

Tracking and Data Relay Satellite (TDRS) K Program Code 454

ON-ORBIT ACCEPTANCE TEST REQUIREMENTS

EFFECTIVE: 04/16/2007
EXPIRES: 04/15/2012

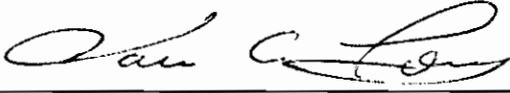


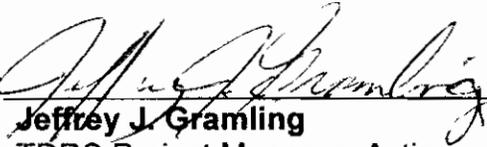
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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-	INITIAL RELEASE	J GRAMLING	04/16/2007

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CONFIGURATION MANAGEMENT (CM) FOREWORD

This document is a Tracking and Data Relay Satellite (TDRS)-K Project Configuration Management-controlled document. Changes to this document require prior approval of the TDRS Project Manager. Proposed changes shall be submitted to the TDRS Configuration Management Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

Requirements conventions are as follows: a requirement is identified by “shall,” a good practice by “should,” permission by “may,” expectation by “will,” and descriptive material by “is” or “are.”

Questions or comments concerning this document should be addressed to:

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1.0 GENERAL

Verification is the process of confirming the functional, performance, and operational requirements of the Tracking and Data Relay Satellite (TDRS)-K System as delivered by the Contractor. All requirements defined within all TDRS K Specifications and Interface Control Documents (ICDs), including contractor-derived system, subsystem, and component level specifications, shall be verified. Acceptable methods of verification shall be testing, analyses, demonstration, and inspection. Evidence of verification shall consist of all simulations, test results and analyses. The TDRS K on-orbit test program may begin upon separation of the spacecraft from the launch vehicle.

The contractors' on-orbit verification program shall include the activation and calibration of the spacecraft and payload. In addition the verification program shall consist of all systems engineering design analyses and analysis of on-orbit test data as defined by the following plans and test procedures:

- a. Flight Operations Verification and Acceptance Plan
- b. Spacecraft On-Orbit Acceptance Test Procedures

The On-Orbit Acceptance Data Package report shall provide the data, analysis, and narrative that describes and evaluates the measured on-orbit performance against requirements.

1.1 SCOPE

This document establishes the minimum on-orbit acceptance test requirements for the TDRS K System as depicted in Figure 1-1 "Verification Hierarchy". The primary sources of requirements to be verified are the "Spacecraft Technical Requirements Specification", the "TDRS K Ground System Requirements Specification", TDRS K Mission Assurance Requirements, and the contractor derived specifications.

A list of abbreviations and acronyms and a glossary are included at the back of this document. The glossary provides definitions of words and phrases used in this document. Requirements terminology is also defined below.

- a. Shall - The verb shall is used to express requirements.
- b. Will - Should, May. The verbs will, should, may and similar verbs are used to help the reader understand requirements. These words do not express requirements.
- c. TBR. To be resolved; contractor design requirement is subject to NASA concurrence.
- d. TBP. To be proposed by the contractor.

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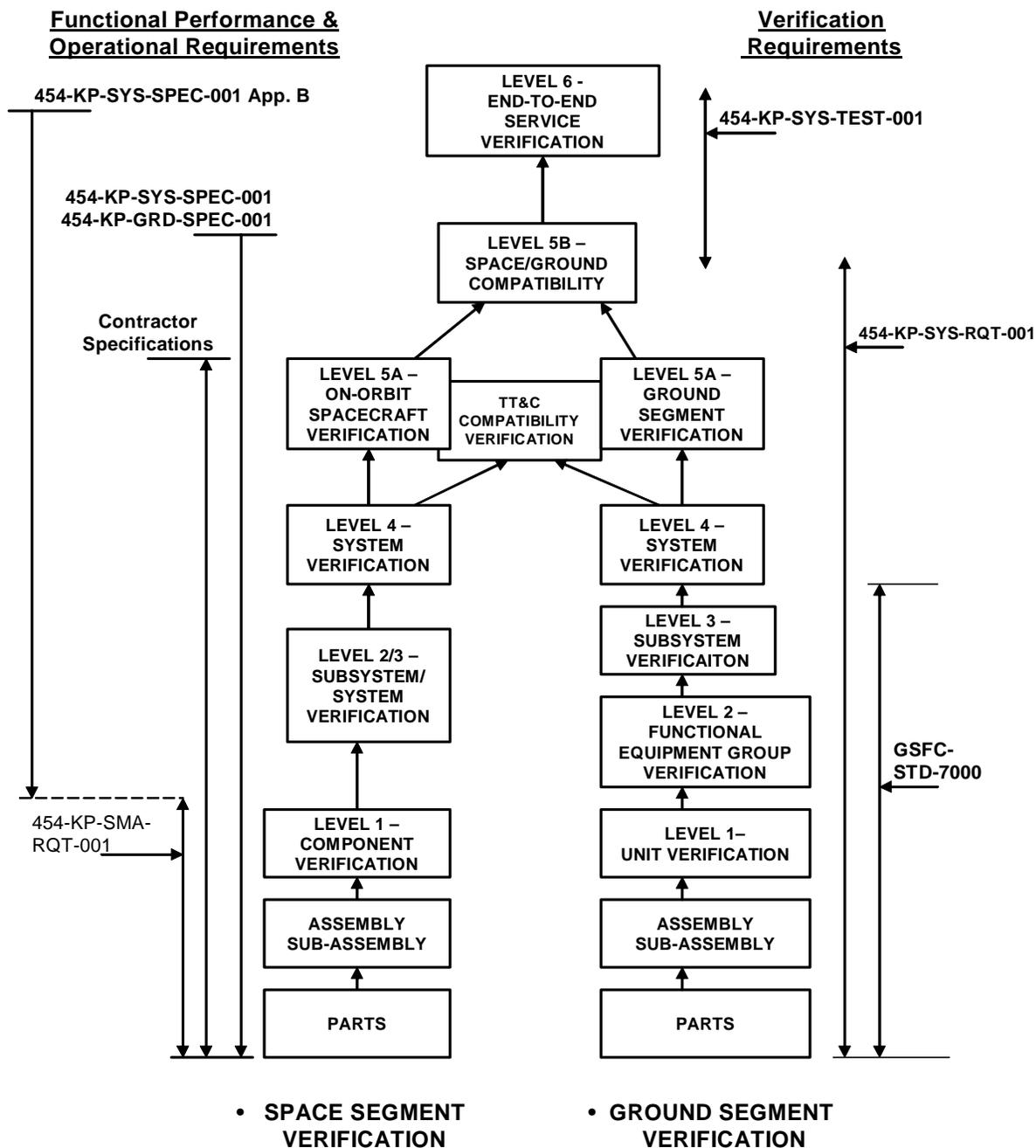


Figure 1-1: Verification Hierarchy

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1.0 APPLICABLE DOCUMENTS

The following documents are applicable to the extent cited herein. In the event of a conflict between this document and those listed below, all cited documents take precedence except GSFC-STD-1000 which has been tailored.

454-KP-SYS-SPEC-001	TDRS K Program Spacecraft Technical Requirements Specification
454-KP-GRD-SPEC-001	TDRS K Program White Sands Complex (WSC) Ground Terminal Requirements
GSFC-STD-1000	Rules for the Design, Development, Verification, and Operation of Flight Systems, Revision C.2, 12 December 2006.
454-KP-SYS-RQT-002	TDRS K Program GSFC Rules Compliance Matrix
GSFC-STD-7000	General Environmental Verification Standard, issued April 2005
454-KP-SMA-RQT-001	TDRS K Program Mission Assurance Requirements (MAR)
454-KP-SYS-RQT-001	TDRS K Program Verification and Validation Requirements

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3.0 GENERAL REQUIREMENTS

3.1 GENERAL VERIFICATION REQUIREMENTS

- a. The on-orbit test program shall verify that the spacecraft is fully compliant with all spacecraft specifications, including verification of all ground station operational interfaces.
- b. On-orbit spacecraft performance shall be verified by a comprehensive test program covering the performance of all subsystems, supplemented by appropriate analyses.
- c. All measurable on-orbit requirements defined within all TDRS K Program specifications and Interface Control Documents (ICDs), including all contractor-derived system, subsystem and component level specifications, shall be verified in accordance with this document.
- d. Methods to be used for verification include testing, analysis, and demonstration.
- e. All test measurements shall be evaluated against pass/fail criteria established before the start of each test. The pass/fail criteria shall be approved by NASA. Measurement values shall be recorded.
- f. Functional performance testing shall be conducted to demonstrate that the hardware and software and their redundant elements meet their performance requirements in all on-orbit operational modes.
- g. Turn-on capability of all components shall be demonstrated.
- h. Each component (including redundant components) shall demonstrate failure-free performance through at least one diurnal cycle of the on-orbit environment.
- i. All Attitude Control System (ACS) spacecraft modes shall be verified by test
- j. Subsystem testing shall include exercise of all functions and modes.
- k. All redundancy shall be verified by test.

3.2 WHITE SANDS COMPLEX (WSC) GROUND STATION TEST EQUIPMENT REQUIREMENTS

- a. All test equipment, including test software, shall be fully checked out and calibrated before use in the on-orbit spacecraft verification program.
- b. The measurement accuracy of all test equipment and test set-ups shall be verified to meet the test measurement required accuracy.
- c. Ground terminal (Space-Ground Link Terminal) SGLT antenna gain calibrations shall be performed prior to the start of the on-orbit verification.
- d. End to End Test terminals (S, Ku & Ka-Band) including the antennas and associated test equipment shall be calibrated daily prior to the start of the on-orbit verification.

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4.0 SPACECRAFT SUBSYSTEM REQUIREMENTS

In addition to the above, the performance of each major spacecraft subsystem shall be functionally verified, including the following verifications and characterizations.

4.1 POWER AND ELECTRICAL SUBSYSTEM REQUIREMENTS

- a. The output power of the solar arrays shall be measured and compared to predictions.
- b. Battery calibrations shall be performed.

4.2 STRUCTURE AND MECHANISM SUBSYSTEM REQUIREMENTS

- a. The mechanical function of spacecraft mechanisms shall be verified by necessary functional performance or test. This shall include verification of proper appendage deployments.
- b. The spacecraft dynamic response to each appendage deployment shall be recorded and compared to analytical predictions.
- c. The center of gravity of each spacecraft shall be verified by test after the spacecraft has reached the geo-synchronous orbit and is located at the test location (150° West).
- d. Control of each Single Access (SA) antenna shall be verified over the entire specified range of motion.
- e. Control of the Space-Ground Link (SGL) antenna shall be verified over the specified range of motion.

4.3 TT&C SUBSYSTEM REQUIREMENTS

- a. Ground station command and telemetry monitoring of on-orbit TDRS K Program spacecraft including S and Ku-band Tracking, Telemetry, and Command (TT&C) shall be verified.
- b. All spacecraft commanding and telemetry modes and rates shall be verified by test, including those using collocation frequencies. These tests shall be performed in both clear and secure configurations of the Communications Security (COMSEC) system.
- c. Final verification of the TT&C subsystem (including Emergency Time Out [ETO]) shall be accomplished after payload activation.

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4.4 ON-BOARD COMPUTER AND FLIGHT SOFTWARE SUBSYSTEM REQUIREMENTS

- a. The ability to load and dump spacecraft memory shall be verified.

4.5 ATTITUDE CONTROL SUBSYSTEM REQUIREMENTS

- a. ACS testing shall verify proper operation of all ACS modes, excluding end of life mode.
- b. Entry into all ACS modes and return to Normal Mode shall be verified by test.
- c. Momentum management and control shall be verified on-orbit.
- d. All attitude sensor and actuator calibrations shall be verified.
- e. Sun acquisition and earth acquisition shall be performed with all appendages deployed. If applicable, other sensor acquisition shall be demonstrated.

4.6 PROPULSION AND REACTION CONTROL SUBSYSTEM REQUIREMENTS

- a. Torque calibration measurements shall be made on each thruster.
- b. The temperature profile of each thruster during normal thruster operation shall be characterized.
- c. The propellant budget shall be verified to satisfy the 15 year mission life requirement.

4.7 THERMAL SUBSYSTEM REQUIREMENTS

- a. All temperature sensor measurements shall be compared to predicted values for the actual spacecraft mode and on-orbit environment. As a minimum, ascent, service, safe-hold and storage mode temperature data shall be correlated with the predicted values.

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5.0 PAYLOAD ACTIVATION AND CALIBRATION

5.1 SPACECRAFT ANTENNA CALIBRATIONS

- a. Antenna azimuth and elevation pattern cuts shall be performed and used to verify that the Multiple Access (MA), SGL and SA antennas have not degraded.
- b. The Multiple Access (MA) phase array antennas shall be calibrated, including verification of the operation of the ground based beam-forming function.
- c. Antenna data over the frequency range and polarization shall be collected. Polarization isolation shall be demonstrated via test.
- d. Antenna calibration data shall be used to update the White Sands Complex (WSC) databases and certify proper antenna pointing function.
- e. Program track for all services shall be verified.
- f. SA antenna Ku and Ka-Band autotrack performance shall be verified. Autotrack acquisition and steady state autotrack shall be included in the verification program for different polarization and shall include different frequencies for the Ka-Band verification.

5.2 PAYLOAD EQUIPMENT ACTIVATION, CHARACTERIZATION AND CHANNEL EVALUATION

The Telecommunication payload activation and verification shall include but not be limited to the following:

- a. Carrier to noise measurements and Antenna Gain to System Temperature ratio validation.
- b. Transmit power verification, Effective Isotropic Radiated Power (EIRP) validation over the specified transmit power range.
- c. Frequency response, and gain flatness for all services.
- d. S and Ka-Band frequency tuning validation for forward and return equipment. Ka-Band tuning tests shall include the Ka-band Return wide band configuration.
- e. Demonstration of minimum self-interference between ETO TT&C equipment and S-band Payload equipment.
- f. Demonstration of S-band SA service minimum self-interference due to wrap-around of forward and return signals. SA equipment tuned for worst case turn-around such as forward equipment is tuned high (2100 MHz) and return equipment is tuned low (2200 MHz).
- g. Verification that all spurious and inter-modulation products are meeting specifications

5.3 SPACECRAFT/WSC GROUND STATION COMPATIBILITY VERIFICATION

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The contractor shall verify spacecraft/ground terminal compatibility using the operational system including space segment and ground segment. The WSC End-to-End Terminal (EET) terminal will be used to simulate users.

- a. The contractor shall verify user services via the TDRS K Program spacecraft. User service requirements are specified in Appendix B of 454-KP-SYS-SPEC-001 and include:

- (1) All forward services: MA, S-Band Single Access (SSA), KuSA and KaSA
- (2) All return services: MA including MA Demand Access Service (DAS) services, SSA, KuSA and KaSA
- (3) All TT&C services.
- (4) All user tracking services.

The service evaluation tests shall included as a minimum, bit error rate, carrier to noise ratio, one way Doppler and two way Doppler evaluation.

- b. Demonstration of Ku and Ka-Band services shall be conducted in the presence of spacecraft dynamic environments such as solar array start/stop of slews, thruster firings, momentum unloads, and SA antenna slews.

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6.0 SPACE NETWORK END-TO-END SERVICE VERIFICATION

- a. The contractor shall support NASA in verifying end-to-end service requirements between operational User Satellites (USATs) and user Payload Operations Control Centers (POCCs). End-to-end service requirements are specified in Appendix B of TDRS-KP-SYS-SPEC-001. This support shall include:
 - (1) Review and analysis of test data
 - (2) Test anomaly resolution
- b. The SN end-to-end service test will verify the functional and performance requirements of operational interfaces to support user services.
- c. The SN end-to-end service test will include handover operations between the operational TDRS F1-F10 and TDRS K Program spacecraft.
- d. The SN end-to-end service test will include ground segment control and monitoring of on-orbit TDRS and TDRS K Program telecommunications payloads under Network Control Center Data System (NCCDS) scheduling and control.
- e. The SN end-to-end service test will demonstrate ground segment and space segment performance using a fully-loaded testing scenario which schedules the maximum simultaneous service capability.
- f. The SN end-to-end service test will be performed at the WSC.
- g. The SN navigation certification and other orbit determination/tracking service evaluations will be performed as required.

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APPENDIX A: ABBREVIATIONS AND ACRONYMS

ACS	Attitude Control System
ADPE	Automatic Data Processing Equipment
CCB	Configuration Control Board
CCR	Configuration Change Request
CMO	Configuration Management Office(r)
COMSEC	Communications Security
CPT	Comprehensive Performance Tests
DAS	Demand Access Service
DCN	Document Change Notice
DSN	Deep Space Network
EET	End-to-End Terminal
EGSE	Electronic Ground Support Equipment
EIRP	Effective Isotropic Radiated Power
ETO	Emergency Time Out
FDL	Flight Dynamics Facility
GSFC	Goddard Space Flight Center
GSTDN	Ground Spaceflight Tracking and Data Network
G/T	Antenna Gain to System Noise Temperature Ratio
ICD	Interface Control Document
I&T	Integration and Test
KM	Kilometers
MA	Multiple Access
MHz	Megahertz
NASA	National Aeronautics and Space Administration
NCC	Network Control Center
POCC	Payload Operations Control Center
RF	Radio Frequency
SA	Single Access
SEC	Second
SGL	Space-Ground Link
SGLT	Space-Ground Link Terminal
SN	Space Network
SSA	S-Band Single Access
STGT	Second TDRSS Ground terminal
TBP	To Be Proposed
TBR	To Be Resolved
TDRS	Tracking and Data Relay Satellite
TOCC	TDRS Operations Control Center
TT&C	Tracking, Telemetry and Command
USAT	User Satellite
WSC	White Sands Complex
WSGT	White Sands Ground Terminal

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APPENDIX B: GLOSSARY

Acceptance Tests - Relative to the on-orbit case, it is the process that demonstrates that hardware is acceptable for on-orbit service. It also serves as a quality control screen to detect deficiencies to provide the basis for acceptance of the spacecraft.

Autotrack - A method of pointing a receive antenna beam wherein a pointing error is measured by observing a received signal and corrected. (see steady-state autotrack)

Autotrack Acquisition - Refers to the condition in which the autotrack error signals are being used to maintain continuous alignment of the SAA boresight axes with the USAT. with an accuracy sufficient to provide the required autotrack mode EIRP specified for forward service.

Channel - Link subdivision used for information transfer and/or USAT range measurement. Examples include I and Q channels, sub-carriers and frequency slots in FDM systems. (See also *RF Channel*.)

Collocation - Placement of two geostationary satellites into orbits having nodal crossings within $\pm 0.1^\circ$ of the same assigned longitude. The two orbits generally have different inclinations.

Command Channel - Channel of the forward link used for transferring commands from a ground terminal to a User Satellite (USAT).

Component - A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are transmitter, gyro package, actuator, motor, and battery.

Configuration - The functional and physical characteristics of parts, assemblies, equipment or systems, or any combination of these which are capable of fulfilling the fit, form, and functional requirements defined by performance specifications and engineering drawings.

Configuration Control - The systematic evaluation, coordination, and formal approval/disapproval of proposed changes and implementation of all approved changes to the design and production of an item the configuration of which has been formally approved by the contractor or by the purchaser, or both.

Co-orbiting USATs - Two or more USATs located at the same nominal point in space and having the same nominal trajectories.

Critical Command - A command which, if inadvertently executed, could cause damage to a spacecraft subsystem or permanently degrade a user service.

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Electromagnetic Compatibility - The condition that prevails when various electronic devices are performing their functions according to the requirements in a common electromagnetic environment.

End-to-End Tests - Tests performed on the integrated ground and flight system to demonstrate that the entire system is operating in a manner to fulfill all mission requirements and objectives.

Failure - See *Nonconformance*.

Faraday Cage - The Faraday Cage is a conductive grounded enclosure designed to attenuate RF fields resulting from normal spacecraft operation and electrostatic discharges that might occur on external services of the spacecraft. The Faraday Cage on the TDRS spacecraft is bounded by the North and South radiators, East/West blankets of the main body, the payload closeout blanket, and the aft closeout blankets including the batteries.

Forward Link - Link from the ground terminal through a TDRS K Program spacecraft to a USAT.

Geostationary Satellite - A geosynchronous satellite with an orbit inclination of $\leq 7^\circ$ less than or equal to 7 degrees. (Note: This definition is consistent with a United States 1990 policy position that regulatory frequency protection for certain communications satellites should extend to satellites with orbit inclinations greater than 5° .)

Geosynchronous Satellite - An earth satellite, the period of rotation for which is equal to the period of rotation of the earth.

I Channel - Data channel supported by 0° to 180° phase modulation of the reference carrier.

Inclination - The angle determined by the plane containing the orbit of an Earth satellite and the plane of the Earth's equator.

Link - Communications path from transmitter to receiver.

Margin - Margin is the difference between allocated value of the quantity (e.g., mass, power, etc.) and the estimated or measured value of a quantity. Margin is usually given in percent, where the numerator is the difference and the denominator is the allocated value of that quantity.

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Mission - As related to a system, refers to the prime intended functions or capabilities. As related to the system specifications, refers to the specified performance characteristics of the system.

Nonconformance - A condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software.

Outgassing - The spontaneous evolution of gas or vapor from a material, and evolution of the decomposition products, in a vacuum.

Part - A hardware element that is not normally subject to further subdivision or disassembly without destruction of designed use.

Payload - Those portions of the TDRS K Program spacecraft that receive, process, frequency convert, amplify, filter and retransmit radio signals to provide telecommunications services to users.

Performance Verification - Determination by test, analysis, inspection or demonstration that a requirement is satisfied.

Pol. 1 - Polarization 1 is the horizontally polarized portion of the SGL downlink.

Pol. 2 - Polarization 2 is the vertically polarized portion of the SGL downlink.

P_{rec} - Space-to-space return link power received by the TDRS K Program spacecraft from a USAT via an isotropic antenna. Total P_{rec} is the P_{rec} of the I channel plus the P_{rec} of the Q channel.

Program Track - A method of pointing a receiver or transmit antenna beam using ephemeris predictions.

Q Channel. Data channel supported by $\pm 90^\circ$ phase modulation of the reference carrier.

Qualification. The process of demonstrating that a given design and manufacturing approach will produce hardware that will meet all performance specifications when subjected to defined conditions more severe than those expected to occur during its intended use.

Reacquisition - (1) Acquisition after loss of carrier and/or sub-carrier lock following initial link acquisition; and (2) acquisition required due to loss of decoding and/or clock synchronization after initial channel acquisition.

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Redundancy ; The use of more than one independent means of accomplishing a given function.

Reliability - The probability that a system, subsystem, component, or part will perform its intended function (1) for a specified period of time and (2) under stated conditions.

Return Link - Link from a USAT through a TDRS K Program spacecraft to the ground terminal.

RF (or IF) Channel - An RF (or IF) path through the relay satellite, the frequency extent of which is limited by filtering within the repeater. Channels are separated from one another by guard bands. A single channel is therefore that frequency-continuous path bounded by guard bands, or by one guard band and the edge of the overall repeater frequency band. The processing of two or more channels in a common circuit or component (such as the preamplifier for example) does not invalidate their identity as separate channels. (See also *Channel*)

Safe-Hold Mode - A non-service providing contingency mode of TDRSS operations in which the satellite autonomously configures and maintains itself in safe thermal and power conditions for an extended period.

Satellite - An individual orbiting structure, including its various functional subsystems, which is separate from the launch vehicle.

Sensor - An electrical, electromechanical, or optical device or instrument for measuring spacecraft attitude and/or motion. Examples are sun sensors, earth sensors, gyroscopes, and magnetometers.

Services - Includes forward and return telecommunications services, tracking services and end-to-end test services provided by TDRSS to users.

Single-Event Upset (SEU)-Induced Anomaly - An interruption or disruption of service caused by SEU (as opposed to a transient data error).

Single Point Failure - A single element of a satellite design, the failure of which would result in loss of mission objectives.

Spacecraft Bus - Those portions of a spacecraft that provide the common services used by the payload and that maintain the health and safety of the spacecraft.

Spacecraft Bus Subsystem - A portion of a spacecraft bus that performs a specific function. The major subsystems of the spacecraft bus are: structure, propulsion and reaction control, attitude control, TT&C, thermal, and power.

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Space-Ground Link (SGL) - A link between a TDRS K Program spacecraft and a ground terminal.

Space-Space Link (SSL) - A link between a TDRS K Program spacecraft and a USAT.

Steady State Autotrack - Refers to the condition in which the autotrack error signals are being used to maintain continuous alignment of the SAA boresight axes with the USAT with sufficient accuracy to provide the required autotrack mode EIRP specified for forward service and the autotrack steady-state G/T specified for return service.

Subsystem - A functional subdivision of a payload consisting of two or more components. Examples are attitude control, electrical power subsystems, and instruments.

TDRS - The tracking and data relay satellites included in the TDRSS baseline architecture (F1 through F10)).

TDRS K Program Spacecraft - The tracking and data relay satellites specified in this document.

TDRSS - The Tracking and Data Relay Satellite System after completion of the TDRS K Program procurement including a constellation of TDRS F1 – F10, TDRS K Program spacecraft; and the White Sands Complex (WSC), and the Guam Remote Ground Terminal (GRGT) capable of supporting the constellation.

USAT - User satellites and suborbital users such as airplanes, balloons and ground-based transponders.

Useful Life - The sum of the required on-ground storage life, the on-orbit operating life, and the on-orbit storage life of the TDRS K Program spacecraft.

Verification - See Performance Verification.

/("slash") - (1) Indicates two or more entities being considered as one or as partners in a larger entity (e.g., the intrasite/intersite communications system); (2) indicates the partners of an interface (e.g., the space/ground interface); and (3) indicates a ratio (e.g., G/T gain-to-noise temperature ratio, 3 km/sec).

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