NORTHROP GRUMMAN FACTS

Tracking and Data Relay Satellite (TDRS) System

System Description/Capability

The Northrop Grumman-built part of the nine satellite TDRSS constellation consists of six satellites. The TDRSS provides near continuous communications services for up to 33 User satellites simultaneously and tracking service for up to 18 User satellites.

Located 22,250 miles above Earth in geosynchronous orbit, these satellites look down on NASA's fleet of low-Earth-orbiting spacecraft, tracking them worldwide and relaying direct two-way communication between them and mission control centers through a ground station complex at White Sands, New Mexico.

Each of the original TDRS satellites was designed to support simultaneous communication service to 24 user satellites and tracking service to three, but the installed ground terminal equipment limits the total number of users in the system to 33 while supporting 18 tracking services. A remote ground terminal in Guam forwards two-way communication data relayed through the TDRS satellite positioned over the Indian Ocean satellites to White Sands for distribution to the user operations centers. Adding the Guam facility to the TDRSS network provides truly world-wide coverage of low-Earth-orbiting spacecraft requiring breaks in coverage only to hand communication and tracking over from one TDRS to the next.

The original three satellite (two operational plus one spare) TDRS system constellation increased communications coverage from the average 19 percent coverage provided by the ground based NASA tracking network to an average 85 percent of a user satellite's orbit. Addition of Guam closed the so-called Indian Ocean gap providing greater than 95% coverage. The original TDRS communication payload accommodates up to 300 MBps data rates, transmitting and receiving in S-, Ku- and C-bands. The next generation of TDRS satellites will support an additional frequency band. Ka-Band Users will be able to operate at data rates up to 800 Mbps. Each satellite relays digital and analog signals including voice and television coverage of Shuttle and International Space Station missions.. .

Originally TDRS was designed to support Space Shuttle operations and other low-Earth orbit NASA satellites. Over time, TDRSS usage encompassed additional U.S Government users, space consortia, international scientific and other users. The first TDRS (Flight 1) launched in 1983 is still in operation and is now dedicated to providing

high data rate communications from the US scientific research station located in the South Polar region.

TDRS Performance Milestones

In 2007, TDRS set a new standard for long life and reliability for geosynchronous satellites. The six successfully launched Northrop Grumman-built TDRS spacecraft, a seventh TDRS was lost with the tragic loss of the Shuttle Challenger in 1986, have each satellite has delivered far more than its specified ten-year design life. The constellation has now logged 102 years of combined service. After logging nearly 42 years beyond their design life, and nearly sixty years beyond the calculated mission duration, they have essentially delivered the equivalent of a free communication constellation to NASA.

The six TDRS satellites number among the 26 successful geosynchronous spacecraft built by Northrop Grumman in the last 25 years, all of which are still operating. The oldest satellite in the TDRS system, which has been in operation for over 8700 days, more than 200,000 hours, is still supporting missions, including National Science Foundation Researchers at the South Pole.

Space Segment Configuration

Each of the original TDRS satellites weighs almost 2.5 tons (2,200 kilograms) and is a virtual antenna farm, configured with seven antennas. Giant solar arrays, longer tip-to-tip than the height of a five-story building, were designed to generate more than 1,700 watts of electrical power after ten-years of operation on-orbit.

- Two space-deployable antennas provide Ku-band and S-band single access services. Fully deployed, outer edge-to-outer edge the two antennas span 42.6 feet (13 meters) and weigh just 53.5 pounds (24.3 kg) each.
- A third antenna for multiple access services is a 30-element S-band, phased array of helical radiators (elements) mounted on the TDRS spacecraft body.
- The fourth antenna is the Space/Ground Link antenna, transmitting all the signals received by the other three antennas to the White Sands Ground Terminal for processing and receives signals from White Sands for retransmission to user satellites via other antennas.
- The fifth antenna, the S-band omni, provides near spherical coverage for launch and emergency operations, allowing command and telemetry operations when the spacecraft is not oriented toward Earth.
- Two additional antennas provide C-Band and K-Band commercial communications channels.

When NASA purchased the satellite to replace TDRS Flight 2 lost with Challenger the C- and K-Band commercial communication payloads were eliminated.

Ground Segment

The expanded coverage provided by TDRSS allowed NASA to close a large number of overseas tracking stations while providing dramatic increases in data acquisition from scientific and resource monitoring satellites. No user signal processing is done on-board. To ensure long life and allow for more on-board spacecraft communication channels, as many functions as possible have been removed from the satellite and performed on the ground.

The TDRSS White Sands Complex (WSC) comprises a pair of Ground Stations located three-miles apart. The newest of the two TDRS Ground stations is capable of supporting the full communication capabilities of three TDRS satellites while the original station is capable of supporting two active TDRS satellites. Equipment from the original ground terminal that originally allowed both stations to support three TDRS birds was moved to Guam, allowing a TDRS to be relocated to close the "Indian Ocean Gap".

The WSC is one of the largest and most complex tracking facilities ever built. Its multiprocessor computer network schedules all TDRSS communication and tracking services, collects and routes user service communication and tracking data to-and-from user satellites and their control centers, makes TDRS tracking measurements, steers all TDRS antennas, selects and controls all communications equipment in the satellite and the ground station and collects and reports system status data.

Control functions are performed automatically in response to requests for service. All user satellite telemetry data is relayed by TDRS through White Sands. NASA routes the data to its field centers, such as Johnson Space Center in Houston, Texas, or to the Goddard Space Flight Center in Greenbelt, Maryland. User satellite command data is also routed through White Sands for transmission via TDRS. An additional remote ground terminal in Guam forwards user data relayed through the TDRS over the Indian Ocean region to White Sands for distribution to the user operations centers.

Northrop Grumman integrated and tested the original ground terminal, developed software for the TDRSS system, and integrated the software for the ground station and satellites, tying the space and ground segments together. The TDRSS White Sands Complex undergoes continuous modernization and now has little relationship to the original station. The original architectural decision to make the TDRS satellites as simple as possible has permitted substantial improvements in end-to-end user service performance as new technology in digital receiver technology has been brought on-line.

TDRS Technical Information

Satellite Characteristics

Dimensions When Deployed: 17.41m (57.2 ft.) x 12.98m (42.6 ft.)

- Weight: 2,120kg on orbit (4,668 lbs.)
- Power:
  - 1,700 watts minimum provided at the end of life
  - Two 150x1550-inch solar wings containing approximately 28,000 silicon solar cells

Three 40-ampere-hour nickel cadmium batteries supply full power in eclipse

- Antennas: 7 (3 mechanically steered, 1 electronically steered, 3 fixed)
- Attitude Control: 3-axis stabilized biased momentum system
- Propulsion: 24 one-pound-force monopropellant thrusters provide attitude control and station keeping.
- Operational Orbit: Geosynchronous – 22,250 miles above Earth
- Design Life: 10 years

Ground Station Characteristics

- WSC Sites: Two separate sites on the NASA White Sands Test Facility, New Mexico, 3-miles apart
- Antennas:
  - Three 18.3-meter (60 ft.) Ku-band for TDRS space/ground link (SGL) transmission and reception
  - Three 19 meter (61 ft) dual band (Ku-and S-Band) for TDRS SGL operation and emergency TT&C operation
  - Two 10 meter (32ft.) S-band for emergency TDRS telemetry reception and command transmission.
  - Five 4.5 meter (14.4 ft.) for S- and Ku-band user satellite simulation
- Computers: More than 100 general purpose computers for satellite and ground terminal control and monitoring
- Guam Ground Terminal Site:
  - Remote ground terminal serves the TDRS providing service to satellites over the Indian Ocean.
  - Data to and from user satellites is forwarded to White Sands.
  - One 16.5 meter (53 ft) and one 11 meter (35 ft) dual Ku- S-Band for TDRS for TDRS SGL operation and emergency TT&C operation
  - Two 4.5 meter (14.4 ft.) for S- and Ku-band user satellite simulation

TDRS Launch Dates

Satellite	**Status**	**Launch**
Flight -1	Operating	4/4/83
Flight-2	Lost with Challenger	1/28/86
Flight-3	Operating	9/29/88
Flight-4	Operating	3/13/89
Flight-5	Operating	8/2/91
Flight-6	Operating	1/13/93
Flight-7	Stored	7/13/95
Flight-8 (Boeing)	Stored	6/30/00
Flight-9 (Boeing)	Stored	3/8/02
Flight-10 (Boeing)	Operating	12/5/02

TDRS 'Firsts'

- The largest, most complex communication satellite in orbit in 1983
- The first successful high data-rate communication exchange between two unmanned orbiting satellites.
- First communications satellite with simultaneous three-band frequency service.
- Carried the first three-way international video teleconference between President Ronald Reagan, West German Chancellor Helmut Kohl and the Space Shuttle astronauts.
- The first geosynchronous spacecraft to receive signals from a quasar.
- Many communication and data firsts with the Spacelab, Skylab and Space Shuttle programs.

Customer

NASA, through its Goddard Space Flight Center's Mission Services Program Office.

TDRS - The Next Generation

Growing by 30 percent a year, TDRSS capacity is now at a tipping point. Projected demand requires four more satellites to service many new users who have new and diverse requirements including the desire to operate in a fourth communication frequency band. A NASA Request for Proposal is expected in March 2007 for the design, development, fabrication integration, test and on-orbit acceptance of two satellites, with an option for two more. Planned launch dates are 2012, 2013 and 2015 and 2016 for the option. According to NASA, a contract will be awarded in August, 2007.