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A SPECTRASAT SYSTEM DESIGN BASED ON THE GEOSAT EXPERIMENT

A practical system implementation of Spectrasat that uses much of the heritage from the Navy's Geosat spacecraft is outlined in this article. The system's very low altitude requires active drag compensation, which is implemented with sufficient on-board storage of hydrazine to ensure a three-year lifetime. Using both the APL ground station and the Naval Astronautics Group station in California, global estimates of directional ocean-wave spectra can be generated and transmitted to operational users nearly in real time or stored in national archives for later scientific research.

INTRODUCTION

The Spectrasat end-to-end system described here is designed to provide global measurements of wave spectra for incorporation in the operational products generated by the Fleet Numerical Oceanography Center. The system will also support basic and applied research in oceanography and radar sciences.

The design features a single composite radar instrument (see MacArthur, this issue) that simultaneously measures wave spectra at C band and Ku band. A 275-kilometer-altitude, sun-synchronous orbit will provide global coverage at approximately 23 degree-longitude spacings every 24 hours. Data will be stored on board the spacecraft for approximately 9 hours and then transmitted to the Satellite Tracking Facility at the Applied Physics Laboratory either directly or via the Naval Astronautics Group ground station at Pt. Mugu, Calif. The ground system will preprocess the data for distribution to a variety of users.

The following sections outline a general concept for both the Spectrasat spacecraft and its associated ground data-processing and distribution system.

THE SPECTRASAT SPACECRAFT

The general scientific and operational requirements for Spectrasat have already been addressed by Beal, Jackson, and MacArthur in the preceding three articles. The purpose of the spacecraft (Figs. 1 and 2) is to provide the necessary structure, power, thermal, attitude, velocity control, telemetry, command, and tracking-beacon functions required to support the radar instrument. Both the basic configuration and the various subsystems are similar to the flight-proven Geosat design. Important deviations are described in the following subsystems discussions.

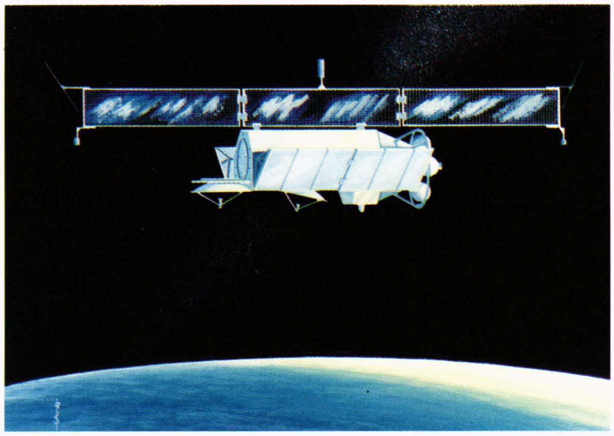
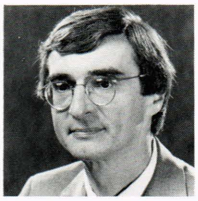


Figure 1—An artist's rendition of Spectrasat (color sketch by Roger Simmons).

The radar spectrometer includes redundant telemetry and command interfaces. This redundancy is continued through the spacecraft subsystems, as shown in the functional system block diagram (Fig. 3).

Command System

Ground commanding of the spacecraft is accomplished with a very-high-frequency (VHF) uplink from the APL ground station. The command systems receives, authenticates, and executes commands for spacecraft



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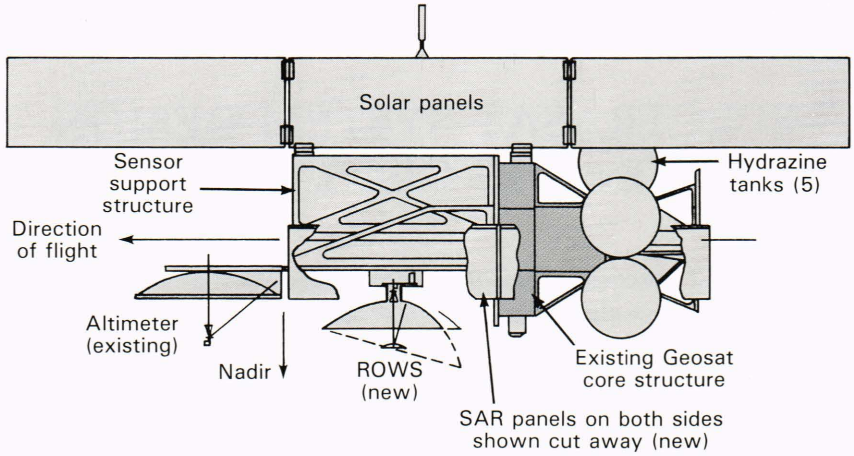

Figure 2—Spectrasat orbital configuration.

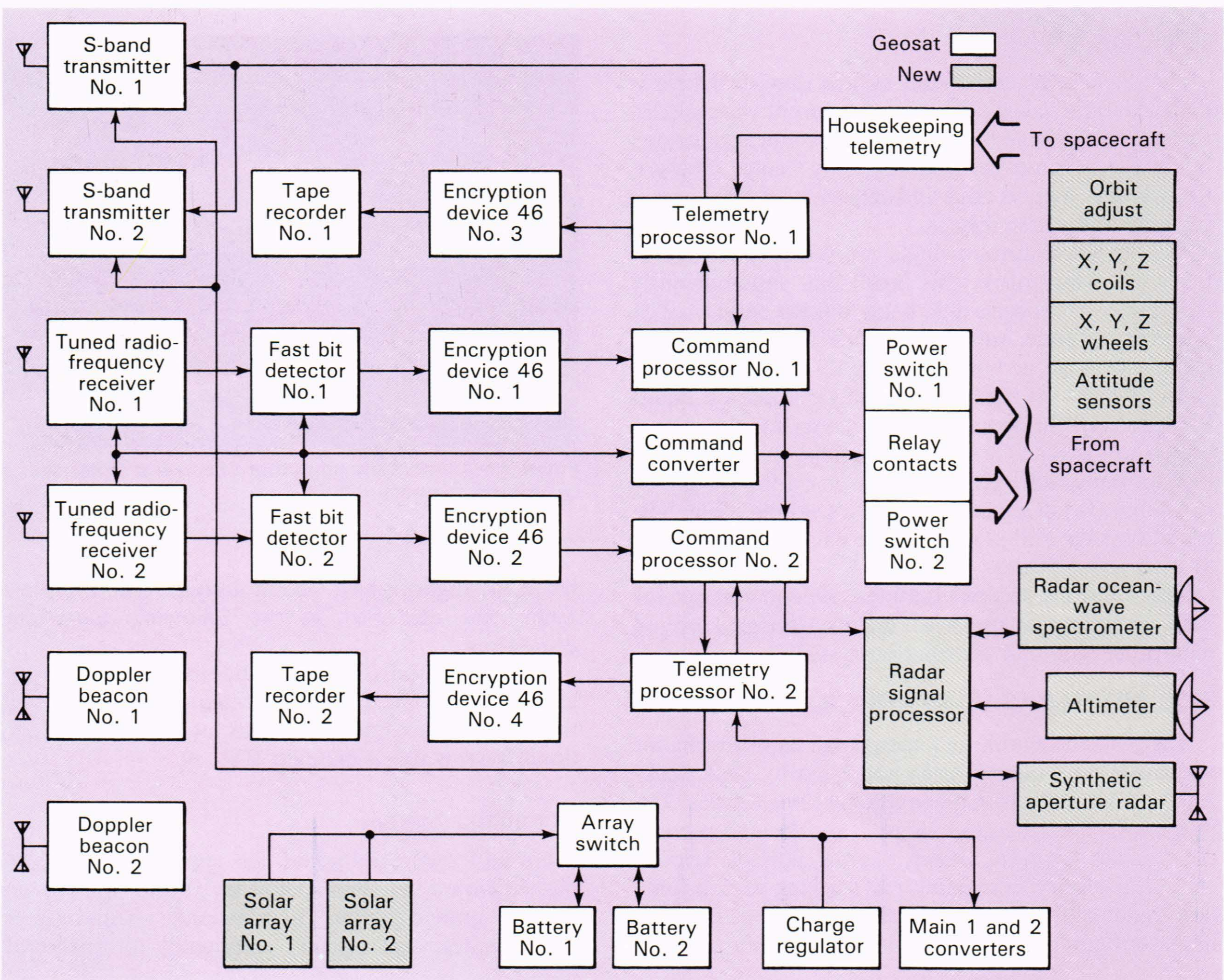

Figure 3—Spectrasat system block diagram.

configuration control on a real-time or delayed basis. The command system is redundant and consists of two linearly polarized antennas, tuned radio receivers, bit detectors, command processors, and one set of power-switching relays that use redundant coils and contacts. Command capabilities consist of relay contact closure for power switching (relay commands), pulses to drive the relays within user packages (pulse commands), and generation of data to control the internal configurations (data commands) of the subsystem. The system supplies 68 relay commands, 28 pulse commands, and 21 data commands.

Telemetry System

The telemetry system consists of a redundant telemetry processor, two S-band transmitters, two tape recorders, and two encryption units. The subsystem receives the digital science-data stream from the radar at 8.5 kilobits per second and combines it with the housekeeping data (1.5 kilobits per second) collected from the spacecraft subsystems. The data are formed into a single time-annotated frame and transmitted to the ground station via the S-band link (2207.5 megahertz) either in real time or as the dump of 12 hours of stored encrypted data from the Odetics (5×10^8-bit) dual-track tape recorder. The telemetry processor consists of two electrically identical redundant halves sharing a nonredundant housekeeping commutator. The digital circuitry uses complementary metal oxide semiconductor chips with some transistor-transitor logic where required by higher speeds or interface requirements.

Doppler System

Spacecraft ephemerides will be derived by tracking dual-frequency (150/400 megahertz) Doppler-system transmissions. The Doppler system consists of two spaceborne transmitters and a ground network of tracking stations. The two ultrastable and coherent frequencies are broadcast by the satellite continuously and are received at ground stations that are a part of the NAVASTROGRU (Naval Astronautics Group) Operational Network. The received Doppler signals, along with the time data from a precise ground clock, are routinely forwarded for spacecraft position determination by NAVASTROGRU.

Power Subsystem

The power requirements for Spectrasat are similar to those of Geosat. Spectrasat sensors require 240 watts and spacecraft housekeeping is estimated to require 100 watts. A modification to the Geosat solar array that will simultaneously take advantage of the sun-synchronous orbit and minimize frontal area (hence drag) is envisioned. The array can generate 400 watts of average power. All other power system boxes are identical to those of Geosat.

Attitude Control Subsystem

The pointing requirement for the proposed sensors is ± 0.5 degree in each of the three axes. Attitude knowledge of 0.1 degree is readily achieved using horizon scanners for knowledge of pitch and roll and a sun sensor for determining yaw. Three momemtum wheels will provide the necessary stability, while momentum dumps can be accomplished with magnetic coils.

Velocity Control System

The spacecraft system design for Spectrasat is driven by the need to maintain the spacecraft orbit at low-altitude operation for a period of three years. A trade-off between synthetic aperture radar performance and spacecraft fuel requirements was made for altitudes from 225 to 300 kilometers. Figure 4 shows the hydrazine fuel requirement as a function of altitude. The atmospheric density is taken for a period of modest solar activity with an exospheric temperature of 100 K. A drag coefficient of 3.0 is assumed for the configuration as shown in Fig. 2, which has a frontal cross-section area of approximately 3 meters squared.

As a practical compromise between improved system performance and increased fuel requirements, an orbit altitude of 275 kilometers is selected. The hydrazine fuel needed to maintain that altitude for three years is 890 pounds. The average altitude decay is expected to be 1.1 kilometers per day. Using a 5-pound thruster along the velocity vector will require thruster burns for 37 seconds each day to maintain altitude. Five standard spherical hydrazine tanks of 22 inches in diameter (see Fig. 1) provide the required fuel storage.

Spacecraft Structural Configuration

The core structure for the spacecraft is based on Geosat. On the forward end of the configuration (see Figs. 1 and 2), the Geosat altimeter-support structure is replaced by a redesigned sensor-support structure that is an open trusswork designed to attach the altimeter reflector, the radar ocean wave spectrometer, the folded synthetic aperture radar array, and the folded solar array. The aft end of the structure is sized to accommodate the interface for the chosen launch vehicle and the supports for the hydrazine propulsion system. All Geosat-heritage hardware is contained within the core structure. Figure 5 depicts the space vehicle in the launch configuration. The cylindrical envelope demonstrates the ability of the design to be stowed within an ATLAS-H fairing. Other vehicle choices will provide an even larger envelope.

THE SPECTRASAT GROUND SYSTEM

Instrument data will be acquired either directly at the APL station or by relay from the NAVASTROGRU station (Fig. 6). The APL ground station will archive, process, and distribute the data. The ground station, at a location midway between Washington and Baltimore, will also command and control the spacecraft and mon-

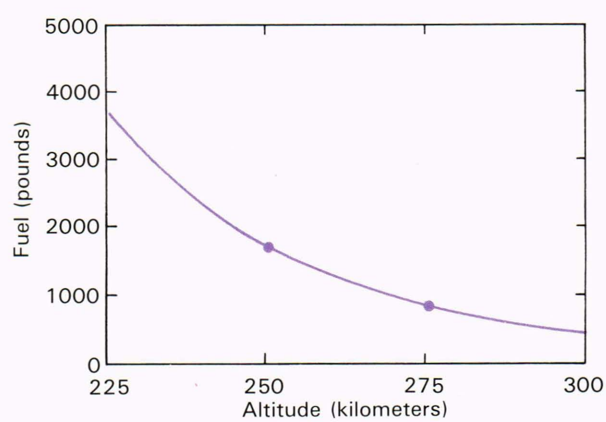

Figure 4—Spectrasat three-year fuel requirement.

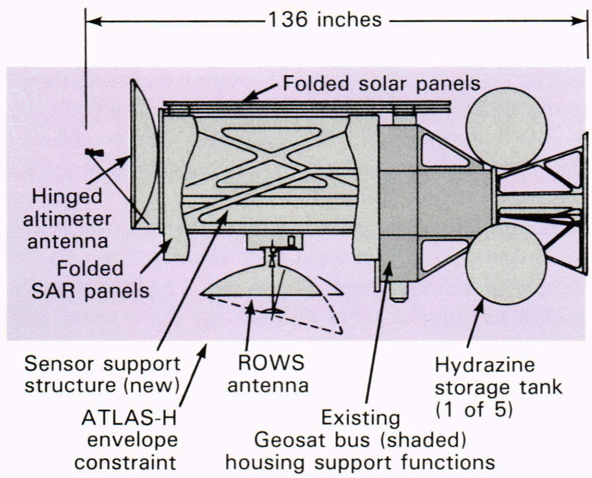

Figure 5—Spectrasat launch configuration.

itor its health and status. Because data transmitted during any pass over the ground station will contain unique environmental information, there is a need for a 24-hour-per-day operational station having a high degree of reliability and maintainability. The spacecraft command and health monitoring functions will be free from single-point failures. Automation is used to reduce operator error. "Store-and forward" techniques are employed extensively to minimize data loss and facilitate recovery from failures.

Station Overview

Figure 7 provides ground station characteristics for uplink command and downlink real-time and dump transmissions. In terms of hardware, the station is partitioned into three elements. Figure 8 is a hardware overview showing the ground station radio frequency (RF), digital, and computer system elements. The ground station RF element, called the Satellite Tracking Facility, is at APL. It consists primarily of analog equipment required for uplink transmission and downlink reception, and includes the prime and backup antenna systems, two high-power VHF transmitters, redundant receiving and demodulating systems, and timing equipment.

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. The digital element includes fully redundant bit synchronizers, decommutators, analog tape recorders, time-management devices, and crypto equipment. Microcomputer controllers play a key role in the digital element as functional devices and for automation purposes.

The ground station computer element supports a number of functions including spacecraft command, control, and monitoring; data acquisition and processing; and the formatting and transmission of data products. The data processor must accommodate 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) presented during the satellite dumps. The computer system also supports peripheral functions such as prepass

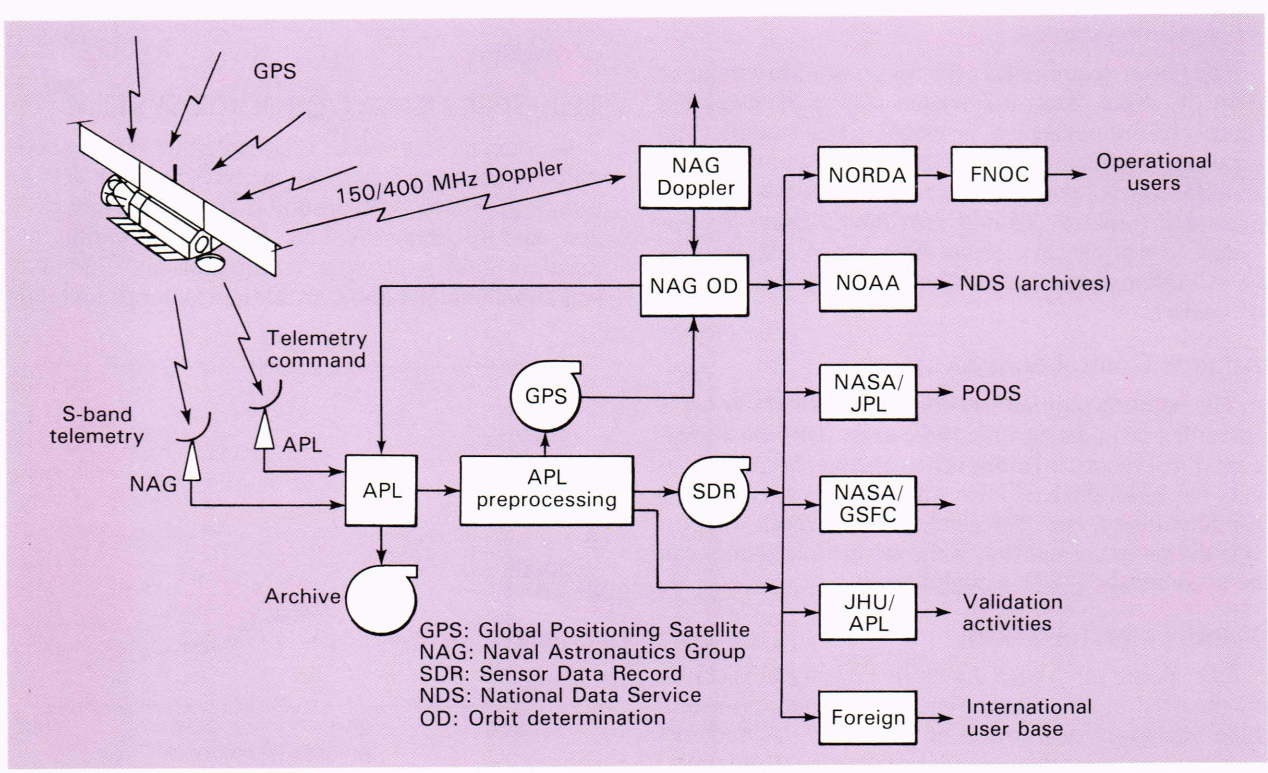

Figure 6—Spectrasat data system.

readiness tests, pass logging, and dump telemetry analysis. 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 these packages will consume most of the 24-hour day.

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

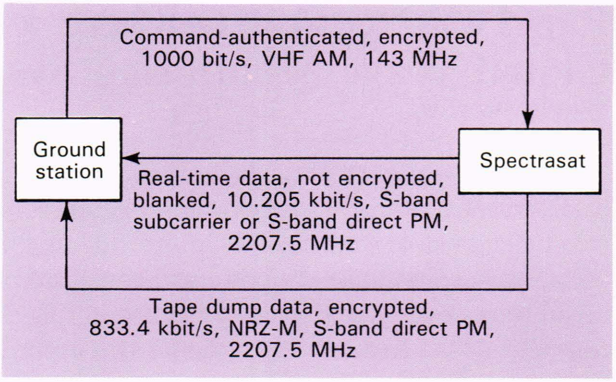

Figure 7—Spectrasat telecommunication characteristics.

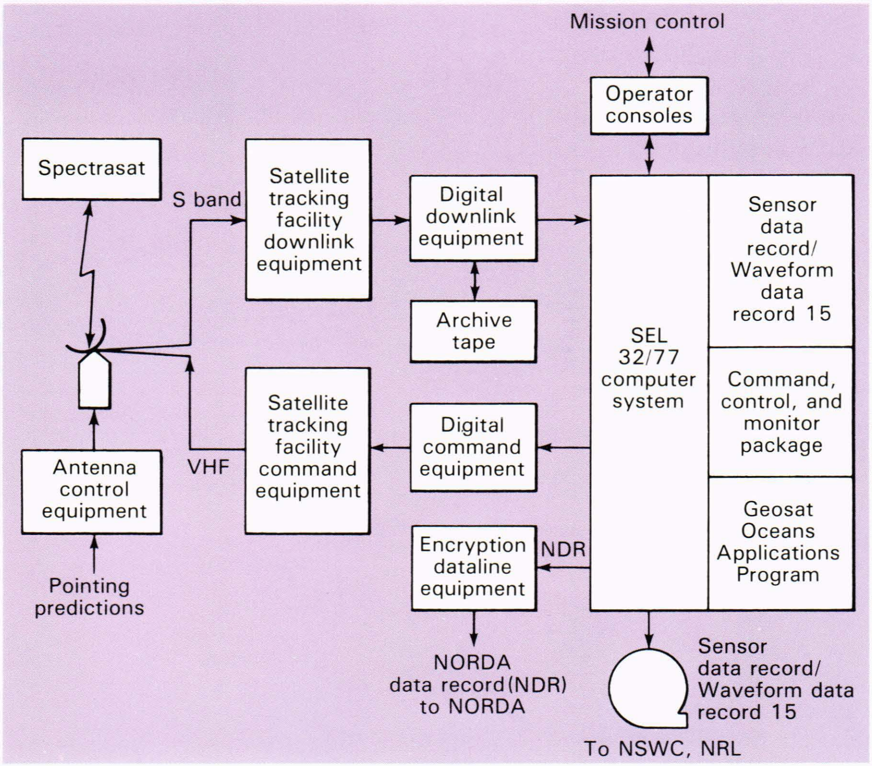

Figure 8—Spectrasat ground station overview.

The sensor data record (SDR) software package is used on a postpass basis to perform data processing and to produce output data products in the form of computer-compatible tapes. Major SDR processing objectives are to remove instrument- and spacecraft-related errors from the data and to time-tag the data accurately. The SDR tapes are distributed to the users as the primary data product.

The software package for the real-time data record performs similar functions and produces a data product similar to the SDR. This product is quickly generated and transmitted to operational users over a 9.6-kilobit-per-second data line.

CONCLUSION

The Spectrasat concept has been configured with a Geosat-class spacecraft for operation at an altitude of 275 kilometers. The selected orbit for the mission is a trade-off between the synthetic aperture radar image-smear problem and the size of the propulsion system necessary to overcome drag forces. A sun-synchronous precession of the orbit plane over the local terminator (i.e., a dawn-dusk orbit) minimizes the frontal area of the solar array and hence the drag forces.

The Spectrasat concept has been sized to be capable of launch by a variety of relatively low-cost, expendable launch vehicles, including ATLAS-H, TITAN II, and DELTA.

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