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THE GEOSAT GROUND STATION

Radar altimetry data for GEOSAT were acquired by a single ground station that also archived, preprocessed, and distributed the data. The ground station commanded and controlled the satellite and monitored its health and status. Because all GEOSAT data dumped over the ground station had unique ocean-surface coverage with high value, the program required a 24-hour-per-day operational station with a high degree of reliability and maintainability. The satellite command and health-monitoring functions were free from single-point failures, and automation reduced operator error. Store-and-forward techniques minimized altimetry data loss and facilitated recovery from failures. In support of the recently completed geodesy mission, the GEOSAT ground station recovered more than 99.85 percent of the altimetry data collected on board the satellite.

STATION OVERVIEW

Figure 1 illustrates data collection at the GEOSAT ground station.[1,2] The altimetry data include a measurement of distance from the satellite to the ocean surface. The altimeter measurement data are recorded on board the satellite and then dumped about twice a day when GEOSAT is in view of the ground station.

Major functions and features of the ground station are the following:

1. Single ground station
   Redundant capabilities
   Store-and-forward design
2. Satellite support
   Command and control
   Health monitoring
3. Altimeter data handling
   Dump data reception and recording
   Data preprocessing and delivery

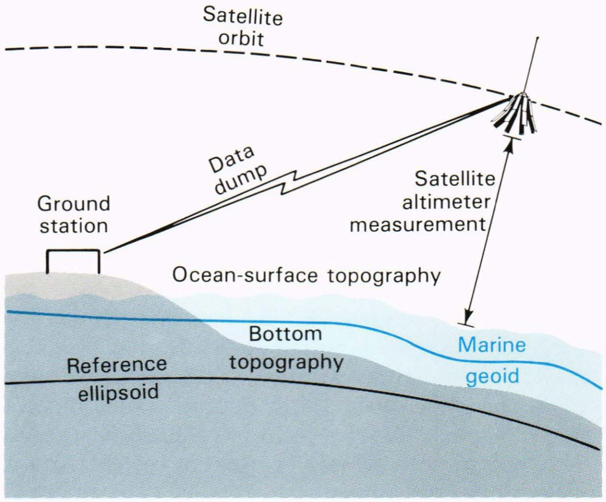

Figure 1—GEOSAT data collection.

Original planning for the GEOSAT mission required a primary ground station at APL and a separately located backup station. However, a suitable backup station could not be identified, so it was decided to provide all backup capability at APL. The use of a single station for a long-term operational mission was considered a program risk, but functional redundancy and several levels of store-and-forward capability reduced the risk.

The GEOSAT ground station provides for command and control of the satellite and for monitoring its health and status. In support of the altimeter, the station receives, records, and archives the mission data and then preprocesses and formats the data for distribution to the data users.

Figure 2—Exterior view of APL's Satellite Tracking Facility.

GROUND STATION HARDWARE AND SOFTWARE

The GEOSAT ground station is located at APL's Satellite Tracking Facility (Fig. 2) and is partitioned into RF, digital, and computer system elements as shown in Fig. 3. The digital and computer system elements are enclosed in a shielded room for secure processing. Figure 4 shows these hardware elements and also the three major ground system software packages that reside on

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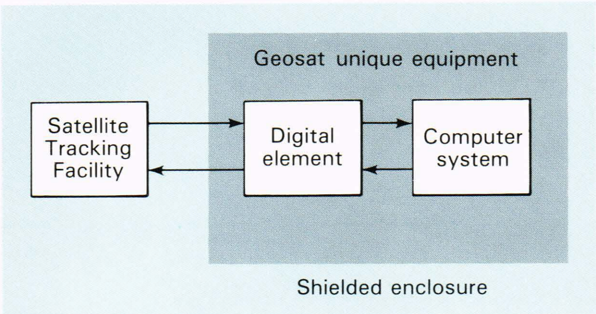

Figure 3—GEOSAT ground station.

the computer. Two are data product packages and the third is software for command, control, and monitoring of the satellite. Figure 5 is a more detailed system diagram of the GEOSAT ground station.

The RF element is the existing Satellite Tracking Facility that has been extensively upgraded to support GEOSAT.[3,4] It consists primarily of analog equipment required for uplink transmission and downlink reception. A 60-foot parabolic dish is used as the primary VHF uplink antenna system; it also receives the composite S-band downlink from GEOSAT. A manually steered eight-turn VHF helix and an autotracking 5-meter S-band dish antenna provide, respectively, uplink and downlink redundancy. The facility includes prime and backup high-power VHF transmitters, redundant receiving and demodulation systems, and timing equipment. Figure 6 shows the station operations room.

The digital element of the ground station serves as an interface and buffer between the RF element and the computer system. It also performs the functions of data-archive recording, encryption/decryption, and time tagging. The digital element has a limited capability to perform command and real-time telemetry monitoring functions in the event of a computer system failure; it includes fully redundant bit synchronizers, decommutators, analog tape recorders, time-management devices, and crypto equipment. Microcomputer controllers play key roles in the Satellite Tracking Facility and digital element as functional devices and for automation.

The ground-station computer element supports a number of functions, including spacecraft command, control, and monitoring; data acquisition and processing; and formatting and transmission of data products. The data processor accommodates numerous input/output demands resulting from real-time processing during satellite passes, as well as from postpass processing of the voluminous data set (approximately 450 megabits) received during the satellite tape-recorder dumps. The ground station computer has a 32-bit word architecture with real-time capability and high throughput; it consists of an SEL 32/77 minicomputer with associated peripherals, including 300-megabyte disk drives, digital tape units, cathode-ray-tube display consoles, line printers, and high-speed input interfaces.

There are three distinct software packages associated with the ground station computer. Taken together, software operations using them consume much of the 24-hour day. The command, control, and monitor software

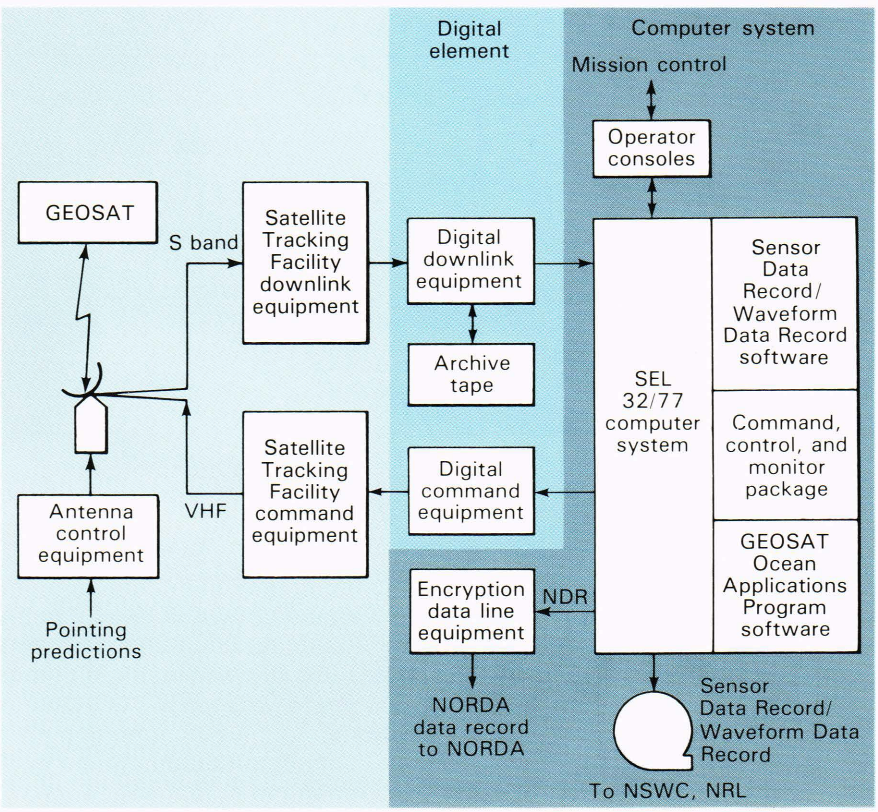

Figure 4—GEOSAT ground system.

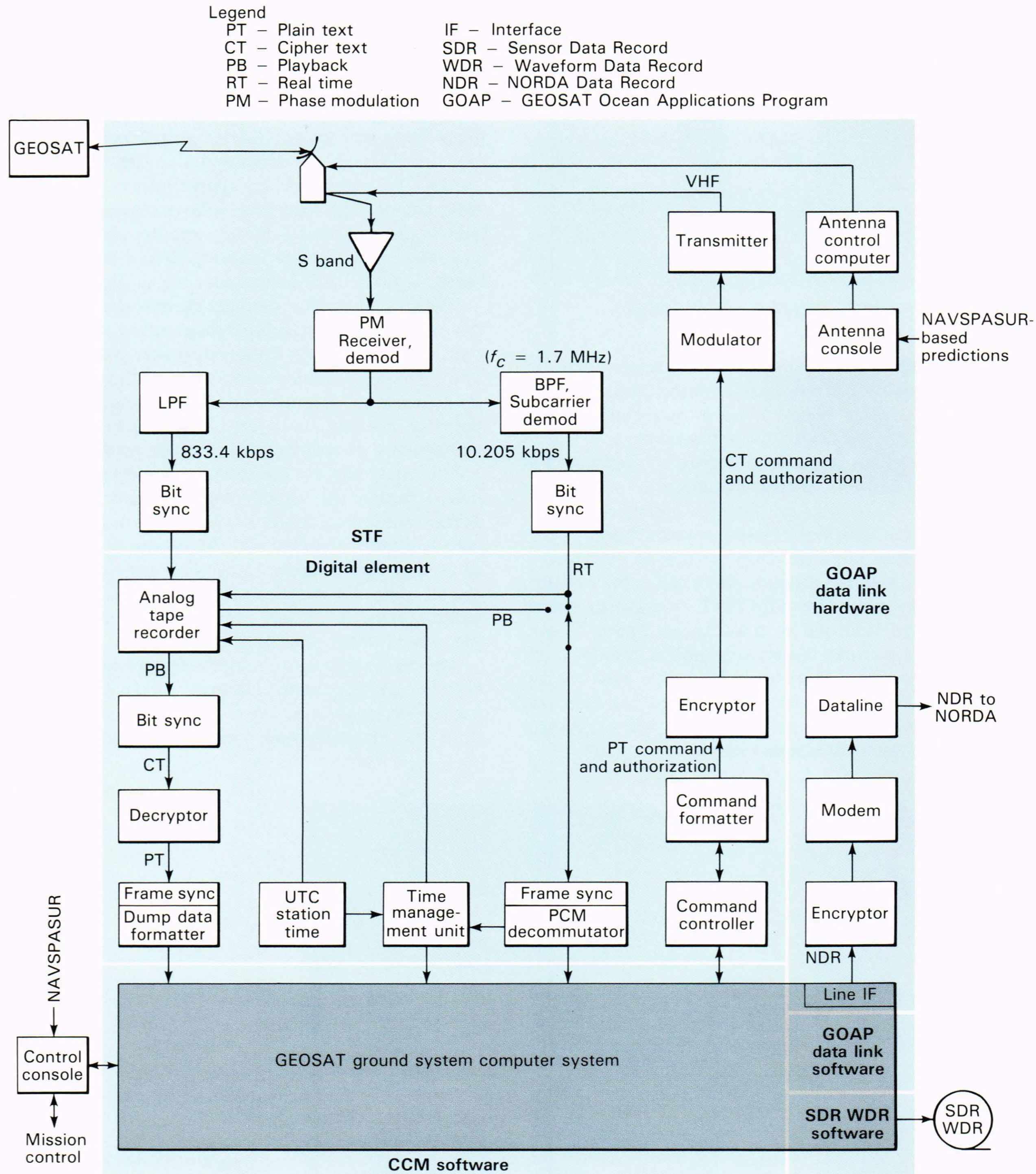

Figure 5—System diagram of the GEOSAT ground station.

package consists primarily of real-time satellite support functions performed during passes. The software also supports prepass readiness test functions and postpass logging and data test operations.

The software package[5] for the Sensor and Waveform Data Records is used on a postpass basis to perform altimetry data processing and to produce output products in the form of computer-compatible tapes. The Sensor Data Record—the prime data product of the ground station—is generated using algorithms derived from the Seasat-1 mission and from several recently developed radar altimetry techniques. The major processing objectives are to remove GEOSAT instrument- and spacecraft-related errors from the altimetry data and to time tag

Figure 6—Operations room of the Satellite Tracking Facility.

the data accurately. After further processing at the Naval Surface Weapons Center, the data are used to provide improvements in the earth's gravitational models.

The Sensor Data Record is a classified computer-compatible tape that includes the basic altimeter-measured height, automatic gain control, and significant wave height in addition to corrections for satellite and instrument errors; backscatter coefficients and wind speed are also estimated. The processing includes data merge (gap filling), the conversion to engineering units, time tagging, and data quality testing. Some ground station data are combined with the altimetry data. The Sensor Data Record is comprised of processed data records spanning 1-second intervals of altimetry data (10 altimeter measurements), with corrections computed once every second. It contains processed data from a 24-hour measurement period. The Waveform Data Record is an unclassified computer-compatible tape that consists of raw waveform samples from the altimeter and a header identical to the Sensor Data Record.

The software package[6] for the GEOSAT Ocean Applications Program performs functions similar to those of the Sensor Data Records but produces a data product (the NORDA Data Record) that must be quickly generated and transmitted to the Naval Ocean Research and Development Activity (NORDA) over a 9.6-kilobit-per-second data line. After further processing at NORDA, the data are used to provide timely and accurate environmental information for the prediction of oceanographic parameters.

Table 1 gives an overall summary of the ground station performance characteristics.

STATION OPERATION

The GEOSAT orbit is such that two to three satellite passes (a "cluster"), approximately 100 minutes apart, occur in view of the ground station about every 12 hours. The timing of the clusters precesses so that they occur at various hours of the day over the 18-month GEOSAT mission span. The four to six daily contacts with the satellite are the only opportunities to acquire altimetry data, to transmit commands, and to monitor real-time telemetry.

Figure 7 shows the GEOSAT telecommunications characteristics for uplink command and downlink real-time and tape-recorder playback (dump) transmissions. During an onboard recorded playback (dump) pass, GEOSAT is commanded to play back data from its onboard tape recorder using the 2207.5-megahertz S-band downlink. The recorder typically contains 450 megabits of encrypted data accumulated at 10.205 kilobits per second during the elapsed 12-hour period since the last cluster dump. Data playback at the 833.4-kilobit-per-second downlink dump rate requires about 10 minutes. The 10.205-kilobit-per-second real-time bit stream generated during the pass is also transmitted on the S-band downlink on a modulated 1.7-megahertz subcarrier.

Figure 8 illustrates operations during a pass. The phase-modulated downlink is received and demodulated within the Satellite Tracking Facility (see also Fig. 5). The encrypted dump data and unencrypted real-time

Table 1—Ground station characteristics.

Transmit antenna gain	26 dB (60-ft dish) 12 dB (helix)
Transmit power	1 kW
Receive gain/system temperature	24 dB/K (60 ft) 14 dB/K (5 m)
Maximum pointing error	<0.1 deg (60 ft)
Receive circuit margins, dump data (10^{-7} bit error rate, 10-degree elevation)	>10 dB (60 ft) >3 dB (5 m)
Real-time telemetry sample time	3.2 sec
Altimetry data time tag error	<100 μsec
Data processing time (12-hour altimetry data)	~1.5 hr (SDR) ~2 hr (NDR)
Data delivery	<2 weeks (SDR) <2 weeks (WDR) <4 hr (NDR)

SDR—Sensor Data Record
WDR—Waveform Data Record
NDR—NORDA Data Record

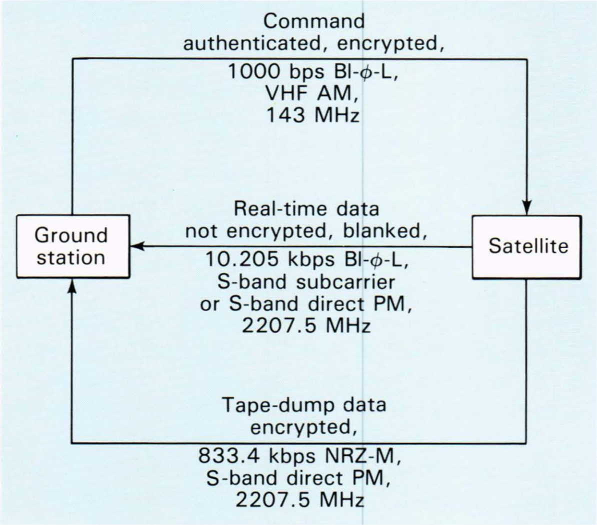

Figure 7—GEOSAT telecommunications characteristics.

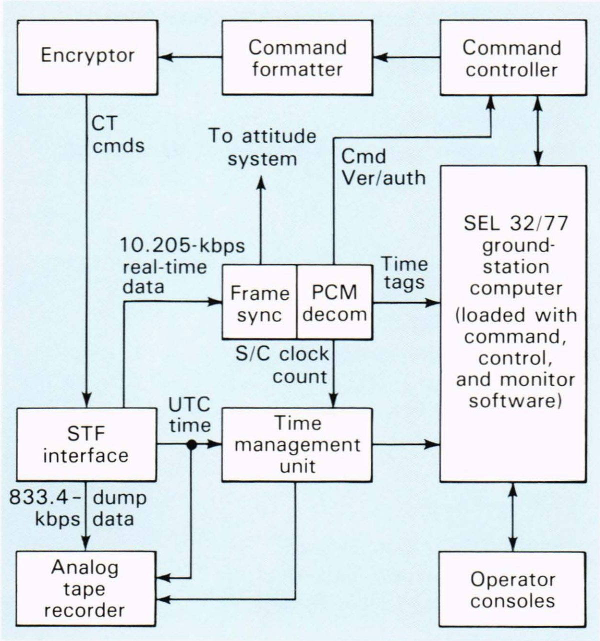

Figure 8—Pass support configuration for the digital element/computer system.

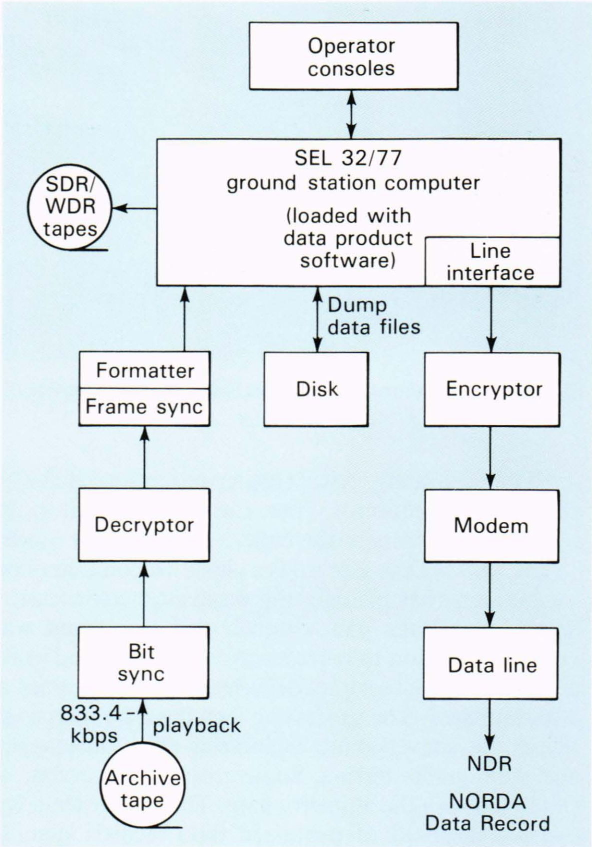

Figure 9—Postpass equipment configuration.

data streams are separated by appropriate filters and are then bit synchronized and recorded on separate tracks of an analog tape. Timing information is also recorded on the tape, which then becomes a GEOSAT archive tape. The archive tapes, containing the altimetry data in encrypted form, are stored at APL for an extended time after the operational phase of the mission.

The 10.205-kilobit-per-second real-time bit stream is decommutated and passed to the SEL computer system. The spacecraft clock count is extracted and entered into a time-management unit along with the station time. The time-management unit output consists of a series of time-tag messages, each having a unique spacecraft clock count and a concomitant station time (GMT). The messages are entered into the ground station computer and used to generate a corrected time tag for each processed altimetry data frame. The system provides time tagging accuracy of better than 100 microseconds.

Spacecraft status is derived from the real-time telemetry stream for display, monitoring, and logging during the pass. (The ground system also can display and check data from the real-time dump telemetry data recorded on the archive tape on a postpass basis.) Ground station status and control parameters are also monitored during the pass. Note that a separate output of the digital element is passed to displays for real-time attitude operations during passes.

Command sequences are generated and checked through the ground station computer and then encrypted and uplinked to the spacecraft through the very-high-frequency transmitting system. Command authentication and verification are checked through the real-time telemetry downlink. The command, control, and monitoring software uses executable "runstate" files that contain all operations planned for the satellite during a supported pass. The software also can manually command the satellite during a pass. Normally, preplanned runstate commanding is done with verification of the proper execution of commands via real-time telemetry.

Figures 9 and 10 describe postpass operations. After the pass, the archive tape is played through a decryptor. The decrypted dump data are frame synchronized and recorded directly onto a storage disk of the computer system. The data are later processed to produce the Sensor and Waveform Data Records.

Postpass data processing of the Sensor Data Record is a classified operation performed within a secure shielded enclosure that contains the digital element and the computer system. Sensor Data Record tapes are generated and verified by an independent processor at APL and are then delivered to the Naval Surface Weapons Center within two weeks after the data are received at APL.

The Waveform Data Record consists of unclassified computer-compatible tapes that are also verified by an independent computer at APL and are then delivered to the Naval Research Laboratory within two weeks after the reception of dump data at APL.

An unclassified housekeeping data record is also generated that contains all satellite and radar altimetry data, excluding height data. The record is processed using an IBM 3033 computer and personal computers at APL to provide a postpass assessment of spacecraft health and

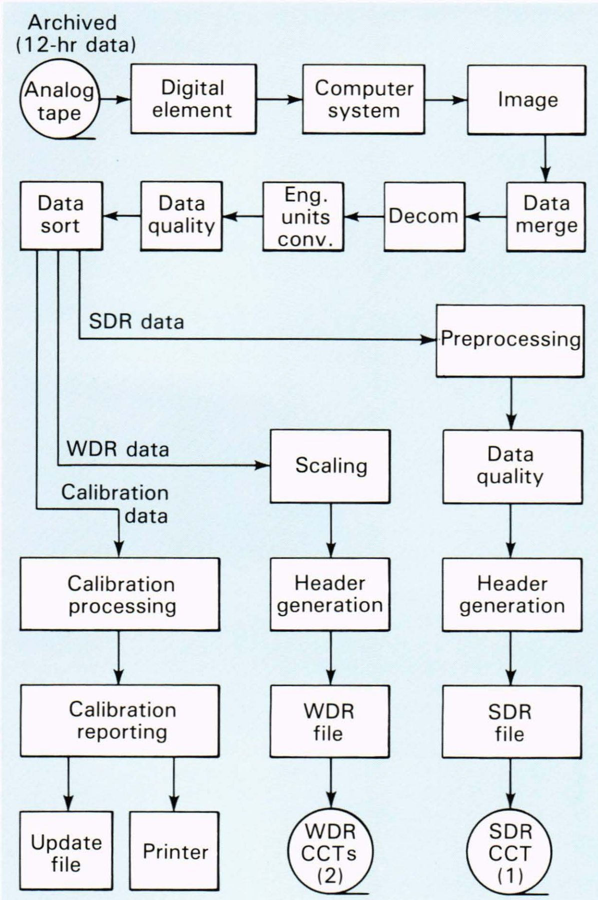

Figure 10—SDR/WDR data flow.

sor Data Record but optimized for execution time. The timeliness requirement is that the largest possible portion of the most recent altimetry data be preprocessed and sent to NORDA within four hours of the satellite measurement. It takes approximately two hours to process and send 12 hours of altimetry data to NORDA. This product is also classified and is used for the prediction of oceanographic parameters. As it is being processed, the NORDA Data Record is transmitted through an encryptor into a 9.6-kilobit-per-second communications line to the NORDA facility in Bay St. Louis, Miss. Ordinarily, these processing operations precede Sensor Data Record processing.

The temptation to merge functions of the three major software packages was strongly resisted during development of the ground station. They are isolated and protected from one another by rigid time separation of their operations and interact in a controlled manner only through files left in the computer after one package has been cleared and a new package loaded. The potential for interaction among the software components is thus localized to those files. The isolation of software components is considered a key factor in the on-time delivery of the GEOSAT ground system.

health and status. Figure 11 shows the system for GEOSAT trend and long-term monitoring.

Software modules developed for the GEOSAT Ocean Applications Program are used to process the altimeter data to form the NORDA Data Record, which results from a processing operation similar to that for the Sen-

GROUND STATION SUPPORT SUMMARY

The GEOSAT ground station has operated reliably over the 567-day span of the geodesy mission. The entire system (satellite and ground) was declared operational only 19 days after launch. All command and monitoring functions were supported consistently during the mission.

Table 2 summarizes the altimeter support performance record. Data from over 8100 orbits have been archived and processed, corresponding to a dense grid with a 5-kilometer average spacing at the equator. All the 1178 GEOSAT dump passes were supported with less than 0.15 percent of the available altimetry data lost because of equipment or operational failure at the station.

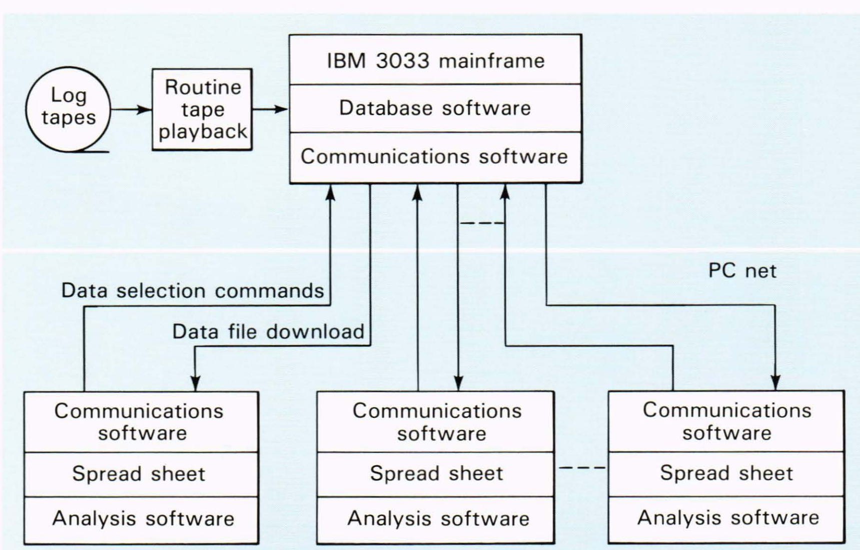

Figure 11—GEOSAT long-term monitoring.

Table 2—GEOSAT ground station performance.

Satellite launch March 12, 1985
System operational March 31, 1985
Geodesy mission completed September 30, 1986
Satellite support
3105 contacts
1178 tape recorder dumps
100 percent dump pass support record
Altimetry data support
8100-orbit data set processed with 5-kilometer average grid spacing at equator
99.85 percent of available altimetry data delivered to geodesy users

This performance over a relatively long time interval is due in part to functional redundancy, to a reprocessing capability afforded by store-and-forward design features, and to the designed-in prepass test capability. It also results from professional support by dedicated operations teams.

FUTURE GROUND STATION ACTIVITIES

With the conclusion of the geodesy mission, the GEOSAT ground station entered a new phase of support for the GEOSAT Exact Repeat Mission. The first requirement was to support an orbit adjustment during October-November 1986. After that, the ground station began support of data collection for up to 2½ years for research in environmental oceanography.

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