TRACKING AND DATA RELAY SATELLITE SYSTEM STATUS

Malcolm McMullen
Assistant Vice President-Advanced Planning
Space Communications Company
Gaithersburg, Maryland

Abstract

The Tracking and Data Relay Satellite System (TDRSS) is approaching launch readiness, with operations scheduled to commence in 1983. This paper describes TDRSS including the commercial communications or Advanced Westar (AW) components and the launch, network, and test elements being employed to bring the system to operational readiness for user support. Users and user equipment are also discussed.

INTRODUCTION

The TDRSS is to provide leased services to NASA for tracking and data relay of user spacecraft for a period of ten years commencing in 1983. The Space Communications Company (SPACECOM) is the prime contractor, owner and operator of TDRSS, including the AW portion. SPACECOM is a partnership affiliated with Continental Telecom Inc. (formerly Continental Telephone Corporation), Fairchild Industries, Inc., and Western Union Corporation.

The TDRSS will consist of four spacecraft in orbit supported by a ground station complex at White Sands, New Mexico. TDRSS scheduling for user support will be directed from the NASA Network Control Center at Goddard Space Flight Center, Greenbelt, MD. An extensive test program has been implemented to assure the readiness of this system. For support of launch operations the Kennedy Space Center (KSC), the Johnson Space Center (JSC) and the worldwide tracking, telemetry and command facilities of the NASA Spaceflight Tracking And Data Network (STDN) and the Air Force Satellite Control Facility (AFSCF) will be employed. Extensive tests and simulations utilizing these connected facilities will be conducted prior to the TDRSS launches.

The first TDRSS spacecraft is scheduled for launch in January 1983 with the second launch scheduled in June 1983. Limited user support, on a best-efforts basis primarily for Space Shuttle and Landsat-D, will commence prior to the second launch. Full system capability will be provided with both TDRSS subsequent to completion of service acceptance tests during the third quarter of 1983.

THE TRACKING AND DATA RELAY SATELLITE SYSTEM

The concept of a satellite data relay system at geosynchronous altitude dates back to at least 1964 when the author proposed such a system with two spacecraft for support of the then planned U.S. Air Force Manned Orbiting Laboratory (MOL) missions. Such a system would have increased communications coverage for the MOL astronauts from 15% or so of their time in orbit to more than 85%. Next year TDRSS will provide more than 85% coverage of Spacelab orbits. Full coverage from the surface of the earth to several thousand kilometers is provided by TDRSS except for a segment over the Indian Ocean, as indicated by Figure 1. An additional ground station would have been required to fill this gap, but was not included in the program to reduce costs. The spatial distribution of TDRSS coverage and satellite longitudes are shown in Figure 2 which is a view as though looking down upon the North Pole. TDRS-East is over the Atlantic and TDRS-West is over the Pacific; the spare will be at 79° W such that it has a complete view of the United States and may thus be used for domestic commercial communication or NASA support. The single access (SA) S and K-band antennas are gimballed, and are steered from the ground; their coverage pattern is broader than the pattern for the multiple access (MA) S-band phased array system (also steered from the ground) as indicated in Figure 2.

In addition to TDRS-East, TDRS-West and the spare, which will be shared between the NASA and commercial services, it is planned to station a fourth TDRS at 91° W longitude to provide commercial domestic communications service at C and K-bands. The complete system is shown in Figure 3. At White Sands 18-meter K-band dishes will support the East, West and spare TDRS, while a 9-meter K-band dish will support the fourth, or AW satellite. A co-located control center at White Sands will provide tracking, command and telemetry support for the entire system as well as tracking and data relay services and interfaces with NASA. Communications such as commands that are transmitted from the TDRS to a user are designated FORWARD Link services, while those from the user to the TDRS such as telemetry and sensor data are designated RETURN Link services. The TDRSS services are shown in Figure 4 and 5.

TDRSS GROUND SEGMENT

The TDRSS ground segment, designated as the White Sands Ground Terminal (WSGT), is located near Las Cruces and the White Sands Missile Range, New Mexico, to take advantage of low rainfall conditions, thereby enhancing K-band communications operations, and also to utilize U.S. government property while achieving the desire longitude for system control.

The WSGT is shown in Figure 6. The three 18-meter K-band dish antennas used to control and to communicate with TDRS-East, TDRS-West and the spare, as well as a backup 6-meter S-band tracking, telemetry, and command (TT&C) dish are aligned north and south, with the TT&C dish to the south. A k-band 9 meter dish is on order and will be used for TT&C, as well as test and checkout purposes for AW capabilities. This antenna will be placed to the southeast of the present antennas. S and K-band antennas for simulation and axial ratio testing purposes are mounted on the roof of the facility which includes 3066m^2 (33,000 sq. ft.) of floor space. A planned addition of approximately equal size will provide space for a depot, software training and maintenance, and more office areas. The principal technical elements in the present WSGT facility consist of six (6) operations consoles, two (2) Univac 1181 mainframe computers, nine (9) Digital Equipment Corporation 1170 computers, 322 racks of equipment, and 60 and 412 cycle uninterruptible power systems. The facility is fully secured with a double chain link fence system and other safeguards required to maintain the WSGT at the Secret level. The TDRSS command links are secured with a KG-46 system. Figure 7 provides a WSGT functional diagram. The technical functions are entirely under computer control such that the operators in the TDRS Operations Control Center (TOCC) need intervene only to respond to problems. User service scheduling messages, user orbit information in the form of state vectors and a force model and other messages are received by the computer system from the computers at the NASA Network Control Center (NCC) at GSFC. The WSGT computers then schedule station equipment strings, prepare TDRS satellite antenna pointing commands, and implement the entire system configuration as required to acquire and to support the user at the proper time. Upon establishing the links with the user spacecraft, and depending on the service requested, commands can be sent from the user control center to the user spacecraft, and telemetry and tracking data can be received. Nearly a million lines of code are required in the WSGT software to perform all the functions required. It is planned that as of the last quarter of 1982 all the WSGT facilities, software, and operators will be in place and checked out, and that final preparations for launch support and TDRS flight support will be underway.

TDRSS SPACE SEGMENT

The TDRS is a three-axis stablized spacecraft weighing approximately 2268 kg (5000 lbs.) and spanning 17 meters (over 57 feet).

Six TDR spacecraft are being built to support the four-spacecraft constellation for ten years. A ground spare will be available for call up upon failure of an on-orbit TDR spacecraft. Each TDRS is designed to provide ten years of S and K-band services, and seven years of C-band services. Figure 8 illustrates the TDR spacecraft features. Two 4.9 meter deployable, gimballed mesh antennas provide the single access S and K-band services for NASA or K-band spot beams for the AW commercial services. Since the

NASA and AW services share K-band components in the TDRS, they cannot be operated simultaneously. A body mounted S-band phased array system of 30 elements provides service for multiple access (MA), low data rate users. For TDRS TT&C and for user data between TDRS and WSGT the Space Ground Link (SGL) K-band antenna which is gimballed and pointed from the ground is utilized, providing a 650 GHz downlink. An S-band omni antenna is utilized for backup to the SGL link for TT&C only. Bodyfixed C and K-band antennas for AW pruposes complete the complement of seven TDRS antenna subsystems. The C-band subsystem is independent of the other spacecraft communications subsystems and may be operated simultaneously with them. AW payload information, including coverage patterns, is presented in Figures 9 through 14.

LAUNCH SEGMENT

The TDR spacecraft will be the first to be placed in geosynchronous oribt by the Space Shuttle and the Inertial Upper Stage. The 21,088 kg (46,500 lbs.) up weight of the TDRS/IUS combination exceeds weights previously lifted on Shuttle and the TDRS weight of 2268kg (5000 lbs.) is very close to the maximum capacity of the IUS. The second STS orbiter, Challenger (099), together with a new lightweight external tank has been selected for the first TDRS mission so as to provide more weight margin. This will also be the first IUS mission aboard Shuttle. Payload flow at KSC will be through the Vertical Processing Facility (VPF) where the TDRS will be mated to the IUS. Subsequently, the mated TDRS/IUS will be transported to the Rotating Service Structure (RSS) and inserted in the RSS. Final preparations such as hydrazine loading and battery charging will be conducted in the RSS. Extensive testing, including network tests between TDRS/IUS, JSC, AFSC and WSGT will be conducted during the KSC operations.

After STS launch and attainment of approximately a 241 km (150 nmi) circular parking orbit at about Launch (L) + 1 hr. the payload bay doors will be opened and the orbiter will be oriented so that the payload bay faces earth, thereby providing TDRS thermal control. During the parking orbits communications tests will be run between the TDRS/IUS and monitoring elements in the STDN, AFSCF, and WSGT, and a GO/NO-GO decision to deploy the TDRS/IUS will be made. Deployment will be accomplished by elevating the TDRS/IUS to an angle of 58° on a tilting mechanism in the IUS cradle, and utilizing spring forces for separation. Subsequently, the orbiter will back away from TDRS/IUS, and after sufficient separation has occurred IUS first burn will take place. During the transfer orbit the IUS will conduct roll maneuvers for TDRS thermal control, and will also conduct dipout maneuvers approximately every hour. The dipouts permit pointing the TDRS TT&C S-band antenna pattern at the earth for communication with STDN stations through which commands generated at WSGT will be sent to TDRS.

After separation of the first IUS stage near apogee of the transfer orbit the second stage burn occurs, circularizing the orbit at apogee. IUS residual velocities are trimmed using the IUS reaction control system. The IUS then orients to the TDRS appendage deployment attitude and the TDRS solar panels, SGL and C-band antennas are deployed; the SA antennas are deployed after IUS separation. The IUS then separates and performs a maneuver to avoid any further contact with TDRS. The entire launch sequence from STS liftoff at KSC to IUS separation from TDRSS is on the order of 16 to 19 hours depending on geosynchronous orbit insertion longitude.

Mission management of the launch phase provides a challenge because of the many elements involved and the requirement for two GO/NO-GO decisions, one for KSC launch and the other for the on-orbit deployment from the Challenger. The Mission Management Plan prepared by Spacecom and approved by NASA calls for TDRSS project representation at KSC, JSC, AFSCF and of course WSGT. The NASA and Spacecom project managers will be located at JSC until after TDRS/IUS deployment from STS. Subsequently, they will fly to WSGT to complete the launch phase of the mission.

SYSTEM TESTING

WSGT hardware installations were substantially completed by early 1982, and systems tests between WSGT and the GSFC control center facilities were begun in April 1982. Figure 15 shows a typical test configuration. The NCC or its surrogate sends scheduling messages and other messages through the NASA Communications System (NASCOM) to WSGT where various simulators are used to exercise the system and to return signals to GSFC in a manner similar to an actual operation. Later stages will include data flows with the AFSCF and JSC to insure the AFSCF capability to strip the TDRS telemetry data from the IUS telemetry, and the JSC capability to strip IUS telemetry from the orbiter data stream. Flight mission simulations will be run in the L-90 day period. Figures 16 and 17 show the prelaunch data transmission simulation tests that will be run when the TDRS, IUS and orbiter are at KSC. Similar data flows will apply on orbit. Completion of TDRSS acceptance tests will occur after launch and successful establishment in orbit of both TDRS-East and TDRS-West, scheduled for the third quarter 1983.

TDRS USERS AND USER EQUIPMENT

While it is planned that the first 90 days after launch of a TDRS will normally be devoted to spacecraft test and checkout, it is expected opportunties for user testing and support in this period may occur and will be utilized as schedule permits. Such early users are expected to include Shuttle and Landsat-D. Spacelab is one of the first programs to require full use of the two TDRSS system upon completion of TDRSS acceptance testing.

In general, TDRS users require medium to high gain (for spacecraft) antennas which can track the TDRS being used. Power amplifiers of 5-20 watts represent a typical range; all data must be in a digital format and various coding systems are used. Various user antenna configurations are possible, such as the 1.8-meter high gain S and K-band two-axis gimballed dish on a 3.8 meter bifold boom that is utilized by Landsat-D (Figure 18). The long boom provides a clear field of view above spacecraft obstructions such as the solar panels, although gimballed antennas introduce non-trivial vibrations for applications such as Landsat-D.

Another type of antenna that may be used for TDRSS applications at S-band is the Electrically Steerable Spherical Array (ESSA) (Figure19). A microprocessor controls a switching power divider which directs power to the circular radiating elements on the surface of a sphere or hemisphere to form one or more directed beams or omni-directional coverage. From 7 to 23 dB gain is provided at S-band. The NASA Earth Radiation Budget Satellite (ERBS) program is expected to use an ESSA antenna for communication with TDRSS.

A standard transponder has been developed under NASA sponsorship for use with either the TDRSS or STDN S-band services. Features include compatibility with the TDRSS MA or SSA services as well as STDN, internally programmed acquisition sequence, automatic reconfiguration for TDRSS or STDN, command detector, and a transmitter in 1.0, 2.5 and 5.0 watt versions, among others.

CONCLUSION

Full implementation of the TDRSS is nearing completion, with system operations scheduled to commence in 1983. TDRSS will provide a range of user satellite coverage and data throughput not previously achievable with ground station networks. The TDRSS leased services will be provided to the government by SPACECOM for a period of ten years beginning in 1983. TDRSS also includes an extensive C and K-band communications capability with coverage of the United States, Atlantic, and Pacific areas; the C-band coverage may be provided simultaneously with the tracking and data relay services. A number of activities are being conducted for the first time in implementing the TDRSS, such as the provision of leased tracking and data relay services to the government, sharing a geostationary platform between government and commercial uses, and launch on Shuttle/IUS. User spacecraft equipment is available to permit early utilization of TDRSS for tracking and data relay purposes.

ACKNOWLEDGEMENTS

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GLOSSARY

AW	Advanced WESTAR System	NUTI	NASCOM User Traffic Interface
BRTS	Bilateration Ranging Transponder System	OSCF	Operations Support Computing Facility
C-BAND	3.7 to 6.4 GHz	PCM	Pulse Code Modulation
ESSA	Electrically Steerable Spherical Array	POCC	Project Operations Control Center
JSC	Johnson Space Center	PSS	Portable Simulation System
KBPS	Kilobits/Second	SADA	Solar Array Drive Assembly
kg	Kilogram	S-BAND	2- to 2.3 GHz
km	Kilometer	SGL	Space Ground Link
KSA	K-band Single Access	SOC	Simulation Operations Center
KSC	Kennedy Space Center	SSA	S-band Single Access
K-BAND	11.7 to 15.2 GHz	STDN	Spaceflight Tracking and Data Network
MA	Multiple Access	TDRS	Tracking and Data Relay Satellite
MBPS	Megabits/Second	TDRSS	TDRS System
MHz	Megahertz	TLM	Telemeter; Telemetry
NASA	National Aeronautics and Space Administration	TOCC	TDRSS Operations Control Center
NASCOM	NASA Communications Network	T&C(TT&C)	Tracking, Telemetry, and Command
NCC	Network Control Center (GSFC)	WSGT	White Sands Ground Terminal
NGT	NASA Ground Terminal (at WSGT)		
NSCI	NASA System Control Interface		

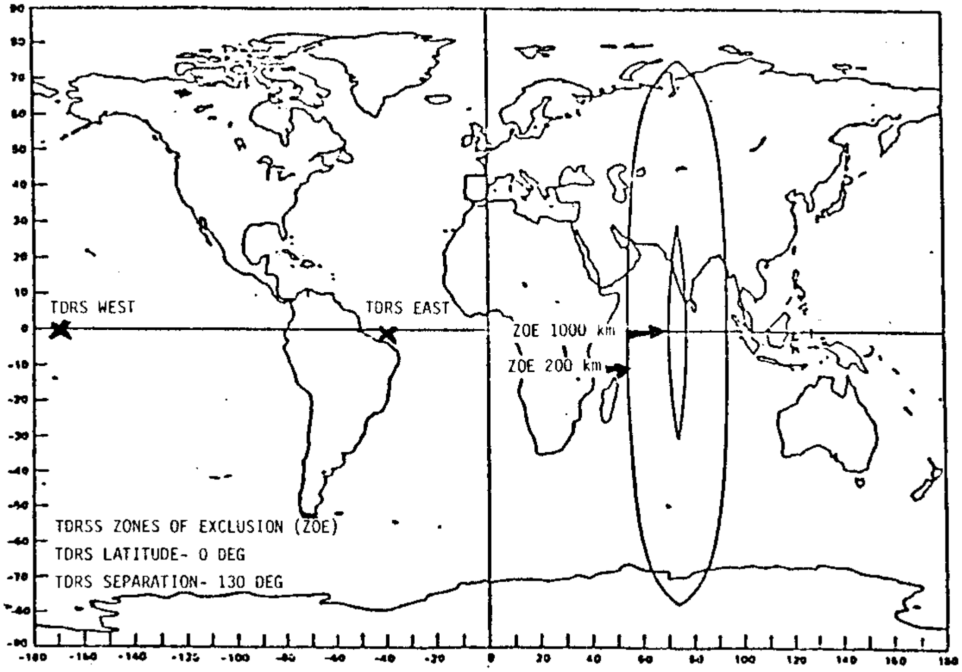


FIGURE 1.
TDRS COVERAGE LIMITS

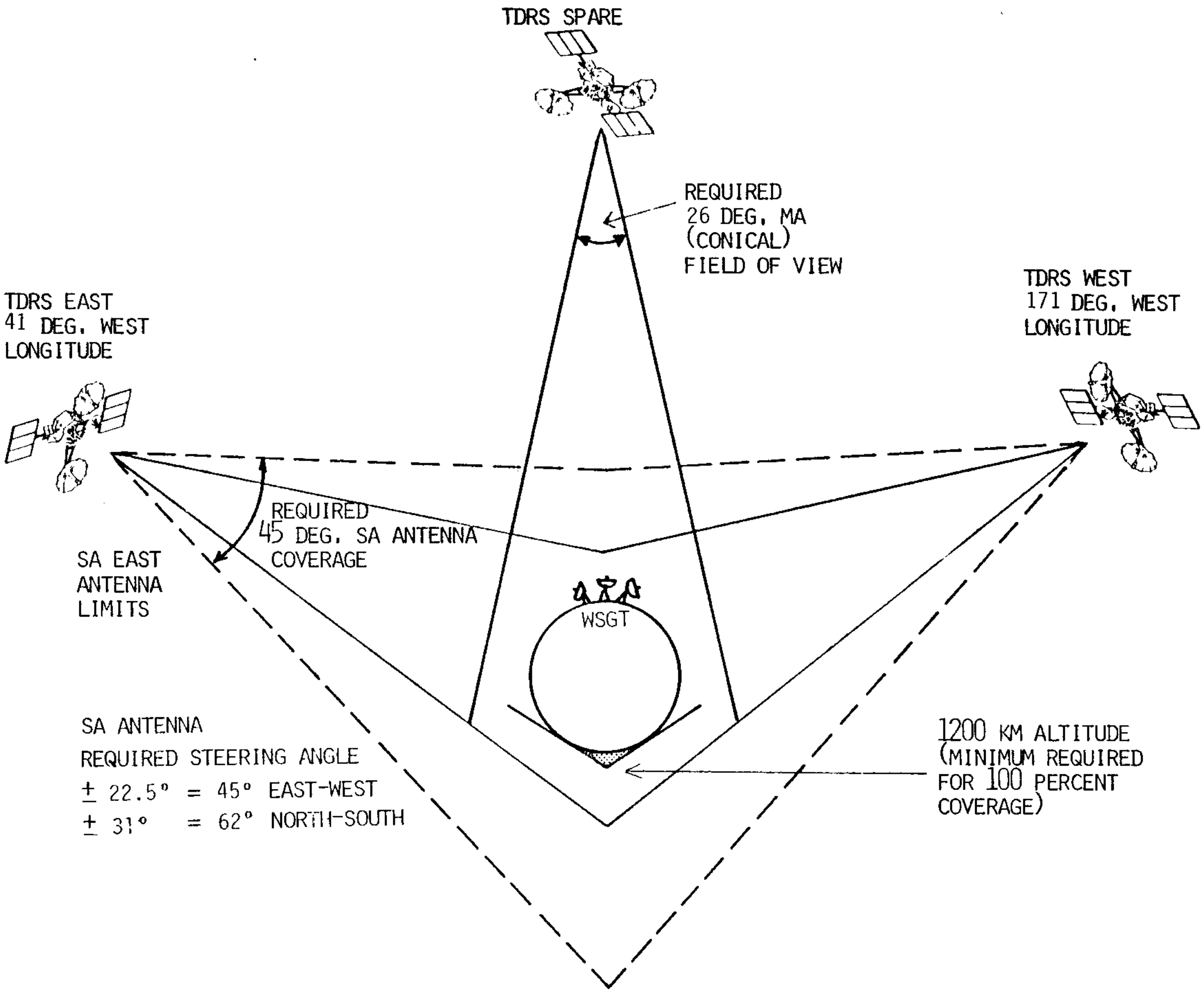


FIGURE 2.
TDRSS SERVICE COVERAGE PATTERNS

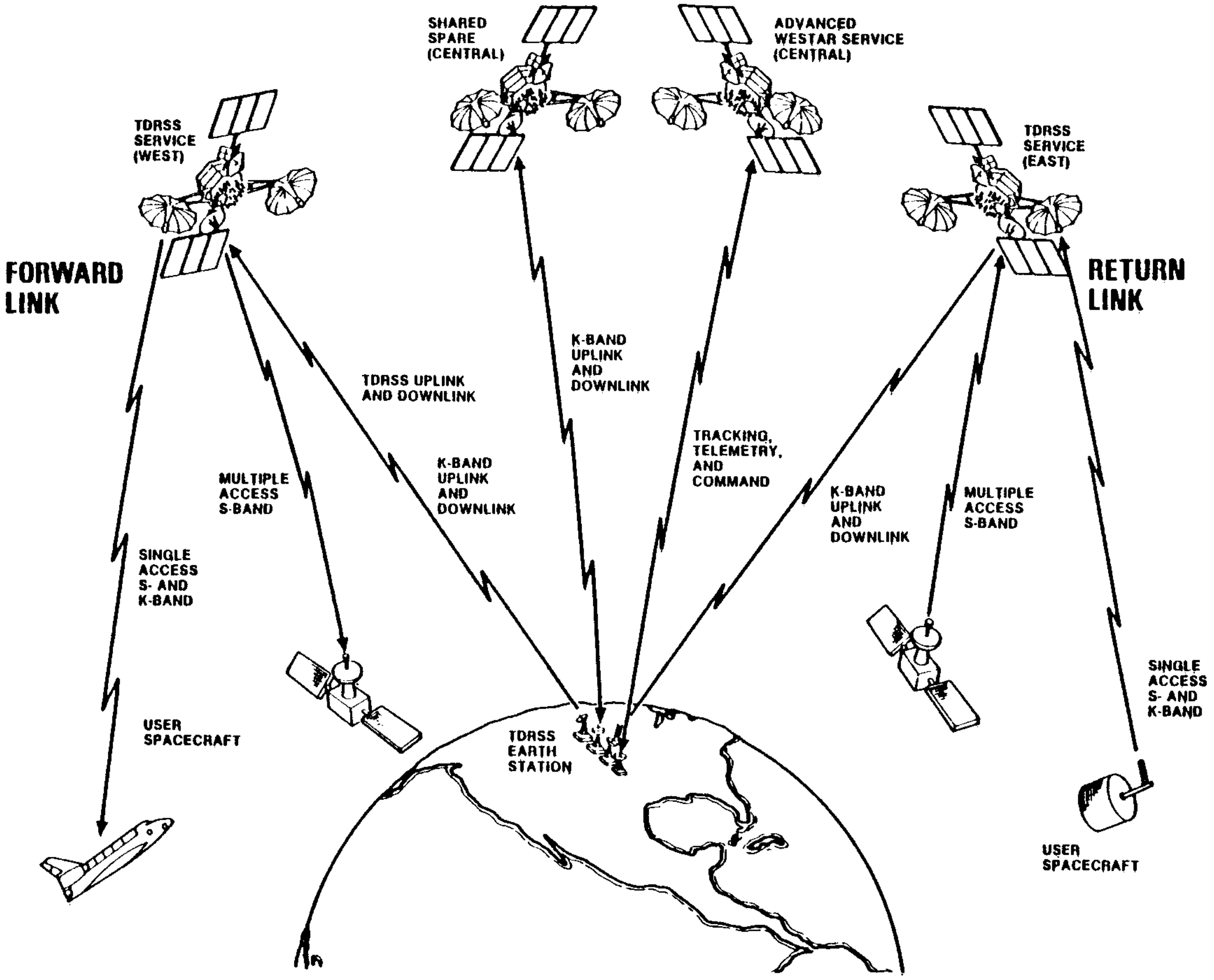


FIGURE 3.
TDRSS TELECOMMUNICATIONS SERVICES

COMMUNICATION SERVICES

SERVICE	LINKS (2 SAT.)	LINKS (3 SAT.)*	MAXIMUM DATA RATE/SERVICE
MA FORWARD	2	3	10 KBPS
SSA FORWARD	4	6	300 KBPS
KSA FORWARD	4	6	25 MBPS
MA RETURN	20	20	50 KBPS
SSA RETURN	4	6	12 MBPS
KSA RETURN	4	6	300 MBPS

*USING SPARE

FIGURE 4.
TDRSS SERVICE REQUIREMENTS

- PROVIDES INDUSTRY STANDARD C-BAND TRANSPONDER PERFORMANCE
- 48 STATE CONUS COVERAGE, PLUS HAWAII AND PORTION OF ALASKA
- SPACECRAFT AT 79°W (SPARE), 91°W (AW)
- 12 TRANSPONDERS PER TDRSS
  - 40 MHz TRANSPONDER BANDWIDTH, 36 MHz USEABLE BANDWIDTH
  - 60 MBPS DIGITAL DATA CAPACITY PER TRANSPONDER
  - UPLINK 5925-6425 MHz; DOWNLINK 3700-4200 MHz

FIGURE 5.
TDRSS SERVICE REQUIREMENTS (Cont.)

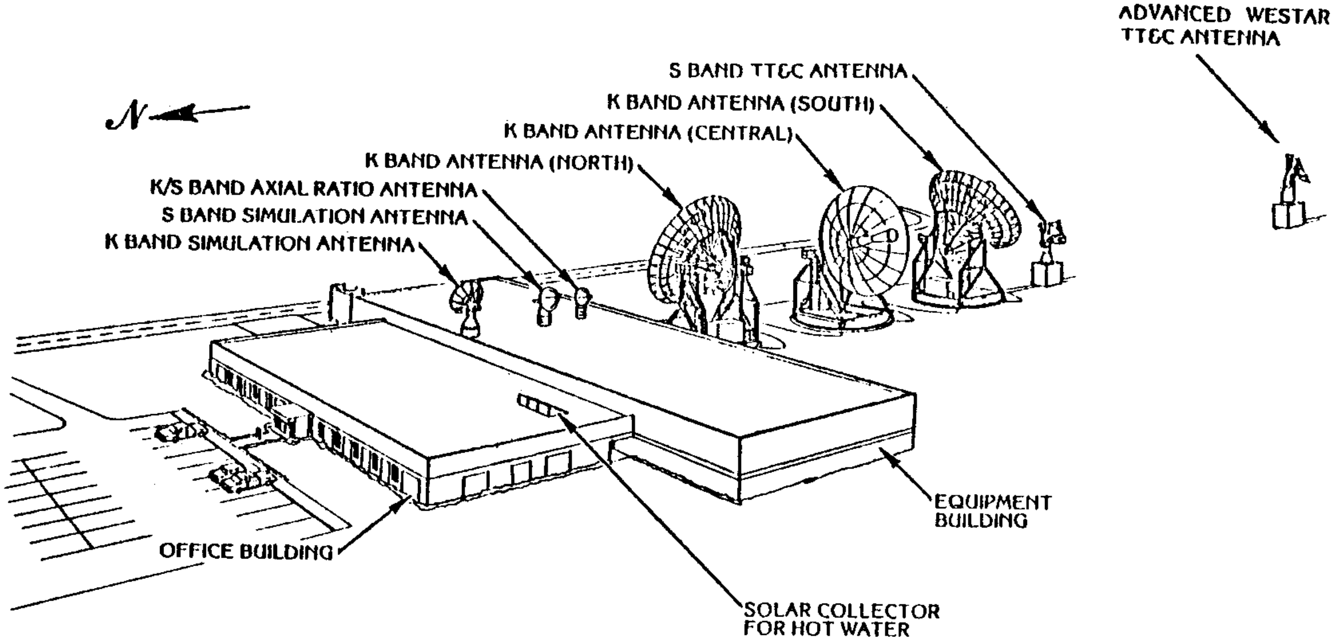


FIGURE 6.
WHITE SANDS GROUND TERMINAL

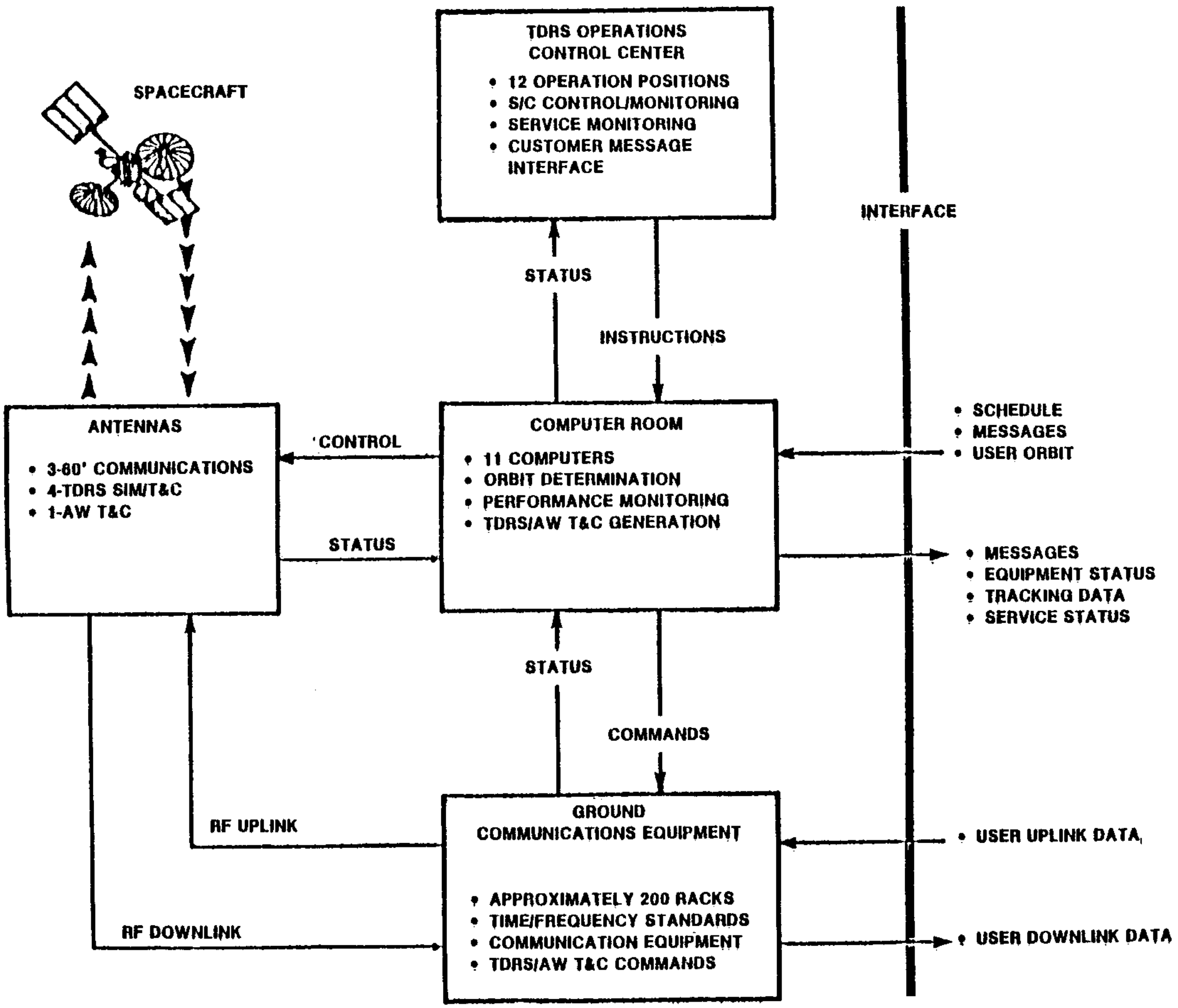


FIGURE 7.
THE GROUND STATION

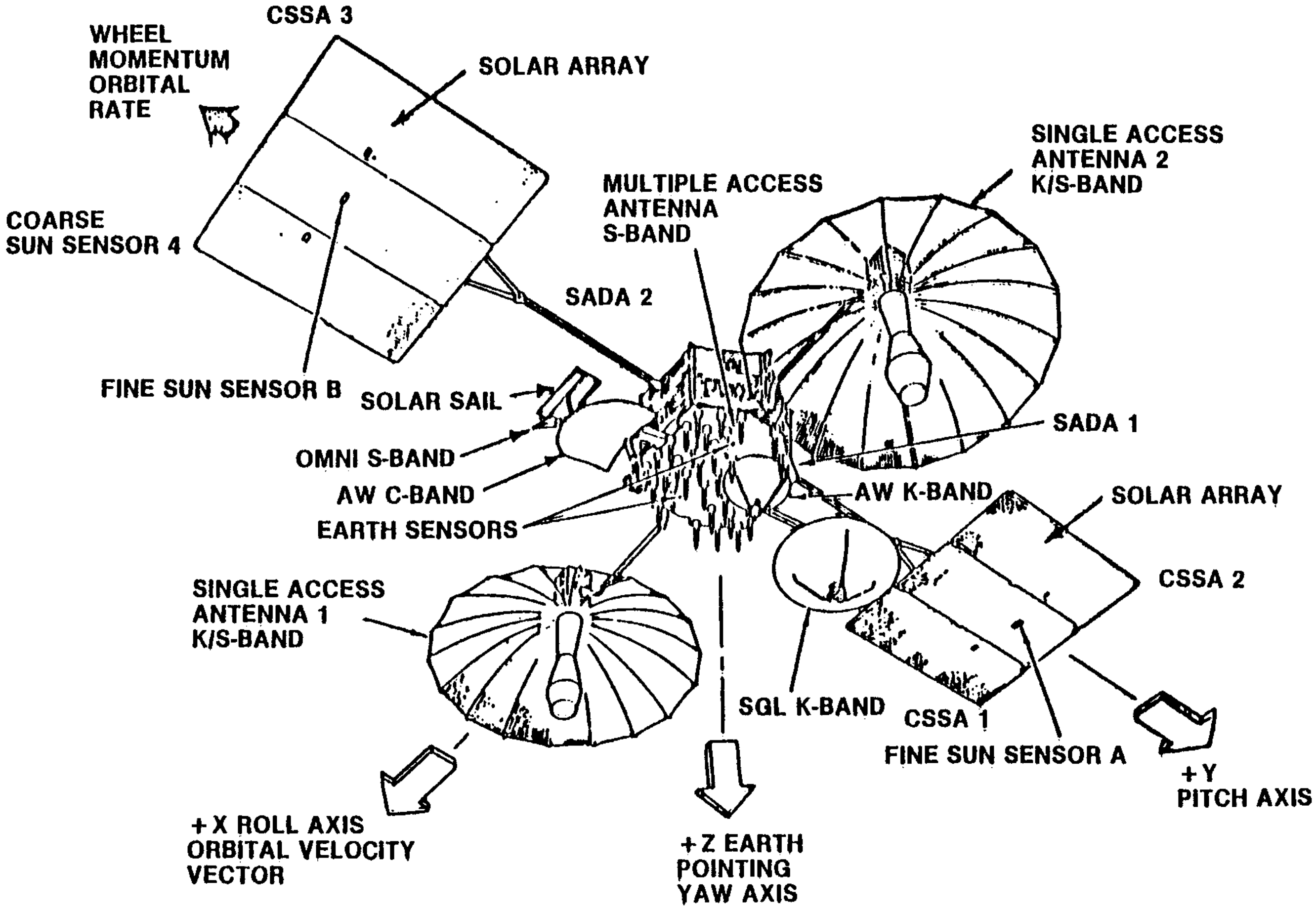


FIGURE 8.
TDRSS SPACECRAFT ON-ORBIT
CONFIGURATION AND SPATIAL ORIENTATION

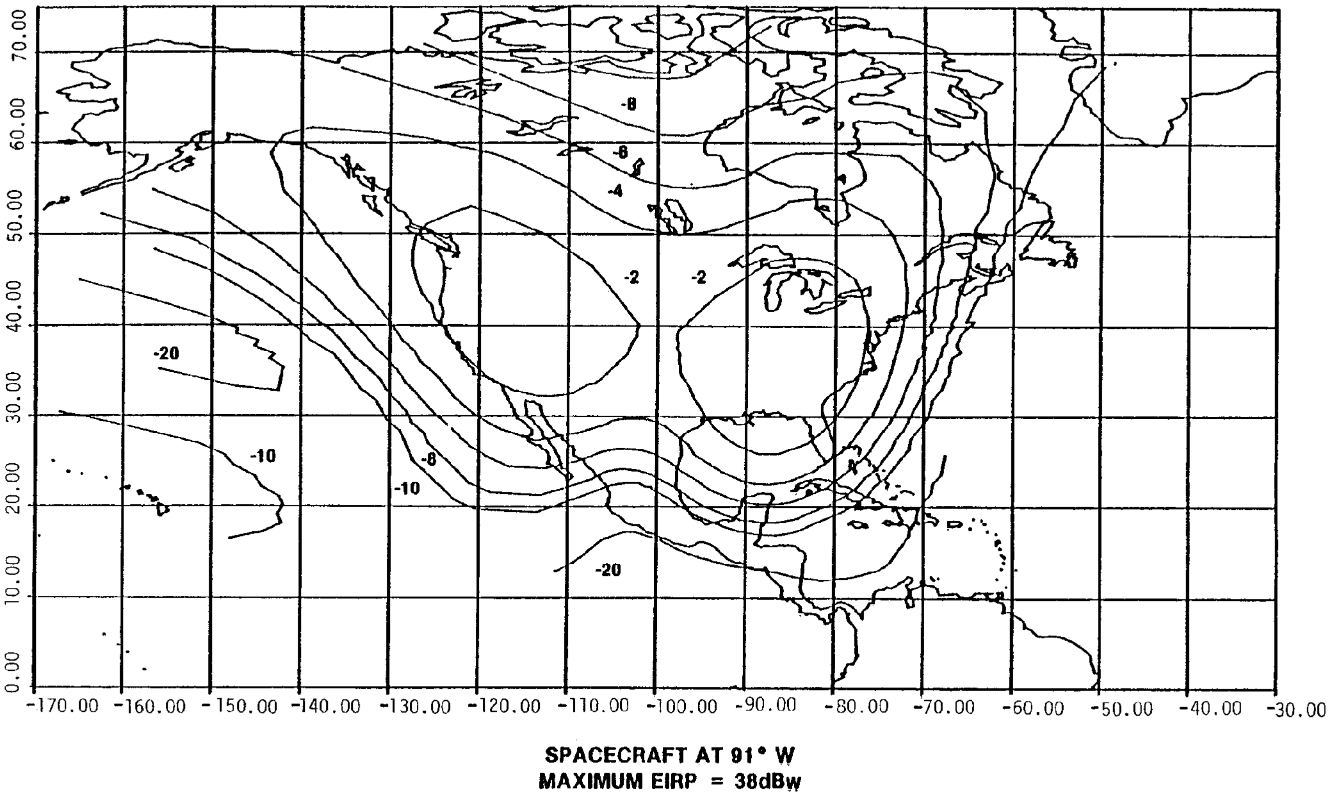
- PROVIDES INDUSTRY STANDARD C-BAND TRANSPONDER PERFORMANCE

- 48 STATE CONUS COVERAGE, PLUS HAWAII AND PORTION OF ALASKA

- SPACECRAFT AT 79°W (SPARE), 91°W (AW)

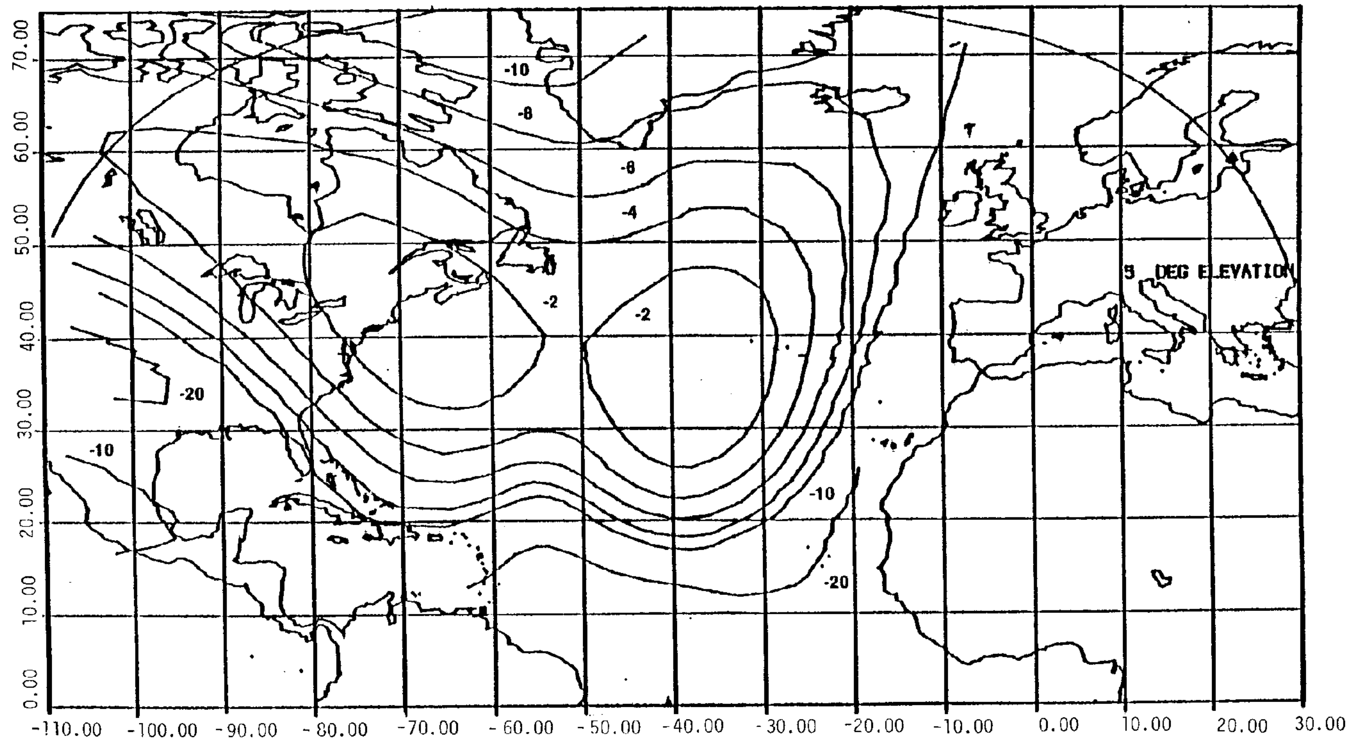
- 12 TRANSPONDERS PER TDRSS
  - 40 MHz TRANSPONDER BANDWIDTH, 36 MHz USEABLE BANDWIDTH
  - 60 MBPS DIGITAL DATA CAPACITY PER TRANSPONDER
  - UPLINK 5925-6425 MHz; DOWNLINK 3700-4200 MHz

FIGURE 9.
TDRSS C-BAND PAYLOAD



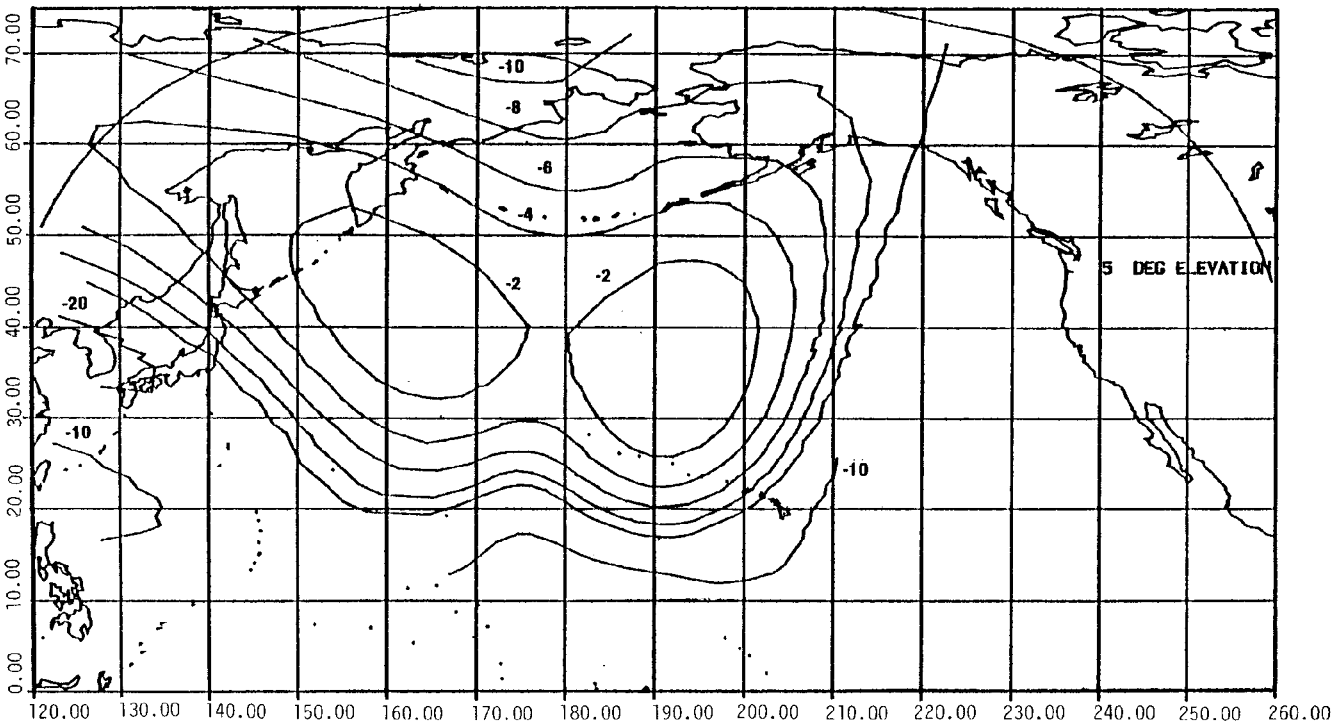
SPACECRAFT AT 91° W
MAXIMUM EIRP = 38dBw

FIGURE 10.
TDRSS C-BAND ANTENNA COVERAGE



SPACECRAFT AT 41° W
MAXIMUM EIRP = 38 dBw

FIGURE 11.
TDRSS C-BAND ANTENNA COVERAGE



SPACECRAFT AT 171° W
MAXIMUM EIRP = 38 dBw

FIGURE 12.
TDRSS C-BAND ANTENNA COVERAGE

- 48 STATE CONUS COVERAGE
  - EAST, WEST AND CENTRAL AREA BEAMS
  - NEW YORK, MIAMI, LOS ANGELES, SAN FRANCISCO SPOT BEAMS

- 4 TRANSPONDERS PER TDRSS
  - 225 MHz TRANSPONDER BANDWIDTH, 160 MHz USEABLE BANDWIDTH
  - 250 MBPS TRANSMISSION RATE PER TRANSPONDER
  - UPLINK 14.0-14.5 GHz; DOWNLINK 11.7-12.2 GHz
  - SATELLITE SWITCHED, SPACE AND TIME, DIVERSITY MULTIPLE ACCESS (SS/SDMA/TDMA)

FIGURE 13.
TDRSS Ku-BAND PAYLOAD

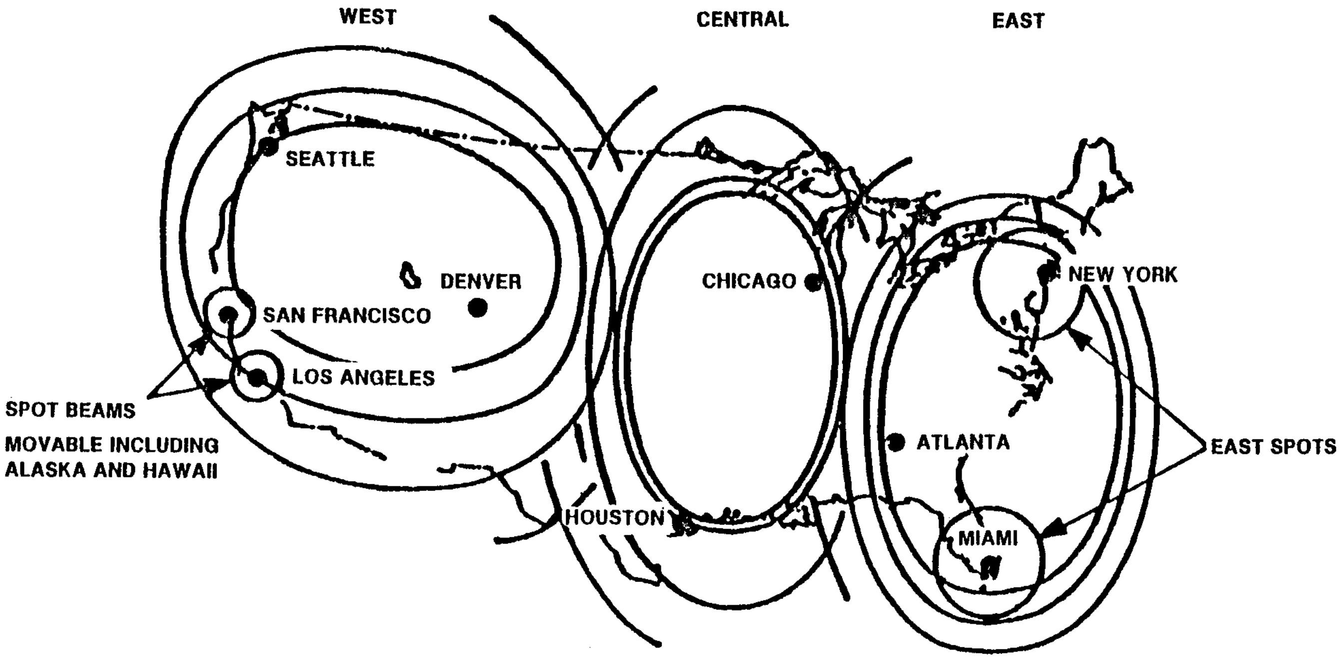


FIGURE 14.
ADVANCED WESTAR K-BAND ANTENNA COVERAGE

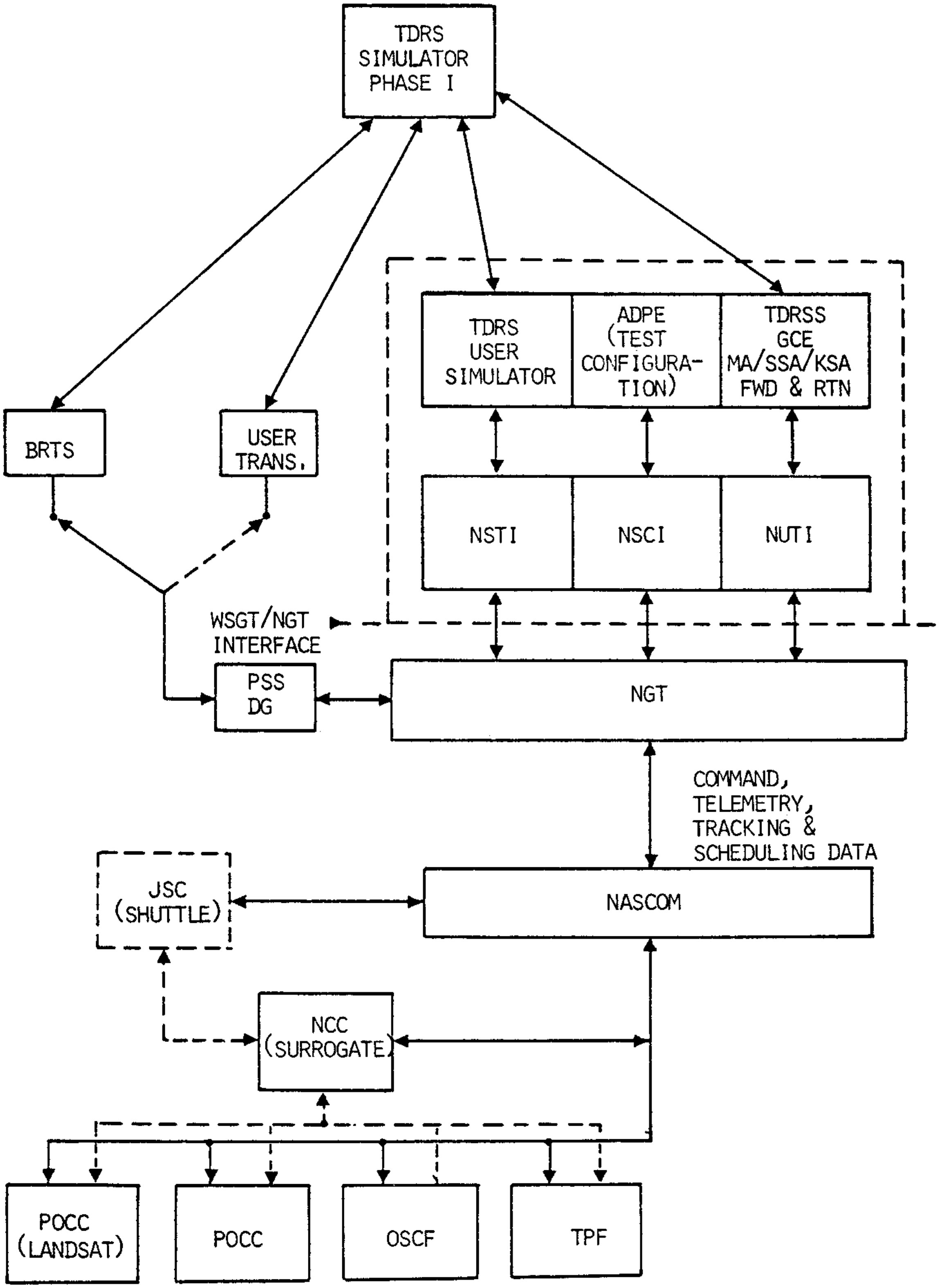


FIGURE 15.
TYPICAL TEST CONFIGURATION
(OPERATIONAL SCENARIOS)

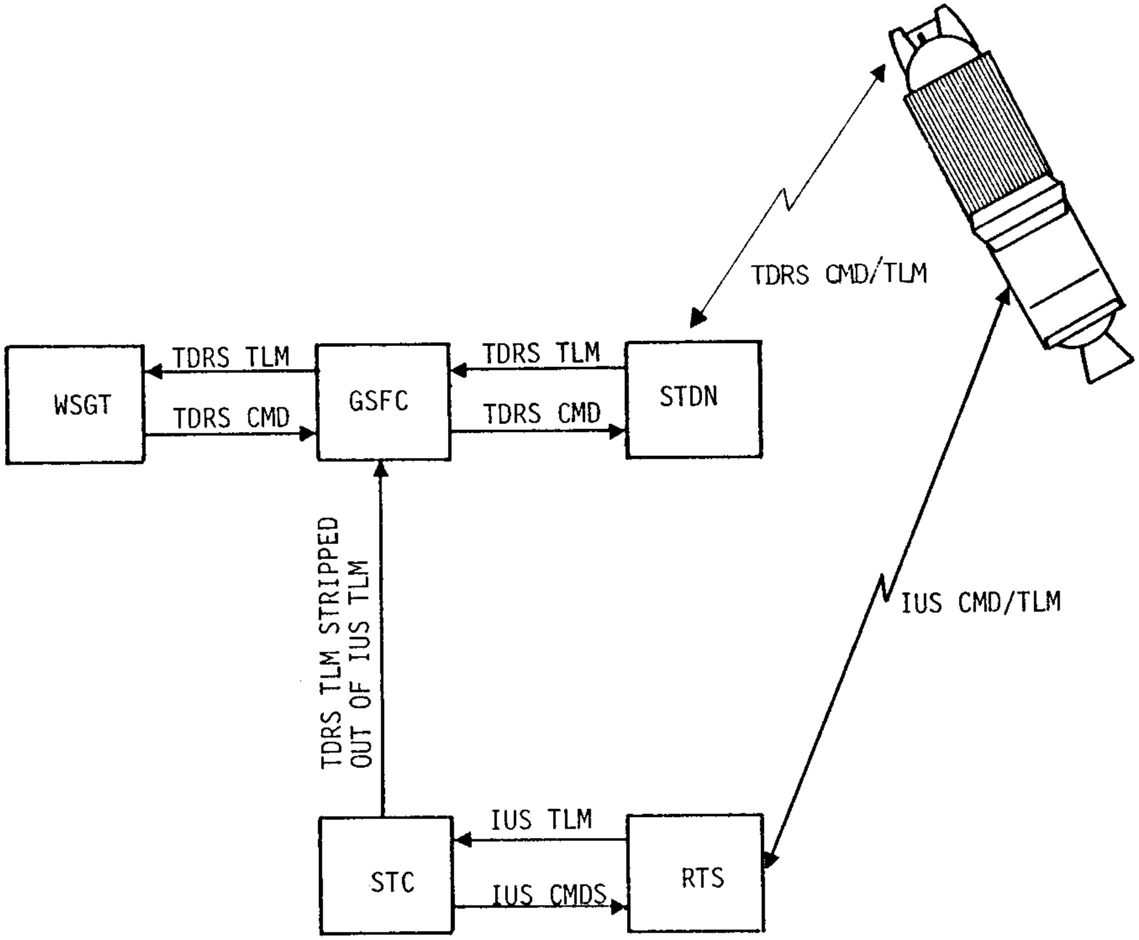


FIGURE 16.
PRELAUNCH IUS/TDRS DOWNLINK DATA TRANSMISSION SIMULATION TEST

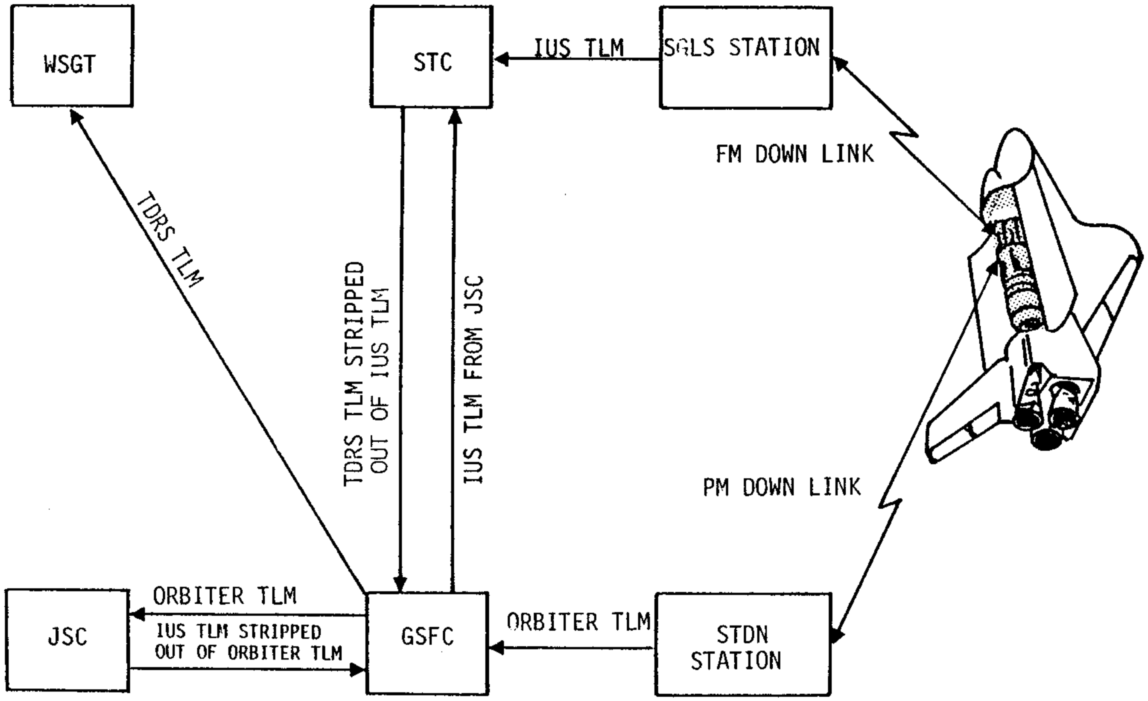


FIGURE 17.
PRELAUNCH ORBITER/IUS/TDRS DOWNLINK DATA TRANSMISSION SIMULATION TEST

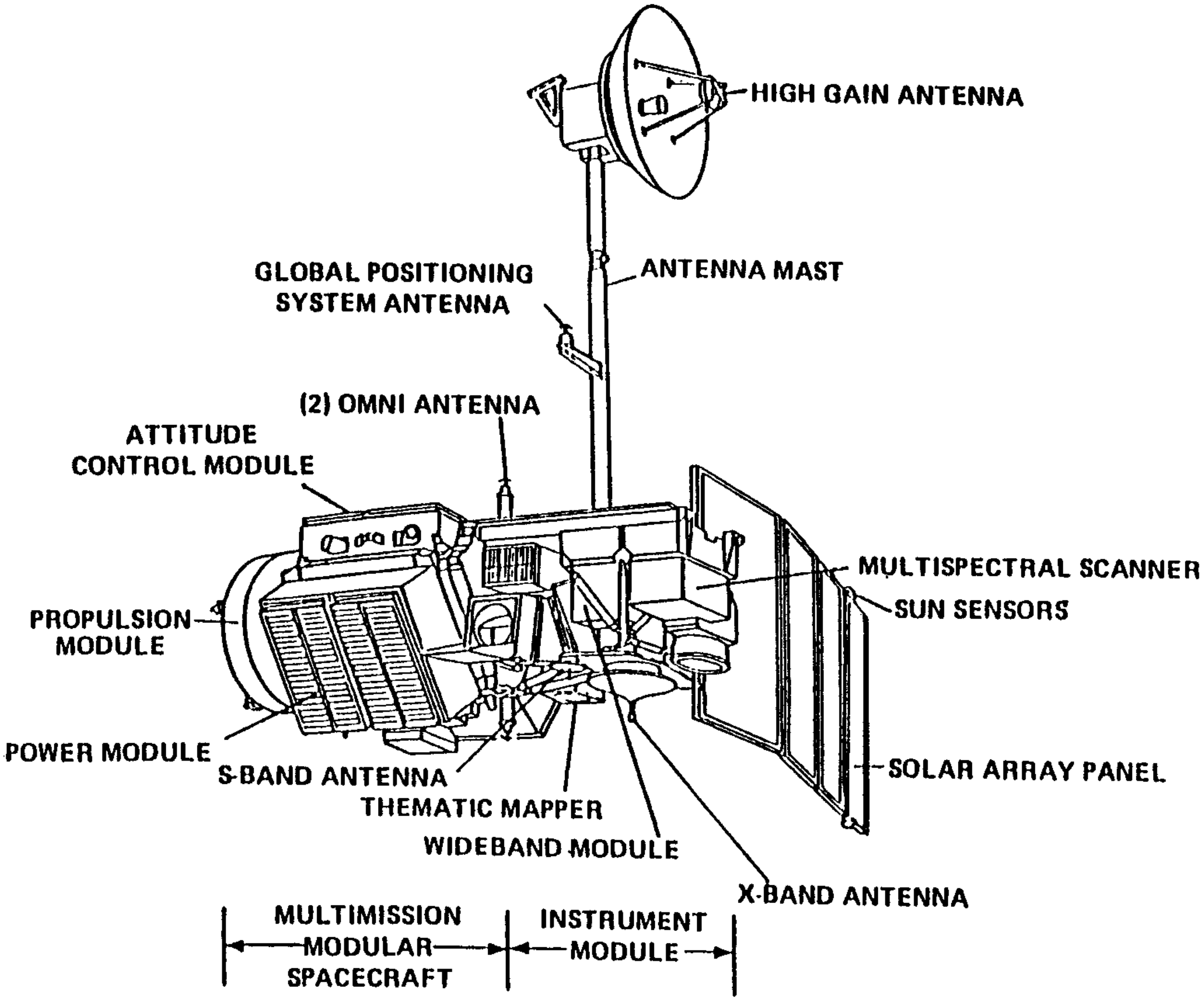


FIGURE 18.
LANDSAT D FLIGHT SEGMENT

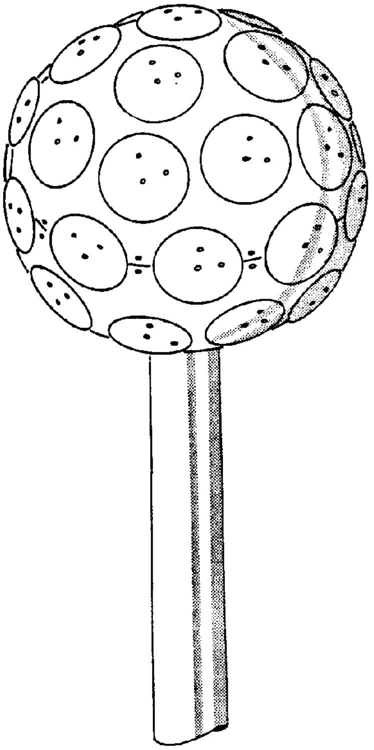


FIGURE 19.
ESSA S-BAND ANTENNA