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

GODDARD SPACE FLIGHT CENTER (GSFC) RULES COMPLIANCE MATRIX

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

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CONSULT THE TDRS CONFIGURATION MANAGEMENT OFFICE (CMO)
301-286-9043
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

SIGNATURE PAGE

Approved by: ________________________________ Date: 4/16/07

Jeffrey J. Gramling
TDRS Project Manager, Acting
NASA/GSFC, Code 454

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DOCUMENT CHANGE RECORD

Sheet 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
-	INITIAL RELEASE	J GRAMLING	04/16/2007

CONFIGURATION MANAGEMENT (CM) FOREWORD

This document is a Tracking and Data Relay Satellite (TDRS) 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:

TDRS Configuration Manager
TDRS Configuration Management Office
Mail Stop 454
Goddard Space Flight Center
Greenbelt, Maryland 20771

PREFACE

The attached matrix tailors the reference version of GSFC-STD-1000 for the TDRS K Program. The reference version was issued as Rev. C.2 on 12 December 2006.

Requirements not specifically tailored in this document are applicable TDRS K Program Requirements unless superseded by the *Spacecraft Specification* (454-KP-SYS-SPEC-001), the *Ground Specification* (454-KP-GRD-SPEC-001), the *TDRS K Program Mission Assurance Requirements (MAR)* document (454-KP-SMA-RQT-001), or the *TDRS K Program Verification and Validation Requirements* document (454-KP-SYS-RQT-001).

Within the scope of the TDRS K Program procurement, firmware shall consist of two parts, a hardware element, and a software element. References to hardware include the hardware element of firmware, and references to software include the software element of firmware.

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1.01	Requirements Management	A requirements management process shall be developed throughout the lifecycle that includes requirements identification, tracking, and documentation as well as a flow-down and traceability of Level 1 requirements to implementation requirements.	F			
1.02	Development & Implementation of Mission Operations Concept	The Mission Operations Concept and Plan shall be defined and its implementation shall be verified throughout the lifecycle.	F			
1.03	Verification of Mission Requirements	A process that ensures all mission requirements are verified shall be developed.	F			

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1.04	System Modes	System and sub-system (e.g., ACS, FSW, EPS, etc.) modes and states shall be properly identified and verified.	F			
1.05	Single Point Failures	Single point failures that inhibit the ability to fully meet minimum mission success requirements shall be identified, and the risk associated with each shall be characterized, managed, and tracked.	F			
1.06	Resource Margins	Resource margins shall be met in accordance with Table 1.06-1.	F (mass margins TBR)		The offeror shall propose suitable mass margins against launch vehicles proposed consistent with the maturity of his proposed design, In accordance with the objectives of GSFC-STD-1000, the offeror shall identify minimum mass margin requirements to be maintained at PDR and CDR.	

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1.07	End-to-End GN&C Phasing	All GN&C sensors and actuators shall undergo end-to-end phasing/polarity testing after spacecraft integration and shall have flight software mitigations to correct errors efficiently.	F			
1.08	End-to-End Testing	System end-to-end testing shall be performed using actual hardware or simulation, and shall apply from input to instrument(s) through the spacecraft, transmitted to receiving antennas, and through the ground system-- reconciled against what is physically achievable before launch, and consistent with associate mission	F			

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		risk.				
1.09	Test Like You Fly	All GSFC missions shall follow a, "Test Like You Fly (TLYF)--Fly Like You Test" approach throughout all applicable lifecycles.	F			
1.10	Logistics and Spares	All projects shall define a plan for required spare units (including spare EEE parts) that is compatible with available resources and acceptable risk.	F (TBR for flight spares)		Prime Contractor shall propose an approach for flight spares for Govt. approval. Ground spares/logistics shall be compliant with inherent and operational availability requirements.	

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1.11	Qualification of Heritage Flight Hardware	All use of heritage flight hardware shall be fully qualified and verified for use in its new application. This qualification shall take into consideration necessary design modifications, changes to expected environments, and differences in operational use.	F			
1.12	Units of Measurement	All design elements shall be specified and designed to ensure the consistent and compatible use of physical units of measure.	F			

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1.13	Performance Demonstration During Qualification Testing	During qualification testing, hardware shall demonstrate expected (i.e.: within-tolerance) performance over a range of conditions that envelops the worst-case operating parameters anticipated to occur during the planned operational mission. Testing at all levels (system, sub-system, and component) shall have clearly defined pass/fail criteria.	F			

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1.14	Mission Critical Telemetry and Command Capability	Continuous telemetry coverage shall be maintained during all mission-critical events. Mission-critical events shall be defined to include separation from the launch vehicle; power-up of major components or subsystems; deployment of mechanisms and/or mission-critical appendages; and all planned propulsive maneuvers required to establish mission orbit and/or achieve safe attitude. After separation from the launch vehicle, continuous command coverage shall be maintained during all following mission-critical events.	F		Contractor shall justify any exception to this rule, and provide the Government with detailed fault tolerance and "safe-hold" control information for evaluation.	

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1.15	GSE Use at Launch Site	All testing of operations of flight systems at the launch site or in the field shall only use GSE and test configurations that have been previously used with the flight hardware.	F			
1.16	Ground Systems Configuration	Mission-critical software and hardware under configuration control shall be used when I&T and mission operations are performed.	F			

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1.17	Safe Hold Mode	All spacecraft shall have a power-positive control mode (Safe Hold) to be entered in spacecraft emergencies. Safe Hold Mode shall have the following characteristics: (1) its safety shall not be compromised by the same credible fault that led to Safe Hold activation; 2) it shall be as simple as practical, employing the minimum hardware set required to maintain a safe attitude; and 3) it shall require minimum ground intervention for safe operation.	F			

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1.19	Initial Thruster Firing Limitations	All initial thruster firings shall occur with real-time telemetry and command capability. If alternate actuators (e.g. reaction wheels) are present, the momentum induced by initial firings shall be within the alternate actuators' capability to execute safe recovery of the spacecraft.	F			
1.20	Manifold Joints of Hazardous Propellants	All joints in the propellant manifold between the propellant supply tank and the first isolation valve shall be NDE-verified welds.	F			

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1.21	Overpressurization Protection in Liquid Propulsion Systems	The propulsion system design and operations shall preclude damage due to pressure surges ("water hammer"). (Note: See also "Unintended Propellant Vapor Ignition.")	F			
1.22	Purging of Residual Test Fluids	Propulsion system design and the assembly & test plans shall preclude entrapment of test fluids that are reactive with wetted material or propellant.	F			
1.24	Propulsion System Safety Electrical Disconnect	An electrical disconnect "plug" or set of restrictive commands shall be provided to preclude inadvertent operation of components.	F			

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1.26	Safety Inhibits & Fault Tolerance	If a system failure may lead to a catastrophic hazard, the system shall have three independent, verifiable inhibits (dual fault tolerant). If a system failure may lead to a critical hazard, the system shall have two independent, verifiable inhibits (single fault tolerant). Hazards which cannot be controlled by failure tolerance shall have separate, detailed safety requirements that must be met.	F			

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1.27	Propulsion System Overtemp Fuse	Flight fuses for wetted propulsion system components shall be selected such that overheating of propellant will not occur at the maximum current limit rating of the flight fuse. (Note: See also rule 2.06 "System Fusing Architecture.")	F			
1.28	Unintended Propellant Vapor Ignition	Propulsion system design and operations shall preclude ignition of propellants in the feed system.	F			

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1.29	Leakage of Hazardous Propellant	Propulsion systems shall be dual fault tolerant (3 independent inhibits) to external leakage of hazardous propellant, which is a catastrophic hazard. Components where fault tolerance is not credible or practical (e.g. tanks, lines, etc.) shall use design for minimum risk.	F			
1.30	Controller Stability Margins	The Attitude Control System (ACS) shall have stability margins of at least 6 dB for rigid body stability and 30 degrees phase margin, and 12 dB of gain margin for flexible modes.	F			

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1.31	Actuator Sizing Margins	The Attitude Control System (ACS) actuator sizing shall reflect specified allowances for mass properties growth.	F			
1.32	Thruster and Venting Impingement	Thruster or external venting plume impingement shall be analyzed and demonstrated to meet mission requirements.	F			
1.33	Polarity Checks of Critical Components	All hardware shall verified by test or inspection of the proper polarity, orientation, and position of all components (sensors, switches, and mechanisms) for which these parameters affects performance.	F			

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1.34	Closeout Photo Documentation of Key Assemblies	Projects shall produce closeout photographic documentation of key assemblies during the manufacturing process and of the final integrated configuration "as flown."	F			
1.35	Maturity of New Technologies	All technologies shall achieve a TRL 6 by PDR. Not applicable to technology demonstration opportunities.	F			
1.36	Block-Redundant Component Failures	Failures in block-redundant components shall not damage the redundant block nor prevent successful switching to the redundant block (where the primary block has failed).	F			

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1.37	Stowage Configuration	When a spacecraft is in its stowed (launch) configuration, it shall not obscure visibility of any attitude sensors required for acquisition, and it shall not block any antennas required for command and telemetry.	F			
1.38	Configuration Command Confirmation	Every configuration command shall have a direct telemetry confirmation and a secondary indirect confirmation.	F			

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2.01	Flight Electronic Hardware Operating Time	One thousand (1000) hours of operating/power-on time shall be accumulated on all flight electronic hardware (including all redundant hardware) prior to launch, of which at least 200 hours shall be in vacuum. The last 350 hours of operating/ power-on time shall be failure-free.	TBR		Contractor shall propose and justify tailoring based on previously qualified components, RF components, Digital components, Power control components, ACS components, and level of integration (e.g. transponder burn-in > transmitter burn-in) and component type (e.g. TWTA burn-in> SSPA burn-in). The contractor shall justify requirements for components that operate only during launch and/or transfer orbit.	
2.02	EEE Parts Program for Flight Missions	A EEE parts program shall be planned and implemented for all flight missions for the purpose of part selection, de-rating, screening, and overall qualifications.	F			

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2.03	Radiation Hardness Assurance Program	A Radiation Hardness Assurance (RHA) Program shall be planned and implemented for all flight missions to verify component- and system-level radiation hardness by CDR.	F			
2.04	Dedicated Hardware ETU and EGSE	All new developments with TRL 5 or lower at Pre-Phase A shall have a dedicated hardware ETU & EGSE.	F			
2.05	System Grounding Architecture	A system grounding concept shall be developed for all missions.	F			
2.06	System Fusing Architecture	A system fusing architecture shall be developed for all missions, including the payloads. (See also 1.27 "Propulsion System Overtemp	F			

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		Fuse.")				
2.07	End-to-End Test of Release Mechanism for Flight Deployables	A release mechanism test for the flight deployable components shall be performed as an end-to-end system-level test under worse-case conditions and a realistic timeline.	TBR		All TDRS deployments shall be fully characterized including first motion and complete travel. In the 1 G ground test environment, tests may be partitioned into segments, as needed, for example, to provide for necessary G negation..	
2.09	Spectrum Allocation Considerations	National spectrum paperwork shall be developed for all new GSFC missions, as well as analysis of mission compliance with national and international spectrum regulations and recommendations. This will include the	F			

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		determination of what specific carrier frequencies should be recommended for these missions to minimize potential interference.				
2.10	Electronic Design for Flight Missions	All flight mission electronics design and development shall comply with the GSFC Electronics Design and Development Guidelines 500-PG-8700.2.2.	F			
2.11	EMI/EMC Design for Flight Missions	All flight mission systems/subsystems shall comply with EMI/EMC requirements in GEVS Section 2.5.	F			

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2.12	Printed Circuit Board Coupon Analysis	All flight printed circuit boards (PCBs) shall be verified by coupon testing.	F			
2.13	Electrical Connector Mating	Mating of all flight connectors which can not be verified via ground tests, shall be clearly labeled and keyed uniquely, and mating of them shall be verified visually to prevent incorrect mating.	F			
2.14	Capping of Test Points and Plugs	All test points and plugs must be capped or protected from discharge (ESD) for flight.	F			
2.15	Flight and Ground Electrical Hardware	The use of pure tin, cadmium, and zinc plating in flight and ground electrical hardware shall be prohibited	F			

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2.16	Solar Arrays	Solar arrays shall be designed in accordance with 563-PG-8700.2.2, and tested to withstand the environment to which they will be exposed. The q-panel and the array shall be tested under illumination at the highest predicted temperature, and in accordance with AIAA S-111-2005 and AIAA S-112-2005.	F			
2.17	I&T Development Input	Integration and Test discipline test expertise shall be used throughout the product lifecycle.	F			

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3.01	Verification and Validation Program for Mission Software Systems	A thorough verification and validation process shall be applied to all mission software systems. This process shall trace customer/mission operations concepts and science requirements to implementation requirements and system design, and shall include requirements based testing of all mission elements, and end-to-end system operations scenario testing.	F			

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3.02	Elimination of Dead Software/Code	GSFC missions shall not deploy systems containing dead software/code. For purposes of this rule, dead software/code is defined as: "Unreachable Code; Unused Code; Unused Design Capabilities; Unneeded Features in Commercial Code; Test Features; Debug Features; and Meaningless Code".	TBR		Contractor shall justify exceptions based on previously qualified and independently verified flight code.	
3.03	High Fidelity Interface Simulation Capabilities	A software simulation capability shall be provided for each external interface to FSW. Both nominal and anomalous data inputs to FSW shall be configurable in real-time using the procedure language of the FSW test	F			

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		workstation.				
3.04	T&C System Selection Trade Study for Operations Ground System	An engineering trade analysis shall be performed on the selection of the flight operations telemetry and command (T&C) system. This analysis shall define the benefits, costs, and risks associated with each candidate system. The trade shall explicitly address potential reuse of the I&T T&C system, as well as the use of government-provided versus commercial	N/A		TDRS K &L has specified a STDN compatible TT&C interface. This is required for integration into the operational Space Network. Optional system approaches are not under consideration.	

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		systems.				
3.05	Flight / Ground System Test Capabilities	Flight system interface and functional capabilities shall be provided to support ground system development and test, and flight operations development, test and training. These capabilities shall be provided via a combination of one or more spacecraft simulators and the actual spacecraft. The	F			

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		spacecraft capabilities, access time, and schedule required to support ground system/ operations development and test shall be defined by and negotiated with the ground system and operations team.				
3.06	Dedicated ETU for Flight Software (FSW) Testing	An ETU flight data system testbed shall be dedicated to FSW teams specifically for FSW development and test. Such ETUs are supplemented by external interface simulators as specified in Rule 3.03. Hardware and I&T teams shall not plan to use the FSW ETUs for their critical path	F			

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		schedule. The number of flight data system testbed units shall be sufficient to support the FSW development schedule and the overall mission schedule.				
3.07	Flight Software Margin Warnings	Flight software development teams shall adhere to the resource margins specified in Table 3.07-1.	F		Requirement applies except where higher margins are required by TDRS K Program specifications.	
3.09	Software Development Approach	Acquisition and development of software shall be performed in accordance with the requirements of NPR 7150.2. GSFC in-house developments	F			

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		shall use practices documented in GSFC GPG-8700.5 and reflected at the software.gsfc.nasa.gov website.				

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3.10	Flight Operations Preparations and Team Development	Mission preparation tests shall require a minimum of 2 successful end-to-end tests (to include launch and early orbit simulations), and 2 day-in-the-life simulations, and a minimum of 200 hours with the flight ops team running the flight system. Flight operators shall participate as test conductors during integration and test (I&T) at a minimum as specified in the tests above.	F			

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3.11	Long Duration and Failure Free System Level Test of Flight Software	Ground test of the fully integrated FSW system shall include demonstration of error free operations-like scenarios over an extended time period. The minimum duration uninterrupted FSW system-level test (on the highest fidelity FSW testbed) is 72 hours for class A and B, 48 hours for class C, and 36 hours for class D missions respectively.	F		TDRS K is a class B mission.	

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3.12	Visibility of Spacecraft State	Onboard telemetry and downlink priorities shall be defined to unambiguously report the state of the spacecraft and instruments to ground operators early in each ground tracking pass--specifically identifying any faults experienced.	F		Contractor shall propose compliance as a function of mission phase and mode.	

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3.13	Operational Software Redundant Element	The updating of code/software should be limited to a single target memory device under user ground control and monitoring. Under no circumstances shall prime and redundant memories be modified concurrently, or before the operational performance of the change is properly assured in a single unit.	F			

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3.14	Command Procedure Changes	Command procedures and mission databases (on-board and ground) shall be controlled (treated with the same rigor as changes to the flight critical software). This includes formal configuration management, peer review by knowledgeable technical personnel, and full verification with up-to-date simulations wherever possible. (Routine loads to perform nominal operations may require less test rigor.)	F			

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3.15	Test and GSE Software Interfaces	Test and GSE (Ground support Equipment) software that interfaces with or evaluates flight software and hardware shall be acceptance tested before testing with FSW and flight hardware	F			
4.01	Contamination Control, Planning, and Execution	Specific contamination control requirements and processes (such as analytical modeling, laboratory investigations, and contamination protection and avoidance plans) that support mission objectives shall be identified.	F			

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4.03	Structural Analysis and Design Factors of Safety	Structural analysis and design factors of safety shall apply to all systems in accordance with GEVS Section 2.2.5.	F			
4.06	Validation of Thermal Coatings Properties	All thermal analysis shall employ thermal coatings properties validated to be accurate for materials and mission flight parameters over the lifecycle of the mission.	F			
4.07	Solder Joint Intermetallics Mitigation	All materials at a solder joint shall be selected to avoid the formation of potentially destructive intermetallic compounds.	F			

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4.08	Space Environment Effects on Material Selection	Thorough evaluation of the environmental effects of the trajectory paths/orbits shall be assessed for the impact on materials selection and design.	F			
4.09	Mechanical Test Factors and Duration	The project shall employ the mechanical test factors and durations in accordance with Section 2.2.4 of GEVS-SE.	F			
4.10	Minimum Workmanship	All electrical, electronic, and electro-mechanical components shall be subjected to minimum workmanship test levels as specified in GEVS Section 2.4.2.5.	F			

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4.11	Testing in Flight Configuration	Mechanical environmental testing (sine, random & acoustic) of flight hardware shall be performed with the test article in appropriate (e.g. launch, landing, etc.) configuration. Hardware that is to be powered on for launch shall be powered on for testing.	F			
4.12	Structural Proof Testing	Primary and secondary structures fabricated from nonmetallic composites, beryllium, or containing bonded joints or bonded inserts shall be proof tested in accordance with GEVS-SE Section 2.4.1.4.1.	F			

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4.13	Modal Survey Characterization	A modal survey shall be performed for flight hardware that has modes in the frequency range as specified in GEVS-SE Section 2.4.1.2.	F			
4.14	Structural Qualification	Structural tests that demonstrate that flight hardware is compatible with expected mission environments shall be conducted in compliance with GEVS 2.4.	F			

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4.15	Torque Margin	The Torque Margin (TM) requirement defined in GEVS section 2.4.5.3 shall apply to all mechanical functions, those driven by motors as well as springs, etc. at beginning of life (BOL). End of Life (EOL) mechanism performance shall be determined by life testing, and/or by analysis; however, all torque increases due to life test results and/or analysis shall be included in the final TM calculation and verification. Margins shall include all flight drive electronics effects and limitations.	F			

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4.18	Deployment and Articulation Verification	All flight deployables, movable appendages, and mechanisms shall demonstrate full range of motion and articulation under worst-case conditions prior to flight.	F		In the 1 G ground test environment, tests may be partitioned into segments, as needed, for example, to provide for necessary G negation	
4.20	Fastener Locking	All threaded fasteners shall employ a locking feature.	F			
4.22	Precision Component Assembly	When precise location of a component is required, the design shall use a stable, positive location system (not relying on friction) as the primary means of attachment.	F			

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4.23	Life Test	A life test shall be conducted, within representative operational environments, to at least 2x expected life for all repetitive motion devices with a goal of completing 1x expected life by CDR.	F			
4.24	Mechanical Clearance Verification	Verification of mechanical clearances and margins (e.g. potential reduced clearances after blanket expansion) shall be performed on the final as-built hardware.	F			

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4.25	Thermal Design Margins	Thermal design shall provide adequate margin between stacked worst-case flight predictions and component allowable flight temperature limits. Note: This applies to normal operations and planned contingency modes. This does not apply to cryogenic systems.	F			
4.26	Thermal Design Margins - Unplanned Conditions	For credible abnormal conditions, the thermal design shall maintain temperatures with allowable flight temperature (AFT) limits extended by +/- 5C (Flight Acceptance (FA) temperature range).	F			

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4.27	Test Temperature Margins	Components and systems shall be tested beyond allowable flight temperature limits. The margin required for proto-flight thermal vacuum testing is 10C beyond allowable flight temperature limits. Acceptance test margin may be reduced to 5C. For actively controlled systems with selected/variable setpoints, the margin may be reduced to 5C. For active control systems with a fixed setpoint, margin shall be demonstrated by increasing or decreasing (as appropriate) the heat load (internal or external) by at least 30% and still maintain the control temperature.	F			

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4.28	Thermal Design Margin Verification	All subsystems/systems having a thermal design with identifiable thermal design margins shall be subject to a Thermal Balance Test at the appropriate assembly level per GEVS Section 2.6.	F			
4.29	Thermal-Vacuum Cycling	All systems flying in unpressurized areas shall have been subjected to a minimum of eight (8) thermal-vacuum test cycles prior to installation on a spacecraft. Four (4) of these cycles may include cycles at the subsystem or instrument level of assembly.	F			

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5.04	Instrument Testing for Multipaction	Active RF components, such as radars, shall be designed and tested for immunity to multipaction.	F			
5.05	Fluid Systems GSE	Fluid systems GSE used to pressurize flight systems shall be single-fault tolerant against over-pressurizing the flight system.	F			
5.06	Flight Instrument Characterization Standard	Flight instruments and their components shall be characterized for performance over their expected operating temperature range.	N/A			
5.08	Laser Development Contamination Control	All flight laser development shall include an approved laser-specific Contamination Control Plan (CCP).	N/A			

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5.09	Cryogenic Pressure Relief	Stored cryogen systems (and related GSE) shall be single fault tolerant against over-pressurization due to blockage or failure of a relief path.	N/A			

NOTES

1. The Project Manager's assessment should be based on planned compliance with the principle:
   "F" - The project plans to fulfill the principle.
   "N" - The project does not plan to fulfill the principle. "N" always requires the project to request a waiver or deviation.
   "N/A" - The principle does not apply to the project in any phases. (Example: There are no lasers, so rules regarding lasers do not apply).

2. The Project Manager shall include references to any relevant documentation that supports verification of the principle.

3. The Project Manager shall supply comments or a rationale for every principle for which the project does not plan to demonstrate full compliance.

4. The Project Manager shall indicate the ITA waiver or deviation number if applicable.

APPENDIX A – ABBREVIATIONS AND ACRONYMS

ACS	Attitude Control System
AFT	Allowable Flight Temperature
BOL	Beginning of Life
CCP	Contamination Control Plan
CDR	Critical Design Review
CM	Configuration Management
CMO	Configuration Management Office(r)
EEE	Electrical Engineering
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPS	Electrical Power System
ESD	Electrostatic Discharge
ETU	Engineering Test Unit
EOL	End of Life
FA	Flight Acceptance
FSW	Flight Software
GEVS	General Environmental Verification Specification
GN&C	Guidance, Navigation, and Control
GPG	Goddard Procedural Guideline
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
I&T	Integration and Test
NASA	National Aeronautics and Space Administration
NDE	Non-destructive Evaluation
NPR	NASA Procedural Requirements
PCB	Printed Circuit Board

APPENDIX A – ACRONYM LIST (Continued)

PDR	Preliminary Design Review
RF	Radio Frequency
RHA	Radiation Hardness Assurance
TDRS	Tracking and Data Relay Satellite
T&C	Telemetry and Command
TLYF	Test Like You Fly
TM	Torque Margin
TRL	Technology Readiness Level