STATUS REPORT
ON
TDRSS

W. Morris Holmes, Jr.
Senior Engineer
Defense and Space Systems Group
TRW Inc.

ABSTRACT

The NASA Satellite Tracking and Data Network (STDN) will be replaced by the Tracking and Data Relay Satellite System (TDRSS) during the 19801's. The coverage available to user satellites will be increased dramatically and very high data rates will be provided. Real-time data analysis and adaptive satellite control will be possible with the availability of continuous two-way communications. TDRSS will provide these benifits while lowering the cost of tracking and communicating with NASA satellites.

Communication requirements will be different for satellite designers in the 1980 period. TDRSS user satellites will require higher transmitter power and more sensitive recievers, and will communicate using special TDRSS modulation formats. There will be less on-board data storage.

This paper provides an overview of the TDRSS as it is being built. The major system features are described, and some of the system characteristics that will affect user satellite mission planning are considered.

INTRODUCTION

In 1980 the Tracking and Data Relay Satellite System (TDRSS) will begin operation. Every year NASA launches scientific and experimental satellites. These satellites generate large volumes of valuable data. Today this data is stored in the satellite, usually in a tape recorder, and "dumped" at high speed when the satellite is in view of one of NASA's Satellite Tracking and Data Network (STDN) stations. Collection of satellite data by STDN is expensive since a large number of stations are required, and many of these must be located in foreign countries where staffing and operating expenses are high.

When TDRSS starts operation NASA’s scientific and experimental satellites will send their data “up” to a Tracking and Data Relay Satellite (TDRS) instead of “down” to an earth station. TDRSS will increase the percentage of time that satellites can transmit data to the ground. This will reduce the requirements for data storage on-board satellites and will allow missions that generate so much data that it cannot be stored by existing tape recorders.

TDRS will be operated at a “synchronous altitude” of about 35,800 km, where they will circle the earth once every 24 hours. Because their orbit period is synchronous with the earth’s rotation, the TDRS remain located over fixed locations on the earth’s surface.

Most of NASA’s satellites operate at much lower orbital altitudes than TDRS. Satellites looking at the earth operate at altitudes from 200 km to about 1,000 km since they can “see” more detailed by being close. Satellites that look away from the earth, such as space telescope, also operate at low altitudes since a launch vehicle (rocket or Shuttle) can carry a much larger payload to low orbit.

Because the TDRS are so high, they look down at the earth and the satellites that use TDRSS (user satellites). One TDRS can “see” more than half of all the user satellite orbits. Two TDRS could see all of NASA’s low and medium orbit satellites, all the time, if their locations weren’t constrained by the need for both TDRS to see a common ground station. Because of this constraint, we use the orbit configuration shown in Figure A.

With 130 degree spacing between two TDRS, there is a small “shadow zone” where neither TDRS can see a user satellite. The area that isn’t covered gets smaller with greater user satellite altitude, and for user satellites above about 1200 km, TDRSS provides 100 percent coverage. The areas not covered are plotted in Figure B for several user satellite altitudes.

TDRSS and STDN coverage of user satellites at various altitudes is compared in Figure C. The comparison shows that TDRSS is far superior for coverage of low and medium altitude user satellites, while earth terminals provide better coverage for very high altitude user satellites, while earth terminals provide better coverage for very high altitude satellites and deep-space missions. The important difference is that TDRSS provides 85 percent coverage for low altitude user satellites while STDN can provide only 15 percent. This is especially vital since most of NASA’s scientific and experimental satellites are in low and medium altitude orbits.

Since only two or three TDRS and one ground station can handle all of NASA’s low and medium altitude satellites, TDRSS can provide superior coverage at much lower cost than just maintaining the current STDN. TDRSS will more than pay for itself by allowing

NASA to close the STDN stations that are not required for high altitude satellite and deep-space mission coverage.

System	Percentage Coverage at			
	200 km	1200 km	36,000 km (Synchronous)	Very High (Planetary, etc.)
One TDRS	55.5%	70%	19%	5%
TDRSS (Two TDRS)	85.0%	100%	38%	10%
One Earth Station	1.5%	8%	42%	50%
Current STDN	15.0%	<80%	100%	100%
Post-TDRSS STDN	7.5%	<40%	100%	100%

Figure C. Coverage of User Satellites for Different User

SYSTEM DESCRIPTION

TDRSS is being built now, and the first satellite will be launched in late 1980 by the Space Transportation System STS or Shuttle). There are two interesting features of TDRSS that affect the way the system is designed. First, TDRSS will be owned and operated by Western Union, and the services to NASA user satellites will be leased to NASA for a ten-year period after the system becomes operational. Second, the system is shared between TDRSS and commercial Advanced WESTAR use. Both of these features are incorporated to provide the lowest possible cost to NASA for the TDRSS services.

TDRSS will consist of four satellites in orbit (Figure D). Two of these are designated active TDRS. TDRS East and TDRS West are in synchronous orbit at locations separated by 130° of longitude as described. Their locations are 65° to the east and west of White Sands, New Mexico, where the TDRSS ground station is located.

A third satellite is designated Advanced WESTAR. This satellite provides domestic United States commercial communications for Western Union as part of their nationwide communications system. The fourth satellite is designated the on-orbit spare and provides rapid replacement of services if one of the other three satellites fails. There will be a fifth satellite in storage which can be launched in a relatively short time to replace the spare, should this be necessary.

All of the satellites are identical. Although the TDRSS and Advanced WESTAR missions are quite different, the satellite communications payload can be reconfigured by commands from the ground to support either mission. Furthermore, the requirements for numbers and types of transmitters and recievers, and the satellite power requirements, are similar enough to allow efficient utilization of the satellite hardware in both missions.

Designing a shared system with identical satellites has several advantages:

- Design costs are reduced, since only one satellite must be designed rather than two

- Only one in-orbit spare is required to support both missions. Two spares would be required without sharing

- Hardware failures in the satellite may affect only one mission. Satellites may be interchanged between TDRSS and Advanced WESTAR missions to avoid the need for additional replacement launches.

White Sands was chosen as the optimum location for the TDRSS ground segment, Figure E, after a detailed study of potential sites. Some of the advantages of the White Sands site includes:

- Low geographic latitude. Low latitude increases the angle between the two TDRS in orbit while maintaining line-of-sight communications with the ground station.

- Provides down-range coverage of Cape Kennedy launches. Locating the station any further west would move the TDRSS “blind spot” into a critical region where second-stage launch vehicle operations occur on many missions.

- Very little rain. The radio frequencies used by TDRSS for communication between TDRS and ground are disrupted by heavy rainfall. This disruption will occur very seldom at White Sands.

TDRSS is leased communication service, and as such, does not need to know the content of the data being transmitted. The interface point between TDRSS and NASA ground communication system, NASCOM, is at the White Sands station. Figure G is a simplified ground station block diagram which shows the TDRSS/NASCOM interfaces. Four types of operational information flow across this interface. These are:

(1) Date from NASCOM to be transmitted to user satellites

(2) Data from user satellites to be transmitted By NASCOM to user control centers

(3) Schedules and control orders from the MASA TDRSS control center telling TDRSS where to point antennas and when to provide certain types of service, and

(4) TDRSS reports and status data to notify NASA of the current condition of TDRSS

Two other types of data across the NASCOM/TDRSS interface provide for data flow to and from simulated seer satellites. TDRSS has the capability to generate signals simulating almost any user satellite that the system is specified to operate with. TDRSS will accept simulated user data, transmit it to TDRS with a simulated user signa., and return it to NASA through the regular TDRSS channels. TDRSS will also recieve signals from the TDRS using simulated user recievers and return this data to NASA for comparison with the transmitted data. The simulation capability will aid NASA in the development of user satellite communication hardware and provides diagnostic information on TDRS performance.

TDRSS generates modulated radio signals at the White Sands station for transmission through a TDRS to user satellites, and demodulates radio signals which have passed through TDRS from user satellites. The TDRS does no processing of user satellite traffic, in either direction, other than reception, frequency translation, amplification, and radiation through the appropriate antennas. The TDRS operates as a “bent pipe” repeater, and all of the signal processing equipment is in the ground station.

In addition to modulating and demodulating user satellite signals, the ground station uses the signal modulation to measure the range to the user satellite, and the range-rate or first derivative of range. This data allows NASA to determine the position of user satellites to the same accuracy currently provided by the STDN network.

THE SPACE SEGMENT

The Tracking and Data Relay Satellite, Figure I, is large by any standard. In comparison to previous synchronous orbit satellites, it is huge. A TDRS will weigh 5000 pounds in synchronous orbit at the beginning of life. When TDRS unfolds its antennas and solar panels, it will measure over 57 feet along the solar panel axis, and over 42 feet across the large antennas.

TDRS is carried into low orbit by shutt.e. An Interim Upper Stage (IUS) rocket takes TDRS to synchronous orbit and places it “on-station.” Each satellite is tested for proper operation at a longitude close to the middle of the United States before moving to its operational location as TDRS East, TDRS West, Advanced Westar, or spare.

Three different types of communication are provided by a TDRS. TDRS. Two of these use the sixteen-foot diameter deployable dish antennas. These antennas must be mechanically pointed at user satellites. Because of this, they can normally provide communication with only one user satellite. Hence, they are called “Single-access” antennas. The communications systems are called SSA, for S-Band singleaccess, and KSA, for K-Band single-access. The terms S-Band and K-Band refer to frequency ranges of 2 to 2.3 GHz and 13.7 to 15.2 GHz, respectively.

The SSA system transmits data at rates from 100 bits per second (bps) to 300 kbps to user satellites, and recieves data at rates from 100 bps to 12 Mbps from user satellites. The KSA system transmits data from 1000 bps to 25 Mbps to user satellites and recieves data from 1000 bps to 300 Mbps from user satellites. The KSA system provides higher data rates because the higher frequency allows higher antenna gains and wider allocations of frequency spectrum. The SSA system is less expensive for user satellites with low gain antennas.

There are two SA antennas per TDRS, and three TDRS in the system, so six user satellites can normally be serviced at one time by the SSA and KSA systems combined. If a SSA user satellite is located close to a KSA user, both can be serviced by a single SA antenna. This type of operation will occur after Shuttle releases an independent payload, for example. Under this special condition, as many as twelve SA users could be simultaneously serviced.

The Multiple Access System uses thirty helix antennas, mounted on the TDRS front platform, as a phased away antenna to form up to twenty independent antenna beams directed towards user satellites. The beams are actually formed in the White Sands station. The number of beams is limited by the amount of ground hardware. Twenty users may be tracked through one TDRS or through any combination of the three TDRS in orbit.

The MA system can transmit from 100 bps to 10 kbps to user satellites and recieve from 100 bps to 50 kbps from user satellites. The lower data rate capability is the price paid for the large number of channels. The availability of twenty channels allows almost full-time coverage of many users.

The round solid dish antanna deployed on one side of the satellite is the Space Ground Link (SGL) antenna. All signals to and from user satellites go through this antenna to or from the White Sands ground station.

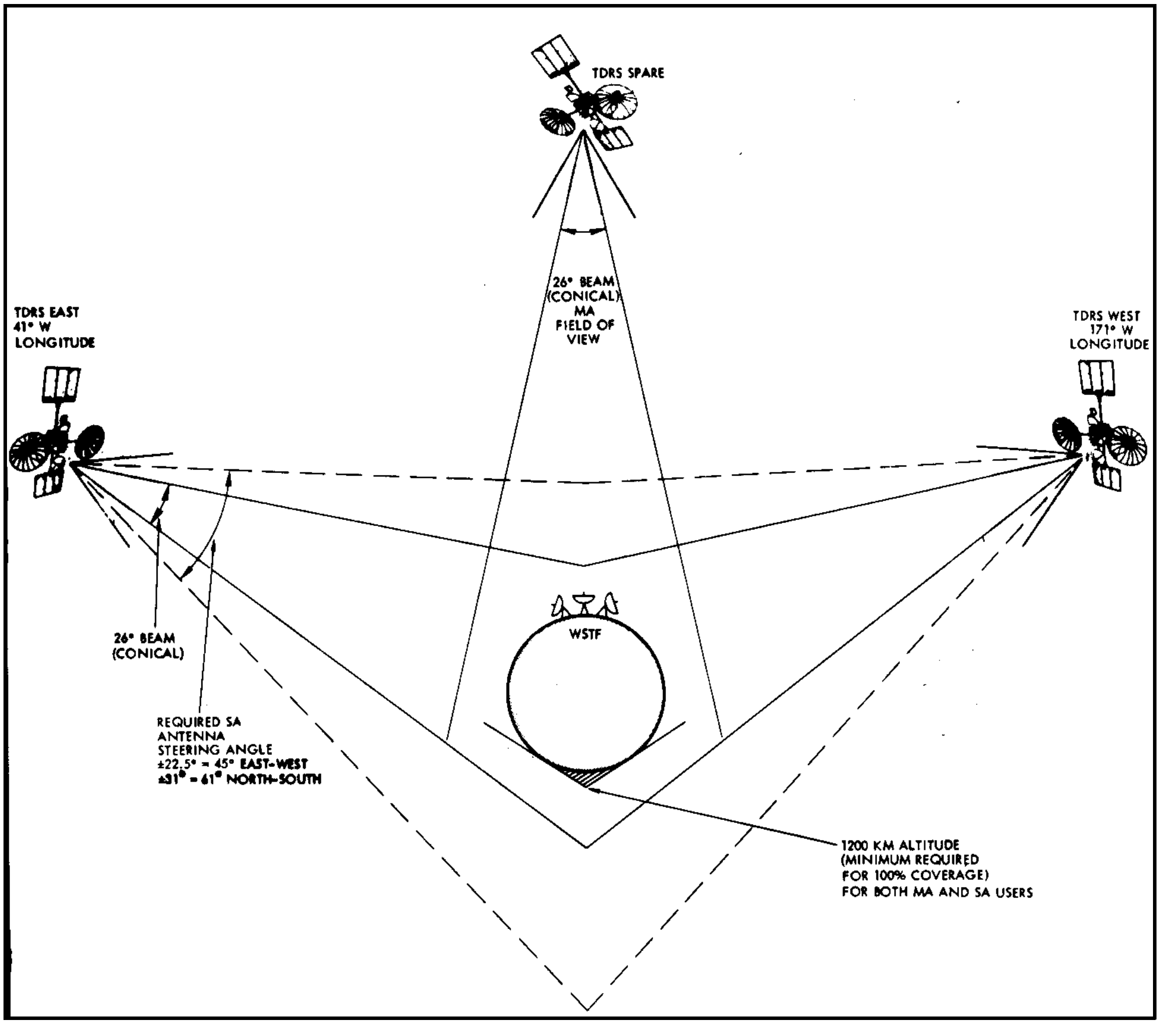

Figure A TDRSS System Configuration and Coverage Limits

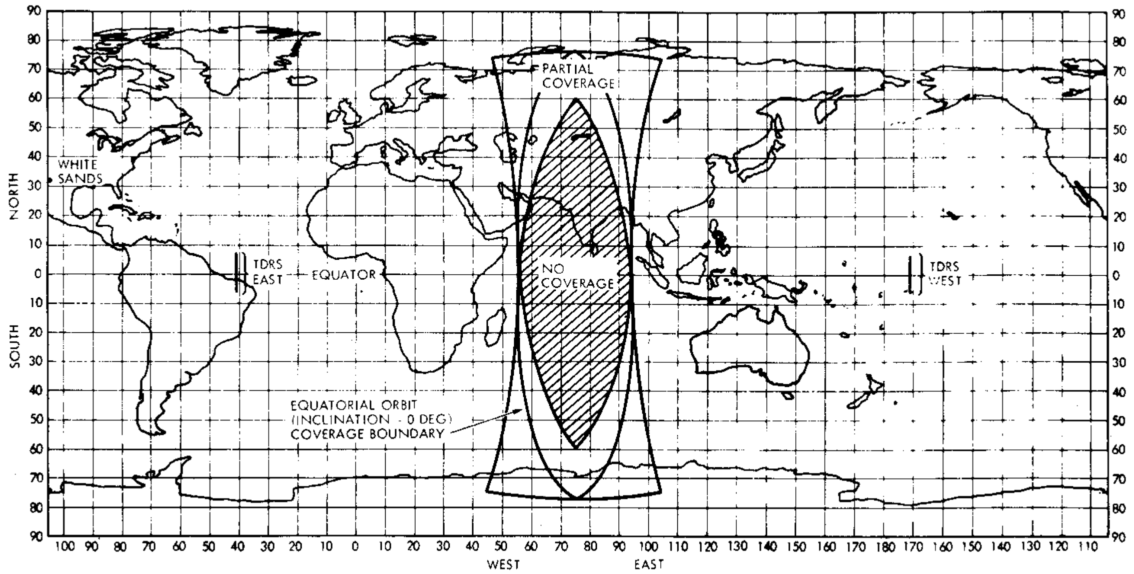

Figure B-1. Coverage for 200 km User Satellite Altitude 7 Degrees TDRS Inclined Orbits with 180 Degrees Phasing

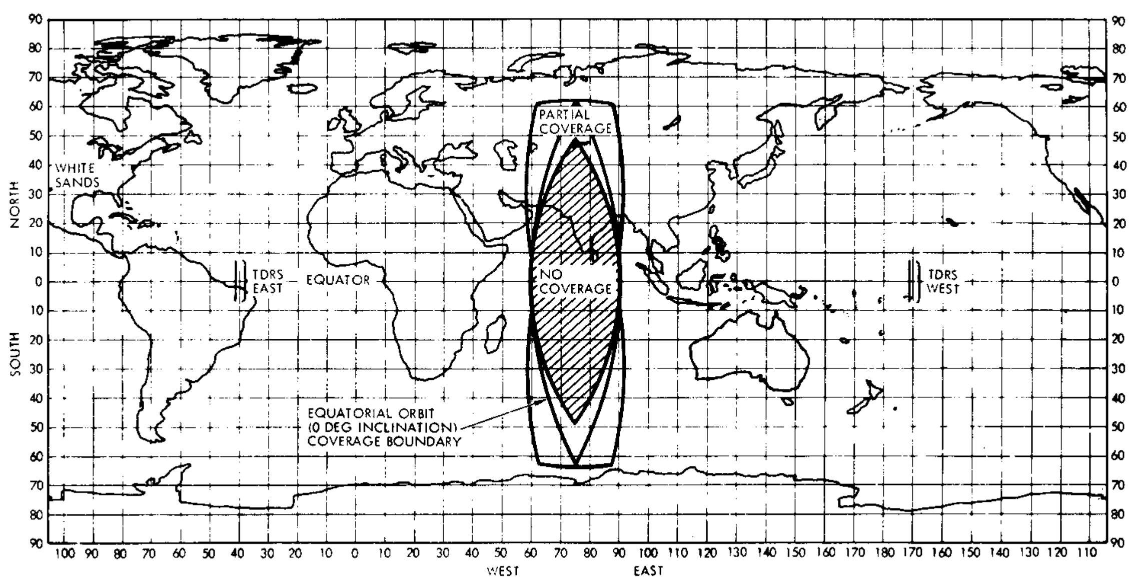

Figure B-2. Coverage for 400 km User Satellite Altitude 7 Degrees Inclined Orbits with 180 Degrees Phasing

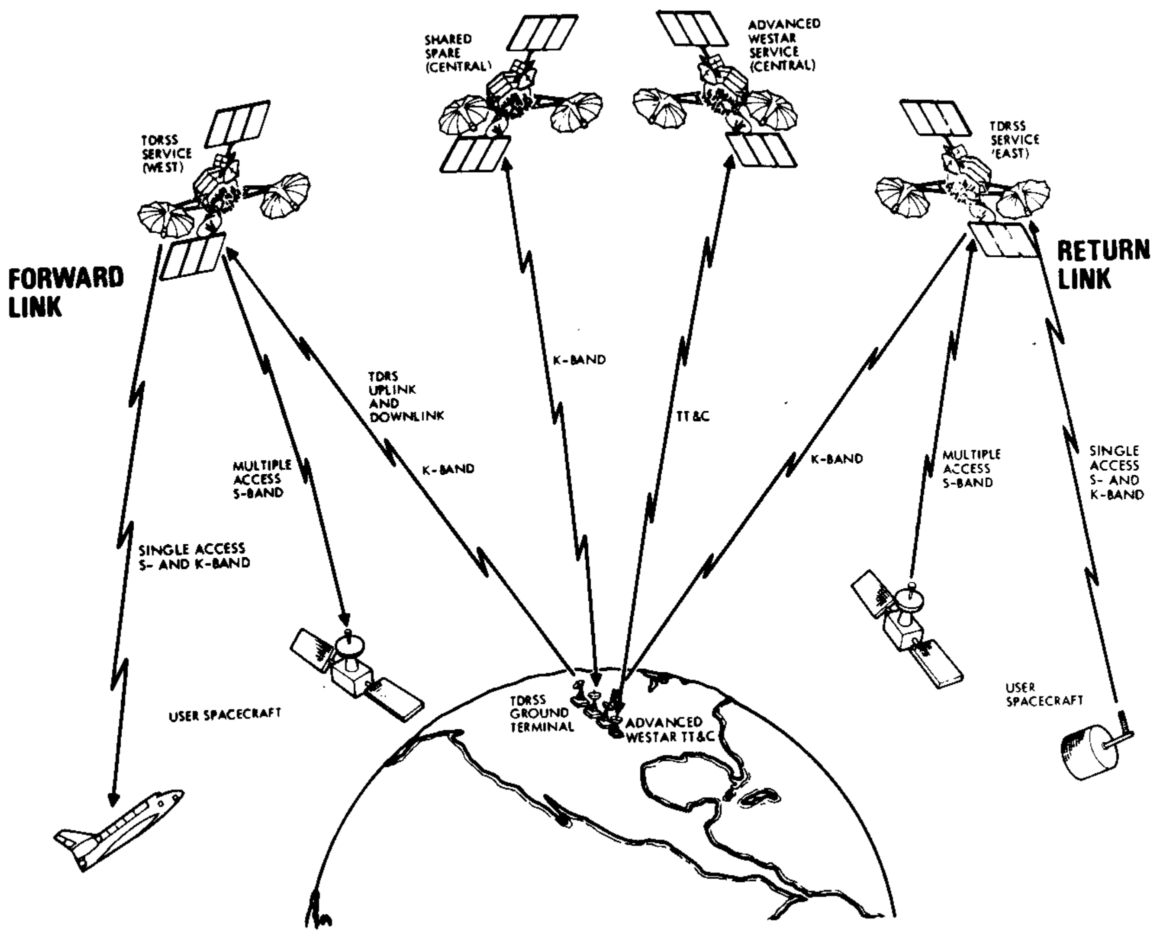

Figure D TDRSS SYSTEM CONFIGURATION

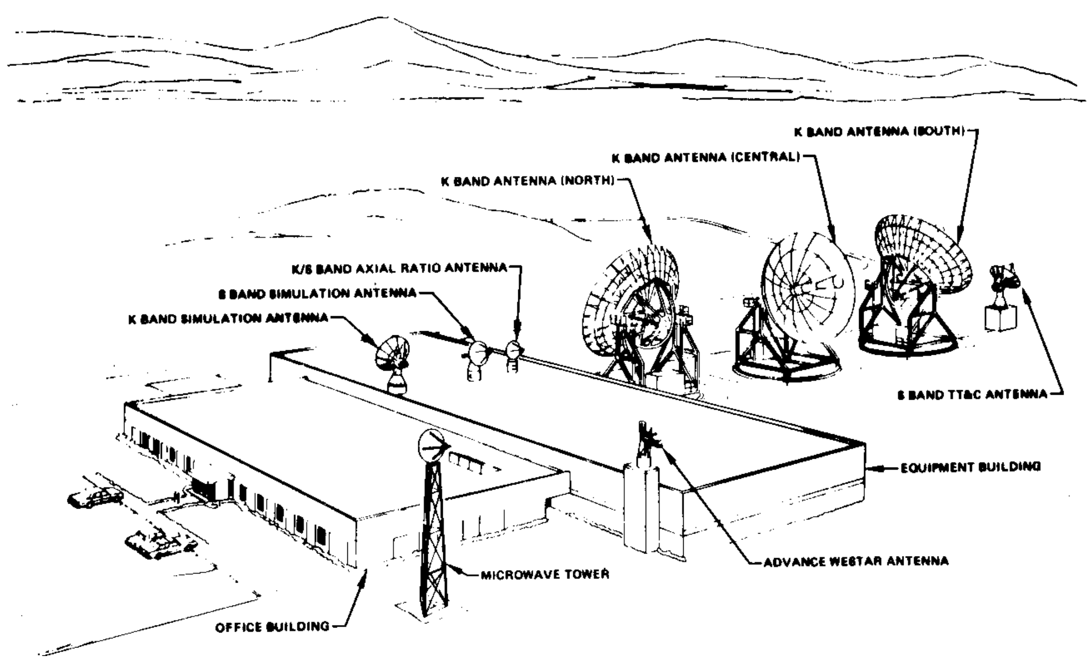

Figure E. Ground Segment Artists Conception

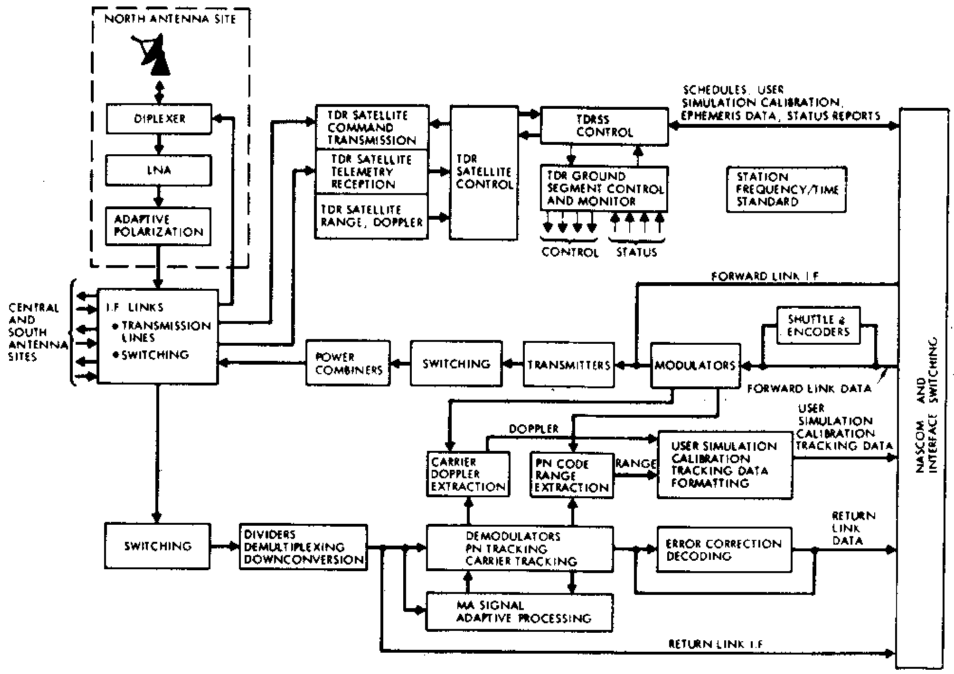

Figure G. Ground Segment Processing of User Traffic and TDRS TT&C

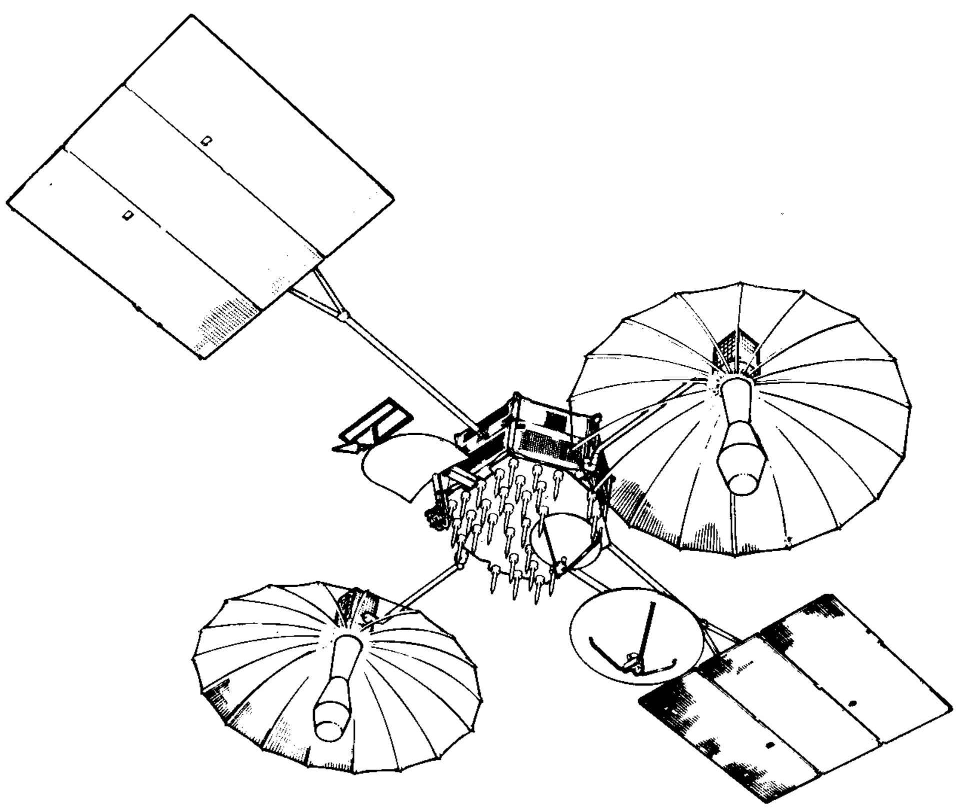

Figure I . Spacecraft Configuration