SPACE TRACKING AND DATA SYSTEM, EMPHASIZING
THE COMMERCIAL ASPECTS

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Abstract

Near-earth orbit tracking and data acquisition activities are evolving from a ground tracking station network located in the U.S. and around the world, to a space network of two tracking and data relay satellites plus an in-orbit spare in geosynchronous orbit.

This paper briefly discusses the major elements that comprise this evolving Tracking and Data Relay Satellite System (TDRSS) Network that provides the basis for the tracking and data relay satellite (TDRS) operations in the 1980's and emphasizes the commercial aspects of the system.

Concept of a Space Network

The TDRSS was conceived to permit NASA to continue to provide service to the user spacecraft community in an era of rapidly-increasing technological demands. The STDN has in the past expanded the capability of its ground stations, but the complexity and quantity of new service requirements makes the work of this type of tracking network more difficult and less efficient. The impact of the cost for maintaining and improving a large network of ground stations in overseas locations required a new approach which culminated in the lease for service system named Tracking and Data Relay Satellite System.

The TDRSS achieves an approximate (85 percent minimum) coverage of user satellite orbits by the 130 degree longitudinal separation of its East and West satellites in high geostationary orbits, as shown in Figure 1.

Two dedicated TDRS are positioned at 171° and 41° West longitude, and the spare is located centrally at 79° West longitude. The data relay function is provided by telecommunications systems operating at S-Band (2025-2300 MHz) and at Ku-Band (13.750-15.115 GHz).

The TDRS also contains twelve C-Band (5925-6425 MHz uplink, 3700-4200 MHz downlink) transponders that operate independent of the S and Ku-Band data relay systems. NASA, under the terms of the contract with SPACECOM for operation of the TDRSS, has full authority and control over the utilization of the TDRS system, including the use of the C-Band telecommunications transponders.

Background

NASA awarded a contract to an industry team headed by Western Union Space Communications, Inc., which later became Space Communications Company (SPACECOM), a jointly-owned partnership with Continental Telecom Inc. and Fairchild Industries, Inc.

Under contract with NASA, SPACECOM owns and operates the system to provide TDRSS service to NASA under a lease agreement for a period of 10 years which was initiated in 1983. The system leased from SPACECOM includes space and ground segments with the ground segment known as the White Sands Ground Terminal (WSGT).

The WSGT and the TDRSS space segment are only one portion of the total TDRSS network. To use the space and ground segments, NASA provides an interface at White Sands. This interface facility is called the NASA Ground Terminal (NGT) and is co-located with the WSGT. Other facility elements are located at the Goddard Space Flight Center (GSFC), Greenbelt, Maryland, and include the Network Control Center (NCC) for operations control and management of the network resources, Operations Support Computing Facility (OSCF) for tracking operations, NASA Communications Network (NASCOM) for the common carrier interface at all geographical locations, and the Simulation Operations Center (SOC) for conducting testing. The Interface to the TDRS at Kennedy Space Center (KSC) is through the Merritt Island (MIL) relay system colocated with the Merritt Island Spaceflight Tracking and Data Network (STDN) station. Also located at the MIL

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Figure 1. TDRS/Telecommunications Space Segment Configuration

STDN station is the Shuttle Launch Support System (SLSS) for providing a communication interface with the Shuttle. A mobile Compatibility Test Van (CTV) is used at user spacecraft contractor facilities and interfaced to the TDRS for test purposes.

Elements of the TDRSS End-to-End Network

Major elements of the TDRSS Network consist of:

- o Tracking and Data Relay Satellite System (TDRSS)

This leased element consists of the TDRSS ground segment at White Sands, WSGT, and the TDRSS space segment including the two operational and one in-orbit space TDRS.

- o NASA Ground Terminal (NGT)

The terminal is colocated with the WSGT and provides the interface between the leased TDRSS and the NASA system.

- o Network Control Center (NCC)

The NCC, located at GSFC, provides the focal point for NASA operations with the TDRSS and other network elements.

- o Operations Support Computing Facility (OSCF)

The OSCF, located at GSFC, provides the network with orbital predictions and definitive orbit calculations for user spacecraft and the TDRS's. The OSCF will receive, validate, calibrate, and archive all network metric tracking

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data to provide orbit determination and computations for developing trajectory information, and for acquisition data and scheduling aids for the network.

o NASA Communications Network (NASCOM)

This provides the common carrier interface at network locations and consists of domestic communications satellites and their interface through earth terminals at GSFC, White Sands, and JSC. On the ground, the network includes a Control and Status system (CSS), Multiplexer-demultiplexer System (MDM), and a message switch system. NASCOM provides for transmission of all return, forward tracking, and operational data between network elements.

o Bilateral Ranging Transponder System (BRTS)

These unattended ground-based transponders provide signals from ground reference points for accurately calculating the TDRS's positions. There are five BRTS presently scheduled for implementation: two to be located at WSGT and one each at Ascension Island, American Samoa, and Alice Springs, Australia.

o MIL Relay and SLSS

The relay located with the Merritt Island STDN Station provides an interface between a user spacecraft in the KSC area and the TRDS's prelaunch checkout. The SLSS provides an interface to the MIL station for Shuttle in a TDRS compatible communication format.

o Project Operations Control Centers (POCC)

The POCC (considered the user) is the prime facility for control of a user satellite. POCC's can be either general purpose, such as the GSFC MSOCC, or mission-unique, such as the Shuttle POCC at JSC and Landsat POCC at GSFC. A POCC is responsible for experiment status processing, command generation, telemetry processing, attitude data handling, payload operations and control, experiment sensory analysis and control, and payload planning analysis.

The Shared (Commercial) System Overview

The shared system design consists of both government and commercial communications payloads on the same spacecraft. Each satellite contains C- and K-band payloads as well as government S- and K-Band payloads. The commercial C-Band payload can operate independently of the S-Band TDRS payload. The commercial K-Band payload consists of a satellite-switched TDMA (SS-TDMA) system which shares common K-Band hardware with the K-band TDRS payload precluding full simultaneous operation.

The ground segment Tracking, Telemetry and Command (TT&C) equipment for the dual-role spacecraft is located at White Sands Ground Terminal (WSGT) near Las Cruces, New Mexico (see Figure 2). Most of the capability of WSGT is directed towards the communications relay services, but certain elements are shared by both missions and are mentioned here.

WSGT performs control and monitor functions and has the capability to support four on-orbit satellites. On-station tracking and ranging, for the purpose of orbit determination, is accomplished for the TDRS communications relay mission using K-Band tracking antennas. Greater tracking and ranging performance can be achieved utilizing two station ranging with a C-Band network. WSGT will interface with telecommunication user earth stations via terrestrial transmission facilities to coordinate mission events and verify satellite payload status.

To support TDRS and C-Band telecommunications operations, WSGT is equipped with K-Band TT&C equipment for normal on-orbit spacecraft operation, and S-Band T&C equipment for operation during orbital insertion and initial spacecraft stabilization. S-Band T&C also provides emergency backup for the K-Band TT&C.

The K-Band T&C system provides telemetry, tracking, and commanding for three on-orbit satellites. The K-Band TT&C communications link is established between one of the 60 foot K-Band antennas at WSGT and the space-to-ground link (SGL) antenna on the TDRS.

The S-Band T&C system provides telemetry and commanding for a single TDRS. The S-Band T&C communication link is created between the 6.1 meter S-Band antenna at WSGT and the S-Band omni antenna on the TDRS.

The C-Band communications payload consists of twelve 36 MHz wide transponders operating in a "bent pipe" mode. Signals are received at the satellite in the 6 GHz band by a linear, vertical polarization, body-fixed antenna, amplified and frequency-translated to the 4 GHz band, then transmitted through the same antenna on linear horizontal polarization utilizing 5.5 watt Traveling Wave Tube amplifiers (TWTAs). The frequency assignments for the twelve channels are shown in the table below:

Channel Number	Receive Frequency (MHz)	Transmit Frequency (MHz)
1	5927-2963	3702-3738
2	5967-6003	3742-3778
3	6007-6043	3782-3818
4	6047-6083	3822-3858
5	6087-6123	3862-3898
6	6127-6163	3902-3938
7	6167-6203	3942-3978
8	6207-6243	3982-4018
9	6247-6283	4022-4058
10	6287-6323	4062-4098
11	6327-6363	4102-4138
12	6367-6403	4142-4178

Figure 2. White Sands Ground Terminal

The commercial K-Band payload consists of four wideband (250 MHz), hardlimiting, channels with four primary regional beams (East, West, Central, East spots) operating under a frequency reuse plan. A 4X4 TDMA switch in the satellite can dynamically change the uplink and downlink interconnections between the four primary antenna beams. Two secondary beams (the West spots) are coupled to the West beam at the IF frequency. The K-Band payload receives and transmits six antenna beams and interconnects those beams with the satellite switch.

The West spots may be considered as subchannels of the West beam channels since transmissions from the West, West Spot #1, and West Spot #2 beams must be time division multiplexed to project interference between them. It is important to note, however, that a transmit burst from an earth station in one of the beams will be simultaneously transmitted down to all three beams.

Summary

The first Tracking and Data Relay Satellite was launched in April 1983. Following the orbit adjust and preliminary systems checkout, the TDRSS was called on for initial support in late 1983. The end-to-end system supported the space shuttle and un-manned missions such as Landsat-4 and the repaired Solar Max satellite. The commercial aspects of the system design remain unchallenged and complicated by factors not of a technical nature. The future scope and utilization of the commercial payloads is still undergoing evaluation.

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