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THE OPERATION OF THE NOAA POLAR SATELLITE SYSTEM

Joseph J. Fortuna
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Office of Systems Integration
Washington, D.C.
November 1974

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Frederick B. Dent, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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CONTENTS

Abstract 1

Section 1. Introduction 2

Section 2. The NOAA polar orbiting satellite 4

2.1. Satellite description 5

2.1.1. The NOAA polar satellite launch vehicle 10

2.1.2. NOAA polar satellite orbit characteristics 10

2.1.3. Satellite subsystems 12

2.1.3.1. Scanning Radiometer (SR) 14

2.1.3.2. Very High Resolution Radiometer (VHRR) 17

2.1.3.3. Vertical Temperature Profile Radiometer (VTPR) . 19

2.1.3.4. Solar Proton Monitor (SPM) 22

Section 3. NOAA polar satellite operational system 23

3.1. Satellite Operations Control Center (SOCC) 23

3.2. Data Processing and Analysis Division (DAPAD) 28

3.2.1. DAPAD operations 29

3.2.2. DAPAF satellite housekeeping telemetry processing 32

3.2.2.1. Real-time telemetry data processing 33

3.2.2.2. Globally stored telemetry data processing . . . 33

3.2.3. DAPAF satellite attitude determination processing 36

3.3. Command and Data Acquisition (CDA) stations 38
3.3.1. Functions of the CDA stations 38
3.3.2. CDA station equipment 38
3.3.3. CDA ground station operations 40
3.4. NOAA Satellite Communications Network (SATCOM) . . . 50

Section 4: Direct broadcast services 55
4.1. The Automatic Picture Transmission (APT) service . . 55
4.1.1. Description of the SR-APT images 56
4.1.2. Functional description of a typical APT ground station 57
4.1.2.1. The SR-Video baseband signal characteristics . . 57
4.1.2.2. The APT receiving system for SR data 58
4.1.2.3. The typical APT display system for SR data . . . 60
4.1.2.4. Proposed correction for image panoramic distortion 62
4.1.2.5. SR-APT information bandwidth and baseband filtering 63
4.1.3. Operational inputs to APT stations from NESS . . . 64
4.2. The High-Resolution Picture Transmission (HRPT) service 64
4.2.1. HRPT ground station design guidelines 65
4.2.2. Functional description of NESS HRPT ground stations 67
4.2.3. The HRPT Sectorizer image processing 69
4.2.4. Products of the NESS HRPT service 71
4.2.5. Operational inputs to HRPT stations from NESS . . 72
4.2.6. Outlook for the HRPT system 72
4.3. Direct broadcast of VTPR and SPM data 73
4.3.1. Satellite data processing and transmission 73

4.4. Direct broadcast VTPR ground receiving system . . . 74
4.4.1. Reduction of direct broadcast VTPR data 76
4.4.2. Operational inputs from NESS to local VTPR users . 79
Section 5: Central services - NOAA polar orbiting satellite system 80
5.1. Ingest system 80
5.1.1. Ingest system hardware 80
5.1.2. Ingest system operation 85
5.1.2.1. Ingest of SPM, VTPR, and recorded telemetry . . 85
5.1.2.1.1. VTPR output 87
5.1.2.1.2. SPM output 87
5.1.2.1.3. Telemetry 87
5.1.2.2. The ingest of SR data 88
5.1.2.2.1. Quality control 90
5.1.2.2.2. Real-time SR ingest 90
5.1.2.2.3. Stretched/gridded image processing 91
5.1.2.2.4. Reduction of SR attitude data 91
5.1.2.3. Beacon data 91
5.1.2.4. Ingest of VHRR data 92
5.2. The DAPAF central processing system 93
5.2.1. DAPAF central processing system hardware 93
5.2.2. DAPAF central processing system software 96
5.2.2.1. SR data processing 96
5.2.2.1.1. Major functions of SR processing 97
5.2.2.1.2. Normalization and calibration 100
5.2.2.1.3. Enhancement 101

5.2.2.1.4. Earth location 101

5.2.2.1.5. Mapping and gridding 103

5.2.2.1.6. Sea-surface temperature processing 105

5.2.2.2. VTPR data processing 107

5.2.2.2.1. Overall data flow 107

5.2.2.2.2. Geographical location of data 110

5.2.2.2.3. Calibration procedure 111

5.2.2.2.4. First-guess field 111

5.2.2.2.5. Procedures for obtaining clear radiances (CLRAD) 112

5.2.2.2.6 Retrievals 112

5.2.2.2.7. Data outputs and archives 117

References 118

Appendix A: Glossary 120

Appendix B: The National Environmental Satellite Service--An Organization Description 126

FIGURES

2-1 The NOAA polar satellite 6
2-2 Satellite orientation 8
2-3 Earth sensors fields of view 9
2-4 SR instrument 15
2-5 SR output 16
2-6 VTPR instrument 21
3-1 NOAA operational system elements 24
3-2 Operational data flow 26
3-3 DAPAF digital data handling system 31
3-4 Digital Data Processor (DDP) ingest system 35
3-5 CDA major subsystem block diagram 39
3-6 Number of blind orbits on alternating days 42
3-7 Reliable acquisition periods as a function of ascending node 43
3-8 CDA station, functional block diagram 46
3-9 Generalized NOAA system concept 51
3-10 SATCOM wideband microwave link 53
4-1 APT baseband signal 59
4-2 SR-APT ground receiving and display system 61
4-3 NESS HRPT ground station 68
4-4 HRPT signal characteristics 70
4-5 Digital data frame and message structure 75
5-1 Digital Data Handling System 81
5-2 Telemetry subsystem, block diagram 83

5-3 Ingest sequence for single orbit 86

5-4 SR data ingest functions 89

5-5 NOAA computer complex, initial system configuration . 94

5-6 NOAA computer complex, final system configuration . . 95

5-7 SR data processing, overall data flow 98

5-8 SR CDC 6600 software 99

5-9 Flow diagram for sea surface temperature computation model 106

5-10 VTPR software system 108

5-11 VTPR processing (ITOS-D) 109

B-1 NESS organization chart 127

TABLES

3-1 ITOS ground communications 52

3-2 SATCOM wideband circuit 54

4-1 SR-APT VHF link analysis 60

4-2 HRPT link analysis 66

4-3 VTPR small terminal link calculation and parameters . 76

4-4 Suggested VTPR ground station equipment 77

5-1 Summary of daily central computer processing 97

THE OPERATION OF THE NOAA POLAR SATELLITE SYSTEM

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ABSTRACT. The operation and maintenance of the NOAA Polar Satellite System involves a great variety of activities in many locations throughout the United States of America. This report is to summarize this system and to provide interested people with a perspective of the operational NOAA polar orbiting satellite system. The NOAA polar system description serves as a reference for developers of short-range modifications of the system. This system description serves as a guide as to how services are generated for users of the system's output. This report is primarily for use within the National Environmental Satellite Service and its parent organization, the National Oceanic and Atmospheric Administration. A glossary of terms is included for those less familiar with the system. The reader is cautioned that the system is described either as it was or was intended to be with the introduction of the third operational spacecraft NOAA-3 in the late fall of 1973. Specific plans to update this document in the future have not been made; however, your comments on the document and its need for revision are welcome.

Section 1

INTRODUCTION

The NOAA Polar Satellite System is a major component of the National Environmental Satellite System. The system is operated and maintained by the National Environmental Satellite Service (NESS). The polar system described in this document is the operational satellite "NOAA." In addition to the NOAA system, the operational system includes a geostationary satellite system, which will be described in future publications. The operational environmental satellite system is intended to provide global data on the Earth's environment regularly and reliably each day. The capabilities of the system enable the National Oceanic and Atmospheric Administration (NOAA) to:

a. Monitor the environment day and night, and

b. Broadcast medium- and high-resolution data directly to local ground stations within radio range of the satellite.

These capabilities provide the basis for environmental services that benefit the public by contributing to the commerce of the nation and to the safety of its citizens. The environmental fields served are meteorology, oceanography, hydrology, and space environment.

To the field of meteorology, the polar system provides input data for numerical weather prediction. Numerical weather forecasts are computed in large-capacity electronic data processors using mathematical models of the atmosphere. Processed data retrieved from the NOAA Vertical Temperature Profile Radiometer (VTPR) are a major source of input for the numerical models.

Polar satellite data also are used in aviation meteorology for the prediction of temperatures, for cloud identification and location, and for wind measurement. The data also support marine meteorology, providing enroute weather information and information for forecasting sea conditons.

For oceanography, the retrieved satellite data provide information on sea-surface temperatures and ice-field conditions.

The satellite data also are useful in the identification of snow and ice-fields and other water features for hydrology services.

The Earth's space environment also is monitored by sensors aboard the NOAA polar satellite. These sensors monitor energetic particles, electromagnetic radiation, and magnetic fields near but outside the Earth's atmosphere. These data are used to forecast ionospheric and geomagnetic storms and solar activity.

The total NOAA Polar Satellite System consists of four major elements:

a. A single polar orbiting NOAA satellite,

b. An operations system that includes: Satellite Operations Control Center (SOCC), two Command and Data Acquisition (CDA) stations, a communications network, and a central processing facility (DAPAF),

c. A direct broadcast service that transmits raw environmental data to local users within radio range of the satellite, and

d. A central service to transmit to the users products derived from satellite data.

These four elements of the NOAA system are described in subsequent sections.

Section 2

THE NOAA POLAR ORBITING SATELLITE

The NOAA polar operational satellite, an Improved TIROS Operational Satellite (ITOS), was developed under the guidance of the Goddard Space Flight Center ITOS Project. The ITOS satellite is an outgrowth of NASA's TIROS meteorological development program. The operational name of the ITOS, "NOAA," was assigned by the Department of Commerce. The NOAA satellite, its launch vehicle, its orbit, and its major subsystems are described in this section.

The NOAA polar satellite is a three-axis-stabilized satellite shaped like a rectangular prism. The satellite has a deployable solar array and a momentum wheel that gyroscopically stabilizes the satellite to provide an Earth oriented platform for the environmental sensors. Reaction between the Earth's magnetic field and magnetic-torque devices controls the yaw and roll attitude parameters and total system momentum. A sampled data servosystem with an error input derived from the attitude relation between the satellite and the Earth's horizon controls satellite pitch by momentum interchange between the momentum wheel and the satellite. Passive elements are used for a thermal fence and radiator surfaces; the thermal fence has a variable absorptivity characteristic that changes with Sun angle. The passive temperature control system is augmented by active thermal controls that maintain desired temperatures by varying the radiator surface area. Communications links between the satellite and ground stations include a beacon telemetry link, a command link, and a real-time data link (APT-SR), all in the VHF band, and a real-time data link (HRPT) and a stored data playback link in the S-band. The power supply subsystem is a solar-cell battery-regulator system that provides power for operation of the satellite throughout the 6-month mission design life of each satellite.

The primary environmental sensors acquire Earth cloud cover data in the visible and infrared energy spectra, and vertical temperature profile data. The cloud cover data can be broadcast immediately to local receiving stations and recorded on tape aboard the satellite for later readout to CDA stations. Vertical temperature profile data are tape recorded for later readout. Both Very High Resolution Radiometers (VHRR) are operated in a phased mirror mode. Daytime and nighttime cloud cover data in both the visible and the infrared regions are time multiplexed for direct transmission to VHRR ground stations through the satellite's High Resolution Picture Transmission (HRPT) system. Up to 9 minutes of time multiplexed VHRR data may be stored on a VHRR recorder for subsequent transmission to a CDA station. One of the redundant Scanning Radiometers (SR) provides direct readout of data on both nighttime and daytime cloud cover and cloud top temperatures. The SR visible and infrared data also are transmitted to one of the CDA stations. Both the real-time and the stored SR data are transmitted in a time multiplexed mode. A vertical temperature profile of the atmosphere obtained from the Vertical Temperature Profile Radiometer (VTPR) is recorded globally on a track of the Scanning Radiometer Recorder (SRR) tape for subsequent transmission to a CDA station.

Automatic Picture Transmission (APT) ground stations can receive direct-broadcast SR (APT) data from the NOAA Polar Satellite System. A modification of the APT ground station is required to receive the 48-lines-per-minute (lpm) SR data. The High Resolution Picture Transmission (HRPT) direct broadcast service requires new local-user ground stations. The CDA stations transmit the commands originating at TCC and SOCC to the satellite, and transmit to DAPAF the data received from the satellite under the direction of SOCC. TCC controls satellite operation during launch and initial checkout, and evaluates the operational performance of the satellite. SOCC programs and controls the satellite during its operational phase. NESS processes the data in its Data Processing and Analysis Facility (DAPAF) and distributes derived products.

2.1. SATELLITE DESCRIPTION

Figure 2-1 shows the satellite equipment module (main body), the deployable three-panel solar array, the passive thermal-control fence, the active thermal controllers, and the momentum wheel and scanning mirror assembly. The satellite, including a satellite separation ring for mating the satellite to the launch-vehicle second stage, weighs approximately 334 kg (735 lb). Figure 2-2 shows the satellite orientation and the various panels that make up the satellite. Figure 2-3 shows relationships of the Earth sensor fields of view with the satellite in an operational configuration; the sensor fields of view have enough clearance to prevent interference by other elements on the satellite.

The central equipment module or main body of the satellite is a rectanglular prism with a base approximately 101 by 101 cm (40 by 40 in) and an overall height of approximately 145 cm (57 in). The main body houses the data gathering sensors (VPTRs, SRs,

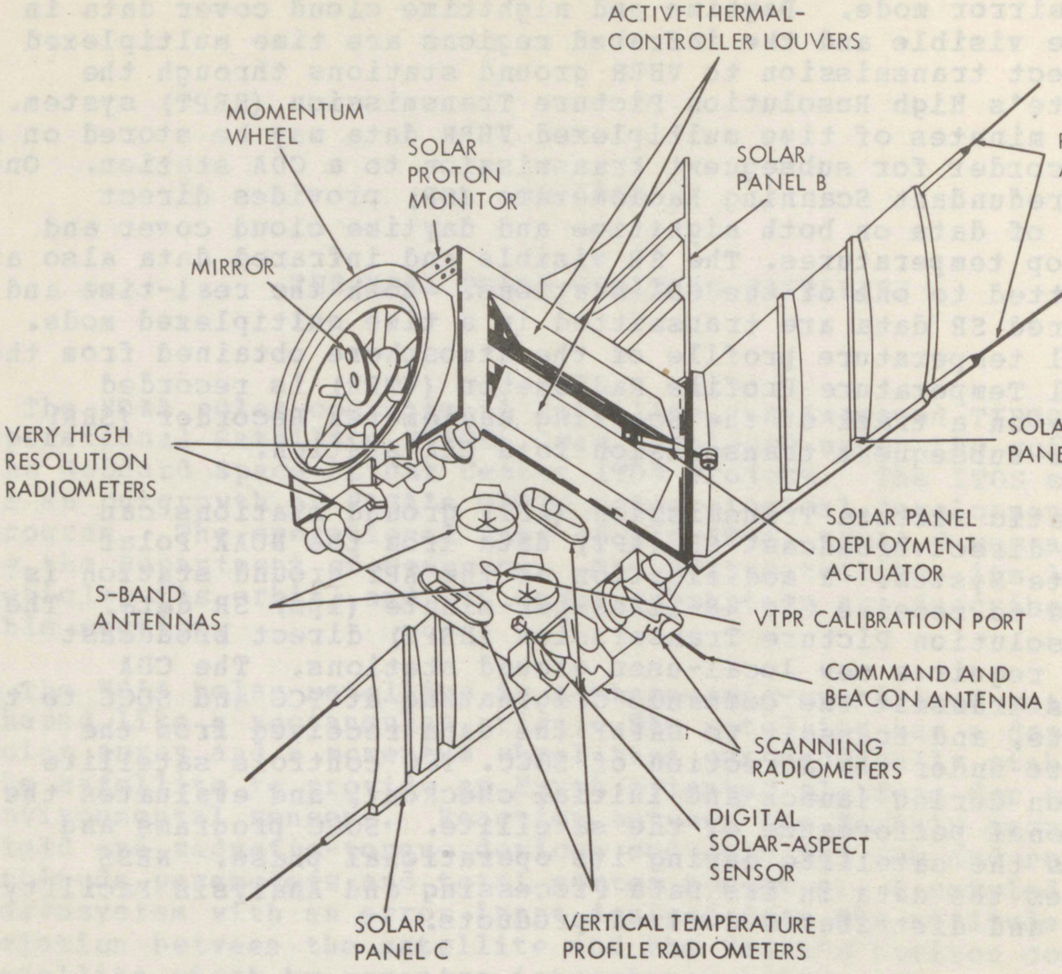


Figure 2-1.--The NOAA polar satellite.

(VHRRs) and associated support subsystems (such as power, command, and communications). The baseplate and two side panels are used as mounting surfaces for the subsystems. To facilitate satellite integration, panels 1 and 3 are hinged to the baseplate so that the three surfaces can be laid flat and the components assembled and checked out electrically before completion of the structural assembly. Access ports in the Earth-viewing and anti-Earth side of the satellite permit minor repairs or adjustments after final assembly. The S-band antennas over the access hole in the Earth-viewing panel are hinged structures that can be rotated out of the way for access to the interior of the satellite.

The solar array consists of three identical panels independently hinged to panels 1 and 3 and the anti-Earth panel of the satellite. Each panel is 92.5 by 165.6 cm (36.4 by 65.2 in) and in mission mode lies in the orbit plane. The panels are slightly curved (fig. 2-2) for adequate clearance during separation of the satellite from the launch vehicle. In launch configuration, the solar panels are folded against the sides of the central equipment module. Following the initial orientation maneuver, squibs are actuated, allowing a spring/hydraulic-damper actuator to deploy each array panel until it is positioned normal to the satellite pitch axis. This configuration permits an unimpeded field of view for all Earth-viewing sensors. Thermal control of the satellite is achieved by using passive and active control elements. The passive elements include a variable solar absorptance thermal fence and fixed radiator surfaces. All radiator surfaces and thermal fence fins are finished with black velvet coating to prevent degradation of optical properties by space radiation. Active control is accomplished with two temperature-controlled, moving louvers on each equipment side that cover or expose radiator surfaces as required. Figure 2-2 shows the location of the louvers on the satellite. The net effect of conduction and radiation coupled to the thermal-control surfaces of the fence and radiators controls internal temperature distribution. Baseplate radiation surfaces keep the high thermal-dissipation units within specifications. Distribution of the radiator area controls internal temperature gradients. Satellite surfaces not used for temperature control are blanketed with insulation to limit radiative heat transfer from these areas.

The pitch-control loop consists of a momentum-wheel assembly (MWA) consisting of a wheel, a direct current drive motor, a scanning mirror, pitch and roll senors, and an associated pitch control electronics unit. The MWA is mounted on the satellite baseplate, with the momentum wheel and scanning mirror exterior to the equipment module (fig. 2-1). The momentum wheel, operating in mission mode at a nominal speed of 150 revolutions per minute (rpm), provides gyroscopic stiffness and acts as a momentum source and sink. At the nominal orbital altitude of 1,464 km (790 n mi), the pitch-control loop keeps one surface of the satellite normal to the local vertical. The pitch-control loop is a first-order sampled-data servo system whose error input comes from redundant IR sensors attached to the shaft of the momentum wheel. A scanning mirror attached to the momentum wheel proper permits the canted pitch sensors to be body-fixed. Roll sensors in this assembly derive their scanning motion from the mirror. The wheel, motor, and sensors are packaged as an integral unit.

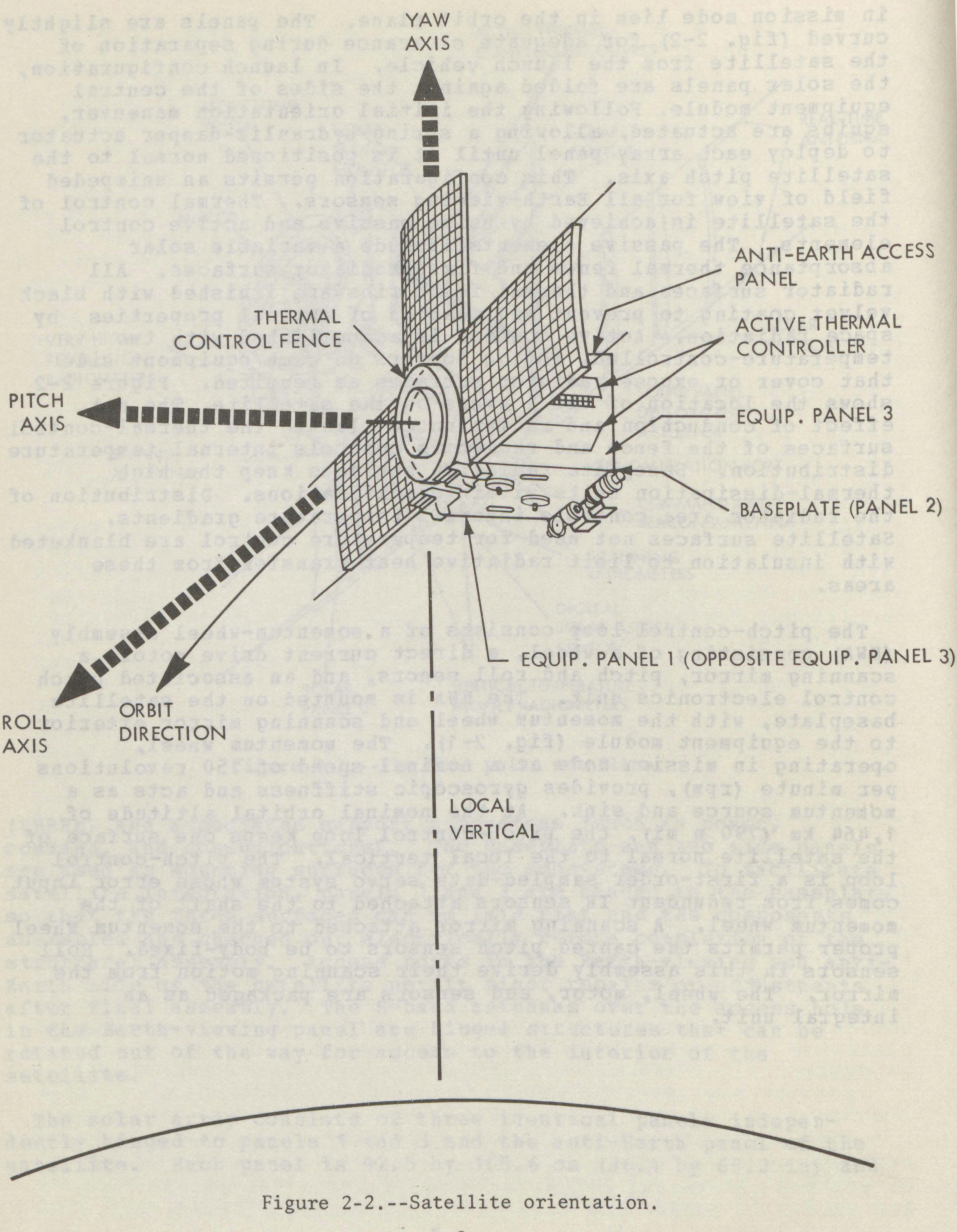


Figure 2-2.--Satellite orientation.

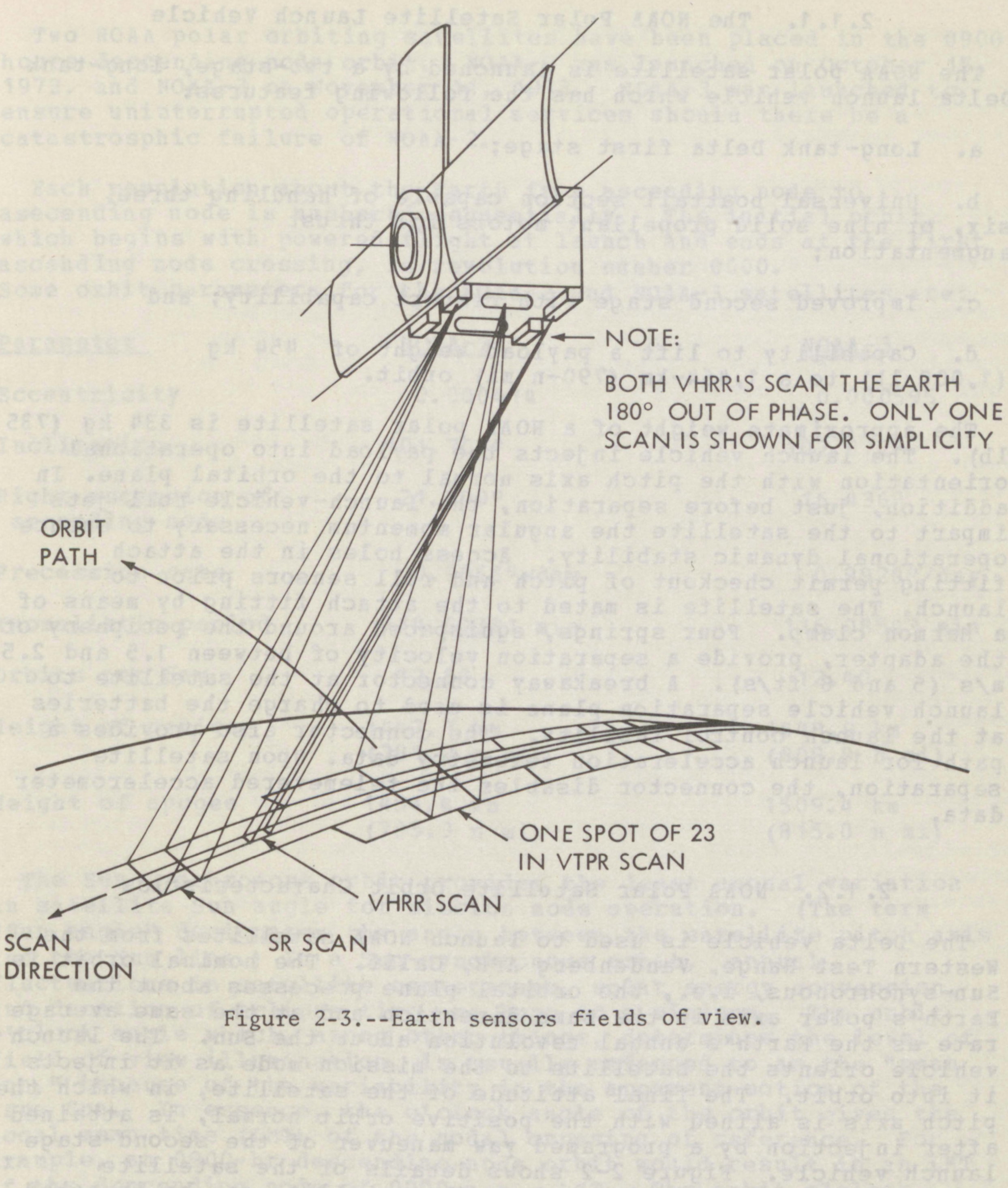


Figure 2-3.--Earth sensors fields of view.

2.1.1. The NOAA Polar Satellite Launch Vehicle

The NOAA polar satellite is launched by a two-stage, long-tank Delta launch vehicle which has the following features:

a. Long-tank Delta first stage;

b. Universal boattail section capable of handling three, six, or nine solid propellant motors for thrust augmentation;

c. Improved second stage with restart capability; and

d. Capability to lift a payload weight of 454 kg (1,000 lb) to a 1,464-km (790-n mi) orbit.

The approximate weight of a NOAA polar satellite is 334 kg (735 lb). The launch vehicle injects the payload into operational orientation with the pitch axis normal to the orbital plane. In addition, just before separation, the launch-vehicle roll jets impart to the satellite the angular momentum necessary to ensure operational dynamic stability. Access holes in the attach fitting permit checkout of pitch and roll sensors prior to launch. The satellite is mated to the attach fitting by means of a Marmon clamp. Four springs, equispaced around the periphery of the adapter, provide a separation velocity of between 1.5 and 2.5 m/s (5 and 8 ft/s). A breakaway connector at the satellite to launch vehicle separation plane is used to charge the batteries at the launch control facility. The connector also provides a path for launch acceleration telemetry data. Upon satellite separation, the connector disables the telemetered accelerometer data.

2.1.2. NOAA Polar Satellite Orbit Characteristics

The Delta vehicle is used to launch NOAA satellites from the Western Test Range, Vandenberg AFB, Calif. The nominal orbit is Sun-synchronous, i.e., the orbital plane precesses about the Earth's polar axis in the same direction and at the same average rate as the Earth's annual revolution about the Sun. The launch vehicle orients the satellite to the mission mode as it injects it into orbit. The final attitude of the satellite, in which the pitch axis is alined with the positive orbit normal, is attained after injection by a programed yaw maneuver of the second-stage launch vehicle. Figure 2-2 shows details of the satellite orientation during mission mode. The satellite can be launched in either of two orbital configurations: an ascending node crossing at 1500 hours or a descending node crossing at 0900 hours local solar time. (The ascending node is the longitude at which the satellite crosses the Equator from south to north; the descending node is the longitude at which the satellite crosses the Equator from north to south.)

Two NOAA polar orbiting satellites have been placed in the 0900 hours descending node orbit. NOAA-2 was launched on October 15, 1972, and NOAA-3 on November 11, 1973. NOAA-3 was launched to ensure uninterrupted operational services should there be a catastrosphic failure of NOAA-2.

Each revolution about the Earth from ascending node to asecending node is numbered sequentially. The initial orbit, which begins with powered flight at launch and ends at the first ascending node crossing, is revolution number 0000. Some orbit parameters for the NOAA-2 and NOAA-3 satellites are:

Parameter	NOAA-2	NOAA-3
Eccentricity	0.000414	0.000595
Inclination	101.707°	102.072°
Right ascension of ascending node	21.499°	16.436°
Precession rate	0.9865°/day	0.9928°/day
Anomalistic period	114.90381 min	116.08543 min
Orbits per day	12.53	12.40
Height of perigee	1447.7 km (781.7 n mi)	1449.9 km (809.9 n mi)
Height of apogee	1454.4 km (785.3 n mi)	1509.4 km (815.0 n mi)

The Sun-synchronous orbit provides the least annual variation in satellite Sun angle for mission mode operation. (The term "Sun angle" designates the angle between the satellite pitch axis and the Sun line.) In a Sun-synchronous orbit, annual fluctuations in satellite temperature, solar energy conversion, and duration of eclipse time are kept to a minimum. The orbit o'clock angle which, among other things, determines the level of field-of-view illumination, is usually referred to as the "mean Sun," because of the variability in the apparent motion of the true Sun. In essence, the o'clock angle of the orbit gives the local mean time (LMT) of the nodal crossing of reference. For example, an 0900-hr descending node orbit would result in an LMT of the descending node of 0900 a.m., LMT. The orbit o'clock angle may also be defined as the difference in right ascensions of the ascending node and the local hour angle of the Sun. At the nominal altitude of 1,464 km (790 n mi), Sun synchronism requires an orbit inclination of 101.7°. For these conditions, the orbit plane rotates eastward at a rate of 0.9857°/day (360/365.24), the value required to maintain a constant angle between the orbit plane and the mean Sun; this configuration is necessary to offset the average angular motion of the Earth as it orbits the Sun. In geographic coordinates, orbit plane rotation corresponds to a westward drift of about 0.25° of longitude/min, causing each successive nodal crossing to occur some 28.8° farther westward.

2.1.3. Satellite Subsystems

Non-sensing functions of the NOAA polar satellite are accomplished by the use of command, vehicle dynamics, thermal, communications, and power subsystems. The communications subsystem includes telemetry, transmitters, antennas, and associated circuits. (Sensor subsystems are described individually in subsequent sections.)

The dual command receiver and the enable-tone detectors of the dual decoder are powered continuously. The command receivers detect and amplify received signals. The outputs of the receivers are passed to their respective associated decoders. Decoder selection is made by ground station transmission of the appropriate command enable tone. (See sec. 3.3.) Detection of the correct enable tone energizes the selected decoder. Receipt and detection of the correct command address directs power to the circuitry of the selected decoder thus permitting subsequent command reception and decoding. As commands are received, verification data are retransmitted to the CDA station via a VHF beacon transmitter to confirm correct receipt of a command. Outputs of the decoder are used to select a programer and a time-base unit. The dual programer provides the signals for all remote sequencing of satellite subsystems such as the recorders and attitude correction subsytems. The dual time-base unit provides all the timing signals and frequencies needed to operate the spacecraft subsystems. The detected command signals are routed to the command distribution units (CDUs) where the commands are converted to appropriate actions. The CDUs also receive inputs from the programers.

The S-band link is used both for real-time VHRR data transmission (called High Resolution Picture Transmission--HRPT) and for transmission of the data stored on magnetic tape recorders. The real-time VHRR signals are placed on subcarriers by the VHRR processor. The outputs of the VHRR processor are connected to the redundant 1.7-GHz S-band transmitters. The remote data are processed by the dual multiplexer, which contains redundant multiplexers that can accept simultaneous inputs from one or two Scanning Radiometer Recorders--SRR--(two SRR data signals and two SRR flutter-and-wow signals), and a VHRR recorder (one VHRR data signal and one VHRR flutter-and-wow signal). The signals are transferred to appropriate channels and combined. The outputs of the redundant mutiplexers are connected to the VHRR processors for cross coupling to the S-band transmitters. Selection of the redundant subsystem is made by powering the selected unit rather than by external signal switching. Each of the two S-band arrays provides right-hand, circularly polarized radiation and has a pattern shaped to maximize the gain at points that correspond to maximum communication ranges. Each S-band antenna consists of crossed dipoles over a ground plane.

The real-time scanning radiometer (Automatic Picture Transmission APT) is broadcast on either of two VHF transmitters, one with a frequency of 137.5 MHz, the second with a frequency of 137.62 MHz. The selection of the operational transmitter is made by command from a CDA station. (Users of this service are normally advised by SOCC at least 3 days in advance of APT transmitter changes.) The output of the energized transmitter is applied to the real-time antenna coupler that provides a quadrature feed for two half- wavelength dipoles mounted on the end of one of the solar panels. The dipoles are configured to provide a linearly polarized directive pattern in a 110° cone centered on the local vertical.

The command RF carrier in the 148-MHz band is received on the command and beacon antenna, a monopole configuration that accepts signals over a look angle of 4 pi steradians. The command-receiver coupler provides isolation, couples the received power into both channels of the dual-command receiver, and maintains an impedance match. Real-time telemetry data are transmitted to the CDA ground stations by the beacon transmitter. Beacon transmitter 1 and set 1 of a dual subcarrier oscillator (SCO) are associated permanently as a unit as are beacon transmitter 2 and set 2 of the dual SCO. The two SCOs are used to transmit the pulse amplitude modulated (PAM) housekeeping telemetry from the Digital Data Processor (DDP), the analog VTPR data, the attitude data, the command verification accelerometer vibration data during launch, and the Digital Solar Aspect Sensor (DSAS) signals. Data are switched to the SCO channels by the CDU upon ground commands. The beacon transmitter output passes through the beacon filter network to a monopole antenna.

The NOAA polar satellites from NOAA-3 on have two VHF Beacon transmitter frequencies. One, 136.77 MHz, is identical to the redundant beacon pair on the NOAA-2 satellite. The other frequency, 137.14 MHz, is also used to broadcast VTPR, SPM, telemetry, and satellite time code directly to users in digital form. This direct broadcast service is provided only when the 137.14 MHz beacon transmitter is selected.

The two frequencies enable SOCC to eliminate ground station interference when two or more NOAA satellites are broadcasting within radio range of receiving stations. This dual frequency concept is also used in the APT direct broadcast service described earlier.

This real-time beacon service permits local readout stations to process the VTPR data to obtain temperature profiles of the atmosphere. The SPM data are processed to yield proton density and energy measurements along the satellite's orbital path. The time code is relative satellite time that can be useful in identifying data. The engineering telemetry generally is of no use to local readout stations.

These data streams are output by the satellite DDP. Each data stream phase-modulates the beacon RF carrier. The RF spectrum bandwidth is 8.5 kHz. The digital data phase-modulates the Beacon Transmitter 0.24 radians assuming a rectangular waveform. At the output of the receiver, the digital data rate is at 512 bits per second (bps) and is contained in the frequency band from 50 Hz to 770 Hz.

The power subsystem is composed of a solar array, power supply electronics, batteries, and external shunt dissipators. The solar array consists of solar cells mounted on one side of the three solar panels; the cells are wired in series-parallel combinations to provide component redundancy. The electronics unit has a control amplifier that, with the shunt dissipator, dissipates power generated by the solar array in excess of the satellite requirements. Tapered charge controllers regulate the charge rate of two batteries, dependent on battery charge condition and temperature. The series regulator provides the regulated -24.5-volt power that most of the satelllite subsystems use. The dual command receiver, SRs, VTPRs, S-band transmitters, pitch control motors, and dual decoder operate from the unregulated output of the power subsystem. The batteries are used to supply power during the night portion of the orbit and when satellite demands exceed the power available from the solar array during the daytime.

The satellite's envirommental sensors (SRs, VTPRs, SPM, and VHRRs) are supported by these satellite subsystems.

2.1.3.1. Scanning Radiometer (SR).

The NOAA-2 Scanning Radiometer (SR) is a two-channel scanning instrument sensitive to energy in the visible spectrum (0.5 to 0.7 micrometers) and in the infrared (IR) window region (0.5 to 0.7 micrometers). On NOAA-3 and all subsequent satellites the visible channel has been broadened to include 0.4 to 1.1 micrometers. The wider energy range provides better delineation of land-water boundaries. These energy spectra are gathered by a 5-in (12.7-cm) elliptical scan mirror with a plane surface area of 100.4 cm^2. The scan mirror is set at an angle of 45° to the scan axis and rotates at 48 rpm; a Cassegrainian-type optical system (fig. 2-4) focuses the energy. After passing through a dichroic beam splitter and relay lens, the infrared window radiation is collected by a thermistor bolometer, the size of which (5.3 milliradians (mr)) defines the Instantaneous Field of View (IFOV).

The dichroic beam splitter reflects the visible energy which is focused on and detected by a silicon photovoltaic detector. The size cf the detector and its field stop limits the IFOV to approximately 2.8 mr. A Sun shield keeps direct and reflected solar radiation from entering the field of view of the instrument.

The SR istrument is a line scan device. Global coverage is achieved from continous horizon-to-horizon cross-track scanning by the mirror combined with the forward motion of the satellite. Since the mirror rotates at a constant angluar rate, the geometric resolution of the ground field of view decreases as the distance from the subsatellite point increases; an image produced from these signals will appear foreshortened near the horizons.

The 5.3-mr IFOV of the infrared channel provides a ground resolution of approximately 4 n mi at the satellite subpoint. Successive lines are contiguous at the subpoint and overlap as the distance from the subpoint increases. In equatorial regions, contiguous data between successive orbits will occur at a point about 1,449 km frcm the subsatellite point; at this point the data zenith angle is 60° and the IFOV spot is about 12.9 by 19.3 km. The visible channel, with a 2.8-mr IFOV resolves a 3.2-km spot at the subpoint. This spot size increases to approximately 6.4 by 12.9 km at the equatorial contiguity point. It should be noted that there is a 3.2-km gap between visible channel scan lines at the subpoint. The gap is not apparent in the display and

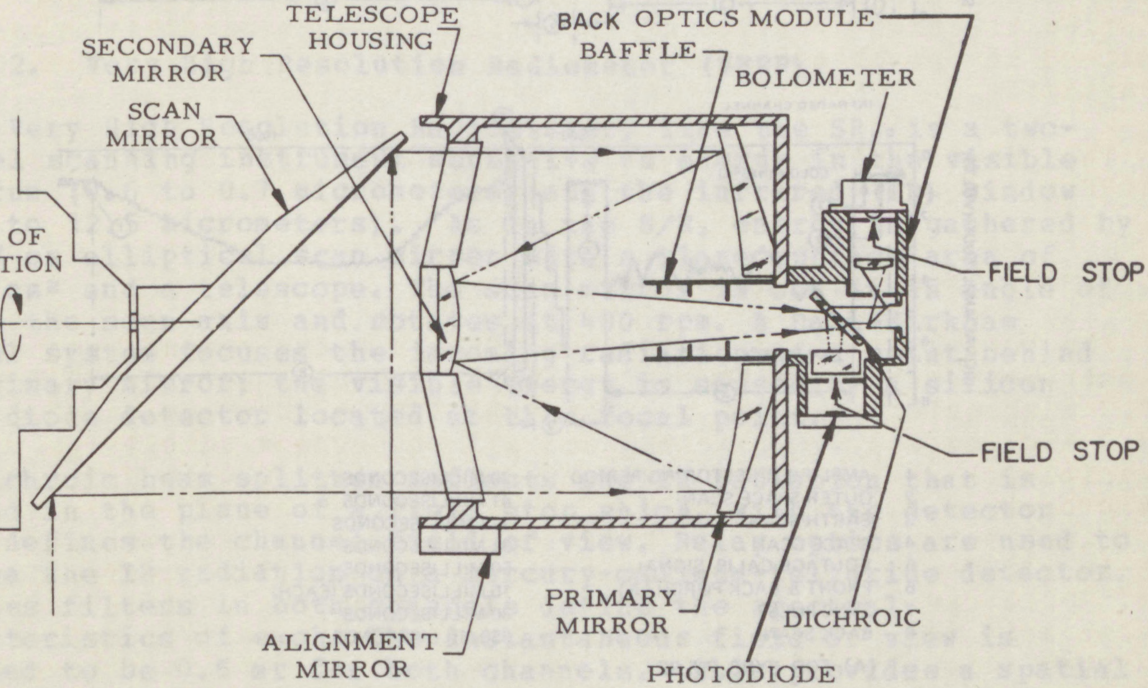


Figure 2-4.--SR instrument.

disappears entirely at distances more than about 1,208 km from the subpoint.

The radiometer views the Earth during approximately one-third of the period required for one full rotation of the scanning mirror. During the remaining two-thirds of each rotation, the mirror views space and the instrument housing. During this time, telemetry and synchronization data are put into the data stream. The discriminated data output for the infrared and visible channels of the NOAA polar satellite is shown graphically in figure 2-5.

Once each scan, while the instrument is viewing space, the baseline of detected signals is restored to a preset zero level. During the remainder of the scan (Earth view), the output of the radiometer is equal to the difference in detected energy between the zero point and the radiating (reflecting) surface. In

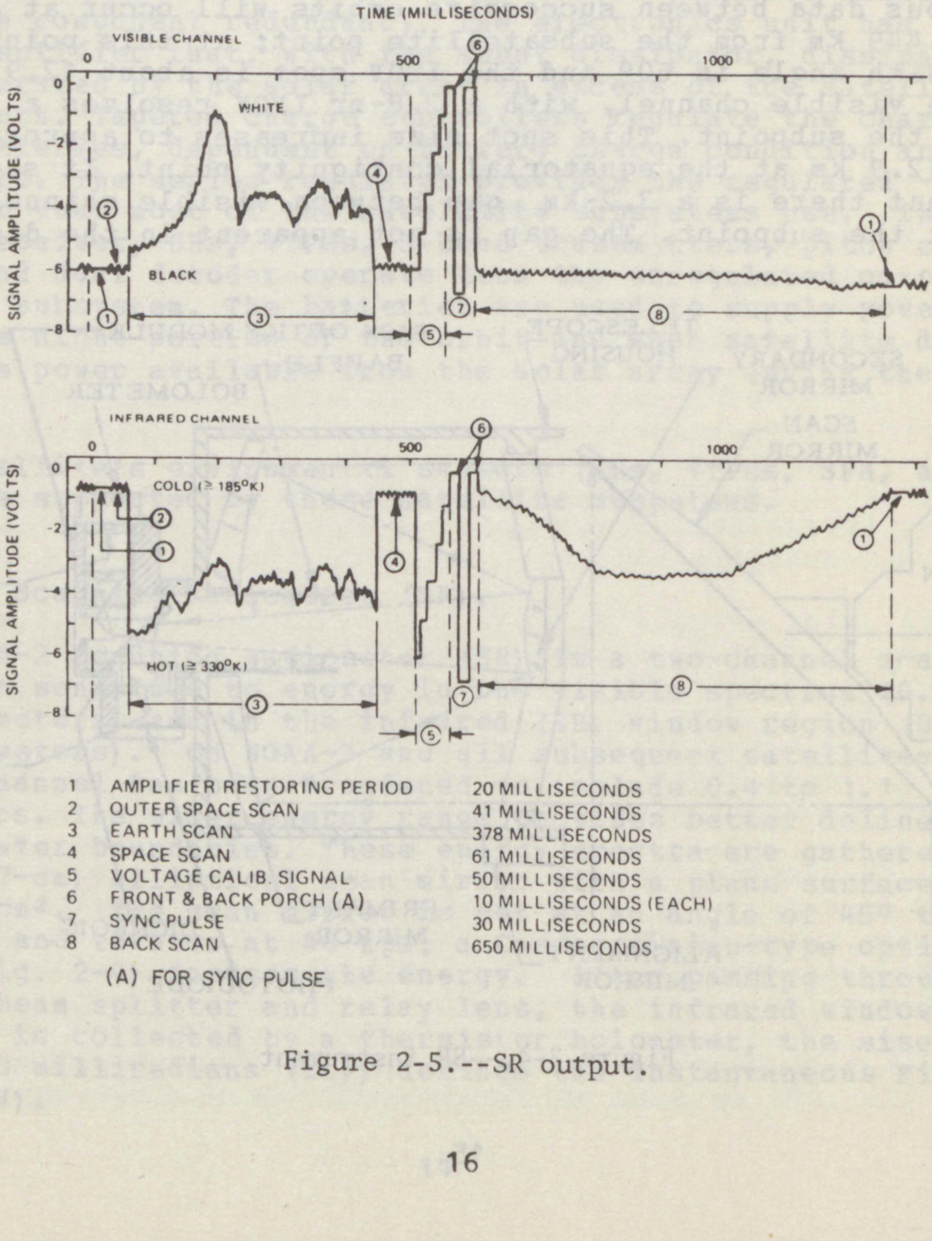


Figure 2-5.--SR output.

operation, the anti-Sun-side horizon, where restoration of signal baseline occurs, is well defined and provides a zero radiance level for calibration. The Sun-side horizon is evident in the data, but the output level is indeterminate because the warm Sun shield gradually enters the field of view of the instrument and changes the output level. This signal level restoration technique, using cold space as a reference, removes the effect of self-emission by the optics.

The IR channel data of the SR may be used to determine the equivalent blackbody temperature of the radiating surface. The ability to determine this temperature accurately is charaterized by the instrument noise-equivalent differential temperature. For practical purposes, the noise-equivalent differential temperature may be considered the temperature differential that can be discerned by the instrument when scanning from one uniform blackbody to another. Actually it is the blackbody energy differential of the target which, when sensed by the instrument, is equal to the root-mean-square (rms) noise level. The instrument response is linear with input energy, and system noise is not affected by target temperature. However, a warm target will have a significantly lower noise-equivalent temperature differential than a cold target, because temperature is not linear over the energy scale, but varies exponentially by a power of 4. System noise is affected by the temperature of the radiometer itself, so no single constant can be used to fully define the system noise-equivalent differential temperature.

2.1.3.2. Very High Resolution Radiometer (VHRR).

The Very High Resolution Radiomteter, like the SR, is a two-channel scanning instrument sensitive to energy in the visible spectrum (0.6 to 0.7 micrometers) and the infrared (IR) window (10.5 to 12.5 micrometers). As in the S/R, energy is gathered by a 12.7-cm elliptical scan mirror with a plane surface area of 100.4 cm^2 and a telescope. The scan mirror is set at an angle of 45° to the scan axis and rotates at 400 rpm. A Dall-Kirkham optical system focuses the incoming radiation at a point behind the primary mirror; the visible energy is sensed by a silicon photo diode detector located at this focal point.

A dichroic beam splitter reflects the IR radiation that is focused in the plane of a field stop which, with the detector size, defines the channel field of view. Relay optics are used to reimage the IR radiation on a mercury-cadimum-telluride detector. Bandpass filters in both channels define the spectral characteristics of each. The instantaneous field of view is designed to be 0.6 mr for both channels. This provides a spatial resolution of approximately 0.8 km at the satellite subpoint.

The infrared detector is cooled to its operating range (-168°C) by a radiant cooler. A large cooling patch is used to bring the detector temperature below the level that provides the desired S/N ratio; thermostatically controlled heaters then warm the detector and maintain the desired temperature. A special baffle protects the detector from ice which has been known to form from outgassing moisture at these low operating temperatures. The cooling patch itself is suspended on belts to minimize heat conduction between it and the remainder of the radiometer.

In a manner similar to that used for the Scanning Radiometer, the zero point for detected energy is restored to a preset zero level once each scan while the mirror is viewing space. The output of the radiometer during the remainder of the scan is equal to the difference in detected energy between space and the radiating surface target, providing a zero radiance level for calibration purposes. The Sun-side horizon will probably be of indeterminate level as the radiometer scans across the solar illuminated target used for visible channel calibration. These targets (one for each radiometer) are illuminated once per orbit as the satellite reaches polar regions. The remainder of the scan period is given over to viewing space and instrument housing while telemetry and appropriate synchronization data are inserted in the data stream.

The satellite can be programed to record 8.5 min of VHRR data on tape during any orbit except for one of the blind orbits when the spacecraft is out of contact with either CDA. (Only one 8.5-min segment can be selected during the blind period.) The stored data are played back upon command from the controlling CDA station. The VHRR real-time service (High Resolution Picture Transmission--HRPT) can be programed for either partial or full orbital periods. Partial HRPT orbital segments are programable in N out of eight equal orbital partitions. The partitions do not need to be contiguous, but may be chosen in any desired coverage pattern.

The HRPT service is provided via an S-band transmitter (1697.5 MHz). In the primary mode of data transmission, the two VHRR instruments operate in a "time sharing" manner. In this mode the two instruments are slaved together but 180° out of phase. While radiometer no. 1 is viewing the Earth, no. 2 is looking upward at its housing. Through electronic switching, the infrared channel data from one radiometer are transmitted then, one-half a scan period later, the visible data from the second instrument are transmitted. The data from the two channels are not coincident, so there is an offset of about 8 km at the contiguity point on the Earth. Prelaunch alinement measurements determine the degree of noncoincidence. The prelaunch figures can be used to correct for offset when gridding the images. These corrections can reduce coincidence uncertainty to less than one-third of a degree in latitude, or to less than 32 km (20 n mi).

In the event of the failure of a single VHRR instrument, two backup data transmission techniques are available. One backup mode involves selecting only one channel. In this mode, the data format, transmission characteristics, and S/N ratio remain unchanged; however, backscan information is transmitted in place of the data from the other channel during the remaining time of a scan period. The second backup mode involves transmitting data from both channels of a single VHRR instrument in a frequency multiplexed scheme. However, operating in this mode significantly degrades the effective S/N ratio.

Once the data are received, they can be used in the same manner as SR data. The infrared channel data can be used to determine the equivalent blackbody temperature of a target. The noise-equivalent differential temperature (measured at the instrument's output) is about 0.5°C for a 27°C scene and 2.0°C for a -88°C target. These values are degraded by transmission, receiving, and data processing equipment. In the primary time sharing backup mode of operation, local ground stations can expect noise-equivalent differential temperatures about four times these values. In the frequency multiplexed mode of operation (backup alternative 2), the noise-equivalent differential temperature will degrade to 4° to 5°C at 27°C and to 20° to 25°C for scenes at -88°C. VHRR data recorded onboard the satellite also are degraded more than those received directly via the HRPT service.

2.1.3.3 Vertical Temperature Profile Radiometer (VTPR).

The Vertical Temperature Profile Radiometer is a multispectral, passive scanner aboard the NOAA satellites. The VTPR instrument samples the atmosphere twice a day over most regions of the Earth. These samples are statistically transformed into vertical temperature soundings (profiles) by the National Environmental Satellite Service. The statistical technique permits the deduction of emitted radiation from cloud-free areas.

Two VTPR instruments on each satellite measure energy in eight spectral intervals or channels of the infrared energy spectrum. There are six discrete channels within the 15-micrometer carbon dioxide absorption region, one in the 11-micrometer water vapor "window" region, and one the 18-micrometer water vapor absorption region of the infrared absorption spectrum. Measurements from these eight channels profile the atmospheric temperatures from the Earth's surface to 30,480 m (100,000 ft).

The VTPR instrument is equipped with a single optical system and a pyroelectric detector. The individual spectra of interest are defined through a wheel that contains eight spectral filters. The wheel rotates at 120 rpm, bringing each of the eight filters into the optical path of the detector every 62.5 milliseconds (ms). Thus 0.5 s is required to obtain a complete atmospheric profile. The radiation optical path is detected by a mirror that scans the Earth in 23 equal steps a distance of 31.45° to either side of the orbit path. The scan and the satellite motion combine to provide essentially global coverage, although gaps in coverage do occur between successive orbits in the equatorial regions.

The instrument field of view is 2.235° by 2.235°. This provides a ground resolution of approximately 110 km^2 (32 n mi^2) at the subpoint. One complete scan of 23 steps will sweep across an area approximately 59 by 1,364 km (32 by 736 n mi). The time to complete one scan is 12.5 s, 1 s of which is required for the mirror to retrace prior to starting a new sweep.

The VTPR is designed to have an absolute accuracy better than 0.5 percent and relative accuracy between channels of 0.125 percent, execpt for one of the carbon dioxide (Q-branch) channels which has a 0.25 percent relative accuracy. Calibration is used to check the absolute radiance calibration and linearity of the instrument. For calibration, the instrument first looks at space (a 4°K target) for 16 s and then at an internal blackbody source (approximately a 285°K target) for 15 s. The telemetry data needed for data interpretation are inserted in the data stream during mirror retrace and calibration periods.

The S/N ratio of the instrument is maintained through the data processing and transmission link. The instrument analog output is digitized to 10 bits per response before storage on the satellite recorder. The signal from the detector is fed to an integrator that optimizes the system S/N ratio by accurately measuring the data level of the input. From the integrator, the signal is input to a buffer amplifier that brings all the signals to a common baseline and raises the level of the Q-branch channel data by a factor of four to make the best use of the digital range. This is necessary because of the limited response in the narrow bandwidth of the Q-branch channel. Though radiometric accuracy is not improved by raising the signal level, the quantification error (±0.5 bits) is limited to the same percentage as that present in data from the other seven channels. Finally, the data are digitized, formatted, and stored with appropriate telemtery information on the satellite recorder, or are used to phase-modulate the 137.14-MHz beacon transmitter. The phase modulation is performed on NOAA-3 and subsequent NOAA satellites. The VTPR instrument is shown in figure 2-6.

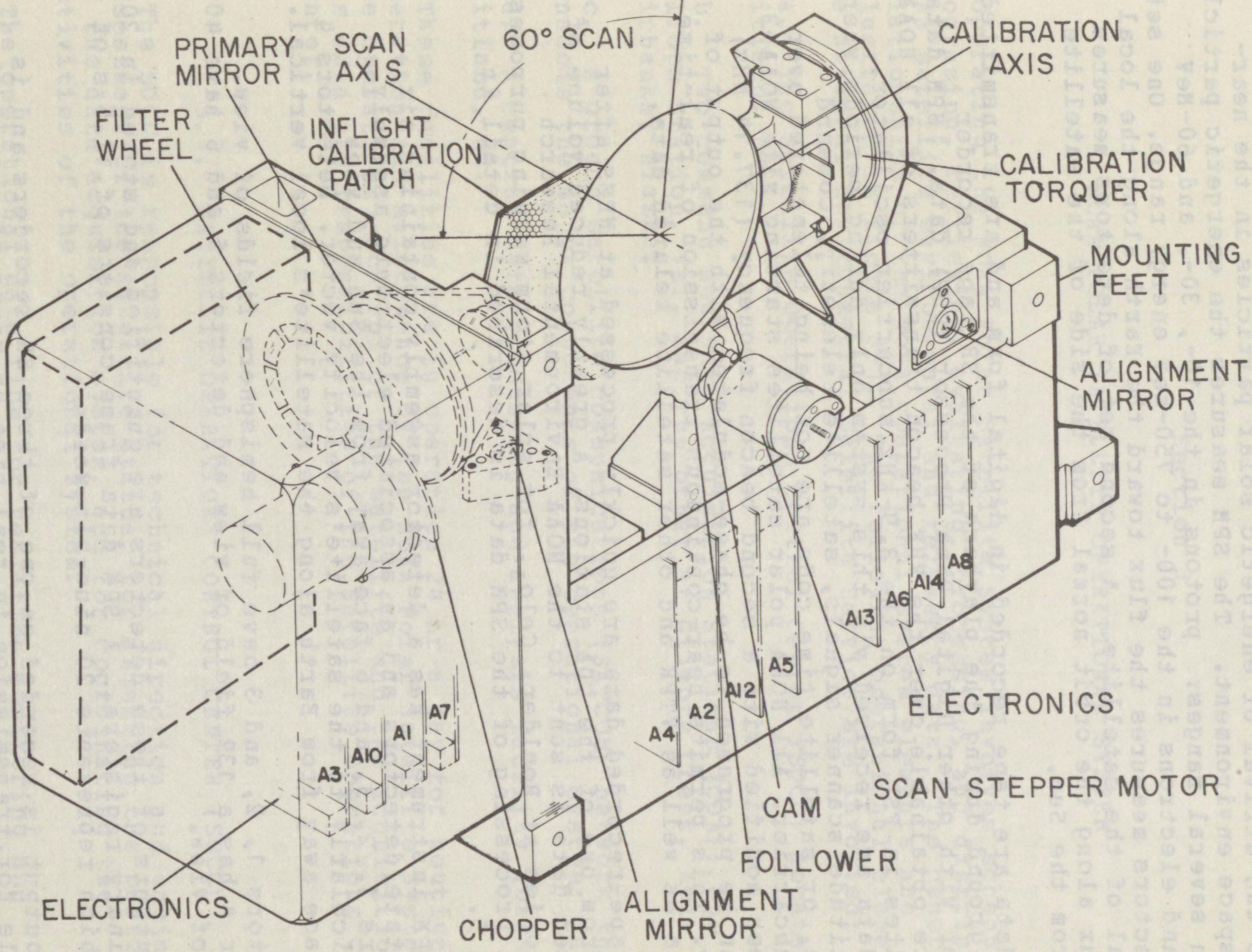


Figure 2-6.--VTPR instrument.

2.1.3.4. Solar Proton Monitor (SPM).

The Solar Proton Monitor measures the flux of energetic particles (protons and electrons) in several energy ranges and detects the arrival of energetic solar particles in the near-Earth space environment. The SPM measures the energetic particle flux in several ranges: protons in the 10-, 30-, and 60-MeV range and electrons in the 100- to 750-keV energy range. One set of detectors measures the flux toward the Earth along the local vertical of the satellite. A second set of detectors measures the flux along the orbit normal from the side of the satellite away from the Sun.

The data are tape recorded in digital form and are transmitted to the ground during the playback of the SR tape recorder together with other Digital Data Processor (DDP) data. SPM data also are obtainable over the VHF beacon transmitters of all NOAA satellites in FSK form on the 3.9-kHz subcarrier oscillator. These data are received via this system only during periods when the attitude scanner signals, satellite telemetry, command confirm, or satellite time code are not being telemetered over this subcarrier. All NOAA polar satellites starting with NOAA-3 have been modified with a second beacon frequency (137.14 MHz) that can be programed to be phase-modulated with the output of the DDP. This permits near-continuous transmission of real-time SPM data as well as VTPR and other satellite related data.

The tape-recorded data are quickly processed at NESS after relay from one of the CDA stations. A greatly reduced volume of processed data is sent to the NOAA Environmental Research Laboratories at Boulder, Colo., for solar storm warning purposes. Central processing of the SPM data is described in detail in section 5.

The SPM instrument has a detector assembly containing six solid-state detectors and an associated electronic assembly. Detectors 1, 2, 3, and 6 face away from the Sun and view perpendicularly to the satellite's velocity vector. Detectors 4 and 5 face away from Earth along the satellite's local vertical.

Detectors 1, 2, and 3 have full hemisphere fields of view. Detector 4 has a 13° field of view and detectors 5 and 6 have 40° fields of view.

The outputs of these detectors are quantified and stored in 20-stage binary registers. A SPM data frame consists of 12.5 s of data, which represents 20 nine-bit words.

This output is recorded on one of three SR recorders and is available for transmission in real time by means of one of the techniques described earlier using the satellite's VHF beacons.

Section 3

NOAA POLAR SATELLITE OPERATIONAL SYSTEM

Operating the NOAA Polar Satellite System involves scheduling, programing, retrieving, evaluating, processing, and distributing NOAA satellite environmental and telemetry data. The general relationships of the NOAA operational system elements are illustrated in figure 3-1. The following operational elements of the National Environmental Satellite Service are involved:

a. The Satellite Operations Control Center (SOCC) located in Suitland, Md.;

b. Two command and Data Acquisition Stations (CDA), one at Wallops Station, Va., and the other at Gilmore Creek, near Fairbanks, Alaska;

c. A ground satellite communications (SATCOM) network that connects the major components of the operational system; and

d. A central data processing and analysis facility (DAPAF) in Suitland, Md.

These facilities are in operation 24 hr a day for routine operation and maintenance of the NOAA Polar Satellite System. The operational control of the satellite and the acquisition of its data are responsibilities of the Satellite Operations Control Center.

3.1. SATELLITE OPERATIONS CONTROL CENTER (SOCC)

The SOCC is responsible for technical direction and engineering assessment of the satellite status, for assessing the performance of the data acquisition system, and for coordinating the activities of the operational system.

The operational data flow for real-time monitoring and assessment of the NOAA satellite system is shown in figure 3-2. The voice circuits are used for real-time coordination and implementation of program messages. During a satellite acquisition, the CDA station relays satellite housekeeping telemetry and CDA

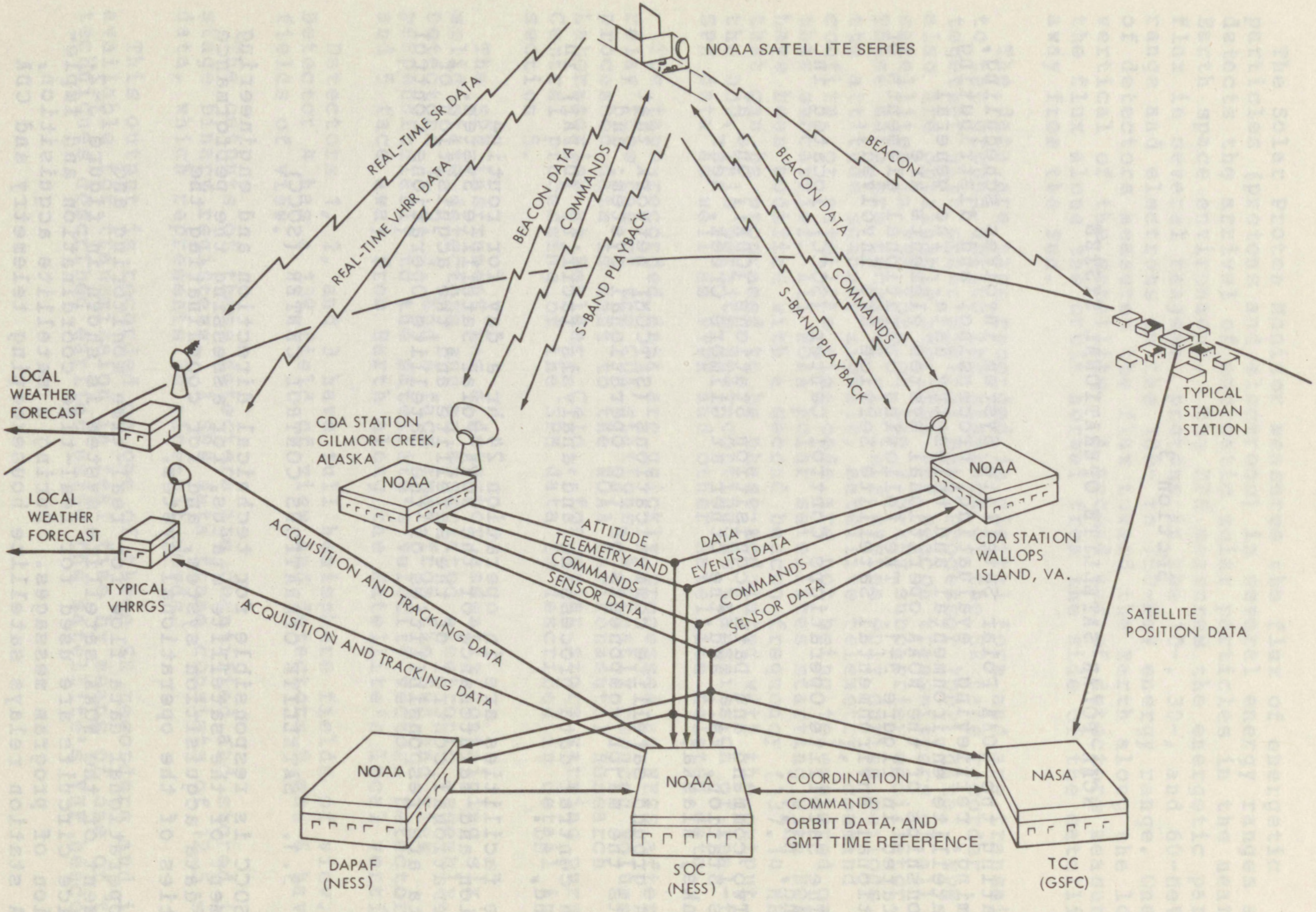


Figure 3-1.--NOAA operational system elements.

station events telemetry to SOCC via the SATCOM communications network.

After data acquisition is complete, the CDA station transmits (via teletype) to SOCC a summary of major acquisition events and parameters. From these real-time and post-acquisition data, SOCC:

a. Identifies and reports nonroutine occurrences and attempts to correct system problems by coordinating and implementing capabilities and resources;

b. Determines the satellite attitude from horizon sensor data, Digital Solar Aspect Indicator (DSAI) data, and from DAPAF attitude determination programs based on ingested Scanning Radiometer infrared sensor data;

c. Prepares, coordinates, and disseminates a long-term schedule of satellite acquisitions, beacon selections, and APT and HRPT transmitter schedules; and

d. Originates and transmits to the CDA stations the specific command programs and station interrogation schedules for daily operations based on:

1) Analysis of CDA to satellite look angles,

2) Analysis of satellite data requests,

3) Analysis of satellite power budget, and

4) Analysis of CDA station status;

e. Predicts satellite attitude parameters;

f. Programs for satellite magnetic attitude control and maintenance of satellite system momentum for pitch control;

g. Notifies and coordinates changes to satellite interrogation programs and operating instructions with the CDA, the NESS Analysis Section, and other operational components of the Data Processing and Analysis Division (DAPAD);

h. Ensures the timely transmission from CDA stations of all operational environmental data to DAPAD's Data Processing and Analysis Facility and to Offutt AFB; and

i. Is also responsible for implementing emergency plans for ensuring the integrity of the operational system.

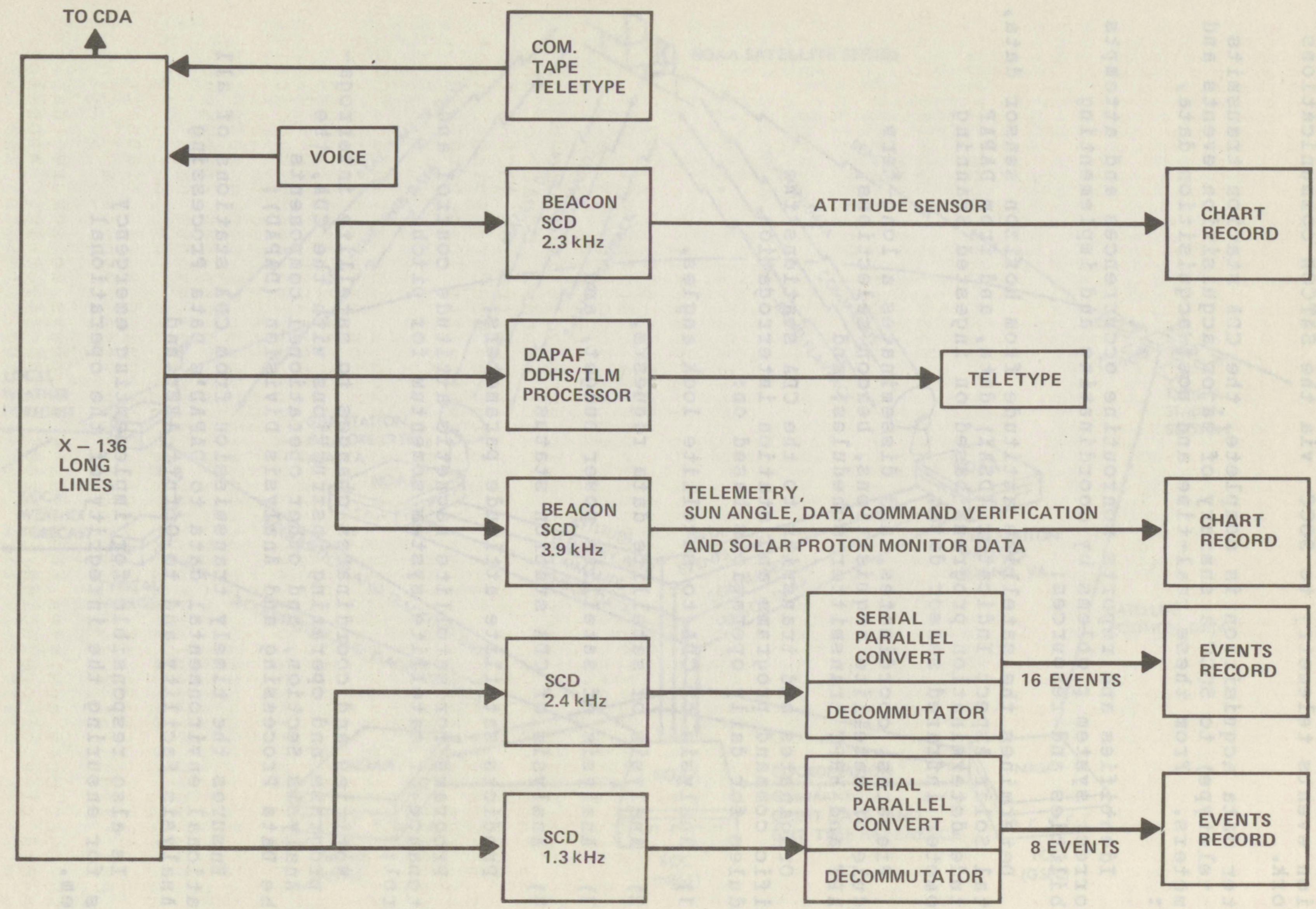


Figure 3-2.--Operational data flow.

These tasks are accomplished on around-the-clock, 7-day-a-week crew operation. The crews perform these tasks using the long-term schedule of readout activities. This schedule is prepared each week for the subsequent week by SOCC. The preparation of this schedule plan requires that all data coverage goals and system constraints for the week be defined by SOCC management. Schedules are prepared each Sunday by the SOCC day shift. Each crew uses these plans as the basis for developing interrogation programs with the CDA stations. The programs are prepared and transmitted by teletype 24 hr in advance of the acquisition.

Executing these programs requires that SOCC coordinate with the CDA and DAPAF. Real-time changes to these programs occasionally occur. When this happens, SOCC, DAPAF, and the CDA coordinate, using data and voice communications channel conference calls.

Beacon data received from the CDA are recorded on analog Brush recorder charts, and manual telemetry and attitude measurements are made. Simultaneously, the data are recorded on a multi-channel magnetic tape recorder and ingested by DAPAF.

A real-time quick-look analysis of the analog telemetry records is performed by the SOCC crew during an acquisition. SOCC also receives from DAPAF a teletype message containing data from as many as 20 preselected telemetry channels after a nominal delay.

Telemetry values beyond tolerance are identified and checked thoroughly by SOCC crews after the command-interrogation occurs. After each acquisition, DAPAF provides a computer printout of the actual telemetry data for all channels. SOCC uses these printouts to monitor the short-term status of the satellite. SOCC personnel graph individual telemetry channels by revolution number and assess them for anomalous patterns and trends. Copies of the printouts are provided to the satellite contractor (RCA-Astro Electronics Division--RCA-AED) and to the Goddard Space Flight Center TOS Evaluation Center (TEC), where the long-term assessment of the satellite is made.

Major status events at the CDA station are received at SOCC and DAPAF in real time. SOCC displays station events data on a 20-channel chart recorder, on 5 channels of an 8-channel Brush recorder, and on a teletype printer. The first of these displays receives data directly from the CDA on two frequency subcarriers; the data are frequency multiplexed and transmitted to Suitland over Channel D of the SATCOM wideband network. (The 20 channels of events information are time division multiplexed/frequency shift keyed.) The teletype printer displays events data transmitted by DAPAF. These events data are preselected by SOCC and usually consist of all satellite command words transmitted by the CDA, and stored data S-Band transmitter turn-on and turn-off.

The SOCC crew analyzes these data displays to ensure that the intended plan of operation is progressing smoothly. Anomalous events require a quick response from all participants; therefore, real-time voice data connections are used by SOCC to coordinate corrective actions.

The postdata acquisition activities by SOCC involves a critique of system performance and the coordination of environmental data transfer from the CDA to Offutt AFB and to DAPAF. The critique of system performanace involves review of equipment, procedures, communications, and satellite performances. Deviations from normal operations are identified, and work is started to bring the system back to normal before the next satellite acquisition.

SOCC also performs a short-term assessment on the satellite using the engineering data telemetered by the satellite, Sun angle and attitude information, and observed anomalous events. SOCC has a professional staff to perform short-term satellite monitoring.

The long-term satellite status monitoring and assessment is performed by GSFC's TEC, which is staffed by the satellite contractor (RCA-AED). TEC is under the technical direction of the GSFC ITOS Project Manager, and is collocated with GSFC's Meteorological Data Handling System (MDHS). TEC acquires most of the satellite data through the MDHS facility and some status reports and raw satellite data directly from the CDA stations by mail or teletype.

Early in 1974, when the TEC function is moved to the SOCC facility in Suitland, Md., the name will be changed to the ITOS Monitoring Group. This Group will be under the technical direction of the Chief of the NESS Satellite Operations Control Center.

3.2. DATA PROCESSING AND ANALYSIS DIVISION (DAPAD)

The DAPAD, at Suitland, Md., is part of NESS central operations. DAPAD processes, analyzes, and provides for distribution of NOAA data. DAPAD uses general and specific-purpose computer equipment to locate, format, and digitize satellite input data and to produce scale-rectified digital map printouts and other summaries of environmental observations. Gridded images of the Earth's cloud cover are produced on photofacsimile display equipment. DAPAD also supports SOCC by processing satellite beacon data for satellite operation and management.

DAPAD produces the environmental data in forms that permit optimum storage of large quantities of data, and rapid manual and automatic information retrieval.

DAPAD provides the following support for operational management of the NOAA satellite:

a. Computes Equator crossings;

b. Computes antenna pointing angles for the CDA stations on punched paper tape for direct teletype transmission;

c. Prepares satellite ephemeris;

d. Provides SOCC with predictions of the following:

1) Satellite location at any given time;

2) Times at which the satellite is above the horizon, antenna limits at each CDA station, and local coordinates of the satellite from each CDA station during contact intervals;

3) Solar angles at the satellite subpoint and image centers;

4) Principal point for sensors as a function of time; and

5) Location of Sun glint in the images;

e. Provides SOCC with predictions of times when a given NOAA satellite will be close enough to another NOAA satellite in orbit to produce a conflict in command and acquisition of data;

f. Provides real-time processing of selected portions of satellite telemetry;

g. Determines satellite attitude from the scanning radiometer data;

h. Provides electronically digitized gridded images and gridded rectified mosaics;

i. Provides SOCC with information for acquiring and gridding real-time transmission data (APT, HRPT, DB-BCN) in appropriate message code. These data are prepared on punched paper tape for transmission over worldwide teletype networks; and

j. Provides analytical and technical consultants and computer support to Goddard Space Flight Center for many phases of the NOAA mission.

3.2.1. DAPAD Operations

For real-time operational support, DAPAD receives data from the CDA stations via the SATCOM X-136 longlines facility. CDA station events and NOAA satellite beacon data are digitized and ingested by the Digital Data Handling System (DDHS). This equipment is operated and maintained in DAPAD's Data Processing and Analysis Facility (DAPAF).

The DDHS consists of a redundant set of data processing equipment. Figure 3-3 shows the functional operation of the DDHS. These functions are duplicated in identical sets of primary equipment to provide operational reliability. The DDHS is operationally divided into two distinct systems, or sides. The two sides are identical except that side 2 (shown at the bottom of fig. 3-3) has an additional card reader and line printer accessible to or from the EMR 6130 computer.

The DDHS has five basic subsystems:

a. A Signal Distribution Unit (SDU),

b. Two telemetry subsystems (one per side),

c. Two computer (EMR 6130/6050) pairs for each side,

d. Central disk storage memory, and

e. Peripheral equipment, such as tape drives, printers, and card readers.

The SDU functions as a switching and routing mechanism for the incoming signals. The SATCOM longline communication circuits from the two CDA stations are the major inputs to this device. Signals on these circuits can be routed to either side of the DDHS; both sides of the DDHS can be used simultaneously to ingest data from the two CDA stations. Two analog tape recorders record all inputs. The SDU outputs the various satellite and station event signals to the telemetry subsystem of the DDHS.

The telemetry subsystem handles all signals to be ingested by the system, not just telemetered data as its name implies. The telemetry subsystem accepts and processes both frequency modulated (FM) and pulse code modulated (PCM) input signals. The subsystem also receives, demodulates, and decodes CDA station events which are received as time division multiplexed/frequency shift keyed (TDM/FSK) signals.

FM signals are demodulated into analog signals which, in turn, are quantized and time division multiplexed into 8-bit bytes (binary data words). The digital bytes are placed into a 16-bit buffer-register, called a bit packer. A signal conditioner packs one or two of the resulting 8-bit words into one parallel binary word. These words are transferred to the telemetry data channel for entry to the EMR 6130 computer. Thus, the signal conditioner is the interface between the quantizers and the telemetry data channel in the telemetry subsystem.

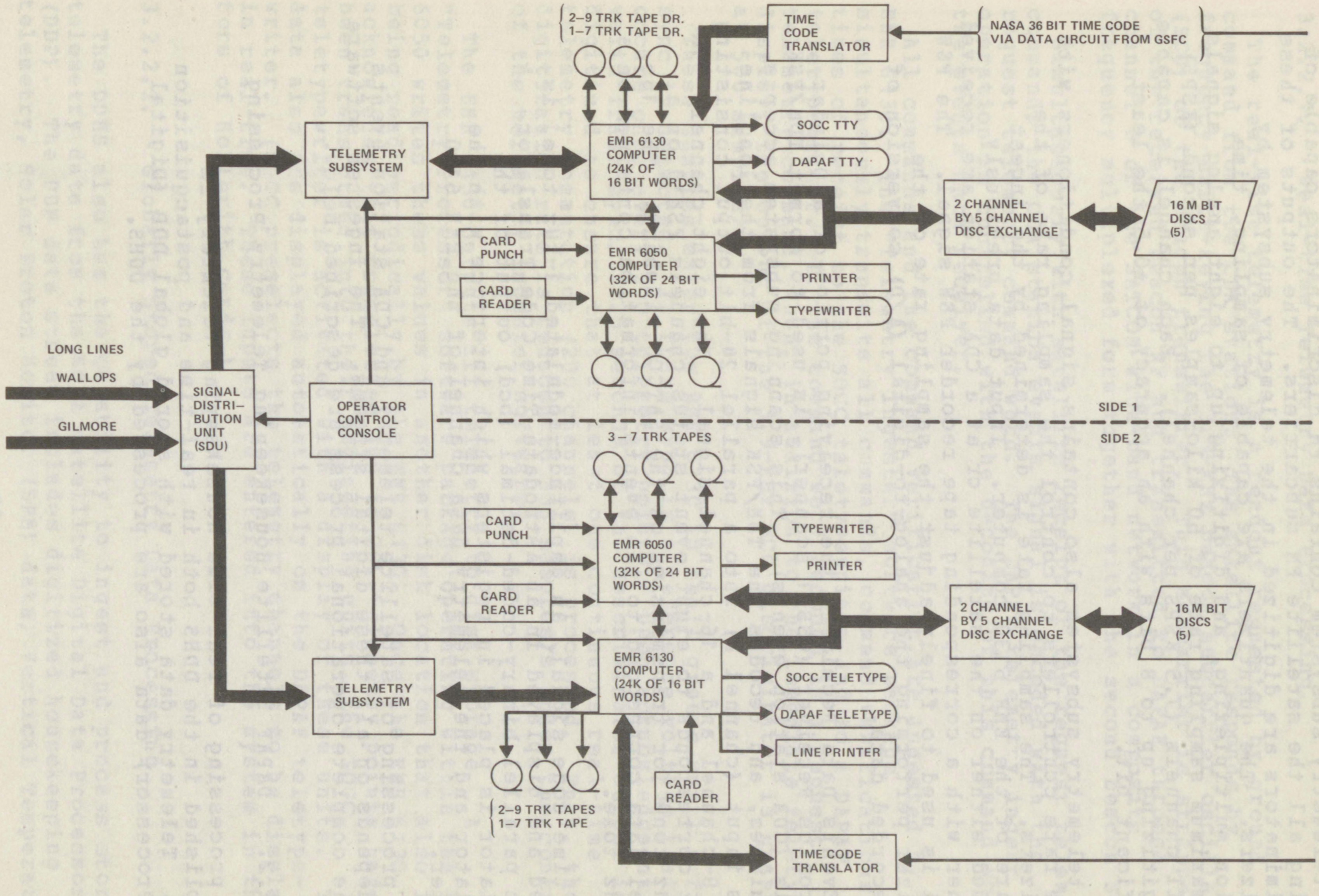


Figure 3-3.--DAPAF digital data handling system.

The telemetry subsystem contains FM discriminators capable of handling all the satellite FM subcarriers. The outputs of these discriminators are digitized in the telemetry subsystem by quantizers. The quantizers are capable of sampling, time division multiplexing, and digitizing up to eight analog signals at a maximum sampling rate of 60 kilo-samples per second (KSPS) for all channels (7.5 KSPS per channel). Each channel is capable of digitizing up to 8 bits with an accuracy of ±0.5 the least significant bit.

The telemetry subsystem also contains signal conditioners with sample rate controllers to control the sampling rate of the quantizers. The sampling rate is determined by the ingest software of the EMR 6130 computer. Input data previously recorded either on the satellite or at a CDA station are received together with a corresponding tape recorder F&W signal. The F&W signal is used to finely adjust the sampling rate of the quantizer performing the analog-to-digital (A/D) conversion of the recorded data.

An Events Data Receiver, the receiving portion of a Quindar Electronics Receiver (QSS-1 scanner), is used to format TDM/FSK signals (CDA station events). This scanning subsystem accepts, demodulates, and decodes the TDM/FSK signals from the longline events input (channel D) into a parallel 24-bit output consisting of an 8-channel and a 16-channel signal. The eight-channel output corresponds to eight event status channels FSK'd on a 2400-Hz tone for transmission on the SATCCM wideband. The 16-channel data correspond to the events information contained on a 1300-Hz tone.

The time code signal, an amplitude-modulated 1-kHz tone, is decoded and displayed in an Astrodata Time Code Translator. A 30-bit parallel binary-coded-decimal (bcd) output of the translator is placed in registers which interface with the translator and the telemetry data channel of the EMR 6130 computer.

The processing of satellite telemetry and CDA station events data depends on all these digital streams. The ingester software and the complete operational process are described below.

3.2.2. DAPAF Satellite Housekeeping Telemetry Processing

The processing of real-time housekeeping telemtery is accomplished in the DDHS both in real-time and postacquisition modes. Telemetry data stored with stored global DDP (Digital Data Processor) data also are processed by the DDHS.

3.2.2.1. Real-time Telemetry Data Processing.

The real-time telemetry is a readout requested by ground command from the CDA station. The satellite responds by frequency-shift-keying the 3.9-kHz beacon subcarrier oscillator (SCO) of the beacon transmitter. This subcarrier is stripped out of the received beacon RF and transmitted to DAPAF through channel B of the SATCOM wide-band network in a composite frequency multiplexed form together with the second beacon SCO.

Simultaneously with satellite receipt of the request telemetry command, the CDA station events signal is encoded with the request telemetry command word. The DAPAF telemetry ingest operation is controlled with the decoding of this command word in the events data receiver.

All commands and the command verification are ingested by the EMR 6130. The "Telemetry Ingester" software package simultaneously transmits all commands, command verifications, and times of receipt to the SOCC teletypewriter and to a DAPAF teletypewriter. If the command word decoded is a request telemetry command, then, in addition to the immediate teletype display, the output of the 3.9-kHz SCO discriminator is quantized at 500 samples/s.

These samples enter the EMR 6130 in small groups until a frame sync is detected. (A frame sync is a reference voltage that occurs once every 200 telemetry points.) Upon acknowledgment of a valid frame sync, 12.5 seconds of the descriminator output is digitized to ensure that at least one continuous real-time telemetry commutation (200 channels) is processed. Then, the digitization rate is reduced to 333 samples/s under the control of the telemetry ingester software.

The EMR 6130 outputs all telemetry to disk storage. A "Telemetry Processor" software package operating within the EMR 6050 writes these values in another disk location that also is being read periodically by the EMR 6130. Once the EMR 6130 acknowleges that preselected (up to 20) telemetry points have been transformed into their engineering units, the SOCC teletypewriter is activated with a display of these units. These data also are displayed automatically on the DAPAF teletypewriter. (SOCC preselects the telemetry channels to be displayed in real time. These inputs are entered into the system in the form of Hollerith cards.)

3.2.2.2. Globally Stored Telemetry Data Processing

The DDHS also has the capability to ingest and process stored telemetry data from the NOAA satellite Digital Data Processor (DDP). The DDP data stream includes digitized housekeeping telemetry, Solar Proton Monitor (SPM) data, Vertical Temperature

Profile Radiometer (VTPR) data, and a 24-bit satellite time code. The DDHS DDP ingest data flow is shown in figure 3-4.

The stored DDP data are played back through the CDA station during each acquisition and are relayed directly to DAPAF for processing. The DDP output is a pulse code modulated signal received at both the CDA and DAPAF at a 10.667-kilobit/s rate.

DAPAF receives this data stream over channel A of the SATCOM wideband communication link. A data modem designed especially for the DDP data stream and the SATCOM wideband circuit is used at both CDA stations and at DAPAF. The output of the DAPAF DDP modem is input into a PCM bit/frame synchronizer subsystem of the the DDHS. The frame synchronizer provides interrupt and status signals to the EMR 6130 computer and routes the DDP data through the EMR 6130 telemetry data channel into the EMR central processing unit.

The DDHS bit synchronizer can accommodate input rates between 10 bps and 10^6 bps; these rates are controllable by local or remote programing. The ingest synchronization rate for DDP data is controlled remotely through the EMR 6130 DDP ingest software.

The frame synchronizer can accommodate up to 2×10^6 bps. Frame patterns from 4 to 33 bits, lengths up to 511 data words, and data word-length from 1 to 7 syllables are programable. The format pattern for the DDP data consists of 400 one-syllable, 16-bit words. The 400-word frame contains 2 frame syncs, 2 time code words, 20 SPM words, 178 digitized telemetry words, and 198 VTPR words.

Upon the receipt of frame synchronizer interrupt signal, the DDP ingest software program signals the telemetry data channel to input DDP data to the computer.

The DDP ingest software separates the VTPR, SPM, and telemetry data. The VTPR data are stored on a nine-track tape drive together with the corresponding time code. The SPM and telemetry data and the corresponding time code data are stored on 16-megabit storage disks for processing.

Processing of VTPR and SPM data is discussed in section 5. The processing of the ingested stored housekeeping telemetry is described below.

Three software programs are used in the EMR 6050 for the processing of telemetry data. These are called "TLMCK," "TLMPR," and "TIMCALC."

The TLMCK routine checks selected telemetry channels against tolerence limits provided by SOCC. The software is capable of monitoring all the telemetry channels of the NOAA satellite. Data on any channel, found to be outside of prescribed limits,

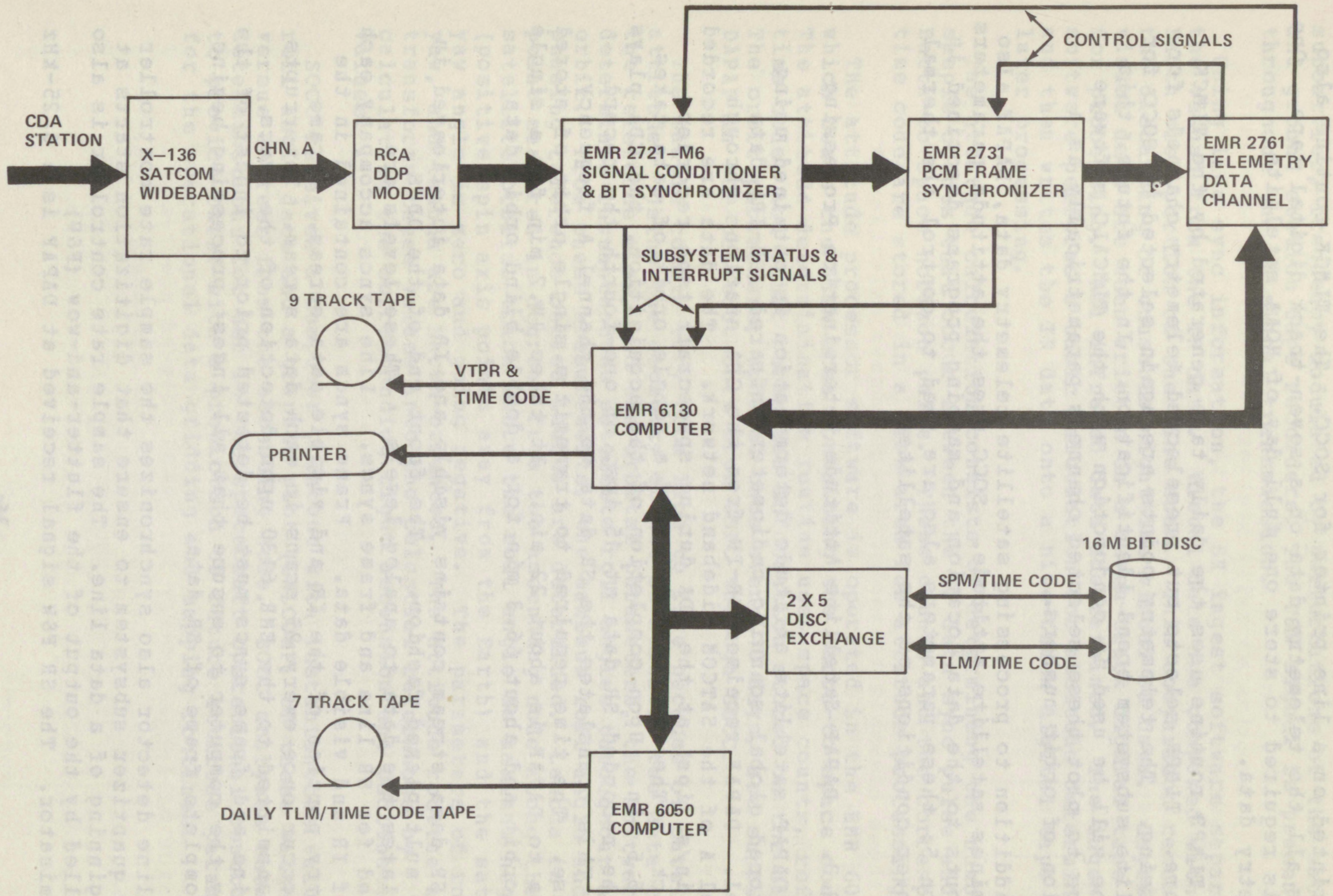


Figure 3-4.--Digital Data Processor (DDP) ingest system.

are printed on a line printer for SOCC. The TLMCK routine also writes all the telemetry data on a seven-track digital tape. One tape is required to store one full day of NOAA satellite telemetry data.

The TLMPR routine uses the daily tape generated by the TLMCK software. TLMPR selects out preselected telemetry channels for processing. The telemetry points are again selected by SOCC for satellite subsystem trend identification. In the future, this routine will be used in conjunction with the TLMCALC software package to plot these selected channels parametrically as a function of orbit numbers.

In addition to processing satellite telemetry data, DAPAF also determines satellite attitude. SOCC uses the attitude parameters as inputs to the data location and mapping programs described in section 5; these parameters also are used to control the thermal and power conditions of the satellite.

3.2.3. DAPAF Satellite Attitude Determination Processing

The DAPAF satellite attitude determination is obtained using the stored global scanning radiometer-infrared (SR-IR) data channel. DAPAF receives SR-IR from the CDA stations through channel A of the SATCOM wideband network. The data are recorded at 60 in/s (ips) at the CDA during spacecraft tape recorder playback. The CDA acquisition of a single orbit of data takes about 5.5 min. Upon completion of the acquisition, the CDA plays back the recorded SR data at 15 ips, or one-fourth the record rate. This translates the SR data to the channel A frequency response. The time required to transmit a single orbit of stored SR data to DAPAF is about 22 min. It takes 44.2 min for a single blind orbit and about 66.3 min for a double blind orbit data dump.

The SR data stream contains visible and IR data interleaved in a time multiplexed fashion. The front end of the DDHS demodulates the data to analog levels. These levels are searched for SR line and frame syncs. Line syncs accompany each scan of IR and visible data. Frame syncs are contained in the telemetry portion of the IR and visible data stream. Frame syncs occur once every 25 scans in each data stream. Interrupts are transmitted to the EMR 6130 upon detection of the syncs. Both line and frame syncs must be detected prior to ingest of the data by the computer to ensure that all ingest processing begins on a complete frame of SR data.

The line detector also synchronizes the sample rate controller of the quantizer subsystem to ensure that digitization starts at the beginning of a data line. The sample rate controller is also controlled by the output of the flutter-and-wow (F&W) discriminator. The SR F&W signal received at DAPAF is a 6.25-kHz subcarrier, frequency modulated by perturbations of the satellite and ground station tape recorders. The F&W signal is present throughout the SR signal transmission.

Using line sync information, the SR ingest software separates the visual from the IR data. Visual data are compared with the Earth view portion of the line scan. This comparison results in the discarding of unusable nighttime visual SR data. Daytime visual data are then written on a seven-track digital tape drive for processing. All infrared data are retained. The ingest software performs a basic calculation for attitude determination and then writes the IR data onto a nine-track digital tape for later processing.

The attitude calculation consists of determining the number of sample counts that occur between the IR data sync pulse and the Earth-to-space horizon pulse. These counts and the corresponding time code are stored in a disk area for attitude processing.

The attitude processor software is operated in the EMR 6050 which reads the disk area containing the Earth-to-space counts. The attitude determinination routine uses space counts, reference time code, and orbit parameter information stored on the disk. The orbit parameters, updated once every 10 days, are supplied to DAPAF in ADP printout form from GSFC through SOCC.

The sample counts vary from line to line because of satellite attitude. Using the geometry of the SR scanner, the data counts, the reference time, and the orbital parameters, the software determines instantaneous satellite roll angles throughout an orbit. From these measurements, the maximum roll angle and a phasing reference called lambda are determined. Lambda is the point measured in degrees from the ascending node along the satellite orbital track where the roll angle is maximum negative (positive spin axis points away from the Earth) and the satellite yaw angle is zero and going negative. The parameters of roll, yaw, and lambda are Earth-oriented. The attitude routine also transforms these values into the celestial references by calculating the corresponding right ascension and declination values.

SOCC receives a computer printout with instantaneous values of roll angle data and a graphic plot (CALCOMP) of these values versus degrees from the ascending node. SOCC analyzes these determinations for use in the spacecraft operational control and to provide DAPAF with a prediction of future attitude parameters for the operational data gridding and mapping routines.

3.3. COMMAND AND DATA ACQUISITION (CDA) STATIONS

The CDA stations, located at Gilmore Creek, Alaska, and Wallops Station, Va., function as relay stations between the Satellite Operations Control Center (SOCC) at the National Environmental Satellite Service (NESS) and the NOAA satellite. The Gilmore CDA is operated and maintained by a civilian contractor under the GSFC's prime Space Tracking and Data Acquisition Network (STADAN) contract. The Wallops CDA is completely operated and maintained by NESS personnel. The stations, as currently configured, are compatible with two generations of spacecraft: the ESSA APT and ESSA AVCS satellites; and the NOAA series of satellites.

3.3.1. Functions of the CDA Stations

The basic functions of the CDA stations are to: (1) Receive from SOCC the program of commands for the satellite and to convert these commands to audiofrequency tones suitable for modulating the command carrier radiofrequency (RF); (2) transmit commands to the satellite; (3) receive the satellite transmissions and to demultiplex the subcarrier signals that carry sensor data and other data used for determining satellite orientation and for evaluating satellite performance; (4) record these subcarrier signals on magnetic tape; and (5) process and transmit these data, either in real time or by playback of the magnetic tape, to other facilities of the ground complex for reduction and evaluation. In addition, the CDA stations have equipment to monitor and display received data and to provide a backup capability for some of the evaluation and reduction functions.

3.3.2. CDA Station Equipment

Functionally, each CDA station is arranged into six major subsystems (fig. 3-5): Master timing equipment, programing equipment, signal processing equipment, recording equipment, longline data transmission equipment, and teletype and voice communications equipment. In addition, a station control panel and associated circuits provide for central control and monitoring of major station operational functions and a.c. power to the equipment racks.

The master timing equipment, synchronized to a time standard, provides time reference for all CDA station equipment and generates signals that start various events leading to the transmission of automatically initiated command programs.

The programing equipment sets up programs of commands to the satellite prior to satellite acquisition, for timing and generating commands in the proper transmission sequence.

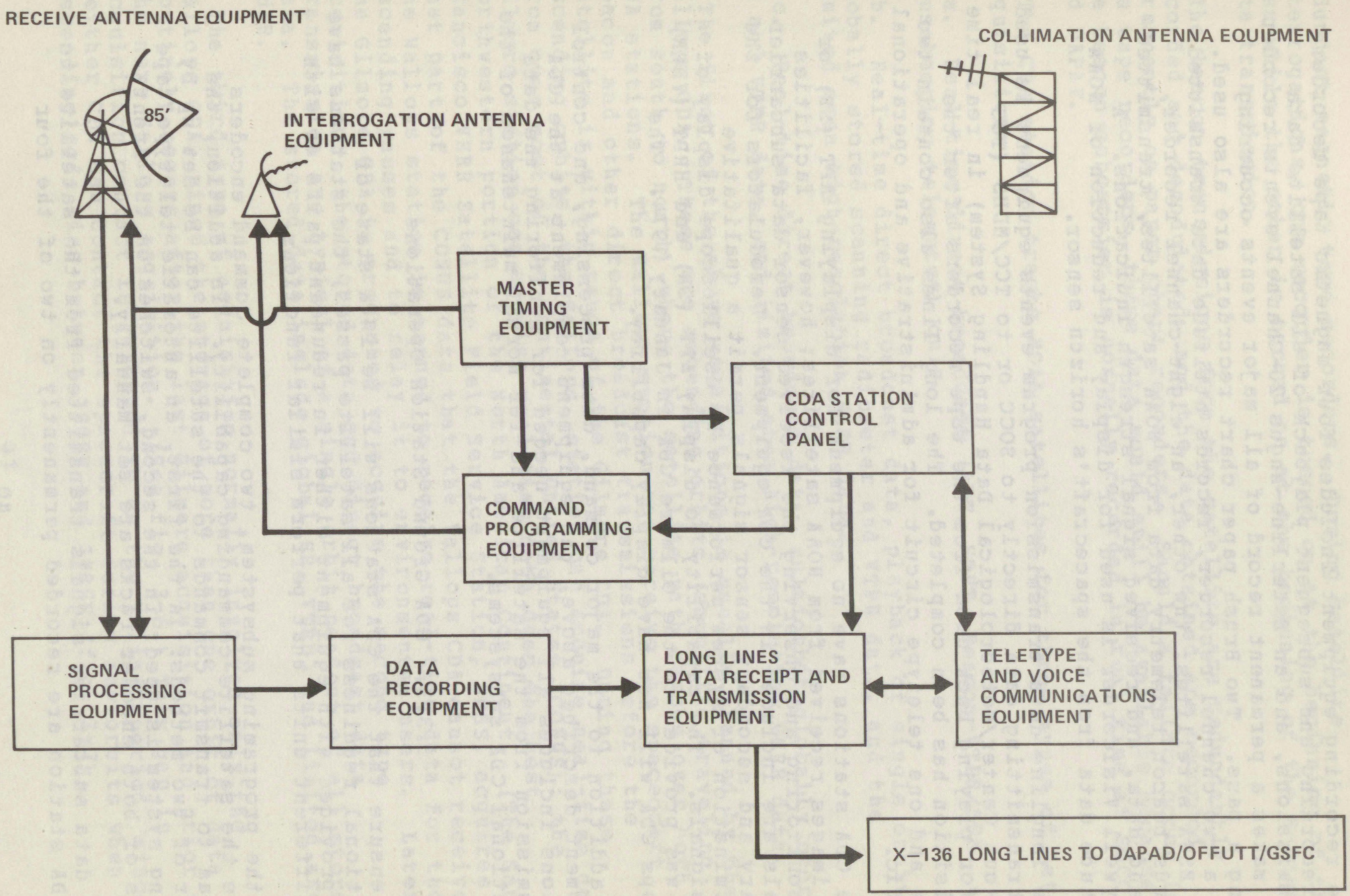


Figure 3-5.--CDA major subsystem block diagram.

The recording equipment includes four magnetic tape recorders for recording and subsequent playback of all satellite data transmissions, and an Esterline-Angus 20-Channel events recorder that makes a permanent record of all major events occurring during a pass. Two Brush paper chart recorders are also used. One, a two-channel recorder, records attitude data transmitted from ESSA satellites; the other, an eight-channel recorder, records beacon telemetry data from NOAA satellites, transmitted command data, and received signal strength indications. A Honeywell Visicorder is used for display and reduction of NOAA attitude data from the spacecraft's horizon sensor.

The longline data transmission program events equipment is used for transmitting data directly to SOCC or to TCC/MDHS (TOS Checkout Center/Meteorological Data Handling System) in real time and for playing back data from the tape recorders after the acquisition has been completed. The long lines also contain two voice and one teletype circuit for administrative and operational traffic.

The CDA stations have no equipment for displaying APT (SR) or VHRR images received from NOAA satellites; however, facilities for monitoring and observing the received sensor data subcarrier signals are included in the CDA equipment. Demodulators for the primary and secondary sensor signals permit a qualitative determination of system performance by oscilloscope display of the signals. The capability to display APT (SR) and HRPT (VHRR) data was provided to the Gilmore CDA in January 1974. The Wallops CDA will not have display capability.

In addition to the major command, data processing, and control equipment described above, the equipment complement at the CDA stations includes all equipment needed for monitoring the data transmission from the satellite and for normal maintenance of the operational CDA subsystems.

3.3.3. CDA Ground Station Operations

To ensure that the CDA stations will be in a state of operational readiness for all satellite passes, the stations have been provided with equipment either in redundant pairs or with two different units that perform similar functions.

In the programing subsystem, two complete command encoders ensure the satellite-commanding capability. In addition, the program to transmit commands to the satellite can be set up by either of two methods: in the first, an automatic teletype tape reading system is used; in the second, switches on the front panels of both encoder racks are set manually.

The data subcarrier signals transmitted from the satellite to the CDA station are recorded permanently on two of the four redundant magnetic tape recorders. During satellite interrogations, one recorder is turned on at the beginning of the pass while the other is turned on at the beginning of the S-band data transmission.

The beacon transmissions from the satellite are redundantly recorded and demodulated, and the data obtained are recorded permanently on paper chart recorders. Should a failure occur in the tape recorders, these data would still be available because the beacon subcarrier is normally recorded in real time at SOCC and DAPAF.

The CDA station tracks NOAA satellites for three types of data acquisition:

a. Real-time direct broadcast (APT, HRPT, Beacon-VTPR/SPM housekeeping telemetry) only.

b. Real-time direct broadcast data, playback of single orbit, globally stored scanning radiometer and VTPR data, and the limited area high-resolution VHRR data.

c. Real-time direct broadcast data, multiorbit globally stored SR and VTPR data, and limited area high-resolution VHRR data.

The first of the above acquisitions is usually planned by the Wallops CDA. These are ascending orbits (satellite traveling from south to north) where the satellite path passes over both CDA stations. The Wallops station can receive the spacecraft beacon and other direct broadcast transmissions before the satellite is within range of the Gilmore CDA. During these ascending orbits, the Wallops station can acquire real-time data from over most of the Continental United States (CONUS); the Gilmore station can acquire real-time data over the most northwestern portion of the North American Continent. (The San Francisco VHRR Satellite Field Service Station, SFSS, acquires that part of the CONUS data that the Wallops CDA cannot receive.) The Wallops station is manned to receive real-time data for these ascending passes and to relay it to environmental users. Later the Gilmore CDA is programed to acquire the second type acquisition: the stored data and direct broadcast data transmission are typical of a single orbit readout of all stored data. The stored data include global SR, VTPR, and limited area VHRR.

The third type of acquisition normally involves only the Wallops CDA, since the storage of more than one orbit of data routinely occurs after the last Gilmore acquisition and prior to the next Wallops acquisition. (See fig. 3-6.) This gap in acquisition contact is referred to as the "blind" period, since neither CDA can contact the spacecraft during any orbits when the ascending node lies between 180°W and 148°E (fig. 3-7).

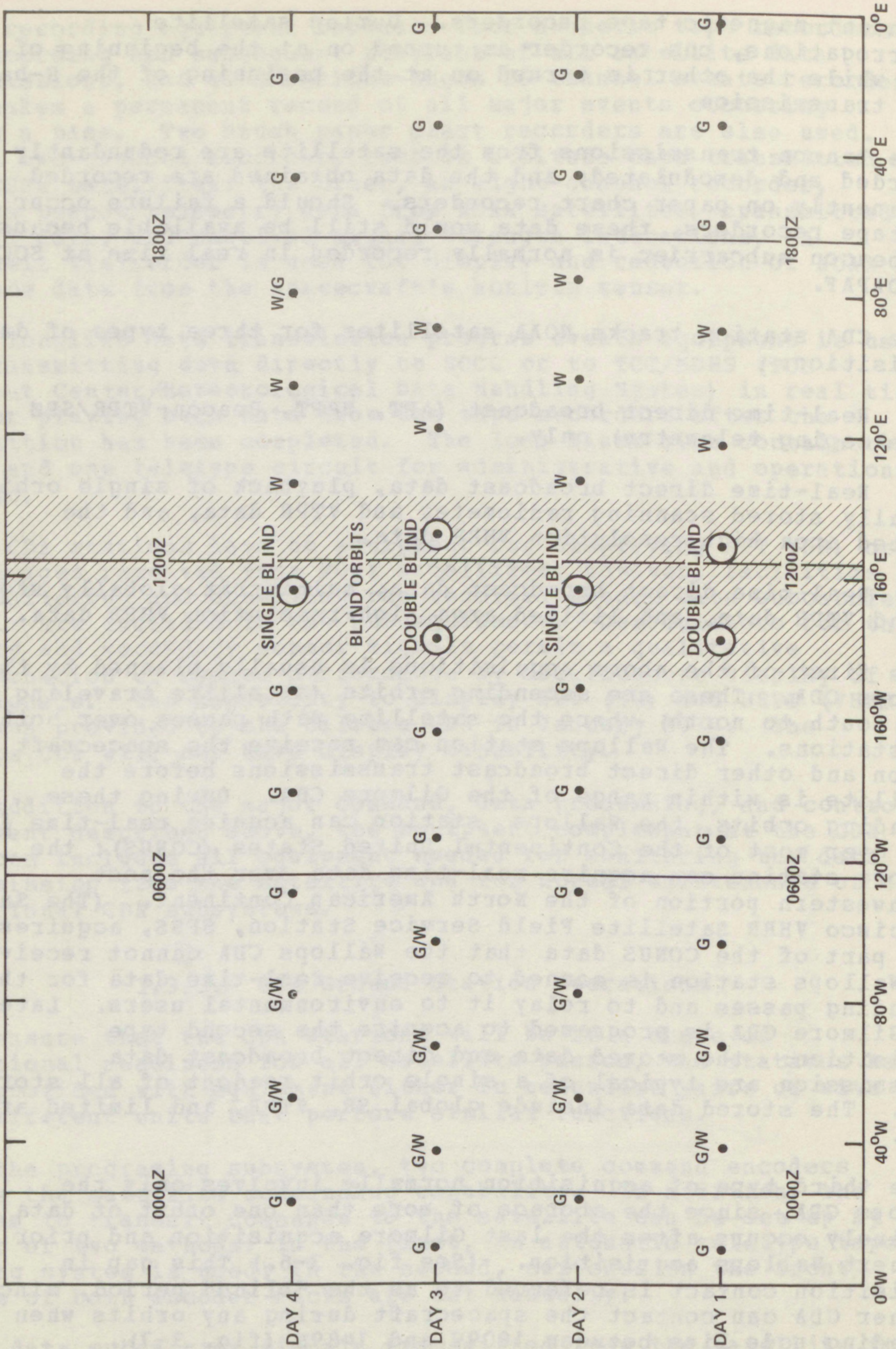


Figure 3-6.--Number of blind orbits on alternating days.

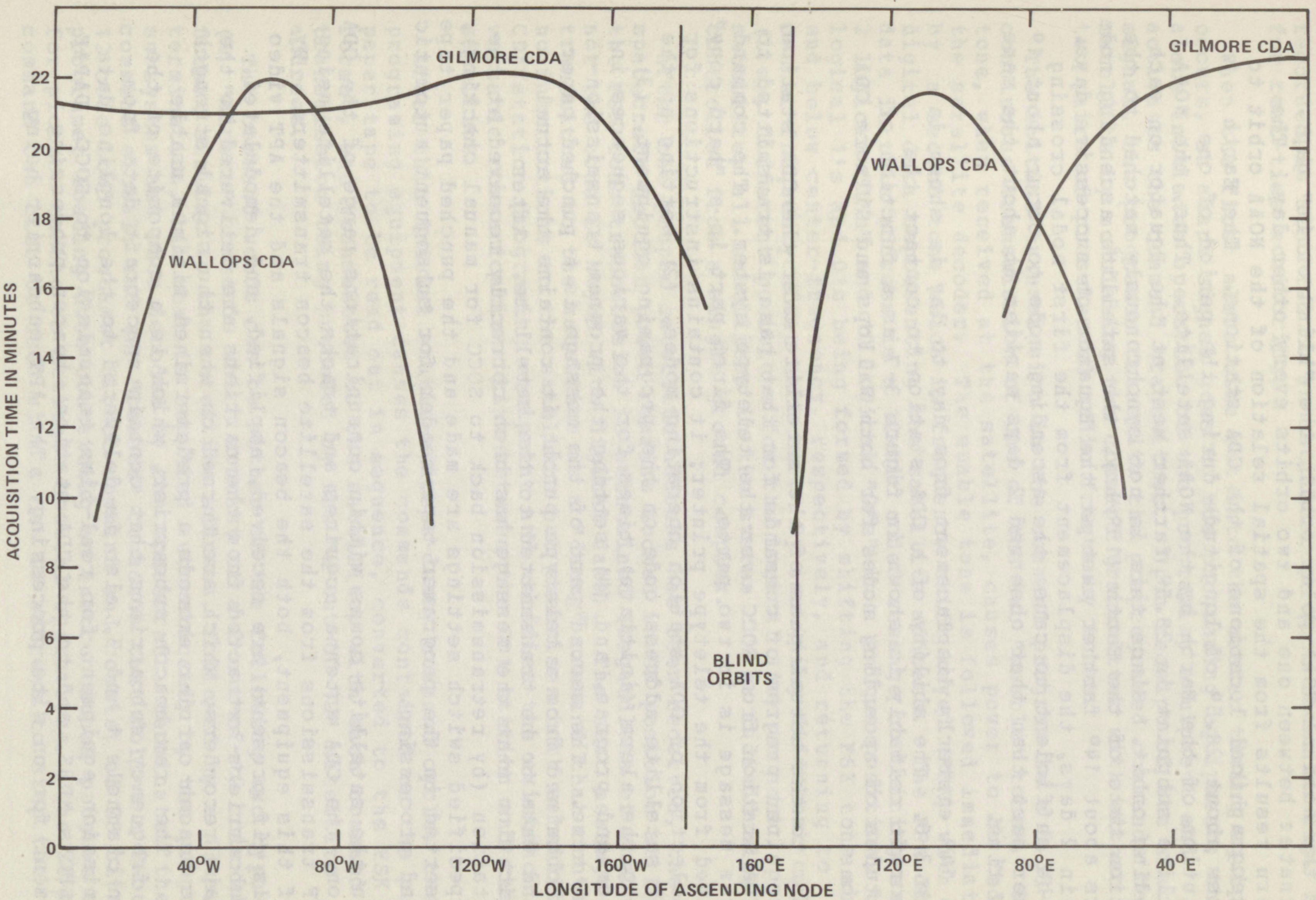


Figure 3-7.--Reliable acquisition periods as a function of ascending node.

For the nominal NOAA polar orbit, the "blind orbit" gap alternates between one and two orbits every other day. The pattern results from the spatial relation of the NOAA orbit to the geographical locations of the CDA stations. The Earth rotates about 28.5° of longitude during the period of one revolution of the Earth by the NOAA satellite. Thus, the NOAA satellite subpoint is 28.5° farther west at the Equator on each suceeding orbit. Since this is not synchronously matched to the rotation rate of the Earth (15°/hr), the satellite ascending node occurs about 14° farther east at the Equator on successive days. Thus in 2 days, the displacement from the first nodal crossing will be sufficient to cause the ascending node to occur about 1° farther east than that observed 2 days earlier at about the same local time.

The 14° easterly displacement from day to day is shown in figure 3-6. The ability of a CDA station to contact the spacecraft reliably is shown in figure 3-7 as a function of longitudes of ascending nodes for both Wallops and Gilmore CDA stations.

Prior to the actual pass of the satellite over the CDA station, the required program of commands for that pass is transmitted to the CDA station from SOCC over the teletype system. The command program message is in two parts. The first part is a "hard copy" obtained from the teletype printer; it contains instructions for (1) selection of CDA station operating modes, (2) setting up the proper satellite address code on the programing equipment, (3) setting the alarm (initiate) times for the various sequences in the command program, and (4) setting the program transmission-length time. The second part of the message is a punched paper tape, obtained from a teletype punch; it contains the actual command data to be transmitted to the satellite. After verification that the message has been correctly received at the CDA station (by retransmission back to SOCC for manual checking), the specified switch settings are made and the punched paper tape is inserted in the programer tape reader for subsequent automatic command processing.

When the satellite comes within communications range of the CDA station, the CDA antenna acquires and tracks the satellite using the RF transmissions from the satellite beacon transmitters. By use of this equipment, both the beacon signals and the APT video signals (if present) are received, amplified, and demodulated. The subcarriers extracted from the carriers are delivered to the CDA tape recorders, which are turned on when the signal strength of the beacon carrier exceeds a predetermined minimum usable level. The raw beacon subcarrier, which is a composite of the audio frequency subcarriers that contain spacecraft data from beacon channels 1 and 3, also is delivered to the longline data transmission equipment for real-time transmission to SOCC, DAPAF and GSFC's MDHS, and to the CDA station beacon processing equipment for on site processing. The APT subcarrier being recorded is also fed to an oscilloscope (not shown on fig. 3-8) for real-time monitoring.

When the first alarm time set into the master timing equipment occurs, an alarm signal goes to the programing equipment; this alarm initiates operation of the programing equipment and activates the command transmitter. Upon receipt of the alarm signal, the programer transmits the preprogramed commands to the satellite by modulating the command transmitter with either of two pairs of preselected audio frequency tones.

The initial transmission in the command program is a 5.35-sec continuous transmission of one of the two "enable" tones. This tone, when received at the satellite, causes power to be fed to the satellite decoder. The enable tone is followed immediately by a second tone which is frequency shift keyed (FSK) with digital data representing the satellite address. The FSK digital data in this address is a 12-bit coded message containing exactly 2 logical "1's" and 10 logical "0's" in a unique position, the logical 1's and 0's being formed by shifting the FSK tone above and below center-frequency, respectively, and returning to center-frequency after each bit. By assigning different codes (i.e., different positions for the logical 1's) to each satellite, all satellites in the system can be individually controlled from a single ground complex.

After the proper satellite address has been received, the spacecraft decoder power remains locked in ON position as long as the FSK tone transmission is maintained (regardless of whether or not the tone is keyed with digital data). The next message transmitted to the satellite is a "dummy" command that contains no instructions to the satellite but exercises both satellite and CDA station programing equipment and verifies the existence of a workable communications link between the CDA station and the satellite.

After this initial enable-address-dummy command cycle, the programing equipment causes the commands contained on the punched paper tape to be read out in sequence, converted to the FSK format, and transmitted to the satellite, with each command word transmission being preceded by the "2-out-of-12" satellite address.

The command words can be either of the following two types: (1) "direct" commands which consist of a 2-out-of-12 code with a format similar to the satellite address, followed by a 13th, or termination, bit that is supplied automatically by the programing subsystem and when decoded by the spacecraft, terminates the command signal; and (2) "remote" commands that follow a 2-out-of-12 code load programer direct command and consist of 28 bits of programer loading data containing an instructional program either for picture-taking or attitude control operations. The 28-bit command can also be used with a Set II address to step the

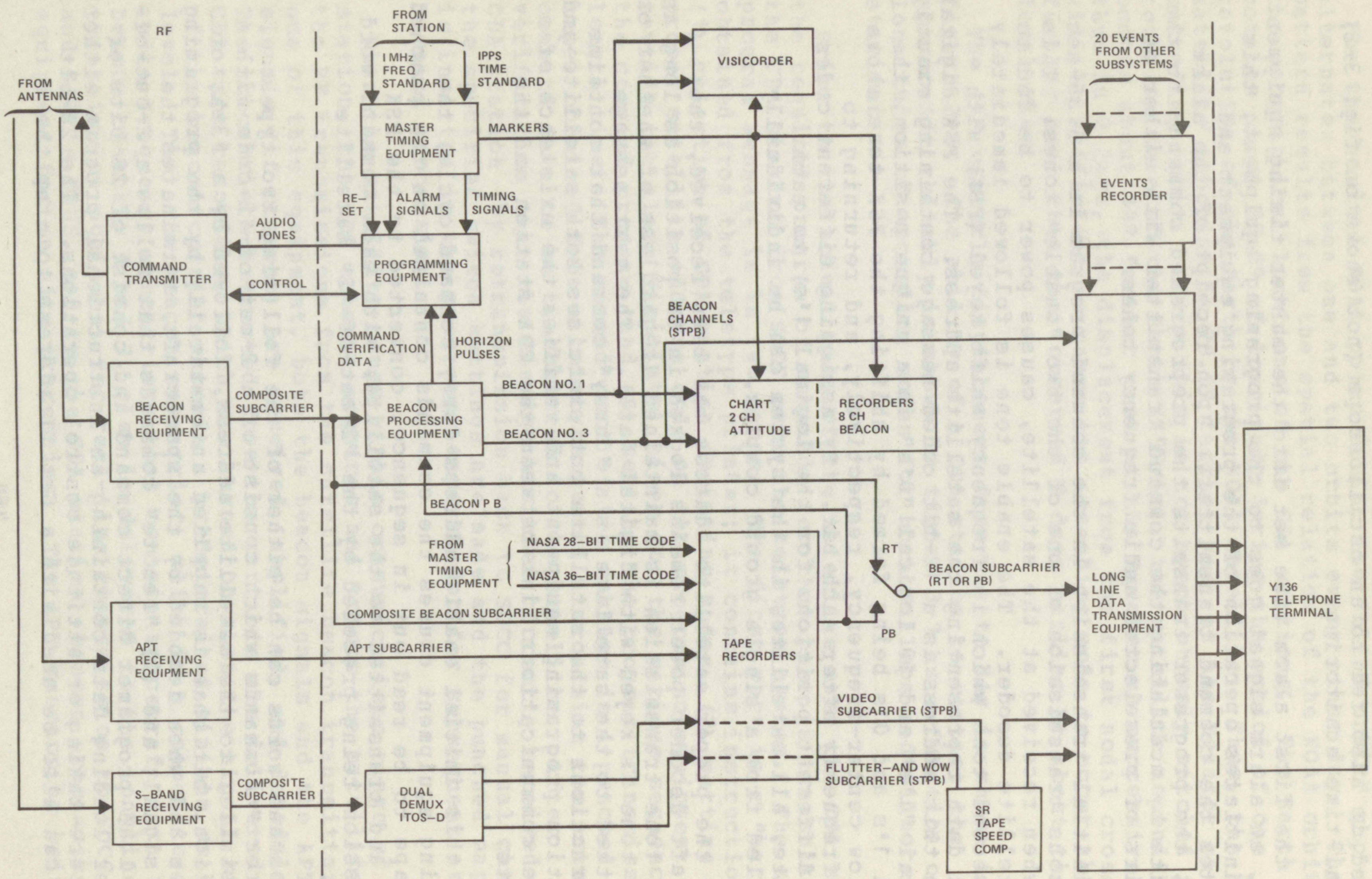


Figure 3-8.--CDA station, functional block diagram.

telemetry commutator in the "manual" mode. The updating of remote commands is done by using a clock-derived pulse every 6.5 s.

As each FSK digital command is received by the satellite, it is decoded, reconstructed, and retransmitted to the CDA station via the 3.9-kHz beacon subcarrier. At the CDA station, the command verification data are compared with the data being transmitted; any errors detected by this comparison process cause an error alarm signal to be generated. Depending upon the mode of operation selected for the command verification function, the programing eqtipment will (1) cause the error-containing command word to be retransmitted automatically, (2) cause programer operation to stop until the transmission is reinitiated by manual action, or (3) ignore the error indication entirely.

Upon completion of the first sequence in a command program, the programing equipment goes into a "hold" status, but maintains FSK center-frequency tone transmission to keep the satellite "enabled." In multisequence command programs, subsequent alarms from the alarm timer will cause any remaining sequences to be processed as described above; however, it is not necessary to repeat the enable tone. (A total of six command sequences can be programed.)

A preset transmission-length timer keeps the command transmitter and the FSK tone ON until the preset time has elapsed. The timer then produces a reset signal that (1) causes the programing equipment to turn off, (2) ends the FSK tone, and (3) turns off the command transmitter plate power.

Throughout the pass, the beacon-processing equipment accepts the composite beacon signal from the satellite and separates and demodulates the two subcarriers of the composite. The demodulated data from the 2.3-kHz beacon subcarrier, which contains attitude data, is fed to the CDA attitude recorder for use in attitude reduction at the CDA station. The demodulated output of the 3.9-kHz subcarrier is recorded on one channel of the eight-channel beacon recorder together with video signal, beacon signal strength indications, and command data.

A 20-channel Esterline-Angus events recorder provides a direct, real-time record of significant events that occur during the satellite pass. This unit is useful for checkout of CDA equipment prior to a pass, for analysis of malfunctions that occur during the pass, and for postpass analysis of station operation.

The longline data transmission equipment is used to relay data received at the CDA stations to other units of the ground complex. During APT interrogations, this equipment transmits the composite beaccn subcarrier directly to SOCC, DAPAF, and TCC/MDHS as the data are received at the CDA station. Units in the subsystem sample and commutate major CDA station events and command program data and transmit these data in the form of multiplexed, frequency shift keyed audio tones to SOCC to permit that facility to monitor CDA operation in real time. In addition, the longline data transmission equipment, operating in conjunction with the recorder, enables playback and transmission of the recorded composite beacon subcarrier and command events to any facility in the ground complex after the pass is over.

At the conclusicn of the satellite pass, the data taken (i.e., the chart records and magnetic tapes) are arranged in a systemized format and are transmitted to the various cognizant agencies.

When the command to play back video data is transmitted to the satellite, the second recorder in the CDA station is turned on; this recorder operates at 60 ips. The video-receiving equipment at the CDA station receives and amplifies the RF carrier, separates the composite subcarrier from the RF carrier, and delivers the composite to the CDA recorders and the NOAA demultiplexers.

The NOAA satellites have four operational modes that may be commanded to select sensor playback (stored) data. The data played back in each mode are:

Mode	Data
A	VHRR real-time (prime).
B	VHRR real-time (prime) and VHRR real-time (backup).
C	VHRR real-time (prime), VREC PB, VREC F&W, SRR-B video, SRR-B F&W, and DIGITAL-B.
D	SRR-A video, SRR-A F&W, SRR-B video, SRR-B F&W, DIGITAL-A, DIGITAL-B, and VHRR real-time (prime).

Throughout the pass, the beacon-processing equipment accepts the composite beacon signal from the satellite and separates and demodulates the subcarrier contained in the composite. The composite beacon subcarrier consists of two subcarriers--channels

1 and 3. Channel 1 contains attitude data that are demodulated and displayed on a Visicorder, a two-channel light sensitive paper recorder. Channel 3 is used for command verification, Sun angle data, and telemetry. Channel 3 is modulated with real-time Solar Proton Monitor (SPM) data if none of the foregoing have been selected. The demodulated output of beacon channel 3 is presented on one channel of the eight-channel beacon recorder, together with video and beacon-signal strength indications and command data. The demodulated signals from each beacon channel may also be displayed on the Visicorder, although this is intended primarily for use in reduction of horizon sensor attitude data. The phase-modulated data on the 137.14-MHz BCN is recorded on analog tape recorders in composite form. The Wallops CDA has the capability to phase-demodulate these data for later processing. The Gilmore CDA can only record the phase modulated IF.

At the end of the satellite pass, the individual signal subcarriers and the associated flutter-and-wow (F&W) subcarriers are played back from one of the recorders and transmitted to the Data Processing and Analysis Division (DAPAD) at NESS and the Global Weather Central (GWC) at Offutt AFB, Neb., where the data are processed for environmental use. However, to make the signal subcarriers and the F&W subcarriers compatible with the telephone-voice channels of the ground complex communications network, the SR and VHRR data are played back at slower rates than the CDA record rate. This reduces the instantaneous frequency range of each video subcarrier to within the 13- to 30-kHz bandwidth and the range of the F&W subcarriers to 6250±300-Hz bandwidth, both of which can be carried by the telephone equipment.

The NOAA satellite tape recorders have speed variations that adversely affect the display of image data unless a compensation technique is used on the ground. SR tape speed compensation is done at both CDA stations with a technique called the Z-axis correction system. The SR tape speed compensation device receives the F&W tone from the CDA video tape recorder and demodulates the frequency-modulated signal to analog levels. Simultaneously, the SR data stream output from the same tape recorder is time delayed and demodulated to analog levels. The F&W analog levels are used to detect and correct speed variations in the satellite recorders. The magnitude of the error is determined, and a compensation correction voltage is applied to the delayed SR analog voltage level. This compensation signal increases or decreases the SR signal level depending on the detected speed error. The corrected SR analog level is then used to frequency modulate a carrier tone. This tone and the original F&W signal are then transmitted to DAPAF and GWC for processing.

The stored Digital Data Processor (DDP) data are received at the CDA at a 10.667-kilobit/s rate. These data are translated to the SATCOM wideband link by a unique modem. This frequency translation enables transmission of the DDP data over channel A of the SATCOM wideband at the same rate the CDA receive them. Thus, DDP data usually are transmitted immediately to DAPAF, GWC, and GSFC from the CDA demultiplexer. SR data are recorded at the CDA at 60 ips and played back through the SATCOM wideband at 15 ips. The VHRR data (either HRPT or VHRR Recorder (VREC) data) require an 8 to 1 decrease in tape speed (recording rate is 60 ips, retransmission rate is 7.5 ips) to permit transmission on channel A. VREC data transmission time over channel A is about 80 min; this so restricts the transmission of other data that VHRR data usually are mailed from Gilmore and Wallops to DAPAF in the form of analog tape recordings. Wallops, however, can digitize the data and transmit it to DAPAF over another wideband circuit.

When data aquisition and transfer are completed at the CDA, the supporting data, i.e., chart records and magnetic tapes, are arranged in a systematized format and transmitted to various cognizant agencies.

3.4. NOAA SATELLITE COMMUNICATIONS NETWORK (SATCOM)

Components of the NOAA polar operational system are linked together by SATCOM, a unique communication system. The SATCOM network also is used with the geostationary satellite system. This document describes only the portion of SATCOM used for the NOAA Polar Satellite System.

Figure 3-9 is a block diagram of the NOAA SATCOM communication network. The network consists of the satellite and the following facilities:

Command and Data Acquisition (CDA) Stations

- Gilmore Creek, Alaska
- Wallops Island, Va.

Satellite Operations Control Center (SOCC) - Suitland, Md.

Goddard Space Flight Center (GSFC) - Greenbelt, Md.

Offutt Air Force Base - Omaha, Neb.

Once the data are received at the CDA stations, they must be be transmitted to the location where they will be processed and analyzed. Processing of the telemetry data must be done in real time to verify satellite status as commands are transmitted. Transmission of sensor data can be delayed until the end of the data acquisition period. The requirements for ground communication from Wallops or Gilmore to Suitland are shown in

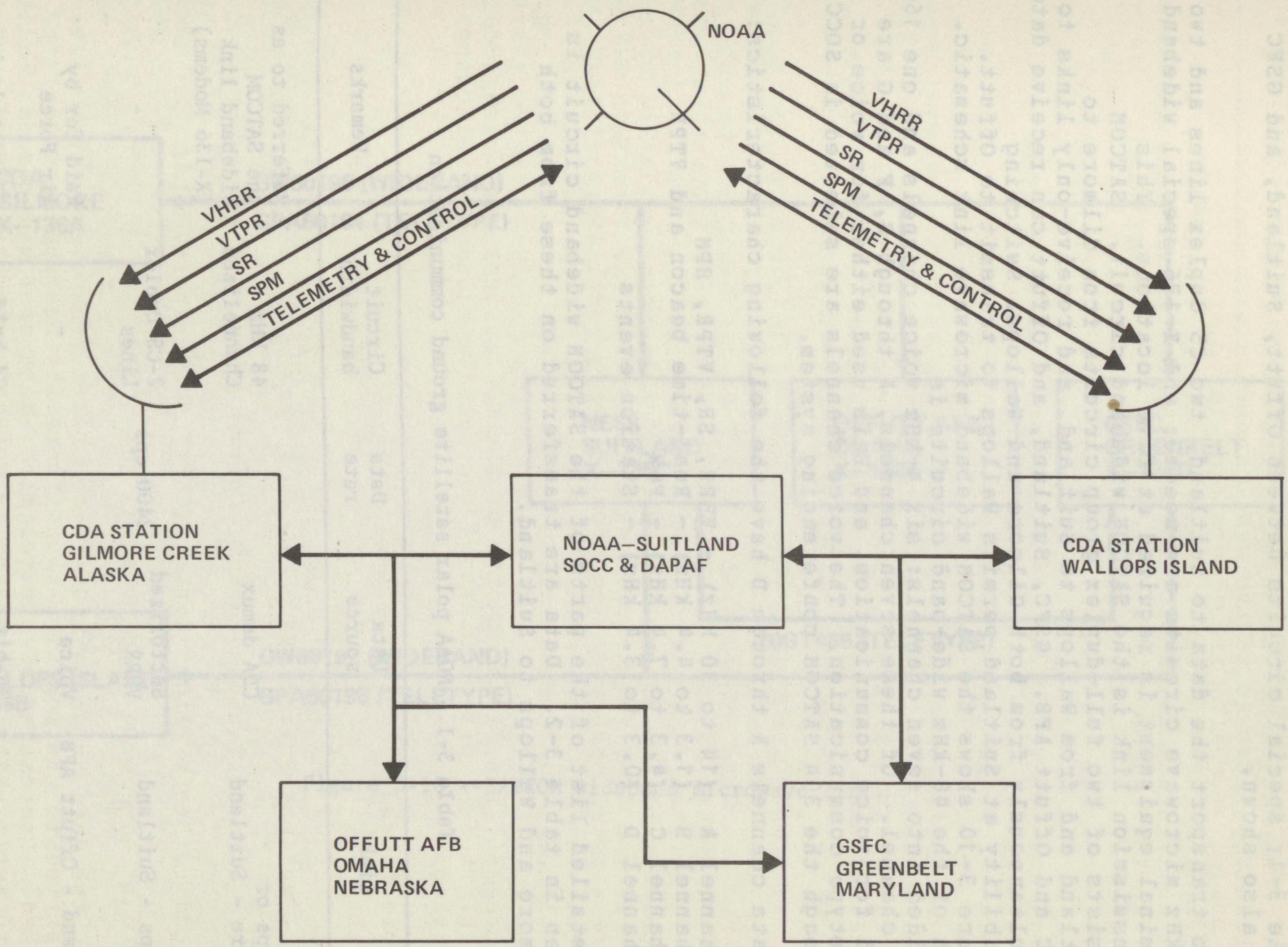


Figure 3-9.--Generalized NOAA system concept.

table 3-1; special circuits between Offutt, Suitland, and GSFC are also shown.

To transport the data to Suitland, two C5 duplex lines and two 48-kHz microwave circuits are needed; and X-136 special wideband terminal equipment is required at five locations. This transmission link is the SATCOM wideband circuit. SATCOM consists of two full-duplex group circuits from Gilmore to Suitland and from Wallops to Suitland, and receive-only links to GSFC and Offutt AFB. GSFC, Suitland, and Offutt can receive data simultaneously from both Gilmore and Wallops. Switching capability at Suitland permits Wallops to transmit to Offutt. Figure 3-10 shows the SATCOM wideband microwave link schematic. Each of the 48-kHz wide-band circuits is divided into seven channels: six 4-kHz voice channels and one 16-kHz channel. Of these seven channels, A through G, F and G are used for voice communication, and E is used either for voice or teletype communication. The voice channels are selected in SOCC through the 304 SATCOM conferencing system.

Data channels A through D have the following characteristics:

Channel A (14 to 30 kHz) - VHRR, SR, VTPR, SPM
Channel B (1.3 to 4.4 kHz) - Real-time beacon and VTPR
Channel C (4.3 to 7.4 kHz) - F&W
Channel D (0.3 to 3.4 kHz) - Station events

A detailed list of the parts of the SATCOM wideband circuit is given in table 3-2. Data are transferred on these from both Gilmore and Wallops to Suitland.

Table 3-1.--NOAA polar satellite ground communication

Link	Data source	Data rate	Circuit bandwidth	Remarks
Wallops or Gilmore - Suitland	CDA demux	-	48 kHz Channelized	Referred to as the SATCOM wideband link (X-136 Modems)
Wallops - Suitland	Sectorized VHRR	2400 cps	2-C5 Duplex Lines	-
Suitland - Offutt AFB	Voice	-	-	Paid for by Air Force
GSFC - Suitland	36-bit time code	2300 cps	C4 half duplex	Circuit designation 70-GD-309

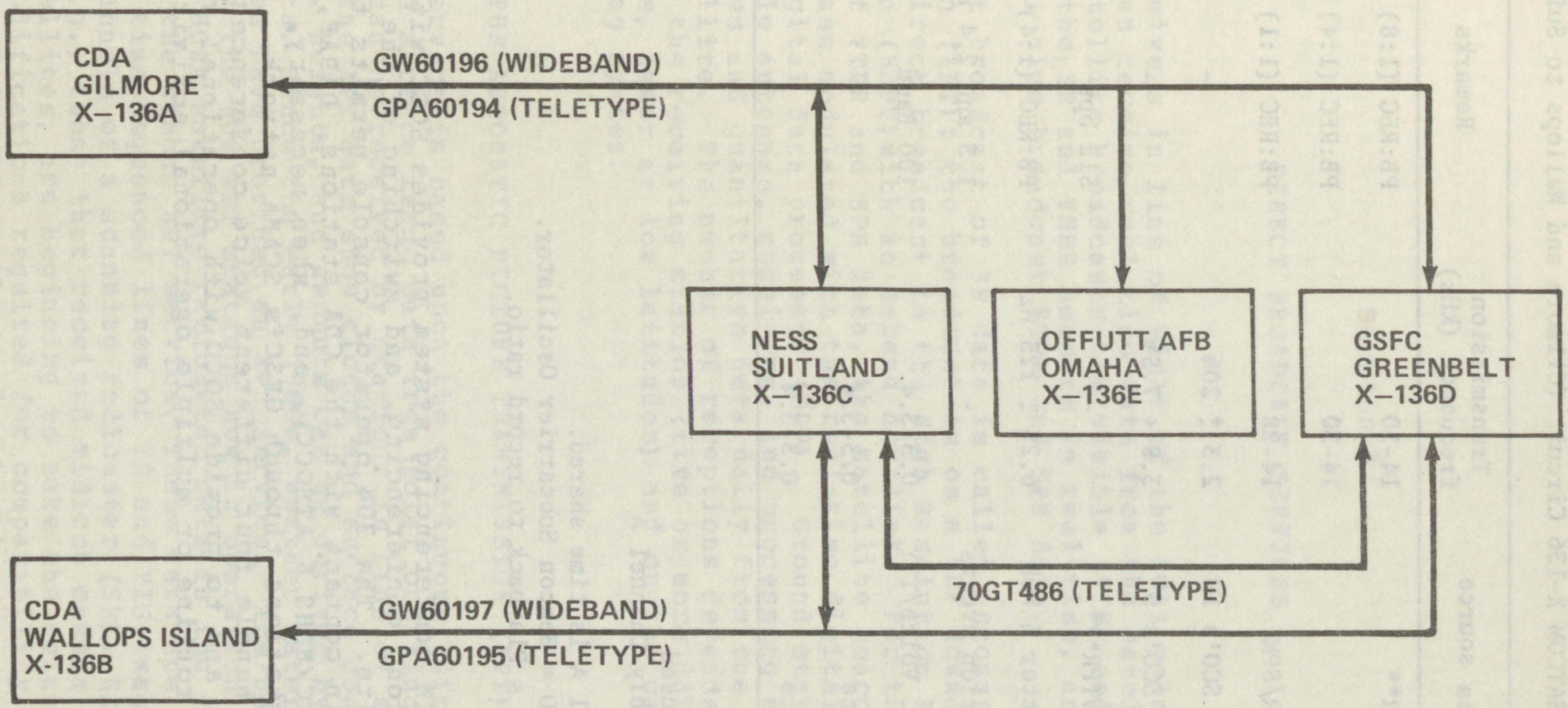


Figure 3-10.--SATCOM wideband microwave link.

Table 3-2.--SATCOM X-136 Circuit (Gilmore and Wallops to Suitland).

Channel designation	Data source	Transmission frequency (kHz)	Remarks
A*	VHRR**	14-30	PB:REC (1:8)
A	SR	14-30	PB:REC (1:4)
A	VTPR/SPM	14-28	PB:REC (1:1)
B	BCN SCO's 1M	2.3 ± 20%	-
B	BCN SCO's 3	3.9 + 7.5%	-
A	RT VTPR***	-	512 bps
C*	Flutter & WOW	6.25 ± 125 Hz	PB:REC (1:4)
D	Station events	-	1.3 and 2.4 kHz carriers
E	Alt. Voice/TTY	0.3-3.4	100 Baud
F	Voice	0.3-3.4	
G	Voice	0.3-3.4	

*To Offutt AFB
**Not routinely used
***Unknown; probably Channel A

Notes: Channel A is time shared.
BCN SCO = Beacon Subcarrier Oscillator.
PB:REC = Playback to record ratio.

The 304 SATCCM conferencing system provides SOCC with voice circuit selection, conferencing, and switching of the voice and teletype circuits. The 304 operator console permits the SOCC crew to maintain contact with the CDA stations, DAPAF, data users, GSFC (TTC/MDHS & ATSOCC), and, when necessary, with any of NASA's STADAN stations through GFSC's SCAMA network. The console can be used to handle four different voice conferences simultaneously, and to provide SOCC with operational voice control during routine or multiple operational activites.

Section 4

DIRECT BROADCAST SERVICES

Local receivers in line of sight of the NOAA polar orbiting satellite can receive real-time data from the satellite sensors. The NOAA satellite broadcasts the visible (VIS) and infrared (IR) data from the SR and VHRR sensors in real time, and, starting with NOAA-3, also broadcast VTPR and SPM data.

The direct broadcast of SR data is called Automatic Picture Transmission (APT); the broadcast is on a VHF downlink. For VHRR data, the direct broadcast is the High Resolution Picture Transmission (HRPT) with an S-band downlink. For the direct broadcast of VTPR and SPM data, the satellite beacon carrier (VHF) is phase modulated with the real-time digital data stream from the digital data processor (DDP). Ground stations equipped with suitable antennas, receivers, and processing equipment can obtain images and quantitative data daily from one or more passes of the satellite. The number of receptions depends on the latitude of the receiving station (five or more daily at midlatitudes, fewer at low latitudes) and on the capabilities of the receiving system.

4.1. THE AUTOMATIC PICTURE TRANSMISSION (APT) SERVICE

The APT service is based upon the continuous, direct broadcast of cloud and surface image data from polar orbiting satellites. The signal can be received by stations in line of sight of the satellite. The APT data show clouds and surface conditions. Cloud types, heights, and amounts can be derived by examination of these data. Since the early 1960s, weather satellites of the United States have provided an APT Service. Its popularity is indicated by the 600 APT stations now in operation around the world. The NOAA satellite radiometer data is the type first provided by the Nimbus APT service. These data are transmitted in the form of time-sequenced lines of IR and VIS imagery from separate channels of a scanning radiometer (SR). Existing APT stations, e.g., those that received vidicon camera data from earlier satellites, are beginning to make the relatively minor equipment modifications required for compatibility with the NOAA SR-APT, i.e., primarily a change in the line repetition rate of the display device. This new form of APT service will be continued on future NOAA satellites.

The essential appeal of the APT service to local users is twofold:

a. The receiving/display systems are inexpensive, ranging from a few hundred dollars (US) when built from surplus equipment, to many thousands of dollars when purchased from any one of several manufacturers.

b. The images can be recovered in real time; the only source of delay is film processing.

So long as APT stations retain these two features, the receiving/display system and the produced images will be relatively unsophisticated. Within this framework, however, there is a wide variety of receiving/display equipment, and many important uses for the imagery.

The NOAA-2 SR and the associated spacecraft signal processing are discussed in detail in section 2.1.3.1. The basic technical requirements for and the operation of SR-APT ground stations are described below.

4.1.1. Description of the SR-APT Images

The primary products of SR-APT are infrared (IR) and visible (VIS) images that can be recorded either at 48 or 96 lpm. The ratio of line length to line spacing in the recorder is nominally 800 (400 for the 96-lpm system). Such images retain the full resolution of the SR. The subpoint resolutions are 7.8 km for the IR and 3.9 km for the VIS; these are degraded by a factor of 2 to 3 near the edges of the image (±60° from zenith) because of the scan rotation and the earth's curvature. The aspect ratio (defined in the glossary appendix) of the raw imagery data will be 1:1 at the subpoint, but degraded to 1:15 at approximately ± 45° from nadir.

With a 48-lpm image recorder, the IR and VIS images will be side by side, each approximately one-third the line length (image width) of the display. By changing the recorded speed to 96 lpm, doubling the line width, and suppressing the signal in alternate lines (to avoid interlacing of IR and VIS imagery), the image width is doubled and the overall appearance is much improved. With the 96-lpm device, the image intensity can be controlled separately for IR and VIS. With the 48-lpm system the intensity must be set somewhere between saturation for the VIS data and washout (weak) for the IR data.

The images are ungridded and unstretched. A proposed "linearization" adapter to correct the panoramic distortion of the imagery is discussed in section 4.1.2.4.

APT stations at midlatitude are able to receive as many as three successive passes of SR imagery during the day and as many again at night; at higher latitudes, more passes are available. The duration of a pass is approximately 17 minutes when the satellite is tracked to elevations as low as 5° above the local horizon. This would be more than sufficient imagery data for a 10-in image per pass. Actual size depends on the particular display device; the example here is for an 8-in, 48-lpm facsimile recorder. The image covers a roughly square area approximately 3,200 km on a side, with the edges of the image severely distorted but still useful.

Images are the primary APT products. The imagery data can be processed quantitatively at receiving stations where the interest is in determining the temperature fields (Earth surface and cloud tops).

4.1.2. Functional Description of a Typical APT Ground Station

4.1.2.1. The SR-Video Baseband Signal Characteristics

The characteristics of the APT baseband signal are illustrated in figure 4-1. The IR and VIS channels are time multiplexed within a single revolution of the 48-rpm scanning radiometer. The IR data occupy the first 625 ms of a single revolution; the VIS channel data are delayed 625 ms by the SR recorder and inserted during the last half of the revolution period. The capability of a single channel (IR or VIS) transmission from the spacecraft is maintained as a backup mode. Figure 4-1 shows the SR-APT signal characteristics. The following characteristics should be noted:

a. Seven 300-Hz pre-Earth synchonization pulses (at A and A') precede each set of data.

b. The post-Earth synchronization porches (F,F',H,H') are 10 ms in duration; the playback sync pulse (G, G') is 30 ms.

c. Approximately 400 ms of Earth imagery (C,C') is in each data set. The SR views the Earth for only about one-third of the 1,250-ms rotation period.

d. The telemetry window for IR (E) consists entirely of voltage calibration steps (five steps, six levels, each of 10-ms duration). The VIS telemetry window (E',F') consists of 11 lines of data for calibrating the IR output and 14 lines of voltage calibration steps. Except for the voltage calibration steps, the inserted backscan, and the thermistor outputs, the information in these telemetry windows is for engineering evaluation and computer processing purposes and so is of no direct interest to the average APT user.

4.1.2.2. The APT Receiving System for SR Data.

For best imagery, a baseband S/N ratio (p-p video/rms noise) of at least 40 dB normally and no more than 30 dB under the worst operational conditions should be recovered for the image display device. The link analysis (table 4-1) shows that the antenna should have an effective gain of at least 11 dB at 130 to 196 MHz and the system noise temperature (Ts) should be less than 1,700°K near the horizon. Typically, a crossed yagi array or a helix antenna with a positionable mounting should have sufficient gain and beamwidth (as high as 50° at half power levels) to make for easy manual tracking of the spacecraft. A preamplifier of some sort is required to achieve a Ts of 1,700°K. For the maximum available coverage of the local region, the video signals should be recoverable at tracking elevations at least as low as 5° above the local horizon. An APT station with this capability at midlatitude could receive as many as three successive passes of SR data from NOAA-2 twice daily.

The FM receiver must be equipped with automatic frequency control (AFC), automatic gain control (AGC), and a meter to indicate the signal strength for tracking purposes. Programed tracking is a worthwhile addition to the system. The receiver must be tunable to the carrier frequencies (137.50 and 137.62 MHz) with a bandwidth of 50 kHz (27.2 kHz RF spectral BW plus doppler shift and instability margin). The FM carrier must be demodulated to recover the AM subcarrier. The baseband signals of the IR and VIS data (video bandwidths of 450 Hz and 900 Hz, respectively) are then detected and filtered. Selection of the optimal filter for the individual user is discussed in section 4.1.2.5. A typical APT ground station is diagramed in figure 4-2.

A tape recorder might be added to the system to protect against loss of data during any malfunctions of the image recording device and could be used for certain image processing purposes. The tape recorder requirements are:

a. Record and playback at 19.5 cm/s and sufficient tape length to hold data from a single pass,

b. Record and playback amplitude stability,

c. Compatible with the 2400-Hz subcarrier of the video baseband signals, and

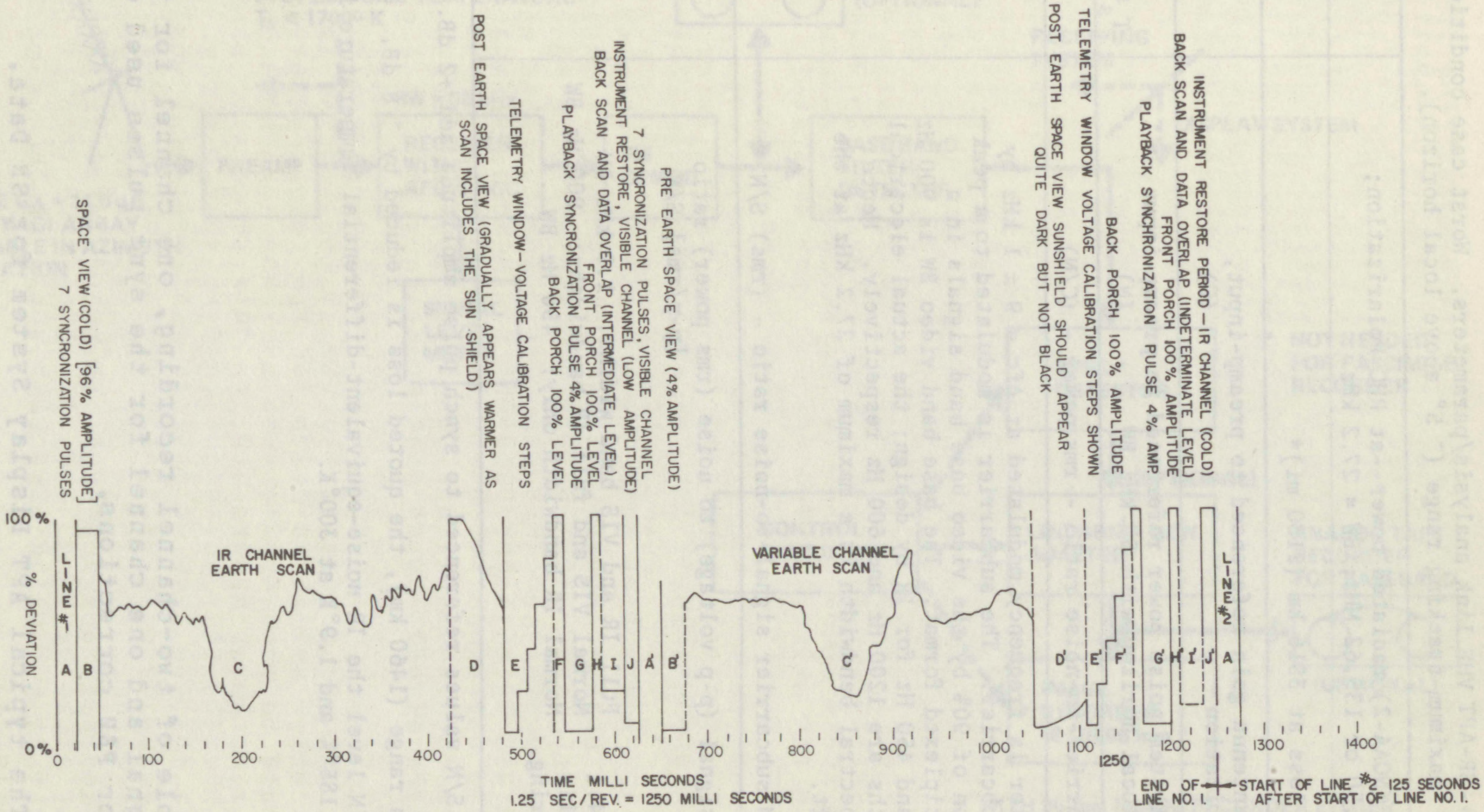


Figure 4-1.--APT baseband signal.

Table 4-1.--SR-APT VHF link analysis/parameters. Worst case conditions at maximum tracking range (~ 5° above local horizon).

Spacecraft (NOAA-2) radiated power--at RHC Polarization; fc = 137.50 or 135.62 MHz; BW = 27.2 kHz	29 dB
Space path loss at 3516 km (2180 mi)*	-147 dB
Effective antenna gain referenced to preamp-input, RHC polarization (C)	11 dB
Effective system noise power referenced to preamp-input at near local horizon with 50-kHz BW (N)	-119 dBm $T_s \cong 1700°K$
Received carrier-to-noise ratio - rms power - (C/N)	12 dB
The carrier is frequency modulated at $\Delta fc = 9 \pm 1$ kHz by the AM subcarrier. The subcarrier is modulated to a peak modulation of 90% by the video base band signals in a time-multiplexed format. The base band video BW is 900 Hz for VIS and 450 Hz for IR by design; the actual electrical band widths are 1200 Hz and 600 Hz respectively. Hence the RF spectral bandwidth is a maximum of 27.2 kHz at the spacecraft.	
Received AM subcarrier signal-to-noise ratio - (rms) S/N	30 dB
Base band signal (p-p voltage) to noise (rms power) ratio - [p-p/rms] S/N	
Refer to Section 4.1 for details on filtering. Full IR and VIS band widths: 1.2 kHz BW	34 dB
Normal VIS and full IR bandwidths: 900 Hz BW	35 dB†
Normal IR bandwidth only: 450 Hz BW	38 dB

Note: For S/N values referenced to synch pulse amplitude add +2 dB.

*At minimum range (1460 km), the quoted loss is reduced by ~ 8 dB.

†At this S/N level the IR noise-equivalent-differential temperature is 9.3°K at 185°K and 1.9°K at 300°K.

d. Capable of two-channel recording, one channel for the imagery signal and one channel for the sync pulses used during playback for F&W corrections.

4.1.2.3. The typical APT Display System for SR Data.

The SR imagery can be displayed by a 48 lpm recording drum or other line-drawing device. This requires a minimal modification

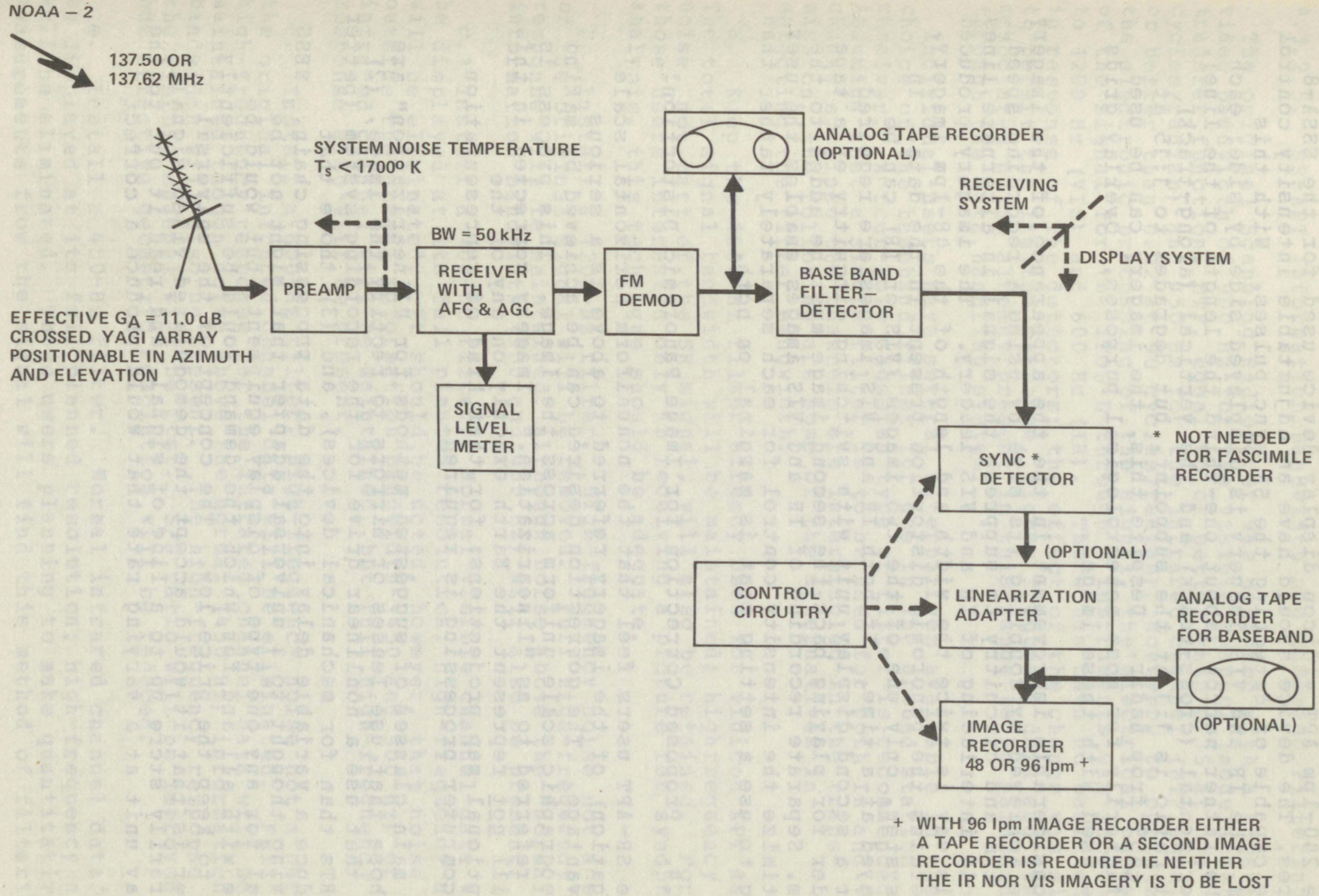


Figure 4-2.--SR-APT ground receiving and display system.

to the 240-lpm APT vidicon display device used for the ESSA-8 pictures. The device should have an adjustable intensity control and be capable of detecting the SR sync pulses. With this system, the IR and VIS imagery is displayed side by side; each will be rather narrow (about one-third the length of the line). The horizcntal (cross-track) and the vertical (along-track) aspect ratio is 1:1 at the subpoint, but degrades to 1:15 at about ±45° from nadir. Despite this, the imagery can be used satisfactcrily for most meteorological purposes. Overlay grids can be used with these images.

A considerable improvement in the the appearance of the imagery can be achieved by doubling its size by using a recording speed of 96 lpm and circuitry to suppress the signal in alternate lines to avoid interlacing of IR and VIS imagery. The imagery produced in this way is twice the width and length of the 48-lpm imagery, but retains the panoromic distortion present in the data. In this system, only one of the two images (VIS or IR) can be displayed at a time. If both IR and VIS images are required, either a second display unit with switching circuitry or a tape recorder for playing back the second image must be added to the system. Separate recording of IR and VIS images enables the user to optimize the intensity control for each separately rather than having to use a setting that is marginal on both.

4.1.2.4. Proposed Correction for Image Panoramic Distortion.

Some SR-APT users feel that the nonuniform horizontal scale (elongation) of the imagery referred to above is a serious disadvantage. The correction desired can be achieved by making the geographic scale uniform across the image. This process is often referred to as "linearization." Imagery corrected in this way will <u>not</u> represent the Earth exactly on any of the conventional map projections; for that kind of representation, full computer processing is required.

The main classes of suggested methods for "linearization" are (1) those that use lenses or mirrors to rectify the image, (2) those that use a nonlinear drive for the recording system (better for CRTs than for mechanical devices), and (3) those that introduce a variable delay into the data processing chain. NESS is giving thought to a universal adapter that might not be optimal for any one type of display equipment, but would be usable with all and for which the demand would be sufficiently great to keep the price low. The concept of the universal adapter is that it would accept the demodulated video signal, temporarily stcre up to a line of signal, and read it out to the display unit at a varying rate that would produce a correct image.

4.1.2.5. SR-APT Information Bandwidth and Baseband Filtering.

The original Scanning Radiometer was designed with a baseband video bandwidth of 900 Hz for the visible channel (modulation transfer function, MTF, equal to or better than 0.15 at 175 cycles/radian) and 450 Hz for the infrared channel (MTF equal to or better than 0.22 at 90 cycles/radian). However, to optimize the electronic processing of the signal, the electrical bandwidth of the signal for the ITOS D through G instruments was increased to 1200 Hz (VIS) and 600 Hz (IR). There has been no basic change in response of the detectors; the effect of the change was simply to permit the limited response, higher frequency data and its associated noise already present in this range to be maintained through the data handling system.

Individual users have several alternatives available in the choice of the baseband filter for use in the ground station receiver. A four-pole Gaussian type of filter is recommended. Assuming that a single filter is to be used for both IR and VIS channels, since the channels are intermingled in the transmission, the following are some of the alternatives in selecting the filter bandwidth:

a. Keep the 1600-Hz filter already used for vidicon APT data. The total signal bandwidth will be maintained; highfrequency noise, not part of the SR signal, will also be retained. For those users interested only in receiving a picture for synoptic analysis, this technique should be adequate.

b. Install a 1200-Hz filter. High-frequency noise not a part of the original signal will be removed. Full high-frequency response will be maintained, although noise above the "normal" information bandwidth (900 and 450 Hz) will also be present.

c. Install a 900-Hz filter. Normal visible channel data will be displayed at its full planned resolution; high-frequency noise will be eliminated. It should be noted, however, that noise outside the normal information bandwidth (450 and 900 Hz) of the infrared channel will be maintained, but full high-frequency response also will be present.

d. Install a 600-Hz filter. High-frequency noise not a part of the original infrared channel data will be eliminated. Full high-frequency response for the infrared channel data will be maintained though noise above the normal (450 Hz) information bandwidth will also be present. The high-frequency response of the visible channel will be lost. S/N ratio will be improved, but effective geometric resolution will be reduced.

e. Install a 450-Hz filter. Normal infrared channel data will be displayed at its full planned resolution; high-frequency noise will be eliminated. Those users planning to make quantitative measurements from the signal will find this method of filtering probably will provide an optimized signal insofar as ground resolution and effective S/N ratio of the received signal are concerned. It must be considered that since the visible channel response above 450 Hz will be eliminated by this filter, the effective resolution will be reduced from 2 miles to 4 miles.

f. Install a filter with bandwidth less than 450 Hz. The effective geometric resolution of both channels will be reduced, but effective S/N ratio for both channels will be improved by elimination of noise.

4.1.3. Operational Inputs to APT Stations From NESS

APT stations receive the following operational support from NESS:

a. Satellite ephemeris data (Equator crossing times, longitudes, and sub satellite points for reference orbits) for satellite tracking and gridding the data. These APT Predict Messages are sent daily via teletype.

b. Satellite change of status messages as a part of the APT Predict Message for such things as switching from prime to backup modes in either the downlink frequency (137.50 or 137.62 MHz) or in the transmitted imagery (from IR and VIS time-multiplexed to IR only or to VIS only).

c. Calibration curves or other information on performance of scanning radiometers--on request.

d. Grid overlays for APT imagery--on request.

NOAA's APT Coordinator also provides information on current and planned direct readout satellite activities, including spacecraft launches, changes in sensor performance, and other characteristics of spacecraft behavior that could have an impact on APT ground station data acquisition or use. This information is contained in unscheduled APT Information Notes distributed to those who request they be kept informed of direct readout satellite activities. The Director of NESS also provides assistance upon request in planning , building, and modifying APT stations.

4.2. THE HIGH RESOLUTION PICTURE TRANSMISSION (HRPT) SERVICE

High Resolution Picture Transmission (HRPT) is the continuous, direct broadcast of VHRR data from NOAA-2 to local users with suitable ground stations. HRPT data are of significantly higher resolution than the APT data. VHRR subpoint resolution is 0.87 km for both IR and VIS in contrast to 3.9-km and 7.8-km resolutions for the Scanning Radiometer VIS and IR data. HRPT service is to be continued on future NOAA satellites.

VHRR data and associated spacecraft signal processing and transmission are described in section 2.1.3.2. The basic requirements and plans for HRPT ground stations are described below.

4.2.1. HRPT Ground Station Design Guidelines

The selection of a design for an HRPT receiving-display system involves cost tradeoffs in terms of image quality, throughput time, and growth capacity in image processing. The basic NESS design guidelines in these areas are as follows.

a. The antenna-receiver system should provide a baseband S/N (p-p/rms) of at least 30 dB, and, for best results, 40 dB under the worst conditions of tracking elevations and spacecraft transmission modes. (Refer to table 4-2 for a link analysis of the various parameters.) The baseband criterion is somewhat dependent upon the particular display device used and has been judged on the performance of the Muirhead M112B. On the M112B, the image quality is noticeably degraded below about 40-dB S/N and becomes quite poor below about 30-dB S/N. For quantitative uses of the data, a S/N ratio of 40 dB is highly desirable.

b. The throughput time (from loss of spacecraft signal to image recording independent of photo lab) should be about 30 min for the first 6 min of VIS and IR data. The processing should include gray scale lookup tables and center of Earthscan selection.

c. The system should have growth capability for:

1) gridding, 2-power magnification, panoramic distortion removal, and nonlinear gamma amplification (i.e., variation of the intensity as a function of original intensity); and

2) an advanced VHRR with four digital channels of imagery data.

The growth capability can be achieved by modular design of the RF subsystem and by a minicomputer-based image processing subsystem with unique software for each job.

Table 4-2.--VHRR-HRPT link analysis for NOAA-2 at maximum tracking range ~ 5° above local horizon

Parameter	Power
Spacecraft radiated power: fc = 1697.5 MHz; BW = 1 MHz; RHC polarization	38.2 ± 1.4 (rss)dBm
Space path-loss at 3516 km (2180 mi.)*	-169.2 ± 1 dB
Effective antenna gain (16-ft diameter dish) referenced to preamp input (assume 40% overall efficiency in auto track)	34 ± 1 dB
Effective system noise, power referenced to preamp input:** near local horizon; BW = 1 MHz; preamp/receiver of figure 4-3; T_s = 269 ± 25°K	-114.3 ± 0.5 dBm
Received carrier-to-noise (C/N) ratio (rms power)	17.3 ± 2 dB
Baseband signal (p - p voltage)-to-noise (rms power) - S/N(p - p/rms):	
Prime modes (IR 1 and VIS 2, or IR 2 and VIS 1): IR and VIS channel basebands (f_{m_b} = 35 kHz) are time-multiplexed and frequency modulated on 99-kHz subcarrier with $\Delta f_{sc} \cong$ 35 kHz. The modulated subcarrier (f_M = 163 kHz) is frequency modulated onto 1697.5 MHz carrier with $\Delta f_c \cong$ 326 kHz.	48.8 ± 3 dB
IR-only backup modes (IR 1 or IR 2): Same as prime modes without time-multiplexed VIS	48.8 ± 3 dB
Two-subcarrier backup modes (IR 1 and VIS 1, or IR 2 and VIS 2): IR channel FM on 99-kHz subcarrier and VIS channel FM on 249 kHz; for both f_{m_b} = 35 kHz, $\Delta f_{sc} \cong$ 29 kHz. Subcarriers frequency multiplex on 1697.5-MHz carrier, with f_M = 313 kHz, and Δf_c = 160 kHz for 249 kHz, and f_M = 163 kHz, and $\Delta f_c \cong$ 55 kHz for 99 kHz subcarriers	33.2 ± 3 dB (on 99 kHz) 36.7 ± 3 dB (on 249 kHz)
Playback with Prime or IR-only modes: Same as above except $\Delta f_c \cong$ 100 kHz	33.2 ± 3 dB

*At 1460 km (minimum range), loss is improved by about 8 dB.

**With antenna between zenith and about 50° elevation, T_s is reduced about 40°K.

4.2.2. Functional Description of NESS HRPT Ground Stations

The design selected by NESS for HRPT stations at the Wallops CDA, the Gilmore CDA, and the SFO SFSS is shown in figure 4-3. This design satisfies the requirements of section 4.2.1 and will be installed at the three locations by early 1974.

The link analysis for the SFO SFSS 16-ft parabolic dish antenna is shown in table 4-2. The 85-ft dish antennas used at the CDAs give about 16 dB more gain than the SFO 16-ft antenna; hence the baseband S/N requirements are satisfied with considerable margin. During the playback of recorded data from the satellite, the 16-ft dish antenna is inadequate, but the 85-ft dish antenna is adequate.

The antenna systems are capable of continuous autotrack down to 5° above the local horizon in all azimuth directions. An uncooled paramplifier is used as a preamplifier to give a maximum effective system noise temperature of 270°K, the maximum noise temperature taken at pointing angles near the local horizon. The FM receiver is heterodyne with mean-of-peaks AFC and an IF bandwidth of 1 MHz. Two 140-kHz bandwidth FM demodulators (centered at 99 ± 1.4 kHz and 249 ± 1.2 kHz) deliver the DC to 35-kHz baseband signal of the VHRR. The 249-kHz channel is needed only fcr the two-subcarrier HRPT backup mode. The transmission modes are listed in table 4-2 and are described in more detail in section 2.1.3.2.

The NESS display system consists of: a specially built front end with synchronizers, analog-to-digital (A/D) converters, and control circuitry; a minicomputer with special VHRR software; dual digital tapes; dual 120-rpm, 250 lpi Muirhead display devices; and a transmitter for distributing the processed data over 4-kHz land lines.

This system, with digital interface equipment, 120-rpm displays, and a C-5 line transmitter, is called the VHRR Display System.

All real-time VHRR data from the RF receiver is digitized to eight-bit samples and written on digital tape. After the pass, the digital tapes are rewound and played back through the system to the two 120-rpm displays and the land-lines. The IR and VIS data streams are parallel, providing redundancy and reduced throughput time. That is, the IR and VIS data are handled separately and simultaneously through the A/D converters, buffers, digital tapes, and 120-rpm display devices.

Note: Although the spacecraft-stored VHRR data is not an HRPT product, the VHRR Display System can process the stored data. This capability is used at the CDA stations and at Suitland, Md.

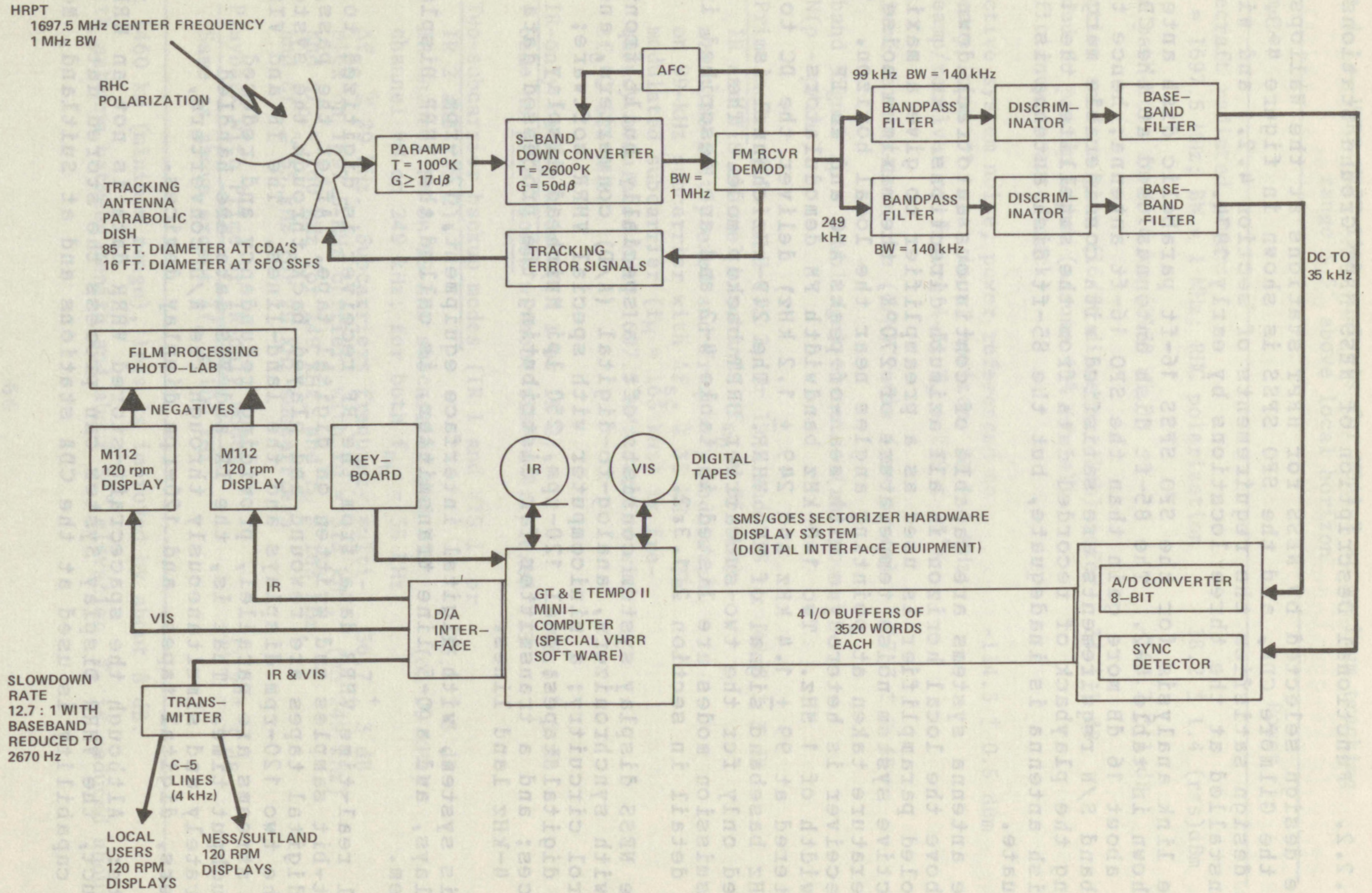


Figure 4-3.--NESS HRPT ground station.

In addition to the NESS system, a number of other VHRR display systems are under development, ranging in type from CRT devices to laser beam recorders.

4.2.3. The HRPT Sectorizer Image Processing

The minicomputer of the VHRR display system is programed to make the HRPT data compatible with the Muirhead M112B display. The displayed image is to have a 1:1 aspect ratio with the full resolution of the radiometer. Some details of the processing of HRPT data are discussed below.

The HRPT display from the Muirhead M112 (120 rpm, 250 lpi) is a 10-in image centered at the subpoint with a 1:1 aspect ratio. The VHRR at the 400-rpm scan rate with 0.6-mr IFOV, provides 69.8131 IFOV/ms. Hence for the 1:1 aspect ratio on the M112 with 250 lpi on the vertical axis, 3.5809 ms (250 IFOV/in divided by 69.8131 IFOV/ms) of data per inch is required on the horizontal axis. The sectorizer output rate (a hardware constraint of 8400 bytes/s) is 4,200 bytes/line for an 11-in display; for the 10-in display there are 3,818 bytes/line of imagery plus 382 bytes of filler. The VHRR baseband signal is sampled at the rate 106.62124 samples/ms, for 3.05 samples/cycle of information baseband. This gives 1.53 eight-bit samples per IFOV.

With the data syncs, approximately 66 ms of data per scan (one Earth view plus calibration, sync, and TLM as shown in fig. 4-4) of each IR and VIS are taken into the input buffer of the minicomputer for a total of about 7,040 bytes which are repacked to 3,520 words. Averaging and repacking of the 12 telemetry steps and the space scan center are performed to yield 4 bytes of time code and 13 bytes of averaged telemetry. These 17 bytes are added to the Earth scan data to give a total 5,340 bytes per scan of both IR and VIS to be written on the digital tapes.

The digital tape recording rate is 72,000 bytes/s with 13 ms required for each start and stop. A total of 100 ms is required to record one scan of either IR or VIS imagery data with averaged telemetry and time coding, leaving about 50 ms. between the end of write and start of write for the next scan. As soon as the minicomputer CPU has finished with one scan of IR data, it shifts to the averaging, repacking, and writing of the next VIS scan and so on.

Note 1: At any instant four input-output (I/O) buffers of 3,520 words (7,040 bytes) each are in process for two consecutive scans of IR and VIS data.

Note 2: The digital tapes take 1,600 bytes/in. Hence each 5,340-byte record requires 3.3375 in plus 0.6 in for EOR. The two tapes can record 17.5 min of both IR and VIS data in the

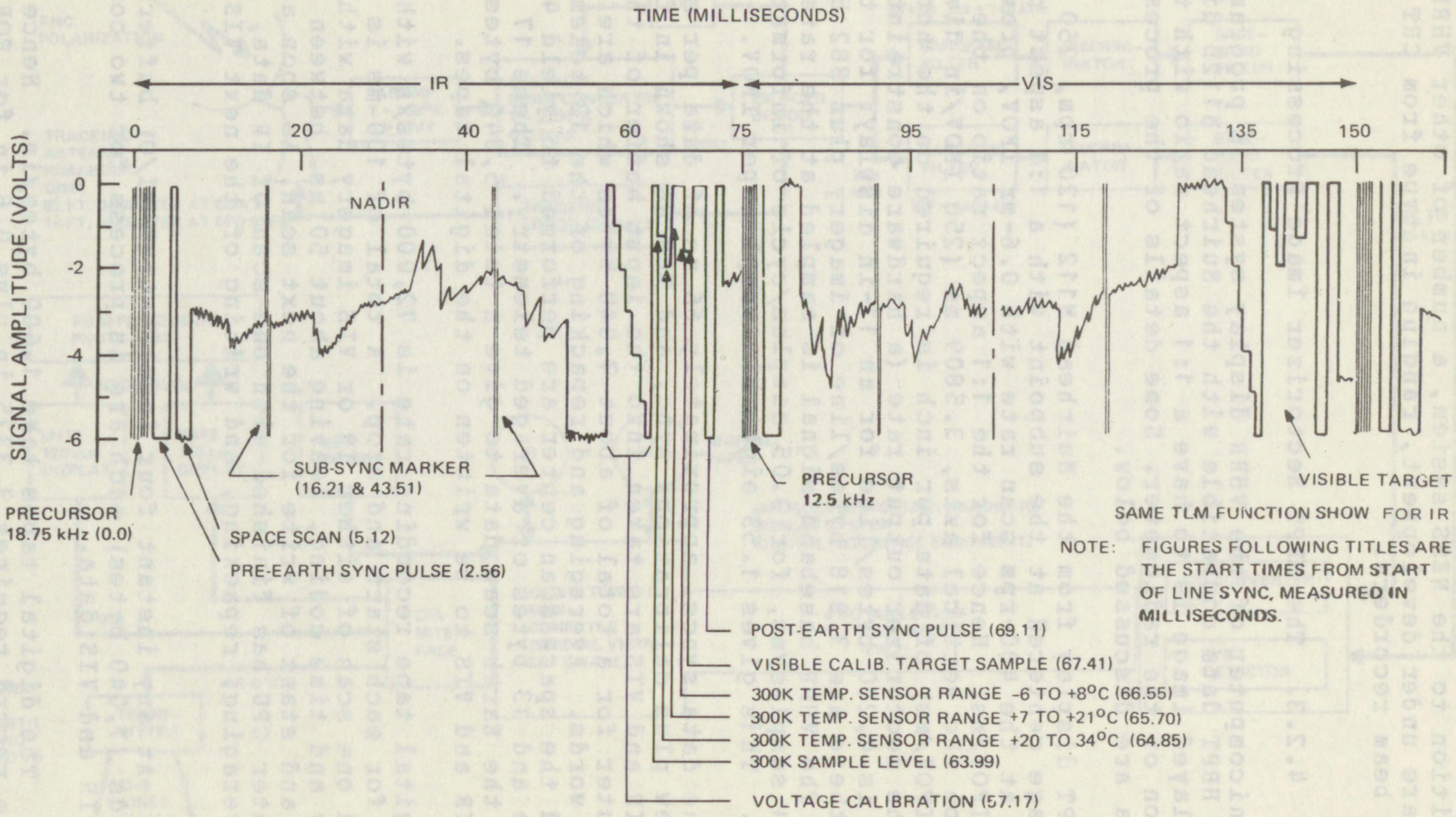


Figure 4-4.--HRPT signal characteristics.

buffered form; this is sufficient for one full satellite pass of maximum duration.

After the satellite pass, the IR and VIS tapes are rewound and played back into the minicomputer simultaneously. There the 3,818 bytes/scan that are centered in the middle of the Earth view plus 382 bytes of filler are selected. There is provision for separate IR and VIS gamma type lookup tables before the image output. In sequence, 2,400 lines (scans) of 3,818 bytes each plus 100 lines of documentation are fed through a D/A interface to the M112 displays and C-5 line transmitter. The 100 lines of documentation include:

a. Time from last record (line) output,

b. Orbit number (keyboard input),

c. VIS or IR labels,

d. HRPT or VREC (keyboard input) labels, and

e. Telemetry wedge (gray scale).

Note: The packed TLM from the last 100 lines of output imagery are averaged to generate a rectangular gray scale 60 spots wide by 100 lines long.

In this manner, one VIS and one IR 10-in image are produced for every 6 min of received data. The images are simultaneously displayed and transmitted over the 4-kHz C-5 lines.

4.2.4. Products of the NESS HRPT Service

The products of the NESS HRPT display system are 10-in IR and VIS images with the following characteristics.

a. 1:1 aspect ratio at the subpoint.

b. Centered at the satellite subpoint giving approximately 70% of the total earthscan; the 10-in image covers a rectangular area about 2,580 km on a side and requires about 30 min of processing for each 6 min of received data.

c. 2,400 lines of 3,818 eight-bit samples per line, so that:

1) The image resolution is 0.87 km at the center and 1.33 km at the edges, and

2) The image gray shading is delivered by a 256 shades-of-gray input. The lookup capability is for six to eight bits.

d. a maximum gap of about 320 km occurs at the Equator between the 10-in images of successive orbits.

Digital tapes of IR and VIS VHRR data could be considered HRPT products in that they are used for archiving data for later processing to obtain quantitative information.

The Wallops, Va., and the SFO SSFS HRPT stations will receive five NOAA-2 passes per day and the Gilmore, Alaska, HRPT station will receive at a least eight passes per day (maximum pass duration is about 17 min). The number of day and night passes will vary by season. Both IR and VIS, day-only images from each reception will be displayed at the HRPT stations and will be transmitted via 4-kHz C-5 lines to NESS at Suitland, Md., and to local users with 120-rpm display devices. The HRPT display system for VHRR data received at Wallops will probably be located at NESS.

4.2.5. Operational Inputs to HRPT Stations from NESS

NESS will furnish the following information to the HRPT stations:

a. Orbital elements of the NOAA satellites. With these elements very accurate predictions of the satellite location are possible.

b. Satellite command schedules, change of status messages and other pertinent information as a part of the <u>APT predict message</u>. The HRPT stations will be notified when their reception is to be degraded or wiped out by playback to CDAs or by change from the prime real-time transmission mode to a backup mode.

c. Overlay grids as required.

4.2.6. Outlook for the HRPT System

The NESS-HRPT ground stations were designed for growth in the areas of more elaborate image processing (e.g., gridding and distortion removal) and adaptation to more advanced radiometers. At present, however, and for several years to come, the NESS HRPT stations will operate as described in sections 4.2.3 to 4.2.5. More immediate growth of the domestic HRPT system can be expected in terms of the number of local users receiving VHRR imagery over C-5 lines from the NESS HRPT stations. Global coverage will be possible if other data users install independent HRPT stations.

4.3. DIRECT BROADCAST OF VTPR AND SPM DATA

In addition to APT and HRPT, the NOAA polar orbiting satellites subsequent to NOAA-2 broadcast VTPR and SPM data directly via the beacon transmitter. A digital data channel consisting of the VTPR, SPM, spacecraft time code, and engineering telemetry data, phase modulate the beacon carrier and the two subcarriers on the NOAA-2 Beacon. The VTPR data can be processed on the ground to yield temperature profiles of the atmosphere. The SPM data can be processed to yield the proton density and energy along the spacecraft's path. The time code is relative spacecraft time and is used to identify data. The engineering telemetry is of no general use to the local user. The other two subcarrier data channels on NOAA-2 also carry engineering data not of direct interest to the local user.

Considerable interest in the direct broadcast of VTPR data (DB-VTPR) has been shown by portions of the meteorological community. Norway and France are already preparing to receive DB-VTPR data and to compute temperature profiles. It is reasonably certain that other independent groups will soon have similar capabilities. The interest of local users in the SPM data is not predictable at this time, but probably is slight.

The VTPR and SPM sensors and the digital data processor and associated spacecraft signal processing are described in detail in section 2. The basic requirements for the DB-VTPR ground system are discussed below. The RF requirements can be stated quite precisely, but the data reduction techniques range over a wide spectrum of sophistication and accuracy. With regard to the reduction of VTPR data, a technique with the minimal level of sophistication and accuracy is outlined, and some steps for improvement are mentioned. The processing of SPM data is not discussed here. (For information, see NOAA TM NESS 29, "The Operational Processing of SPM and FPR Data," and NOAA TM NESS 49, "The Operational Processing of Solar Proton Monitor Data," listed in the references.)

4.3.1. Satellite Data Processing and Transmission

The satellite digital data processor accepts data signals from various subsystems and formats them into a single continuous serial bit stream with the following information interleaved word-by-word:

a. Frame synchronization,

b. Spacecraft time code,

c. VTPR data, 8 channels digitized to 10 bits,

d. SPM data, digitized to 9 bits, and

e. Commutated housekeeping telemetry.

The digital data frame organization and message structure is shown in figure 4-5. The digital data are recorded simultaneously full time through the orbit on the SR recorder and, upon command, are transmitted in real time via the beacon transmitter.

The digital data and the two other subcarriers phase modulate the beacon RF carrier. The carrier frequency is either 136.77 MHz, currently used for the NOAA-2 beacon, or 137.14 MHz, a recently assigned second beacon frequency programable to avoid interference between two NOAA polar satellites in the same vicinity. The RF spectral bandwidth is 8.5 kHz. The digital data phase modulates the beacon at 0.24 radians assuming a rectangular waveform. After demodulation, the digital data rate is 512 bps and is contained in the frequency band at 50 to 770 Hz.

4.4. DIRECT BROADCAST VTPR GROUND RECEIVING SYSTEM

The requirements for a direct-readout VTPR receiving system have been analyzed with consideration given to ease of implementation and system performance. Except for the antenna, the receiving system can be constructed with standard equipment. The components required are a preamplifier, a receiver with a phase demodulator, a low pass filter, a bit synchronizer, and a PCM decommutator. For processing the data into soundings, anything from a desk calculator to a large-scale computer may be used. A minicomputer is recommended for the simpler data reduction techniques. A linearly polarized antenna with 20 dB gain (and polarization diversity combining) will acquire signals down to a 5° elevation angle with adequate operational margin. A 16-dB gain antenna (and polarization diversity combining) is adequate at 5° elevation with no margin. For elevation angles 20° or greater, a 13-dB gain antenna will suffice. Table 4-3 provides link calculation for a VTPR terminal incorporating an antenna with 16-dB gain.

The critical value for the normalized S/N ratio of the received signal is 26 dB for a 10^{-6} bit error rate. Rapid degradation of the bit error rate occurs for S/N below this level.

A list of suggested components for the ground receiving system, and some U.S. companies that currently supply these components, can be obtained from the Office of the Director of NESS. (See table 4-4.)

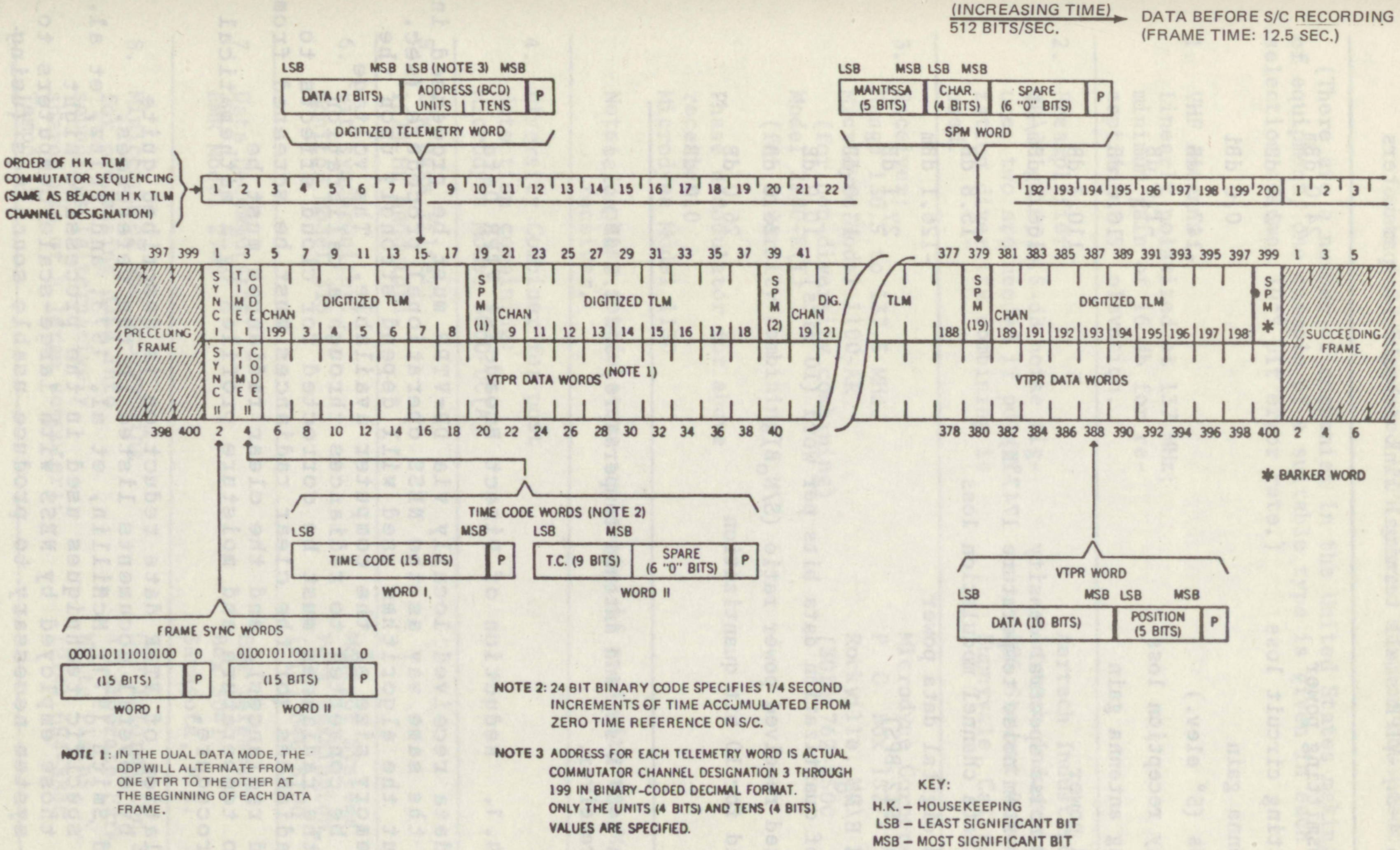


Figure 4-5.--Digital data frame and message structure.

Table 4-3.--VTPR small terminal link calculation parameters

S/C transmitting power	24.0 dBm
Transmitting circuit loss	-2.0 dB
S/C antenna gain	0.0 dBi
Path loss (5° elev.)	-147.3 dB
Diversity reception loss	-1.0 dB
Receiving antenna gain	16.0 dB
Received power	-110.3 dB
*Received noise spectral density (for system noise temperature 1747°K)	-166.2 dBm/Hz
Digital data channel modulation loss	-15.8 dB
Received digital data power	-126.1 dBm
Bit rate (512 BPS)	27.1 dB
Received E/N_o	13.0 dB
Number of quantization data bits per word (10 bits)	10.0 dB
Normalized received power ratio (S/N_oB)	26.0 dB
Threshold for 10 bit quantization	26.0 dB
Margin	0.0 dB

*Based on 1487°K sky and antenna temperature, and 2.8 dB noise figure receiver.

4.4.1. Reduction of Direct Broadcast VTPR Data

Sounding data received locally via DB-VTPR must be processed in essentially the same way as the NESS operational procedure (sec. 5.2.2.2), but the algorithms used will depend strongly upon the speed and memory size of the computer available. The voltage counts must be converted to radiances through a calibration procedure, the radiances must be corrected for cloud effects to get clear radiances (or the clear radiances must be screened from contaminated radiances), and the clear radiances must be converted to temperature and moisture profiles by a mathematical inversion procedure.

The formulation of VTPR data reduction is described quite extensively by several documents listed in the references. (Fleming and Smith 1971; McMillin, et al. 1973; and Fritz, et al. 1972). The specific techniques used in the processing might range from those employed by NESS with large-scale computers to the minimal system necessary to produce usable soundings (using

Table 4.4--Suggested VTPR ground station equipment.

(There are a number of companies in the United States making these types of equipment; one example of a suitable type is given in each case. The selection assumes 10^{-6} bit error rate.)

1.	VHF Antenna: Linearly polarized at 137 MHz; minimum gain of 16 db for reception at 5° elevation.	
2.	Preamplifier: 20-dB gain; 2.5-dB noise figure; two are needed if polarization diversity combining is used.	Aertech Industries Model A 1339 Aertech Industries 825 Stewart Drive Sunnyvale, Calif. 94086
3.	Receiver: Range 136.5 to 137.5 MHz. Microdyne Model 1100-AR (for non-diversity combining) Model 2200-R(T) (for diversity combining) Phase demodulator for above receiver: Microdyne Model 1150 Note: 2 phase demodulators are needed if used with the Model 2200-R(T) receiver.	Microdyne Corporation P. O. Box 1527 Rockville, Md. 20850 (301) 762-8500
4.	Diversity Combiner for post detection combining: Microdyne Model 3600-DC(A)	
5.	Low pass filter: 1024-Hz bandwidth.	
6.	Bit synchronizer: Monitor Model 318	Monitor Systems Port Washington, Pa. 19034 (215) 646-8100
7.	Data Decommutator: EMR Model 2746	EMR Telemetry Box 3041 Sarasota, Fla. 33578
8.	Minicomputer and programming for processing data into soundings (alternatively, shared use of a large computer): Tempo II	GTE Information Systems 4 Corporate Park Drive White Plains, N. Y. 10601 (914) 694-8840

only a small desk calculator). The minimal processing requirements for obtaining usable soundings, with some mention of inexpensive ways to improve the system, are outlined below.

The first step is the calibration of the raw data; this involves the conversion of each VTPR "spot" voltage count to a calibrated radiance value. NESS will provide the sets of calibration coefficients required for this conversion.

The second step is the determination of clear radiances. The geometric size and configuration of the "spots" to be used is arbitrary, depending on the users requirements. Here 8 by 8 and 8 by 7 arrays of spot radiances are used as examples. For each 8 by 8 or 8 by 7 array of spot radiances in the data of the 835 cm^{-1} channel, the several adjacent spots with the highest radiance values would be selected and compared with B(835, Ts), the Planck function value at 835 cm^{-1}, and the temperature (Ts) as read on the first layer of the Earth's surface in the geographical area (i.e., the local area). The closer the value of these highest radiances are to B(835, Ts), the better is the indication that the radiances are in a clear area. Unless the entire array covered by the 8 by 8 area (480 to 650 km) is overcast or uniformly cloudy, it can be assumed that these highest values satisfactorily represent clear column radiances. The Earth location of these clear radiances would then be determined with the use of a map overlay of the orbital path and Equator crossings. By assuming the clear column points found in the 835-cm^{-1} channel for the other channels, the temperature and moisture profiles are retrieved from the clear radiance vector of average radiance values. There is one vector for each array. Whatever the number of clear radiances obtained, averaging is required for each channel. A regression coefficient matrix would be multiplied by the clear radiance vector to get the temperature profile vector for each 8 by 8 or 8 by 7 array of spots (recall that these arrays are arbitrary) for each channel. The retrieved profiles could contain any number of components, say six or more. An updated regression coefficient matrix can be obtained from NESS about once monthly, or can be determined locally by computer.

This most basic technique of VTPR data processing could be improved in any of the following ways:

a. Use SR-APT imagery to determine clear areas for selecting clear radiances.

b. Use radiances of two adjacent spots in the window channel (835 cm^{-1}) and the locally measured ground surface temperature to estimate the clear radiances. This is based on the principle that at any given wavelength, the radiance for a partly cloudy area is related linearly to the radiance in the window channel for varying cloud amounts. The point for a totally clear area is determined by the radiance calculated using Ts, the surface temperature.

c. Use a more sophisticated temperature retrieval method. See Fleming and Smith (1971) for such information.

The addition of a minicomputer to the system would provide much growth potential. With larger computer systems, processing procedures similar to those used at NESS could be implemented. See section 5.2.2.2 and McMillin et al. (1973).

On the average, 4 or 5 passes per day of 17-min duration each will be available to local users at midlatitudes. The area covered by each 17-min pass is approximately 1,900 km wide with elongation (across track) and 5,000 km long (along track).

4.4.2. Operational Inputs From NESS to Local VTPR Users

The DB-VTPR user will be supplied by NESS with:

a. Satellite ephemeris data for satellite tracking and data location. These predict messages are sent daily via TTY.

b. Satellite change of status messages and other pertinent information via TTY as part of predict message.

c. Map overlays of the orbital path and equatorial crossings.

d. Sets of calibration coefficients for calibrating raw radiances (provided in the form of a technical memorandum).

e. Regression coefficient matrix for temperature retrieval from clear radiances (provided in the form of a technical memorandum).

The Director of NESS also provides advice upon request for planning and installing a VTPR ground system.

Section 5

CENTRAL SERVICES - NOAA POLAR ORBITING SATELLITE SYSTEM

The central facility for the operations and control of the NOAA polar orbiting satellite and the central facility used as the link between the satellite sensors and the product users are located at Suitland, Md. The central facility for processing is the Data Processing and Analysis Facility (DAPAF). The satellite operations and control function performed by DAPAF for SOCC are described in detail in section 3. In this section, the product data processing functions that support SOCC are mentioned only for continuity.

The DAPAF functions are accomplished by two separate systems: the data ingest system, known as the Digital Data Handling System (DDHS); and the Central Data Processing System for large-scale computer processing of SR and VTPR products. The SPM products--a punched paper teletype tape and an archival digital tape--are generated by the DDHS. VHRR data can be processed for high resolution imagery by several systems; the DDHS in conjunction with the Digital Muirhead Display (DMD); the ATS digital system using the Digital Picture Terminal; and, by 1974, a VHRR display system using the SMS Sectorizer system hardware.

5.1. INGEST SYSTEM

The Digital Data Handling System (DDHS) performs online handling required for the ingest of data from the CDA stations and for the preparation of data for SOCC and large-scale computer processing. The DDHS comprises four EMR computers. Figure 5-1 is a block diagram of the DDHS. In this section, the hardware capabilities and the operational functions of the DDHS system are described as they relate to the NOAA polar orbiting satellite system.

5.1.1. Ingest System Hardware

The DDHS is redundant in that processing data from a single NOAA satellite requires only half of the system. Each half consists of a telemetry subsystem, an EMR 6130 computer, an EMR

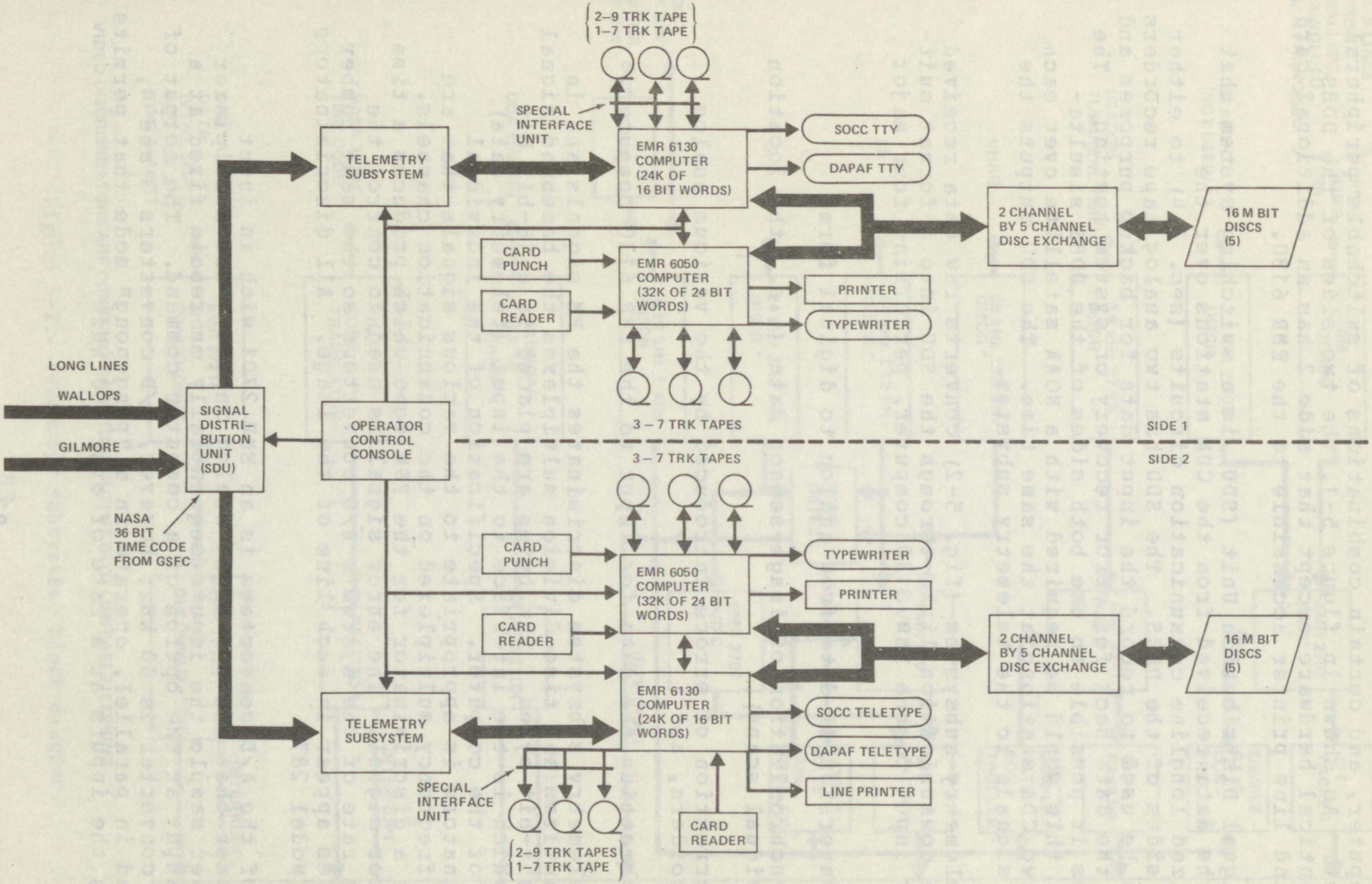


Figure 5-1.--Digital Data Handling System.

6050 computer, and certain combinations of switchable peripheral equipment. As shown in figure 5-1, the two sides of the DDHS have identical hardware except that side 2 has an additional card reader and line printer accessible to the EMR 6130.

The Signal Distribution Unit (SDU) is a switching system that routes the data received from the CDA stations over the channelized longline communication circuits (sec. 3.4) to either or both sides of the DDHS. The SDU has two analog tape recorders that can be used to record the input data for backup purposes and to play the data back for error recovery or system testing. The SDU makes it possible to use both sides of the DDHS simultaneously; this would be required with a NOAA satellite over each of the two CDA stations at the same time. The SDU outputs the various signals to the telemetry subsystem.

The telemetry subsystem (fig. 5-2) converts raw data received from the communication links through the SDU into a format suitable for input to the EMR 6130 computer, performing four major tasks:

a. Conversion of data from analog to digital form,

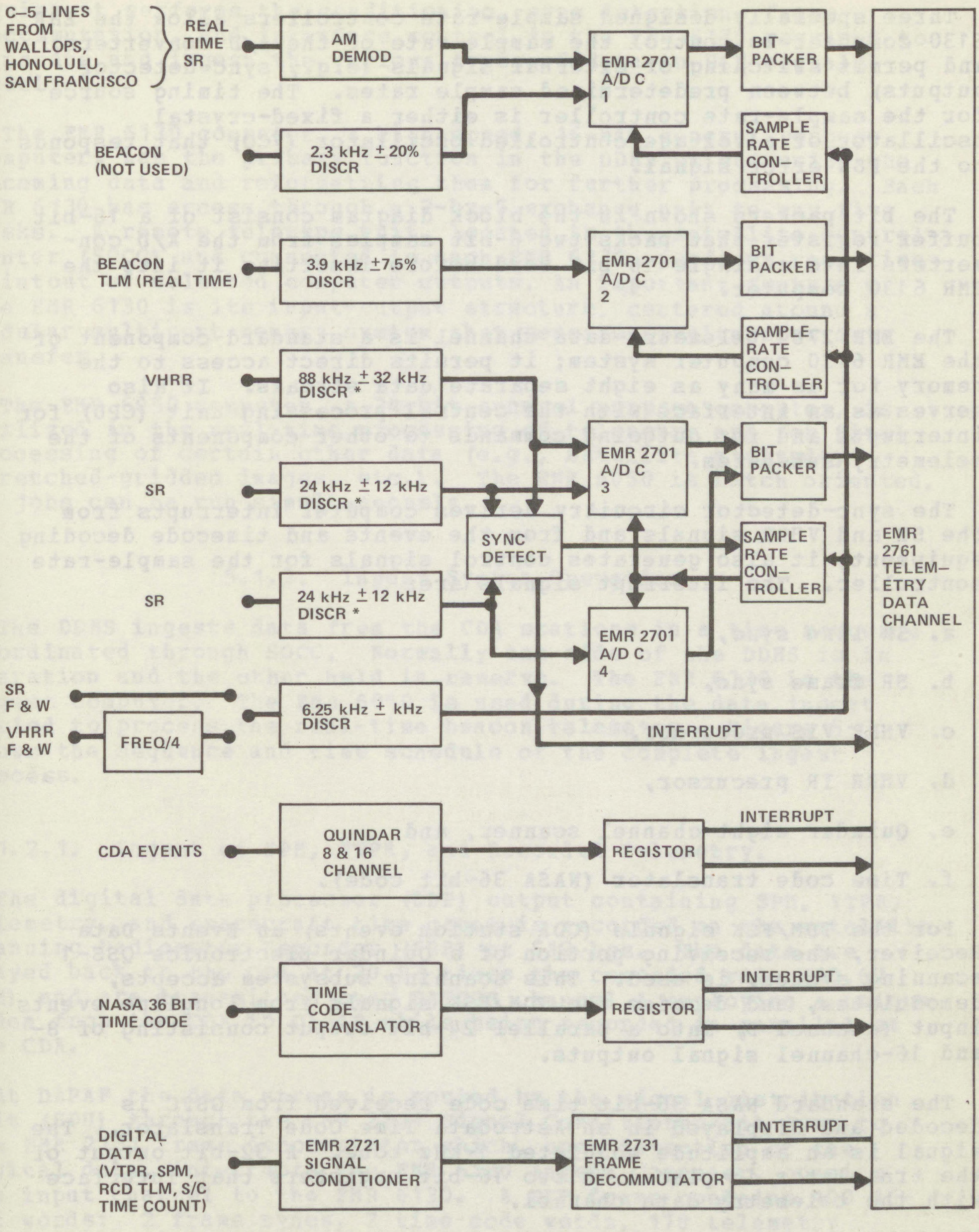
b. Synchronization of image-sensor data (i.e., the location of individual scans),

c. Correction of errors introduced by the various analog tape recorders, and

d. Formatting the data for input to the EMR 6130 computer.

The telemetry subsystem discriminates the FM signals and in turn quantizes and time-division multiplexes the baseband signal into eight-bit bytes. The bytes are placed in a 16-bit bit packer which is the interface to the input (telemetry data) channel of the computer. Specification of the individual discriminators is appropriate to the various signals that are time or frequency multiplexed on the communication channels. There is a discriminator for the F&W tone which produces a time base error signal. The error signal is used to control the sampling rate of the system's A/D converters so the same number of samples appear in each line of the image. All discriminators are EMR model 287.

Each of the A/D converters is an EMR 2701 with an input multiplexer that accepts eight analog inputs. The multiplexer may either sample the inputs sequentially or remain fixed at a single input at the option of a computer command. The output of the A/D converter is 60 kHz; however, A/D converters 3 and 4, connected in parallel, operate in a "ping-pong" mode that permits sampling the inputs at a rate of over 100 kHz.



* VIDEO DISCRIMINATORS ARE CONSTANT AMPLITUDE OUTPUT WITH LOW PASS FILTERING

Figure 5-2.--Telemetry subsystem, block diagram.

Three specially designed sample-rate controllers allow the EMR 6130 computer to control the sample rate of the A/D converters, and permit switching of external signals (e.g., sync-detector outputs) between predetermined sample rates. The timing source for the sample-rate controller is either a fixed-crystal oscillator or a voltage-controlled oscillator (VCO) that responds to the F&W error signal.

The bit packers shown in the block diagram consist of a 16-bit buffer register that packs two 8-bit samples from the A/D converters into a single 16-bit word before inserting it into the EMR 6130 computer.

The EMR 2761 telemetry-data channel is a standard component of the EMR 6130 computer system; it permits direct access to the memory for as many as eight separate data streams. It also serves as an interface with the central processing unit (CPU) for interrupts and for outgoing commands to other components of the telemetry subsystem.

The sync-detector circuitry derives computer interrupts from the SR and VHRR signals and from the events and timecode decoding equipment; it also generates control signals for the sample-rate controller. The interrupt signals are:

a. SR line sync,

b. SR frame sync,

c. VHRR VIS precursor,

d. VHRR IR precursor,

e. Quindar eight-channel scanner, and

f. Time code translator (NASA 36-bit code).

For the TDM/FSK signals (CDA station events) an Events Data Receiver, the receiving portion of a Quindar Electrónics QSS-1 scanning system, is used. This scanning subsystem accepts, demodulates, and decodes the TDM/FSK signals from longline events input (channel D) into a parallel 24-bit output consisting of 8- and 16-channel signal outputs.

The standard NASA 36-bit time code received from GSFC is decoded and displayed in an Astrodata Time Code Translator. The signal is an amplitude modulated 1-kHz tone. A 32-bit output of the translator is placed in two 16-bit registers that interface with the telemetry data channel.

The subsystem also has a capability to handle PCM digital data. The channel consists of the EMR 2721 Signal Conditioner and the EMR 2731 Frame Decommutator, both of which are programable. This equipment performs the conditioning, sync detection, frame decommutation, and interface control to the EMR 6130 required to separate and ingest the various types of data in PCM signals received.

The EMR 6130 computer, a high-speed, 16-bit general purpose computer, has the primary function in the DDHS of buffering the incoming data and reformatting them for further processing. Each EMR 6130 has access through a 2-by-5 exchange unit to any five disks. A remote teletype unit, located in the satellite control center (SOCC) and connected to each EMR 6130, performs real-time printout of selected computer outputs. An important feature of the EMR 6130 is its input-output structure, centered around a modular multiport memory system that permits simultaneous data transfer.

The EMR 6050 computer, a 24-bit general purpose computer, is utilized in the real-time processing of telemetry and for final processing of certain other data (e.g., satellite attitude, stretched-gridded images, etc.). The EMR 6050 is batch oriented, so jobs can be run simultaneously.

5.1.2. Ingest System Operation

The DDHS ingests data from the CDA stations in a time sequence coordinated through SOCC. Normally one side of the DDHS is in operation and the other held in reserve. The EMR 6130 is the ingest computer. The EMR 6050 is used during the data ingest period to process the real-time beacon telemetry. Figure 5-3 shows the sequence and time schedule of the complete ingest process.

5.1.2.1. Ingest of SPM, VTPR, and Recorded Telemetry.

The digital data processor (DDP) output containing SPM, VTPR, telemetry, and spacecraft time count is recorded on the satellite Scanning Radiometer Recorder (SRR) at 512 bps. The data are played back to the CDA at 20.83 times the recorded rate (10.67 PCM) and are transmitted over SATCOM channel A employing a unique modem from the CDA to DAPAF while being recorded in parallel at the CDA.

At DAPAF the data stream is routed by the signal distribution unit (SDU) through the EMR 2721 Signal Conditioner/Bit Sync to the EMR 2731 frame decommutator which, upon detection of the digital data, interrupts the EMR 6130 Ingest Computer, opening the input channel to the EMR 6130. A DDP frame contains 400 16-bit words: 2 frame syncs, 2 time code words, 178 telemetry words, and 198 VTPR words. The EMR 6130, using the Ingest Program, separates the DDP data and formats them according to specifications agreed upon by the users. The TLM data and the SPM

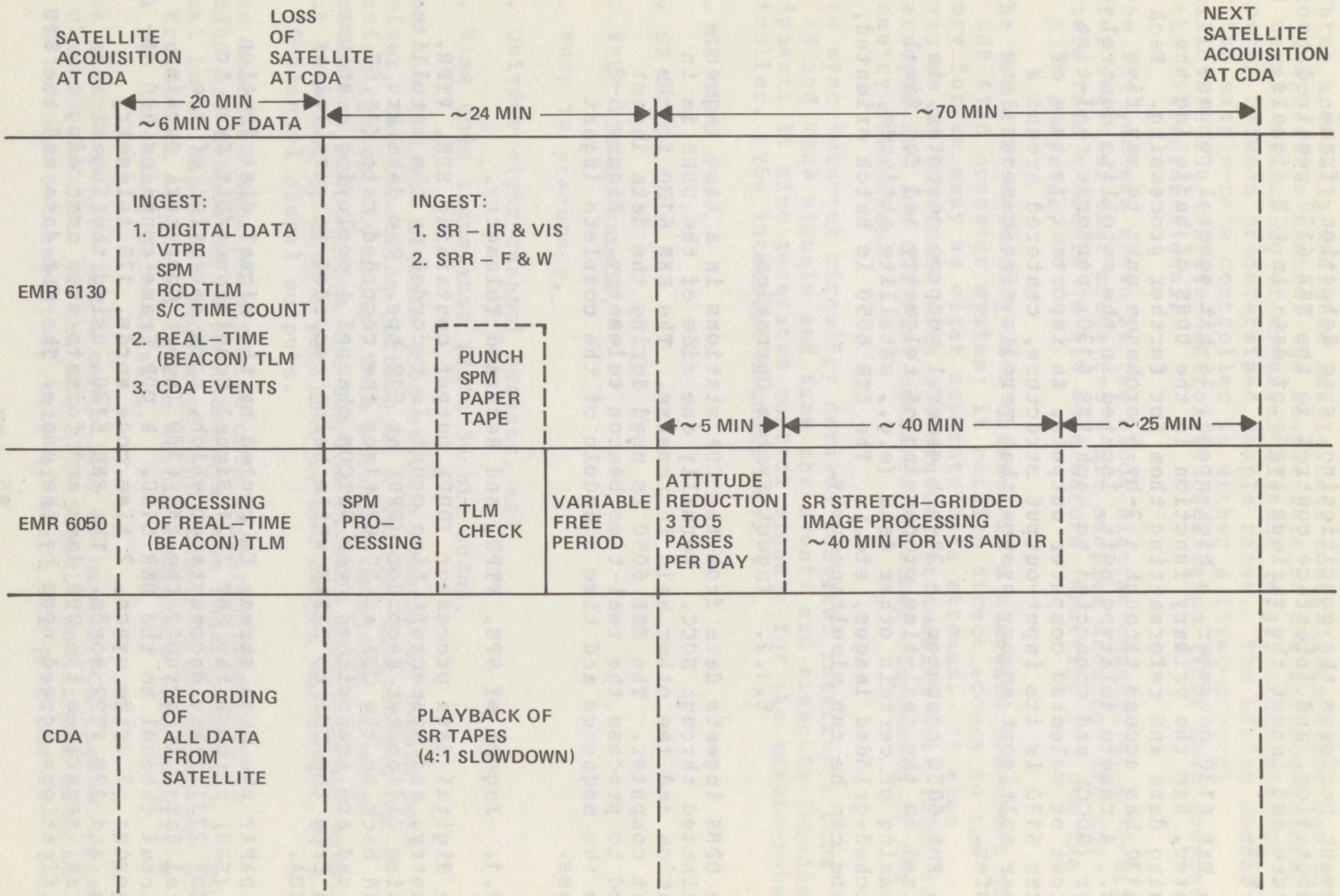


Figure 5-3.--Ingest sequence for single orbit.

data with satellite time count are written on designated areas of the disk; the VTPR data with satellite time count are written on digital magnetic tape. The DDP ingest takes approximately 6 min per orbit.

Some quality control on the DDP data is exercised by the EMR 6130 Ingest Computer. At present, hardware parity checks and the detection of missing frame syncs are the only items handled by the ingest quality control program. More extensive quality control is being developed.

5.1.2.1.1. VTPR Output. Normally, one orbit of data is processed for each readout. One magnetic tape at 800 bpi is sufficient for this amount of data. During the once-a-day blind orbit, up to 230 min of VTPR data are recorded on spacecraft tapes; two tapes may be required at the DDHS for these data. The VTPR data, as recorded on the EMR 6130 digital magnetic tapes, are ready for processing by the large-scale computers.

5.1.2.1.2. SPM Output. Once the SPM data with satellite time count are written on the disk, the data are processed on the EMR 6050. The EMR 6050, using satellite time count and orbit parameter data permanently stored on disk, Earth-locates the SPM data. An archive tape (one per day) is positioned and the Earth-located SPM data are simultaneously recorded for archives and routed to the EMR 6130 where paper tape is punched and output is printed. The paper tape is used for teletyping the data to the Space Environment Laboratory (SEL) at Boulder, Colo. The printed output is used internally by DAPAF for rough quality control checks.

5.1.2.1.3. Telemetry. (See also sec. 3.2.2.) After being written on disk, the recorded telemetry data are archived on a tape (one per day) and checked on the EMR 6050. The program (TLMCK) checks each telemetry channel against SOCC-provided limits on normality (the limits tables are input from disk). The output of the check is a printout of all points that are not within the limits. In practice, the limits are readjusted regularly by SOCC. The TLMCK program is not used for real-time telemetry data.

Once a week, usually on Sunday night, one of the previous day's TLM tapes is used as input to the EMR 6050 for the TLMPR program. The program samples one orbit of data by looking at every 10th frame of SOCC selected channels, and then prints the samples.

In addition, once a week, selected channels for selected time periods are processed on the EMR 6050 with the TLM CALC program. The program generates plots of selected satellite channels (voltages, temperature, etc.) vs. time. These plots are reviewed by SOCC.

5.1.2.2. The Ingest of SR Data.

The SR data stored on the satellite are received and recorded at the CDA station during spacecraft playback. Immediately after loss of signal from a pass, the data are played back from the CDA recorder at a 4:1 slowdown, with CDA tape speed and a Z-axis (amplitude) correction compensation, through channel A (14 to 30 kHz) of the 48-kHz line to Suitland. The spacecraft F&W are transmitted over channel C (4.5 to 7.5 kHz). At Suitland, the data are recorded in parallel and, at the same time, are channeled by the Signal Distribution Unit (SDU) to the telemetry subsystem which conditions the signal for the EMR 6130 Ingest Computer.

In the telemetry subsystem, the FM SR signal passes through the 22.8-kHz discriminator (EMR Model 287) and the spacecraft F&W signal passes through the 6.25-kHz discriminator. A frame of SR is 25 scans of IR and 25 scans of VIS, time multiplexed by individual scan. Each scan has a line-sync pulse before the IR and VIS. Inherent in each scan is a telemetry portion with 50 readings in a frame. A unique 23-kHz tone burst occurs in the telemetry point interval once per frame. The IR and VIS line sync pulses are amplitude detected by searching every 100 ms. The detection of a frame sync interrupts the EMR 6130 to prepare the channel for input of the SR data. Upon line sync detection, digitization commences. The current 58-microsecond sampling interval is the same for both IR and VIS data. The sampling rate is more finely controlled by the spacecraft SRR F&W signal which is demodulated to provide a time-based error signal for the sample rate controller. The Z-axis (amplitude) correction using F&W is performed at the CDA station.

Upon detection of the SR frame syncs, and using IR/VIS line syncs, the digital SR data are ingested by the EMR 6130; the VIS data are written on the seven-track tape and the IR data are written on the nine-track tapes, both at 800 bpi. The digital VIS data are written on a seven-track tape instead of a nine-track tape so they will be compatible with EMR 6050 for processing of the VIS gridded/stretched imagery. The IR data are copied to a seven-track tape for stretch gridding. The nighttime VIS data are detected automatically in the EMR 6130 by comparing the radiance of the Earth view with that of the space view. This comparison reveals whether the VIS data are day or night data--prescribed standards are used--and nighttime VIS data are discarded. The decision sequence is diagramed in figure 5-4.

Simultaneously, the spacecraft 24-bit time count in the TLM block is decoded in the EMR 6130 by a subroutine that uses the 16

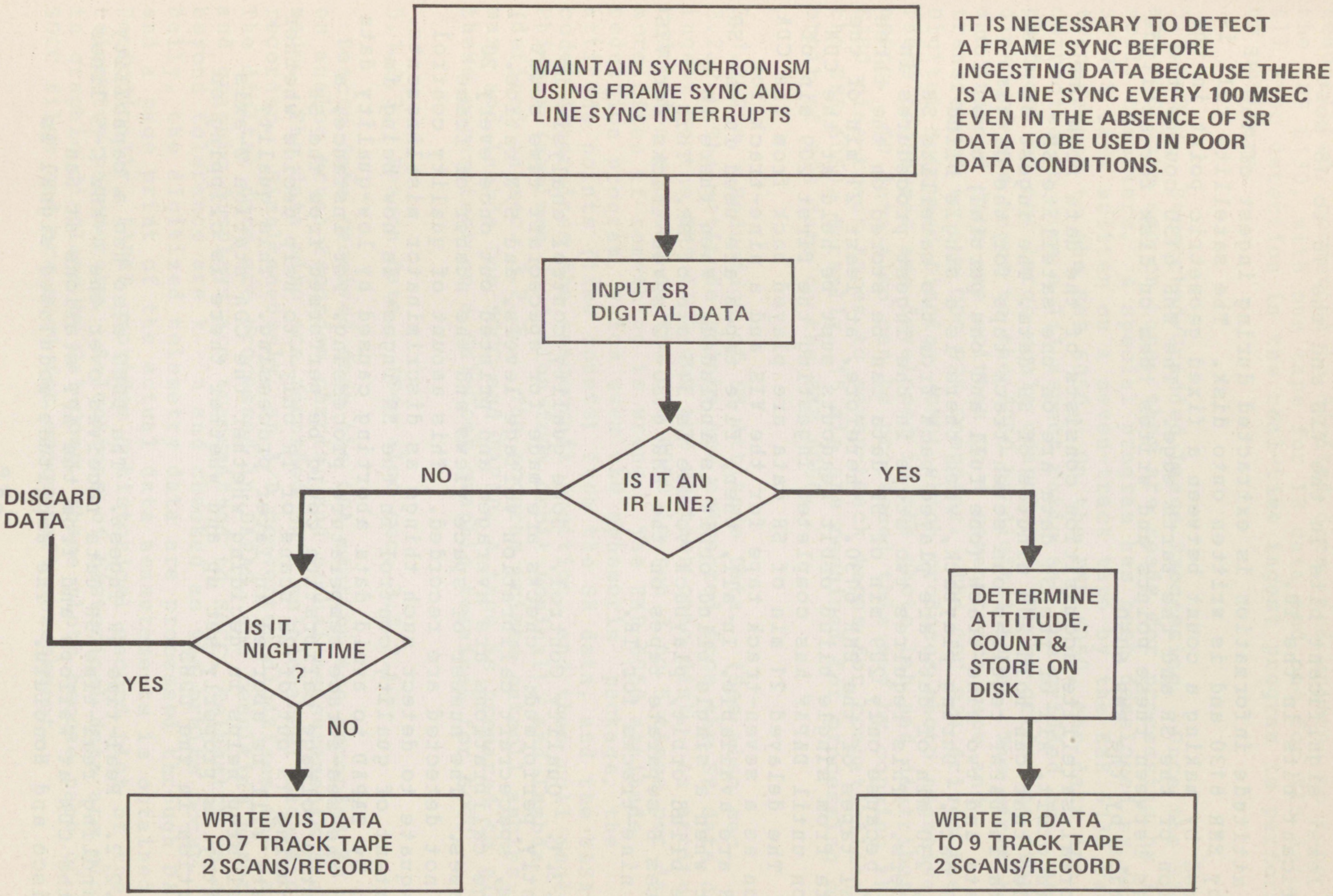


Figure 5-4.--SR data ingest functions.

to 18 least significant bits in the VIS and the 16 to 18 most significant bits in the IR.

The attitude information is extracted during ingest of the SR data by EMR 6130 and is written onto disk. The satellite roll is measured by making a count between a fixed geometric point in the rotation of the SR and the Earth edge. The EMR 6130 counts the samples between these points and writes them on disk for attitude reduction by the EMR 6050.

A normal satellite acquisition consists of the data from one 115-min orbit. All of the SR data are on one satellite SR recorder that can hold 209 minutes of SR data. The ingest of the SR data in DAPAF requires one seven-track tape for the daytime VIS data and two nine-track (one full and one partial) tapes for the IR data. During playback, when there is a single blind orbit, 230 min of data are played back from two satellite SR recorders. This requires two steps in the ingest procedures in DAPAF, because only 209 min of SR data can be stored on the three digital tapes of the EMR 6130. Therefore, at least 21 min of the SR data from single blind orbit readouts must be held at the CDA station until DAPAF has completed ingesting the first 209 min of data. The delayed 21 min of SR data are played back from the CDA as soon as a seven-track tape for the VIS and a nine-track for the IR are available. In all, then, five tapes are used in the SR ingest when a single blind orbit is included. When there is a double blind orbit, playback volume is 345 min of SR. This requires 6 separate tapes on the EMR 6130--2 seven-tracks for VIS and 4 nine-tracks for IR.

5.1.2.2.1. Quality Control. Some quality control analysis is currently performed: checks are made for spacecraft time count errors, spacecraft calibration voltage levels, and S/N ratios. Voltage calibrations are averaged and printed out once every 20 SR frames. The number of space views and the number of frame syncs not detected are recorded. This amount of quality control is adequate to detect such things as discriminator misalinements. The extent of quality control in the SR ingest is now being improved by DAPAD to avoid data aborting caused by low-quality data during the sea-surace temperature processing. For instance, a stairstep voltage calibration could be performed from the SR data--using 13 out of 25 scans of IR only--to help decide whether the data will be aborted in later processing. This quality control step helps in deciding whether the CDA station Z-axis circuitry is properly set up and whether there is clipping or distortion in the DDHS.

5.1.2.2.2. Real-time SR Ingest. The DDHS also has a capability for handling real-time SR data received over the 4-kHz C-5 lines from the CDA at Wallops and from the APT stations at San Francisco and Honolulu. The amplitude-modulated signal is demodulated, converted to digital data, and written to tape by the EMR 6130, with one tape for IR data and one for VIS data. All sync detection in the real-time ingest program is performed by software.

5.1.2.2.3. Stretched/Gridded Image Processing. Once the SRIR and VIS data are on tape, they are ready for processing by large-scale computers. A special program has been developed by which SR VIS data written on a seven-track tape by the EMR 6130 can be transferred to the EMR 6050. On the EMR 6050, the data are corrected to give a 1:1 aspect ratio and are gridded by a program produced on the large-scale computers. These grids are stored on disk and are input to the 6050 by digital tape. The stretched and gridded data are written on a seven-track tape and transferred to the CDC 924 Computer. The CDC 924 drives the Digital Muirhead Display (DMD) which produces photo negatives. These negatives are developed in the photo lab and distributed to users. IR data also can be processed this way by copying the 6130 nine-track tapes to seven-track tapes for compatibility with the EMR 6050. Normally, 15 min are required for processing of an orbit of VIS data on the EMR 6050.

5.1.2.2.4. Reduction of SR Attitude Data. (See also sec. 3.2.2.) The attitude points are extracted from the SR data during ingest by the EMR 6130 and are written onto disk. An attitude reduction program on the EMR 6050 is run 3 to 5 times per day, or more often if something is wrong. The EMR 6050 attitude reduction program, which uses the ephemeris package, the attitude points (time counts) from the SR data, and the NASA time code, determines the spacecraft position, and then roll angles, Phi-max (maximum deviation from orbit nominal), and lambda (defined in sec. 3.2.2). The program prints outroll angles, Phi-max, and lambda for SOCC and DAPAD. A tape is prepared to plot these parameters on a Cal-Comp graphic terminal for SOCC.

5.1.2.3. Beacon Data. (See also sec. 3.2.2.)

Beacon data received from the CDA station are recorded in SOCC on analog Brush recorder charts, and manual measurements are made. The data also are recorded on a multichannel magnetic tape recorder. Simultaneously, an A/D converter digitizes the data. The digital data are processed in DAPAD, and resulting numerical and graphic displays are transmitted to SOCC. Telemetry values beyond tolerance are known and checked as the orbits occur. Daily, the digitized telemetry data are processed through DAPAD, and a page print of the actual data measurements is obtained. Periodically, DAPAD provides a historical record plot of the telemetry parameters. Selections of historical data are plotted in graphic displays by Cal-Comp. These plots become part of the SOCC files and are used for spacecraft assessment.

5.1.2.4. Ingest of VHRR Data.

DDHS Capabilities for ingesting playback spacecraft-recorded VHRR data are limited. An analog tape is mailed in from the CDA station where frequency translations are performed depending on satellite transmission mode. This tape is played at a 2:1 slowdown rate through a discriminator to the A/D converters. The sample rate is controlled by the F&W signal, and the information is written on tape by the EMR 6130 (fig. 5-2). Ingest of VHRR data by this method has a low priority, since the data are used primarily for research. Another capability for ingesting VHRR data that has seldom been used is to record the data at the CDA station and play it at an 8:1 slowdown rate over channel A of the SATCOM 48-kHz line to the DDHS, with F&W on channel C.

The ingested VHRR data can be used with the Digital Muirhead Display (DMD) to produce 10- by 10-in film transparencies. While not related to the DDHS, there are several other methods used to produce VHRR images at DAPAF. Briefly they are:

a. The VHRR data are recorded at the Wallops CDA station, and played back at a 4:1 slowdown rate through the ATS digitizer and 48-kHz digital lines to the ATS digital picture terminal (DPT) at NESS, Suitland. The VHRR data have a low priority on the ATS system; the use of the ATS system is a temporary means for providing researchers with high-resolution images from the NOAA satellite.

b. The VHRR image display system (sec. 4.2) may be used. The SMS sectorizer hardware with VHRR software will be located at the CDA stations and 120-rpm displays will be located at Suitland. The communications will be over 4-kHz C-5 lines. In addition to the CDA stations, a number of HRPT stations across the country could transmit the VHRR data over C-5 lines for use with the 120-rpm displays at Suitland. This system may be in operation during 1974 or 1975.

c. VHRR analog tapes recorded at the CDA station can be used directly with the Image Information, Inc. High Resolution Image Processor at DAPAF. The tapes are mailed to DAPAF on special request for research use.

5.2. THE DAPAF CENTRAL PROCESSING SYSTEM

The Central Processing System hardware is described in section 5.2.1 and operations and software in section 5.2.2. A comprehensive documentation of all the individual products derived from the central processing system is contained in the "Catalog of Operational Satellite Products," NOAA Technical Memorandum NESS 53, March 1974.

Most operational products of the NOAA Polar Satellite System result from large-scale computer processing after the raw data have been ingested by the DDHS (sec. 5.1). These are the SPM punched tapes, the stretched gridded SR image tapes for the DMD, the satellite attitude, and various satellite housekeeping products for SOCC.
Products not obtained through the central processing system are: (1) direct broadcast services, e.g., HRPT, APT, and RT-VTPR (sec. 4); and (2) playback VHRR (sec. 5.1.2.4).

In this section, the functions of the central processing system are described to show in detail the complete flow of data from the satellite sensors to the final products. SR and VTPR data are the main items processed by the system.

5.2.1. DAPAF Central Processing System Hardware

The DAPAF Central Processing System uses the NOAA Office of Management and Computer Systems (OMCS) computer complex at Suitland, Md. The computer complex is shared primarily by NESS and NMC, but there are a number of other users. At present, the complex is based on three CDC 6600 general purpose computers and a variety of peripheral devices and terminals scattered across the country. At present, average DAPAF use of the center is slightly over one-third of center capacity. The operational interface between the DAPAF ingest system (DDHS) and the NOAA computer complex is a set of tape decks, card readers and printers, and a monitor unit physically located near the DDHS; all are linked to the NOAA computers by longlines.

The NOAA computer complex is being converted from CDC 6600 computers to two IBM 360/195 computers. The conversion will be made in phases with the initial system consisting of a single CDC 6600 and the single IBM 360/195 configuration shown in figure 5-5. The final system configuration (fig. 5-6) is projected for completion in March 1974. The objective of the conversion is to increase computing economy by improvements in computing speed and capacity.

The conversion to the IBM 360 system will not involve functional changes in the data processing for several years.

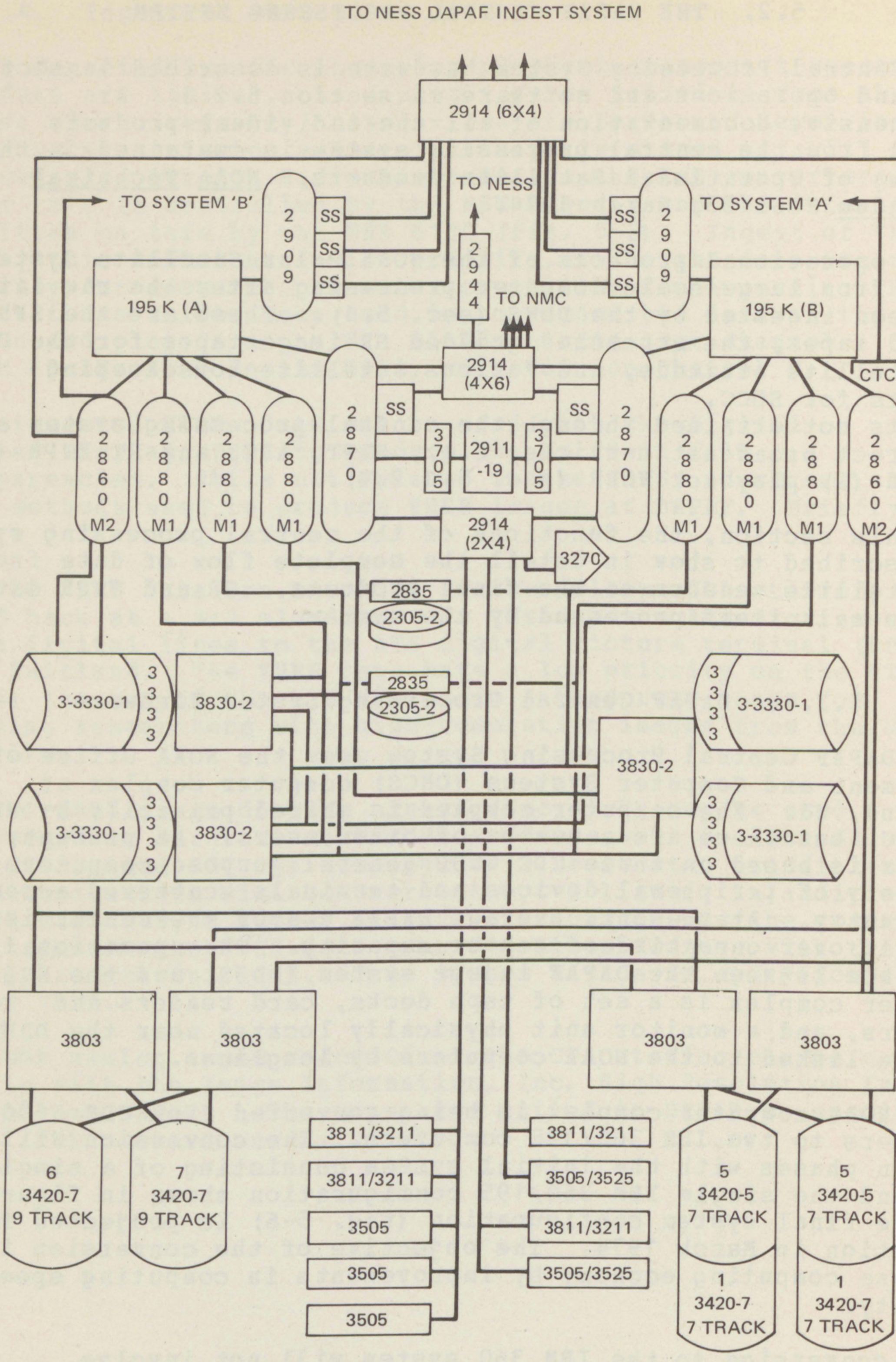


Figure 5-5.--NOAA computer complex, initial system configuration.

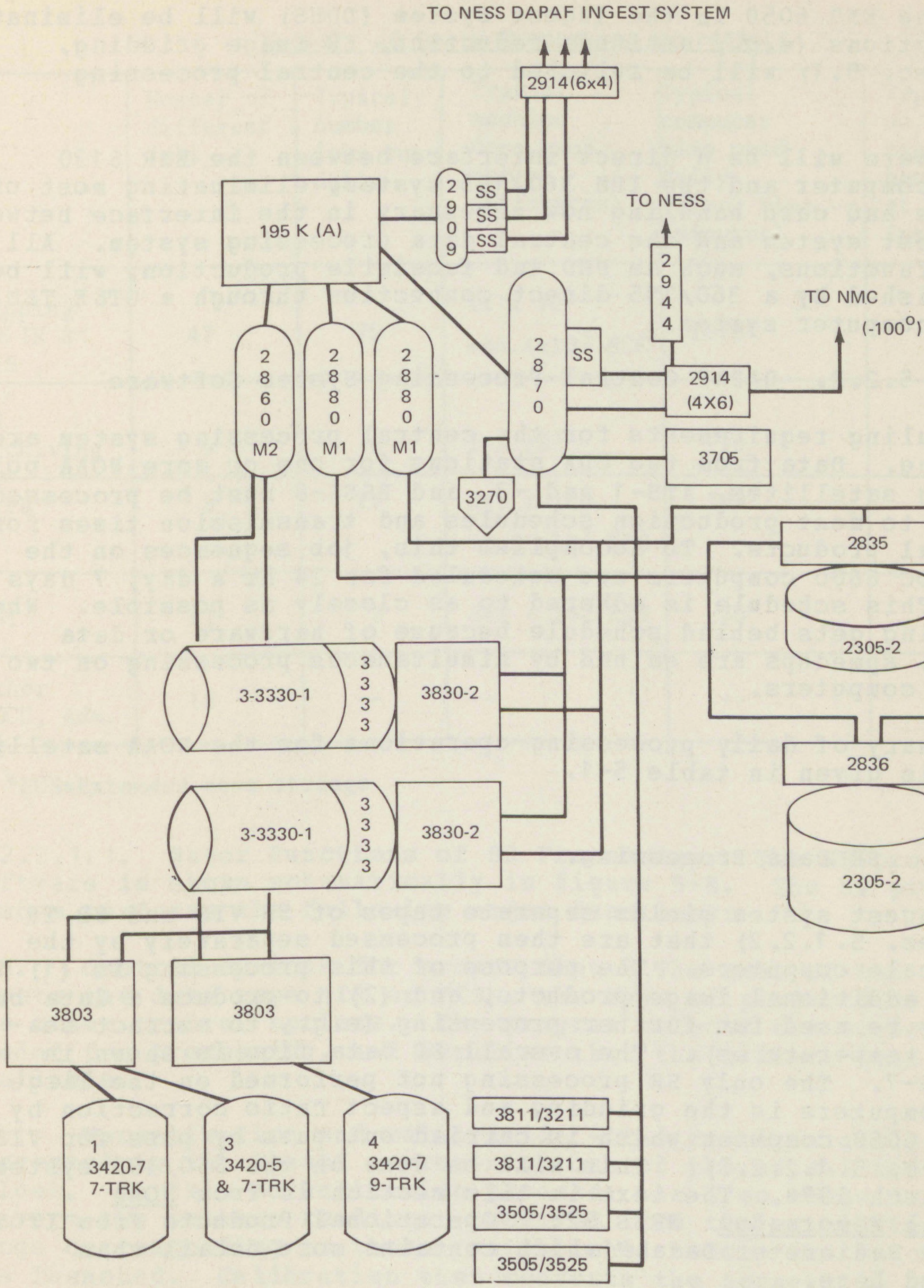


Figure 5-6.--NOAA computer complex, final system configuration.

There are two exceptions:

a. The EMR 6050 in the Ingest System (DDHS) will be eliminated and functions (e.g., attitude reduction, SR image gridding, etc.--sec. 5.1) will be switched to the central processing system.

b. There will be a direct interface between the EMR 6130 ingest computer and the IBM 360/195 system, eliminating most of the tape and card handling now necessary in the interface between the ingest system and the central data processing system. All output functions, such as DMD and facsimile production, will be accomplished by a 360/195 direct connection through a GT&E TEMPO-II minicomputer system.

5.2.2. DAPAF Central Processing System Software

Scheduling requirements for the central processing system are demanding. Data from two CDA stations for one or more NOAA polar orbiting satellites, ATS-1 and -3, and ESSA-8 must be processed quickly to meet production schedules and transmission times for the final products. To accomplish this, job sequences on the three CDC 6600 computers are scheduled for 24 hr a day, 7 days a week. This schedule is adhered to as closely as possible. When processing gets behind schedule because of hardware or data outages, speedups are gained by simultaneous processing on two central computers.

A summary of daily processing operations for the NOAA satellite system is given in table 5-1.

5.2.2.1. SR Data Processing.

The ingest system yields separate tapes of SR VIS and SR IR data (sec. 5.1.2.2) that are then processed separately by the large scale computers. The purpose of this processing is (1) to produce additional image products, and (2) to produce a data base that may be used for further processing (e.g., to extract sea-surface temperatures). The overall SR data flow is shown in figure 5-7. The only SR processing not performed on the large scale computers is the gridding and aspect ratio correction by the EMR 6050 computer which is carried out pass by pass for VIS data (sec. 5.1.2.2.3). This will be done on the 360/195 system as of March 1974. The text in this section is from <u>NOAA Technical Memorandum</u> NESS 52: "Operational Products From ITOS Scanning Radiometer Data," which contains more detail than presented here.

Table 5-1.--Central computer processing for NOAA polar orbiting satellites

Summary of Daily Processing Operations

	Number of different jobs	Typical number jobs run daily	Typical machine core used daily (Kilobytes)	Typical computer time used daily (clock time - minutes)	Typical no. of tapes handled at NESS interface
Mapping SR IR & VIS	47	75	11×10^3 $+44.4 \times 10^3$ ECS*	1075	80
SR archiving	9	9	1×10^3	110	16
VTPR	8	17	2.3×10^3 $+1.8 \times 10^3$ ECS	329	37
SST	11	3	342 + 132 ECS	35	3
Other SOCC, Adm.	15	--	--	--	--

*ECS=Extended core storage

5.2.2.1.1. Major Functions of SR Processing. The SR processing software is shown schematically in figure 5-8. The SR processing system performs the following major functions:

a. Control options for proper flow - The user of the program inputs the data type (IR or VIS), the type of products desired, and other control options. The program selects the segment needed for processing, and verifies that the correct data are available.

b. Normalization and calibration - The raw data are read and converted to the "best" representations of the actual radiative values. In this normalization process, the step wedge is used to convert the voltage readings received from the satellite to a range corresponding to those established before the spacecraft was launched. Calibration then converts the normalized readings into temperatures for IR data, or foot-lamberts for VIS data.

c. Earth location - Using satellite position and attitude information, data times, and a knowledge of sensor geometry,

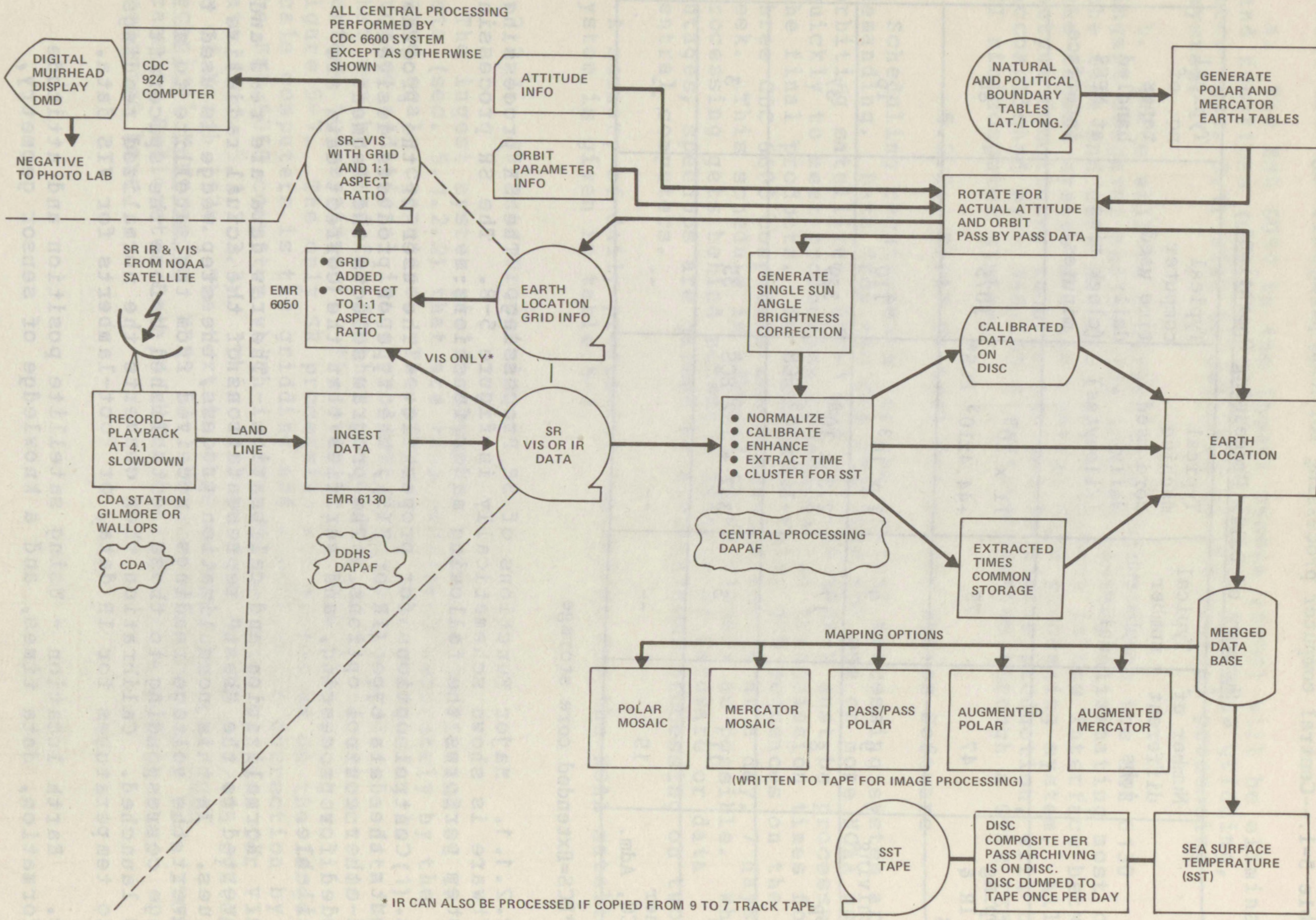


Figure 5-7.--SR data processing, overall data flow.

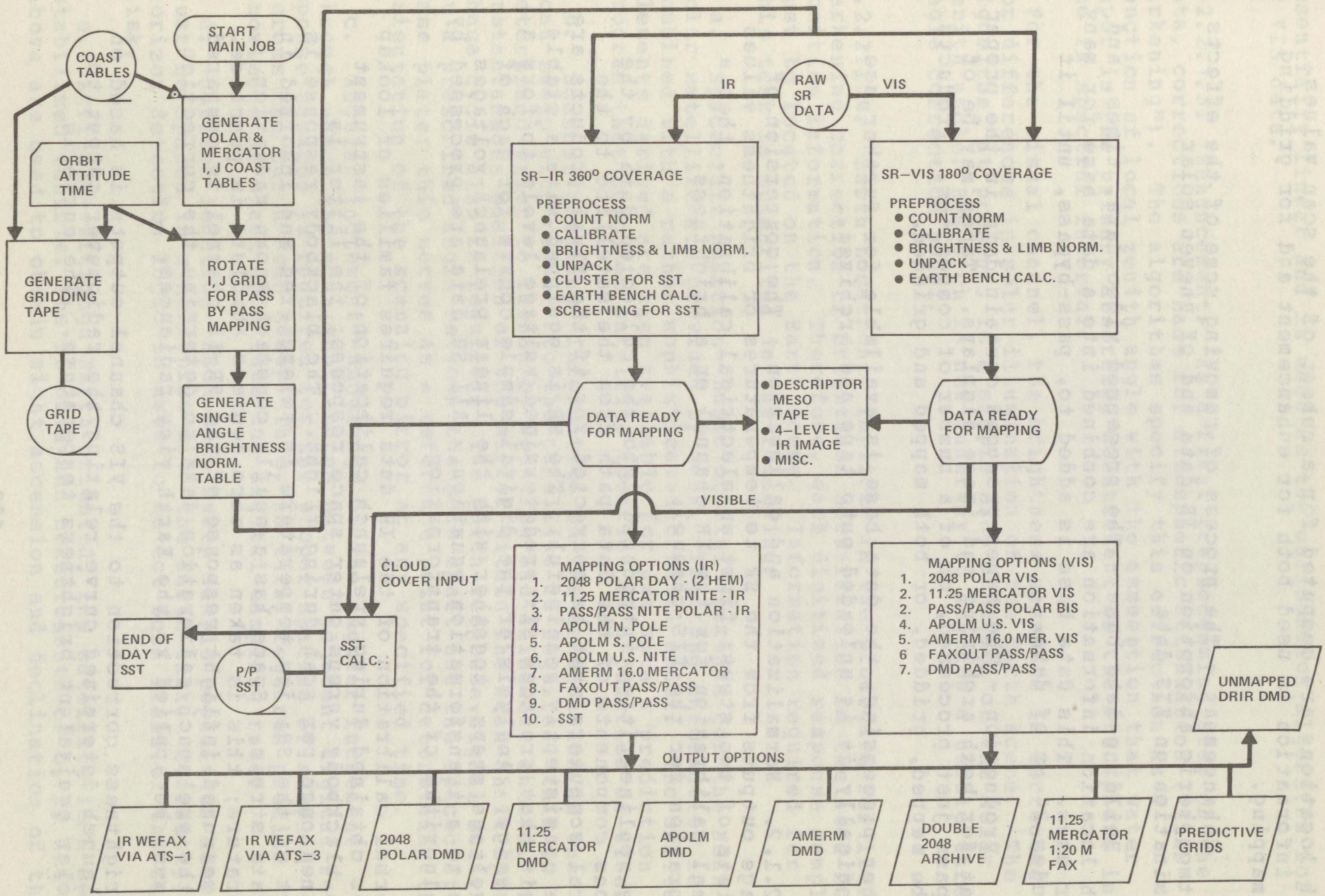


Figure 5-8.--SR CDC 6600 software.

Earth locations are computed for a subset of the scan values. This information is used both for enhancement and for gridding and mapping.

d. Enhancement - The process of removing some of the effects of atmospheric absorption on IR data and of uneven solar illumination on VIS data.

e. Building data base - The processed video data, times, and Earth location information are combined into a data base for many other uses. This data base is added to, pass-bypass, until it includes 24 hr of data.

f. Production - The tapes produced contain data in the proper format for both archiving and image displays. Tapes may be of the pass just processed, or of a number of composites. Products may be mapped, gridded, or both mapped and gridded.

After processing, the data base is available for further use. Periodically it is unloaded onto tape and archived.

5.2.2.1.2. Normalization and calibration. The conversion of voltage outputs from the SR to temperatures or brightness values consists of two steps: first an electrical calibration, then a thermal calibration for the IR channel or a brightness calibration for the VIS channel.

The nonlinearities introduced into the collected data by the various components of the data path from the satellite to the central computers must be corrected for if the final products are to be consistently meaningful. The SR is equipped with a stable circuit that produces six predetermined voltage levels to form a step wedge. Analysis of the digital sample counts for each of the voltage steps, together with the linear prelaunch voltages, leads to a transformation equation. All SR data are processed by the algorithm of the transformation.

Thermal calibration of the IR data requires families of lookup tables obtained during prelaunch calibration of the instrument and a blackbody versus outer space response; the latter is obtained once per scan during flight. The blackbody response is a part of the SR; its temperature is telemetered and inserted in the data stream. Space has a nearly constant known radiation temperature; this is taken as zero degrees Absolute in practice. This measured inflight response of the SR-IR channel is compared with the prelaunch calibration data to determine the correction that must be applied to the Earth view radiances.

A brightness correction to the VIS channel outputs is based on a prelaunch determined curve relating the radiometer output to the solar equivalent brightness temperature. The curve is essentially linear and is used as the calibration algorithm for SR VIS data.

5.2.2.1.3. Enhancement. As a final preprocessing step on the IR data, corrections are made for atmospheric attenuation ("limb darkening"). The algorithms specify this correction as a function of local zenith angle with the assumption that water vapor is the primary absorbing constituent of the atmosphere in the IR spectral interval.

For the visual channel, the brightness response is corrected for differences in solar illumination of the Earth scene. The algorithm, at present, is a simple sine function of the solar zenith angle. Research is now underway to develop a usable three-angle correction model.

5.2.2.1.4. Earth Location. Implicit in the procedure for limb darkening correction or brightness normalization is the need for position information. Therefore, each digitized response sample must be located on the Earth scene. Information required for this task is summarized in the following:

a. Spacecraft position--Basic orbital elements for the NOAA polar satellite are provided by NASA. Tracking information is combined with a rather sophisticated orbital model. The orbital elements derived are then available for use with a prediction program that computes satellite location as a function of time.

b. Scanner mounting--Information on the orientation of the scan sweep with respect to the satellite is required; this is determined prior to launch by mounting and alinement checks. The instantaneous position of the mirror within the scan-shaft spin-phase cycle also is required. The porch response signal occurs at a prescribed angle between the scan shaft and the spacecraft base plate; this serves as a reference point for determining the orientation of the scanning mirror at any specified time.

c. Angular increment--Knowledge of the angular increment through which the scan shaft turns between adjacent digital response samples is required for the proper spacing of samples across the Earth scan sweep. This, in turn, requires precise knowledge of shaft spin rate and digital sampling rate.

d. Horizon location--Each scan sweep sample population also must be spaced in synchronism with the Earth disk. Currently, horizon detection logic is used to detect both limbs of the Earth disk.

e. Attitude--Although Earth oriented, the satellite is a spin stabilized vehicle. The SR data and measurements of b, c, and d above are used to obtain right ascension and declination of the spin vector. The roll and yaw components of this vector are determined by obtaining the angle between Earth horizon and the porch by counting the intervening sample population on each scan sweep. The pitch component is expressed as an error signal between observed positions of horizon pitch pulses and their predicted positions (as specified in the feedback control mechanism).

f. Time--Time is used to relate scan sweeps to orbital positions. A 24-bit, 0.25-s interval counter is used on the satellite for this purpose; its output is reported during the backscan period within each data frame. This relative time is related to absolute time when the counter reset command is issued at the CDA station.

With the above information, the Earth location can be computed because the orientation of the sensing beam is known with respect to a platform whose position and orientation with respect to the Earth also are known at all times. To reduce computation time, the Earth location linkage is provided by means of an open lattice of image points. The three-dimensional image location element vector available at the satellite is converted to an equivalent geocentric vector through coordinate transformation equations to obtain a latitude and longitude location for the sample. Since the original image perspective must be transformed to some standard map projection, the computed location is transformed to an equivalent location on the desired projection. For convenience, map coordinates are expressed as points on a fine-mesh, square overlay grid oriented and scaled to approximate the basic resolution of a sensor sample element. The computer logic is further simplified by using scanner-line-number and sample number intervals in binary steps for the open lattice calculations. The resulting "bench point" calculations for the SR data are made for every eighth line and 32d sample.

In terms of computational efficiency, this image mapping input has drawbacks. With a high density of raw data samples, there is a surplus of samples when they are plotted onto square mesh map array. In addition, a square mesh overlay on a map is not an equal area projection, so the map mesh size cannot be equated to the basic sensor sampling resolution. Thus, several input data samples may overlap for map mesh locations in certain portions of the map. (A square mesh sector on a polar stereographic map encompasses four times as much area at the pole as does a similar sector near the Equator.) An alternate approach starts with the map mesh coordinates and, using the input data scan line and sample number, computes which input sample is most suitable for mapping into that location. By this method, only the desired input samples are unpacked and replotted. Because of the investment of time in developing software, the first (open lattice) method is in use; changes to minimize the computation time and data loss penalties are incorporated as developed.

5.2.2.1.5. Mapping and Gridding. With orthogonal bench point inputs, SR data are mapped daily over the entire globe in polar stereographic format. A tropical belt covering the full 360° longitudinal span is mapped in Mercator format. Several sections are also mapped with finer mesh to retain the maximum input sample volume for special applications.

The mapping algorithm can be summarized as follows:

a. A bench point Earth locator array is computed, and the limits of the equivalent fine mesh map array are calculated.

b. The specified sector of the map image array is transferred from dedicated disk storage into main computer memory.

c. Calibrated input scan data potentially available for mapping are read into main memory.

d. Using scan line and sample number designators, the map array location for a sample is computed from the bench point array. Taking advantage of a rectangular binary population organization, a linear interpolation is made entirely by binary shift logic without using more costly multiple instructions.

e. Candidate samples are replotted in the map mesh array until input sampling is exhausted or until the map array and bench point fields are exhausted.

f. The resulting mapped imagery is replaced in disk memory where it becomes available as a source for display or for other, more quantitative information extraction operations.

Five basic types of SR image products are generated by the large-scale computers. These are: Global polar stereographic mosaics, Mercator mosaics, limited map sectors with augmented resolution, individual sectors mapped by orbital pass, and unmapped images. These are described below.

a. Global polar mosaics

The fine-mesh polar stereographic arrays are alined with the conventional Numerical Weather Prediction (NWP) grid so derived products can be used easily for NWP applications. Subdividing each coarse mesh length into 32 segments produces a 2,048 by 2,048 array with a 7.4-km (4 n mi) mesh size near the Equator. The map distortion factor doubles the mesh size at the poles. Two hemispheric arrays are used for global coverage: a 2,048 by 4,096 vertical rectangle is formed by placing the Northern Hemisphere array above the Southern Hemisphere array. The mesh arrays are alined so the grid line between the poles coincides at 80°W. The mapping program on the CDC 6600 requires 3.2 min of central processor unit (CPU) time (4.2 min wall clock time) for each pole-to-pole hemispheric swath of input data. Nearly 100,000 60-bit words of high speed central memory are required. The disk area dedicated for storage of the global map array can hold more than 1.3 million 60-bit words. The 2,048 by 2,048 arrays are used to map both SR channels, even though this results in substantial coarsening of the spatial resolution of the visual channel data. Data are mapped as eight-bit quantities.

b. Mercator mapping

The overlapped SR Mercator mapping for tropic and subtropic applications is similarly mapped at a common, coarser resolution. In this case the orthogonal square mesh is alined parallel to the Equator with the right-most column at the Greenwich meridian. The overall area covers the full Earth circumference from 40°N to 40°S.

The mesh size is 11.25 elements per degree of geocentric arc at the Equator, equivalent to a resolution of about 9.8 km (5.3 n mi) per mesh in the Tropics. With the Mercator map, spatial resolution improves at the higher latitudes. Data are mapped in six-bit quantities (mapping will be in eight-bit quantities in the 360/195 version).

c. Limited map sectors with augmented resolution

Savings achieved through coarsening the mesh in the mapping described above make the data useful primarily for mesoscale or macroscale applications. Therefore, certain sectors are mapped at higher resolution for specialized uses. Certain "universal" features of the basic mapper software can be used with considerable flexibility to produce such sectors. IR data are currently being mapped at optimum resolution for two polar sectors with mesh size of 64 per NWP mesh (about 7.4-km resolution at the poles) and array sizes of 896 by 512 elements. Another sector of similar size and scale is produced for the contiguous 48 States. Other finer mesh limited area sectors can be produced. One small area has been mapped in conjunction with experimental midwest tornado applications using 128 mesh points for each NWP mesh. Another high-resolution, 20° by 20° Mercator sector with selectable center point location is available for hurricane analysis.

d. Individual sectors mapped by orbital pass

Polar and Mercator-mapped image mosaics produced by the methods described above are made once every 24 hr. There also is a strong need for more timely mapped imagery. Accordingly, polar sectors are now being mapped pass by pass. The IBM 360/195 software will replace this mapping with a facsimile presentation of the pass-by-pass stretched gridded product.

The principal customer for these products receives them by facsimile, so the image sector must be alined to use the recorder display area most efficiently. Accordingly, the map mesh is rotated so the node longitude of the input data approximates the center axis of the map rectangle. With the calibrated sample response truncated to displayable response range, this auxiliary mapping program needs far less frequent input/output service, so computing time for the sector is reduced to 2.5-min CPU time (4-min wall clock time) per pass. Sectors may be produced either from stored or directly transmitted SR data.

e. Earth locator grids in the perspective of unmapped SR imagery

Since mapping image data requires much computer time, unmapped imagery also is produced to fill operational needs. Although pass-by-pass mapped SR products are expected to fill much of the need, it is likely that there will be continued interest in imagery displayed in the perspective and spatial resolution of the original signal. To satisfy this interest, strips of unmapped SR imagery also are produced pass by pass.

By rearranging the equations for bench point Earth locations, image line and spot coordinates corresponding to integral latitude-longitude points are obtained. By selecting an adequate population of such computed points and interpolating filler points, latitude-longitude lines and geographic outlines can be produced and melded with the unmapped images. Scan lines and individual samples are replicated to yield a nearly 1:1 aspect ratio and to compensate for the foreshortening effect of the scanning geometry.

5.2.2.1.6. Sea-Surface Temperature Processing. The following equation is used to calculate the sea-surface temperature, Ts.

$$Ts = Te(\emptyset) + A' \sec \emptyset + B' \sec^2 \emptyset,$$

where Te is the equivalent blackbody temperature as retrieved by the SR instrument, A' and B' are water vapor attenuation coefficients as derived from the VTPR measurements, and Ø is the viewing angle measured at the satellite nadir angle. The computation model data flow is shown in figure 5-9.

An interface has been established between the VTPR and SR Sea-Surface Temperature (SST) models to exchange SR clear column radiance data and the VTPR atmospheric water vapor field data. The VTPR model uses the latest SST field as a baseline to determine clear column radiance needed for the reduction of VTPR

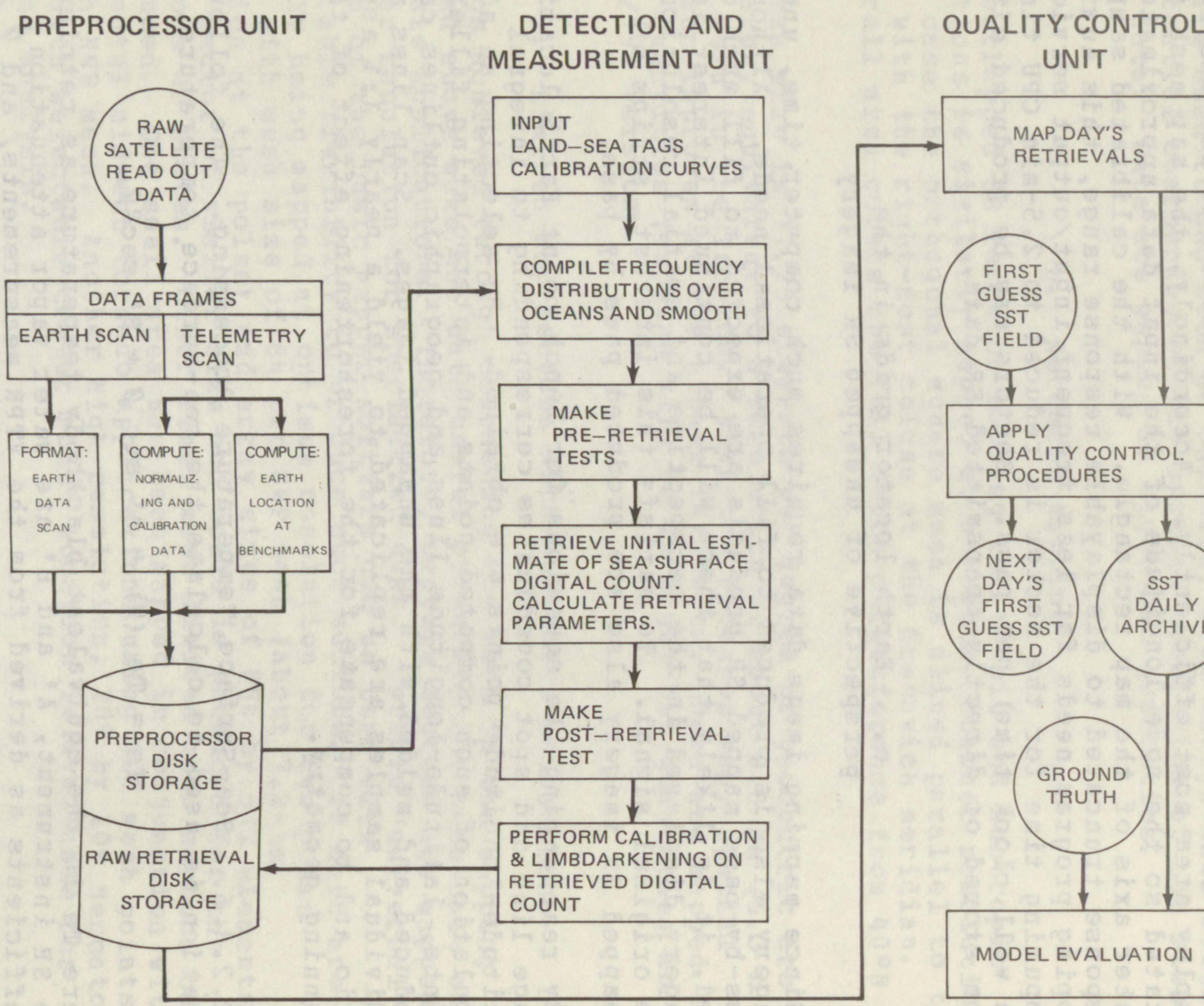


Figure 5-9.--Flow diagram for sea surface temperature computation model.

data. In turn, the SR SST model uses the VTPR atmospheric water vapor measurements to compute necessary atmospheric attenuation corrections.

Attenuation corrections are then applied to the SST retrievals during the mapping phase of the data processing.

Schedules, data handling errors, and mechanical failures can cause the loss of the time-synchronous orbits of the VTPR and SR data pairs. In the event of any such loss of VTPR data, a dual backup system has been designed into the SST model. System 1 incorporates a daily mapping of all attenuation coefficients into a coarse-grid polar stereographic grid field. Data in this field are maintained for 72-hr periods on a latest available data replacement basis. Thus, in the event of loss of the coincident orbital data, the attenuation compensation coefficients will be extracted from this backup field. If data in the backup field should be older than 72 hr, as would occur with failure of the VTPR instrument, then attenuation correction would be derived from an empirical average correction lookup table.

5.2.2.2. VTPR Data Processing.

During the ingest of the digital data by the DDHS, the VTPR data are separated, formatted, and written on digital tapes in a form ready for processing by the large-scale computers. In this section, the VTPR data processing is described in some detail. The material presented here is from NOAA Technical Report NESS 65, "Satellite Infrared Soundings From NOAA Spacecraft."

5.2.2.2.1. Overall Data Flow. The VTPR data flow and software system consists of six major computer programs. Figure 5-10 shows the individual program modules and their relationship within the flow system from the spacecraft to data users. Figure 5-11 shows details of the VTPR data processing.

When the NOAA-2 satellite is above the horizon of either of the two CDA stations, the digital data are played back from an onboard Scanning Radiometer Recorder (SRR) and are immediately forwarded to the NOAA/NESS data processing and analysis facility (DAPAF) in Suitland; here they are demodulated and passed on to the EMR computers for initial processing. The VTPR data are separated from the other spacecraft data and finally written on an output digital magnetic tape by the ingest program in the EMR 6130 computer. Normally, one orbit of data is processed for each readout. However, during one or two orbits each day the satellite does not appear above the horizon at either of the two readout stations, so these orbits of data are stored on the spacecraft until the next readout. In these cases, as much as 209 min of VTPR data may be recorded on one output tape, so two tapes may be required to record all the data at the CDA station.

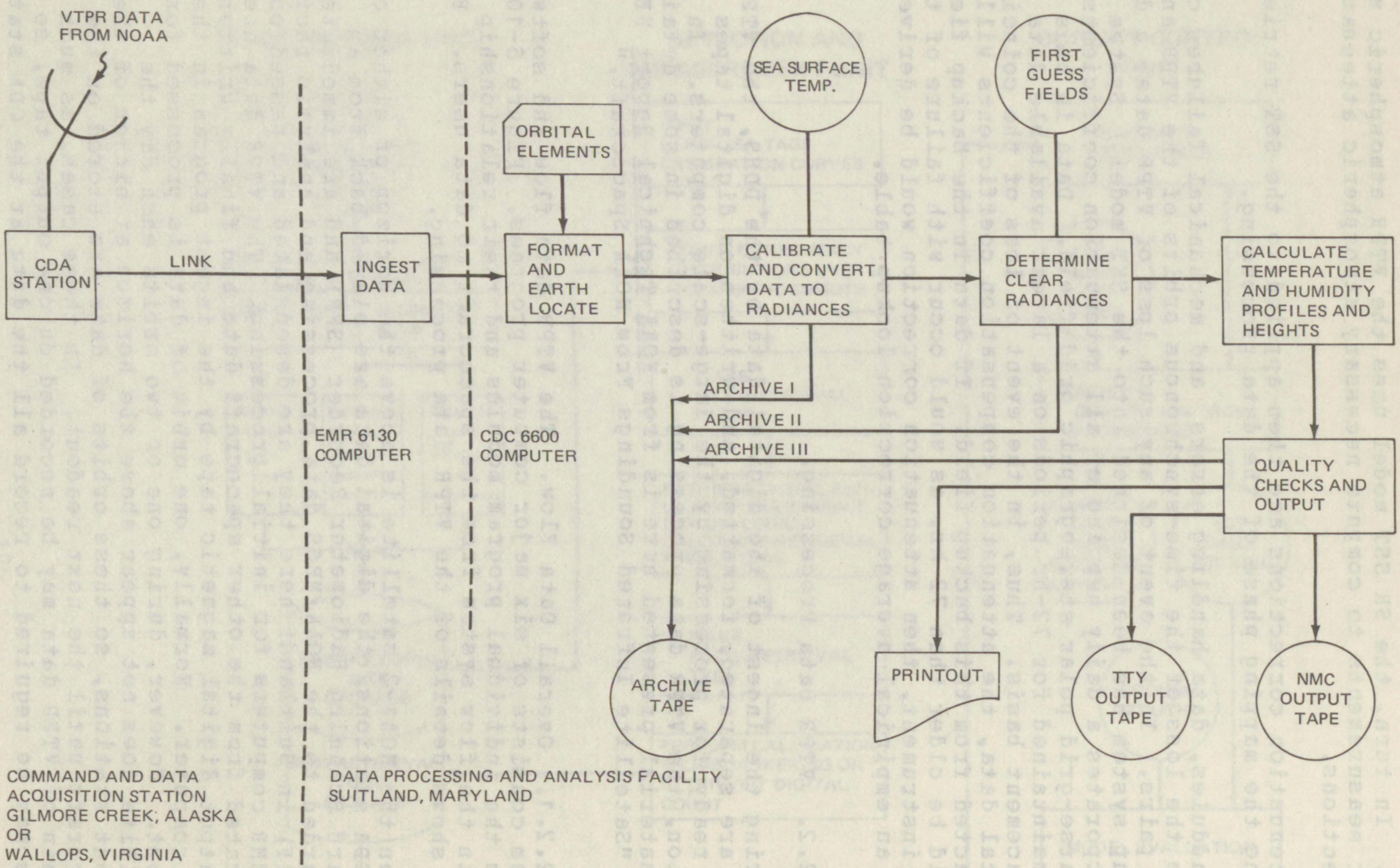


Figure 5-10.--VTPR software system.

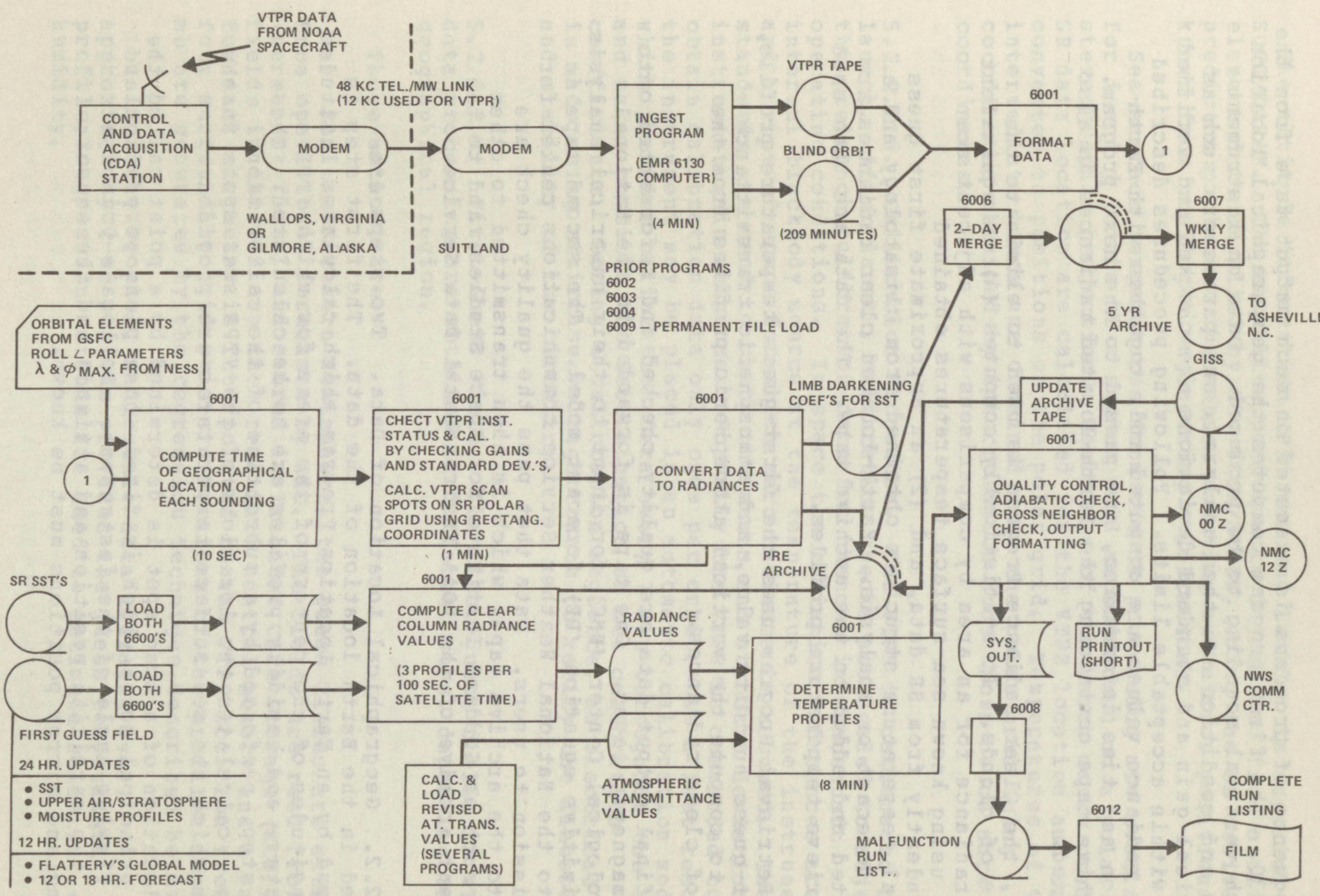


Figure 5-11.--VTPR processing (ITOS-D).

A sequence of programs is executed on each output tape from the EMR 6130. The first program computes the geopgraphical location of each vertical sounding to be produced. Data on instrument status and condition are then analyzed, and parameters such as electrical gain and standard deviations are checked and verified to be within acceptable limits. Following procedures described later, radiance values are computed and, together with Earth location and time information, are passed to the next program. An archive tape containing the Earth-located radiances is also generated.

Next, the Clear Radiance Program is used to eliminate the effects of clouds. It statistically computes (1) an equivalent clear radiance for an area by comparisons with adjacent scan spots, using known sea-surface temperatures obtained independently from SR data, and (2) an approximate first guess vertical temperature structure obtained from climatology and a recent forecast or analysis. Earth-located clear radiances are generated and added to the archive tape. The data are then used to retrieve temperature profiles.

The Retrieval Program uses the first-guess temperature profile, a first-guess humidity value, and atmospheric transmittance values to compute the vertical atmospheric profiles from the input of clear radiances.

The final output data are quality checked and reformatted onto three magnetic tapes. One tape is forwarded to the National Meteorological Center (NMC) for input to their numerical analysis and primitive equation (PE) forecast model. The second tape is given to the National Weather Service communications center for transmission to users. Data that pass the quality check are added to the archive tape, which is then transmitted to other users, such as Goddard Institute for Space Studies, and to the permanent archive of the NOAA Environmental Data Service.

5.2.2.2.2. Geographical Location of Data. Two steps are involved in the Earth location of the data. The first step is performed by an Earth Location Program which calculates latitudes and longitudes of the centers of the areas for which VTPR temperature and humidity profiles are to be calculated. The second step, performed by a subroutine of the calibration program, calculates the locations of the VTPR scan spots in the grid on which the sea-surface temperatures are provided.

The location of a scan spot is determined by a point called the sensor principal point which is fixed on a plane perpendicular to the viewing angle of the instrument. To locate principal points, the satellite position and attitude and the sensor mounting and mirror positions must be known.

The altitude information (Phi max and lambda) is supplied by SOCC/DAPAF. The satellite position is determined from orbital element data supplied by the NASA/STADN, using the GE orbital predictor package. The sensor mounting and mirror positions are known from preflight engineering calibrations.

Sea-surface temperatures from the SR processing are available for i and j points of a square grid superimposed on a polar stereographic projection. Positions of the bench marks used for SR data location are calculated for the VTPR location and are converted to positions on the polar grid. Temperatures of the intermediate boxes are obtained from the polar grid using coordinates obtained by interpolation from known bench mark coordinates.

5.2.2.2.3. Calibration Procedure. The VTPR is calibrated before launch. After launch, calibration checks are needed to adjust the prelaunch calibration data for changes in spacecraft operating conditions. In space the radiation references are the internal blackbody source at the temperature of the instrument and a view of space for which zero radiance is assumed. These standards are used to check the means and standard deviations of instrument gain response. Normally the VTPR is commanded to obtain calibration data only once per orbit. As a last resort the instrument may be placed in an automatic calibration mode which provides calibration data every 7 min throughout the orbit and makes possible the determination of new calibration coefficients. During a calibration sequence, an electrical check is made using staircase voltage counts to verify the linearity and stability of the circuitry.

5.2.2.2.4. First-Guess Field. The first-guess fields in VTPR data processing are obtained in different ways, depending on the geographical region.

These methods are:

a. For the Northern Hemisphere, the guess fields are extracted from operational forecasts by NMC. The fields are read from disk (permanent files) and stored in Extended Care Storage (ECS). The fields in the ECS are then read into central memory and a value for each parameter is interpolated to the VTPR location from the four surrounding grid points. Portions of the profiles above 10 mb are generated by the regression technique described below.

b. For the Tropics, radiosonde data averaged over approximately 2-mo periods provides the guess temperature profile; regression methods are used to estimate relative humidity.

c. For the Southern Hemisphere, the VTPR profiles for a given day are analyzed in conjunction with other available upper air data; these are used to generate the first-guess field for the subsequent day's VTPR processing. Humidity information is provided by regression estimates.

5.2.2.2.5. Procedures for Obtaining Clear Radiances (CLRAD). To eliminate the effects of clouds on the retrieved temperature profiles, a single cloud-free or "clear" radiance is produced from measurements of a number of scan spots. "Clear" radiances for a 7 by 8 or an 8 by 8 box or subarray are obtained from the measured radiances of the scan spots and from the sea-surface temperatures provided by SR data. The technique can be illustrated graphically in that any three measured radiances in a given spectral interval determine a straight line on an I(v-i) vs. an I(v-8) plot, where I(v-i) is a radiance and (v-i) is the central wave number of the spectral interval i. The underlying principle is that the radiance in a column is a linear function of the cloud amount within certain limits.

The atmospheric transmittance for spectral interval 8 (channel 8 of VTPR), which is an atmospheric window, is close to unity and is only slightly affected by the atmosphere. Hence with measured values of I (v-i) and I (v-8) for each of two areas, a straight line is determined on a I (v-i) vs. I (v-8) plot. The radiance of channel 8 for a clear column can be computed using the first-guess atmospheric profiles of temperature and humidity and the surface temperature from the SR data. With the computed clear radiance for the window channel, the clear radiance of the i-th channel is determined using the plot.

Operationally, data from eight successive scans are used to obtain three temperature profiles. A pattern of 23 by 8 scan spots is divided into three subarrays, two containing 8 by 8 spot arrays, and one 8 by 7 spot array. For each subarray, a temperature profile is calculated. In each subarray, clear column radiance is obtained for 49 sets of four adjacent spots (196 spots). The 196 values of clear column radiance are combined to obtain an estimate of the value of clear column radiance for the 8 by 8 or 8 by 7 subarray area. The techniques used in this combination are explained in detail in <u>NOAA Technical Report</u> NESS 65.

A number of checks on the credibility of the computed and measured values are made throughout the processing.

5.2.2.2.6. Retrievals. The temperature and moisture retrieval program derives atmospheric temperature and humidity profiles from the clear radiances produced by the CLRAD program. The retrieval program may be thought of as a sequence of five sections: Input, construction of transmittances and weighting functions, temperature retrieval, moisture retrieval, and output.

a. Input - The required inputs for the retrieval program are:

1) Radiance values of the seven spectral intervals (VTPR channels 1 to 7) from the CLRAD program.

2) Surface temperature (in lieu of computed radiance for the 8th spectral--atmospheric window--interval from sea-surface temperature.

3) First-guess temperature and water-vapor profiles obtained from:

a) For below 10 mb, profiles from forecasts, analyses and climatology as explained in section 5.2.3.4;

b) Tropopause temperature, height, and pressure from NMC; and

c) For above 10 mb, the profile is obtained by regression from radiances in spectral intervals 1 and 2 of VTPR and the first-guess temperature at 10, 30, and 50 mb from recent samples of rocket and radiosonde data.

Finally, the guess temperature profile is interpolated to 100 pressure levels distributed between 1,000 mb and 0.01 mb in even increments on a scale of pressure raised to the 2/7 power.

4) A guess for the mixing ratio profile is obtained from the surface up to 500 mb or so. In areas where no moisture information is provided by NMC (e.g., Southern Hemisphere) the correlation between temperature and mixing ratio is used together with temperature data from conventional soundings.

b. Construction of transmittance and weighting functions - Atmospheric transmittance is assumed to be the product of the individual transmittance of carbon dioxide, ozone, and water vapor. The individual transmittances are estimated for each of the eight spectral intervals of the VTPR. The carbon dioxide and water-vapor corrections are of major importance. The first-guess temperature profile is used with precalculated data on atmospheric transmittance associated with carbon dioxide as a function of temperature to determine corrections to the standard transmittances. The first-guess moisture profiles and the mixing ratio profiles are used to determine corrections to atmospheric transmittances necessitated by the presence of water vapor.

c. Temperature retrieval - The temperature profile is obtained through a modification of the least-squares solution of the radiative transfer equation. This solution can be written as

$$Br(T) = Br(T') + (C)(Rr - Rr'),$$

where the matrix C is given by

$$C = SA^{+}(ASA^{+} + N)^{-1},$$

where $^{+}$ means the matrix transpose.

A description of all terms in these equations follows. The equations yield Br(T), the 100-element Planck radiance profile of the solution temperature profile, T, computed at a reference wavenumber of 700 cm^{-1}. The 100 elements correspond to the 100 atmospheric pressure levels between 0.01 and 1,000 mb mentioned earlier. A solution temperature profile is readily obtained from Br(T). Geopotential thicknesses relative to 1,000 mb are computed from the perfect-gas and hydrostatic equations. In the Northern Hemisphere, heights are obtained relative to the NMC forecast 850-mb height.

The term Br(T') is the Planck-function profile computed at 700 cm^{-1} from the guess temperature profile T'. The vector Rr contains the measured radiances in the first six spectral intervals of the VTPR. Likewise, Rr' is a vector of six radiances calculated by the radiative transfer equation from the surface temperature, the guess temperature profile, and the transmittances. Both Rr and Rr' are scaled to the 700 cm^{-1} reference wavenumber through radiance-equivalent temperatures. The 6 by 100 dimensional matrix A consists of six specified 100-dimensional weighting functions.

Uncertainties in measurements of the radiances originating from instrumental noise and calibration errors, quadrature errors, and uncertainties introduced in obtaining clear radiances, reside in N, a 6 by 6 dimensional variance-covariance matrix. Statistics of the atmosphere comprise the 100-dimensional diagonal matrix S, whose elements are variances of the 700 cm^{-1} Planck radiance profile derived from a set of typical radiosonde measurements. The off-diagonal elements of S, which should contain the correlations among the temperatures at different levels of the atmosphere, are ignored for computational speed and simplicity.

The above equations express the solution as the guess profile plus a linear combination of differences between observed radiances and the radiances calculated from the guess profile. Large errors in the measurements of radiances (large N) will force the solution toward the guess. The solution will also tend toward the guess for layers of the atmosphere with small expected variations in the temperature (small S). Usually one application of the equations will provide a convergent solution in the sense that radiances calculated from the retrieved profile differ from the measured radiances by less than the standard deviation of the errors. Otherwise, the equations are applied again, with T' and Rr' representing the results of the previous iteration. Since the matrix C is nearly independent of temperature, it is held constant from iteration to iteration, thus minimizing computation time.

d. Moisture retrieval - The moisture retrieval begins with a measured radiance at 535 cm^{-1} and the retrieved temperature profile. The solution for the mixing ratio profile W is assumed to have the form

$$W = W' + C\emptyset$$

where W' is the guess mixing ratio profile, C is a constant to be determined, and Ø is an empirical orthogonal function (Alishouse et al. 1967) computed in advance of the retrieval from conventional sounding data. If it is impossible to compute Ø because of lack of reliable data over certain areas, Ø is assumed to be W' itself. The constant C is evaluated in the retrieval through the requirement that 535 cm^{-1} radiance computed from W be equal to the measured radiances within two standard deviations of the measurement errors. Finally the solution W is transformed to dewpoint depression. Only one spectral interval is used to measure water vapor. With this single measurement, only one parameter (e.g., the value of C) can be determined. The distribution of the water vapor is determined by the relatively smooth functions W' and Ø. Another limitation of any moisture retrieval is the dependence on accurate knowledge of the temperature profile since temperature enters strongly into the computation of radiance.

e. Output - For each sounding, the following quantities are passed to the quality control program:

1) Retrieved temperatures, heights, and guess temperatures at the 15 standard levels (1,000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 mb) and at the tropopause;

2) clear radiances in the eight spectral intervals of the VTPR;

3) dewpoint depression at the 5 standard levels up to the 400-mb level; and

4) two coefficients to account for atmospheric attenuation (limb darkening) in the Scanning Radiometer measurements of equivalent temperatures.

The final output from the VTPR is called the Satellite Infrared Sounding (SIRS); it includes location, heights, temperatures, and dewpoint temperature depressions at the mandatory pressure levels up to 400 mb, heights and temperatures up to 10 mb, and temperatures at significant levels. Initially, only data from open water oceanic regions are being released to the user. Before the data are released, several tests are performed. Failure of any one test causes all data up to 100 mb to be deleted. There is no provision for manual adjustment of rejected data; however, operational personnel are provided with orbit-by-orbit summaries from which they are expected to note trends requiring corrective action.

The following tests are performed on the data:

a. A superadiabatic temperature lapse rate test is performed on the tropospheric pressure layers bounded by the mandatory and significant pressure levels to insure a stable profile;

b. A gross error or "neighbor" check is performed on the difference between the NMC forecast first-guess heights and the retrieved heights for all constant pressure levels. Values of this difference are calculated for all points in the neighborhood (within 500 km). A sounding is required to have at least one neighbor or it is automatically rejected. The value of the height difference for the point must agree with the average of the height differences for the other points in the neighborhood to within: ± 200 m with one neighbor; ± 100 m with two neighbors; or ± 75 m with more than two neighbors; and

c. When retrievals are extended to land areas on an operational basis, further location tests will be made to ensure that a proper adjustment has been made for the terrain elevation in the field of view.

The above tests are performed on all retrievals. However, the initial criteria used in the gross error check for the Southern Hemisphere may be adjusted to the quality of available first-guess profiles in this region.

When a retrieval is rejected, the cause is listed for the information of operational personnel. At the conclusion of each data orbit, the rms temperature difference between the first guess and the retrieval (for the lowest 10 standard pressure levels) is plotted on a latitude-longitude grid.

Histograms of the change made to each first-guess temperature are tabulated by mandatory level and by location (the Tropics between 18°N and 18°S and Northern and Southern Hemisphere extratropical areas).

At the end of each computer processing run, coverage charts are plotted on polar stereographic maps for the Northern and Southern Hemispheres and on a Mercator map for the Tropics. Data rejected during the synoptic period are included, but are flagged to indicate any consistent geographical bias.

Additional checks are generated over selected areas or at selected times to monitor the performance of each VTPR channel, the communication links from the data acquisition stations, and the individual internal programs used to generate a SIRS sounding. Some retrieved soundings are compared with standard radiosonde reports, the NMC analyses, and the SR data as a test for meteorological reasonableness. For example, the amount and the pressure height of the cloud output are compared with the SR data to check the algorithms used in the clear radiance program. The 1,000- to 300-mb thickness and the contoured height fields at 300 mb are also compared with the SR data and the NMC forecast and analyses.

A more complete quality control program is being developed.

5.2.2.2.7. Data Outputs and Archives. Soundings that pass the quality control tests are archived and sent to a number of users. Three tapes are prepared to satisfy requirements of various users. One tape is used to send a teletype message; a second tape is sent to the National Meteorological Center (NMC); and a third tape is prepared as a data archive.

a. Teletype messages - Teletype messages are formatted to conform to the code used for SIRS-A and SIRS-B (World Meteorological Organization 1972). Differences in the instrument design and the retrieval procedure require a change in the interpretation of several of the values given.

A number of adjacent measurements are used to obtain "clear" radiances from cloud-contaminated values. These clear radiances are used in the retrieval, so cloud conditions do not affect the reliability of the data as they did the SIRS soundings. The cloud indicator is always set at zero to indicate a clear sounding, and no cloud information is transmitted. This is no indication that no clouds are present.

When the Nimbus-3 and Nimbus-4 satellites were operational, retrievals were attempted only in the Northern Hemisphere where the NMC forecast was available. The 850-mb forecast height was used as a reference level for the height calculations. This procedure is currently used with the VTPR data for regions covered by the NMC forecast. When the 850-mb forecast height is not available, the 1,000-mb height is set to zero; for these cases, the value given is the 300-mb thickness, and the 1,000-mb height is zero.

In summary, north of 21°N all heights are referenced to the NMC 850-mb forecast height. South of 18°N, all heights are actual thicknesses between the given level and 1,000 mb. Between 18°N and 21°N, either method may be used, so the 1,000-mb height must be checked to determine which is used for a given sounding.

To make the SIRS code more compatible with the capability of the VTPR instrument, the code will be modified in the near future, and clear radiances will be sent as a separate transmission.

b. Output to NMC - Soundings supplied to NMC are written on two tapes, one for each 12-hour interval (0600-1800 GMT and 1800-0600 GMT). Data are output as soon as orbits are processed, and NMC uses the tapes as required by their operational schedule. The tapes are not available for general use, but the same soundings appear on the archival tape.

c. Archival tapes - VTPR data are available in different forms (raw radiances, "clear radiances", and retrieved profiles) at three major points in the data processing. These data are written on tape as three separate files, each of which consists of a header record and a number of data records. This tape is transmitted to the Goddard Institute for Space Studies in real time. A copy also is sent to the National Climatic Center. Requests for data and questions concerning formats should be sent to the National Climatic Center, Federal Building, Asheville, N.C. 28801.

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Appendix A

GLOSSARY OF TERMS AND ACRONYMS

a.c.	alternating current power source
A/D	analog-to-digital
ADP	automatic data processing
AFC	automatic frequency control
AM	amplitude modulation
AN	ascending node
APT	Automatic Picture Transmission
Aspect ratio	ratio of the distance depicted in the width to the distance depicted in the length of a displayed image.
ATS	Applications Technology Satellite
ATSOCC	Applications Technology Satellite Operations Control Center
AVCS	Advanced Vidicon Camera System
bcd	binary-coded-decimal
bpi	bits per inch
bps	bits per second
BW	bandwidth
bytes	binary data words
CDA	Command and Data Acquisition
CDC	Control Data Corporation
CLRAD	clear radiance computer program
CONUS	Continental United States
CPU	Central Processing Unit

CRT	cathode ray tube
D/A	digital-to-analog
DAPAD	Data Processing and Analysis Division
DAPAF	Data Processing and Analysis Facility
DB	direct broadcast
dB	decibels
DB-BCN	direct broadcast beacon
DDHS	Digital Data Handling System
DDP	digital data processor
DMD	Digital Muirhead Display
DN	descending node
DPT	digital picture terminal
DR	direct readout
DSAI	Digital Solar Aspect Indicator
ECS	extended core storage
EMR	EMR Corporation
EOR	end-of-record
ESSA-APT	earlier generation of direct broadcast satellite
ESSA-AVCS	earlier generation of stored data satellite
FM	frequency modulated
FSK	frequency shift keyed
F&W	flutter-and-wow tape recorder perturbations
GE	General Electric Corporation
GHz	giga Hertz
GMT	Greenwich Mean Time (Universal Time)
GSFC	Goddard Space Flight Center
GWC	Global Weather Center, Offutt AFB, Neb.

HRPT	High Resolution Picture Transmission
Hz	Hertz
IBM	International Business Machines, Inc.
IF	intermediate frequency
IFOV	instantaneous field of view
I/O	input/output
ips	inches per second
IR	infrared energy spectrum
IRIG	Inter-Range Instrumentation Group
ITOS	Improved TIROS Operational Satellite--pre-operational name for NOAA polar satellite
keV	thousand electron volts
kHz	kilo Hertz
KSPS	kilo samples per second
LMT	Local Mean Time
lpi	lines per inch
lpm	lines per minute
mb	millibars
M Bit	mega bit
MDHS	Meteorological Data Handling System
MeV	million electron volts
mr	miliradians
MWA	Momentum Wheel Assembly
N	north
NASA	National Aeronautics and Space Administration
NESS	National Environmental Satellite Service
NMC	National Meteorological Center

NOAA	National Oceanic and Atmospheric Administration
NOAA/OMCS	NOAA's Office of Management and Computer Systems
NWP	numerical weather prediction
NWS	National Weather Service
PAM	pulse amplitude modulation
pass	Satellite acquisition period with CDA
PCM	pulse code modulation
PE	primitive equation numerical analysis and forecast model
p-p	peak to peak
Q-Branch	energy region in which the carbon dioxide molecule absorbs.
RCA-AED	RCA-Astro Electronics Division
RF	radio frequency
RHC	right-hand circular
rms	root-mean-square
rpm	revolutions per minute
RT	real time
S	south
SATCOM	Satellite Communications Network
S/C	spacecraft
SCAMA	Switching, Conferencing, and Monitoring Arrangement
SCD	subcarrier discriminator
SCO	subcarrier oscillator
SDU	signal distribution unit
SEL	Solar Experiment Laboratory
SFO	San Francisco
SFSS	Satellite Field Service Station

SIRS	Satellite InfraRed Spectrometer
S/N	signal-to-noise power or voltage ratio
SOCC	Satellite Operations Control Center
SMS	Synchronous Meteorological Satellite
SPM	Solar Proton Monitor
SR	Scanning Radiometer
SR-IR	Scanning Radiometer-Infrared channel
SRR	Scanning Radiometer recorder
SR-VIS	Scanning Radiometer-visible channel
SST	sea-surface temperature
STADAN	Space Tracking and Data Acquision Network
TCC	TOS Checkout Center
TDM/FSK	time division multiplexed/frequency shift keyed
TEC	TOS Evaluation Center
TLM	telemetry
TLMCAL	Software under developement to plot selected telemetry channels
TLMCK	Software routine for checking telemetry data with tolerance data
TLMPR	Telemetry software that sorts out every tenth stored telemetry commutaticn for printing
TOS	TIROS Operational Satellite
TRK	track
TTY	teletype
VCO	voltage controlled oscillator
VHF	very high frequency
VHRR	Very High Resolution Radiometer
VIS	visible energy spectrum

VREC	Very High Resolution Radiometer Data Recorder
VTPR	Vertical Temperature Profile Radiometer
WEFAX	Weather Facsimile Experiment- satellite broadcast
WMO	World Meteorological Organization
X-136	SATCOM communication terminal
Z-axis	Compensation system for SR tape recorder speed variations that affect the optical (Z) axis of the displayed image

Appendix B

THE NATIONAL ENVIRONMENTAL SATELLITE SERVICE (NESS)

AN ORGANIZATIONAL DESCRIPTION

NESS is a major component of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). NESS is responsible for the development and operation of the NOAA environmental satellite systems. In this capacity, NESS provides operational products to worldwide users from both its own satellites and satellites operated by the National Aeronautics and Space Administration (NASA). This service has been provided by NESS on an uninterrupted operational basis since February 1966.

Under the NESS Director there are four offices: Research, Operations, Systems Engineering, and Systems Integration. The Office of Research develops techniques and instrumentation for using satellite-borne sensors for meteorology, oceanography, hydrology, and environmental pollution. The Office of Operations is responsible for satellite operations and control, for the acquisition and processing of satellite data, and for its dissemination to users in various forms of final products. New product development involves both research and operations offices. The Office of Systems Engineering provides technical support for system design and implementation. The overall coordination and long-term planning of environmental satellite systems is the responsibility of the Office of Systems Integration. NASA procures and launches the environmental satellites according to the specifications of NESS. NESS liaison with NASA is through the Office of Systems Integration.

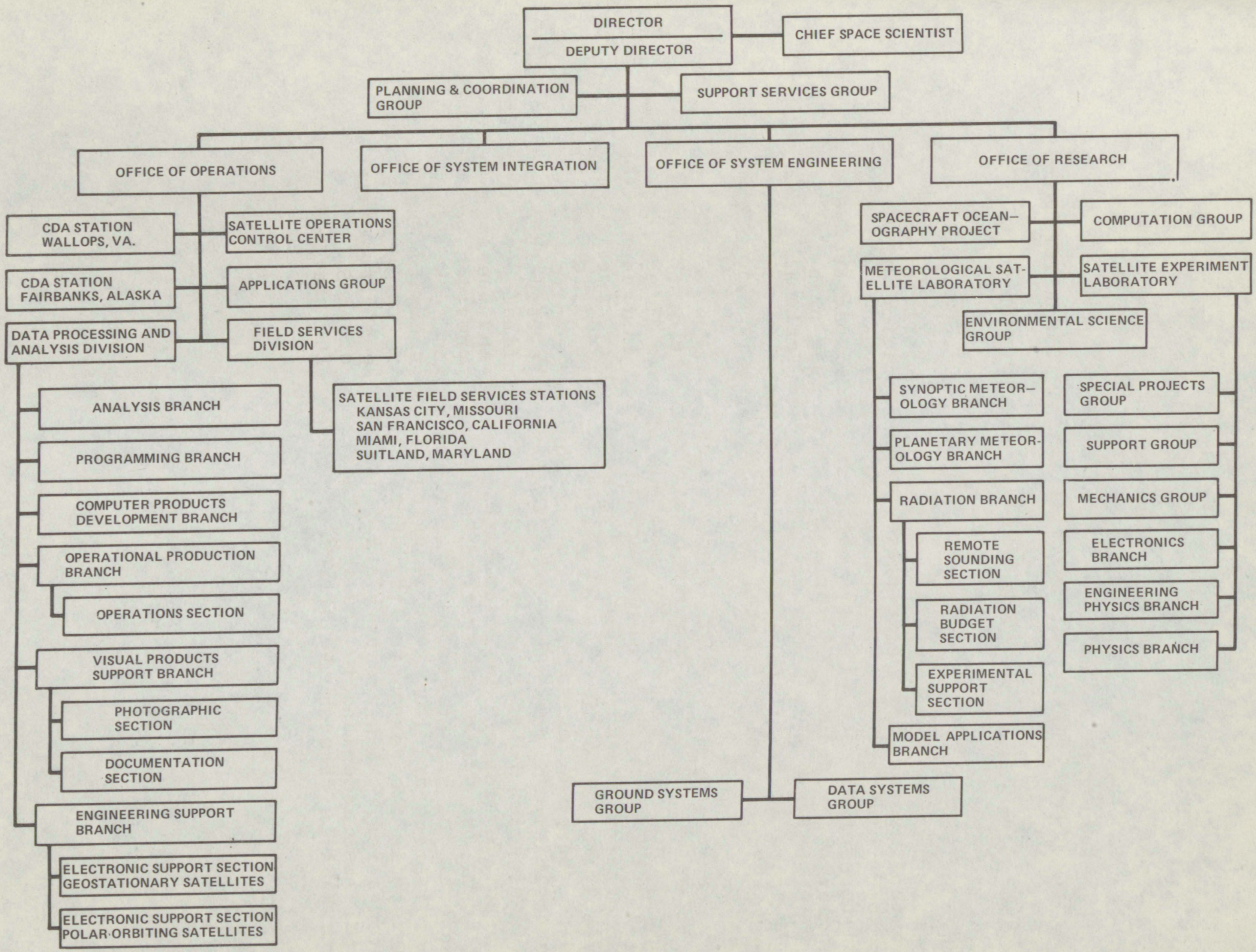

Figure B-1.--NESS organization chart.

(Continued from inside front cover)

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