to locations of suitable photographic areas and times of passes over CDA stations
- Analyses of programming requests from NESC or other agencies
- Analyses of attitude tracking requirements
- Analyses of spacecraft power
- Analyses of CDA station status

1.2.2.7 Program the magnetic attitude and spin control subsystems based upon all available attitude and spin information. Information of the effects of changes in the spacecraft attitude and spin because of programming will normally be transmitted to TOC at least two days in advance of the proposed change.

1.2.2.8 Transmit changes to the program and operating instructions to TOC; program and operating instructions changes may be communicated to the CDA stations via telephone if there are less than two hours before implementation.

1.2.2.9 Ensure the acquisition and timely transmission of all usable data to TOC.

1.2.2.10 Provide TOC the following data, updated as required, to be used as a guide in the preparation of requests for TOS television coverage (with an information copy to GNET):

- Attitude world map (ATMAPW), magnetic attitude prediction (MGAPW) data, and equator crossings

- Limiting factors that apply to interrogation of the spacecraft and acquisition of data:

    Slant range or look angles from the CDA station antenna to the spacecraft

    CDA station antenna elevation

    Separation of spacecraft between interrogations

    Command sequencing

    Spacecraft engineering limitations

- Predicted power available to the spacecraft for programming purposes

- Weekly predicted schedule of CDA station contacts required for engineering checkout

1.2.2.11 Catalog all reports and data coming into and leaving TEC into the permanent TOS file.

1.2.2.12 Prepare and transmit, in cooperation with TOC, a daily report on the progress of engineering checkout.

1.2.2.13 TEC will make manual measurements of the analog V-head horizon sensor strip chart recorder data for determination of instantaneous roll errors, and will produce the attitude for each orbit. TEC, with the assistance of the DSD Theory and Analysis Office, will produce the daily definitive attitude for each day. The daily definitive attitude, plus an attitude prediction, will be transmitted daily to TOC for input to the gridding program; the data will also be used by TEC in programming for spacecraft command and control.

1.2.2.14 Beacon data received from the CDA station will be recorded on analog strip chart recorder charts and manual measurements will be made. The data will also be reccrded on a multichannel magnetic tape recorder. An analog-to-digital converter will digitize the data and it will be formatted and recorded for computer processing and reduction. The normal mode of spacecraft housekeeping telemetry processing will be a quick look of analog records at TEC and a daily computer printout of all engineering units. The deflection levels beyond tolerance levels will be known and will be checked as the orbits occur. On a daily basis, the digitized telemetry data will be computer processed and a page print and card file of the actual data measurements will be made. Once each week the card file will be input to one of the GSFC plotters for a historical record plot of the telemetry parameters. These plots will become part of the permanent TOS files and will be used for spacecraft assessment as required.

1.3 TOC/TEC COORDINATION AND REPORTS

The close relationship and interaction of the TOC and TEC operations will require close coordination of their activities and mutual reporting.

1.3.1 CONFLICTS DURING LAUNCH AND CHECKOUT

During the launch and checkout period, TEC will originate the command programs for a new spacecraft. Simultaneously, TOC will have requirements to command existing TOS spacecraft. Scheduling conflicts in the use of CDA facilities and the communications network can arise. The following procedures will be used to prevent or resolve such conflicts.

Launch windows will be set to minimize conflicts. Replacement spacecraft will be launched into orbits nearly identical to those of the spacecraft replaced. However, injection time will be planned so that the new spacecraft will be half an orbital period ahead of or behind the old one.

Before launch, DSD Theory and Analysis will study potential acquisition conflicts and develop a plan to avoid conflicts in the postlaunch checkout of the whole TOS system. The detailed plan will be issued before the launch of each new spacecraft. The predicted acquisition times for the replaced and the replacement TOS as well as the remaining operational TOS will be considered. System usage will be planned to allow both TEC checkout and TOC operational responsibilities to be satisfied to the greatest extent possible.

The Director of the NESC Office of Operations and the TOS Project Manager will approve this plan. Immediately after launch, the plan will be reviewed in light of the orbit achieved; changes will be made as required and approved by the manager and director.

If unanticipated conflicts develop during launch and checkout, the responsible persons at TEC and TOC will be required to work out solutions. (One possibility is that the noninterference-basis mutual backup agreements may be exercised to relieve CDA antenna-loading conflicts.) If agreement cannot be reached, an appeal will be made to the TOS Project Manager and to the NESC Office of Operations Director. In the event that time does not permit resolution of a conflict through the appeal channel, a decision must be made: during the two days immediately following launch, the new spacecraft will have priority and the TEC decision will prevail; at all other times TOC will make the final decision. If an arbitrary decision is made in this way, a report of the circumstances must be made to the appeal channel by those involved before leaving their duty posts for the day.

1.3.2 REPORTS AND OTHER COORDINATION ACTIVITIES

All reports and data generated in the normal operation of TOS will be collected by TOC and made available to TEC, including the processed telemetry data produced by DAPAF. The objective will be to provide processed data for both daily operations and the evaluation task. To help achieve this, GSFC TOS project personnel will participate with members of NESC in working out specifications for data processing programs as well as for reports and other data.

2. CDA-TEC-TOC MISSION SIMULATION EXERCISE

On a daily basis beginning seven days before launch, sample data will be transmitted from the CDA stations to TEC and TOC. The sample data will consist of video and beacon magnetic training tapes that will resemble as closely as possible the passes of telemetry and video from an actual spacecraft in orbit. Video simulator outputs will also be used for video checks. The sample transmissions will be made on call by TEC via TOC at times that will not interfere with the missions of operational satellites. TEC will coordinate all schedules and programs with TOC, which will be monitoring all transmissions.

In addition to the daily tape transmissions, the CDA stations will compose and transmit appropriate teletype messages associated with the data. Just before the message text, each message will read, "SAMPLE - - - - SAMPLE."

Exercise initiation will begin at T-0 when TEC will transmit a sample TOS program to the CDA stations through TOC. Each CDA station will run the program tape through the CDA programmer and to the long line equipment for relay to TOC/TEC. TEC and TOC will process the received data and coordinate the timing and results. The simulation exercise results will be transmitted to the CDA stations.

2.1 WALOMS SCHEDULE

- T plus 15 minutes - WALOMS will transmit calibration signals to TEC
- T plus 20 minutes - WALOMS will transmit the beacon training tape, monitor horizon sensor and DSAI recorded at the station, and report observations to TEC and TOC.
- T plus 40 minutes - WALOMS will send the video data tape and selected video simulator outputs at 7-1/2 ips to TEC and TOC.
- T plus 50 minutes - WALOMS will reduce the housekeeping telemetry and prepare the sample telemetry and pass summary messages.
- T plus 60 minutes - WALOMS will transmit pass summary message, etc., to TEC and TOC.

2.2 GILMOR SCHEDULE

- T plus 55 minutes - GILMOR will transmit calibration signals to TEC.
- T plus 60 minutes - GILMOR will transmit the beacon training tape, monitor horizon sensor and DSAI data recorded at the CDA stations, and report observations to TEC and TOC.
- T plus 80 minutes - GILMOR will send video data tape at 7-1/2 ips and selected video simulator outputs to TEC and TOC.
- T plus 90 minutes - GILMOR will reduce the housekeeping telemetry and prepare the sample telemetry and pass summary messages.
- T plus 100 minutes - GILMOR will transmit pass summary messages, etc., to TEC and TOC.

3. FIVE-DAY ACTIVATION PLAN

A complete interrogation and telemetry tracking schedule, identical to that to be followed on launch day and the succeeding four days, will be originated by TOC and disseminated to all participating groups approximately two weeks before launch. Beginning on D-9 through D-5 a test run will be simulated for the complete five-day plan. The simulation schedule may be modified by TOC if necessary to obtain operational data from orbiting satellites.

4. COORDINATED READINESS

TEC will initiate coordinated readiness operations beginning ten days before launch. T&DS will exercise STADAN; the CDA stations will be scheduled by TOC as requested by TEC (Table II-1).

5. T&DS MISSION SIMULATION TEST

T&DS will conduct a TOS mission simulation test under the direction of the OPSCON Operations Director and the coordination of the Tracking and Data Systems Manager.

All TOS, NESC, CDA, OPSCON/NETCON, and WTR personnel who will participate in the actual launch operations will be present. Details will be forwarded by TTY to each element of the launch communications net; an outline of events is listed in Table II-2.

All TTY and telephone circuits into OPSCON will be initiated at the direction of the Operations Director.

Table II-1

Coordinated Readiness Countdown

Days Before Launch	Event
D-10	GHNJ will send readiness reports to TEC. TEC will transmit instructions with explanatory notes as necessary to the stations.
D-10	TOC will send NESC ground system readiness reports to TEC. TOC will transmit TEC originator.
D-10	TOC will initiate tests to check the video, voice, and data circuits of TOSCOM. TEC will check the NASCOM TOS circuits.
D-9	TOC/TEC will repeat circuit checks.
D-9	TEC will originate 5-day activation plan.
D-8	TOC/TEC will repeat circuit checks.
D-7	TEC will ensure that nominal WMSAD and ATMAPW predictions are sent to WALOMS, GILMOR, GHNJ, and TOC. WMSAD predicts will be transmitted by TTY and the ATMAPW's by mail.
D-7	Orbit and Attitude Computations Engineer will ensure that the nominal station predictions are sent to STADAN and provided to NETCON/OPSCON in accordance with NETCON's schedule.
D-7	The Tracking and Data Systems Manager will ensure that trajectory predictions are available at all downrange stations.
D-7	T&DS will conduct a launch simulation test, using the actual launch sequences.
D-7	TOC/TEC will repeat circuit checks.
D-6	TOC/TEC will repeat circuit checks.
D-5	TOC/TEC will initiate tests to check the TEC voice circuits at the launch site.
D-5	Orbit and Attitude Computations Engineer will ensure that AADPS is operational.
D-5	TOC/TEC will repeat circuit checks.
D-4	TEC will verify that all nominal orbital and attitude predictive data have been received and are available at the CDA stations.
D-4	TOC/TEC will repeat circuit checks.
D-3	TOC/TEC will repeat circuit checks.

Table II-1 (Continued)

Days Before Launch	Event
D-2	TOC/TEC will repeat circuit checks.
D-1	TEC will send a launch-alert message to GHNJ and to TOC for relay to NESC ground system. NETCON will send a launch alert message to STADAN and all participating agencies.
D-1	TOC/TEC will repeat circuit checks.

Table II-2

T&DS Mission Simulation Test

Time (minutes)	Event
T-90	All participants in position with review simulation instructions; check local equipment
T-60	OPSCON establishes SCAMA call to WTR MDC for relay of vehicle countdown. WTR transmits nominal countdown events from T-30.
	All stations report readiness by TTY to GOPS
	OPSCON establishes SCAMA conference among MCR, WTR, TOC, CDA stations, TEC, RCA-AED, and OPSCON. MDC relays launch progress and significant vehicle status on all circuits
	OPSCON establishes circuit for SCAMA conference to include JOBURG, MADGAR, WNKFLD, WTR, and OPSCON.
T+0	All participating stations start elapsed-time clocks
	MDC reports spacecraft status, including last beacon frequency check of spacecraft and vehicle, and transmits liftoff and flight status over all circuits on LOS.
T+10 to T+30	OPSCON directs JOBURG, MADGAR, and WNKFLD to report telemetry frequency, simulated acquisition, and quick-look events.
T+ --	Post-simulation critique will be conducted by SCAMA conference as requested by the Project Manager

PART III

GSFC OPERATIONS

The TOS project is responsible for spacecraft systems and readiness and for ensuring readiness of all systems for each launch.

The Tracking and Data Systems (T&DS) Directorate is responsible for the operation of STADAN and GSFC ground communications system and for orbital computations and predictions.

(NESC operation of its TOS ground system is outlined in Part V of this plan and described in detail in ESSA publications.)

1. TEC

TEC, operated by the TOS project, is responsible for spacecraft control during the launch and checkout phases until TOC acceptance of the operational spacecraft.

Before that time, TEC will analyze and evaluate all spacecraft data, review ground station and TOC reports, and forward a summary of findings and recommendations to the Project Manager and TOC each day; when the spacecraft is operational, a report on the checkout phase will be filed. The reports will include comments on ground stations and communications performance.

During spacecraft checkout, TEC personnel will evaluate spacecraft performance on a realtime basis. Special attention will be given to attitude during the turnaround maneuver. The performance of the communication and electrical systems used during the turnaround will be recorded and observed for engineering purposes, along with careful checks of the various units of the power system.

Prelaunch Operations. For a two-week period preceding a TOS launch, TEC will prepare for the launch and postlaunch operations. Simulated launch operations will be conducted, with T&DS and TOC coordination. All shifts of the TOS ground system will participate: WALOMS, GILMOR, TEC, TOC, RCA-AED. TEC will transmit simulated command programs to the CDA stations via TOC and supplement the programs with direct voice contact during the scheduled operation. Video and beacon data, either simulated or obtained from an operational TOS, will be received and processed at TEC. Engineering tests will be run to prove out the CDA stations. Normally, TEC 24-hour prelaunch operations will be conducted only during the last few days before launch.

Launch and Initial Maneuver. TEC will operate as the spacecraft control center for the launch and checkout of the TOS. TEC will generate command programs and ground system schedules. TOC will include the TEC requirements in their weekly schedule. TEC will transmit the program to the action and information addresses. TOC will transmit their weekly schedule to GFOM. NETCON will transmit the NETCON schedules to ULASKA. At Fairbanks, the DAF shift supervisor integrates the two schedules. TEC will have voice contacts with GILMOR, WALOMS, RCA-AED, and the launch net on lines monitored by TOC. The CDA stations will transmit data from the APT and AVCS TOS via TOSCOM to TEC and TOC for processing as required. Later system review may indicate the need for additional narrow bandwidth facilities; existing GSFC lines may be used. The initial maneuver commands will be generated at TEC to place the satellite in an operational position. Once the operational position has been achieved, the checkout and performance evaluation of the satellite will proceed.

Checkout Plan and Performance Evaluation. The TOS project will prepare a checkout plan for each spacecraft and submit it to ESSA for review and approval. During the checkout period, TOC will monitor all operations of the new TOS. When the Director of the NESC Office of Operations and the TOS Project Manager agree that the spacecraft is operational, TOC will assume responsibility. The plan will list in detail the operational tests that must be successfully completed to check out a newly launched TOS.

Operational Mode. After control of the spacecraft has been assumed by TOC, the GSFC TOS evaluation team will conduct long-term analyses of the spacecraft data. The evaluation team will normally use raw data recorded at TOC and operational analysis produced by DAPAF. Occasionally, TEC will be used to obtain special TOS data.

When a serious problem arises in the operation of the spacecraft, TOC may request TEC to assume responsibility for determining the nature and extent of the problems, and to determine if there are means of bypassing the difficulty.

1.1 SYSTEMS OPERATIONS - LAUNCH AND CHECKOUT PLAN

Systems operations for TEC will include:

- Realtime systems assessment and evaluation
- Near-real-time systems evaluation
- Attitude determination and maneuvering
- Scheduling and programming
- Engineering documentation and reporting
- Equipment maintenance, operation, and calibration

1.1.1 REALTIME SYSTEMS ASSESSMENT AND EVALUATION

1.1.1.1 Prepass Functions

- Review program of pass to be interrogated
- Review spacecraft subsystem status, based on previous orbit program and telemetry
- Establish voice and data contact with CDA station interrogating spacecraft

1.1.1.2 Functions During a Pass

- Check quality of recorder data
- Verify spacecraft status from preinterrogation telemetry data; issue command program additions as required
- Verify normal systems operations during readout; issue operational changes as required

1.1.1.3 Postpass Functions

- Evaluate data quality of recordings
- Determine precise clock load time relative to spacecraft spin for picture prediction

- Reduce status housekeeping telemetry from strip chart recorder data; maintain daily history of selected data
- Verify all spacecraft subsystems status and update spacecraft status board
- Evaluate station events records and pass summaries
- Complete operations log, including a summary of all events relevant to the interrogated orbit
- Prepare data relative to next interrogation

1.1.1.4 Engineering Data
TEC will use engineering data from the APT and AVCS spacecraft and ground systems for assessment and realtime and near-real-time evaluation as follows:

An 8-channel strip chart recorder will record the return to zero (RZ) digital commands, the satellite and ground error signals, and the time-shared telemetries from SCO 3 of the spacecraft's beacon (which is displayed on channel 8 of the chart recorder), as shown in Table III-1. Channel 8 of the chart recorder contains important spacecraft data such as DSAI and the housekeeping telemetry, which is given a quick-look evaluation onpass as the data is received in real time at TEC from the spacecraft; between passes the data will be checked for out-of-tolerance levels. An analog-to-digital data conversion enables the data to be processed by computer for printout of engineering values for the telemetry points. Channel 8 also contains the command confirm verification which is received in real time to enable TEC to keep a close correlation check with status telemetry and events data on spacecraft response to command. A 20-bit satellite picture time code and a frame of housekeeping telemetry appear with each AVCS frame on both record and playback of each AVCS picture.

A two-channel strip chart recorder will be used at 50 mm/sec to display the two channels of vee-head horizon sensor data which will be analyzed at TEC for determination of spacecraft attitude. An analog-to-digital data conversion will enable the data to be processed by computer for printout of attitude values.

Table III-1

8-Channel Chart Recorder

Channel	
1	Not used
2	RZ digital command
3	Decoder RZ
4	Satellite error
5	Ground error
6	Subcarrier discriminator #1
7	Subcarrier discriminator #2
8	Subcarrier discriminator #3
	Marker pen #1 has 28-bit NASA time code
	Marker pen #2 is not used

The CDA station functions as well as certain commands will be monitored at TEC on a 20-channel events recorder (Table III-2). This information, in real time, is a quick check of the accuracy of the ground station command operation.

Video information from APT spacecraft will be received at TEC direct from the spacecraft as it passes overhead by using the installed APT ground station in GSFC Building 14. Other APT stations will be requested to assist GSFC checkout of APT. The resulting video information will be analyzed to determine the performance of the spacecraft's video subsystem as well as any degradation that may occur during use.

Video information from AVCS spacecraft will be received at TEC via TOSCOM from the CDA stations. The video signal can be checked to see that video subsystems specifications are met and maintained during the operating life of the spacecraft.

1.1.2 NEAR-REAL-TIME SYSTEMS EVALUATION

While GSFC has control of the spacecraft, TEC will perform near-real-time analysis of the TOS spacecraft and the ground systems. Using all available documentation and engineering data, TEC will review and evaluate the efficiency of all procedures and systems and will propose changes or modifications to increase the operational capability of the TOS system. TEC systems evaluation will include:

- Collation of information necessary to determine the use of QOMAC, MASC, and MBC and recommendations for programming

- Assistance to the TEC Manager in determining attitude

Table III-2

20-Channel Events Recorder

Channel	Event
1	APT operation
2	AVCS operation
3	Video receiver AGC (horizontal)
4	Video receiver AGC (vertical)
5	Beacon receiver AGC (horizontal)
6	Beacon receiver AGC (vertical)
7	Ground video frame pulses
8	Command transmitter on
9	Alarm time pulse
10	Blank at TEC and TOC
11	Tone pair "A" in use
12	Tone pair "B" in use
13	Enable tone transmission
14	FSK tone transmission
15	Tape reader mode
16	Automatic command unit mode
17	Blank at TEC and TOC
18	Blank at TEC and TOC
19	Spin count error
20	Command word transmission

- Formulation of procedures to be followed in attitude determination
- Suggestions for changes in techniques
- Evaluation of performance of all spacecraft and ground systems

1.1.3 MANUAL ATTITUDE DETERMINATION

Attitude will be determined in accordance with procedures established in TEC and in accordance with the geometry in Figures III-1, III-2, and III-3.

1.1.3.1 Prepass Functions

- Review and evaluate attitude data received on previous readout
- Determine attitude values predicted for readout

1.1.3.2 Function During a Pass

- Evaluate attitude data quality during readout

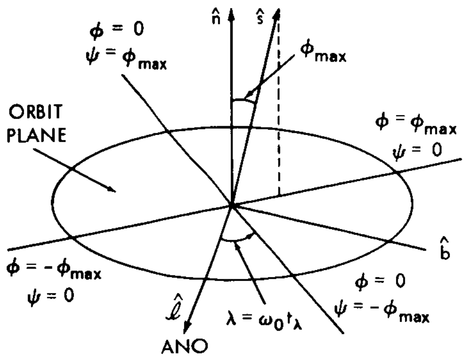
1.1.3.3 Postpass Functions

- Initiate attitude determination process by placing the 2-channel strip chart record on Gerber scanner; review entire readout and select sky-earth and earth-sky transitions for measurements
- Determine maximum roll angle (ϕ max)
- Determine time after descending node when maximum roll angle occurred (λ)
- Determine spin rate
- Predict spin decay and attitude change
- Determine requirements for QOMAC and MASC programming
- Determine spacecraft nutation or precession angle
- Determine gamma angle from DSAI data
- Compare attitude and spin data with data from CDA stations
- Compare attitude and spin values with data from AADPS
- Compare attitude values with predicted values
- Plot all comparative attitude and spin data

1.1.4 TEC EQUIPMENT OPERATION, CALIBRATION, AND MAINTENANCE

1.1.4.1 Communications Lines

All voice and data information from the CDA stations is transmitted via TOSCOM system to TEC over two X-136 microwave terminals (receive only). TEC can talk and transmit TTY messages and commands to the CDA stations via voice TTY circuits through TOSCOM switchboards; equipment is listed in Appendix G.



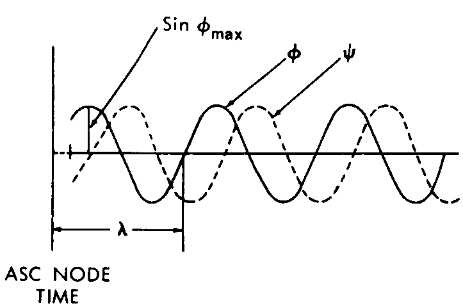
$\sin\phi = \sin\phi_{max} \sin(\omega_0 t - \lambda)$

$\sin\psi = \sin\phi_{max} \cos(\omega_0 t - \lambda)$

ϕ = roll $\quad$ λ = time (or orbit angle) from ascending node to ϕ_0 or ψ_{max}

ψ = yaw

Figure III-1—LBN Coordinate System for Attitude Determination



$\phi = 0$

$\psi = -\phi_{max}$

$\sin\phi = \sin\phi_{max} \sin(\omega_0 t - \lambda)$

$\sin\psi = -\sin\psi_{max} \cos(\omega_0 t - \lambda)$

Figure III-2—Determination of ϕ max and λ

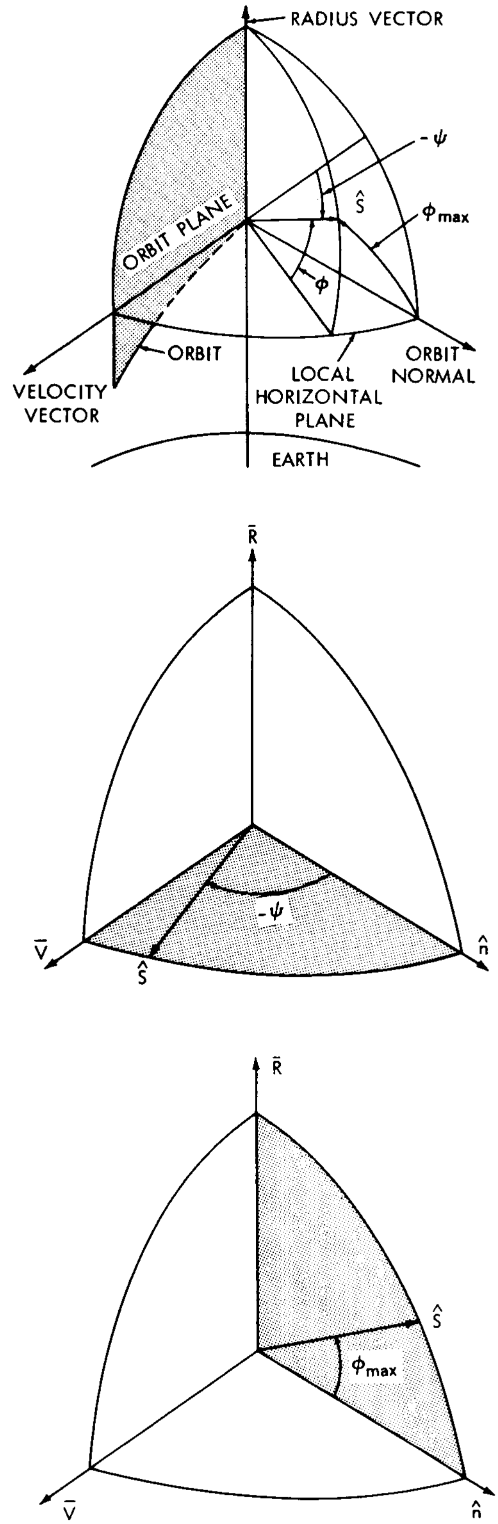


Figure III-3—Attitude Determination Coordinate Presentation

The CDA stations will be transmitting the following information to TEC during normal operations:

- Time-shared beacon SCO #3 with satellite picture time count
- Vee-head sensor data (SCO #1 and #2)
- Station events
- Flutter and wow (slowed-down recording)
- Satellite picture time count (slowed-down recording)
- Video (slowed-down recording)
- Voice
- TTY

Spacecraft data and attendant voice coordination will have precedence over all other use of the lines.

At least once a week each line will be tested for frequency response using an audio oscillator at the CDA station, level at 0-dbm, and frequency steps of 300 cps between 300 and 4000 cps. If obvious trouble is evident on any line, the test will be re-run using steps of 100 cps. The test will be run at any time there is reason to believe the line is not adequate for data transmission. The TOS AVCS signal simulator may also be used for line calibration.

When the line level at TEC drops below -3db from zero within the 300-cps to 4000-cps band or when the level shows more than 10db change from the lowest to the highest points, then the line will be referred to the shift supervisor and a decision made to return the line to the TOSCOM switchboard as inadequate for data reception or transmission.

When data, live or taped, is lost as a result of a defective line, the time of loss of line and return will be logged in the operations log.

1.1.4.2 Logs
The shift chief is responsible for the maintenance of all logs.

Shift Chief's Log. The shift chiefs will maintain a record of operational items, decisions and problems as well as a summary of each shift's operation and information to be passed on to the next shift.

Communications and Operations Log. The equipment operator will record all details of the communications lines (levels, tests and lost time). Noise and signal levels, frequency, phase, and amplitude tests, time of loss of line, and time of return will be entered in this log, along with entries pertaining to the equipment operation, data type, orbit numbers, and time of receipt of all data.

Maintenance and Test Equipment Log. All details of the checkout, calibration, malfunction, repair, and lost time on all equipment and test equipment are to be entered in this log by the maintenance and equipment operator.

All entries in the log books must show the date, GMT time, and name of the operator making the entry. The entry should define the event in sufficient detail to positively identify the event and to enable a comparison to be made with a previous or future event of a similar nature.

Where a piece of equipment is involved, it is essential to enter the serial number (S/N) and/or the equipment. The nature of the repair, malfunction, and adjustment should be stated briefly in terms of the particular component, number (symbols - C-11, R-22, etc.) and, if possible, the cause should be determined and entered.

When a magnetic tape is completed, the tape number, time, day, operation, and the file card identification number will be entered in the operations log.

All tests will be outlined in detail and the data recorded in the log <u>when</u> observed. A carbon may be used with a loose sheet if additional copies are required. The station or stations participating in this test will be listed, along with the operators, time, day, test equipment manufacturer and model numbers, and line numbers.

The conditions under which data are received are of primary importance. The signal levels, interference, noise, and abnormal conditions should be noted when they noticeably deviate from the normal or usual values. This applies to TEC equipment and is particularly important where the communication lines are involved.

The summary of each shift is intended to give the new shift a quick look at all major events, operations, and repairs, with particular emphasis on any unfinished or necessary repairs and tests and their exact status.

1.1.5 OPERATIONAL PROCEDURES

1.1.5.1 <u>Prepass Operations</u>

- Calibrate the equipment in accordance with the respective instruction manuals.

- Establish voice and data contact with the scheduled CDA levels.

- CDA station will transmit and TEC will record on the Brush, Ampex, and Potter recorders the telemetry calibrator steps automatically in the following manner:

  Step from the low frequency side of the telemetry calibrator to the high frequency side. Hold each step for 3 seconds, except center step, which will be held for 6 seconds. Brush recorders may be run at 5 mm/sec for this stepping, but speed must subsequently be returned to 20 mm/sec for the 8-channel Brush and 50 mm/sec for the 2-channel Brush.

- Confirm alarm 1 (A-1) time with CDA and enable appropriate remote control switches, etc., in sufficient time that all recorders are operating at A-1 time.

1.1.5.2 <u>Operation During a Pass</u>

- Monitor equipment for proper operation.

- Substitute backup and/or attempt correction in case of equipment failure. If unable to do so, note for record.

- Evaluate data quality. If quality is poor, attempt to determine if it is caused by equipment, data lines, operation, or actual data.
- Do not interrupt data flow for any of the above, except in an emergency.

1.1.5.3 Postpass Operation

- Turn off remote on all equipment, except Potter
- Place A/D CONVERTER switch to the -1-volt position and insert EOD (end of data) MARKER on Potter tape for at least 15 seconds. Turn off Potter remote.
- Turn on Brush recorder used, switch USE/OFF/CAL to CAL, and insert calibration onto record.
- Unload and reload recorders as required.
- Where required, further identify data recordings.
- If a poor quality of data is not due to equipment or data lines, proceed with transmission of remaining data. Repeat all appropriate steps except equipment calibration. If poor quality is due to equipment or lines, substitute or correct before proceeding.
- Terminate data and voice links after transmission of all data.
- Complete data identification and record files.
- Make appropriate entries in communications and operations logs, in accordance with existing procedures.
- Perform equipment maintenance and log same.
- Reload recorders, where necessary, and prepare equipment for next scheduled pass.

1.1.5.4 APT Operation

- The APT facsimile recorder operation during a TOS-APT satellite pass will be handled as a normal operation as described in the "APT Ground Station Installation, Operation and Maintenance Manual."

1.1.5.5 AVCS Video Operation

- The AVCS video information is recorded on the video tape recorder at 7 1/2 ips and played back into the AVCS video processing equipment at 60 ips. The video signal can then be analyzed to determine that TV specifications are being met.

1.1.6 RESPONSIBILITIES

The shift chief will be responsible, through his assigned operation and maintenance man, for the conduct of the above procedures. He will make all decisions concerning the operation of the equipment, the suitability of the data received, and the acceptability of the communications facilities for mission operations. During the day shift, he will normally consult with the team leader and the TEC Manager. He will maintain the logs as prescribed above.

1.2 SCHEDULING AND PROGRAMMING - LAUNCH AND CHECKOUT PHASE

TEC will originate and send to TOC suggested daily CDA schedules and programs for acquisition of meteorological and engineering data during the initial postlaunch period. NETCON will be an information addressee.

1.2.1 PLANNED OPERATIONS SCHEDULE

Based on information from TEC, TOC will schedule the CDA stations, based upon a nominal orbit. Table III-3 shows typical acquisitions

Table III-3

Typical CDA Acquisitions

Orbit	Command and Data Acquisition
1	WALOMS
2	WALOMS
3	GILMOR
4	GILMOR
5	GILMOR
6	GILMOR
7	WALOMS/GILMOR
8	WALOMS/GILMOR
9	GILMOR
10	GILMOR
11	GILMOR
12	--------
(13)	--------

1.2.2 DAILY SCHEDULE

TEC will originate and transmit to TOC suggested command programs and station interrogation schedules for daily operations, based on the following:

- Analysis of spacecraft position
- Analysis of spacecraft status
- Analysis of predictions received from the DSD computing center as to passes over CDA stations
- Analyses of programming requests from NESC or other agencies
- Analyses of attitude tracking requirements
- Analyses of spacecraft power
- Analyses of COSSAK's and STAPL's
- Analyses of CDA station status
- Analyses of ground communications facilities status

1.2.3 SPACECRAFT PROGRAMMING

TEC will provide programs for TOC to program the spacecraft for engineering and meteorological information based upon the following factors:

- Spacecraft attitude and spin rate
- Spacecraft power available
- Spacecraft subsystem status
- Meteorological requirements
- CDA station schedule
- CDA station acquisitions
- Areas suitable for photographic coverage
- CDA station status
- Ground communications facilities status

TEC will program the magnetic attitude and spin control subsystems via TOC, based upon all available attitude and spin information. TEC will transmit information on the effects of programming changes in the spacecraft attitude and spin to TOC.

TEC will transmit changes to the program and operating instructions to TOC. If there are two hours or less before implementation, TEC will communicate with TOC and the CDA stations via voice; if there are more than two hours, TEC will send TOC a TTY with SS precedence. NETCON will be kept informed of all GILMOR operations for proper scheduling.

1.2.4 SCHEDULING AND PROGRAMMING REQUIREMENTS

Data required by TEC from the Theory and Analysis Office for use in spacecraft programming and CDA station scheduling until the ESSA takeover are:

- A 28-day WMSAD listing WALOMS and GILMOR - available to TEC at least two weeks before the first date of the data.
- Two 14-day ATMAPW's - available to TEC at least four days before the first date of the data.
- A 28-day COSSAK - available to TEC at least two weeks before the first date of the data.
- Equator crossings.
- Picture prediction times.
- Predictive attitude and spin data.

1.3 ENGINEERING DOCUMENTATION AND REPORTING

TEC will evaluate and analyze all TOS data and prepare a daily report for the TEC Manager. All reports received from the CDA stations, including pass summaries, pass picture summaries, daily picture summaries, and all other operations records, will be thoroughly analyzed. Data from the reports will be tabulated and used as the basis for a daily narrative report and a final report. The analytical summaries will be complete appraisals of the entire TOS system, including the spacecraft and all ground elements, events of each day, and all anomalies and failures.

The TEC Manager, in conjunction with NESC, will prepare and transmit a daily progress report on TOS operations.

1.4 COMMUNICATIONS AND DATA TRANSMISSION

1.4.1 CDA STATION STATUS

If data cannot effectively be transmitted from a CDA station or received at TEC, or if CDA station computation and analysis facilities are not operative, TEC, via TOC, will reschedule station interrogation responsibilities. Rescheduling will be accomplished within the framework of the overall planning schedule when possible.

Problems encountered at the CDA stations that affect the station's capability for effective command and data readout in addition to the capabilities of adequate computation, processing, and analysis of the data will be reported to NESC, which is responsible for ensuring that immediate action is taken.

Difficulties with communications facilities will be reported to TOC, which will assess the problem and take corrective action when possible.

TEC will inform the cognizant systems manager when difficulties occur in his system operation.

1.4.2 DATA TRANSMISSION

TEC will have the following responsibilities for receiving TOS data:

- Request the scheduling of voice and data lines for receiving TOS operational data from the CDA stations and to and from TEC and NESC
- Provide TOC, in a timely manner, all operational data for the CDA stations
- Coordinate with DSD for computer communications

1.4.3 DATA PROVIDED TO TOC

TEC will provide NESC the following data:

- Spacecraft status
- Limiting factors that apply to interrogation of the spacecraft and acquisition of data
- Predicted power available to the spacecraft for programming purposes
- Requested schedule of CDA station operations

1.5 GRAPHIC DISPLAYS

TEC will maintain the following special graphic displays:

- Selected telemetry points versus time

- Spin rate versus time
- Spin vector coordinates (ϕ max and λ) using MGAPW and the daily operational definitive attitude values
- Sun-spin vector angle (τ) versus time, using MGAPW and daily operational definitive values
- Power available to the spacecraft per day and the daily power consumption versus time
- Daily interrogation schedule
- Spacecraft status
- CDA station status
- Ground communications facility status

2. ORBIT AND ATTITUDE DETERMINATION

The GSFC Data Systems Division (DSD) will be responsible for systems readiness for early orbit determination and for checkout of the automatic attitude determination system. DSD will determine the TOS orbit, prepare World Map and Satellite Acquisition Data (WMSAD's) and STADAN and CDA station predictions, determine spacecraft attitude using the Automatic Attitude Determination Program System (AADPS), provide attitude predictions, and furnish associated orbit and attitude data as required by the TOS project. When the new TOS is accepted by NESC, DSD support requirements are reduced to TOS orbit determination, minute vector tape production, and provision of STADAN station predictions.

The Orbit and Attitude Computations Engineer, R. D. Werking of the Theory and Analysis Office, has the responsibility for coordination of the early orbit and automatic attitude determination plans. The Orbit and Attitude Computations Engineer will assist NESC by providing orbital data to be used at TOC. He will also provide assistance to TEC in the determination of the best attitude for each orbit of the day and will prepare reports and documents as may be necessary, including a postflight analysis.

The Orbit and Attitude Computations Engineer will be responsible for conducting the orbit determination; including the differential correction, i.e., for the selection, evaluation, and interpretation of the data; the selection of the orbit and attitude theories and the differential correction theory; the analysis and interpretation of the results, the use of the results for predictions, and releasing the results for other operational purposes; and the determination as to when the operation has been completed.

The Advanced Orbital Programming Branch is responsible for programming support as may be needed because of special project demands. The Branch will arrange for representation from the programming staff during the orbit determination period to provide, in an emergency, detailed information on the capabilities of the entire orbit determination program library, as well as guidance in the use of such programs.

The Orbit Determination Section, Operational Computing Branch, is responsible for the preparation and prompt machine computation of world maps and station predictions and for any special computations that may be required. The section will be responsible for the availability and proper running of the various programs used for orbit determination and predictions; it will arrange for suitable representation from the section during the launch and orbit determination period.

The Minitrack Section, Operational Computing Branch, will receive the nominal station predictions prior to launch and is responsible for appropriate processing and transmittal of this to the tracking stations. It will also be responsible for the preparation of a schedule of estimated early tracking data acquisitions for use during the launch and orbit determination period. The section will arrange for suitable representation during the launch and orbit determination period, and will be responsible for receipt and processing of tracking data for input to the IBM 7094 general orbit determination system. In addition, it will be responsible for conversion of prediction data from magnetic tape to paper tape and transfer to NASCOM for transmission to TOC.

The Computer Services Section, Operational Computing Branch, will be responsible for arranging for the presence of the computer operating personnel and for the use of the necessary computing facilities.

2.1 DSD PRELAUNCH SUPPORT

Prior to the launch of each TOS spacecraft a complete prelaunch analysis will be performed by DSD and the results will be published in a document entitled, "Prelaunch Analysis for TOS." A complete manpower list, including the names of persons involved with early orbit and attitude determination will be distributed within DSD.

2.1.1 ORBIT ANALYSIS AND SYSTEM READINESS

Nominal orbital data will be computed from the Delta vehicle trajectory parameters taken directly from the appropriate DTO for the satellite in question. These trajectory parameters taken at third-stage burnout will be used in the Conversion Routine for Orbital Elements (CORFOE) and/or the Douglas transformation program for the computation of the nominal orbital elements.

2.1.2 AUTOMATIC ATTITUDE DETERMINATION PROGRAM SYSTEM (AADPS)

The Orbit and Attitude Computations Engineer will be responsible for the attitude determination and spacecraft status data for TOS during the launch and checkout phase. AADPS, consisting of proven computer programs for digital horizon scanner and telemetry data preprocessing, horizon determination, roll angle computation, status data processing and evaluation; attitude and status analysis, and attitude prediction, will be operated by the Theory and Analysis Office under the direction of the Orbit and Attitude Computations Engineer. The data will be supplied to TEC after each orbit until the wheel orientation is achieved, at which time the data will be supplied on a daily basis or upon special request.

Two modes of attitude determination are employed in AADPS. One mode uses a least-squares-fit of roll observations, while the other mode uses a smoothed-roll observation/sun observation pair to compute spin vector orientation.

A plan for attitude determination using sun and roll observations will be devised for the initial maneuver, given nominal orbit and attitude maneuvers for each TOS spacecraft. This data will be contained in "Prelaunch Analysis for TOS" report to be provided before each launch.

Roll observations obtained from the V-head horizon scanner sensor and sun observations obtained from the digital solar aspect indicator are transmitted to TEC as an analog signal. This signal is processed through an analog-to-digital converter and supplied to the Theory and Analysis Office in the form of a digital tape. Shown in Figure III-4 is the data flow from the satellite to the computer; Figure III-5 is the automatic attitude determination computer system.

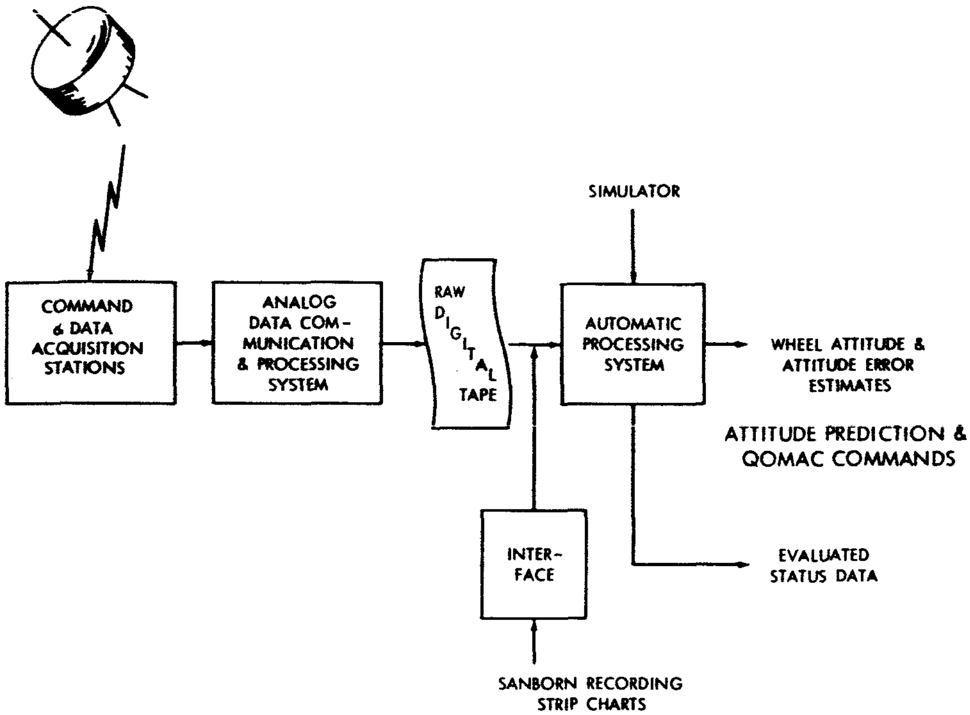


Figure III-4 — Data Flow

A magnetic attitude prediction model with QOMAC capabilities will produce long range (two weeks) and short range (several days) attitude predictions. QOMAC commands can be formulated by the predictor whenever corrective action is desired.

A complete checkout of AADPS and its subsystems for attitude determination and status data reduction will be conducted prior to launch. The system will be operated in closed-loop fashion using available spacecraft test data and simulated data.

2.1.3 DSD PRELAUNCH SCHEDULE

Table III-4 lists the times, events, and responsibilities of DSD during the prelaunch period. Times refer to calendar days.

2.2 EARLY ORBIT AND ATTITUDE DETERMINATION PLAN

2.2.1 ORBIT

TOS will be launched from WTR into different orbital planes; one for APT and one for AVCS. The APT spacecraft will have a descending node at 0900 local time, which requires a launch time of approximately 1430 GMT. Nominal values for the principal elements of the orbit are:

- Period - 113.5
- Perigee - 750 nm
- Apogee - 750 nm
- Inclination - 101.16 degrees (78.84 retrograde)

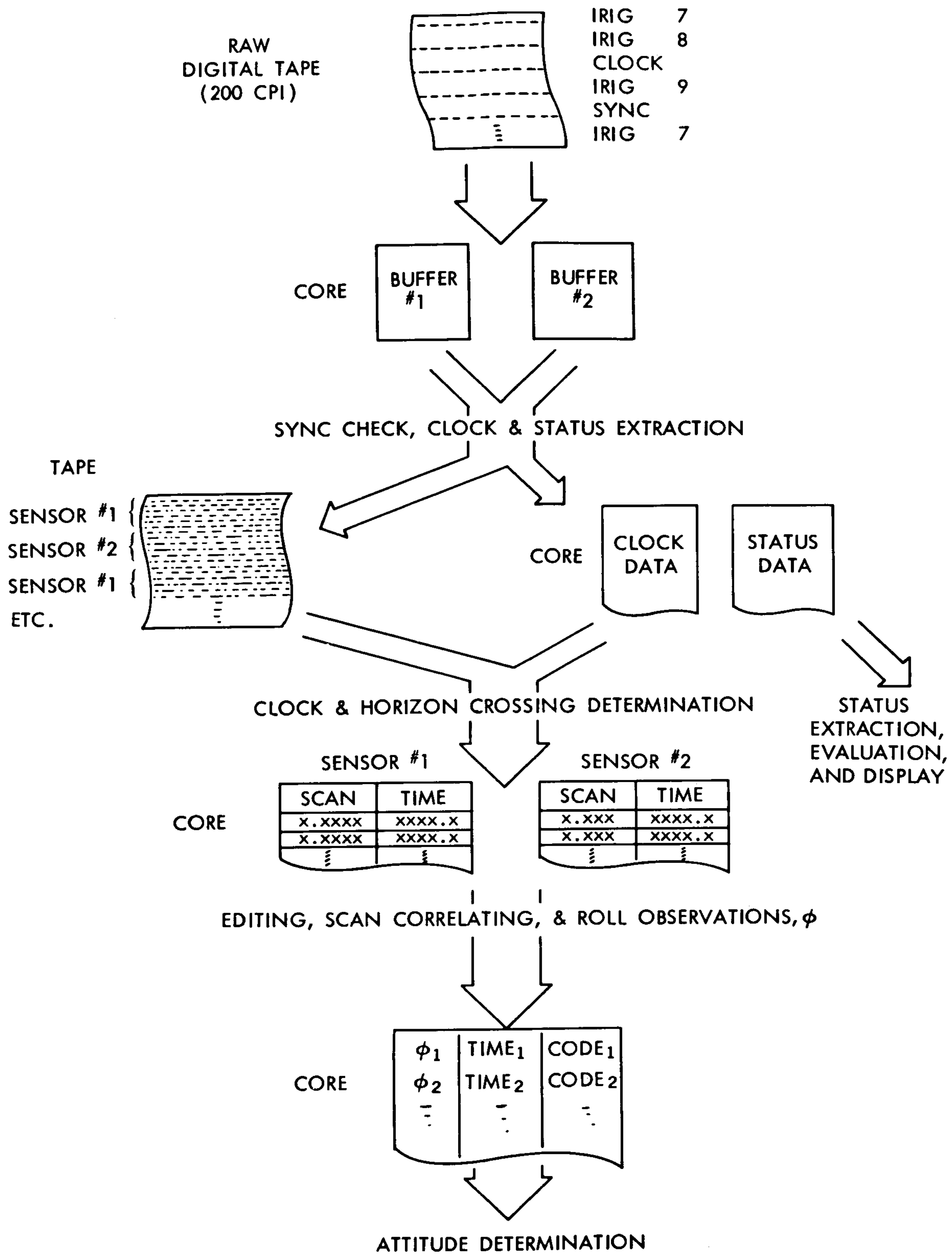


Figure III-5 — Automatic Attitude Determination, System Logic

Table III-4

Schedule for DSD Prelaunch Preparations

Days before Launch	Event	Responsibility of
30	Orbital elements are determined from which are obtained the initial conditions for nominal orbit	Orbit and Attitude Computations Engineer
10	"Prelaunch Analysis for TOS" is presented to the TOS project office	Orbit and Attitude Computations Engineer
7	Nominal world map and station predictions for the orbit are sent to NETCON/OPSCON, with the predictions being transmitted to the stations	Orbit and Attitude Computations Engineer Orbit Determination Section NETCON/OPSCON Minitrack Section
7	Personnel assignments for launch and early orbit and attitude determination period are made	Advanced Orbital Programming Branch Operational Computing Branch Theory and Analysis Office
7	Latest guidance data received from WECO	Orbit and Attitude Computations Engineer Theory and Analysis Office
7	Schedule of early STADAN, radar, and optical tracking data acquisition is prepared	Minitrack Section
7	Predictions are computed for TOS CDA stations	Orbit and Attitude Computations Engineer
7	Tracking network and tracking facility arrangements are verified with NETCON/OPSCON	Orbit and Attitude Computations Engineer
7	Predictions are computed for variations from nominal injection conditions	Orbit and Attitude Computations Engineer Operational Computing Branch
7	Request is made of the Computer Services Section, DSD, for emergency availability of diesel power for the computer during the launch and early orbit and attitude determination period	Orbit and Attitude Computations Engineer

Table III-4 (Continued)

Days before Launch	Event	Responsibility of
3	Statement of computer program requirements for the launch and early orbit and attitude determination period is sent to the Operational Computing Branch	Orbit and Attitude Computations Engineer
2	Readiness of required program is confirmed	Advanced Orbital Programming Branch Orbit Determination Section
1	Briefing of personnel involved in the launch and early orbit and attitude determination period is conducted	Orbit and Attitude Computations Engineer
1	Final confirmation of guidance data is obtained by telephone from WECO	Orbit and Attitude Computations Engineer Theory and Analysis Office
1	Operational Computing Branch confirms availability of computers for orbit and attitude determination	Operational Computing Branch

A Mercator projection map of the world with the nominal TOS sub-satellite track overlay is given in Figure III-6. It is anticipated that sufficient tracking data will be available to make possible the determination of an orbit for TOS within about 9 hours after launch.

Data obtained from the Delta guidance system will be transmitted by telephone from MDC WTR to the Orbit and Attitude Computations Engineer who will be located in GSFC Building 14.

These data are normally available about 30 minutes after liftoff. They will be processed by means of a launch phase program. This program uses trajectory parameters of the second stage of the Delta vehicle and computes the orbit and attitude to be expected if the third-stage performance is nominal. This part of the launch phase operation will be the responsibility of the Theory and Analysis Office. The initial estimate of the orbit and attitude obtained from this launch phase program will normally be used in place of the nominal estimate to begin the differential corrections. It will also be used to provide preliminary predictions to the tracking and telemetry stations and for other purposes if necessary.

The STADAN will take interferometer data as scheduled by NETCON on the basis of the nominal station predictions. Under normal conditions, the data from each tracking pass will have been received from the Communications Division by the Minitrack Section within about 30 minutes after the tracking pass has been completed. The Minitrack Section will be responsible for utilizing the CDC-160A and peripheral equipment to process the interferometer data and to indicate which data points may be spurious or questionable on the basis of ambiguity resolution, consistency, etc. Data on IBM punched cards, together

(Please insert Figure III-6, TOS APT and AVCS Subsatellite Tracks from page III-20 of the original TOS Mission Operations Plan.)

with indications of the potential usefulness, will be handcarried to the Orbit Determination Section representative. Under normal conditions the data will have been processed and evaluated by the Minitrack Section and made available for use in the IBM 7094 within about 15 minutes after they have been received from the Communications Division. The Orbit Determination Section representative will be responsible for processing the interferometer data in the general orbit determination input program and for preparing the data tape for use in the general orbit determination differential correction program. During the early orbit determination phase, the interferometer data will not be smoothed. Under normal conditions, the data will have been processed by means of the general orbit determination input program within about five minutes after being received at the IBM 7094.

Data from the normal T&DS support agencies will be received by the Minitrack Section where they will be transferred to punched cards and made available for use in the IBM 7094. These tracking data cards will be received and processed by means of the general orbit determination program within about 50 minutes after receipt at GSFC.

The general orbit determination programs, including the input program, the differential correction program, the station prediction programs, and such other programs as may be needed, will be operated by personnel of the Orbit Determination Section and the Computer Services Section under the direction of the Orbit and Attitude Computations Engineer. When a satisfactory orbit has been obtained on the basis of data from at least three interferometer passes spanning an interval of at least one orbit, preliminary orbital information will be provided to TEC, TOC, and NETCON/OPSCON. These results will be confirmed by carrying out a differential correction with respect to the interferometer data from four or more interferometer tracking passes. When this has been done, and a satisfactory result has been achieved, the early orbit determination can be considered to have been completed. However, for the first 24 hours or until otherwise advised, the interferometer data should be available for processing by the Minitrack Section no later than one hour after each pass has been completed. This requirement is placed upon OPSCON to ensure that data is transmitted from the stations to COMPUT to be made available to the Orbit Determination Section when attempts are made to update the TOS orbit. The Orbit and Attitude Computations Engineer will notify OPSCON when this service is no longer needed.

Improved orbital elements and predictions based upon additional tracking observations will then be released. The Orbit and Attitude Computations Engineer and the Orbit Determination Section representative will be responsible for providing world maps and printed versions of the station predictions and alerts to TEC, OPSCON, and NETCON. They will also be responsible for furnishing prediction magnetic tapes to the Minitrack Section and a position vector tape to TOC. The Minitrack Section will be responsible for transmitting the teletype versions of the station predictions to the Communications Division.

2.2.2 ATTITUDE

TOS will be placed in orbit with a spin axis orientation similar to the conventional TIROS satellites. The spacecraft spin axis will be in or very near the orbital plane and in the general direction of the velocity vector at injection. The operational orientation is to keep the spin axis perpendicular to the orbital plane which requires the initial wheel maneuver. The orientation maneuver should begin on the first orbit and continue for about 18 orbits. It is important, therefore, to determine the orbit as soon as possible.

To assist in making the determination, two sources of data will be used. All available injection data will be studied and attitude data in the form of horizon scanner and sun aspect data obtained from the satellite will be processed. The injection data will act as a starting point for the rest of the work which will follow.

The attitude data will be received at TEC via the telephone lines from the ground station. After this data is received, digitized, and recorded in TEC, it is processed by AADPS on an IBM 7094. The results are then given to TEC with suggested attitude correction commands. Also supplied to TEC is the status data which was processed through AADPS.

All of this support will be supplied on a pass-by-pass basis until the initial maneuver has been completed or until the Orbit and Attitude Computations Engineer determines that the need for pass-by-pass coverage no longer exists.

During the launch and checkout phase of a TOS mission, orbit and attitude data will be supplied by DSD to various groups. Following is a list of data to be supplied to OPSCON, TEC, and TOC. OPSCON will receive the world map and STADAN predictions, equator crossings, and orbital elements. This information will be supplied every seven days, using the latest orbital information available.

For the first month after launch, TEC will be provided with printouts predicting orbital and picture data and attitude data at the intervals listed:

- A 28-day WMSAD listing GILMOR and WALOMS - available two weeks before first date of data
- 14-day ATMAPW - available four days before the first date of the data
- A 28-day COSSAK - available two weeks before first date of data
- 1-day definitive and 3-day predictive Magnetic Attitude Prediction Wheel-Attitude Smoothing Program (MGAPW-ASP) - available each day
- Status Data Extraction, Evaluation, Reduction (STADEE) - available each day

Both MGAPW and STADEE will be supplied on an orbit-by-orbit basis until the reorientation maneuver has been completed.

The data to be supplied by DSD during the checkout phase is centered around the generation of the position vector tape. The first of these tapes will be made available at the end of the early orbit determination phase. Also to be made available will be the computation of CDA station prediction data. In general this will consist of ENV data which are used to produce drive tapes for the 85-foot dish antennas.

The second position vector tape will be provided approximately three days after launch. Tracking data will be generated and made available to TOC and to ULASKA. This will then become an operational procedure.

Attitude and status data will be provided at regular intervals depending upon the needs of TEC.

3. GSFC OPERATIONS CONTROL

3.1 OPSCON

The T&DS Operations Director in the GSFC Operations Control Center (OPSCON) is responsible for control of the GSFC ground support facilities used during launch. The following may be in OPSCON to assist in the operations.

- Assistant Operations Director
- Tracking and Data Systems Manager
- Network Controller
- Tracking and Telemetry Engineer
- Operations Controller
- Display Manager
- NORAD Liaison

3.2 MISSION CONTROL ROOM

The Mission Control Room (MCR) is divided into two areas. One area is designed for use by GSFC Management personnel and the other area is for use by project personnel. Communication facilities are provided in the management area for monitoring the operational activity. A hot line is also available for direct communication with the Project Manager at the range. The following persons may be in attendance in the MCR management area.

- GSFC Director - Dr. J. F. Clark
- GSFC Deputy Director - Dr. J. W. Townsend, Jr.
- GSFC Assistant Director for T&DS - Mr. J. T. Mengel
- GSFC Assistant Director for Projects - Mr. R. E. Bourdeau
- Other management personnel as invited

The individuals located in the project area of the MCR will have access to communications as required during the mission. The project area of the MCR will accommodate six individuals. The following persons may be in this area:

- Project Representative
- Orbit and Attitude Computations Engineer
- NASA Headquarters Representative
- Launch Vehicle Representative
- ESSA Representative
- Public Information Officer

3.3 TELEPHONE COMMUNICATIONS

OPSCON telephone communications are established to provide for rapid liaison, coordination, and/or data dissemination during the mission.

3.4 DISPLAYS

Prelaunch and realtime launch data pertaining to the mission are displayed on illuminated screens located at the front of OPSCON. The following information will be displayed during the launch and early orbit phase: all of the information may not be displayed simultaneously, displays will be projected as appropriate data is received.

3.4.1 STATION STATUS
The current status of each participating STADAN station is shown by means of individual colored lights placed at the geographic station location on the world map. The lights indicate the following:

- Amber - station not reported or status unknown
- Red - station not ready
- Green - station ready
- Flashing green - acquisition of spacecraft signal
- Amber following flashing green - loss of spacecraft signal

3.4.2 LAUNCH EVENTS AND ORBITAL ELEMENTS
This display presents the nominal and real times of the sequence of events during launch, the nominal and computed orbital elements, and other pertinent information related to the launch vehicle and spacecraft.

3.4.3 DOPPLER PLOT
A nominal doppler plot is displayed. This is a plot of the spacecraft RF frequency shift versus time in seconds. Beginning at liftoff, doppler data will be received on a realtime basis and automatically plotted to indicate the actual velocity performance of the launch vehicle.

3.4.4 MESSAGE DISPLAY
This display is used to view projected mission-oriented teletype messages received from the supporting stations.

3.4.5 FLIGHT PATH ANGLE VERSUS VELOCITY RATIO
This display graphically shows the data received in real time by the GSFC computers. The display indicates the flight path angle versus the ratio of the actual velocity to the velocity which is required to inject the spacecraft into the desired orbit. Three scales are used, each increasing the last by a factor of ten.

3.4.6 SUBSATELLITE PLOT
The nominal subsatellite plot for one or more orbits is displayed. The position of the spacecraft along this plot will be indicated in real time if near nominal orbit is achieved. It is expected that the subsatellite plot will be maintained for no more than seven hours.

3.4.7 COUNTDOWN CLOCK
The countdown clock indicates the latest terminal count as received in OPSCON from WTR. Hold times are also indicated.

3.4.8 GMT CLOCK
A clock indicating GMT is mounted directly above the countdown clock.

3.4.9 PROJECTION SCREEN
A projection screen in the top center is used to view 35-mm slides which show the terminal count and other launch activities.

3.4.10 TRACKING AND TELEMETRY SCHEDULE
This schedule sequentially shows the stations which will acquire spacecraft tracking and telemetry data.

3.5 TELEVISION
Closed-circuit television from OPSCON will be transmitted to the NASA Headquarters Mission Status Room. This monitor will enable the NASA Headquarters personnel to observe the launch activity available in OPSCON. Television monitors will be established in the auditorium of Building 3, GSFC. These monitors will permit those GSFC personnel not admitted to the restricted access of OPSCON to observe the launch activity.

PART IV

FIELD OPERATIONS

Field operations for a TOS/WTR launch are conducted by elements of Unmanned Launch Operations (ULO), Kennedy Space Center (SC), Western Test Range (WTR), the TOS project, the GSFC Space Tracking and Data Acquisition Network (STADAN), the CDA stations, APT stations, and the ground communications net.

1. ULO AND TOS PROJECT

ULO is responsible for Delta launch operations at WTR. ULO is responsible for assuring the accomplishment of all actions necessary for the launch of the TOS spacecraft into orbit, including planning the launch, coordination among NASA, contractors, and the range; range documentation; arranging for the necessary launch support by contractors and other government agencies; establishment and operation of Mission Director Center (MDC) at WTR; and reporting to the Project Manager as established in the TOS Project Development Plan (PDP).

2. WTR FACILITIES

WTR facilities used for an Improved Delta launch include Vandenberg Air Force Base (VAFB) and South Vandenberg Air Force Base (SVAFB) (Figure IV-1). Down-range radar at San Nicholas Island and radar ships are used for launch tracking. The VAFB and SVAFB facilities used for TOS launches include Space Launch Complex-2 East (SLC-2E) (Figure IV-2) and blockhouse, the spacecraft laboratory and telemetry station in Building 34 (Figure IV-3), the Delta Operations Bldg., the WECO ground station, and the NASA offices and Mission Director Center (MDC) in Building 32 (Figure IV-4).

SLC-2E includes the blockhouse (CC-1), the Delta Operations Bldg., vehicle shelters, gantry, umbilical mast, RF tower, and two concrete reinforced shelters for support equipment. The blockhouse control room and launch assignments are shown in Figure IV-5.

The NASA/ULO spacecraft laboratory in Building 34 provides facilities for spacecraft preparation checkout, and handling. Spacecraft assembly area A is a 2380-square-foot high bay; spacecraft assembly area B is a 2856-square-foot low bay. There are also 7 individual labs and a 10,000-square-foot high-bay service area. The nominal temperature is $70° + 3°F$ with a relative humidity less than 50% except in the high-bay service area.

The KSC/ULO office, the Mission Director Center (MDC), Observation Room, and the Communications Center are in Building 32 (Figure IV-6).

The MDC provides communications and display facilities for prelaunch and postlaunch operations. The facilities include two x-y vertical plotting boards, a range readiness board, vehicle events boards, communications consoles, two 21-inch TV monitors, and two digital clocks providing PST/PDT and GMT time.

The NASA/KSC telemetry ground station is located in Building 34, VAFB. The station provides telemetry and Doppler coverage for all prelaunch, launch, and postlaunch operations.

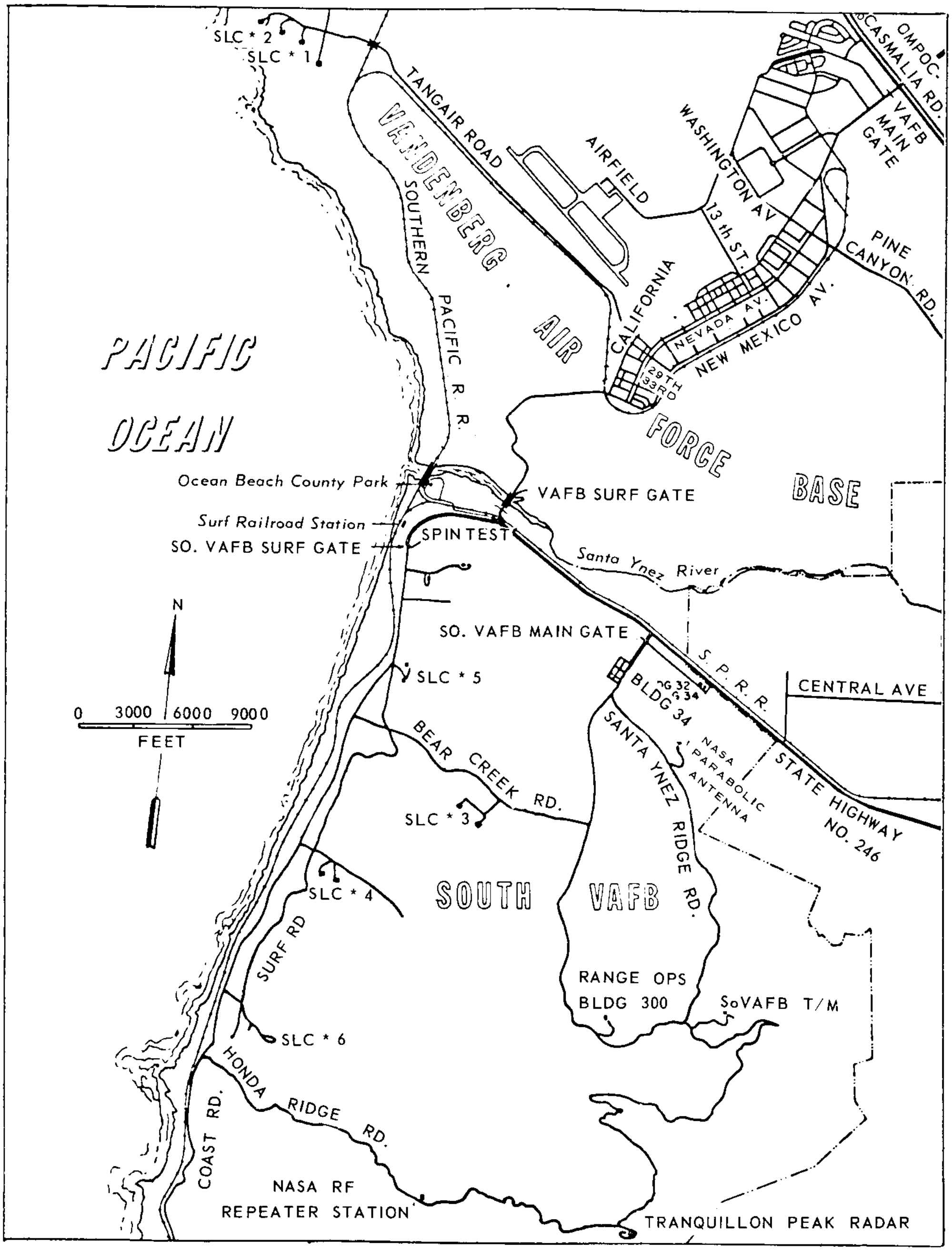


Figure IV-1 – WTR Launch Facilities

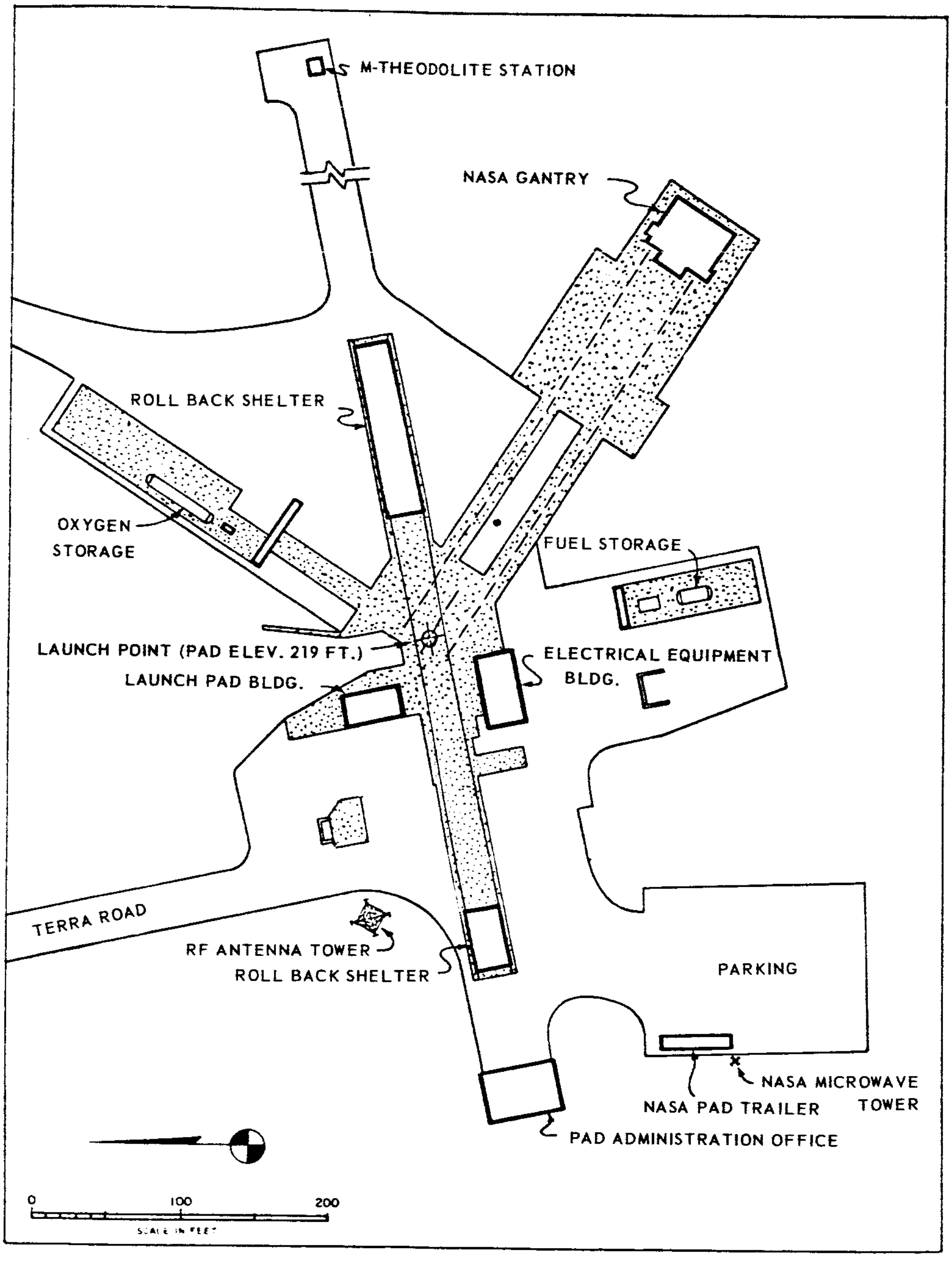


Figure IV-2 – SLC-2E

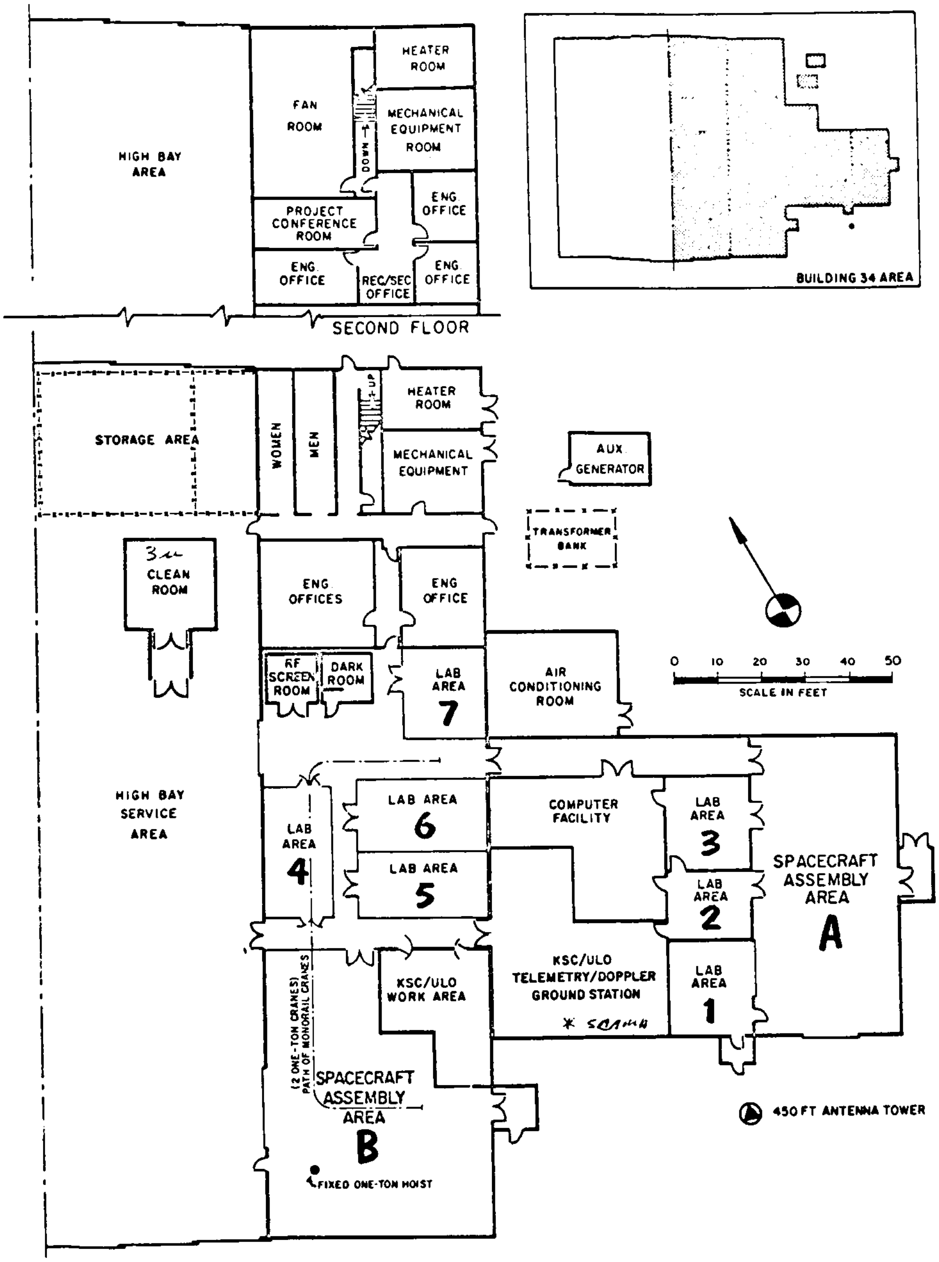


Figure IV-3 — Spacecraft Laboratory — Building 34

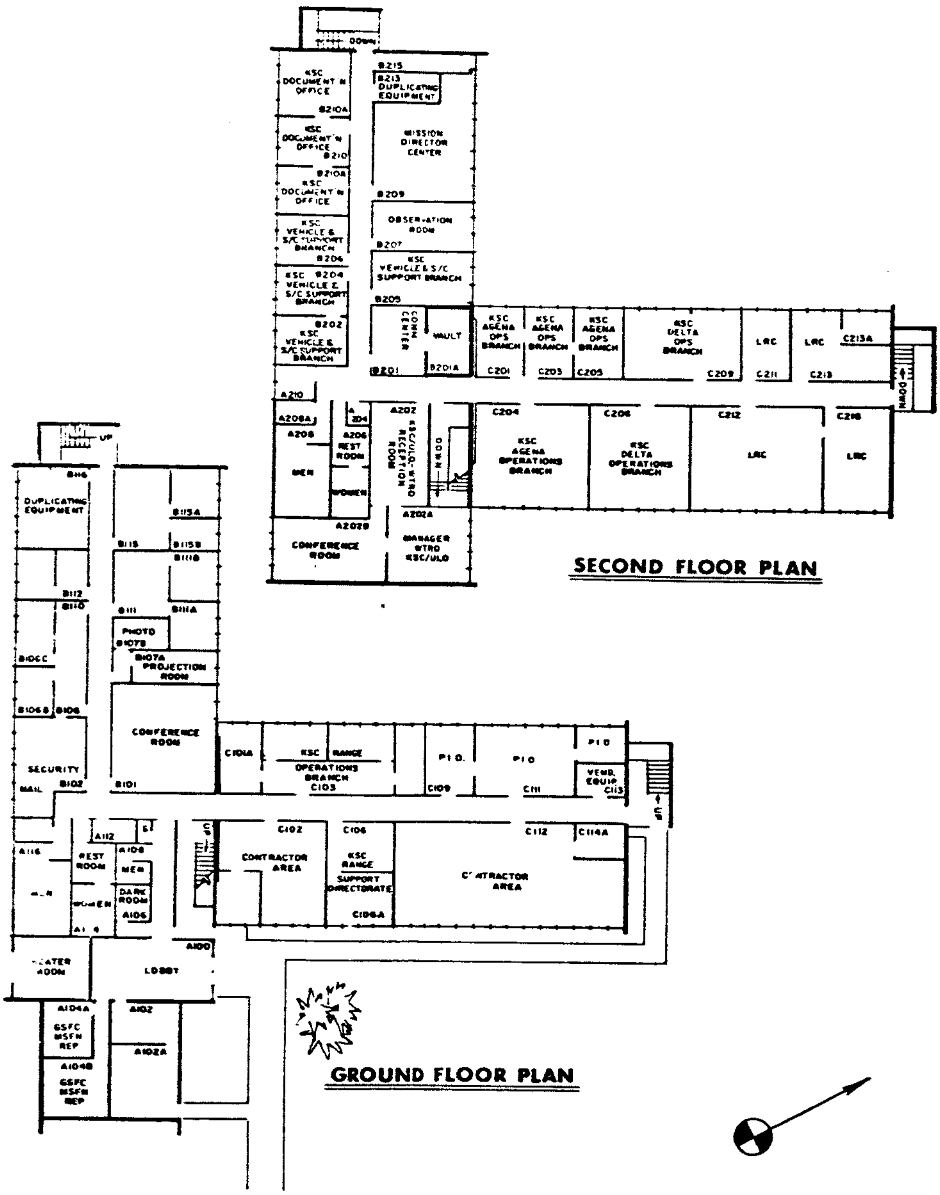
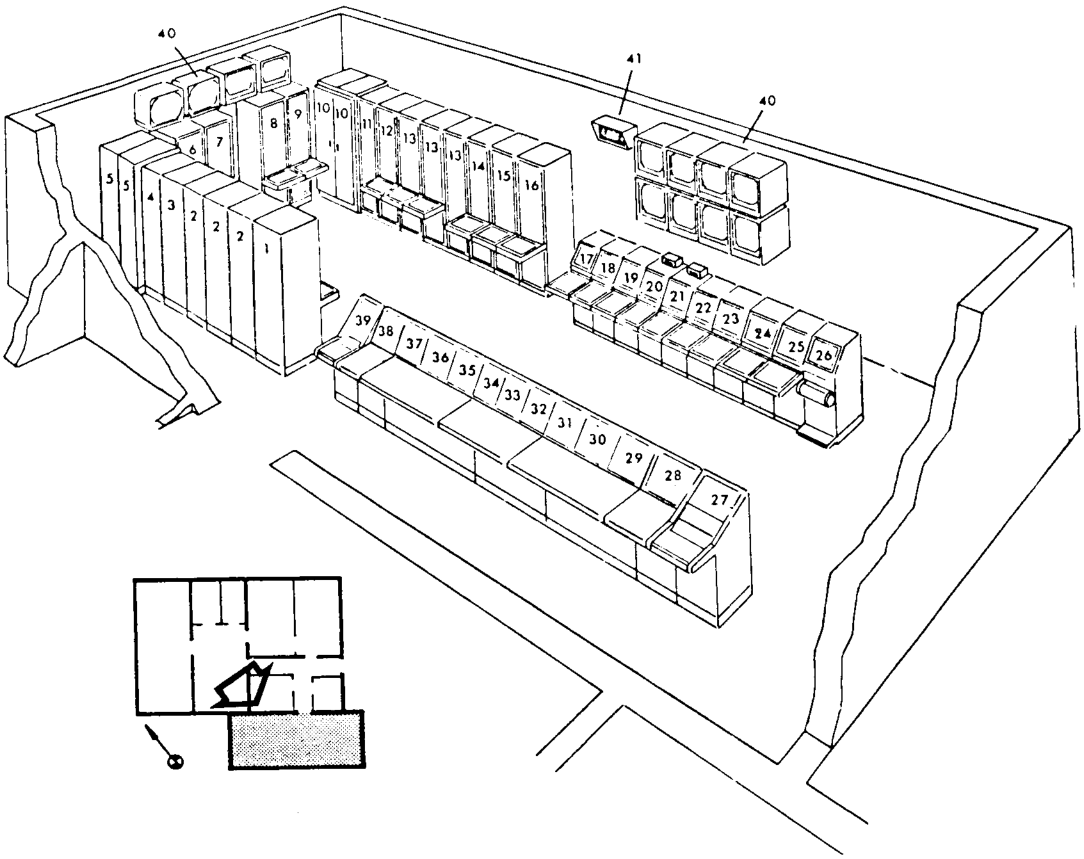
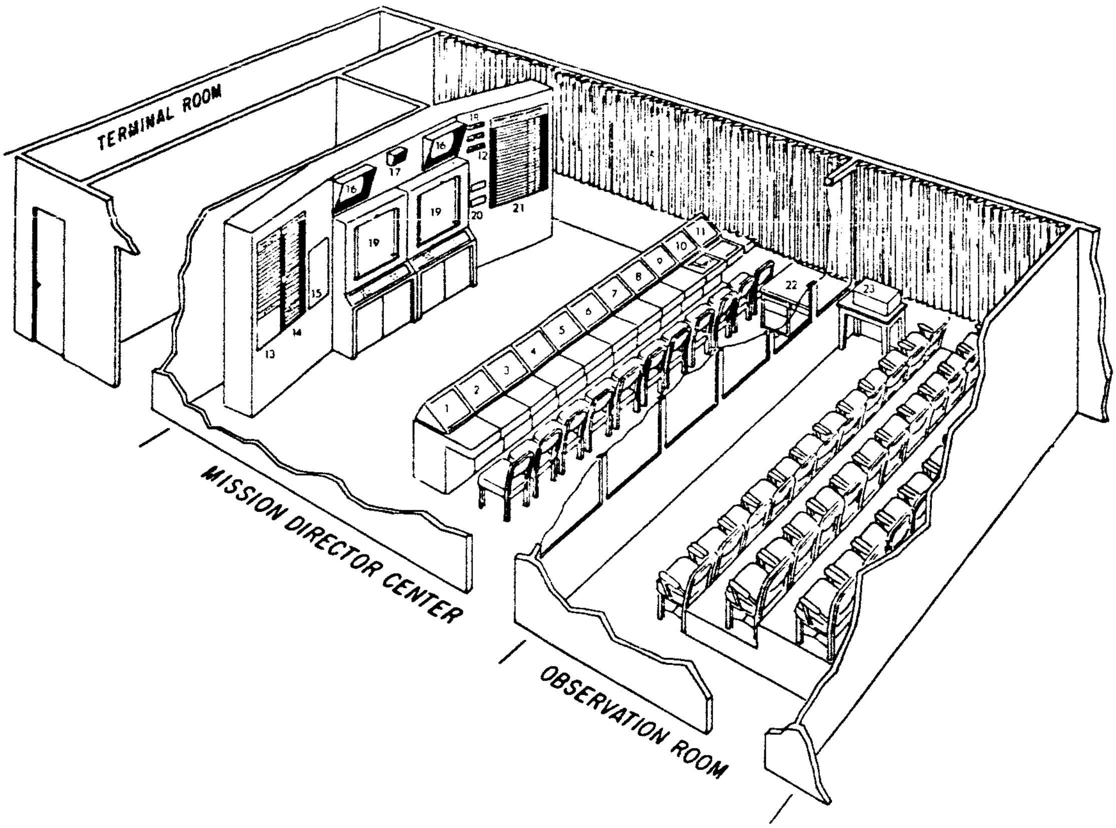


Figure IV-4 – NASA Offices – Building 32



1. LMSC PAD-2 A.E.T. CONS.
2. " " GUID. CONS.
3. " " ELEC. CONS
4. " " PWR. SUPPLY
5. " " I/C BOX
6. " " PNEU. CONS.
7. " " PROP. CONS.
8. " PAD-1 PROP. CONS.
9. " " PNEU. CONS.
10. " " I/C BOX
11. " " PWR. SUPPLY
12. " " ELEC. CONS.
13. " " GUID. CONS.
14. " " A.E.T. CONS.
15. NASA S/C CONSOLE
16. NASA S/C CONSOLE
17. DAC PAD-1 MALFUNCTION & CONT. STATUS CONS.
18. " " PROP. CONT. & MON. CONS.
19. " " LAUNCH ADVISOR CONS.
20. " FAC. CONS.
21. DAC FAC. CONS.
22. " PAD-2 LAUNCH ADVISOR
23. " " PROP. CONT. & MON. CONS
24. " " MALFUNCTION & CONT. STATUS CONS.
25. " PAD-1&2 WECO CONT. CONS
26. " " SPIN MOTOR MON. CONS.
27. USAF FLIGHT SAFETY & CAMERA CONT. CONS.
28. DAC PWR & SAFETY MON. & T/M CONT.
29. " H'STORIAN
30. " ASST LAUNCH COND.
31. " LAUNCH COND.
32. AFSSD LAUNCH TEST DIRECTOR
33. " LAUNCH CONT.
34. NASA TEST DIRECTOR CONS.
35. LMSC LAUNCH COND.
36. " LAUNCH COORD.
37. " TALKER
38. NASA S/C LAUNCH COND.
39. AFSSD COMPLEX SAFETY OFFICER
40. TV MONITORS
41. COUNTDOWN CLOCK

Figure IV-5 – Blockhouse Control Room



1-5. CONSOLES (MANNED BY HEADQUARTERS, MISSION, SPACECRAFT, AND VEHICLE REPRESENTATIVES)
6. MISSION DIRECTOR CONSOLE
7. LAUNCH OPERATIONS MANAGER CONSOLE
8. CENTER CONTROLLER CONSOLE
9. COMMUNICATOR CONSOLE
10. DISPLAYS CONTROLLER CONSOLE
11. DATA COORDINATOR CONSOLE
12. PLUS COUNT INDICATOR
13. PERSONNEL LOCATOR
14. RANGE READINESS INDICATOR
15. INTEGRATED COUNTDOWN CHART
16. TV MONITORS (2)
17. RANGE TALKER
18. TIME COUNT INDICATOR
19. PLOTTING BOARDS (2)
20. LOCAL AND GREENWICH MEAN TIME CLOCKS
21. LAUNCH VEHICLE PROGRESS INDICATOR
22. PIO STATION
23. MOPS END INSTRUMENT

Figure IV-6 – Mission Director Center and Observation Room

RF reception is by the 28-foot parabolic tracking antenna (NASA/TRK-1) located on Santa Ynez ridge, antennas located on Building 34 on a 450-foot tower, and a steerable NASA-9 antenna, with a 148-mc command element installed, and a trihelix antenna for vehicle telemetry and backup support mounted on the roof of Building 34.

Command capabilities include a 50-watt and a 5-kw transmitter for closed loop command checkout and all command requirements.

Vehicle telemetry support includes real-time display of all vehicle telemetry functions on Sanborn or CEC recorders in addition to magnetic tape recordings.

3. WTR ORGANIZATION

NASA activities at WTR are the responsibility of KSC/ULO Western Test Range Operations (WTRO). Figure IV-7 shows the WTRO organizational structure.

3.1 NASA RANGE SUPPORT

The NASA Range Support (NRS) Office is the point of contact for NASA Range User functions with WTR. NRS assures that mission support requirements specified by NASA projects are properly prepared and coordinated, and are submitted to AFWTR in accordance with overall policy.

3.2 RANGE OPERATIONS BRANCH

The Range Operations Branch is divided into sections that function as part of the composite NRS and is the point of contact with AFWTR organizations for each WTRO program. The Delta Missions Office is the Range contact for all Delta missions. The office provides liaison for tracking, data acquisition, range safety, operational support services, project facilities and funding, and scheduling. It is also responsible for data collection, preparation, coordination, and submission of Range documentation.

3.3 DELTA OPERATIONS BRANCH

The Delta Operations Branch is responsible for Delta vehicle technical management and verifies that the vehicle system and supporting aerospace ground equipment are acceptable for launch. The Delta Operations Branch reviews all vehicle test procedures and monitors all tests.

3.4 VEHICLE AND SPACECRAFT SUPPORT BRANCH

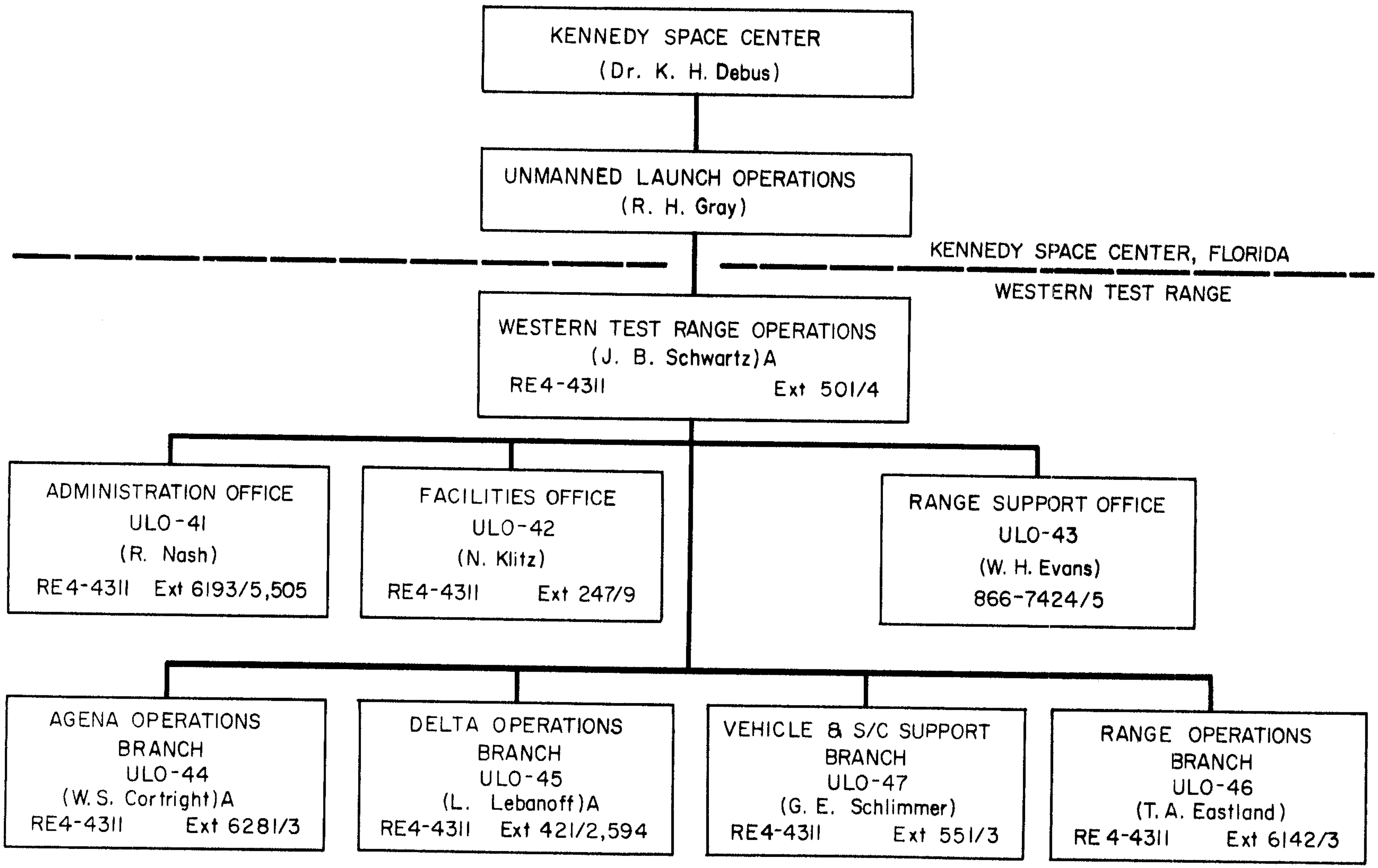
The Vehicle and Spacecraft Support Branch provides engineering, planning, and support for spacecraft/vehicle interfaces, and provides required documentation support. The branch provides prelaunch and launch support including laboratory space, instrumentation, data, and tracking facilities, MDC operations and communications.

4. TOS PROJECT AT WTR

The TOS organization for WTR launches is shown in Figure IV-8.

4.1 MISSION DIRECTOR

The TOS Project Manager, W. W. Jones, has responsibility and authority for ensuring the ultimate success of the overall mission. In the launch organization, he is a member of Project Command with the title of Mission Director. The Mission Director has the responsibility for spacecraft, tracking, and data-acquisition aspects of the mission. Although he will be kept fully informed of vehicle status as transmitted to the Launch Director, he will not participate in vehicle decisions. He is the only person, however, with authority to waive any mandatory mission requirement, whether vehicle, spacecraft, or other. He is located in the WTR MDC.



A - Acting

Figure IV-7 — Western Test Range Operations Organization

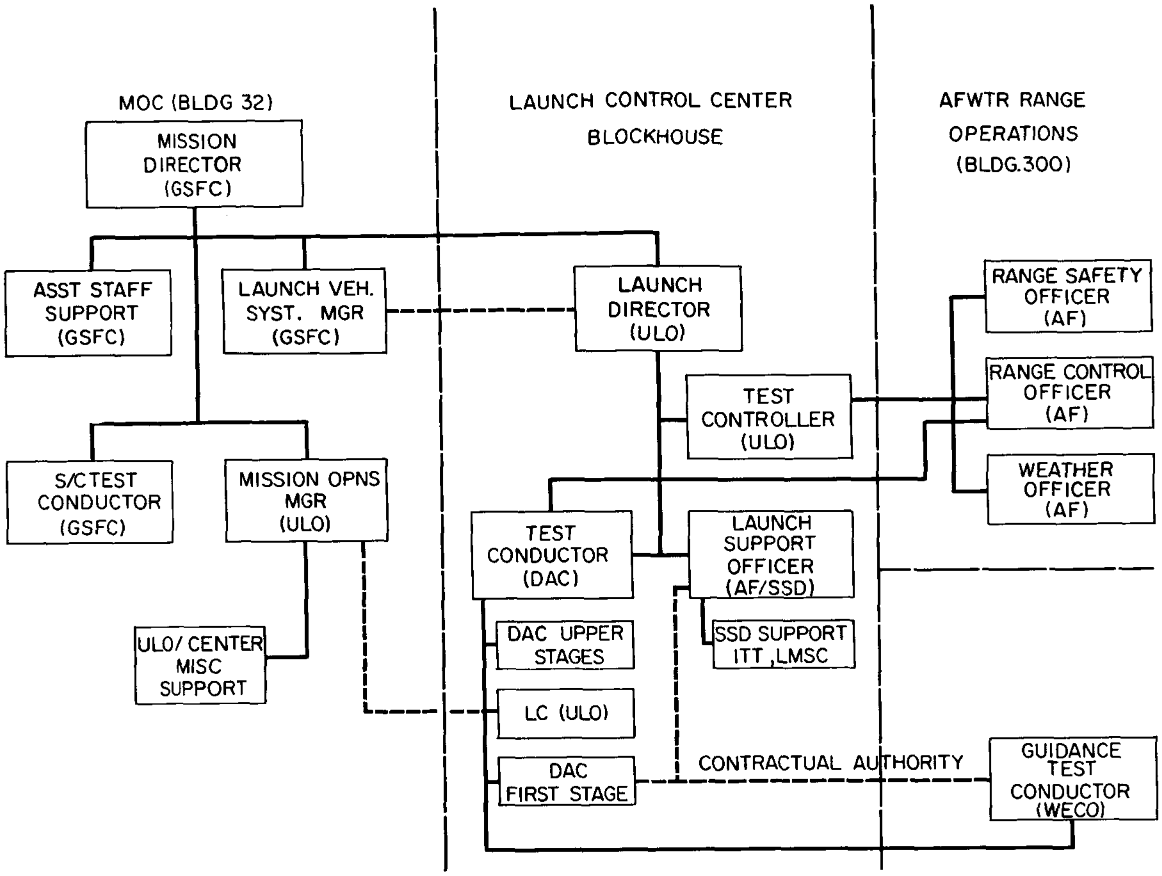


Figure IV-8 – TOS Organization at WTR

4.2 <u>ASSISTANT MISSION DIRECTOR</u>
The Assistant Mission Director is in the MDC in communication with the Project Representative at GSFC, MCR. The Deputy Mission Director monitors the vehicle countdown via Missile Operations Intercom System (MOPS). He receives inputs from the spacecraft monitors and receives inputs from the mission Director on all GSFC operations.

4.3 <u>OPERATIONS AND LAUNCH DIRECTOR</u>
The KSC/ULO Operations and Launch Director has overall responsibility for launch preparation as well as the readiness of required Range support. He is the final authority on questions of countdown procedures and provides final permission to launch. The Operations and Launch Director is located in the blockhouse during launch.

4.4 <u>MISSION OPERATIONS MANAGER (KSC/ULO)</u>
The Mission Operations Manager as the representative of the Manager, WTRO, is responsible for coordinating all KSC/ULO support for the particular mission he is assigned. He will keep the Mission Director informed of all ULO support and provide launch and postlaunch data and information. The Operations Manager will be in the MDC during launch.

4.5 <u>TEST CONTROLLER (KSC/ULO)</u>
The Test Controller is the KSC/ULO representative who acts in the absence of the Operations and Launch Director. He is responsible for coordinating the activities of the Test Conductor, the Launch Support Officer, and support from outside agencies.

4.6 TEST CONDUCTOR (DAC)
The DAC Test Conductor is responsible for conducting all Improved Delta readiness tests and countdown in accordance with NASA directives. The Test Conductor is directly responsible to the Operations and Launch Conductor.

4.7 SPACECRAFT COORDINATOR (KSC/ULO)
The Spacecraft Coordinator, located in the blockhouse, coordinates spacecraft countdown with all other elements of the launch operation. He relays information and progress reports to the MDC and the Operations and Launch Director.

4.8 SPACECRAFT SYSTEMS MANAGER
The Spacecraft Systems Manager, or his representative, reports the status of the spacecraft via MOPS. He reports problems if they arise and recommends whether to hold or scrub the launch. The Spacecraft Systems Manager or his representative is in the blockhouse and is in voice communications with MCC and the Test Conductor. A RCA-AED spacecraft representative is in the launch support van and reports to MCC via MOPS.

5. LAUNCH COMMUNICATIONS

5.1 WTR RANGE COMMUNICATIONS
During the prelaunch tests and launch countdown range communications (Figure IV-9) are provided for use by the Mission Director, spacecraft, launch vehicle, and operations personnel.

Range communications consists of a Missile Operations Intercom System (MOPS) and Voice Direct Lines (VDL). There are eight channels of MOPS available for use during the launch countdown. Four channels are assigned for the booster and second-stage tests and checkout, two channels for spacecraft, one for conduct of the overall count, and one as a KSC engineering net.

The VDL is a private line system programmed on certain consoles connecting key personnel at the MDC, Blockhouse, NASA Telemetry Station, Spacecraft Laboratory, and Range Operations Building. Details of the Range Communications system and operation will be presented in the TOS Operations Summary produced and distributed by KSC two weeks before launch countdown.

5.2 SCAMA
SCAMA may be used to provide the Mission Director with direct contact with GSFC for communications with the Project Representative in MCR, TEC, and the CDA stations. SCAMA is used as the link for relaying launch status data to OPSCON.

5.3 NASA COMMUNICATIONS RULES AND COUNTDOWN
Figure IV-10 is a block diagram of the NASCOM voice launch communications network. Table IV-1 shows the TEC communications countdown.

When directed by GSPA (at approximately T-50 minutes) all participating stations observe the following rules:

- All messages must be as brief as possible consistent with clarity
- Individual message receipts are not sent unless dictated by the message precedence or originators
- Self-addressed number comparisons are utilized if no traffic is received for a period not to exceed 10 minutes

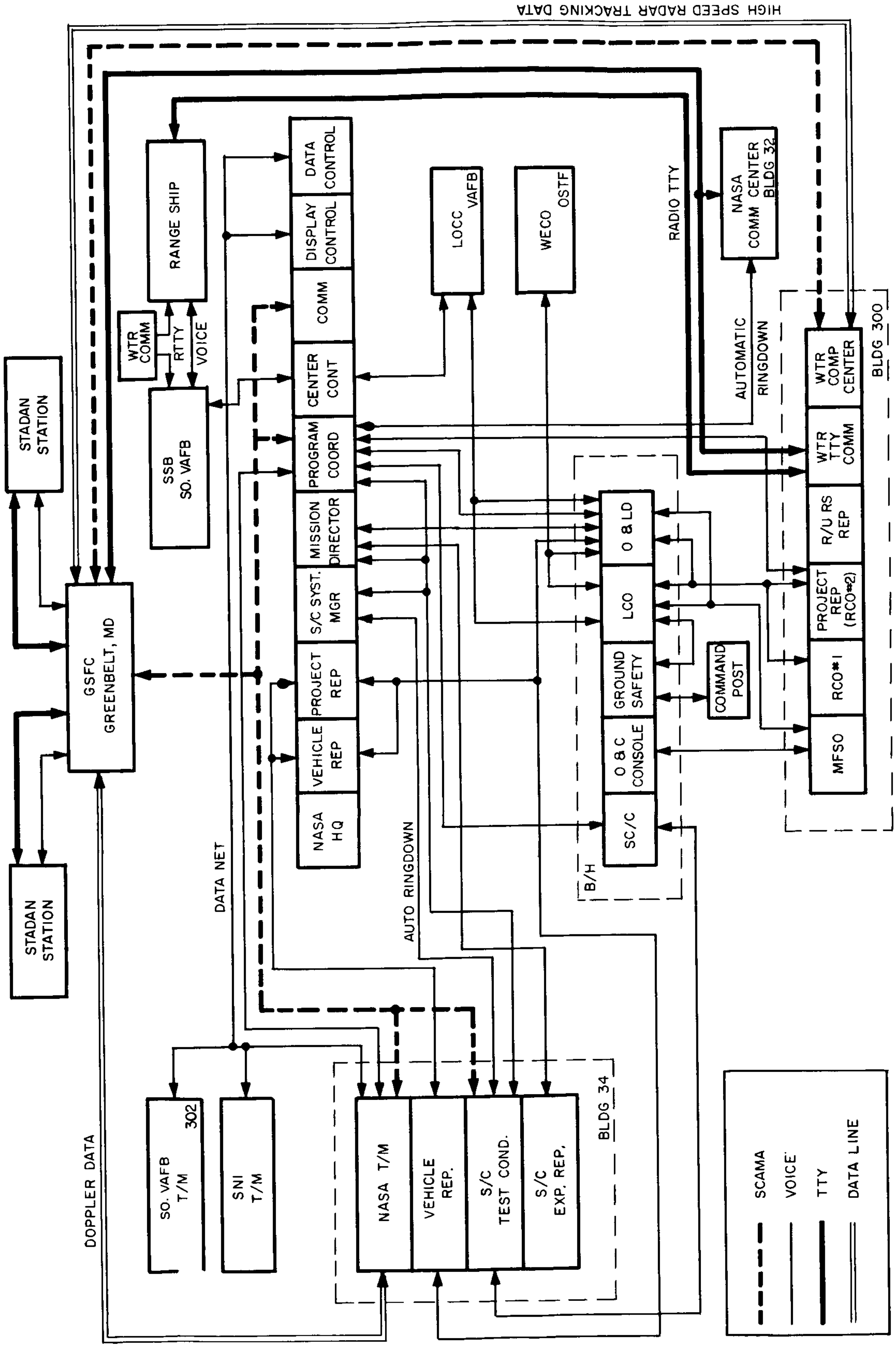


Figure IV-9 – Typical Launch Phase Communications Network

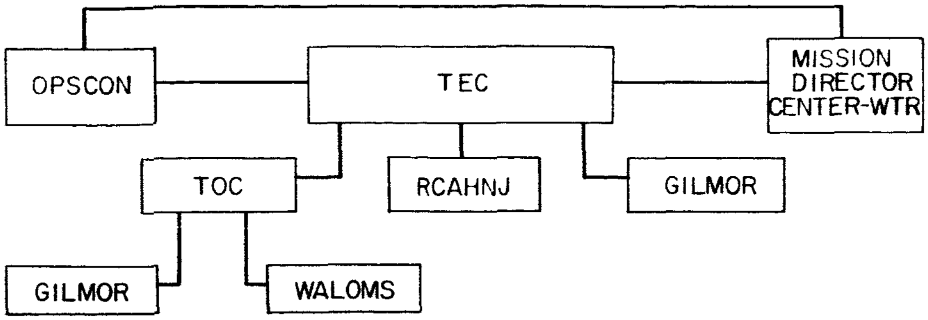


Figure IV-10 — Launch Voice Communications Network

Table IV-1
TEC Communications Countdown

Time Before Liftoff (minutes)	Event
T-510	TEC sends a countdown-initiation message to all TOS stations. Stations report 15 minutes prior to the T-minus times listed below
T-480, T-180, and T-120	TEC relays to the TOS Mission Director at the launch site status reports which have been received from OPSCON and the CDA stations
T-60 (1 hour prior to scheduled liftoff)	OPSCON/TEC initiate the mission conference phone and SCAMA circuits to MCR, TOC, GILMOR, WALOMS, MCC, RCA-AED
T-50 to T-0	TEC/OPSCON receives spacecraft frequencies and all pertinent prelaunch information by phone and teletype from the launch site and OPSCON relays the information to all activities The mission conference line continues until TEC states that it is no longer needed

- GSPA originated teletype circuit checks are answered immediately upon receipt
- Mission precedence is used on all messages as follows:

UU—Urgent–as defined in NASCOP
SS—Special–pass acquisition reports, quick-look, etc.
NN—Normal–preliminary orbital elements, etc.

6. SPACECRAFT AND VEHICLE COUNTDOWN

The countdown events for missions using the Delta vehicle are detailed in the ULO Operations Summary and in the DTO and PRD for the specific mission.

The Test Conductor has overall cognizance of the launch and is responsible for executing the countdown. The countdown is divided into tasks, such as spacecraft preparation, engine checks, electrical system checks, loading of fuel, and loading of liquid oxygen. Each task is assigned to a special crew under the direction of a task leader; several tasks can be accomplished simultaneously. Each task leader must request permission from the Test Conductor before he starts his task, must execute the task in accordance with the Countdown Manual, and must report to the Test Conductor when his task is completed. The task leader must consult the Test Conductor on any problems, and determine a course of action jointly within him.

Tasks involving spacecraft preparation are directed by the Spacecraft Systems Manager, who reports to the Test Conductor. The Spacecraft Systems Manager submits the final spacecraft task events to the Test Conductor prior to R-10 day for integration into the Countdown Manual. Typical R-1 day and R-0 day countdown milestones are listed in Tables IV-2 and IV-3.

7. VEHICLE HANDLING

The Improved Delta vehicle will be stored and checked out at the DAC Santa Monica mission checkout area as shown in Figure IV-11. Each stage will be stored until it is committed to a flight. The first and second stages will then be brought to the grid area and placed in a mission-peculiar configuration. Component, subsystem, system, and all systems tests will be conducted on the vehicle to assure its flight readiness. Each subsystem will be assembled, tested and certified for flight. Only if anomalies or failures are encountered will a subsystem be disassembled while on the launch pad. For example, flight BTL 600 missile-borne guidance equipment (MBGE) will be installed and checked out at Santa Monica. Figure IV-12 is a typical schedule for vehicle preparation at the launch site. Third-stage/spacecraft assembly and alignment will initially be done at Building 34.

8. SPACECRAFT HANDLING

8.1 SHIPMENT OF SPACECRAFT AND SUPPORT EQUIPMENT

The TOS-AVCS spacecraft will be transported from RCA/AED to WTR in an airtight shipping container pressurized with dry nitrogen at a positive pressure of approximately 2 psig. The shipping container, including the spacecraft, weighs approximately 900 pounds, and is 58 inches in diameter and 53 inches high. Both the transmitting antenna and the receiving antenna will be removed from the spacecraft and shipped in a separate package. Four spinup rockets will be installed on the spacecraft, but the rocket terminals will be shorted by means of jumper leads before shipment. These leads will remain in place until just before installation of the third-stage fairing.

8.2 SPACECRAFT HANDLING AT BUILDING 34

If the spacecraft is airlifted to Vandenberg Air Force Base (VAFB) ULO will provide a tractor to haul the spacecraft in its container to the NASA/ULO spacecraft laboratory in Building 34. The spacecraft assembly areas in Building 34 will be used for the operational checks and tests of the spacecraft. Overhead cranes, forklift trucks, and other power-handling equipment will be provided by NASA. In general, this equipment will be manned by NASA operators. At all times that the spacecraft is moved at WTR it will be escorted by AFSSD guards.

Table IV-2
Typical R-1 Day Milestones

Time Before Liftoff	Event*
T-495 (0800)	Countdown initiation
T-490 (0805)	<u>High pressure nitrogen and helium storage bottles on line</u> Engine checks begin
T-360 (1115)	Engine checks complete <u>Range countdown initiation</u> Electrical systems checks begin Spacecraft checks begin

T-350
(1025)
	All systems on external power
	  C-band beacon
	  Telemetry
	  Command destruct receiver
	  WECO guidance
	<u>Range readouts required</u>
	  C-band beacon
	  Telemetry
	<u>Range command destruct checks</u>
	Systems off as readouts complete

T-320 (1055)	All systems off Cool-off period begins
T-290 (1125)	<u>All systems on external power for range go report</u> <u>All systems on internal power for range go report</u>
T-270 (1225)	Spacecraft checks complete
T-265 (1140)	All systems on external power
T-260 (1155)	All systems off
T-250 (1205)	Electrical systems data review
T-240 (1215)	Electrical systems checks complete Range countdown complete <u>Second-stage propellants on station</u> <u>Complex fire water pressure to 125 psig</u> <u>Fire and medical support required</u> (fire support on station suited up) Second stage propellant servicing begins
T-30 (1545)	Second stage propellant servicing complete (Complex fire water will be maintained at 125 psig until second stage propellants are unloaded or launch test is terminated.) Second stage retrorocket pressurization begins
T-0 (1615)	Second stage retrorocket pressurization complete R-day countdown complete Launch camera set up

*Functions and services that require range support are underlined.

Table IV-3

Typical R-0 Day Milestones

Time Before Liftoff	Event*
T-595 (1825)	Contractor countdown initiation High pressure nitrogen and helium storage bottles on line Complex fire water system pressure at 125 psig Fire and medical support required Food servicing required
T-590 (1830)	Spacecraft checks begin
T-560	First stage fueling begins
T-500	Spacecraft checks complete First stage fueling complete No switching - no radiation period begins All ordnance items on station Ordnance and fairing installation begins
T-280	No switching - no radiation period ends Ordnance installation complete
T-235	Fairing installation complete Payload checks begin
T-205	Range countdown initiation Critical power on standby Second stage retrorocket pressurization begins (if required) RF systems and destruct checks begin Receivers on internal power Transmit functions Receivers on internal power Transmit functions Receivers on external power Switch transmitters Transmit functions Receivers off RF systems on-off when readouts complete
T-175	Second stage retrorocket pressurization complete RF systems and destruct checks complete Payload checks complete No switching - no radiation period begins Safe and arm and ordnance hookup begins
T-115	Safe and arm and ordnance hookup complete No switching - no radiation period ends Second stage helium console checks begin Tower removal begins Final preparations begin
T-95	Liquid oxygen setup begins
T-55	Tower removal complete Final preparations complete Second stage helium console checks complete Pad cleared Liquid oxygen flow begins
T-35	Liquid oxygen filling complete Spacecraft checks complete 60-minute built-in hold begins Complex cleared (prior to end of hold)
T-35	60-minute hold ends Complex fire water pressure to 175 psig Terminal count begins
T-0	Terminal count complete Engine start
T+2 seconds	Mainstage and liftoff

*Functions and services that require range support are underlined.

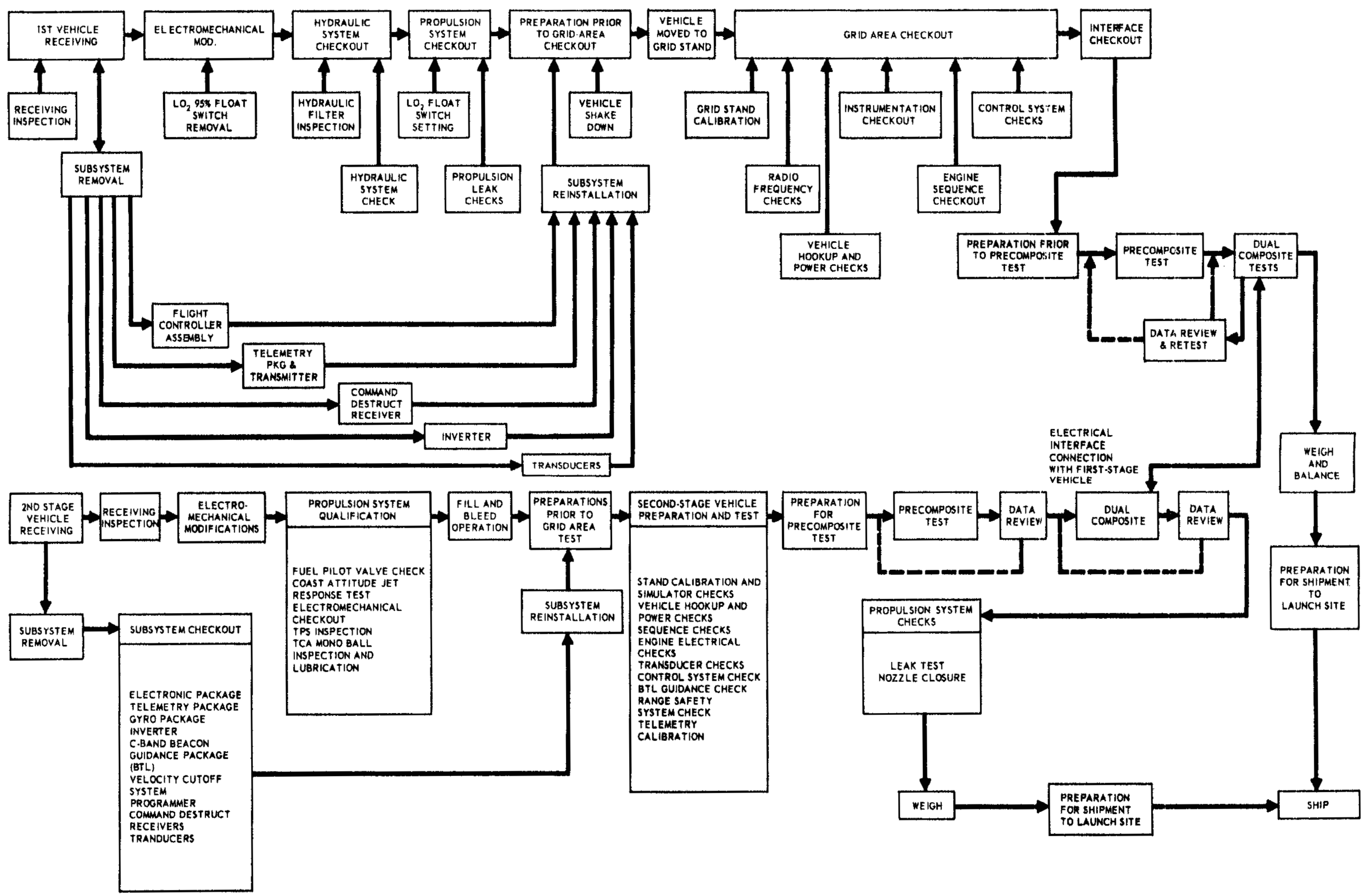


Figure IV-11 — Flow Diagram for Vehicle Checkout at Santa Monica

R DAY	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1ST STAGE		RECEIVAL & REC'G INSP		PRIMA-CORD INSTL	ERECTION & HOOKUP	QUICK LOCKS	PROP. SYSTEM LEAK CHKS		RF COMPATIBILITY	PROPELLANT FLOW TEST	CONTROL & ELECTRICAL SYSTEMS TESTS			SIMULATED FLIGHT	FINAL CONTR. SYST. CHECKS	FINAL LEAK CHKS (VERT. MODE)	SOLID MOTOR INSTL, ALIGN.	INTEGRATED SYSTEMS TEST	FINAL PREPARATIONS ORDNANCE INSTL	F-1 COUNTDOWN: ELECTRICAL TEST, ORDNANCE. 2ND ST. PROP. SERVICE R-0 COUNTDOWN: ORDNANCE, RF CHKS, TEST FLIGHT
2ND STAGE					RECEIVAL & REC'G INSPECTION		PRIMA-CORD INSTL	ERECTION & HOOKUP	2ND ST. QUICK LOOK											
3RD STAGE						RECEIVAL, INSP	MODS & TEST		COMP. ALIGN & BALANCE			ASSEMBLY			BALANCE	ERECT 3RD STAGE				
1ST STAGE SOLID MOTOR								INSPECTION & BUILD-UP												
ORDNANCE CHECKOUT																QUALIFY FLIGHT & BACK-UP				
BATTERY PREP							PROVIDE TEST BATTERIES					PREPARE FLIGHT BATTERIES						PREPARE FLIGHT BATTERIES		
FACILITY REQTS		LAUNCHER PREPS SIMULATOR CHKS															FACILITY CHECKS			
GUIDANCE GROUND STATION									SUPPT LAUNCH TESTING					SUPPORT LAUNCHER TESTING						

Figure IV-12 – Typical Vehicle Preparation Schedule, Launch Site

RCA personnel will unload the spacecraft, prototype model, and all support equipment when it arrives at Building 34 and will move it to the test area. The area will be closed off by all practical means, and only personnel associated with the TOS project will be permitted access.

The launch support van will arrive two weeks before the spacecraft and will be parked alongside Building 34. After launch, the van will be stored and checked out periodically by RCA.

8.3 SEPET AND INTERFERENCE TESTS

A standard electrical performance test (SEPET) will be conducted. Concurrent with performance of the SEPET, and depending upon availability of support personnel and schedule of events, the prototype model will be installed with a dummy third-stage vehicle at the Spin Test Facility. The third-stage/prototype combination will be taken to the launch pad, using the ground handling fixture. Douglas Aircraft Company (DAC) personnel will be responsible (with RCA assistance) for mating the spacecraft to the third stage.

DAC will perform all subsequent handling and installation of the dummy third-stage/prototype combination to the second stage of the launch vehicle. When the installation is completed, RCA will conduct an open-loop transmission test and will support the WTR-directed RF interference tests. When the RF interference tests are completed, the dummy third-stage/prototype combination will be returned to the Spin Test Facility for disassembly. No other tests should be performed with the prototype model. It will be crated in its shipping container and returned to Building 34. After the launch, RCA will ship it to the RCA/AED facility.

8.4 SPIN TEST FACILITY

The spacecraft will be physically turned over to NASA in its shipping container, and transported by NASA truck to the Spin Test Facility.

Upon removal from the shipping container, the spacecraft will be weighed to confirm weight measurements made at RCA/AED before shipment. After the weighing procedures, DAC will mate the spacecraft to the live third-stage vehicle, using standard handling procedures. A weighting ring (approximately 85 pounds) attached to the three hat lugs will provide sufficient force to compress the separation ejection spring. Only personnel immediately concerned with the operations will be permitted in the area; all others will remain in a safe protective area. From the time the spacecraft is mated to the third-stage until launch, the spacecraft will be grounded by means of a grounding lug on the underside of the baseplate.

8.5 SERVICE TOWER

The third-stage/spacecraft combination will be mated to the second-stage launch vehicle in accordance with standard DAC procedures. The launch pad crane will lift the spacecraft handling fixture off its flat-bed truck and hoist it to the eight level. Another crane will lift the third-stage/spacecraft combination from the eight to the ninth level, and the combination will be mated to the second stage of the launch vehicle. The spacecraft optics will then be uncovered, a visual examination will be made, and the charging plug fed from blockhouse will be installed. The spacecraft will be checked out in accordance with Task IV checkout procedures and cameras will be checked. A special test will determine proper optical focus of the TV cameras. In the optical-focus portion of this test, each TV camera will view a 2-foot square light box mounted on a tripod located at least 5 feet from the edge of the spacecraft. A switch at least 10 feet away will control power to the light box.

The third-stage fairing will be installed after the spacecraft has successfully passed the Task IV checkout and after the spinup rocket mufflers and shorting leads are removed.

8.6 SUMMARY OF WTR OPERATIONS SCHEDULE

The following paragraphs describe the major spacecraft events that will occur during the checkout and launch preparations at WTR. R days refer to 8-hour working days before launch; R-O refers to the day on which the actual launch occurs. The outlined schedules should be considered as guide lines only, to be adjusted as required and directed by the Mission and Spacecraft Directors.

R-25 The spare ordnance items will be shipped to WTR for storage until required or until the launch effort is completed.

R-22 The launch support van will arrive at WTR. It will enter the SAFB gate and proceed to Building 34 where it will be parked. After the launch, the launch support van will be stored by NASA until R-22 of the next launch. RCA will provide periodic checkouts.

R-14 The prototype spacecraft and the flight spacecraft will be transported from RCA/AED to WTR in sealed shipping containers which have been purged and pressurized to approximately 2 psig with dry air or nitrogen before sealing. The flight spacecraft will be shipped with the spinup rockets mounted and wired, and with the shorting leads in place. The rocket mufflers will not be installed. The prototype model will not have ordnance items. No battery power can be applied to the rockets because of the open circuits caused by the disabled liftoff switches and the absence of the spacecraft power plug. The required test equipment, spacecraft spares, handling gear, and miscellaneous supplies will be shipped with the spacecraft.

R-13 When the spacecraft and associated equipment arrive at WTR, they will be unloaded by RCA with assistance from WTR personnel as required. If they are shipped to VAFG, ULO will provide transportation as required to haul them to the Spacecraft Lab in Building 34.

R-12 The units will be unpacked and stored as required. The flight spacecraft will be removed from the shipping container and the rocket mufflers will be installed. NASA and RCA representatives will make a quick-look inspection for obvious damage. The flight spares will be unpacked, given quick-look inspections, and stored. The prototype model will be prepared for electrical checks. The launch-support van will be given a standard calibration test.

R-11 Mechanical inspection of the flight spacecraft will be performed. The flight spacecraft SEPET will begin.

R-10 The prototype model will be given a functional electrical check, following the pretest calibration of the launch-support van, and a final mechanical inspection. Following completion of this test and inspection, the prototype model will be delivered in a shipping container to the NASA Spin Test Facility to be mated with the dummy third stage. After mating with the third stage, the assembly will be delivered in a special shipping container to SLC-2E for mating with the booster. The spacecraft functional test will continue on the flight spacecraft.

R-9 The RF compatibility tests with the vehicle will be performed using the prototype spacecraft.

R-8 The flight spacecraft electrical performance test will be completed. The dummy third stage prototype model combination will be removed from the booster and returned, in its special shipping container, to the Spin Test Facility. Removal of the prototype model from the dummy third stage will be completed, and the prototype model will be returned, in its shipping container, to Building 34 for storage. A final mechanical inspection will be made on the flight spacecraft.

R-7 A spacecraft electrical check, with closed-loop RF conditions, will be run to check the proper operation of all subsystems before movement of the spacecraft. The spacecraft will then be placed in its shipping container and transferred by NASA vehicle to the NASA Spin Test Facility. The spacecraft will be given to DAC for mating with the third stage. Weigh-in and alignment will be completed. The spinup rocket mufflers, shorting leads, and protective covers will remain in place at all times except as required for tare weight determination. During the weighing and alignment activities, a minimum number of RCA/AED support personnel will be in the area.

R-6 The alignment activity will be completed. The third-stage/spacecraft assembly will be prepared for transportation to SLC-2E. After the installation of the assembly on the booster, a spacecraft functional check will be performed to determine the operation status of the spacecraft. During the spacecraft functional check, all ordnance protective devices will be in place. Following the spacecraft functional check, the air-conditioning shrouds will be put in place, and battery charging will take place for a period of approximately 4 hours.

R-5 The standard All-Systems Checks will be performed. At the completion of these checks, spacecraft functional checks will be performed. Spacecraft batteries will be charged for a period of 4 hours at the completion of the spacecraft functional checks.

R-4 Spacecraft functional tests to be run nonconcurrent with ordnance installation.

R-3 Spacecraft functional tests to be run nonconcurrent with ordnance installation.

R-2 Spacecraft functional checks will be performed to check the spacecraft status. Spacecraft batteries will be charged for a period of 4 hours following completion of the test. During the battery-charging times, the solar array will be cleaned using liquid freon, paper towels, cotton swabs, and a venturi-effect air-powered vacuum cleaner.

R-1 R-1 day tasks will be performed. Final mechanical inspection of the spacecraft and vacuuming of the solar array will be completed during the 4-hour battery-charging cycle. The spacecraft will be prepared for fairing installation. All ordnance protection will be removed at this time. Following fairing installation, a short Task IV will be performed.

R-0 R-0 Day tasks will be performed. Charging of the spacecraft batteries will be continuous throughout the R-0 activities until launch.

9. LAUNCH CONSTRAINTS

9.1 COUNTDOWN HOLD CRITERIA

The TOS Project determines whether the countdown will be held, based on the criteria listed below.

9.2 SPACECRAFT HOLD

T minus 1 day : Any malfunction is cause for spacecraft hold.

T minus 7 hours : A complete go/no-go program is run. Any malfunction causes a hold.

T minus 3 hours : A go/no-go check is performed after the rocket fueling operation. The TV subsystem is reprogrammed for operation. Any malfunction in the spacecraft causes a hold.

T minus 1 hour : A hold is called as needed to bring the spacecraft batteries to at least 90 percent of full charge before the umbilical is dropped.

9.3 VEHICLE HOLD
All vehicle in-line subsystems must be operational as specified in the Countdown Manual. If more than one telemetry channel becomes inoperative during the countdown, a hold may be called to review the implications to postflight malfunction analysis.

9.4 DATA STATIONS
A hold is called for nonreadiness of the data communications net or for nonreadiness of any CDA station but not for nonreadiness of RCA/AED or TOC.

10. LAUNCH EVENTS

The nominal sequence of events from T-0 through separation of the spacecraft from the third-stage motor is listed in Table IV-4. Note that these events are typical for a TOS launch and do not apply to a specific launch.

During launch and early orbit, data from the range and launch support facilities is transmitted to DSD computing center where the launch trajectory is computed. The data collecting functions of this net are completed when the vehicle passes beyond the range of WTR on the launch trajectory. Trajectory and orbit injection parameters are transmitted to DSD computing center for use in the succeeding orbit-refinement computations.

Frequency versus time data is relayed by data phone to OPSCON on a realtime basis. The Mission Director in MDC or his representative will have relayed to TEC, by telephone or teletype, all other pertinent launch data and information. OPSCON/NETCON and TEC receive the results of initial orbit calculations and trajectory data. From these data, the orbit is refined and ephemeris predictions will be given to TEC.

11. TRACKING

During the launch and early orbit phase, the spacecraft is tracked by the NASA Telemetry Station, a down range ship, and by STADAN, NORAD, and SAO.

11.1 DOWN RANGE SHIP
A Down Range Ship will provide second/third stage spinup and separation. Doppler equipment aboard ship will be used to confirm time of third stage ignition and burnout.

11.2 NASA TELEMETRY STATION
The NASA Telemetry station tracks the spacecraft signal from lift-off until loss of signal. Doppler information is relayed to OPSCON via data phone and the same information is displayed in the MDC, Building 32. Realtime records also provide vehicle functions such as ignition, burnout, and stage separations.

11.3 STADAN
All STADAN interferometer tracking stations are required to track as scheduled by OPSCON/NETCON during this phase and forward the tracking information to GPUT.

During this phase, control of STADAN is exercised by the GSFC Operations Director in OPSCON. Additional personnel are appointed as required by the Operations Director and as dictated by project requirements. This phase starts at T-240 minutes and continues until terminated by the Operations Director. The Operations Controller notifies the stations at the end of the phase.

Table IV-4
Typical Launch Events

Time (sec. after liftoff)	Event	Initiated by
T + 0	Uncage stage I gyros	LO switch
	Start stage I programmer	LO switch
T + 2	Start roll program (plus 6.00944 deg/sec; total angle plus 70.1302 deg)	Stage I programmer
T + 4	Start pitch program (minus 0.99286 deg/sec; total angle minus 9.6010 deg)	Stage I programmer
	Start yaw program (minus 0.55354 deg/sec; total angle minus 5.3527 deg)	Stage I programmer
T + 13.67	Stop first pitch rate	Stage I programmer
	Stop first yaw and roll program rates	State I programmer
T + 14	Start second pitch rate (minus 0.40180 deg/sec; total angle minus 20.3592 deg)	Stage I programmer
T + 64.67	Stop second pitch rate	Stage I programmer
T + 65	Arm Solid Motor Separation	Stage I programmer
T + 65	Start third pitch rate (minus 0.33005 deg/sec; total angle minus 8.1423 deg)	Stage I programmer
T + 70	Solid motor separation	Solid separation timer
	Roll control system gain change	Solid separation timer
T + 80	Enable BTL/WECO	Stage I programmer
	Solid drop (backup)	Stage I programmer
	Roll control system gain change (backup)	Stage I programmer
	Uncage stage II roll gyro	Stage I programmer
T + 89.67	Stop third pitch rate	Stage I programmer

Table IV-4 (Continued)

Time (sec. after liftoff)	Event	Initiated by
T + 90	Start fourth pitch rate (minus 0.20090 deg/sec; total angle minus 8.0360 deg)	Stage I programmer
	Start stage I guidance (3.0 deg per sec steering rate)	BTL/WECO
T + 105	Pitch and yaw control system	Stage I programmer
	Gain change	
	Enable yaw Vernier control	Stage I programmer
T + 123	Enable stage II ignition and pyrotechnic power	4.75-G switch
T + 130	End stage I pitch program	Stage I programmer
T + 139	Enable MECO circuitry	Stage I programmer
	Stop BTL/WECO guidance	Stage I programmer
T + 150.2997	MECO	FIP switch
M + 0	Start stage II programmer	MECO relay
	Blow blast band bolts	MECO relay
M + 4	Blow stage II/I separation bolts	Stage II programmer (Sequence 1)
	Uncage pitch and yaw gyros	Stage II programmer (Sequence 1)
	Enable stage II roll control	Stage II programmer (Sequence 1)
	Start stage II engine	Stage II programmer (Sequence 1)
	Transfer guidance reference power	Stage II programmer (Sequence 1)
	Roll gyro uncage (backup)	Stage II programmer (Sequence 1)
M + 8	Jettison payload fairing	Stage II programmer (Sequence 2)

Table IV-4 (Continued)

Time (sec after liftoff)	Event	Initiated by
M + 25	Start stage II pitch program (minus 0.15773 deg/sec; total angle minus 23.8172 deg)	Stage II programmer
M + 26	Start stage II closed	BTL/WECO
	Loop Guidance	
M + 176	End stage II pitch program	Stage II programmer
M + 354	Arm Oxidizer Probes	Stage II programmer (Sequence 4)
	Arm TPS	
M + 368.3	Stop closed loop guidance	BTL/WECO
	Start open loop steering	BTL/WECO
M + 374.6	Stop open loop steering	BTL/WECO
M + 378.2726	Stage II engine cutoff command	BTL/WECO
	Switch to coast phase control	SECOM relay
	Turn off hydraulics	SECOM relay
M + 378.6126	SECO	
M + 438	Turn off BTL/WECO	Stage II programmer (Sequence 3)
M + 449	Start coast phase pitch program (minus 0.53615 deg/sec; total angle minus 53.0789 deg)	Stage II programmer
M + 548	End coast phase pitch program	Stage II programmer
M + 559	Start coast phase yaw program (plus 0.17463 deg/sec; total angle plus 17.2884 deg)	Stage II programmer
M + 658	End coast phase yaw program	Stage II programmer
M + 938	Fire spin rockets	Stage II programmer (Sequence 5)
	Start stage III ignition wire cutter TDR	Stage II programmer (Sequence 5)

Table IV-4 (Continued)

Time (sec. after liftoff)	Event	Initiated by
M + 938 (Cont.)	Start stage III ignition	Stage II programmer (Sequence 5)
	Time Delay	
	Start Stage III sequence timer	Stage II programmer (Sequence 5)
M + 939	Fire stage III ignition	Ignition wire cutter
	Wire cutters	TDR
M + 940	Blow stage III/II separation bolts	Stage II programmer (Sequence 6)
	Fire retros	Stage II programmer (Sequence 6)
M + 953	Stage III ignition	Pyrotechnic time delay
M + 975.5	Stage III burnout	Depletion
M + 1064	Payload/stage III separation	Stage III sequence timer
	Start Yo release pyro TD	Stage III sequence timer
M + 1066	Release Yo weight	Pyrotechnic TD

11.4 NORAD

The NORAD stations are requested to track the spacecraft for the first five orbits and to send the refined observations, if requested, to GSFC for orbital computations. The first three orbits are especially important in obtaining a precise orbit as soon as possible.

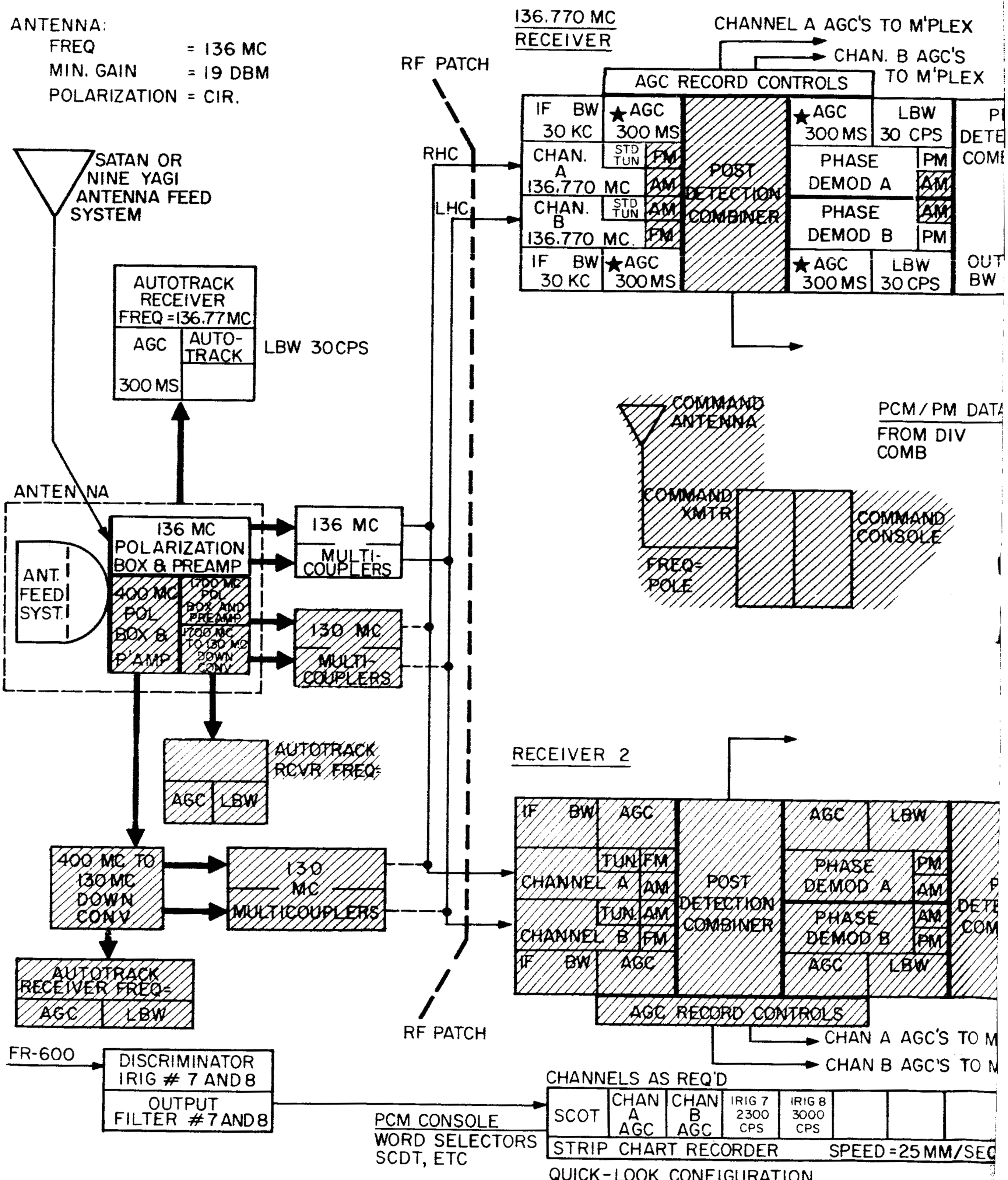
11.5 SAO

The SAO is requested to optically track the spacecraft during the first 24 hours after launch and to supply tracking data, via TTY, to GPUT as soon as possible after the data are obtained.

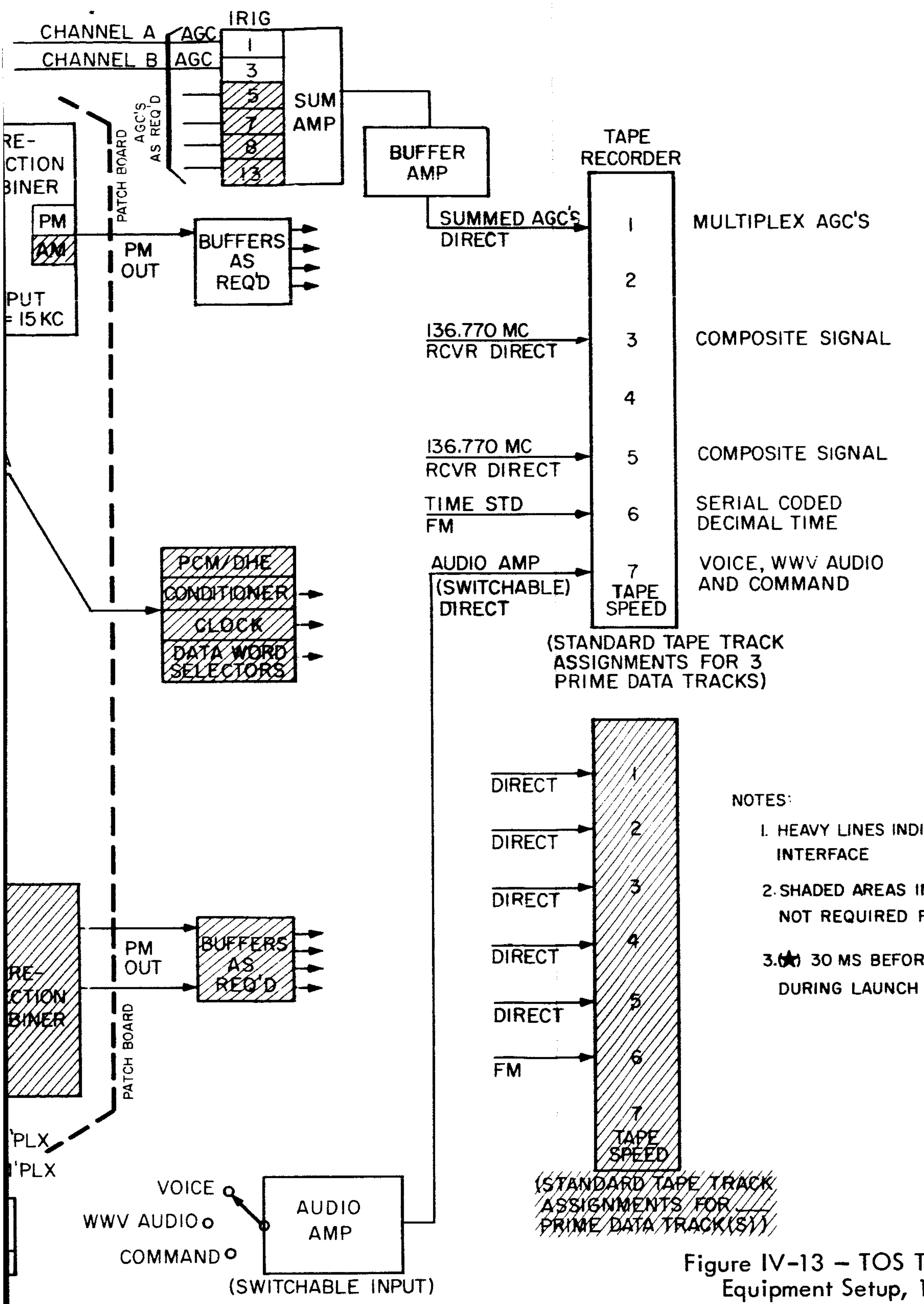
If the 136-Mc beacon should stop transmitting at any time during the active lifetime of the spacecraft, it is anticipated that SAO will be requested to provide GSFC with optical tracking information.

12. STATION TELEMETRY RECORDING

TOS beacon telemetry is used to determine spin rate and third-stage separation. Before despin the spacecraft spins at approximately 126 rpm; after despin it spins at about 10 rpm. Separation occurs about 1274 seconds after liftoff; despin occurs approximately 9 ± 5 minutes after separation. The stations responsible for receiving V-scan data during this phase are WALCOMS, GILMOR, JOBURG, MADGAR, and WNKFLD. Figure IV-13 shows the telemetry system equipment setup for TOS. Table IV-5 lists the equipment and operating parameters.



ANTENNA:
FREQ = 136 MC
MIN. GAIN = 19 DBM
POLARIZATION = CIR.
SATAN OR NINE YAGI ANTENNA FEED SYSTEM
AUTOTRACK RECEIVER FREQ =136.77 MC
AGC
AUTO-TRACK
300 MS
LBW 30 CPS
ANTENNA
ANT. FEED SYST.
136 MC POLARIZATION BOX & PREAMP
400 MC POL BOX & P'AMP
1700 MC POL BOX AND PREAMP
1700 MC TO 130 MC DOWN CONV
136 MC MULTI-COUPLERS
130 MC MULTI-COUPLERS
AUTOTRACK RCVR FREQ=
AGC
LBW
400 MC TO 130 MC DOWN CONV
130 MC MULTICOUPLERS
AUTOTRACK RECEIVER FREQ=
AGC
LBW
RF PATCH
RHC
LHC
RF PATCH
136.770 MC RECEIVER
CHANNEL A AGC'S TO M'PLEX
CHAN. B AGC'S TO M'PLEX
AGC RECORD CONTROLS
IF BW 30 KC
★AGC 300 MS
CHAN. A 136.770 MC
STD TUN
FM
AM
CHAN. B 136.770 MC.
STD TUN
AM
FM
IF BW 30 KC
★AGC 300 MS
POST DETECTION COMBINER
★AGC 300 MS
LBW 30 CPS
PHASE DEMOD A
PM
AM
PHASE DEMOD B
AM
PM
★AGC 300 MS
LBW 30 CPS
COMMAND ANTENNA
COMMAND XMTR
FREQ=
POLE
COMMAND CONSOLE
PCM / PM DATA
FROM DIV COMB
RECEIVER 2
IF BW
AGC
TUN
FM
CHANNEL A
AM
TUN
AM
CHANNEL B
FM
IF BW
AGC
POST DETECTION COMBINER
AGC
LBW
PHASE DEMOD A
PM
AM
PHASE DEMOD B
AM
PM
AGC
LBW
AGC RECORD CONTROLS
CHAN A AGC'S TO M
CHAN B AGC'S TO M
FR-600
DISCRIMINATOR IRIG # 7 AND 8
OUTPUT FILTER # 7 AND 8
PCM CONSOLE
WORD SELECTORS SCDT, ETC
CHANNELS AS REQ'D
SCOT
CHAN A AGC
CHAN B AGC
IRIG 7 2300 CPS
IRIG 8 3000 CPS
STRIP CHART RECORDER
SPEED = 25 MM/SEC
QUICK-LOOK CONFIGURATION



NOTES:

1. HEAVY LINES INDICATE HANDWIRE INTERFACE
2. SHADED AREAS INDICATE EQUIPMENT NOT REQUIRED FOR THIS OPERATION
3. (★) 30 MS BEFORE SPIN DOWN DURING LAUNCH PHASE

Figure IV-13 – TOS Telemetry System Equipment Setup, 136.770 Mc

Table IV-5
Station Telemetry Equipment Configuration for TOS

EQUIPMENT AND PARAMETERS FOR OPERATION

Autotrack System (if used)

	136 MC		400 MC		1700 MC	
	1	2	1	2	1	2
Frequency	136,770	–				
Mode	C.L.	–				
Loop B. W.	30 cps	–				
Cross Corr. B.W.	–	–				
AGC Speed		–				
Antenna Polarization		–				

Telemetry System

	Link #1	Link #2	AVCS Link #3	Link #4	Link #5
General	136.770	235.0	234.00		
Type	FM/PM	FM	Vehicle PDM/FM/FM		
Bit Rate	–	–			
Irig. Nos.		–	9		
Mod. Ind., % Mod. or Ph. Dev.	70%				

Antenna Parameters

Freq. Band	136	235	235		
Min. Gain	19 db	30 db	10 db		
Polarization	RHC	RHC	RHC		

Receiver Parameters

	#1	#2	#3	#4	#5
Frequency	136.77	135.00	234.00 (Vitro #1400)		
Type Tuning	STD	STD			
I.F. B.W.	30 kc	500 kc	500 kc		
Gain Cont. Mode	AGC	AGC			
AGC Speed	300 ms	300 ms			
Demod. Mode		FM			

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Table IV-5 (Continued)

Phase Demod and Combiner

Loop B.W.	30 cps				
AGC Speed	.3 sec				
Demod. Mode	ϕM				
Output B.W.	15 kc				

Discriminators for Link No.(s)________

Link No.	VCO Nos.	Input Channel	Output Filter	Type Data
1	#7 & #8			
3	#9 3.9 kc			

Recording Equipment

Magnetic Tape Recorder Set-up for Link No.(s) 1

Tape Speed 30 IPS

Track Assignments:

Track	Rec. Amp.	Source	Signal
1	Direct	AGC Multiplex	Mult. AGC's
2	Direct	Doppler Stn	Δf Signal
3	Direct	136.770 Mc Rcvr	Composite Signal
4	Direct	Doppler Stn	10 kc
5	Direct	136.770 Mc Rcvr	Composite Signal
6	FM	Time Std	SCDT
7	Direct	Audio Amp	Voice, WWV Audio
Edge	Not Used		

Graphic Recorder Set-up for Link No.(s) 1

Recorder Speed 25 MM/Sec.

Track Assignments:

Track	Source	Signal
1	Time Std	SCDT
2	Rcvr. Chan A	AGC (Irig #1)
3	Rcvr. Chan B	AGC (Irig #3)
4	FR-600 Trk #3	2.3 kc (Irig. #7)
5	Fr-600 Trk #3	3.0 kc (Irig. #8)

12.1 TRACKING SHIP

If a tracking ship is properly positioned, it will be responsible for determining the third-stage spin rate at spinup (approximately 749 seconds after launch) and forwarding the spin rate information to OPSCON by TTY as soon as possible. The PM-detected output of the telemetry receiver tuned to 136.700 Mc is fed to the tunable discriminators tuned to a center frequency of 2300 and 3000 cps with a ±7.5% deviation

The output of the discriminator is displayed in real time on a Sanborn recorder, which is run at a chart speed of 25 mm/sec. The spin rate is determined by observing the frequency of the V-head horizon sensor (Figure IV-14) and subtracting the time of pulse two from the time of pulse one to get the time for one complete revolution and then dividing 60 by the time of one revolution. These stations also monitor for separation and despin. Separation is indicated by the 2300 cps SCO changing from 2473 cps where it is biased at launch back to 2300 cps.

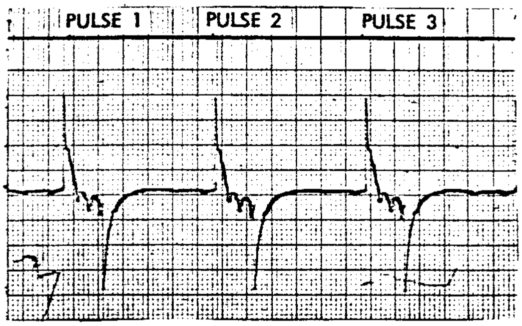

Figure IV-14 — Sample Horizon Sensor Signal

The tracking ship also records and displays second-stage vehicle telemetry in real time. A 234.00-Mc transmitter is FM modulated with the required telemetry aboard the Delta second stage. The tape is shipped as soon as possible after the telemetry has been recorded' to the following address:

Goddard Space Flight Center (NASA)
Attention: Code 470, Mr. W. A. Beck
Delta Project Office
Greenbelt, Maryland, U.S.A.

The equipment setup for recording is as follows: The detected output of the receiver tuned to 234 Mc is fed to the bandswitching subcarrier discriminator tuned to IRIG channel 9 with a ± 7-1/2% deviation and displayed in real time on a Sanborn recorder. The tape recorder track assignments are listed in Table IV-6.

The telemetry is PDM/FM/FM, with 45 channels being transmitted at 20 frames per second, to give an approximately 900 cps bit rate. Channel 1 is the zero-volt calibration channel and channel 24 a 5-volt calibration channel. Channels 44 and 45 are suppressed to provide the synchronization channels. The carrier drift is less than 10 kc with a maximum bandwidth of ± 150 kc.

The receiver bandwidth is 500 kc. The recording time is from acquisition until loss of signal. Trajectory predictions are furnished 7 days before launch.

The tracking ship requirements are:

- Magnetic tape recording (at 30 ips); requires 90 kc response:

  234.0-Mc signal
  136.770-Mc spacecraft signal
  136.770-Mc AGC
  Timing – NASA 36 bit
  Raw doppler data

(Note: 234.0-Mc signal to be recorded on a direct record amplifier).

Table IV-6
Magnetic Tape Recorder Track Assignments

Track	Record Module	Source	Signal
Delta Vehicle Telemetry			
1	Direct	Hallamore Multiplex	234 Mc receiver AGC's
2	Direct	Control track gen. and time STD system	18.24 kc modulated with 60 cps and combined with BCD time
3	Direct	234 Mc receiver	Composite signal
4	(No requirements for recording on this track)		
5	FM	Time STD system	Serial decimal time code
6	Direct	Audio amplifier	WWV audio or voice commentary
Spacecraft Telemetry			
1	Direct	Hallamore Multiplex	136.770 receiver AGC's
2	Direct	Doppler station	f Signal
3	Direct	136.770 Mc receiver	Composite signal
4	Direct	Doppler station	10.0 kc
5	Direct	136.770 Mc receiver	Composite signal
6	FM	Time STD system	Serial decimal time code
7	Direct	Audio Amplifier	WWV audio or voice commentary

- Strip chart AGC recording, 136.770 and 234.0-Mc on same chart
- Strip chart, discriminated 3.9 kc SCO on 234.0-Mc link
- Realtime reports as follows: (from 2300 cps and 3.0 kc SCO)

  "Spinup received"
  "Separation received" (from 2300 cps only)
  "Spinup RPM is ________ cycles per second" (this is obtained from either 2.3 kc or 3.0 kc SCO)

- Strip chart, discriminated 2.3 kc and 3.0 kc from 136.770 Mc
- SCDT time STD

The vehicle tapes are to be shipped to:

Unmanned Launch Operations
P.O. Box 186,
Cape Canaveral, Florida
U.S.A.
Attention: A. J. Mackey

Copies are provided TEC as soon as possible. The realtime reports are made to hangar AE, Cape Kennedy (GCPN) and OPSCON (GOPS) via existing communications means.

The following is a description of the data to be read, and how to read it.

In order to assist in the determination of success or failure of a mission, and to assist in prediction of preliminary orbital parameters, the verification and time of occurrence of third-stage spinup and separation are desired. This data is displayed on the IRIG channel 9 (3.9 kc) on the second-stage telemetry system (234.0 Mc). The data is recorder on magnetic tape and on a direct-write recorder for immediate readout by ship personnel.

Four items of information are desired: occurrence of the events; time of spinup indication; time of separation indication; and spinup RPM.

These times of spinup and separation are reported as accurately as possible, but at least to within ± 1 second (preferably 0.1 second) in Zulu time. Any realtime recordings run for this purpose are not stopped, but continue to run to preclude any possiblilty of stopping on an erroneous indication and missing the real events. Expected wave shapes are shown in Figure IV-15.

At spinup, which occurs at Time A, the voltage level increases from 40% to 95%, and begins cycling at approximately 6 cps. The elapsed time from A to B is 2 seconds. Actual separation occurs at time B, at which time the rate of cycling abruptly decreases and continues to slow down. At time C the cycling stops, and the channel may come to rest at either a 40% or 95% level. This level is not measured. Prior to the spinup time this channel has other steps, all of which are complete by SECO + 1 second. These other events are not reported.

There should be a small loss of signal, 0.3 seconds duration, at spinup + 6 seconds. This is stage-three ignition, and may be reported if observed, but only as a drop in AGC–not as a confirmed ignition event.

Spinup RPM is measured during the time interval from D to B. In this example it is 2.5 cycles per second. It may vary from 2 cycles per second to 6 cycles per second. Exactly 1 second of time is not required, but only this portion of the wavetrain is used. Spin rate can be determined by counting the number of cycles to the nearest tenth, from D to B (1 second interval) to obtain cycles per second. Then spin rate (RPM) equals CPS divided by 2, multiplied by 60.

12.2 JOBURG, MADGAR, AND WINKFIELD

JOBURG, MADGAR, and WINKFIELD are responsible for determining if separation and despin did occur. Procedures for determining separation are as follows:

The normal 2300-cps subcarrier, which phase modulates the 136.770-Mc beacon with V-head horizon sensor information, is biased to 2473 cps from launch until separation of the spacecraft from the third stage. At separation, the bias is removed and the subcarrier frequency returns to 2300 cps.

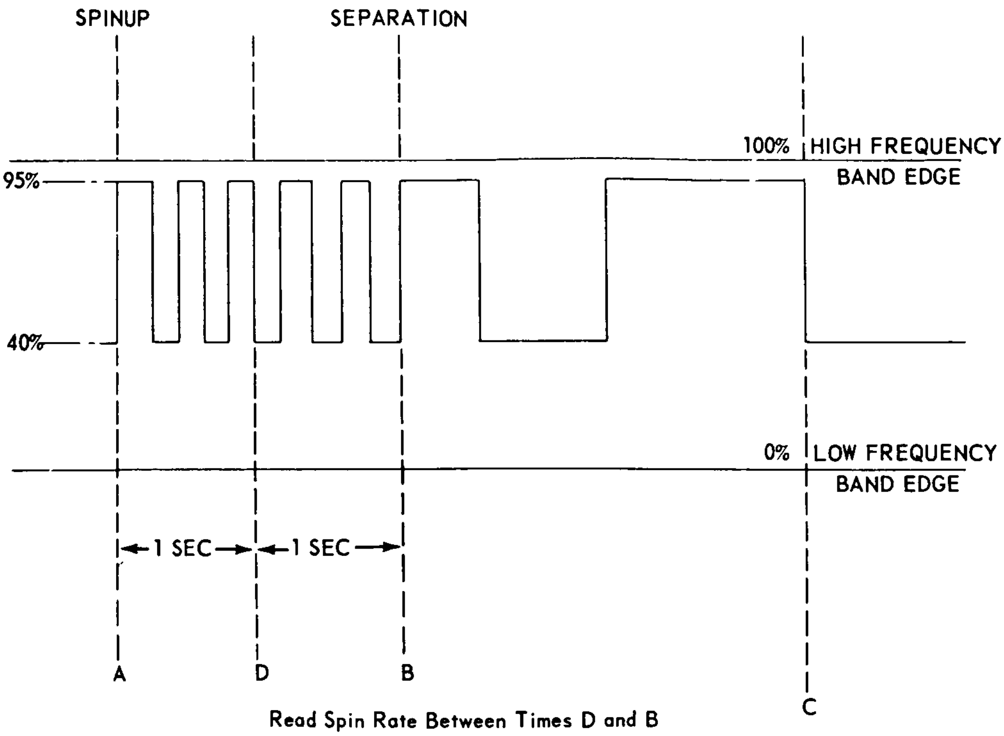

Figure IV-15 – Spinup Wavetrain for TOS 3.9-Kc VCO on 234.0-Mc Carrier

The equipment setup is shown in Fig. IV-27. Separation is determined by observing the center frequency of the 2300 cps subcarrier on the 136.770-Mc beacon. If the center frequency is closer to the 2473-cps side of the record, separation did not occur. If it is closer to the middle of the record, then the separation did occur. This information is forwarded to OPSCON/TEC via SCAMA via TTY.

Procedures for determining spin rate are covered in 12.1, paragraph 2.

12.3 <u>DSAI STADAN SUPPORT</u>

The following STADAN stations record 136.770-Mc telemetry digital solar aspect indicator (DSAI) data for the first 20 orbits as scheduled by TEC through NETCON: SNTAGO, WNKFLD, ORORAL, and JOBURG. SNTAGO is not required for quick look on pass one but report on playback as soon as possible.

The procedure for recording and reporting DSAI is as follows:

To supplement attitude determination data DSAI must be obtained from the 136.77 Mc FM/PM beacon. The Electrac phase demodulator is used to demodulate the carrier. This beacon uses three subcarriers, 2.3, 3.0, and 3.9 kc. The strip chart is operated at 25 mm/sec. The data to be monitored is on the 3.9 kc subcarrier.

The DSAI provides the data indicating the angle between the spin axis and the sun. The DSAI uses a form of gray code binary. The code consists of 8 bits, each having a return to center frequency square wave characteristic. A deflection in the direction of a lower frequency represents a "1" bit, while a deflection in the opposite direction (higher frequency) represents a "0" bit. As a further check, the eighth bit should be a "1."

Before despin the DSAI code is unusable. After despin the DSAI code is repeated every 5 to 6 seconds.

The data is reported to GOPS GOSI as a series of "ones" (1's) and "zeroes" (0's) along with the time at which the reading was made. For example: 112920Z, 11100111. Six consecutive readings are to be reported. It is possible for various types of data to be transmitted on the 3.9 kc SCO, so it is important to look only for data in the form of 8-bit return to center frequency format. If no data of this type is received, GOPS and GOSI should be notified after the pass is completed.

All DSAI quick-look data is teletyped to GOPS and GOSI immediately after the pass is completed.

13. CDA STATION ACTIVITIES

The CDA stations are responsible for acquisition, commanding and disseminating the TOS spacecraft data. The stations are Wallops Station, Virginia (WALOMS) and at Fairbanks, Alaska (GILMOR). During the launch and checkout phase, commands generated by TEC and relayed through TOC are received at the stations and used for spacecraft command as described in Appendix D. Activities during the operational phase are covered under NESC SOP's.

13.1 HANDLING OF SPACECRAFT DATA

All data transmitted from the satellite during the pass over the CDA station is recorded on a tape recorder. This will be the station tape. When AVCS video data are received a second tape recorder also records the video data.

Telemetry data from the 136.770-Mc beacon is recorded on Brush record charts and both magnetic tape recorders. Extracts of these recordings are teletyped to TOC/TEC if directed by TOC. Telemetry is transmitted to TOC/TEC in real time and also with video signals over the broadband line in slightly delayed time. Daily and prepass telemetry calibrations are performed, using the procedures established in the Prelaunch Operational Analysis Handbook. The paper tapes and magnetic tapes are mailed to TOC as directed by TOC.

The AVCS video data is played over the broadband link to DAPAF as directed by TOC.

All recorded data is properly marked and held for degaussing, destruction, or mailing as instructed by TOC.

During the checkout phase, polaroid pictures are made as specified by TOC. Remarks will be made on the pass summary describing the quality of these polaroids, which may be destroyed after completion of the report.

13.2 STATION EVENTS

Each CDA station has a 20-channel events recorder that monitors station performance and some of the spacecraft responses to CDA command. The events recorder is used for postpass reconstruction of the type and timing of commands sent and data received. The events recorder data includes:

- GMT time markers
- Command modes used during the pass
- TV and other signal occurrence and loss

13.3 ATTITUDE DETERMINATION

During spacecraft checkout, TEC determines attitude. TOC performs this function during the operational life of a satellite.

13.4 GRIDDING

No picture gridding is performed at CDA stations.

13.5 OPERATIONS REPORTING

Each station reports to TOC/TEC a summary of all events which occurred during and relative to the interrogation and readout. This is teletyped to TOC/TEC in a pass summary message within 30 minutes after the interrogation. If there are details which delay the message longer than this, they are provided in an addendum which reaches TOC/TEC before the end of the orbital day. Current information is passed immediately to TOC/TEC by voice. CDA station managers keep TOC/TEC fully informed of matters that might affect the capability of the station to command and to acquire data from TOS spacecraft.

14. TOS COMMUNICATIONS NETWORK (TOSCOM)

TOC controls and monitors the communications on the TOSCOM network. During the launch and checkout phase TEC generates programs, etc., and relays them through TOC. The address heading of all messages sent over the TOSCOM begins with a precedence letter designation (PP-priority, or RR-routine). Messages are classified as follows.

Priority:	Programs – Command tapes Programs – Written command messages Pass summaries Equipment status reports Programs – Command tape rebroadcast
Routine:	Tracking tapes Look angles Telemetry summaries Daily manning schedules Attitude messages Administrative messages

If usual or important events occur TOC/TEC is immediately notified, or if operational instruction or important data are needed immediately from TOC/TEC, a voice contact is made to relay the appropriate data, then a TTY message is sent.

The TTY addresses for elements in TOS operations are:

STOC	TOS Operations Center, NESC/ESSA, FOB4, Suitland, Md.
GMOR*/GFOM	CDA station, NESC/ESSA, Gilmore Creek, Alaska
WOMS	CDA station, NESC/ESSA, Wallops Station, Va.
GOSI*/GTEC	TOS Technical Control of Launch and Checkout, GSFC, Greenbelt, Md.
OFUT	TOS STN 8, DOD, Offutt AFB, Nebr.
SSOD	Chief Division (or individual named), Operations Office, NESC, Suitland, Md.

15. TOS APT STATIONS

The APT stations designated by TEC forward the APT Pass Summary and Evaluation Report to TEC. The GSFC controlled stations send a selection of APT pictures, not to exceed six, to TEC for each calendar day. These pictures include all categories possible: best, worst, noisy, etc. Each picture carries the readout time, or number, and other special comments and circumstances which existed. The operating conditions are also indicated. GILMOR is requested to provide pictures which include the terminator. A far east station, to be specified by TEC, will be included to determine the quality of pictures at locations not operating under close NASA or ESSA direction.

Table IV-7 is the format of the APT Pass Summary and Evaluation Report.

*Denotes stations in GSFC NASCOM network, all others are in NESC/TOSCOM network.

Table IV-7

APT Pass Summary and Evaluation Report

This report is to be completed, whenever APT pictures are scheduled to be transmitted within range of the ground station.

Station ______________________________ Date ____________

1. APT signal acq. ____________ Z ____________ Strength ____________ mv
   APT signal fade ____________ Z ____________ Strength ____________ mv

2. Max. receiver signal strength ____________ mv ____________ °elev.

3. Interference ____________ (yes or no) time ____________ Z ______ (min.-sec)
   Identification ____________ Characteristics ____________
   Brief description of interference ____________________________
   ____

4. Pix with video receiver ____________ (yes or no) (If no, comment)

5. Tonal change between fax phase and fax start ____________ (yes or no)

6. Pix size normal ____________ (yes or no) (If no, what size?)
   (Measure video portion only - should be 8" ± 1/4" on Fairchild Fax.)

7. Picture start time ____________ Z (for all complete frames)
   (Were horizontal lines of fiducial marks adequate determiners of pix start?)

8. Grid error from landmarks ____________ °lat. ____________ °long.

9. Synoptic interpretations made ____________ (yes or no) (If no, why not?)

10. Additional comments: ____________________________
    ____

Signed: ______________________________ (Station Manager)

PART V

NESC OPERATIONS

The National Environmental Satellite Center (NESC) is responsible for all TOS operational phases, including spacecraft scheduling, programming and command; data acquisition, processing, dissemination, and archiving; operation of the CDA stations and communications links; and evaluation of spacecraft during the operational phase.

NESC will monitor TOS operations during the prelaunch and launch phases and will participate in coordinated readiness activities.

Figure V-1 shows the NESC organizational structure.

1. TOS OPERATIONAL CENTER (TOC)

Operational control of orbiting TOS spacecraft is vested in the TOS Operations Center (TOC) at NESC. TOC is responsible for technical direction of the TOS command and data acquisition system, monitoring and assessing the spacecraft and CDA station performance, and coordination of the operational phase of the TOS mission. TOC is responsible for the proper flow of TOS operational data as shown in Figure V-2.

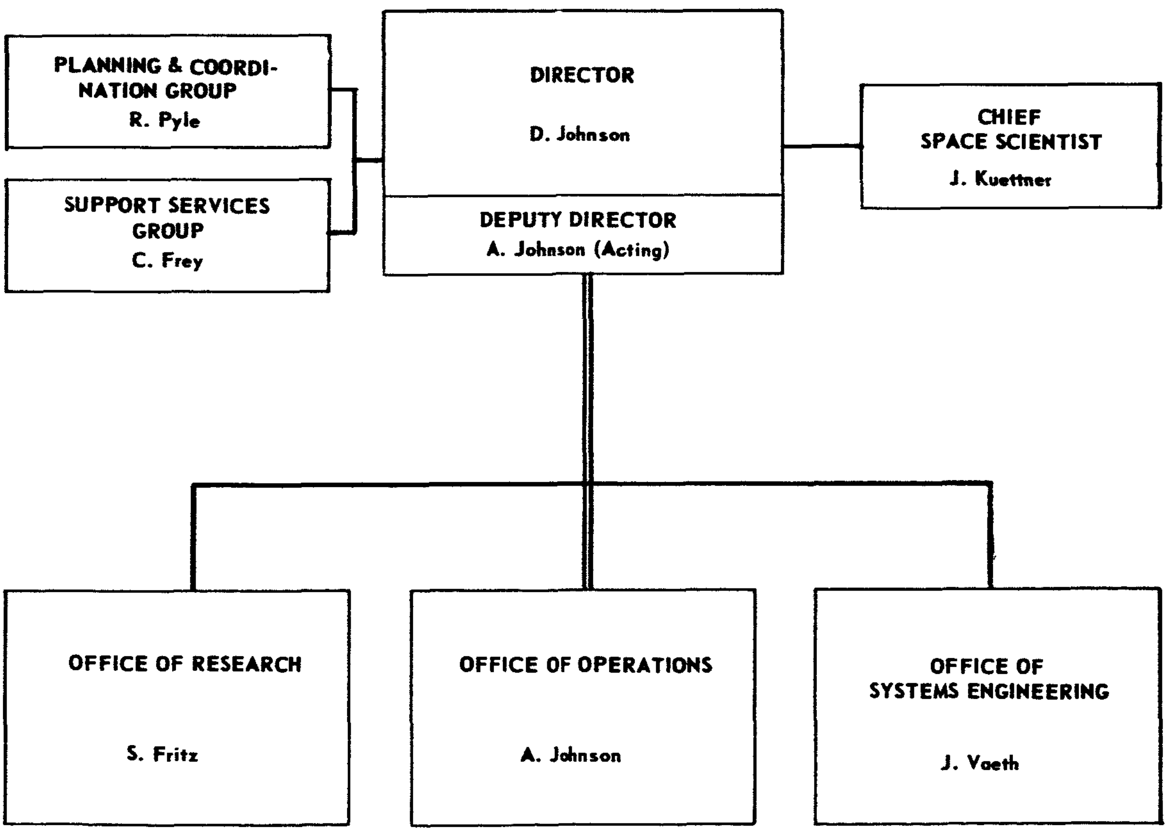

Figure V-1 – National Environmental Satellite Center Organization

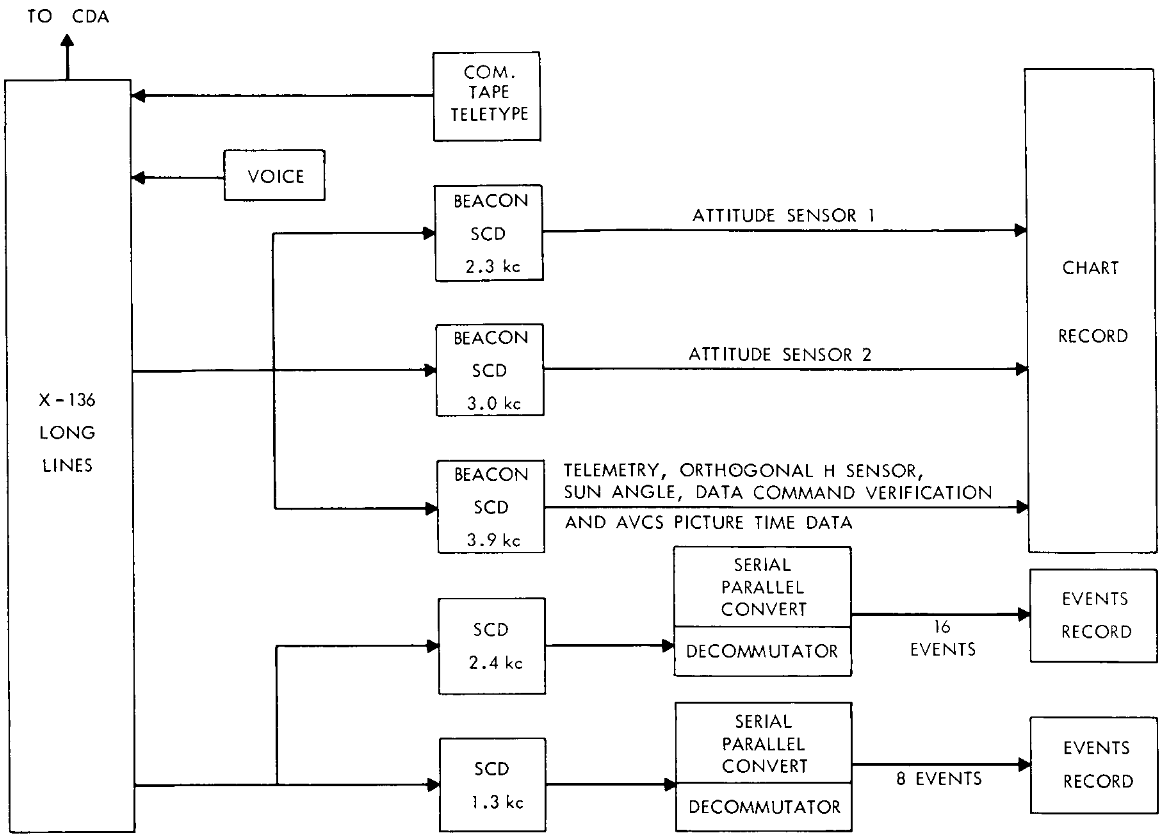

Figure V-2 — TOC Data Flow

1.1 TOC FUNCTIONS

The duties of TOC include realtime monitoring and assessment of the spacecraft and CDA station operation, near-real-time systems evaluation, origination of the spacecraft command programs upon consideration of engineering factors involved, magnetic attitude and spin control programming, attitude determination, and maintenance of engineering and other data records. If engineering considerations require that a choice of picture coverage be made, TOC will be responsive to the requests of the Analysis Section, NESC. TOC is responsible for delivery of TOS operational meteorological and engineering data to the appropriate users.

Assessment of all CDA stations will be coordinated with the Head, Satellite Operations Branch, NESC, and with the station managers. Specifically, TOC will

- Report all information or summaries of data relative to malfunction or nonroutine operation of the system
- Determine the spacecraft attitude from V-head horizon sensors data and DSAI data
- Maintain operations logs and operational engineering and performance records

- Prepare, coordinate, and disseminate a long-term schedule of station readouts based on operation of the spacecrafts in orbit.

- Prepare and transmit daily to CDA stations a schedule of CDA station readouts

- Originate and transmit to the CDA stations the specific command programs and station interrogation schedules for daily operations based on the following:

    Analysis of predictions as to locations of suitable photographic areas and times of passes over CDA stations

    Analysis of programming requests

    Analysis of spacecraft power

    Analysis of CDA station status

- Program the magnetic attitude and spin control subsystems based on all available attitude and spin information

- Transmit changes to the program and operating instructions to the CDA stations, the Analysis Section, and DAPAF

- Insure the timely transmission of all operational data to and from the CDA stations

- Catalog all reports and data coming into and leaving TOC into a permanent TOS file

- Maintain appropriate graphic displays

1.2 ATTITUDE DETERMINATION

TOC will make manual measurements of the analog V-head horizon sensor Brush recorder data for determination of instantaneous roll errors and will produce the attitude for each orbit. TOC with the assistance of DAPAF will produce the definitive attitude(s) for each day. Definitive attitude plus an attitude prediction will be made available to the Analysis Section and DAPAF for input to the gridding programs.

1.3 BEACON DATA

Beacon data received from the CDA station will be recorded on analog Brush recorder charts and manual measurements will be made. The data will also be recorded on a multichannel magnetic tape recorder. Simultaneously an analog-to-digital converter will digitize the data. The digital data will be processed in DAPAF and appropriate graphic displays will be delivered to TOC and the Analysis Section. The normal mode of spacecraft housekeeping telemetry process will be a quick look at analog records at TOC and a computer printout of all engineering units. Telemetry values beyond tolerance will be known and will be checked as the orbits occur. On a daily basis, the digitized telemetry data will be processed through DAPAF and a page print of the actual data measurements will be obtained. Periodically DAPAF will provide a historical record plot of the telemetry parameters. These plots will become part of the TOC files and will be used for spacecraft assessment as required. Copies of these data will be made available by TOC to RCA-AED and TEC as required for use in the postlaunch evaluation.

2. DATA PROCESSING AND ANALYSIS FACILITY (DAPAF)

The DAPAF, at Suitland, Md., is part of the central NESC operating unit and will process, analyze, and distribute the meteorological data. DAPAF will use general and special purpose computer equipment to locate, format, and digitize the input data and to produce scale-rectified-digital map printouts and other summaries of the meteorological observations. Gridded TV photographs of the cloudcover will be reproduced on kinescope equipment. DAPAF will also process beacon data in support of TOC and the evaluation effort.

DAPAF will produce the meteorological data in a manner to permit optimum storage of large quantities of data and rapid manual and automatic information retrieval.

DSD will send minute vector tapes containing the basic orbital elements and the celestial coordinates of the satellite as function of time to TOC for use in DAPAF.

DAPAF will provide the following support for operational spacecraft:

- Compute equator crossings
- Compute antenna pointing angles for the CDA stations on punched paper tape for direct teletype transmission
- Prepare Attitude World Map, Wheel (ATMAPW) and/or World Map and Station Acquisition Data (WMSAD) information
- Provide TOC with predictions of the following quantities:

  Spacecraft location versus time

  Times at which the spacecraft is above the horizon and antenna limits at the CDA stations and local coordinates of the spacecraft from each CDA station during contact intervals

  Solar angle at the satellite subpoint and the picture center

  Spacecraft roll angle versus time

  Picture center as a function of time

  Location of sunglint in the pictures

- Provide TOC with predictions of those times at which a given TOS spacecraft will be close enough to another TOS spacecraft in orbit to produce a conflict in command and acquisition of data
- Provide realtime processing of selected portions of spacecraft telemetry
- Determine spacecraft attitude and spin rate from the digital spacecraft infrared V-head horizon sensor data
- Provide TOC both long and short range predictions of spacecraft spin-axis attitude, incorporating magnetic, gravitational, and eddy-current torque effects
- Provide the NESC Analysis Branch with electronically gridded pictures, grids for pictures, digitized pictures, digitized gridded pictures, and gridded rectified mosaics as required

- Provide TOC with the information necessary for manual gridding of APT pictures in the proper APT message code. This data will be presented on punched paper tape for transmission over worldwide teletype networks.

- Provide analytical and technical consultants and computer support to the TOS project for many phases of the TOS mission.

3. ARCHIVAL PLANS

Archiving of TOS data is the responsibility of NESC. The NESC Photographic Laboratory will process all film for archival purposes. The final repository of TOS archival film is the National Weather Records Center (NWRC) of ESSA's Environmental Data Service at Asheville, N. C. Duplicate films of TOS picture sequences will be available to the public on request to NWRC. The film will be supplied in the form of 35-mm positive transparencies or negatives on 100-ft reels. All pictures and picture sequences will be accompanied by the documentation necessary for data retrieval.

The Photographic Laboratory, NESC, will be responsible for archiving video data and will perform the following functions:

- Record in a master film file all original film negatives.

- Check and record density values of all original films.

- Request reruns as necessary directly from DAPAF.

- Assemble all checked films into final orbital sequence.

- Mail final archival products to NWRC.

The Photo Lab will reproduce original films and prepare archival films. The film products will be distributed by NESC in accordance with an archival distribution formula. DAPAF will provide TEC with a copy of a representative negative daily and 50 copies of an 8 x 10 selected annotated glossy print weekly.

Appendix A

APT SPACECRAFT

1. BASIC TOS SPACECRAFT

The basic spacecraft comprises:

- Dynamics and attitude control subsystems
- Programmer subsystem
- Command subsystem
- Command distribution unit
- Telemetry subsystem
- Power subsystem
- Camera subsystem

The structure is that of the TIROS spacecraft. It is an 18-sided right polyhedron, 22.5 inches high and 42 inches in diameter, consisting of a reinforced baseplate carrying most subsystems and a cover assembly (hat) with solar cells mounted on the outer top and sides; dynamics control coils and nutation dampers are mounted inside the hat (Figure A-1). Openings in the hat are provided for the various sensors mounted on the baseplate. A crossed-dipole antenna projects from the bottom of the baseplate and a monopole antenna projects vertically from the top center of the hat.

The entire assembly is strengthened to accommodate the severe launch vibration environment and to provide margin for future growth.

2. APT SUBSYSTEM

The APT configuration is the basic spacecraft carrying two redundant APT camera subsystems. Figure A-2 shows the baseplate layout; Figure A-3 is a spacecraft block diagram. The APT subsystem is a camera and transmitter combination (Figure A-4) designed to transmit slow-scan television pictures of the cloudcover below the spacecraft. Transmission is automatic and in real time.

The APT subsystem consists of three major elements: the camera assembly, containing lens, shutter, vidicon, deflection coils, focus coils, and video amplifier; the electronics module, containing video processing circuits, sweep generators, shutter drive, switching and timing circuits, and power converters; and the FM transmitter. Major control and timing functions are provided by the spacecraft programmer and command distribution unit (CDU).

A Tegea Kinoptic, 108-degree, wide-angle lens is used with an electromagnetically controlled focal plane type shutter. Exposure time will nominally be 1.5 milliseconds, reducing smear because of the spacecraft's spin to the order of 1 TV line. The camera housing is magnetically shielded to protect against adverse effects of both earth and spacecraft magnetic fields.

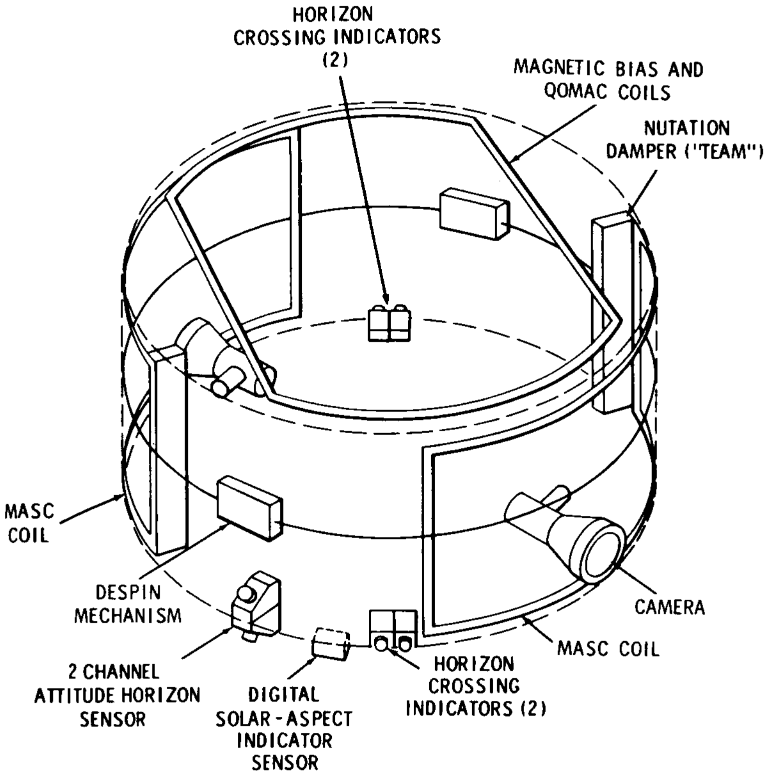

Figure A-1 — Structure and Controls Mounting

The 1-inch diameter vidicon operates on a basis of long-term image retention by the photoconductor. To obtain a better signal-to-noise ratio under the very slow readout conditions characteristic of the APT, a pulsed-beam readout method is used. The video is converted from an amplitude-modulated pulse stream to an analog format after amplification.

The faceplate of the vidicon has reticle marks which appear in the video format. These marks aid in relating the picture to an actual position on the earth's surface.

The 208-second picture readout cycle is divided into two basic periods. During the first 8 seconds, a "start" tone horizontal phasing pulses are generated while the vidicon is prepared and exposed. During the 200 seconds which follow, the vidicon is read out at a 4-lines-per-second rate, producing an 800-line picture with scan lines perpendicular to the orbit track.

The video baseband signal amplitude modulates a 2400-cps subcarrier producing a double sideband signal with a spectrum from 800 cps to 4000 cps. This subcarrier signal modulates the FM transmitter. A video coupler provides redundancy cross-strapping between cameras and transmitters.

The FM transmitter is deviated ±10 kc maximum and produces a minimum 5 watts output at a carrier frequency of 137.500 Mc. Transmission bandwidth will be less than 30 kc.

Four or eight APT pictures per orbit may be programmed at 64-spin intervals (nominally 352 seconds apart).

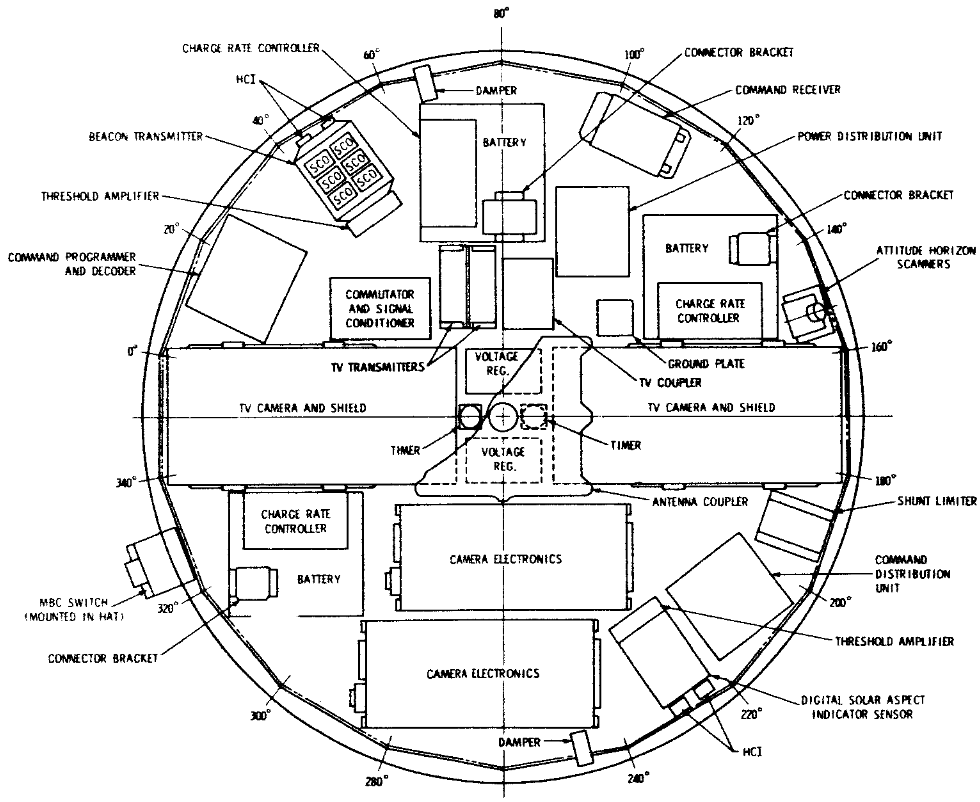

Figure A-2 — Baseplate Layout

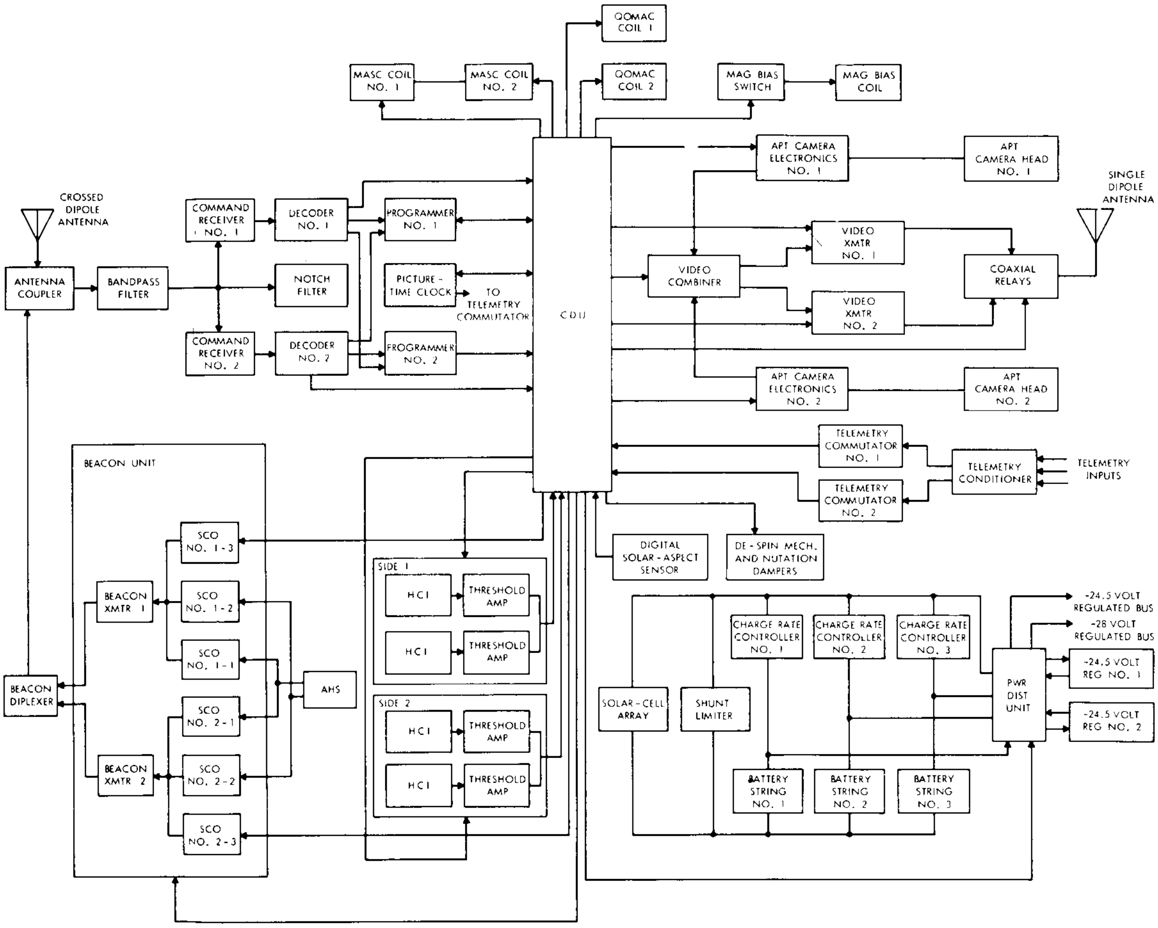

Figure A-3 — APT Spacecraft Block Diagram

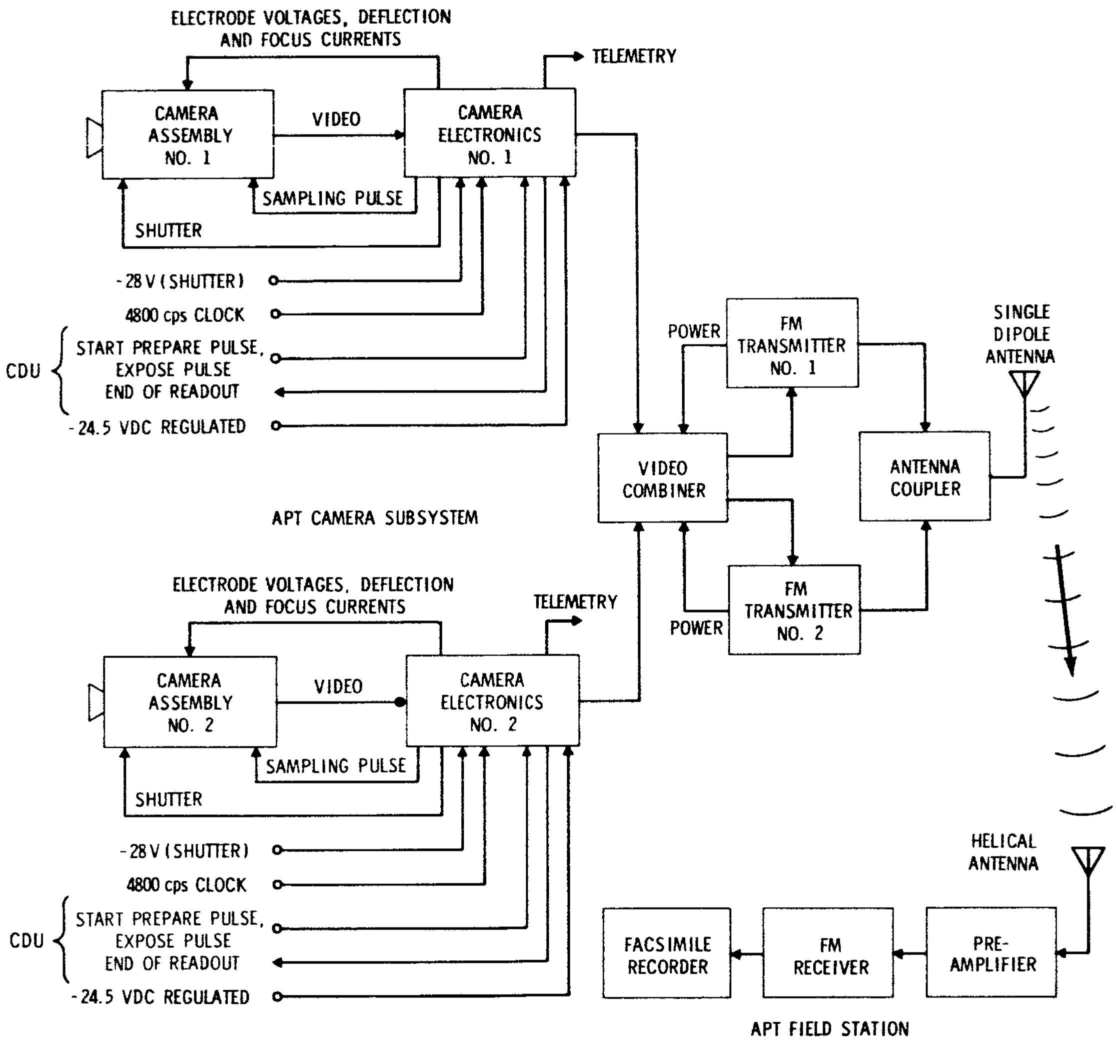

Figure A-4 — APT Camera Subsystem, Block Diagram

At the nominal spacecraft attitude and altitude of 750 nm, each picture will cover an area 1700 nm on a side (Figure A-5). There will be approximately 30 percent overlap between pictures taken along the track. Pictures on successive orbits will be contiguous at the equator with a growing overlap as the latitude increases and the successive orbit tracks converge.

Depending on their latitude, APT stations will receive pictures from two or three consecutive passes each day. It is expected that these stations will have a 10- to 15-minute contact time for approximately 50 to 75 percent of the orbits during which the spacecraft is in view of the station. Since at least one complete picture may be received in 10 minutes, each station has an excellent opportunity to obtain a picture of the local daytime cloudcover each day.

The location of the center of the picture can be determined at the APT station with a knowledge of spacecraft ephemeris and time of picture receipt. With known fixed deviation being considered, the station should be able to locate the picture center to within 15 miles on the earth's surface.

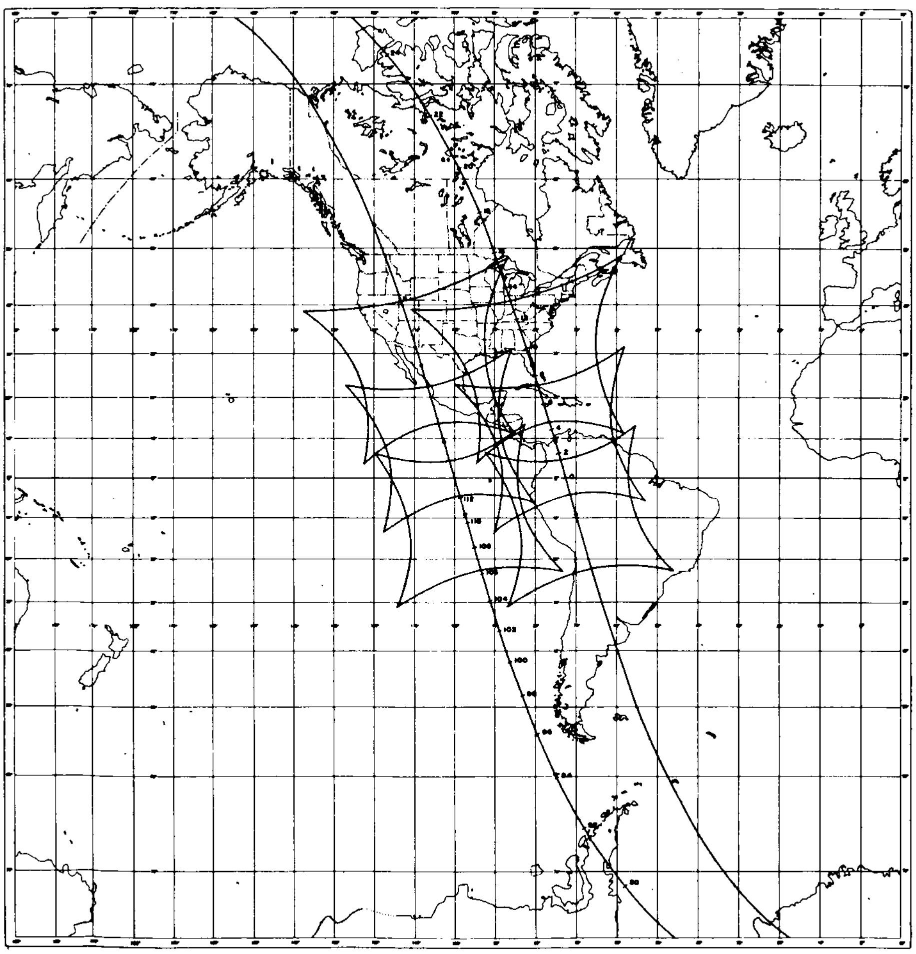

Figure A-5 — Typical APT Camera Coverage

3. ATTITUDE AND DYNAMICS

The TOS spacecraft incorporates techniques to provide precise attitude control, camera pointing, spin-rate control, and timing functions.

3.1 ATTITUDE CONTROL

The pictures must be taken when the camera optical axis is collinear to within 1 degree of the local vertical, i.e., looking straight down, anywhere in the sunlit portion of the orbit.

The spacecraft spin axis, in orbit, will be maintained normal to the orbital plane to within 1 degree. The view axes of the two cameras are mounted normal to the spin axis; therefore, as the spacecraft rotates about its axis, each camera alternately looks toward and away from the earth. The wheel attitude will be established and accurately maintained with the quarter-orbit magnetic attitude control (QOMAC), magnetic bias control (MBC), and nutation dampers.

QOMAC uses a current-carrying coil to generate a controlled magnetic field which interacts with the earth's magnetic field to torque the spinning spacecraft. The programmer, after instructions from the ground station, reverses the direction of the current in the coil each quarter orbit. The phasing of these switching points will be controlled so that for over half an orbit the nominal average torque axis position and direction of torque are controllable.

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3.2 ATTITUDE DETERMINATION AND CAMERA TRIGGER

3.2.1 V-HEAD HORIZON SENSORS

For satisfactory picture taking, the spin axis must be maintained normal to the orbit plane and the camera shutter must be triggered at the desired instant in the rotation. Spin axis attitude is determined from telemetry of outputs from both channels of the attitude horizon sensor (AHS) and from a telemetered digital solar aspect (DSAI) sensor output. Telemetered data from the horizon crossing indicator (HCI) may also be used to derive attitude data. The solar aspect sensor is most useful in initial maneuvers when both channels of the V-head sensor do not intersect the earth, or in the event of failure of one of the V-head elements. When the V-head scanner data is used and nutation is allowed for, the uncertainty in roll and yaw at time of shutter should be less than 0.5 degree.

The AHS contains two infrared bolometers with optical axes in a V-configuration (Figure A-6). The optical paths of the sensors may intersect with the earth as the spacecraft spins; measurement of the earth-sky time ratios between the pulses is used to determine spin axis attitude. The digital solar aspect indicator produces a code indicative of the solar aspect angle once each rotation of the spacecraft. Resolution is 1 degree over a 128-degree range.

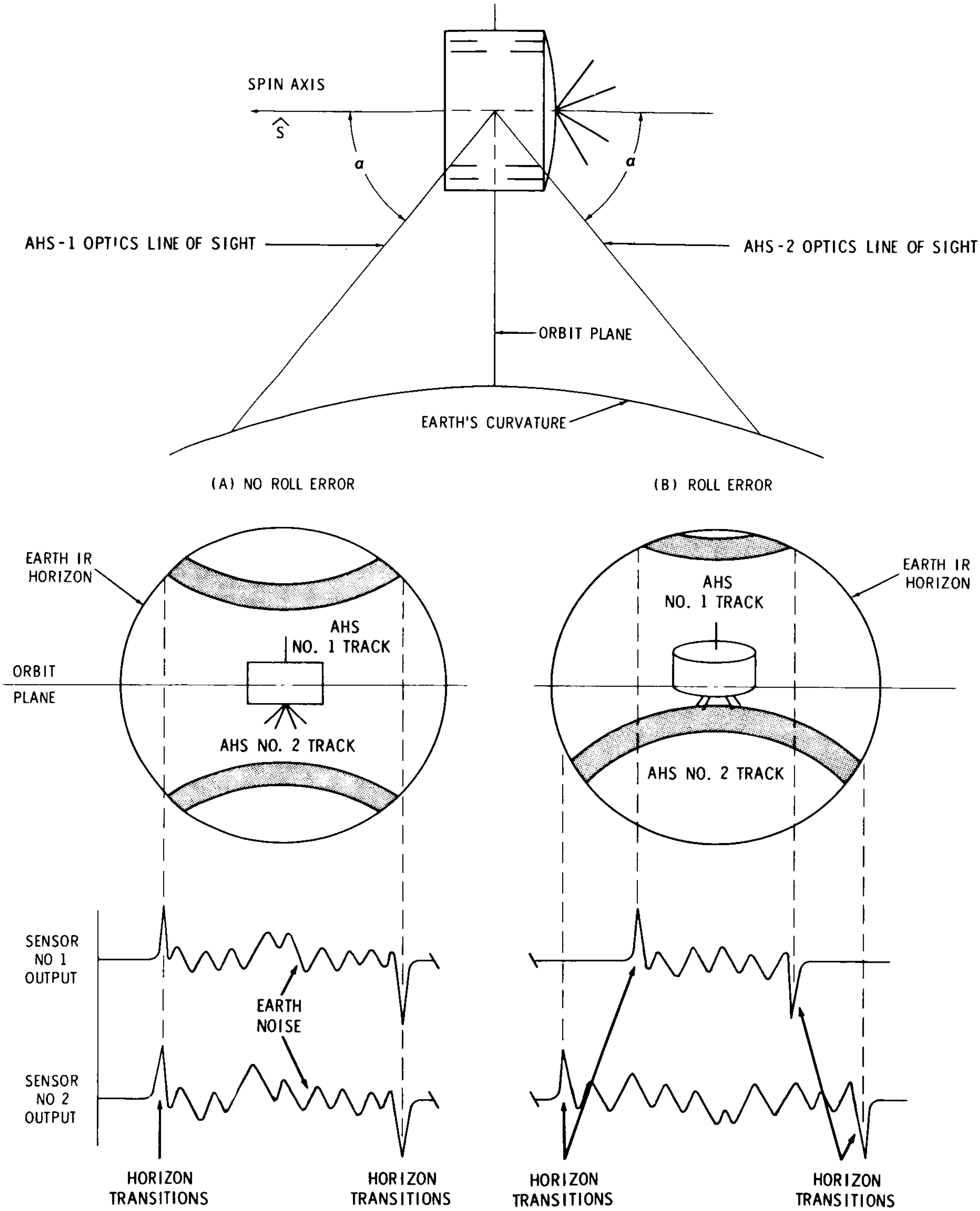

Figure A-6 — Attitude Horizon Sensor Geometry

Data from the AHS will be transmitted continuously, in real time, on two of the three SCO's of the telemetry transmitter, each channel of the AHS on its own SCO. DSAI will be timeshared on the third SCO with the HCI and other functions.

3.2.2 HORIZON CROSSING INDICATORS (HCI)

Separate infrared horizon crossing indicator (HCI) sensors are used to trigger the camera shutter (Figure A-7). The HCI's have view axes normal to the spin axis; a pair is mounted with view axes 180 degrees apart and interconnected so that only the leading edge of the sky-earth transition is controlling.

A pair, in conjunction with a horizon synchronized counter device, afford phasing of camera function with spin, where necessary, including the shutter action. Because the redundant cameras are also mounted 180 degrees apart, a sensor pair may be used with either camera by command control of the phasing between camera and sensor pair. The angle between the sensor view axis and camera view axis (angle α, Figure A-7) is adjusted to be equivalent to half the angle subtended by the earth at the nominal altitude (750 nm) of the spacecraft. This reduces the signal processing required, because the camera will be looking straight down at the instant the sensor passes through the sky-earth transition point. Therefore, the triggering of the shutter will occur simultaneously with the transition pulse. The random deviation of this pulse from nominal will be of the order of ±0.5 degree at 750 nm.

If nominal altitude is not achieved, pictures will not be taken when the camera is looking vertical. For orbits varying 50 nm from nominal, this "pitch" error will be of the order of 1 degree. It will be a known factor, therefore correctable in data processing.

3.3 SPIN RATE CONTROL

The spin period of the spacecraft is 5.50 ± 0.025 seconds, which is the prepare period of the APT camera. The spin rate is controlled by the MASC device. The spin decay is nominally 0.1 rpm per week (approximately 0.060 seconds in period) which can be counteracted with 15 minutes of MASC operation per week. Therefore short bursts of MASC operation on a once-a-day basis can hold the spin period within the ±0.025-second tolerance.

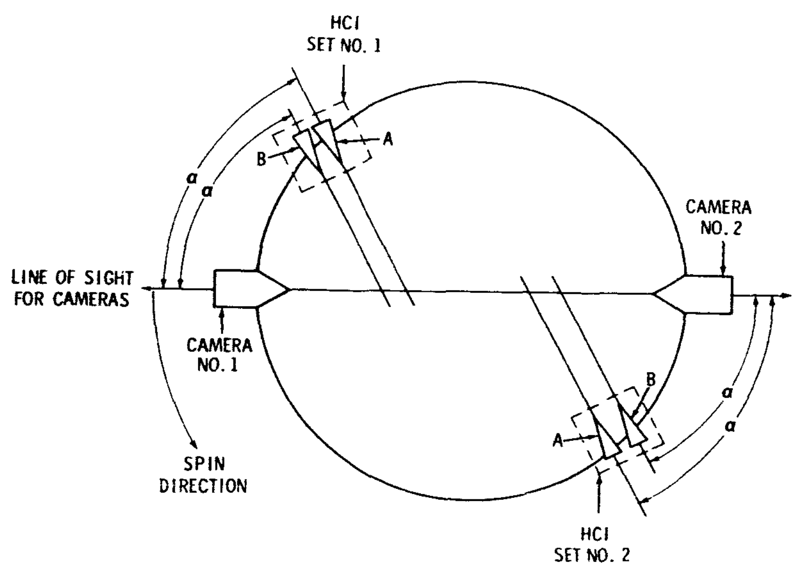

Figure A-7 — Orthogonal Horizon Sensors

The MASC device is a current-carrying coil mounted in the hat assembly, with the normal-to-the coil plane perpendicular to the spin axis; the HCI pairs commutate the coil current about the local vertical.

The MASC operation is command controllable to afford either spinup or spindown. Average spin period over a 5-minute interval may be determined to within less than 1 millisecond by use of the telemetered output of the HCI, the AHS sensor output, or the DSAI output.

3.4 TIMING FUNCTIONS

Spin rate is used to control picturetaking time, orbit counting, and other programmer functions to within a half-spin per orbit. Therefore, operational programming will be based on spin count from a given point in the orbit. Flexibility in the programmer affords proper picturetaking and orbit timing well beyond the spin-rate variation within which the cameras will perform satisfactorily.

3.5 INITIAL ACQUISITION OF ATTITUDE AND SPIN

The spacecraft and the vehicle third stage spin at a nominal 126 rpm during third-stage burn and before separation. After separation the nutation dampers are released to reduce spacecraft wobble and a yo-yo despin mechanism is released to reduce the spin rate to approximately 10.9 rpm. Spinup rockets or MASC may be used to increase the spin rate, if necessary.

After orbital injection, a maneuver to orient the spin axis to orbit normal will be initiated on orbit 0001, using the high-torque QOMAC mode of 10-degrees precession per orbit (Figure A-8). A maximum of four orbits of QOMAC can be programmed on the first acquisition.

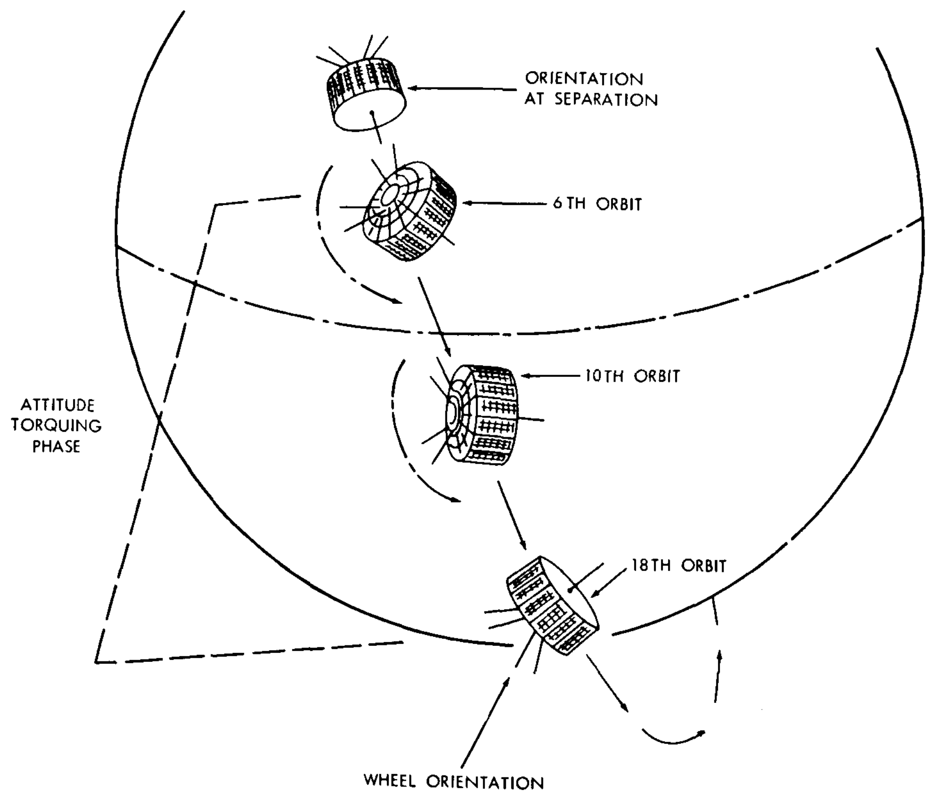

Figure A-8 – Typical Wheel Orientation Maneuver (Orbit numbers are approximate)

Once the spacecraft precesses to within 10 degrees of orbit normal, the QOMAC device will be switched to the low-torque mode, 2 degrees per orbit, and the MASC will be actuated to adjust the spin period. Low and high speed modes are available for MASC.

After attitude and spin-rate acquisition, the spin axis will be permitted to drift for a day. During this period, the precession direction and rate will be monitored to determine the residual magnetic bias of the spacecraft. MBC will then be energized and adjusted to establish a new dipole moment, which will induce an approximately 1-degree-a-day precession rate.

4. PROGRAMMER

The programmer is a small computer incorporating digital micrologic modules in a clock logic arrangement (Figure A-9). It will be turned on and off and programmed by a CDA station through the command subsystem. A program message will be a 28-bit instruction indicative of:

- Number of attitude correction cycles (QOMAC)
- Number of spins between end of programming and start of chosen cycle
- Number of pictures per cycle (APT)

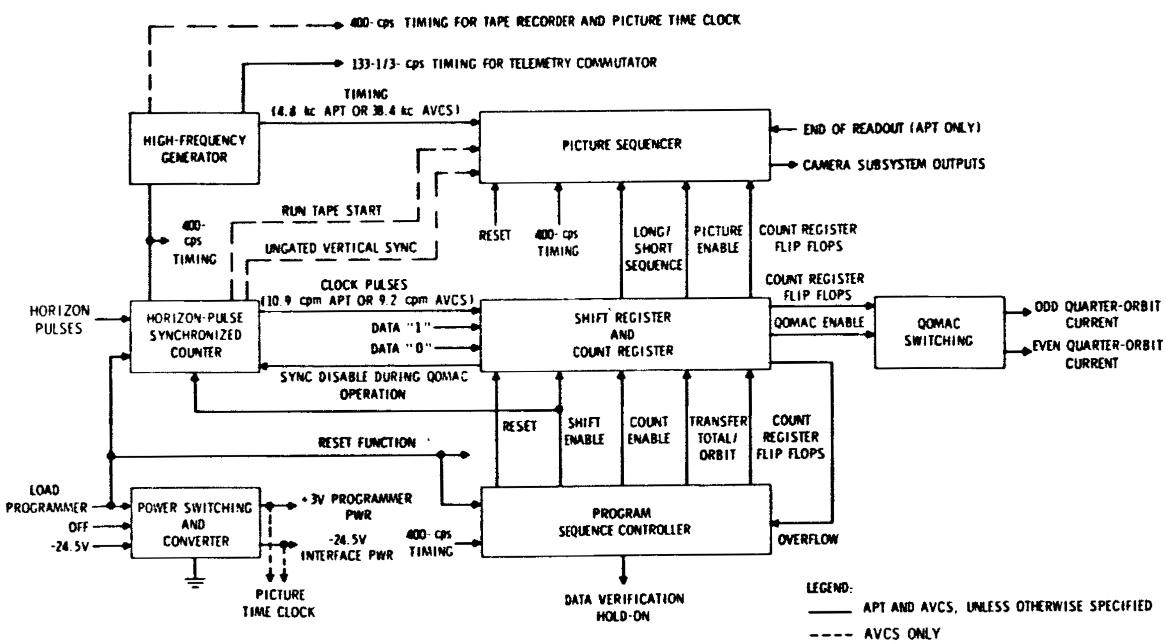

Figure A-9 — Programmer Block Diagram

- Number of spins in an orbit
- Selection of QOMAC or picturetaking control

The spacecraft carries two redundant programmers, either of which may control QOMAC or picturetaking. Both functions may be accomplished simultaneously with both programmers operating.

The programmer has the capability of:

- Initiating picturetaking and attitude-correction cycles at a point remote from the CDA station. The delay is derived from spin count and will be a maximum of about 188 minutes.
- Controlling the number of pictures to be taken on each orbit and the interval between pictures. Either a 4- or 8-picture sequence may be programmed at an interval of 352 seconds (64 spins) between pictures.
- Turning camera power off at the end of a sequence, and restarting the cycle in the next orbit. Therefore, the orbit period becomes a basic timing cycle. Orbit periods which may be accommodated with nominal spin-rates will be from approximately 94 minutes to 188 minutes (1024 to 2048 spins). The programmer will repeat the sequence each orbit until turned off or reprogrammed by ground command.
- Providing synchronization of spacecraft operations with the spacecraft spin-rate, automatically rephasing if synchronization is disturbed, and providing backup horizon crossing pulses if the HCI output pulses are interrupted, thereby permitting the satellite spin-rate to be a timing source. A horizon sync counter is synchronized to the sky-earth transition pulse output of the orthogonal horizon sensor. It discriminates against earth noise pulses which may follow this leading edge pulse by means of a gating operation using outputs from the HCI. The output is one pulse per spin of the spacecraft, generated in phase with the output of the HCI associated with the camera being used. Perfect synchronization will be afforded with spin periods varying from 5.12 seconds up to 100 milliseconds longer than the nominal 5.5-seconds spin period.
- Providing quarter-orbit timing and control of number of cycles for QOMAC operation. In the QOMAC mode the programmer is not synchronized to horizon pulses, because the horizon sync counter is programmed to operate in a free running mode at the nominal spin rate. This is necessary because in the initial orientation maneuvers immediately after launch the orthogonal horizon sensors do not see the earth. Quarter-orbit periods which may be accommodated are from 24 to 47 minutes.
- Providing synchronized control of the camera subsystems. The outputs of the programmer supply power control of camera and transmitter, initiation of prepare cycle, shutter trigger, and gated timing.
- Providing the precise frequencies required. The programmer will incorporate a crystal-controlled oscillator nominally accurate to 5 parts in 10^{-5}. Outputs from divider chains are available for desired frequencies.

5. COMMAND SUBSYSTEM

The command subsystem comprises two redundant fixed-tuned AM receivers/tone detectors and decoder units (Figure A-10). The receiver and tone detectors operate

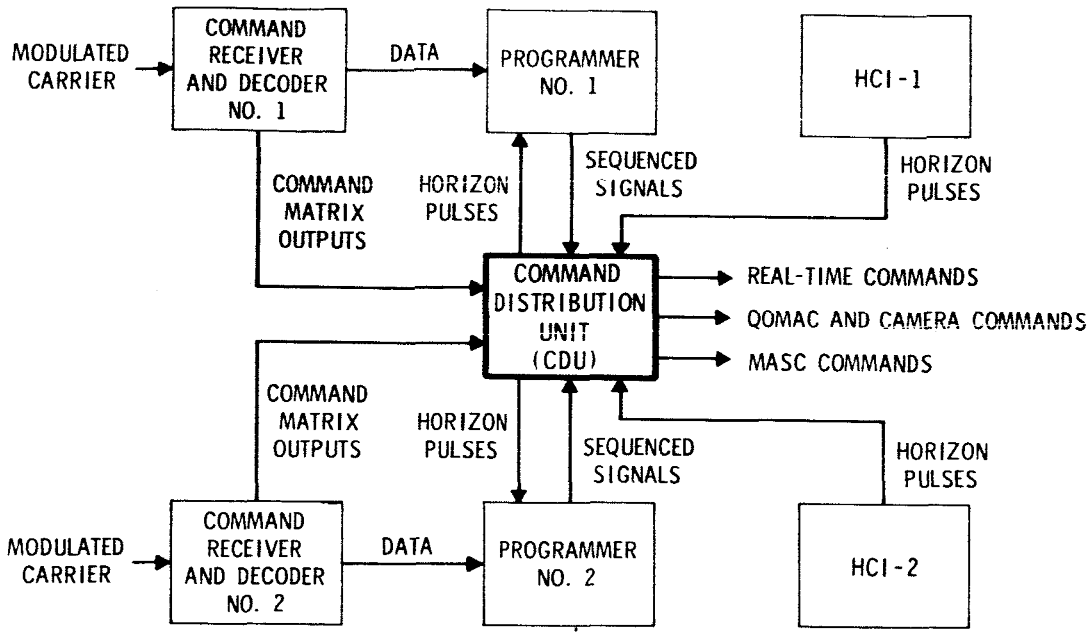

Figure A-10 — Command Distribution Unit

continuously, while the decoder is powered upon receipt of a particular enable tone, different for each of the redundant decoders. After enabling, a digital spacecraft address is transmitted, followed by the digital command. The outputs of the redundant decoders appear on matrices which are ORed in the CDU before distribution. When a load programmer command is received and is followed by a normal bit stream, the system stays open until the programmer is completely filled.

If the signal drops out for a short period, or if a suitable spacecraft address is not received within a given period, the decoder power is removed and the subsystem reverts to a standby condition. Receipt of an improper code causes the decoder registers to reset.

Data is transmitted by a single FSK tone on an amplitude-modulated carrier using return-to-zero (RZ) binary code. No synchronism is required between ground station and spacecraft except in timing program commands to ensure proper start time of program. The satellite's spin period is used as the basic timing at the ground station.

6. COMMAND DISTRIBUTION UNIT (CDU)

The outputs of the redundant command decoder matrices are ORed in the CDU (Figure A-10) for redundancy selection, power control for subsystems, attitude and spin control switching, and many other functions. Programmer sequenced signals are routed to the camera subsystem through this unit. The satellite's spin period is used for basic CDU timing along with onboard time generators.

7. TELEMETRY SUBSYSTEM

The telemetry subsystem (Figure A-11) transmits attitude sensor data, command verification, and operating condition (housekeeping) data for all subsystems. A phase modulated

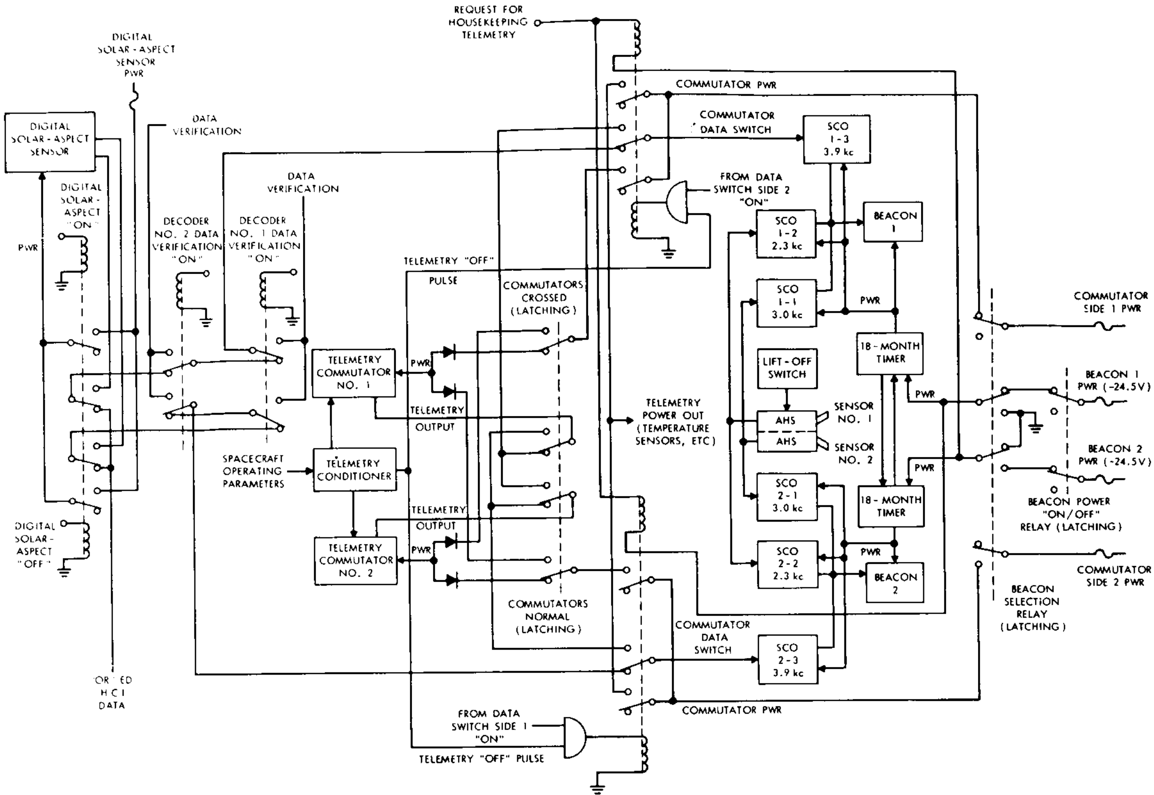

Figure A-11 — Telemetry Subsystem

transmitter at 136.770 Mc (which also serves as a tracking beacon) drives the crossed-dipole antenna with 250 milliwatts nominal RF output. The transmitter is modulated by three standard IRIG FM subcarriers, which will carry the following on a time-shared basis in the priority listed:

- Housekeeping data
- Command data verification
- Solar aspect sensor
- Camera trigger sensor (summed HCI), shutter actuation marker, and spin-control operation summed together

A single commutated frame of telemetry will be produced upon receipt of a normal command or receipt of a long-tone backup command. If the transmitters are powered, the frame is transmitted. The commutator is turned off at the end of each frame, and the system reverts to the next priority mode.

Whenever coded command is being received, the data bits are automatically transmitted over the telemetry transmitter (provided a frame of commutated telemetry is not being generated). This verification begins immediately after receipt of valid command sync and automatically ceases when the last bit of a valid command is received in the registers.

If neither commutated telemetry nor command verification is transmitted, either digital solar aspect data or a summed output is produced continuously, selectable by command.

The following appear as summed signals:

- The outputs of the HCI sensors, useful for spin-rate measurements and diagnostic purposes

- The shutter marker, again useful for diagnostic purposes because it indicates the point on the sloping leading edge of the HCI output where the shutter was actuated

- Levels indicating the MASC operating status

8. POWER SUPPLY SUBSYSTEM

The power supply subsystem comprises solar cells for source of all power, batteries to carry peak and spacecraft night loads, protective circuits such as the charge rate controller and shunt limiters, output regulators, and the required fusing (Figure A-12). Power output is available on both regulated and unregulated buses.

With nominal orbital parameters and full mission operation, the array current output requirement is of the order of 1.4 amps. At nominal orbit beginning of life, the solar

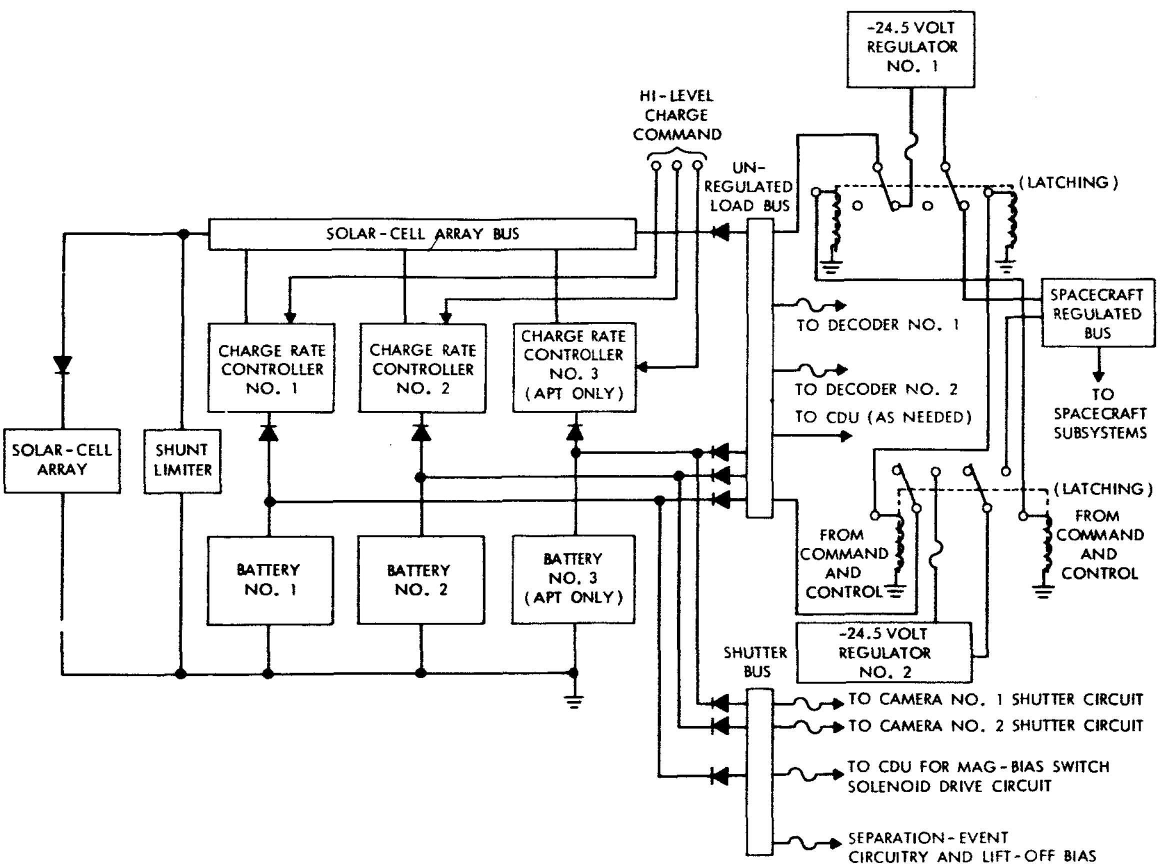

Figure A-12 — Power Subsystem

array output is expected to be of the order of 2.4 amps. After 6 months in orbit this figure is expected to drop to 1.4 amps due to radiation damage.

The solar array consists of approximately 10,000 1x2 cm, N-on-P solar cells mounted on the outer surface of the hat, with a nominal efficiency of 9 percent, air mass zero. The cells are assembled in series parallel; the number of cells in a series string varies over the spacecraft surface to provide optimum power match, particularly after degradation.

The battery packs consist of 4-amp-hour, rectangular, nickel-cadmium cells connected in series strings of 21 cells. Three are used on the TOS APT to permit loss of one battery pack without sacrificing the mission.

Protection is afforded by shunt limiters on the array output and charge-rate controllers, which maintain the array output voltage below a safe level of -33 volts. A charge-rate controller associated with each battery pack, commandable to a normal charge rate of 400-milliamp per battery pack or to a 50 percent higher charge rate.

A regulated output bus is provided at 24.5 ± 0.5 volts. Redundant regulators are provided, switchable upon command. The regulator receives its input from the regulated bus and has a 5-amp output capability.

A separate unregulated bus will also be used for high, momentary loads, such as for shutters, isolating these transient loads. Current for the unregulated bus is supplied by the solar array and batteries in a parallel arrangement. In orbit daytime, the solar array furnishes power for both battery charging and system loads. The batteries supply additional power for high peak loads and orbit nighttime.

9. SPACECRAFT COMMUNICATIONS

Three spacecraft/ground station communication links are used in TOS APT. Commands are transmitted by means of a 250-w minimum output AM transmitter and a 9-db minimum gain, circularly polarized, tracking antenna at the CDA station. The spacecraft command reception antenna is the crossed dipole mounted below the spacecraft baseplate. The same command radio frequency and modulation tones will be used for all spacecraft since each will have a unique address code. With nominal attitude and altitude and 5-degree tracking antenna elevation, this system will have an operating margin of the order of 9 db.

The crossed-dipole antenna used for telemetry transmissions and as a tracking beacon is omnidirectional to within nominally ±6 db. It transmits a 136.770-Mc, 250-mw, PM signal continuously, but may be turned on and off by command.

The FM transmitter generates 5 w at 137.500 Mc, using the monopole antenna on the hat. At nominal attitude and altitude, the worst case spacecraft antenna gain is approximately -4 db. Transmission bandwidth will be of the order of 30 kc.

Appendix B

AVCS SPACECRAFT

1. BASIC TOS SPACECRAFT

The basic spacecraft comprises:

- Camera subsystems
- Dynamics and attitude control subsystems
- Programmer subsystem
- Command subsystem
- Command distribution unit
- Telemetry subsystem
- Power subsystem
- IR subsystem

The structure is that of the TIROS spacecraft. It is an 18-sided right polyhedron, 22.5 inches high and 42 inches in diameter, consisting of a reinforced baseplate carrying most subsystems and a cover assembly (hat) with solar cells mounted on the outer top and sides; dynamics control coils and nutation dampers are mounted inside the hat (Figure B-1). Openings in the hat are provided for the various sensors mounted on the baseplate.

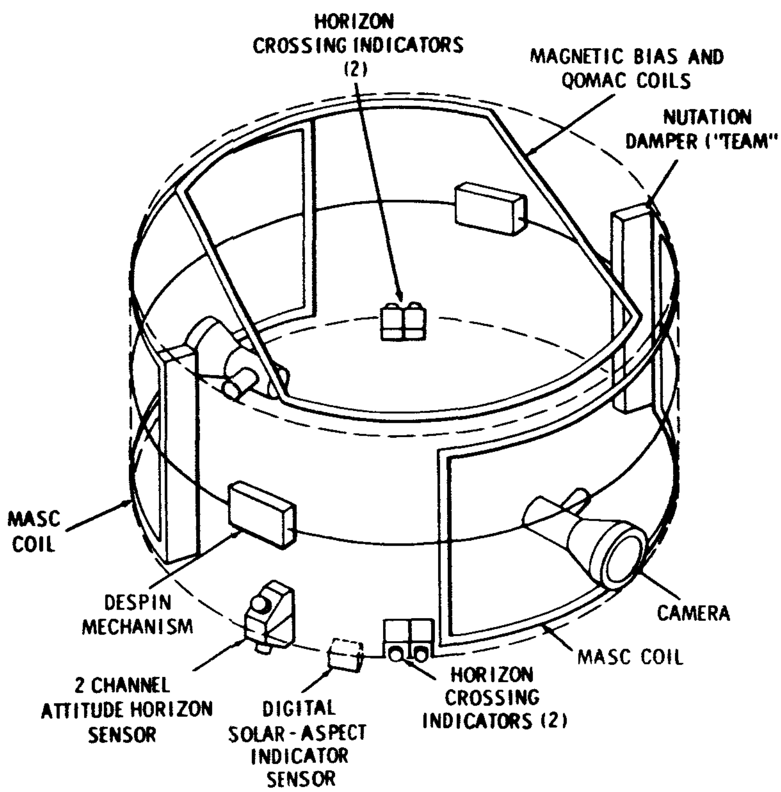

Figure B-1 – Structure and Controls Mounting

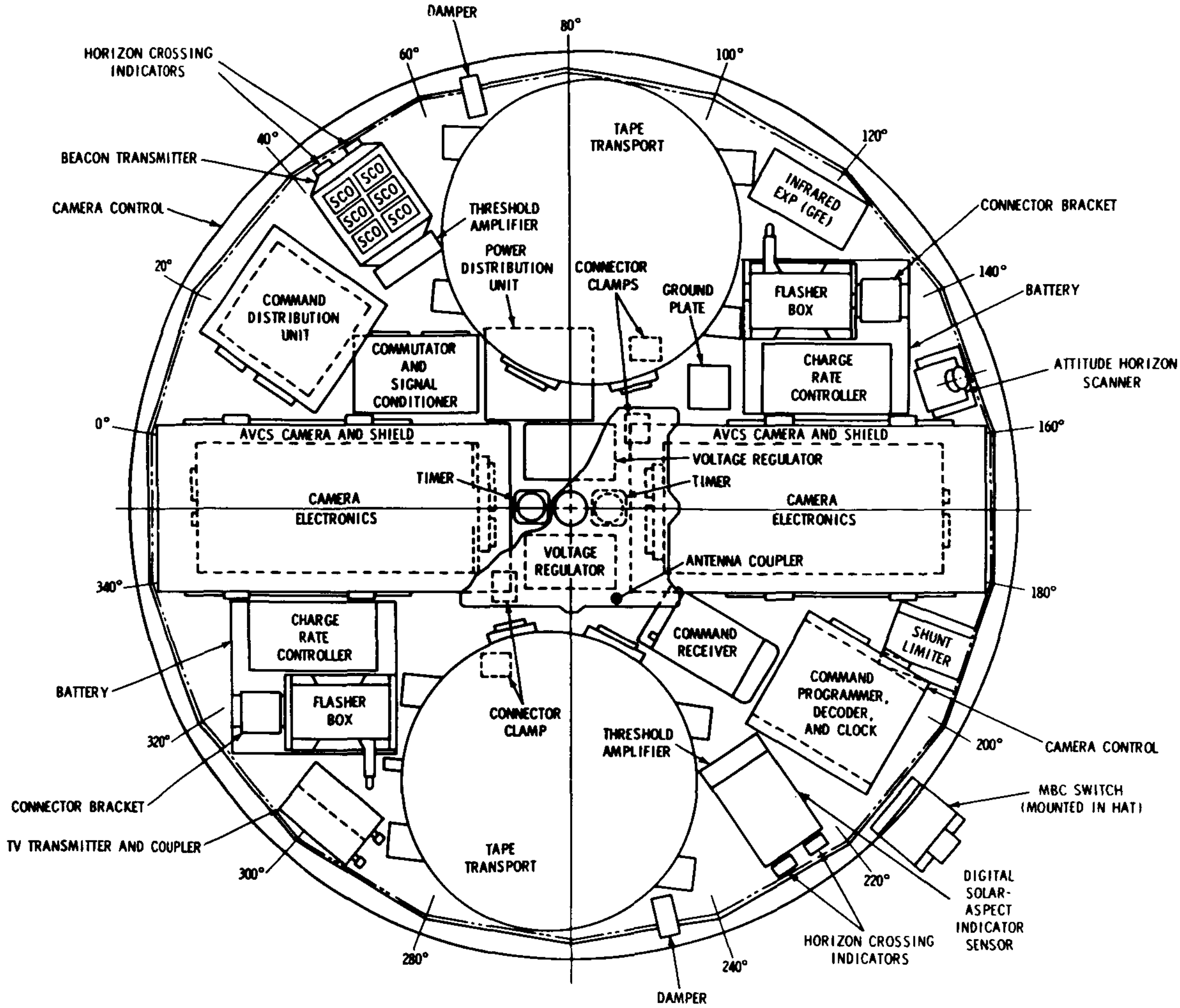

Figure B-2 – AVCS Baseplate Layout

A crossed-dipole antenna projects from the bottom of the baseplate and a monopole antenna projects vertically from the top center of the hat.

The entire assembly is strengthened to accommodate the severe launch vibration environment and to provide margin for future growth.

Because it is spin-stabilized, the spacecraft is carefully balanced to ensure proper orientation of the spin axis with respect to the sensor view axis.

The AVCS configuration is the basic spacecraft carrying two redundant AVCS equipments. Figure B-2 is the baseplate layout; Figure B-3 is a spacecraft block diagram. The AVCS is a camera, tape recorder, transmitter combination designed to record a series of remote, daytime cloudcover pictures for subsequent playback to a large data acquisition facility. The camera and tape recorder are essentially the same as those employed in Nimbus. As configured for TOS, the major elements of the subsystem are the camera assembly, camera electronics, camera controller, tape recorder, and transmitter. Major control and timing functions are provided by the spacecraft programmer and command distribution unit.

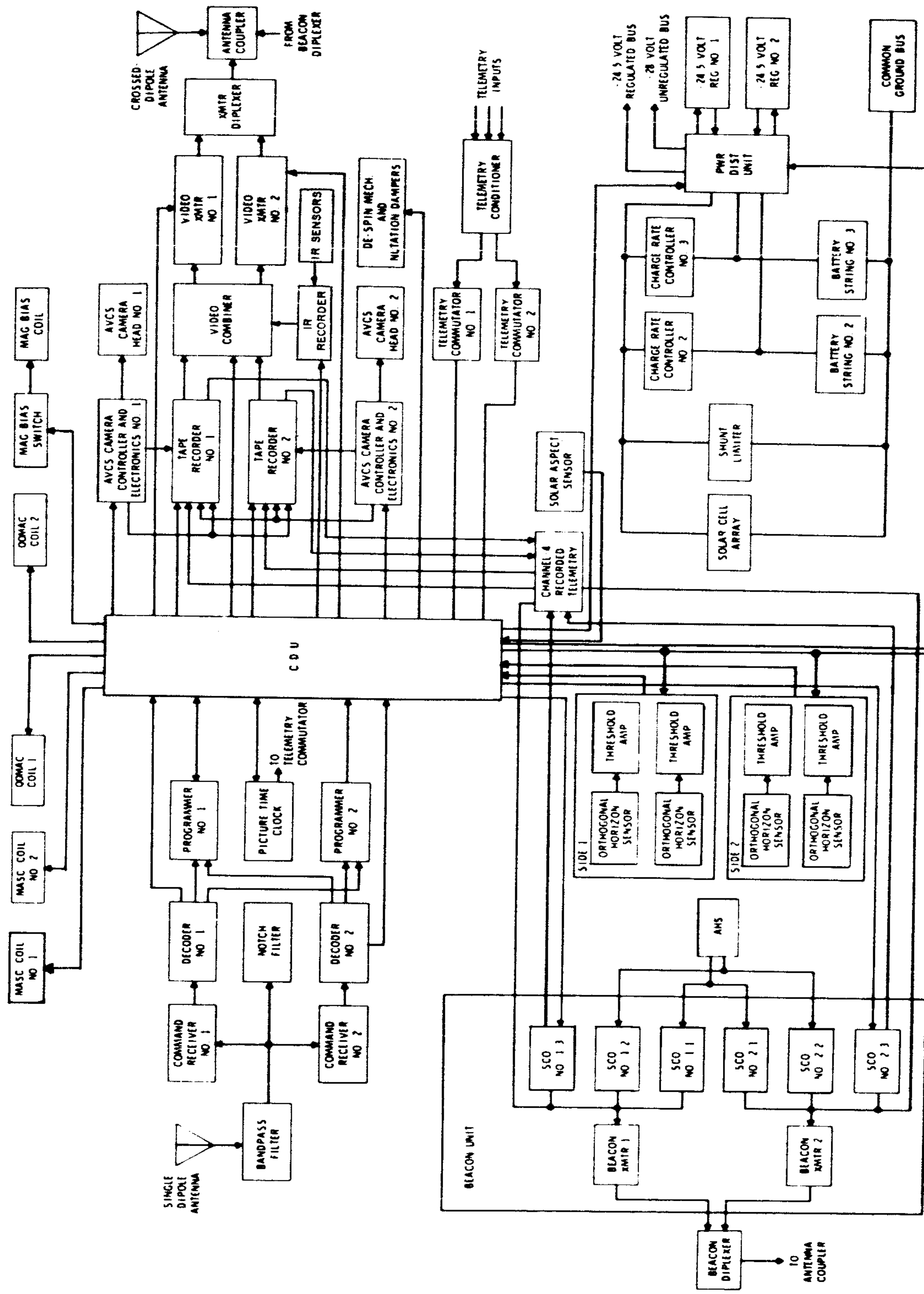

Figure B-3 – AVCS Spacecraft Block Diagram

The IR subsystem consists of a flat plate radiometer, an incremental recorder, and associated record/playback electronics.

2. AVCS SUBSYSTEM

The camera assembly (Figure B-4) includes lens, shutter, gray-scale calibrator, 1-inch vidicon, yoke assembly, and preamplifier. The lens and shutter are the same as for the APT-TOS, a Tegea Kinoptic, 108-degree wide-angle lens and an electromagnetically controlled focal plane shutter.

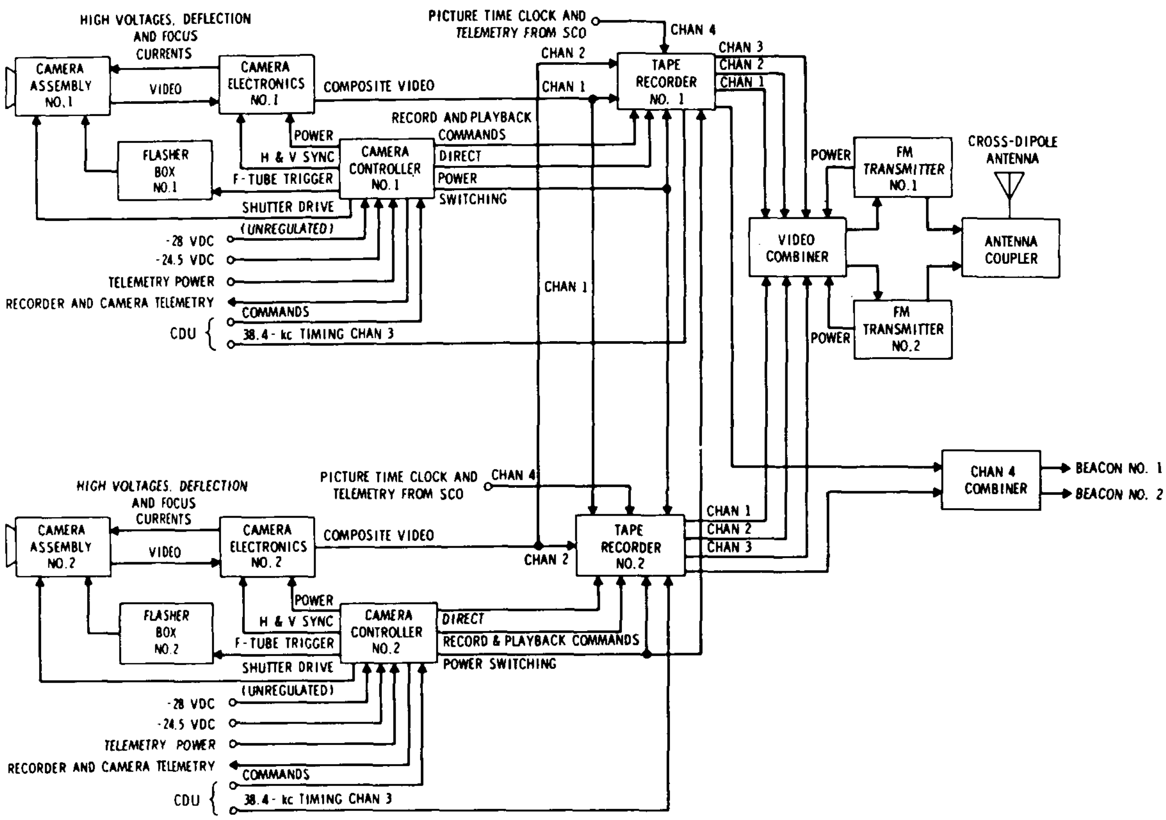

Figure B-4 – AVCS Camera Subsystem Diagram

Exposure time will nominally be 1.5 milliseconds to reduce smear to less than one TV line. The camera housing will be magnetically shielded to negate the adverse effects of uncontrolled magnetic fields.

The 1-inch vidicon has an inherent storage property which permits a nominal 6.5-second frame scan time. Concurrent with shutter actuation, a flash tube of known intensity exposes a 16-increment gray scale on each frame for picture calibration.

The camera electronics comprise video amplifiers, deflection generators, power converters, and other ancillary circuits. The composite video output from the electronics is produced at a 133-1/3-line-per-second rate with a video bandwidth of 60 kc and a dynamic range of 50 to 1. Horizontal sync pulses are provided at all times.

A nominal frame of video comprises 0.25 seconds of blanked video followed by 6.25 seconds of vidicon scan video (833 lines) and a final 0.25-period of blanked video.

A precise flutter and wow correction tone is generated to permit compensation for the vagaries of the tape recorders in the system when the final picture presentation is made. This flutter and wow tone is gated so as to appear only during the nominal frame time, thereby acting as a "vertical sync."

Upon command to playback, the tape recorder runs in the opposite direction from recording. As a result, the first picture recorded in the CDA station is the last picture taken by the camera.

The recorder has four tracks, runs at 30 ips, and has the capability to record 36 AVCS pictures in a start-stop mode of operation on one track.

Two tape recorders will be carried; to afford cross-strapped redundancy the track assignments on both are the same, with inputs paralleled. Track 1 records camera 1 output; track 2 records camera 2 output; track 3 records flutter and wow tone; and track 4 records a frame of picture time code and commutated telemetry.

FM recording of video is accomplished by applying the 60-kc video baseband to the input of a voltage controlled oscillator (VCO) with center frequency at 192 kc, maximum deviation ±48 kc. Since it is inefficient to record this high a frequency spectrum, the VCO output is divided by two before recording. On playback the video modulated FM signal with spectrum limited to a maximum of 120 kc is not doubled to its original state until it reaches the ground station. This not only conserves RF spectrum on transmission, but affords a more efficient communications link.

The flutter and wow tone is recorded as a 38.4-kc unmodulated signal. On playback it is divided by four to 9.6 kc to permit multiplexing with the video for transmission.

To record a frame of time and telemetry, the output of the appropriate telemetry subcarrier oscillator (SCO) is recorded in a manner similar to that of the picture data recording. Upon playback, the tape recorder output is demodulated onboard, thus recovering the original SCO signal. This signal is then transmitted to ground via the telemetry transmitter simultaneously with transmission of video data via the AVCS transmitter.

The camera controller accepts power and timing inputs from the programmer and CDU, processing them for distribution throughout the AVCS. The controller also processes telemetry signals before they are fed to the telemetry commutator. A video combiner permits cross-strapping redundant camera/tape recorders with the redundant transmitters.

The AVCS transmitter accepts multiplexed video subcarrier and flutter and wow tone from the video tape recorder and radiometric data from the IR recorder. It is deviated a maximum of ±125 kc at a carrier frequency of 235.000 Mc. Transmission bandwidth will be a maximum of 500 kc. Including the between-picture gap, a nominal transmission time of 10 seconds for each recorded picture will be required. On interrogation after a blind orbit, 24 pictures will be recorded, requiring a 4-minute playback. The tape recorder can be read out between picturetaking cycles without losing a picture or interrupting a sequence.

Direct pictures (recorder VCO output before recording) may be obtained for diagnostic purposes through this transmitter link also.

Six or twelve AVCS pictures per orbit may be programmed at 40 spin (260 second) intervals. The 833-line pictures at nominal altitude and attitude will cover an area of 1700 nm on a side (Figure B-5). There will be 50 percent picture overlap along the track, and the pictures from successive orbits will be contiguous at the equator with a growing overlap as the latitude increases and the orbit tracks converge; complete coverage is thereby ensured. Playback of the radiometer data is ground controlled.

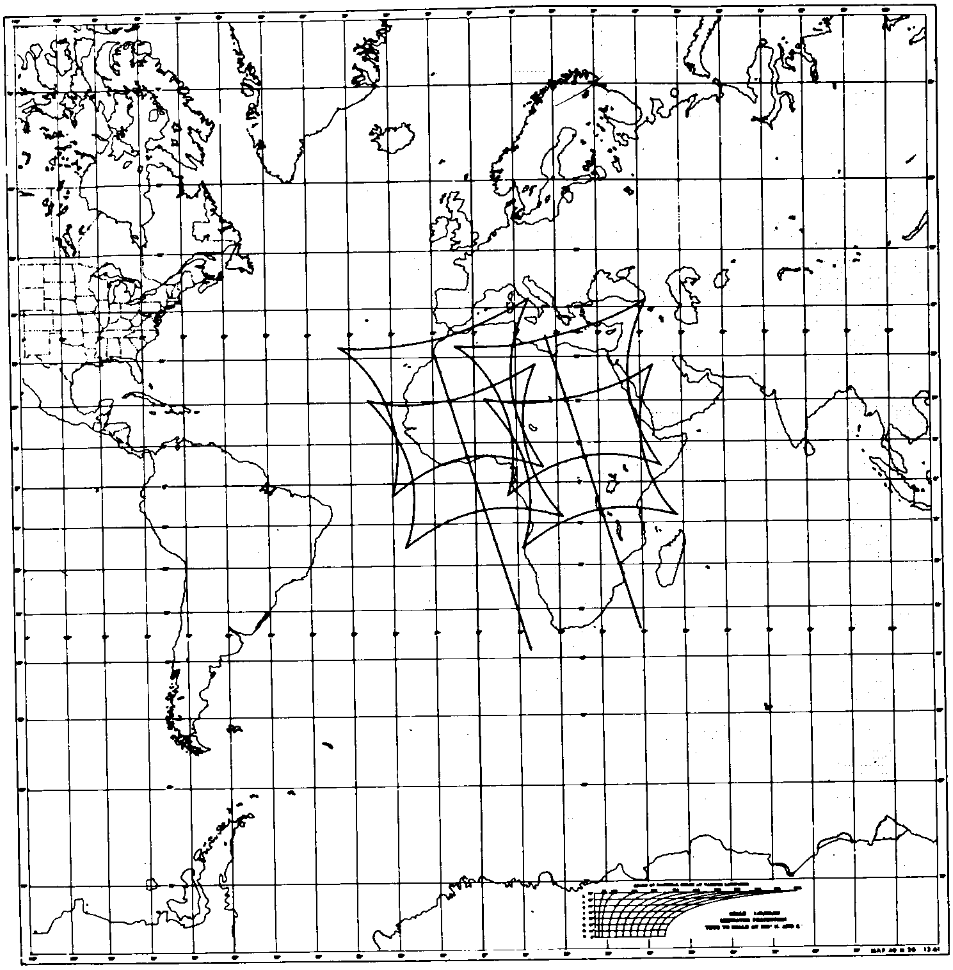

Figure B-5 – AVCS Camera Coverage

3. ATTITUDE AND DYNAMICS

The TOS spacecraft incorporates techniques to provide precise attitude control, camera pointing, spin-rate control, and timing functions.

3.1 ATTITUDE CONTROL

The pictures must be taken when the camera optical axis is colinear to within 1 degree of the local vertical, i.e., looking straight down, anywhere in the sunlit portion of the orbit.

The spacecraft spin axis, in orbit, will be maintained normal to the orbital plane to within 1 degree. The view axes of the two cameras are mounted normal to the spin axis; therefore, as the spacecraft rotates about its axis, each camera alternately looks toward and away from the earth. The wheel attitude will be established and accurately maintained with the quarter-orbit magnetic attitude control (QOMAC), magnetic bias control (MBC), and nutation dampers.

QOMAC uses a current-carrying coil to generate a controlled magnetic field which interacts with the earth's magnetic field to torque the spinning spacecraft. The programmer, after instructions from the ground station, reverses the direction of the current of the current in the coil each quarter orbit. The phasing of these switching points will be controlled so that for over half an orbit the nominal average torque axis position and direction of torque are controllable.

MBC will be used to eliminate any unwanted spin axis drift in orbit; MBC will null the spacecraft's residual dipole moment and compensate for the effects of the regressing orbit, thereby reducing the number of QOMAC cycles required for station keeping. The magnitude and polarity of the dipole compensations afforded by MBC is controlled from the ground by command.

An effective nutation damping system will be provided to rapidly reduce any imparted nutation to a negligible value. Two tuned energy-absorbing mass (TEAM) dampers will rapidly reduce any nutation cone half angle to a value below 0.7 degree. A liquid damper will maintain the nutation angle at a level of the order of 0.2 degree. A low nutation angle is desired for accuracy of camera aiming and for facilitating the processing of data from the V-head horizon sensor.

3.2 ATTITUDE DETERMINATION AND CAMERA TRIGGER

3.2.1 V-HEAD HORIZON SENSORS

For satisfactory picture taking, the spin axis must be maintained normal to the orbit plane and the camera shutter must be triggered at the desired instant in the rotation. Spin axis attitude is determined from telemetry of outputs from both channels of the attitude horizon sensor (AHS) and from a telemetered digital solar aspect indicator (DSAI) output. Telemetered data from the horizon crossing indicator (HCI) may also be used to derive attitude data. The solar aspect sensor is most useful in initial maneuvers when both channels of the V-head sensor do not intersect the earth, or in the event of failure of one of the V-head elements. When the V-head scanner data is used and nutation is allowed for, the uncertainty in roll and yaw at time of shutter should be less than 0.5 degree.

The AHS contains two infrared bolometers with optical axes in a V-configuration (Figure B-6). The optical paths of the sensors may intersect with the earth as the spacecraft spins; measurement of the earth-sky time ratios between the pulses is used to determine spin axis attitude. The digital solar aspect indicator produces a code indicative of the solar aspect angle once each rotation of the spacecraft. Resolution is 1 degree over a 128-degree range.

Data from the AHS will be transmitted continuously, in real time, on two of the three SCO's of the telemetry transmitter, each channel of the AHS on its own SCO. DSAI will be timeshared on the third SCO with the HCI and other functions.

3.2.2 HORIZON CROSSING INDICATORS (HCI)

Separate infrared horizon crossing indicator (HCI) sensors are used to trigger the camera shutter (Figure B-7). The HCI's have view axes normal to the spin axis; a pair is mounted with view axes 180 degrees apart and interconnected so that only the leading edge of the sky-earth transition is controlling.

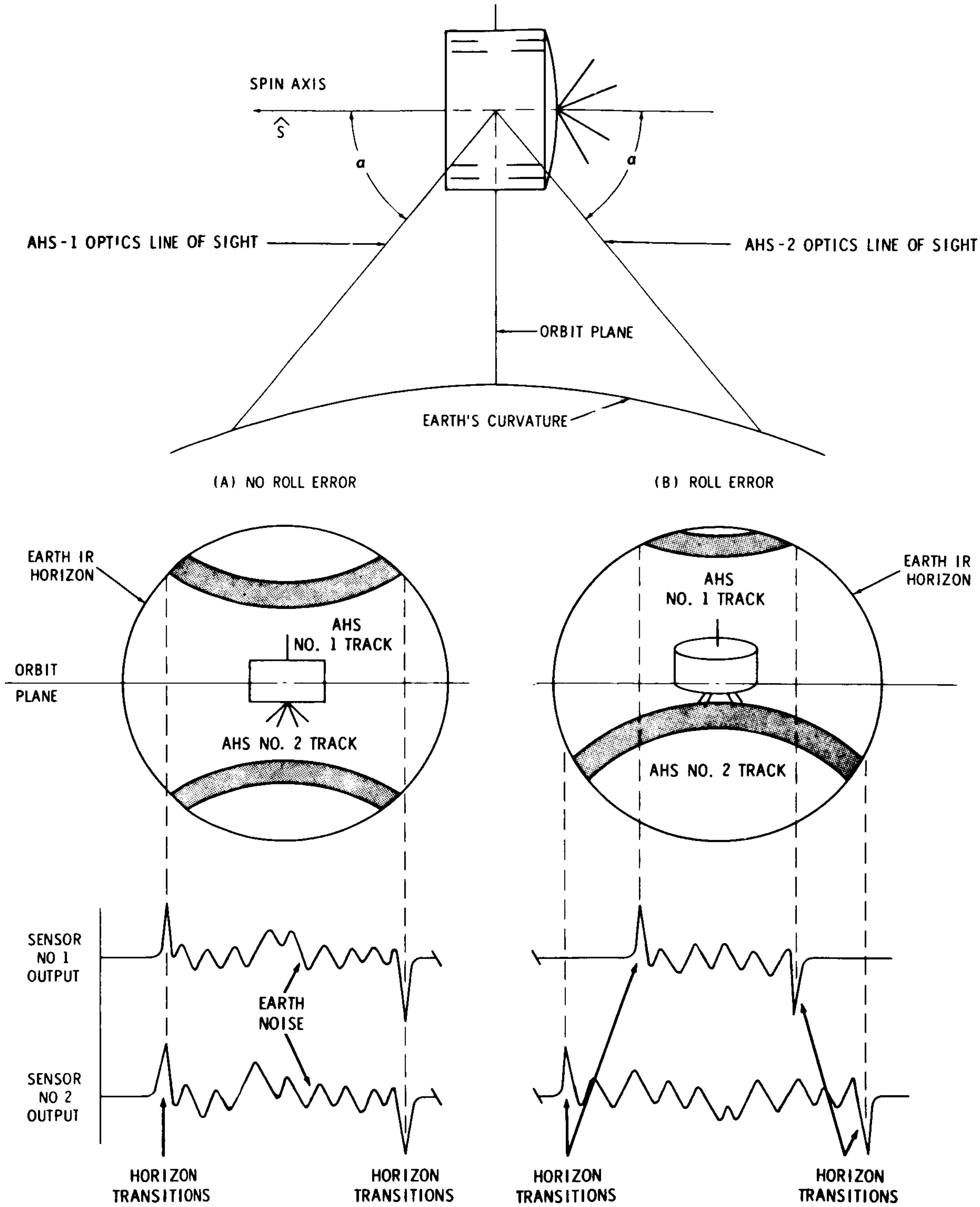

Figure B-6 — Attitude Sensor Geometry

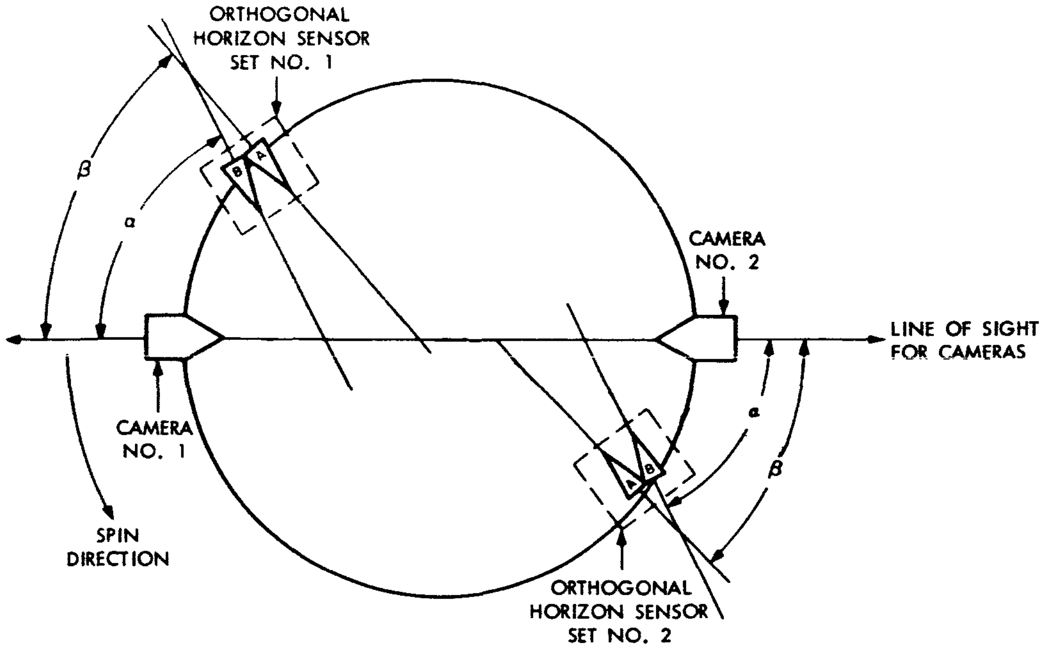

Figure B-7 – Orthogonal Horizon Sensor

The pair, in conjunction with a horizon synchronized counter device, affords phasing of camera function with spin, where necessary, including the shutter action. Because the redundant cameras are also mounted 180 degrees apart, a sensor pair may be used with either camera by command control of the phasing between camera and sensor pair. The angle between the sensor view axis and camera view axis (angle α, Figure B-7) is adjusted to be equivalent to half the angle subtended by the earth at the nominal altitude (750 nm) of the spacecraft. This reduces the signal processing required, because the camera will be looking straight down at the instant the sensor passes through the sky-earth transition point. Therefore, the triggering of the shutter will occur simulataneously with the transition pulse. The random deviation of this pulse from nominal will be of the order of ± 0.5 degree at 750 nm. (Sensor pair A will provide pictures looking straight down, sensor pair B will provide pictures looking 15 degrees offset from vertical along the track.)

If nominal altitude is not achieved, pictures will not be taken when the camera is looking vertical. For orbits varying 50 nm from nominal, this "pitch" error will be of the order of 1 degree. It will be a known factor, therefore correctable in data processing.

3.3 SPIN RATE CONTROL

The spin period of the spacecraft is 6.50 ± 0.025 seconds, the period of one AVCS picture readout. The spin rate is controlled by a MASC device. The spin decay can be counteracted with MASC operation. Short bursts of MASC operation on a once-a-day basis can hold the spin period within the ± 0.025-second tolerance.

The MASC device is a current-carrying coil mounted in the hat assembly, with the normal-to-the coil plane perpendicular to the spin axis; the HCI pairs commutate the coil current about the local vertical.

The MASC operation is command controllable to afford either spinup or spindown. Average spin period over a 5-minute interval may be determined to within less than 1 millisecond by use of the telemetered output of the HCI, and AHS sensor output, or the DSAI output.

3.4 TIMING FUNCTIONS

Spin rate is used to control picturetaking time, orbit counting, and other programmer functions to within a half-spin per orbit. Therefore, operational programming will be based on spin count from a given point in the orbit. Flexibility in the programmer affords proper picturetaking and orbit timing well beyond the spin-rate variation within which the cameras will perform satisfactorily.

3.5 INITIAL ACQUISITION OF ATTITUDE AND SPIN

The spacecraft and the vehicle third stage spin at a nominal 126 rpm during third-stage burn and before separation. After separation the nutation dampers are released to reduce spacecraft wobble and a yo-yo despin mechanism is released to reduce the spin rate to approximately 10.9 rpm. Spinup rockets or MASC may be used to increase the spin rate, if necessary.

After orbital injection, a maneuver to orient the spin axis to orbit normal will be initiated on orbit 0001, using the high-torque QOMAC mode of 10-degrees precession per orbit (Figure B-8). A maximum of four orbits of QOMAC can be programmed on the first acquisition.

Once the spacecraft precesses to within 10 degrees of orbit normal, the QOMAC device will be switched to the low-torque mode, 2 degrees per orbit, and the MASC will be actuated to adjust the spin period. Low and high speed modes are available for MASC.

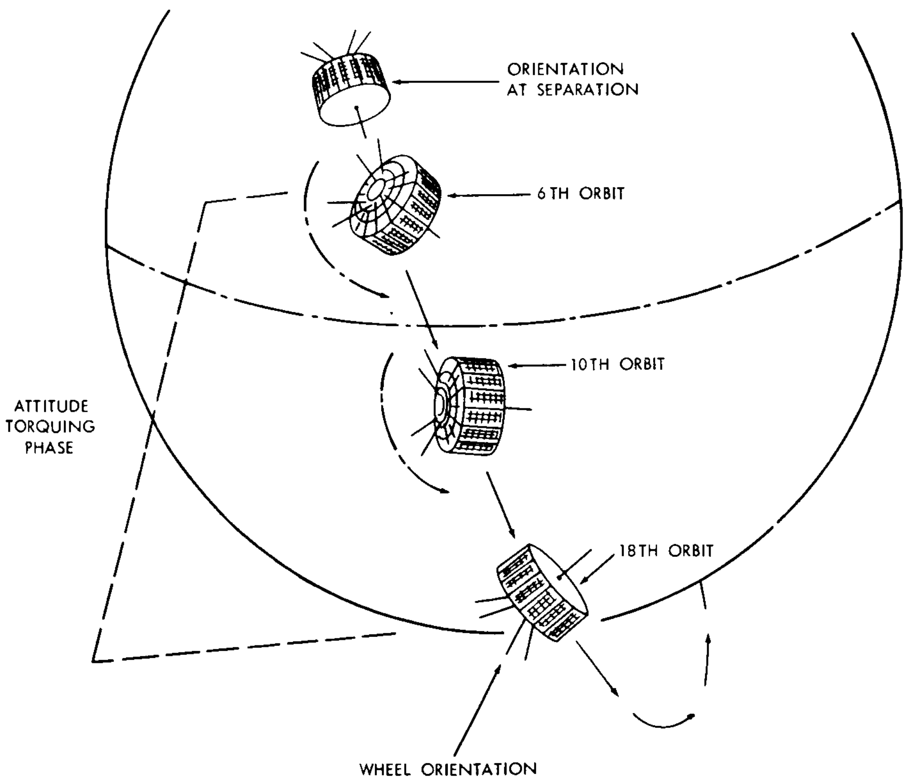

Figure B-8 —Wheel Orientation Maneuver

After attitude and spin-rate acquisition, the spin axis will be permitted to drift for a day. During this period, the precession direction and rate will be monitored to determine the residual magnetic bias of the spacecraft. MBC will then be energized and adjusted to establish a new dipole moment, which will induce an approximately 1-degree-a-day precession rate.

4. PROGRAMMER

The programmer is a small computer incorporating digital micrologic modules in a clock logic arrangement (Figure B-9). It will be turned on and off and programmed by a CDA station through the command subsystem. A program message will be a 28-bit instruction indicative of:

- Number of attitude correction cycles (QOMAC)
- Number of spins between end of programming and start of chosen cycle
- Number of pictures per cycle (APT)
- Number of spins in an orbit
- Selection of QOMAC or picturetaking control

The spacecraft carries two redundant programmers, either of which may control QOMAC or picturetaking. Both functions may be accomplished simultaneously with both programmers operating.

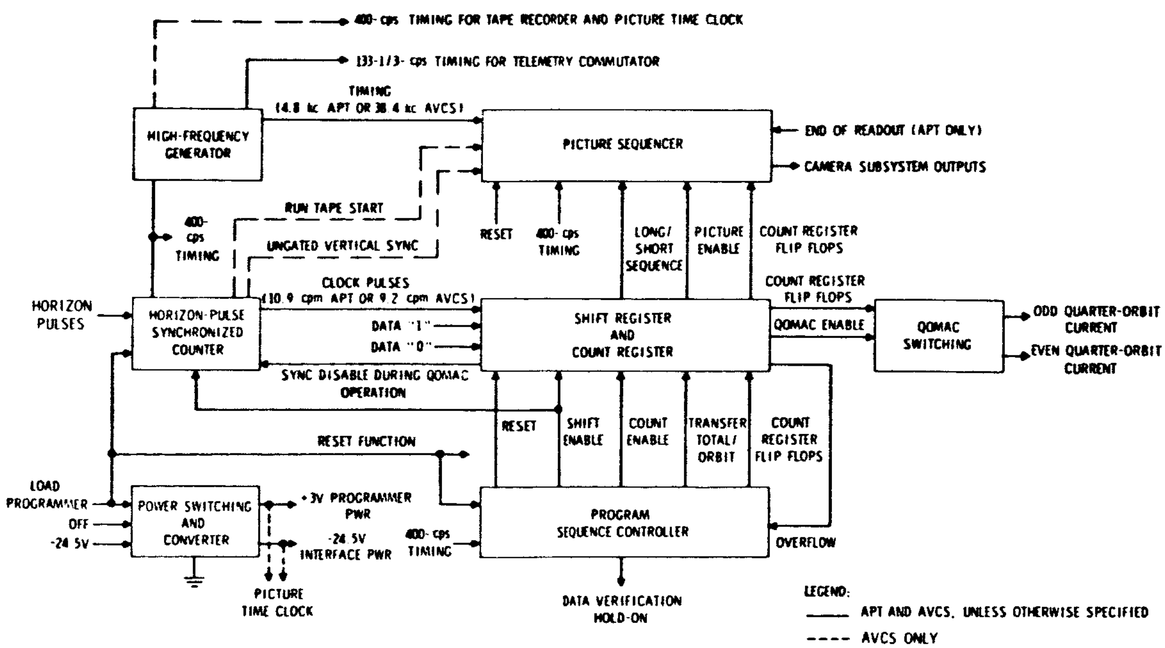

Figure B-9 — Programmer Block Diagram

The programmer has the capability of:

- Initiating picturetaking and attitude-correction cycles at a point remote from the CDA station. The delay is derived from spin count and will be a maximum of about 222 minutes.
- Controlling the number of pictures to be taken on each orbit and the interval between pictures. Either a 6- or 12-picture sequence may be programmed at an interval of 260 seconds (40 spins) between pictures.
- Turning camera power off at the end of a sequence, and restarting the cycle in the next orbit. Therefore, the orbit period becomes a basic timing cycle. Orbit periods which may be accommodated with nominal spin-rates will be from approximately 69 minutes to 180 minutes (641 to 1684 spins). The programmer will repeat the sequence each orbit until turned off or reprogrammed by ground command.
- Providing synchronization of spacecraft operations with the spacecraft spin-rate, automatically rephasing if synchronization is disturbed, and providing backup horizon crossing pulses if the HCI output pulses are interrupted, thereby permitting the satellite spin-rate to be a timing source. A horizon sync counter is synchronized to the sky-earth transition pulse output of the orthogonal horizon sensor. It discriminates against earth noise pulses which may follow this leading edge pulse by means of a gating operation using outputs from the HCI. The output is one pulse per spin of the spacecraft, generated in phase with the output of the HCI associated with the camera being used. Perfect synchronization will be afforded with spin periods varying from 5.12 seconds up to 100 milliseconds longer than the nominal 6.5-seconds spin.
- Providing quarter-orbit timing and control of number of cycles for QOMAC operation. In the QOMAC mode the programmer is not synchronized to horizon pulses, because the horizon sync counter is programmed to operate in a free running mode at the nominal spin rate. This is necessary because in the initial orientation maneuvers immediately after launch the orthogonal horizon sensors do not see the earth. Quarter-orbit periods which may be accommodated are from 28 to 56 minutes.
- Providing synchronized control of the camera subsystems. The outputs of the programmer supply the camera with horizontal sync, vertical sync, power control, shutter and flash tube trigger pulses, gated timing signals, and tape recorder control.

5. COMMAND SUBSYSTEM

The command subsystem comprises two redundant fixed-tuned AM receivers/tone detectors and decoder units. The receiver and tone detectors operate continuously, while the decoder is powered upon receipt of a particular enable tone, different for each of the redundant decoders. After enabling, a digital spacecraft address is transmitted, followed by the digital command. The outputs of the redundant decoders appear on matrices which are ORed in the CDU before distribution. When a load programmer command is received and is followed by a normal bit stream, the system stays open until the programmer is completely filled.

If the signal drops out for a short period, or if a suitable spacecraft address is not received within a given period, the decoder power is removed and the subsystem reverts to a standby condition. Receipt of an improper code causes the decoder registers to reset.

Data is transmitted by a single FSK tone on an amplitude-modulated carrier using return-to-zero (RZ) binary code. No synchronism is required between ground station and spacecraft except in timing program commands to ensure proper start time of program. The satellite's spin period is used as the basic timing at the ground station.

6. COMMAND DISTRIBUTION UNIT (CDU)

The outputs of the redundant command decoder matrices are ORed in the CDU (Figure B-10) for redundancy selection, power control for subsystems, attitude and spin control switching, and many other functions. Programmer sequenced signals are routed to the camera subsystem through this unit. The satellite's spin period is used for basic CDU timing along with onboard time generators.

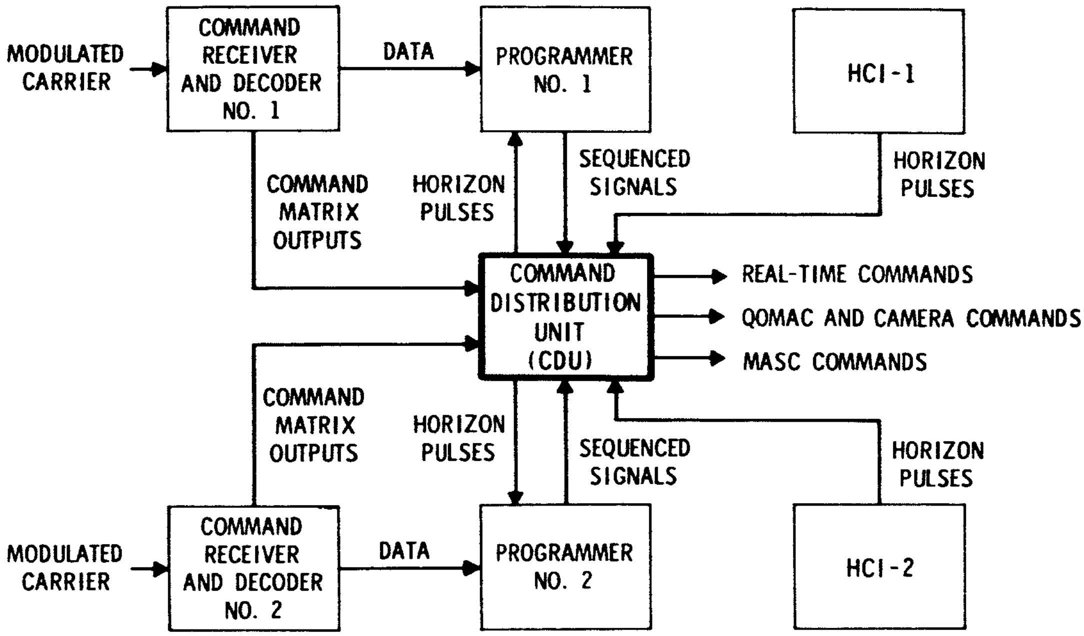

Figure B-10 – Command Distribution Unit

7. TELEMETRY SUBSYSTEM

The telemetry subsystem (Figure B-11) transmits attitude sensor data, command verification, and operating condition (housekeeping) data for all subsystems. A phase modulated transmitter at 136.770 Mc (which also serves as a tracking beacon) drives the crossed-dipole antenna with 250 milliwatts nominal RF output. The transmitter is modulated by three standard IRIG FM subcarriers, which will carry the following on a time-shared basis in the priority listed:

- Time code
- Housekeeping data
- Command data verification
- Solar aspect sensor
- Camera trigger sensor (summed HCI), shutter actuation marker, and spin-control operation summed together

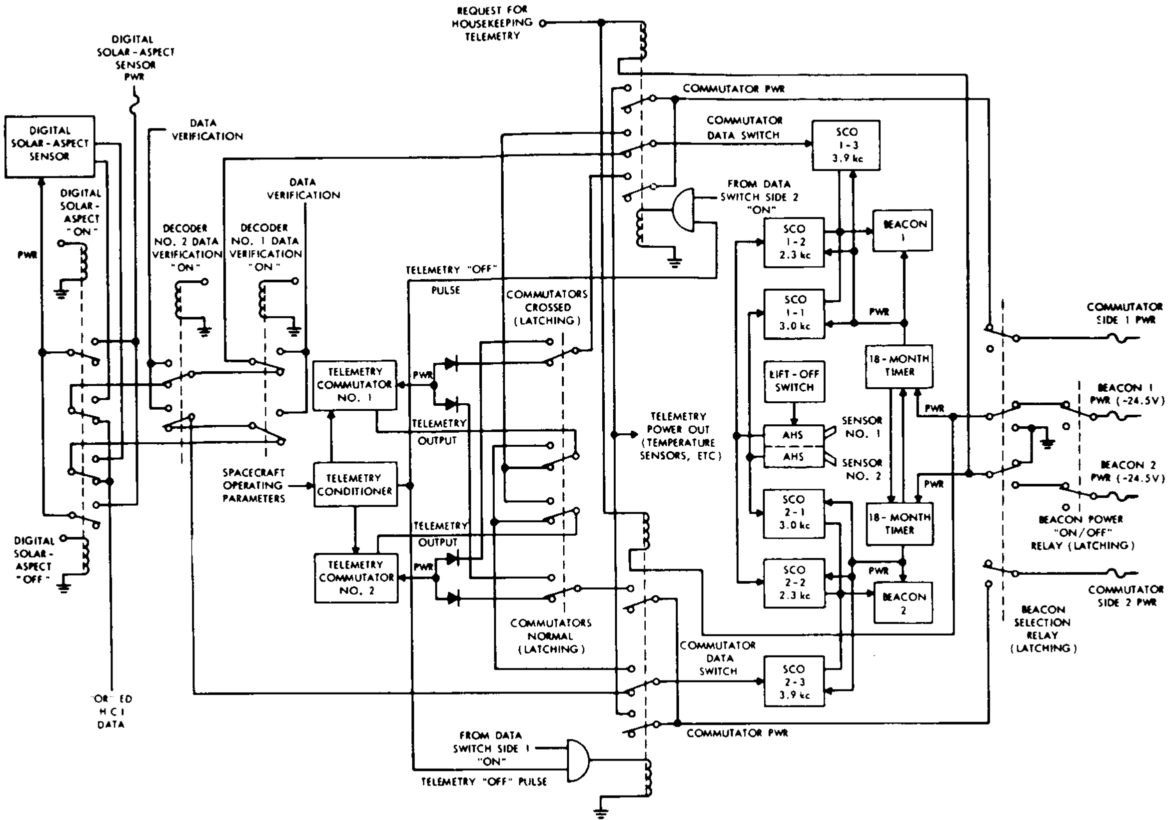

Figure B-11 — Telemetry Subsystem

A single commutated frame of telemetry will be produced upon receipt of a normal command or receipt of a long-tone backup command and each time an AVCS picture is taken. If the transmitters are powered, the frame is transmitted. The commutator is turned off at the end of each frame, and the system reverts to the next priority mode. Just before the start of each frame of telemetry time code data is transmitted.

Whenever coded command is being received, the data bits are automatically transmitted over the telemetry transmitter (provided a frame of commutated telemetry is not being generated). This verification begins immediately after receipt of valid command sync and automatically ceases when the last bit of a valid command is received in the registers.

If neither commutated telemetry nor command verification is transmitted, either digital solar aspect data or a summed output is produced continuously, selectable by command.

The following appear as summed signals:

- The outputs of the HCI sensors, useful for spin-rate measurements and diagnostic purposes
- The shutter marker, again useful for diagnostic purposes because it indicates the point on the sloping leading edge of the HCI output where the shutter was actuated
- Levels indicating the MASC operating status

8. POWER SUPPLY SUBSYSTEM

The power supply subsystem comprises solar cells for source of all power, batteries to carry peak and spacecraft night loads, protective circuits such as the charge rate controller and shunt limiters, output regulators, and the required fusing (Figure B-12). Power output is available on both regulated and unregulated buses.

With nominal orbital parameters and full mission operation, the array current output requirement is of the order of 0.8 amps. At nominal orbit beginning of life, the solar array output is expected to be of the order of 2.4 amps. After 6 months in orbit this figure is expected to drop to 1.4 amps due to radiation damage.

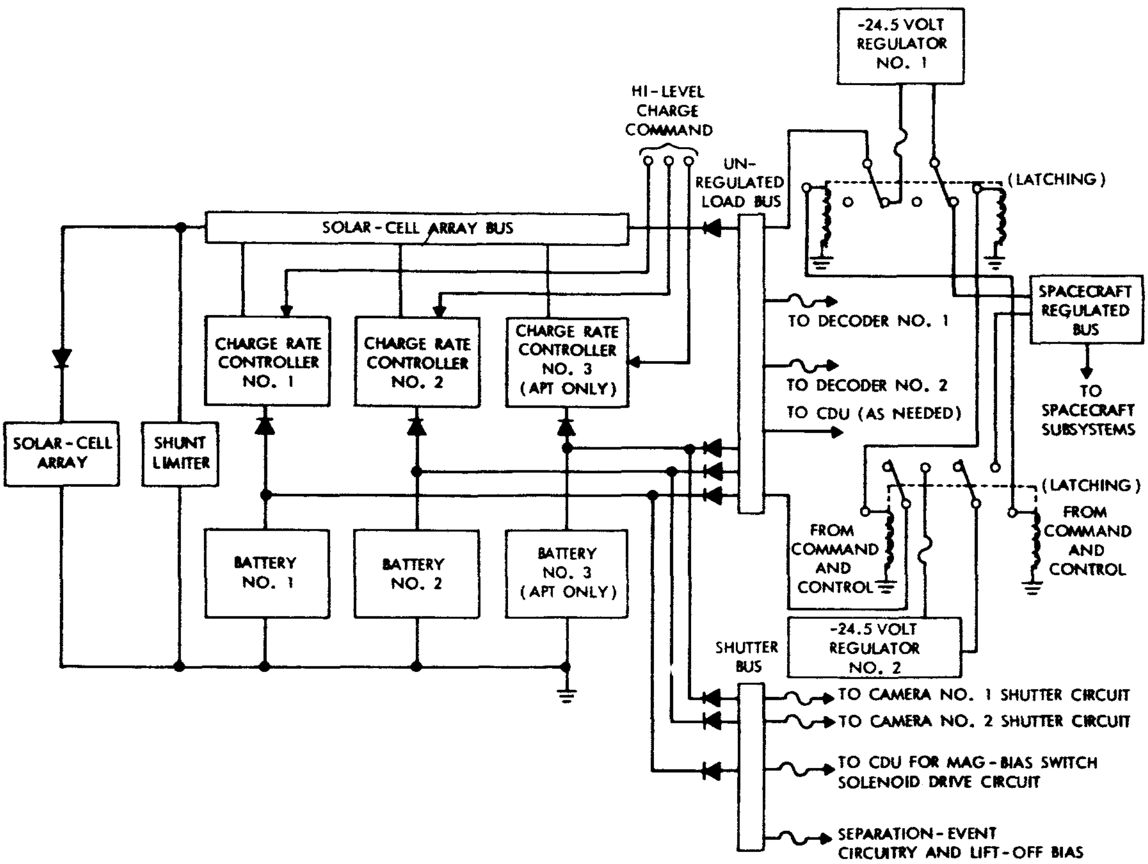

Figure B-12—Power Subsystem

The solar array consists of approximately 10,000 1x2 cm, N-on-P solar cells mounted on the outer surface of the hat, with a nominal efficiency of 9 percent, air mass zero. The cells are assembled in series parallel; the number of cells in a series string varies over the spacecraft surface to provide optimum power match, particularly after degradation.

Two standard battery packs are used; each consists of 4-amp-hour, rectangular, nickel-cadmium cells connected in series strings of 21 cells.

Protection is afforded by shunt limiters on the array output and charge-rate controllers, which maintain the array output voltage below a safe level of -33 volts. A charge-rate controller associated with each battery pack, commandable to a normal charge rate of 400-milliamp per battery pack or to a 50 percent higher charge rate.

A regulated output bus is provided at 24.5 ± 0.5 volts. Redundant regulators are provided, switchable upon command. The regulator receives its input from the regulated bus and has a 5-amp output capability.

A separate unregulated bus will also be used for high, momentary loads, such as for shutters, isolating these transient loads. Current for the unregulated bus is supplied by the solar array and batteries in a parallel arrangement. In orbit daytime, the solar array furnishes power for both battery charging and system loads. The batteries supply additional power for high peak loads and orbit nighttime.

9. SPACECRAFT COMMUNICATIONS

Three spacecraft/ground station communication links are used in TOS APT. Commands are transmitted by means of a 250-w minimum output AM transmitter and a 9-db minimum gain, circularly polarized, tracking antenna at the CDA station. The spacecraft command reception antenna is the monopole at the top of the hat. The same command radio frequency and modulation tones will be used for all spacecraft since each will have a unique address code. With nominal attitude and altitude and 5-degree tracking antenna elevation, this system will have an operating margin of the order of 9 db.

The crossed-dipole antenna used for telemetry transmissions and as a tracking beacon is omnidirectional to within nominally ± 6 db. It transmits 136.770-Mc 250-mw PM signal continuously, but may be turned on and off by command.

All TOS AVCS spacecraft will use 5-w FM transmitters at 235.000 Mc. Transmission bandwidth will be of the order of 500 kc. Sleeves on the crossed-dipole antennas will afford transmission capability at this frequency. The pattern is omnidirectional to within ±6 db. The transmitter will be radiating only during AVCS tape recorder playback and when requesting a direct picture, nominally 2 to 4 minutes each orbit.

Appendix C

VEHICLE

The TOS spacecraft will be launched by the improved Delta vehicle, DSV-3E, As shown in Figure C-1. The Delta vehicles, built by Doublas Aircraft Company (DAC), are described in detail in the Delta project PDP. Specific vehicles and launching procedures for each spacecraft will be described in the Detailed Test Objectives (DTO) and Program Requirement Document (PRD).

The improved Delta is a three-stage vehicle with an overall length of approximately 91 feet and a maximum body diameter of 8 feet. Nominal launch weight is 136,000 pounds.

The first stage is a Douglas Aircraft Company (DAC) modified Thor missile (Rocketdyne MB-3 Block III) with three strap-on Thiokol TX 33-52 solid-rocket motors producing 346,000 pounds of thrust. The second stage is an Aerojet General AJ10-118-E with liquid-propellant engine producing 6,000 to 7,800 pounds of thrust. A forward equipment and guidance compartment houses the WECO 600 radio-guidance system, the flight-vehicle controller, and other instrumentation. A spin table which supports the third stage is mounted at the forward end of the second stage. The third stage is an Allegany Ballistic Laboratory (ABL) X-258 solid-propellant rocket.

The main propulsion system is Rocketdyne MB-3 Block III engine using LOX and RJ-1 propellants. The main engine is gimballed for pitch and yaw attitude control from liftoff to main engine cutoff. Two 1,000-pound-thrust liquid propellant vernier engines provide roll control during main engine burning as well as picth, yaw, and roll attitude control from main engine cutoff to first-to-second stage separation. A fire-in-the-hole technique is utilized in the first-to-second stage separation, which is initiated 4 seconds after main engine cutoff.

The second stage is powered by an Aerojet General Corporation AJ10-118-E. The tankage diameter of the AJ10-118-E is 54.7 inches. The aft skirt attaches to the larger diameter tankage. The guidance compartment structure is tapered from 54.7 inches at the aft end to 60 inches at the forward end. The structure has the capability of supporting a 1,200-pound payload on the spin-table support adapter or a 2,000-pound payload at the periphery of the 60-inch diameter. The liquid-propellant engine uses inhibited red fuming nitric acid (IRFNA) and unsymmetric dimethylhydrazine (UDMH) propellants. The engine is gimballed for pitch and yaw attitude control. A cold gas system utilizing nitrogen gas and six fixed nozzles provides roll control during second-stage burning as well as pitch, yaw, and roll control during the coast period and after second-stage engine cutoff. Two fixed nozzles fed by the propellant tank helium pressurization system bottles provide retro thrust during second-to-third stage separation.

The third stage solid-propellant ABL X-258 is spin stabilized before separation from the second stage. The third stage/spacecraft fairing attaches to the forward face of the guidance compartment structure and protects the third-stage motor and spacecraft from aerodynamic heating during the boost flight. A spring is contained in the payload attach structure for third-stage to spacecraft separation. A shroud is attached to the second stage for protection of the third stage and spacecraft during flight through the atmosphere. The second-to-third stage connection consists of a spin table and petal arrangement fixed to the second stage and a band containing explosive bolts which hold the third stage on the petals. Spinup is accomplished by a set of rockets fixed to the spin table.

First and second stage preprogrammed autopilots control the vehicle and sequence operations from liftoff to second-to-third stage separation. The second-stage autopilot utilizes

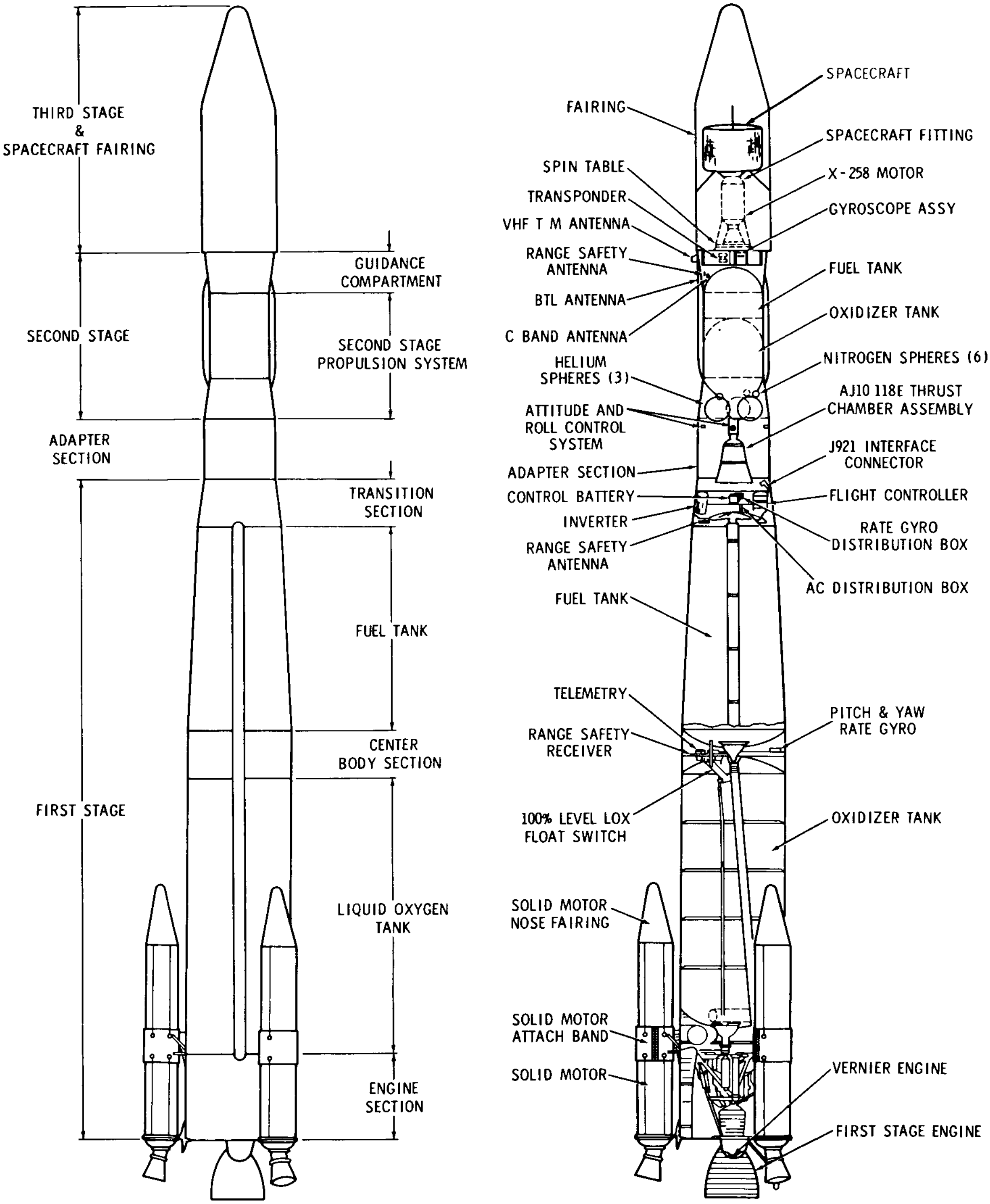

Figure C-1 — Improved Delta Profiles

MIG gyros and can supply five discrete steering command and six flight sequence signals. Between second-stage liftoff and third-stage separation, up to three pitch rates and two yaw rates are allowed by the five discrete commands. The third-stage attitude is obtained from second-stage pitch-and-yaw rates during the second-stage coast period. The coast phase rates are limited between 0.1 and 1.0 degrees per second.

The improved Delta separation schematic is shown in Figure C-2. At first-stage main engine shutdown, the blast bands covering the exhaust ports on both the first-stage transition section and adapter section are jettisoned. Approximately 4 seconds later, the first-to-second-stage explosive separation bolts are fired and second-stage ignition occurs. The third-stage/spacecraft fairing is jettisoned approximately 10 seconds after second-stage ignition. Third-stage/spacecraft separation from the spin table occurs 2 seconds after spinup, and the second-stage vehicle retro system is actuated. Spacecraft separation occurs after third-stage burnout.

NORAD will track each TOS during the early orbit phase as requested by GSFC. Objects expected to attain orbit are the spacecraft, rocket motor, support petal parts, yo-yo despin weights and cables, and assorted attachment hardware.

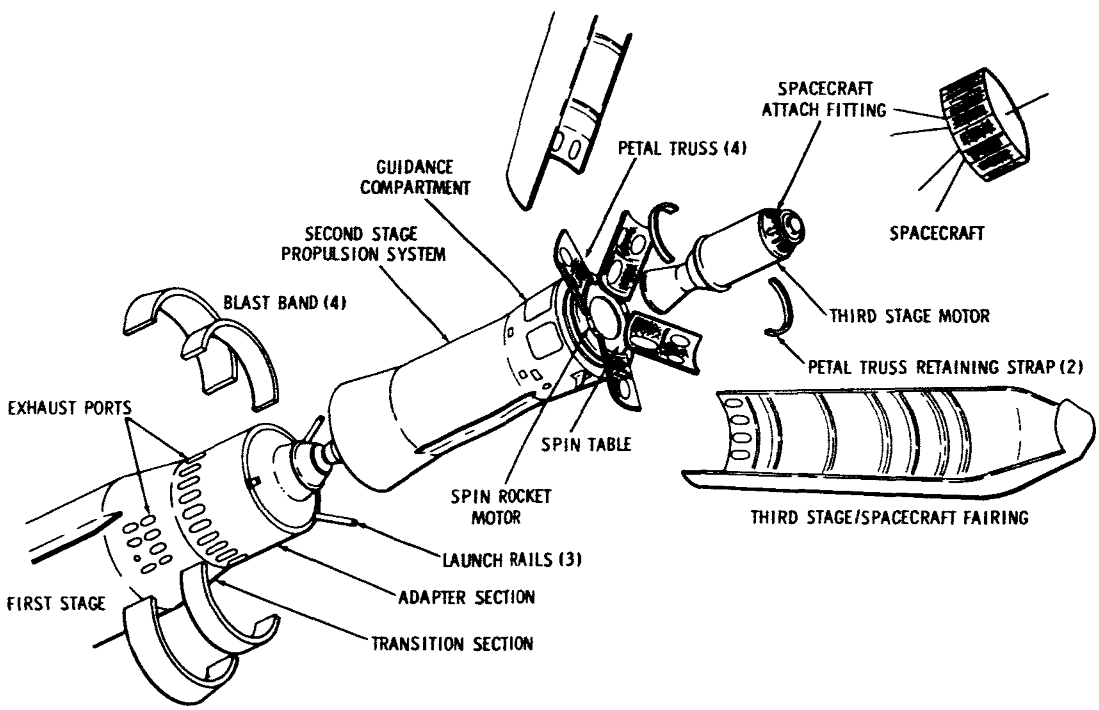

Figure C-2 — Delta Separation Schematic

Appendix D

CDA Stations

The CDA stations (Figure D-1) transmit command programs to the spacecraft, acquire and record meteorological and engineering data from the spacecraft, and transmit all data via the TOS system communications network as instructed to TOC. The ESSA CDA stations are at Fairbanks, Alaska (GILMOR), and Wallops Station, Va. (WALOMS). A ground station at RCA-AED, Highstown, N. J. (RCAHNF), can receive transmissions from the spacecraft but cannot command. This station is not part of the ground communications system. The GSFC R&D station antenna at Fairbanks, ULASKA, may be available upon request for GILMOR backup on a noninterference basis, according to a reciprocal agreement between NASA and ESSA. A similar agreement exists with respect to Wallops Station facilities. The CDA stations receive station schedules and spacecraft command programs from TOC.

Normally, beacon data and timing signals are transmitted from the CDA stations in real time as they are received from the spacecraft. Video data are transmitted by playing the tape recorder back at 7-1/2 ips, 1/8th the recording speed. This reduces the subcarrier instantaneous frequency range to 18 to 30 kc and the baseland to 7-1/2 kc. The flutter and wow subcarrier is, then, 6.25 kc. A slow-time demodulator is used for monitoring.

1. GILMORE CREEK, ALASKA (GILMOR)

Equipment at each CDA station includes an RF section, video section, spacecraft command and control equipment, beacon telemetry processing section, and tape recorders and communications terminals. Figure D-2 shows the CDA station unique equipment layout. The configuration of the electronic and electromechanical equipment is basically the same at GILMOR and WALOMS.

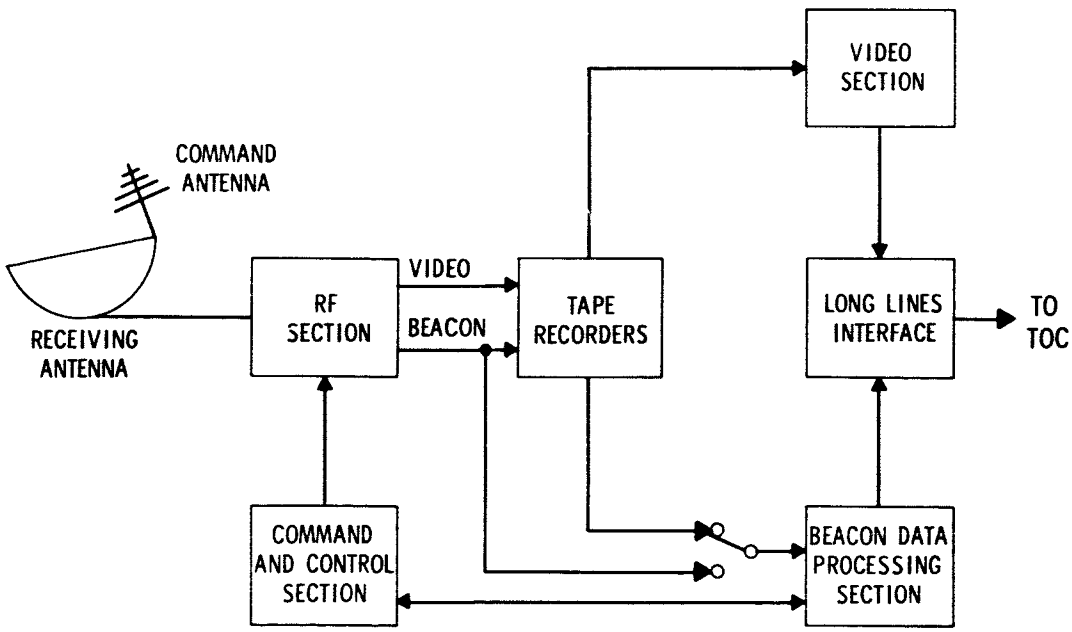

Figure D-1 — CDA Station Diagram

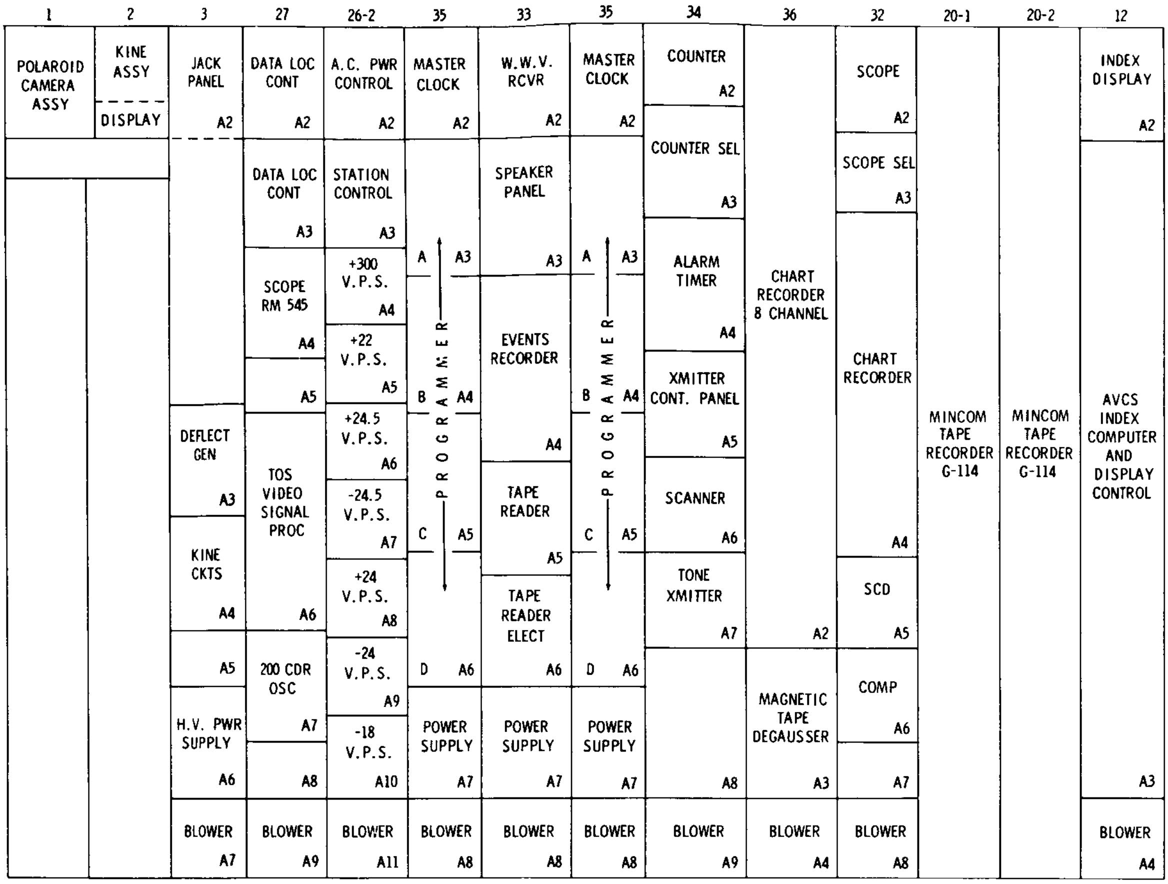

Figure D-2 — CDA Unique Station Equipment

The GILMOR station includes equipment for:

Commanding the spacecraft
Receiving, combining, and demodulating the beacon, AVCS, and APT signals
Recording
Data transmittal

1.1 ANTENNA

The main antenna for the GILMOR station is an 85-foot-diameter paraboloid with a focal length of 36 feet. The surface, consisting of double-curved aluminum sheet panels, is separate from the reflector structure to permit independent adjustment. At 136 Mc, the antenna has a gain of approximately 27 db with a 6-degree beamwidth; at 235 Mc, the gain is 30 db. Figure D-3 shows the GILMOR antenna keyhole pattern.

The antenna has five operational modes:

Will automatically track the 136-Mc signal transmitted from the spacecraft
Can be operated manually
Can be driven by an antenna programmer
Can be slaved to an acquisition antenna which may be added later
Can be operated in various search modes for initial acquisition

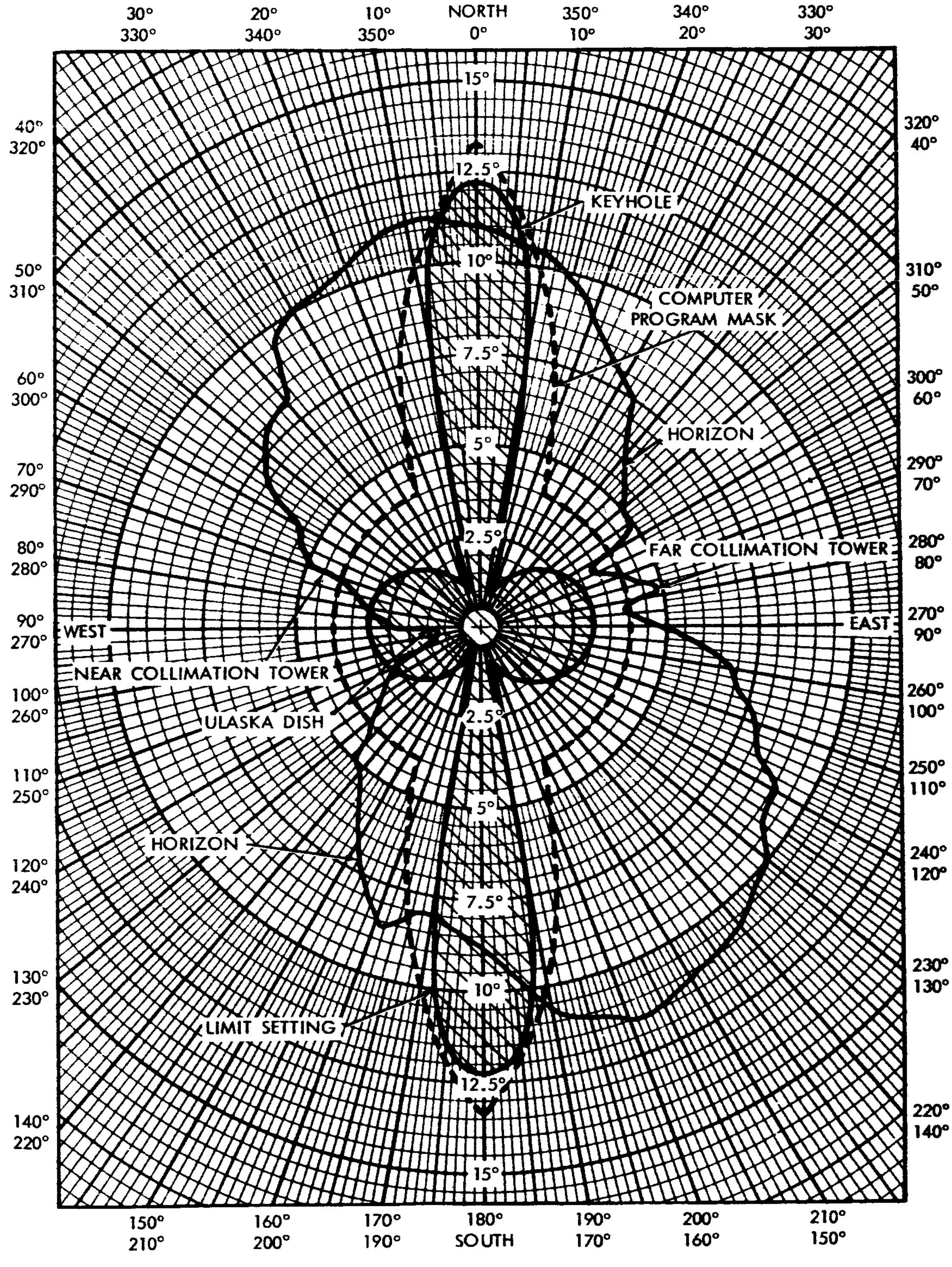

Figure D-3 – GILMOR Antenna Keyhole Pattern

The antenna reflector is mounted on an X-Y mount designed specifically for tracking spacecraft, with the advantage that there are no gimbal-lock positions in the sky area above the horizon. This permits optimum tracking of spacecraft without requiring excessive shaft velocities from the antenna-drive system.

Antenna feeds will have a monopulse autotrack capability on 136 Mc and 1700 Mc. The multifrequency antenna-feed cluster consists of two separate systems; a set of four crossed dipoles for the 136-Mc to 137-Mc band, and a set of four crossed dipoles for the 1700-Mc band. Standard monopulse circuitry with coaxial hybrids obtains the sum-channel and tracking-channel outputs from the array of four dipoles.

The feed system permits the antenna control operator to switch-select any of four polarization senses for reception of 136-Mc signals (two linear and two orthogonal circular).

Antenna polarization will be righthand circular. The best circular should be selected for tracking, but only when data is not being transmitted.

1.2 RF SECTION

RF equipment includes receiving, combining, and demodulating equipment for beacon, AVCS, and APT signals, and command transmitting equipment.

During the prelaunch phase, T&DS will conduct engineering tests of the TOS ground station equipment. These tests will be the basis for the prepass tests that will be run at the stations during postlaunch operations. The purpose of these tests is to provide prelaunch assurance that all TOS and DAF subsystems are compatible and that the integration between subsystems has been completed.

The tests will consist of RF loop tests where calibration signal generators are modulated with information from either satellite simulators or magnetic tapes. Input signal levels to the RF preamplifiers will be varied in order to obtain dynamic range and threshhold data. The demodulated data will be recorded and played over the microwave links to GSFC where appropriate.

The RF equipment includes low-noise preamplifiers and down convertors. All tracking and data signals are translated down to the 130 to 140 Mc band. General Dynamics/ Electronics Diversity, (GD/E) telemetry receivers are used for all data reception. A post-detection diversity combiner provides a combining action for either the two linear or two orthogonal circular polarization. The diversity receiver has selectable IF bandwidths of 10, 30, 100, 500, 1000, and 3000 kc. The 500 kc bandwidth has replaced the standard 300 kc bandwidth. An Electrac phase demodulator provides coherent place demodulation for the beacon telemetry signal. A predetection diversity combiner provides polarization diversity. Table D-1 lists the setup procedure for the Electrac phase demodulation.

The setup procedures for beacon telemetry are as follows:

1. Use standard station procedure to check meter calibration for phase modulation.

2. Set the modulation sensitivity control on the CSG-1 for a peak deviation of 23 degrees using only one subcarrier. Remove this subcarrier.

3. Set the modulation for a peak deviation of 23 degrees by varying the level of the second subcarrier. Remove this subcarrier.

4. Repeat step 3 for the 3rd subcarrier.

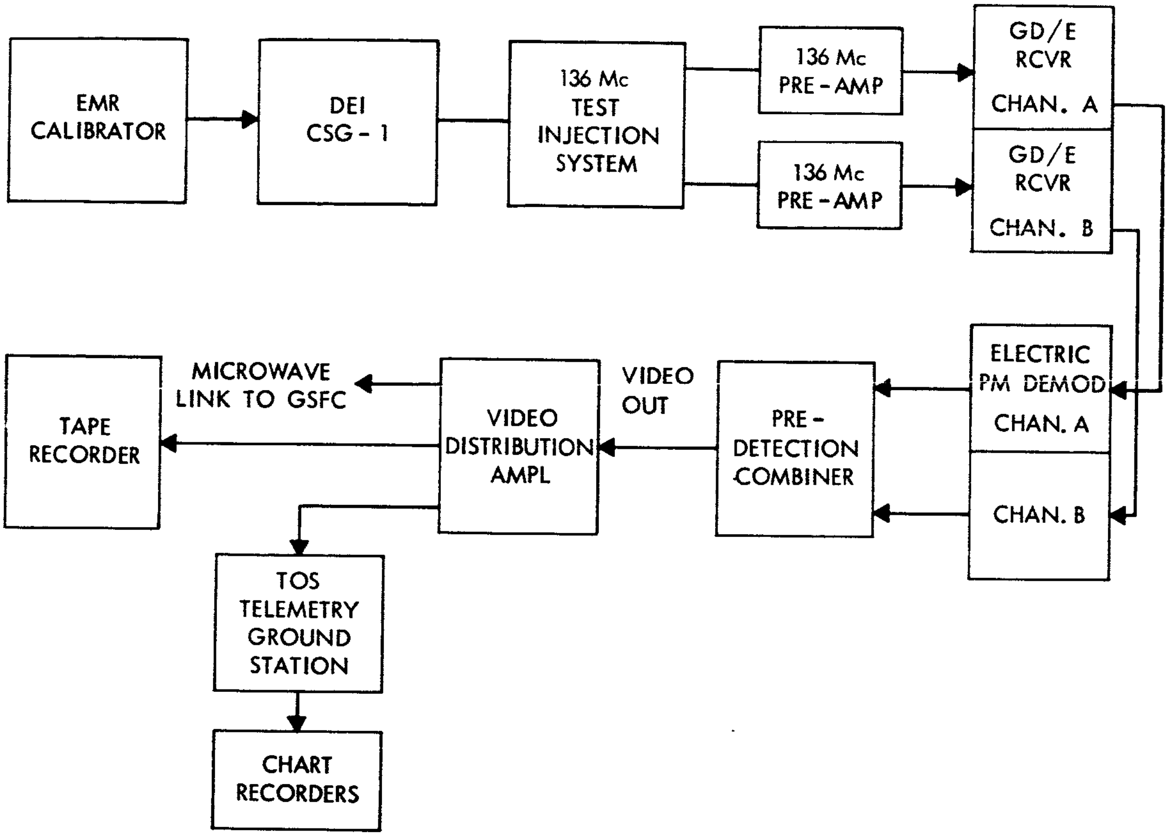

Figure D-4 — Beacon Telemetry, Block Diagram

Table D-1

Setup Procedure, Electrac Phase Demodulator

Tracking BW	30 CPS
Calibrate	OPR
BW KC Demodulator	15
Demodulator Selector	on
AGC Seconds	0.3

5. Inject all subcarriers into the CSG-1.

6. Set the CSG-1 output power alternator for a signal level of 75 dbm into the 136 Mc preamplifiers.

7. Transmit this data over the microwave link to GSFC.

8. Repeat step 7 for an input signal level of -105 dbm.

9. Repeat step 7 for an input level of -110 dbm.

10. Repeat step 7 as the input signal level is reduced in 2 db steps. Record the system threshold level.

Figure D-4 is a block diagram of the beacon telemetry RF loop test.

The beacon and telemetry information is received on a 136.77 phase-modulated carrier. Three SCO's in the satellite simultaneously modulate the carriers. The General Dynamics Electronics (GD/E) diversity receiver in conjunction with the Electra phase lock demodulator will be used to receive and demodulate the PM data. The EMR calibrator in the telemetry ground system will be used to modulate the DEI CSG-1 calibration signal generator. The signal generator RF output will be fed through the test injection system into the receiving system. The output of the Electrac phase demodulator diversity combiner will be fed to the CDA ground station on site and at GSFC by the microwave link.

The setup procedure for the GD/E diversity receiver is listed in Table D-2;

Table D-3 shows the Mod I telemetry receiver setup at Lima.

1.3 VIDEO SECTION

The video section includes all equipment assocated with the production of AVCS TV pictures and a video simulator. The output of the diversity combiner is a frequency-modulated subcarrier which is deviated between 72 kc and 120 kc at a rate up to 60 kc, and a 9.6-kc subcarrier containing the flutter and wow information. The two bandpass filters separate the video signal from the flutter and wow frequency, and the video subcarrier frequency is then doubled without affecting the video baseband (60 kc). The video can be processed at the CDA stations to provide back-up to NESC for engineering analysis and to permit equipment checks and alignment. The station equipment includes a polaroid camera to provide the capability of reading out selected frames.

Table D-2

Setup Procedure, GD/E Diversity Receiver

	Beacon Telemetry	AVCS-TV
Frequency Selectro Switch	136.77 Mc	135 Mc
Bandwidth Switch	30 kc	500 kc
Mode Selector	---	FM
Analog Tuning Selector Switch	STD	STD
Gain Control Mode	AGC	AGC
AGC Speed	300 m sec	300 m sec
Signal Calibrator	OFF	OFF
BFO function	OFF	OFF

Table D-3

MOD I Telemetry Receiver, Lima

FREQ.	136.77 Mc
IF BW	30 kc
IF MODE Switch	10 cps
Receiver Function Switch	REC
BFO	OFF

The AVCS camera and its associated electronics provide a baseband signal which has a bandwidth of approximately 0 to 60 kc. This signal frequency-modulates a 96-kc subcarrier (peak deviation of 24 kc) (Figure D-5). The spacecraft transmitted signal consists of a 96-kc subcarrier along with a 9.6 kc flutter-and-wow correction tone that, in turn, frequency-modulates the 235 Mc TV transmitter.

To simulate this condition, a magnetic tape and a video simulator have been provided which contains a composite signal consisting of both the modulated 96-kc subcarrier and the flutter-and-wow correction tone.

The video information recorded on the magnetic tape will be used to modulate a Booton 202-J FM signal generator. The RF output of the signal generator is fed through the 235 Mc test injection network into the receiver system. The FM demodulated output of the GD/E receiver is recorded and then played down the microwave link to GSFC at 1/8 speed followed by a direct transmission from the Video Simulator.

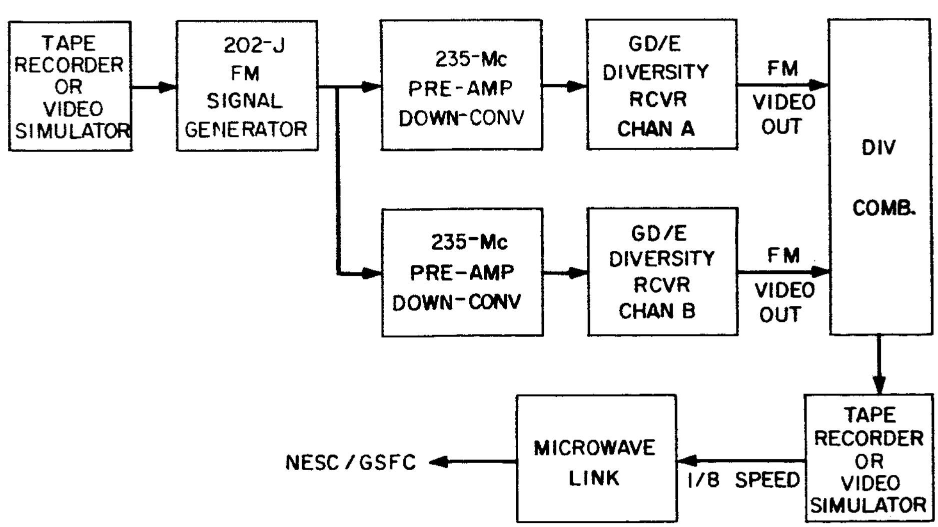

Figure D-5 — AVCS Block Diagram

There are four TOS/AVCS video simulators, one for each CDA station, another at NESC and the fourth unit at RCA for spacecraft testing. The TOS/AVCS video simulator is a precision piece of test equipment and has been designed and will be operated as a device for testing the video handling portion of the TOS ground stations including the long lines. The signals generated will correspond to those normally present at the inputs to and the outputs from the video processor and flutter and wow processor; the output of the video demodulator; and the outputs of the Grand tape recorder when replayed at speeds corresponding to $7\frac{1}{2}$ and 30 inches/second. A separate channel will provide a signal to simulate the inputs to the spacecraft transmitter.

The outputs from the simulator will be in the form of an analog video signal, a frequency modulated video carrier, a flutter and wow modulated carrier and a combined video and flutter and wow channel. It will be possible to inject noise into the signal channels and to insert flutter and wow modulation from an external source.

There are four selectable test patterns as simulator output. They are:

a. Vertical bar
b. Stairstep
c. Crosshatch
d. Constant grey

Between 400 and 800 lines can be displayed when the vertical bar pattern is selected.

Detailed performance specifications, operator control, mechanical design, and limitations of the TOS/AVCS Video Simulator may be found in the following documents.

1. RCA R65-101 Requirements Specifications for TOS/AVCS Signal Simulator.

2. Addendum to TOS Instructions and Operating Handbook.

Topics of the Addendum will be supplied to all organizations and units concerned with the operation of and the results from the video simulator.

Inputs to the simulator are as follows:

a. Flutter and Wow Modulation
b. Video Noise Input
c. Video Carrier Noise Input
d. Flutter and Wow Carrier Noise Input
e. Combined Noise Input

The simulator shall operate from 115V ± 10%, 60 cps ± 1 cps supplies. The total power consumption will be less than 250 watts.

Table D-4 lists the FM signal generator setup procedures.

Table D-4

Setup Procedure, 202-J FM Signal Generator

Frequency	235 Mc
MOD Meter	FM
DEV kc	300
INT MOD	OFF

The setup procedures for AVCS are:

1. Modulate the 202-J FM signal generator with the composite video signal derived from the tape recorder (or Video Simulator)

2. Turn on the tape recorder (or Video Simulator) and set the modulation control on the 202-J for a maximum frequency deviation of 120 kc. The deviation will vary as a result of the variable modulation components contained on the tape. Rewind the tape when this setup has been completed (or put Video Simulator in standby)

3. Set the 202-J output power level for an input signal level input of -80 dbm into the RF pre-amplifier

4. Turn on the tape recorder (or Video Simulator) that modulates the 202-J. Record the output of the GD/E receiver on the tape recorder

5. Repeat setps 3 through 5 for an input level of -90 dbm

6. Repeat steps 3 through 5 for an input level of -95 dbm

7. Repeat steps 3 through 5 for input signal level increments of 2 db until threshold is determined

8. Play the recorded data over the microwave link to NESC-GSFC at 1/8 speed

9. Set Video Simulator to "Slow Time 2." Connect video and flutter and wow carrier outputs to the microwave link.

10. Turn on Simulator and serially transmit 693 and 792 resolution patterns, a gray scale raster and a crosshatch raster.

1.4 COMMAND SECTION

In the command section, punched-tape is fed into the tape reader. The digital command programmer generates the digital codes determined by the tape and by other inputs. The outputs of the digital command programmer are a frequency shift keyed (FSK) command tone and a spacecraft enable tone, which is suitable for driving the command transmitter. The transmitted commands and the verification data (decoded commands retransmitted by the spacecraft on a beacon channel) are compared automatically. Performance of the command section is checked and verified by a spacecraft-type receiver-decoder combination, which receives the RF signal from the command antenna and provides decoded commands to the comparator. Successful comparison with the output of the digital command programmer ensures proper ground station operation.

Commands are received at the CDA station by means of a teletypewriter which provides a punched tape (each station can also make a command tape with its own teletype equipment). The tape uses a 5-level code; the complete command-sequence tape is inserted in the tape reader. The tape reader begins to advance the tape and reads upon receipt of a pulse from the alarm timer. Upon reading a command, the tape reader causes the digital command programmer to generate a sync pulse, an address, and the command. After an interval determined by internal electronics, the entire message is transmitted, and the tape advances to read the next command.

The command systems tests are used to check the interfaces between the TOS CDA station and the command transmitter in the DAF ground station. A test of command transmitter interference on the beacon telemetry will also be made. Arrangements will be made to radiate into space while the telemetry signals are being simulated in a system loop test. Figure D-6 is a block diagram of the command transmitter interference test.

The command transmitter test is conducted as follows:

Set up the beacon telemetry system as in part 1 through 7 of the Setup

Procedure, Beacon Telemetry

Modulate the command transmitter. Set the modulation percentage for 90 percent on one tone from the command programmer

Transmit into space while processing beacon telemetry data. Record the loss of data in the beacon telemetry system

Polarization circular

1.5 TRACKING (85-FOOT DISH)

Antenna polarization circular

Receiver mode - closed loop

Receiver bandwidth - 100 cps

2. WALLOPS STATION, VA. (WALOMS)

The WALOMS antenna was bought by ESSA and is being erected by GSFC T&DS. T&DS has contracted for design and installation of the entire facility, including site development and construction, additional instrumentation, test equipment, spares, and engineering services, using ESSA funds, T&DS will supervise training of ESSA maintenance and operating (M&O) personnel; ESSA will operate the station.

Target date for beginning WALOMS system checkout is March 1, 1966. Existing antenna facilities at Wallops Station may be used for interim operations. ESSA-supplied M&O personnel, backed up by on-site GSFC and other personnel, will operate the station after

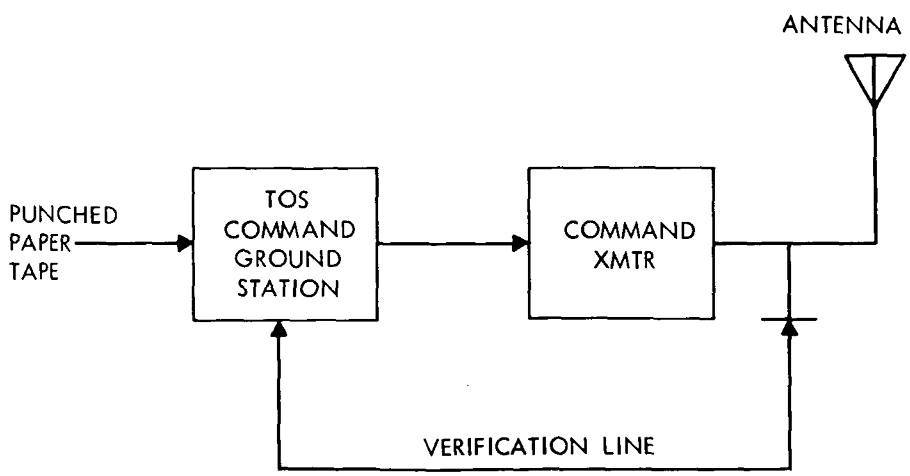

Figure D-6 — Command Transmitter Interference Test, Block Diagram

March 1, 1966. Four weeks of final acceptance testing will begin that same date on a noninterference basis with critical TOS orbits. GSFC contractor will assist in training of ESSA staff as agreed by separate negotiations. NASA will supply to ESSA all plans, a reproducible copy and one additional copy of "as-built" drawings, system and equipment manuals, wiring diagrams, and specifications used by NASA in the design and construction of the facility.

A detailed description of WALOMS is given in the GSFC Data System Development Plan (DSDP), titled TOS U.S. Antenna CDA Station, dated December 30, 1964. WALOMS includes:

A solid-surface hydraulically driven 85-foot-diameter parabolic antenna with an X-Y gimbaling mechanism, having an overall height of approximately 120 feet, a focal length of 36 feet, and weighing approximately 350 tons

Electronic equipment, consisting of receiving systems for both tracking and data acquisition, antenna data systems, servo-hydraulic drive and control system, collimation system including optical system, and TOS unique equipment interface terminals

Communications equipments and facilities, including data-transmission systems

An emergency power plant

A single-story operations building with basement, having a ground-level floor area of approximately 4500 square feet; a single-story building with an area of approximately 2000 square feet to house the emergency power plant equipments and miscellaneous utilities.

Driveway, aprons, parking area, sanitary facilities, etc.

Figure D-7 indicates the extent of the keyhole for a standard pedestal orientation in which the X (lower) axis is aligned north-south. A spacecraft in the direction of N 0°E at an angle above the horizon of less than 12.3 degrees cannot be acquired along the centerline of the major lobe of the antenna. In the direction of N 90°E, a spacecraft must be at least 3 degrees above the horizon to allow signal acquisition. The minimum look-angle above the horizontal plane at other azimuth angles can also be determined. Based on the site location at Wallops and the critical TOS orbits, an optimum orientation of the X axis has been determined to be N 0°E, and the antenna will be installed with that alignment.

The antenna is capable of tracking at rates up to 3 degrees per second, with an acceleration not exceeding 5 degrees per second squared. The design of the antenna provides for braking and for five operational modes:

Automatic track on a spacecraft signal; the severity of the multipath transmission effects which will be present during the critical orbits of TOS is expected to preclude the use of this operational mode when the spacecraft is less than approximately 10 degrees above the horizontal plane

Program track, using teletype drive-tape input derived from orbital predictions furnished the station via TOC

Manual position and manual velocity modes, in which the rate and motion of the antenna are controlled by the ball-tracker device.

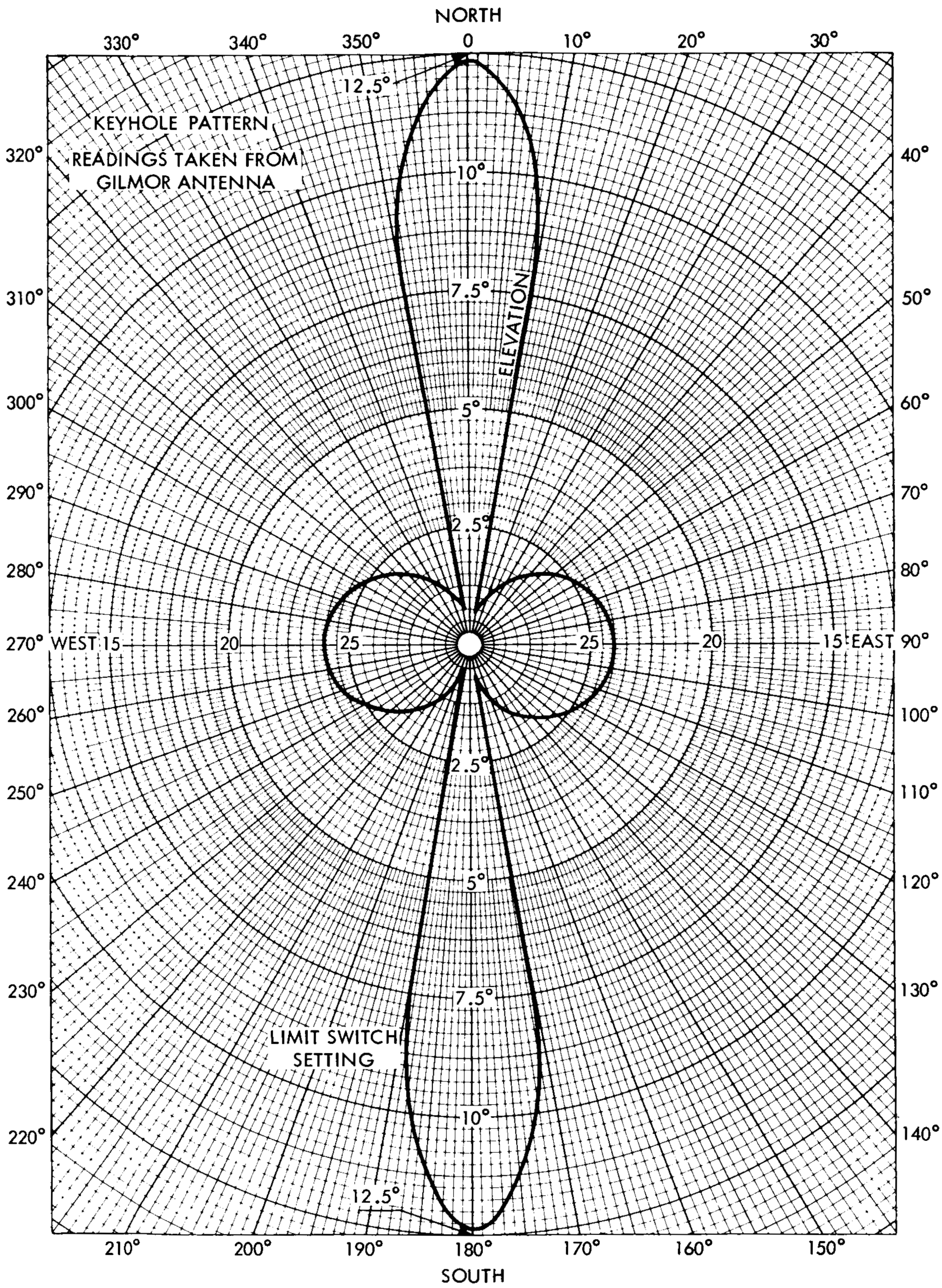

Figure D-7 – WALOMS Antenna Keyhole Pattern

Slaved drive, in conjunction with an acquisition aid system which supplies synchro information generated by the acquisition aid antenna equipments

Search mode, which can be superimposed over all modes of operation except the manual velocity mode

In the programming function a perforated tape containing precomputed orbital information transmitted from TOC is applied to a tape reader. Antenna position and timing commands read from the tape are used to generate, by interpolation, 1-second drive points, which are converted into analog voltages used to drive the antenna along the predicted orbital path.

The TOS unique equipment is identical to that for GILMOR.

Appendix E

APT STATIONS

The APT ground stations acquire cloud picture data from TOS APT satellites and reproduce them as photographic images on facsimile recorders or other suitable devices. APT ground stations have been installed at ESSA, Navy, Army, and Air Force installations as well as at many international locations and at some private agencies.

TOC will be responsible for producing and distributing APT daily alert and ephemeris prediction messages, which will include the minimum predictive data required by the ground stations to determine the antenna tracking angles to acquire the data from the spacecraft and to geographically orient the acquired pictures. The daily messages will be distributed over national and international meteorological teletypewriter circuits. The format of the daily message and the description of its use is contained in the APT User's Guide.

Detailed instructions on determining the antenna look angle for acquiring data from the spacecraft as well as procedures for geographic orientation of the pictures are also contained in the APT User's Guide.

Operational evaluation of the APT system by selected APT ground stations will be requested during the checkout of the system by TEC and later during the lifetime of the satellite as deemed necessary by TOC. These later requests will be initiated by TOC through the national and international meteorological teletypewriter networks. The APT Pass Summary and Evaluation Report (Table IV-8) will be completed as requested by TOS whenever the APT TOS satellite is programmed for pictures in range of the APT station.

The APT User's Guide will be distributed to World Meteorological Organization members and will be available from the Government Printing Office, Washington 20025, D. C.

Appendix F

TOS EQUIPMENT

TOC has the capability of receiving and tape recording data from both ground stations simultaneously, however the display of data on Brush recorders can only be performed one station at a time. Video data from both CDA's can be relayed simultaneously through the TOSCOM and processed in DAPAF.

The equipment used in TOC is:

- Ampex tape recorder
- 8 channel Brush recorder
- 2 channel Brush recorder
- 20 channel Esterline Angus recorder
- Test and calibration equipment for the above
- APT antenna and receiver

Communications facilities and responsibilities of the TOS communications (TOSCOM) system are:

- 304 voice switching network and control
- TTY to CDA's and TEC
- Control of wideband data lines

Figure F-1 is the layout at NESC; DAPAF is described in the NESC TOS Data Utilization Plan.

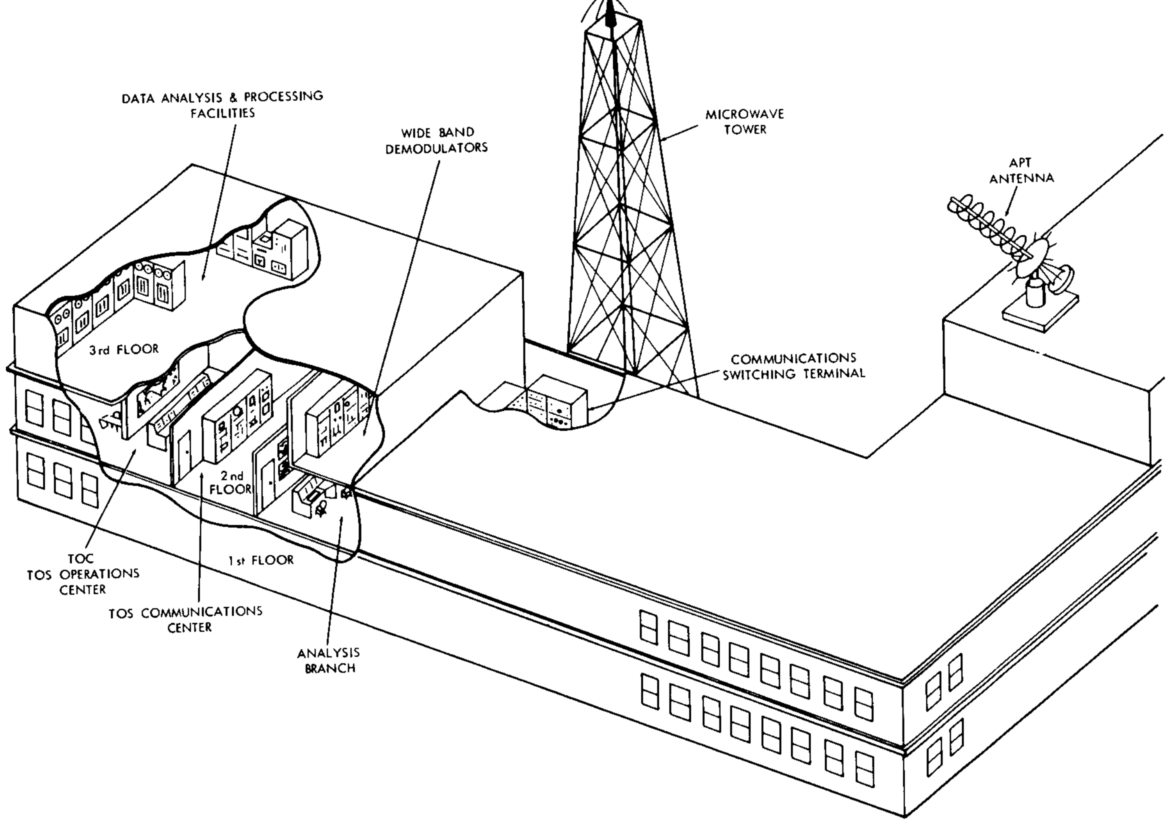

Figure F-1 — NESC, Wing O FOB 4, Suitland, Md.

Appendix G

TEC

1. TEC EQUIPMENT

The equipment in TEC will consist of recorders, processing and display devices which will enable the TEC crew to perform effectively during the launch and checkout phases of the TOS system.

All data signals which arrive at TEC will be recorded on magnetic tape. Most information, such as beacon data, V-scan, telemetry, etc., will be displayed in real time on chart recorders for instantaneous monitoring. Recording equipment includes:

- Tape recorders:

  Mincom or equal - Video data
  Ampex - Analog data

- Brush 8-channel recorder - telemetry
- Brush 2-channel recorder - V-scan
- Esterline Angus 20-channel recorder - events
- APT facsimile recorder

Other information such as the slowed-down video data and the flutter and wow signal will be recorded on the video tape recorder at 7-1/2 ips and played back at 60 ips. The AVCS video signal will be processed and displayed in the kinescope rack complex. Polaroid pictures will enable an analysis of picture quality, timing, interference, etc., by TEC personnel. The APT video signal can be obtained by the CDA stations and transmitted to TEC in the same manner, however, normal test procedures at TEC will be to use the installed APT ground station to obtain pictures for analysis.

The beacon information will also be processed by an analog to digital converter and the digital signals recorded on magnetic tape. This digital tape is then fed directly into a computer for a complete tabulation of telemetry information, attitude determination and predictions, and other spacecraft criteria which are used by TEC in their evaluation of TOS spacecraft.

Additional TEC equipment includes:

- Data processing equipment
  Telemetry calibrator
  Balanced line amplifiers
  Discriminators
  Scanner receivers
  Switching unit

- Test equipment. All other equipment assigned to TEC, not of an operations use, is to be considered test equipment

- APT ground station

- Station switching and control rack
- 2 M-28 R/O and 3 M-28 ASR TTY's
- Analog to digital converter with magnetic tape recorder (in procurement)

2. FUNCTIONAL STRUCTURE

The TEC functional structure is shown integrated with TTCC in Figure G-1.

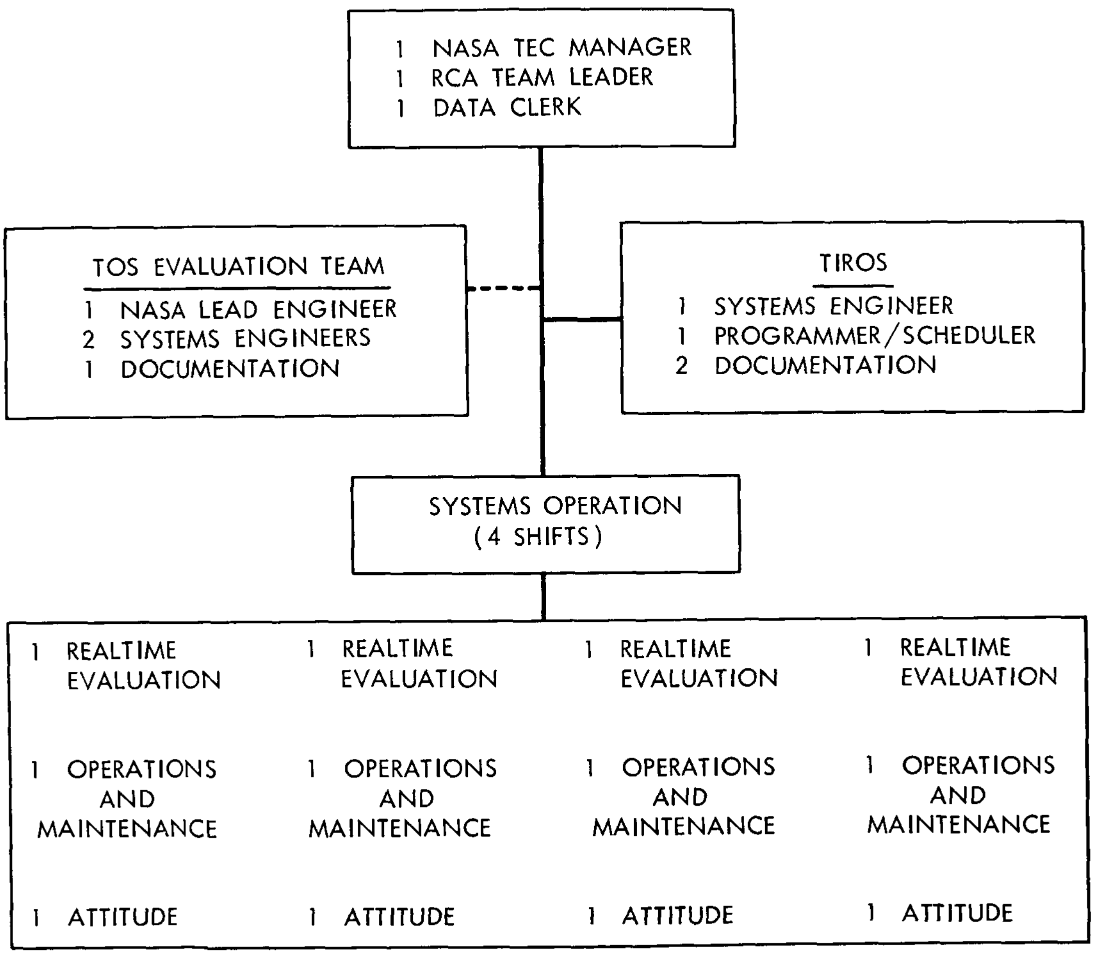

Figure G-1 — TEC Functional Structure

Appendix H

GROUND COMMUNICATIONS

1. COMMUNICATIONS LINKS

The communications links for the TOS ground system include wideband video, alternate TTY/voice, narrowband data, and voice channels (Figure H-1).

2. COMMUNICATION FACILITIES

The TOS communications will have X-136 wideband terminals to receive all data from WALOMS and GILMOR. The X-136 terminals are part of a 48-kc broadband communications system for TOS. The channel assignments are as follows:

Channel A - 24 kc - Video
Channel B - 4 kc - Beacon
Channel C - 4 kc - Flutter and Wow
Channel D - 4 kc - FSK Multiplex
Channel E - 4 kc - Alternate voice/Teletype
Channel F - 4 kc - Voice
Channel G - 4 kc - Voice

3. GSFC SUPPORT COMMUNICATIONS FOR LAUNCH AND CHECKOUT

The NASA communications (NASCOM) global network provides ground communications support for all NASA spaceflight programs. These communications facilities, in conjunction with the 304 switching unit at NESC, will be used for launch and checkout and STADAN coordination.

Communications links to all participating stations will be provided as required via NASA Communications Division's facilities (in combination with ESSA facilities).

4. NESC COMMUNICATION FACILITIES

NESC will operate the TOS Communications (TOSCOM) net.

4.1 LONGLINE SYSTEM

For the operational system, 48-kc data channels from GILMOR and WALOMS will be operated by NESC. The TOS terminals at WALOMS and GILMOR will consist of one X-136 send/receive terminal and a hot spare, which can be switched onto the 48-kc wideband link connecting the TOS station and NESC if the primary terminal fails. This terminal, although full-duplex, will usually operate with WALOMS and GILMOR to send spacecraft and station events data to NESC. NESC will transmit operational instructions, programming data, and other data as necessary to WALOMS and GILMOR. GSFC will be suitably bridged to receive WALOMS and GILMOR data transmission and all transmissions from NESC for spacecraft and system evaluation. Offutt AFB will have two X-136s to receive only.

4.2 NESC X-304 VOICE COMMUNICATIONS

Three exterior two-way voice circuits between the 304 patching and switchboard at NESC and TEC will be used for voice communications. These circuits can be patched to any station in the TOS system through the Suitland 304 board.

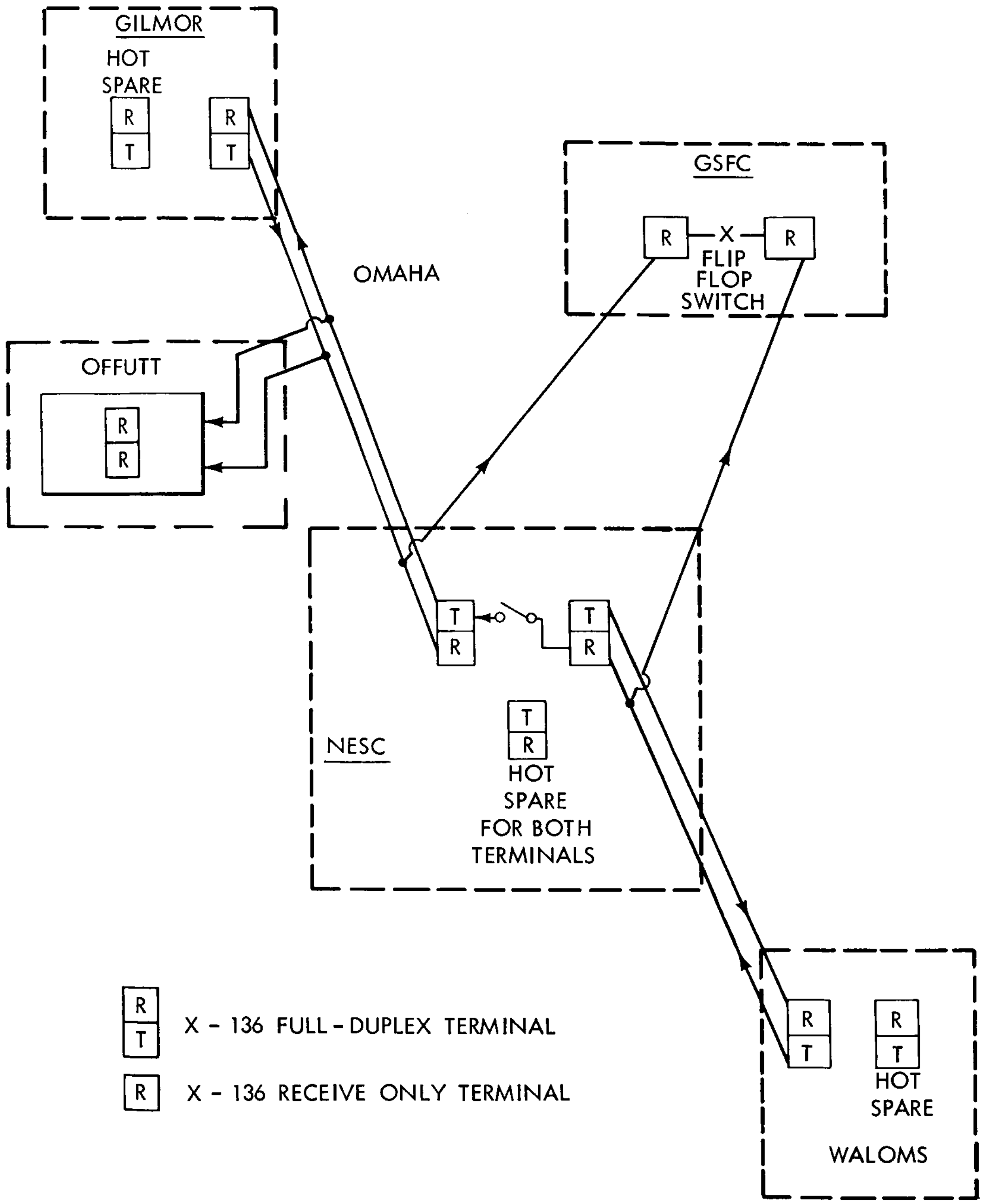

Figure H-1 — Wideband Communications

A two-way voice tie-trunk with disable feature will interconnect the SCAMA switchboard at GSFC with the 304 switchboard during prelaunch, launch, and checkout phases.

DIRECTORY

This directory includes a GSFC organization chart (Figure I-1) and a list of individuals and their offices and phone numbers. All persons are at GSFC unless listed as elsewhere.

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Turnbull, H. A., Code 530

Vaccaro, M. J., Dr., Code 200
Varson, W. P., Code 506

Wasielewski, E. W., Code 100
Werking, R. D., Code 547
White, W. A., Code 614
Wiley, T. N., Code 571
Wright, R. L., Code 247

Young, T. C., Code 570

Zavos, B., NESC
Zeman, J., ULO/KSC

Tracking Stations: via C. Bock, Code 530, Operations Support Office

COLEGE (6)
FTMYRS (6)
GILMOR (10)
JOBURG (10)
KANO (2)

KAUAI (2)
LIMAPU (6)
MADGAR (2)
MOJAVE (6)
NEWFLD (6)
ORORAL (10)

QUITOE (10)
ROSMAN (10)
SNTAGO (10)
ULASKA (10)
WNKFLD (6)