GODDARD TECHNICAL STANDARD

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Goddard Space Flight Center

Greenbelt, MD 20771

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Superseding GSFC-STD-1000G

Goddard Space Flight Center

Rules for the Design, Development, Verification, and Operation of Flight Systems

Goddard Space Flight Center

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GSFC-STD-1000
Revision H

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INTRODUCTION

Purpose:
The Goddard Open Learning Design (GOLD) Rules specify engineering principles and practices which have evolved in the Goddard community and are intended to describe foundational principles without being overly prescriptive of an implementation "philosophy." Each GOLD Rule specifies requirements in the form of a Rule Statement, along with supporting rationale, and guidance in the form of typical lifecycle phase activities and verifications. The GOLD Rules provide visibility to GSFC Senior Management when a project deviates from standard GSFC "best practices".

Scope:
The GOLD Rules are intended to apply to all space flight projects (and where applicable, associated ground projects) regardless of implementation approach or mission classification (except where explicitly noted). Although not required, an a priori Mission Exceptions List (MEL) may be proposed at the start of a Program and/or Project, to highlight rules which may not apply to that mission. If a MEL is submitted and approved, waivers will not be required for exceptions covered by the MEL unless changes occur to the underlying basis for exception. For rules that include multiple elements (e.g., "test as you fly"), waivers and exceptions are valid for the specific elements indicated in a MEL or waiver and do not constitute a global approval to waive all elements of that rule. Other exceptions that arise during execution of the mission still require waivers, as appropriate. A MEL approved at the program level for multi project programs will be reviewed at key points in the program lifecycle (e.g. at the release of a new Announcement of Opportunity) to validate its applicability for new Projects within that program. Projects may choose not to apply GOLD Rules to internal constituents of Commercial-Off-The-Shelf (COTS) items and Projects should not apply GOLD Rules to standard components with established reliability. (See definition in "Glossary and Acronym Guide" at the end of this document.) Such items should be selected based on (1) successful past history and known vendor capabilities or (2) the fact that the product is the only available solution, in which case, the risk should be assessed and tracked by the project. GOLD Rules apply to commercial (not off-the-shelf) procurements to the extent that the rules are placed into contracts. (Note: by definition, if GSFC chooses to change COTS developer processes for an item, the item is no longer COTS.)

GSFC Rules are governed by **GPR 8070.4**, which also describes the process for submitting waivers. A technical authority designated for each rule will be responsible for requirements validation, rationale verifications, related guidance and lessons learned, and participation in the evaluation of proposed changes and waivers. **Note, for any rule listing multiple owners, the project should work any waiver requests with the owner designated as "primary" and it will be the responsibility of the "primary owner" to get concurrence from the other owners or subject matter experts.**

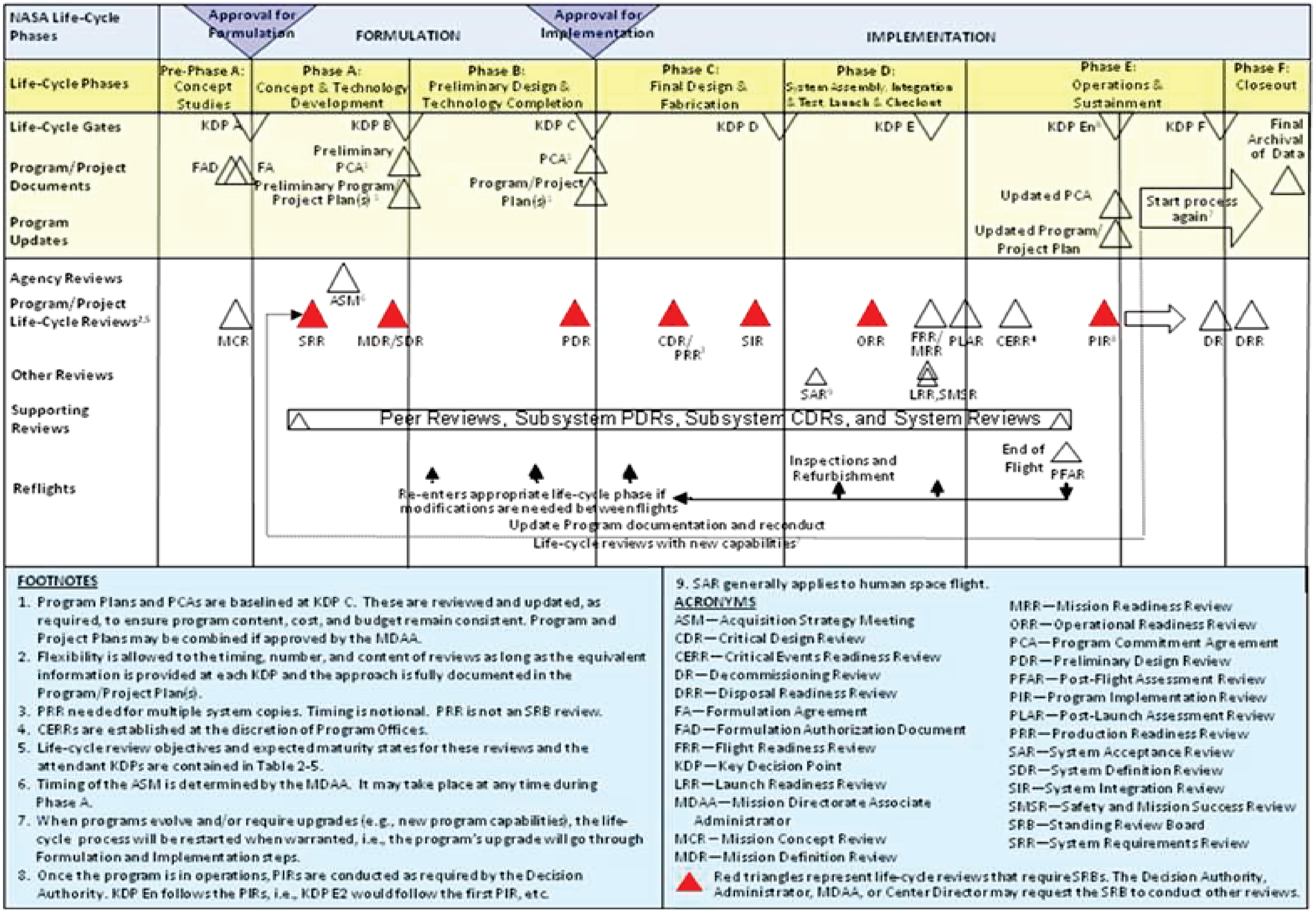

Figure 1 (Reference: NPR 7120.5, The NASA Project Lifecycle)

User's Guide

Rule #	Title				Discipline		
Rule	Rule Statement – The requirement.						
Rationale:	Statement(s) providing justification, clarification and/or context.						
Phase:	<A	A	B	C	D	E	F
Activities:	Rule-associated best practices, within each phase, to ensure compliance (guidance only)						
Verification:	Rule-associated best practices, within each phase, to ensure compliance (guidance only)						
Revision Status: When implemented/modified		Owner: Subject Matter Expert / Technical Authority				Reference: Supporting Materials	

Figure 2

1.05	Single Point Failures				Systems Engineering		
Rule:	Single point failures that prevent the ability to fully meet Mission success requirements shall be identified, and the risk associated with each shall be characterized, managed, and tracked and the system trades necessary to determine the need and effectiveness of mitigation efforts (e.g., redundancy, selection of robust parts, etc.) commensurate with mission class shall be conducted and documented.						
Rationale:	Robust design approaches make the elimination of single point failures desirable. From a risk management perspective, it is recognized that the acceptance of some single point failures may be prudent. In these cases, it is essential to understand the attendant risks and ensure that they are communicated to senior management.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify all requirements necessary for Mission success. 2. Determine if a breach of any of these requirements will cause the mission to fail.	1. Identify failures that would cause the mission to fail and develop a design strategy to avoid single point failures.	1. Identify failures for all hardware and software that performs mission-critical functions. 2. Develop a design to avoid single point failures.	1. Design mission-critical elements to avoid single point failures. 2. Identify and communicate single point failures to stakeholders and review panels 3. Characterize the risk likelihood and consequences of any single point failures 4. Identify mitigation strategies for the single point failures identified	1. Communicate single point failures to stakeholders and review panels. 2. Provide mitigation status of any identified single point failures	N/A	N/A
Verification:	1. Verify or present management exceptions at MCR.	1. Verify or present management exceptions at MDR.	1. Verify or present management exceptions at PDR.	1. Verify or present management exceptions at CDR.	1. Verify or present management exceptions at PER and PSR.	N/A	N/A
Revision Status: Rev. E, Updated Rev G		**Owner:** Mission Engineering and Systems Analysis Division (590)			**Reference:**		

1.06	Resource Margins				Systems Engineering		
Rule:	Mission-level resource margins shall be met in accordance with Table 1.06-1.						
Rationale:	Compliance with these margins improves performance on cost and schedule as well as overall mission performance. NOTE: Flight software margin guidelines are covered in Rule 3.07.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify resource margins. 2. Identify the percent of resource that was determined by estimation, calculation or measurement.	1. Update resource margins. 2. Identify the percent of resource that was determined by estimation, calculation or measurement.	1. Update resource margins. 2. Identify the percent of resource that was determined by estimation, calculation or measurement.	1. Update resource margins. 2. Identify the percent of resource that was determined by estimation, calculation or measurement.	1. Update resource margins.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at ICR and MDR.	1. Verify at PDR and confirmation review.	1. Verify at CDR.	1. Verify at PER and PSR.	N/A	N/A
Revision Status: Rev H.		**Owner:** Mission Engineering and Systems Analysis Division (590)				**Reference:** AIAA S-120A-2015, Mass Properties Control For Space Systems	

Table 1.06-1 Technical Resource Margins

All values are assumed to be at the end of the phase unless otherwise specified

Resource	Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E
Mass *	≥15% at all times before SRR	≥15% at SRR	≥10% at PDR	≥5% at CDR and >2% at SIR	0	
Power (wrt EOL capacity)**	≥25%	≥20%	≥15%	≥10%	≥5%	
Propellant***	3σ***				3σ	
RF Link NSN DTE****/SN SR	>3dB/>0dB	>3dB/>0dB	>3dB/>0dB	>1dB/>0dB	>1dB/>0dB	

* Mass Margin

- Basic mass is the current estimated mass of dry hardware based on an assessment of the most recent design (not including mass growth allowance); in the past also referred to as current best estimate
- Mass Growth Allowance (MGA) is the predicted increase to the basic mass of an item based on an assessment of the hardware category/design maturity/fabrication status in alignment with AIAA S-120A-2015. MGA is applied bottoms-up at the MEL line level by the responsible design engineer (PDL). MGA is not to be assigned top-down.
- Predicted mass = Basic + MGA; in the past also referred to as maximum expected value.
- Allowable mass is the limit against which mass margins are calculated, typically the mass allocation or launch vehicle capacity; in the past, also referred to as Maximum Permissible Value.
- Mass margin = Allowable – Predicted.
- Mass margin (%) = (Allowable-Predicted)/Basic X 100. Note Basic mass is in the denominator in alignment with the AIAA S-120A-2015 definition.
- The terms “reserve” and “contingency” are not to be used in relation to mass margins.
- Margin and MGA apply to dry mass only. Fuel margins are handled through Delta-V margins applied against the predicted mass.
- Requirement is applicable at the mission level. Mission elements/payloads should establish mission-appropriate mass margin guidelines against their allocations.
- Mass margins apply at milestones, not strictly by phase, with ramps between milestones (in alignment with AIAA S-120A-2015).

** Power (against end-of-life) margin (in percent = (available-estimated)/available x 100). At launch there shall be 5% predicted power margin for mission critical, cruise and safing operating modes as well as to accommodate in-flight operational uncertainties.

*** The 3-sigma variation is due to the following: 1. Worst-case spacecraft mass properties 2. 3-sigma low launch vehicle performance 3. 3-sigma low propulsion subsystem performance (thruster performance/alignment, propellant residuals) 4. 3-sigma flight dynamics errors and constraints 5. Thruster failure (applies only to single-fault-tolerant systems)

**** Flight RF Comm Systems using NSN DTE ground stations should be designed for a minimum 3dB link margin for nominal modes of operation. That margin may be reduced for Phase C/D if final hardware performance (flight or ground) is less than expected. Mission users of non-NSN ground stations (commercial, partners, etc.) should use the NSN DTE link guidelines listed here; assumes EOL properties.

1.07	**End-to-End Phasing/Polarity Checks**				**Systems Engineering**		
Rule:	All hardware whose performance is affected by polarity, orientation or position (sensors, switches, mechanisms and actuators) shall be verified by test and inspection for the proper polarity, orientation and position of all components. This includes all GN&C sensors and actuators which shall also undergo full end-to-end (i.e., from sensor stimulus to actuator response) phasing/polarity testing after spacecraft integration in the final flight configuration (hardware and software). All hardware that cannot be fully verified end-to-end in flight configuration shall have flight software mitigations to efficiently correct phasing/polarity errors. The test methodology and results for all polarity/phasing testing shall be independently reviewed.						
Rationale:	Inadequate verification of signal phasing or polarity can result in unexpected on-orbit performance and possible loss of mission. Component-level and end-to-end phasing tests and flight software mitigations can ensure correct operation.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Identify all polarity-dependent components in the preliminary design and define interface requirements for those components. 2. Design flight software to include capability to fix polarity problems via table upload. 3. Ensure that preliminary design provides capability for testing functionality of polarity-dependent components and end-to-end mission system level and develop test plans for those components.	1. Update ICDs to include phasing/polarity definition. 2. Review component-level phasing/polarity test plans. 3. Write flight S/W to include capability to fix phasing/polarity problems via table upload. 4. Create unit-level & end-to-end phasing/polarity test plan.	1. Perform unit-level phasing/polarity tests. 2. Test flight S/W for table upload functionality. 3. Perform end to-end phasing/polarity test for all hardware and hardware combinations. 4. Develop & test contingency flight ops procedures for fixing phasing/polarity problems. 5. Conduct an independent review of the methodology and results	N/A	N/A
Verification:	N/A	N/A	1. Verify through peer review and at PDR.	1. Verify through peer review and at CDR.	1. Verify phasing methodology/results at PSR and FSW/Ops mitigations at ORR.	N/A	N/A
Revision Status: Rev. H		**Owner:** Mission Engineering and Systems Analysis Division (590)				**Reference:**	

1.08	System End-to-End Testing				Systems Engineering		
Rule:	System end-to-end testing shall be performed in the final flight configuration, hardware and software. End-to-end testing shall be from instrument(s) sensor input, through the spacecraft, to a command and telemetry ground system.						
Rationale:	End-to-end testing is the best verification of the system's functionality						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify end-to-end tests that represent system-level functions.	1. Review and update the list of end-to-end tests and analyses identified in Pre-phase A. 2. Define success criteria for verification and incorporate into verification plan. 3. Review and update verification plan and schedule. 4. Identify facilities required for end-to-end testing.	1. Review and update list of end-to end tests and analyses identified in Phase A. 2. Review and update verification plan and schedule. 3. Identify test plans and facilities that need to be in place for end-to-end testing.	1. Draft final verification plan. 2. Sign off on plan, put under CM test schedule. 3. Identify and schedule sequence of analyses and testing for verifying end-to-end flight performance. 4. Quantify the fidelity of each verification step.	1. Perform end-to-end testing per the plan developed in Phase C.	N/A	N/A
Verification:	1. Verify all elements of the operating observatory and ground system at MCR.	1. Verify at MDR.	1. Verify at SDR or SRR, PDR.	1. Verify at CDR.	1. Verify at PSR and LRR.	N/A	N/A
Revision Status: Rev. F, Updated Rev G		**Owner:** Mission Systems Engineering Branch (599)				**Reference:** GEVS 2.9	

1.09	Test as You Fly	Systems Engineering

Rule: All GSFC missions shall follow a "Test as You Fly (TAYF) - Fly as You Test" approach, throughout all applicable life cycle phases. Each deviation to this approach, along with the rationale for the deviation, shall be documented and a waiver submitted. A project may elect to hold an engineering peer review (EPR), chaired by the rule owner or their designate, in the CDR time frame to discuss the expected TAYF exceptions, rationale and associated risks. This EPR can serve as an expedited method for achieving rule owner acceptance of the project's TAYF waivers. The TAYF exceptions list, along with the EPR minutes shall be maintained by the project configuration management systems. Deltas to the list shall be discussed at subsequent milestone reviews. Note: A waiver or exception to this rule will be based only on the specific elements that appear and are approved in the request and is not a global approval to waive TAYF for all elements.

Rationale: Testing of all critical mission-operation elements as they will be flown greatly reduces the risk of encountering negative impacts upon Mission success, from partial to full loss of mission capability.

Phase:	<A	A	B	C	D	E	F
Activities:		1. Develop the preliminary test plan employing a TAYF philosophy.	1. Develop final test plan, employing a TAYF philosophy. 2. Develop a preliminary list of TAYF exceptions, rationale and associated risk.	1. Develop test procedures employing a TAYF philosophy. 2. Submit TAFY exceptions waiver or conduct an EPR with the rule owner.	1. Perform testing per plan / procedures. 2. Document deltas to exceptions list developed in Phase C.	N/A	N/A
Verification:		1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A

Revision Status:	Owner:	Reference:
Rev. H	Mission Engineering and System Analysis Division (590, Primary) and Instrument Systems and Technology Division (550)	

<table>
<tr><td>1.11</td><td colspan="4">Qualification of Heritage Flight Hardware</td><td colspan="3">Systems Engineering</td></tr>
<tr><td>Rule:</td><td colspan="7">All 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.</td></tr>
<tr><td>Rationale:</td><td colspan="7">All hardware, whether heritage or not, must be qualified for its expected environment and operational uses.</td></tr>
<tr><td>Phase:</td><td><A</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>Activities:</td><td>1. Identify/list heritage hardware to be used and make a cursory assessment of "use as is" or delta-qual.
2.Determine life expectancy of the residual spare flight hardware to be used from previous flight projects including implications of obsolete parts.</td><td>1. Update hardware list and identify the qualification requirements.
2. Assess through the peer review process the ultimate applicability of previously flown/heritage hardware designs.</td><td>1. Refine/finalize heritage hardware list and the required qualification requirements.</td><td>1. Qualify heritage hardware as part of overall qualification of mission hardware.</td><td>1. Develop, test, and integrate the flight articles.</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Verification:</td><td>1. Review summary documentation at MCR.</td><td>1. Review summary documentation at MDR.</td><td>1. Review summary documentation at PDR.</td><td>1. Review summary documentation at CDR.</td><td>1. Review summary documentation at PER and PSR.</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="3">Revision Status:
Rev. F, Updated Rev G</td><td colspan="3">Owner:
Mission Systems Engineering Branch (599)</td><td colspan="2">Reference:</td></tr>
</table>

1.14	**Mission Critical Telemetry and Command Capability**				**Systems Engineering**		
Rule:	During time-sensitive events where failure to execute could result in failure to meet mission objectives, event telemetry shall be monitored and downlinked in real-time and/or recorded for downlink later. Mission-critical events include separation from the launch vehicle; power-up of major components or subsystems; deployment of mechanisms and/or mission-critical appendages; initial thruster firings and all planned propulsive maneuvers required to establish mission orbit and/or achieve safe attitude. Following launch vehicle separation, critical deployments, and initial orbit attitude acquisition, continuous command coverage shall be maintained during all subsequent mission-critical events.						
Rationale:	With continuous telemetry and command capability, operators can prevent anomalous events from propagating to mission loss. Also, flight data will be available for anomaly investigations.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify and document potential mission-critical events in concept of operations. 2. Identify and document in concept of operations all potential needs for communications coverage, such as TDRSS or backup ground stations.	1. Update concept of operations. 2. Identify requirements for critical event coverage in ground system design.	1. Address and document coverage of mission critical events in draft of Mission Operations Concept. 2. Address critical event coverage in requirements for ground system design.	1. In Operation Plan, identify telemetry and command coverage for all mission-critical events.	1. Update Operations Plan. 2. Address telemetry and command coverage of critical events in Operations Procedures.	1. Perform critical events with telemetry and command capability.	N/A
Verification:	1. Verify or present exceptions at MCR.	1. Verify or present exceptions at MDR.	1. Verify or present exceptions at PDR.	1. Verify or present exceptions at CDR.	1. Verify or present exceptions at ORR.	1. Verify telemetry capability for events not excepted in Phase D during mission operations.	N/A
Revision Status: Rev. H		**Owner:** Mission Systems Engineering Branch (599)				**Reference:**	

1.17	Safe Hold Mode				Systems Engineering		
Rule:	All spacecraft shall have a power-positive, thermally safe, 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 and (2) it shall employ the minimum hardware set required to maintain a safe attitude.						
Rationale:	Safe Hold Mode should behave very predictably while minimizing its demands on the rest of the spacecraft. This facilitates the survival, diagnosis, and recovery of the larger system. Complexity typically reduces the robustness of Safe Hold, since it increases the risk of failure due to existing spacecraft faults or unpredictable controller behavior.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Ensure that requirements document and operations concept include Safe Hold Mode.	1. Ensure that requirements document and operations concept include Safe Hold Mode.	1. Identify hardware & software configuration for Safe Hold Mode. 2. In preliminary assessment, demonstrate that no single credible fault can both trigger Safe Hold entry and cause Safe Hold failure. 3. Analyze performance of preliminary Safe Hold algorithms.	1. Establish detailed Safe Hold design including entry/exit criteria and FDAC requirements for flight software. 2. In final assessment, demonstrate that no single credible fault can both trigger Safe Hold entry and cause Safe Hold failure. 3. Analyze performance of Safe Hold algorithms. 4. Via a rigorous risk assessment, decide whether or not to test Safe Hold on-orbit.	1. Implement Safe Hold Mode. 2. Verify proper mode transitions, redundancy, and phasing in ground testing. 3. Execute recovery procedures during mission simulations. 4. Perform on-orbit testing if applicable.	N/A	N/A
Verification:	1. Verify through peer review and at MCR.	1. Verify through peer review and at MDR.	1. Verify through peer review and at PDR.	1. Verify through peer review and at CDR.	1. Verify at PER and FOR.	N/A	N/A
Revision Status: Rev. H		**Owner:** Attitude Control Systems Engineering Branch (591)				**Reference:**	

1.19	Initial Thruster Firing Limitations				Systems Engineering		
Rule:	If alternate actuators (e.g., reaction wheels) are present, the momentum induced by initial thruster firings shall be within the alternate actuators' capability to execute safe recovery of the spacecraft. For subsequent firings, the Attitude Control System and Failure Detection and Correction shall be designed to limit excessive momentum beyond the capacity of the RWAs.						
Rationale:	Polarity issues and thruster underperformance typically occur early in the mission. Both conditions can result in a spacecraft emergency due to excessive spacecraft spin rates.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. The Attitude Control System (ACS) Concept shall ensure that thrusters will not be required during launch vehicle separation for a 3-sigma distribution of cases. The concept for operations shall ensure that, except in case of emergency, all thrusters can be test-fired on-orbit prior to the first delta-v maneuver.	1. The Attitude Control System shall design the thruster electronics, size and place the thrusters, and size other actuators (e.g. reaction wheels) such that a failed thruster can be shut down and the momentum absorbed before power or thermal constraints are violated. The activities specified in Pre-Phase A shall be maintained.	1. Hardware (processors, power interfaces, data interfaces, etc.) and software shall ensure that anomalous thruster firings will be shut down quickly enough to allow recovery of the spacecraft to a power-safe and thermal-safe condition. 2. Develop design and operations concept consistent with the activities established in Pre-Phase-A.	1. Establish detailed recovery procedures. Finalize design and operations concept consistent with the activities established in Pre-Phase-A.	1. Test failed thruster conditions with the greatest possible fidelity. Verify transitions and polarity. 2. Ensure that recovery procedures have been simulated with the flight operations team. 3. During on-orbit testing, thrusters shall be test fired to verify polarity and performance prior to being used in a closed loop control.	1. Ground contact shall be maintained during thruster firings.	1. Maintain activity per Phase E. 2. Document any lessons learned.
Verification:	1. GN&C and system engineering organizations shall verify at MCR.	1. GN&C and system engineering organizations shall verify at MDR.	1. GN&C and system engineering organizations shall verify at PDR.	1. GN&C and system engineering organizations shall verify at CDR.	1. GN&C and system engineering organizations shall verify at SAR. 2. Follow-up at Operational Readiness Review (ORR).	1. Document lessons learned.	1. GN&C and system engineering organizations shall verify at DR. 2. GN&C and system engineering organizations document lessons learned.
Revision Status: Rev. H			**Owner:** Attitude Control Systems Engineering Branch (591)			**Reference:**	

1.20	**Wetted Joints of Hazardous Propellants**				**Systems Engineering**		
Rule:	All joints in the propellant lines between the propellant supply tank and the first isolation valve shall be NDE-verified welds.						
Rationale:	Failure of wetted joint poses a catastrophic threat to personnel and/or facility.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Confirm system requirements for welded tubing joints between the propellant supply tank and the first isolation valve.	1. Present weld & technician certification plans and NDE plans.	1. Certify integrity of welds by NDE.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. E, Updated Rev. G		**Owner:** Propulsion Branch (597)				**Reference:**	

1.21	Over Pressurization Protection in Liquid Propulsion Systems				Systems Engineering		
Rule:	The propulsion system design and operations shall preclude damage due to pressure surges ("water hammer"). (Note: See also rule 1.28 "Unintended Propellant Vapor Ignition.")						
Rationale:	Pressure surges could result in damage to components or manifolds, leading to failure of the propulsion system, damage to facilities, and/or safety risk to personnel.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Perform pressure surge analysis, based on worst-case operating conditions, to determine maximum surge pressure. 2. If maximum surge pressure is greater than system proof pressure, incorporate design features to reduce surge pressure below proof pressure.	1. Demonstrate by test that maximum surge pressure is less than proof pressure of the affected components and tubing manifolds. 2. Demonstrate by test that surge-suppression features (if applicable) do not lead to violation of flow-rate/pressure drop requirements. 3. Demonstrate by analysis that flight SW and/or on-orbit procedures will prevent operation of propulsion system beyond conditions assumed in pressure surge analyses and tests.	N/A	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	N/A	N/A	N/A
Revision Status: Rev. E		**Owner:** Propulsion Branch (597)				**Reference:**	

1.22	Purging of Residual Test Fluids				Systems Engineering		
Rule:	Propulsion system design and the assembly & test plans shall preclude entrapment of test fluids that are reactive with wetted material or propellant.						
Rationale:	Residual test fluids can be reactive with the propellant or corrosive to materials in the system leading to critical or catastrophic failure.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. If test fluids are used in the assembled system, present plans for purging & drying of system.	1. Demonstrate that the method for drying the wetted system has been validated by test on an equivalent or similar system.	1. Verify dryness of wetted system by test.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PSR.	N/A	N/A
Revision Status: Rev. E		**Owner:** Propulsion Branch (597)				**Reference:**	

1.23	Spacecraft “OFF” Command			Systems Engineering			
Rule:	No single command shall result in Spacecraft "OFF." This includes both the single string spacecraft case and the redundant spacecraft with one side failed case.						
Rationale:	Requiring multiple actions to power off the spacecraft will mitigate the possibility of an unintentional spacecraft power off.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Complete applicability assessment.	1. Reassess and update applicability. 2. Complete initial compliance assessment, based upon applicability.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in draft technical requirements and Design-To specifications. 3. Define verification approach.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in technical requirements and Design-To specification baselines. 3. Update verification approach.	1. Reassess compliance. 2. Perform verification activity.	N/A	N/A
Verification:	Verify at MCR.	Verify at SRR, MDR	Verify at PDR.	Verify at CDR and SIR.	Verify at ORR, SMSR, and FRR.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G		**Owner:** Mission Systems Engineering Branch (599)			**Reference:**		

1.24	Propulsion System Safety Electrical Disconnect				Systems Engineering		
Rule:	An electrical disconnect "plug" and/or set of restrictive commands shall be provided to preclude inadvertent operation of propulsion system components.						
Rationale:	Unplanned operation of propulsion system components (e.g., “dry” cycling of valve; heating of catalyst bed in air; firing of thrusters after loading propellant) can result in injury to personnel or damage to components.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Present design and/or operational plan that preclude unplanned operation of propulsion system components.	1. Present detailed design of electrical disconnect and/or set of restrictive commands to preclude unplanned operation of propulsion system components. 2. Present detailed plan for verification of operation after installation for flight (for electrical disconnect plugs). See rule 2.25, Electrical Interface Verification.	1. Demonstrate the effectiveness of the disconnect and/or set of restrictive commands by test.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. E, Updated Rev. G		**Owner:** Propulsion Branch (597)				**Reference:**	

1.25	Redundant Systems				Systems Engineering		
Rule:	When redundant systems or functions are implemented, the redundant components, or functional command paths, shall be independent, such that the failure of one component or command path does not affect the other component or command path. The design shall avoid routing of redundant power/signals through a single connector, relay, integrated circuit or other common interface.						
Rationale:	For redundancy to have its desired effects to enhance system reliability, care must be taken to maintain independence between the redundant and primary systems.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Complete applicability assessment.	1. Reassess and update applicability. 2. Complete initial compliance assessment, based upon applicability.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in draft technical requirements and Design-To specifications. 3. Define verification approach.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in technical requirements and Design-To specification baselines. 3. Update verification approach.	1. Reassess compliance. 2. Perform verification activity.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at SRR, MDR, and PNAR.	1. Verify at PDR and NAR.	1. Verify at CDR and SIR.	1. Verify at ORR, SMSR, and FRR.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G		**Owner:** Mission Systems Engineering Branch (599)				**Reference:**	

<table>
<tr><td>1.27</td><td colspan="4">Propulsion System Overtemp Fuse</td><td colspan="3">Systems Engineering</td></tr>
<tr><td>Rule:</td><td colspan="7">Flight fuses (or other over-current protection devices) for wetted propulsion system components shall be derated per Table 4 of Section F3 of EEE-INST-002 relative to the current at which overheating of propellant will occur. (Note: See also rule 2.06 "System Fusing Architecture.")</td></tr>
<tr><td>Rationale:</td><td colspan="7">Propulsion components such as pressure transducers normally draw very low current, and therefore their fuses are usually oversized. In such cases it may be possible for a malfunctioning component to overheat significantly without exceeding the rating of the fuse. Any wetted component (i.e., in addition to fuses) that could be continuously powered should also be considered. Exceeding the auto-ignition temperature of propellant can result in mission failure or critical/catastrophic hazard to personnel and facility.</td></tr>
<tr><td>Phase:</td><td><A</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>Activities:</td><td>N/A</td><td>N/A</td><td>1. Present fusing plan for wetted propulsion system components.</td><td>1. Present mitigation plan and/or over-current thermal analysis to show that wetted components will not exceed maximum allowable temperature of propellant at the maximum current limit rating for the flight fuse.
2. Verify that a single failure within the drive electronics of pulsed components will not result in the pulse components being continuously powered.</td><td>1. Verify by inspection of QA records that the correct flight fuse has been installed.</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Verification:</td><td>N/A</td><td>N/A</td><td>1. Verify at PDR.</td><td>1. Verify at CDR.</td><td>1. Verify at PER or PSR.</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="3">Revision Status:
Rev. E, Updated Rev. G</td><td colspan="3">Owner:
Propulsion Branch (597)</td><td colspan="2">Reference:
EEE-INST-002</td></tr>
</table>

1.28	Unintended Propellant Vapor Ignition			Systems Engineering			
Rule:	Propulsion system design and operations shall preclude ignition of propellants in the feed system.						
Rationale:	Ignition of propellant vapor can occur due to a variety of conditions including (1) mixing of fuel and oxidizer in pressurant manifolds via diffusion and condensation; (2) pyrotechnic valve initiator products entering propellant manifolds; (3) adiabatic compression of gas due to pressure surges, i.e., "water hammer" effects. These conditions can cause hardware damage and/or mission failure.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Present design analysis, including pyro valve firing sequence and/or propellant line initial pressurization, supporting mitigation of conditions for ignition of propellant vapors. 2. For bipropellant systems, demonstrate by analysis that the design provides adequate margin against diffusion and condensation of propellant vapors in common manifolds.	1. Demonstrate by analysis or test that pyro valve firing sequence and/or propellant line initial pressurization plan will not promote conditions for ignition of propellant vapor. 2. For bipropellant systems, demonstrate by test that selected pressurant system components exhibit vapor diffusion resistance per the Phase B analysis.	N/A	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.		N/A	N/A
Revision Status: Rev. E		**Owner:** Propulsion Branch (597)			**Reference:**		

1.30	Controller Stability Margins				Systems Engineering		
Rule:	The Attitude Control System (ACS) shall have stability margins of at least 6db for rigid body stability with 30 degrees phase margin. The magnitude of the flexible modes transmission in the open-loop transfer function shall be less than minus 12dB.						
Rationale:	Proper gain and phase margins are required to maintain stability for reasonable unforeseen changes and uncertainty in spacecraft configuration.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify in the Attitude Control System (ACS) Concept if the gain and phase margin requirements will be difficult to meet due to the spacecraft configuration.	1. Update the ACS concept and identify if the gain and phase margin requirements will be difficult to meet due to the spacecraft configuration.	1. Design all control modes so that the rigid body stability margins are at least 6 dB of gain margin and 30 degrees of phase margin. 2. Ensure that the magnitude of the flexible modes in the open-loop transfer function is less than minus 12dB.	1. Stability analyses should include all flexible mode effects, sample data and delay effects (and other nonlinear effects such as fuel slosh) incorporated with adequate evaluation of mode shape, damping and frequency uncertainties.	1. Verify that the stability analyses presented at CDR encompass the "as built" mass properties and flexible body models. 2. Update CDR analyses if necessary to verify that stability margin requirements are met.	N/A	N/A
Verification:	1. GN&C and system engineering organizations verify at MCR.	1. GN&C and system engineering organizations verify at MDR.	1. GN&C and system engineering organizations verify at PDR.	1. GN&C and system engineering organizations verify at CDR.	1. GN&C and system engineering organizations verify at PSR.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. F, Updated Rev. G	Attitude Control Systems Engineering Branch (591)	ACS Handbook

1.31	Actuator Sizing Margins				Systems Engineering		
Rule:	The Attitude Control System (ACS) actuator sizing shall reflect specified allowances for mass properties growth.						
Rationale:	Knowledge of spacecraft mass and inertia can be very uncertain at early design stages, so actuator sizing should be done with the appropriate amount of margin to ensure a viable design.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. ACS actuators (including propulsion) shall be sized for the current best estimate of spacecraft mass properties with 100% design margin.	1. ACS actuators (including propulsion) shall be sized for the current best estimate of spacecraft mass properties with 50% design margin.	1. ACS actuators (including propulsion) shall be sized for the current best estimate of spacecraft mass properties with 25% design margin.	N/A	N/A	N/A
Verification:	N/A	1. GN&C and system engineering organizations shall verify at MDR.	1. GN&C and system engineering organizations shall verify at PDR.	1. GN&C and system engineering organizations shall verify at CDR.	N/A	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. F	Attitude Control Systems Engineering Branch (591)	ACS handbook

1.32	Thruster and Venting Impingement			Systems Engineering			
Rule:	Thruster or external venting plume impingement shall be analyzed and demonstrated to meet mission requirements.						
Rationale:	Impingement is likely to contaminate critical surfaces and degrade material properties and can also create adverse and unpredictable S/C torques and unacceptable localized heating.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Develop analytical mass transport model. 2. Update as design evolves.	1. Refine analysis based on updated designs.	1. Refine analysis based on updated designs. 2. Measure venting rates during T/V tests and verify analysis.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PSR.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. F	Mission Engineering and Systems Analysis Division (590)	

1.37	Stowage Configuration				Systems Engineering		
Rule:	When a spacecraft is in its stowed (launch) configuration, it shall not obscure visibility of any attitude sensors required for acquisition and shall not block any antenna required for command and telemetry.						
Rationale:	Establishment of spacecraft communications and acquisition of safe attitude are the two highest-priority post-separation activities and should not be dependent on completion of deployments.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Demonstrate by inspection that mechanical subsystem concept allows for full visibility of sensors and telemetry & command antennas.	1. Demonstrate by field-of-view analysis that mechanical subsystem preliminary design allows for full visibility of sensors and telemetry & command antennas.	1. Demonstrate by field-of-view analysis that mechanical subsystem detailed design allows for full visibility of sensors and telemetry & command antennas.	1. Ensure during I&T that mechanical subsystem detailed design allows for full visibility of sensors and telemetry & command antennas.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. E		**Owner:** Mission Systems Engineering Branch (599)				**Reference:**	

1.39	**Propellant Sampling in Liquid Propulsion Systems**				**Systems Engineering**		
Rule:	Liquid propellant quality shall be verified by sampling at point of use prior to loading spacecraft propulsion system.						
Rationale:	Contaminated propellant could result in damage to components or manifolds, leading to failure of the propulsion system with a potential impact on mission success. If detected after loading propellant into the flight system, purging and cleansing the propulsion system of contaminants would incur significant cost and result in launch delay.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Ensure propellant sampling is included in project planning.	1. Include propellant sampling requirements in the propulsion system design process including the design of the GSE. 2. Include discussions of propellant sampling requirements in Ground Operations Working Group (GOWG).	1. Incorporate propellant sampling in development of fuel loading procedures. 2. Incorporate propellant sampling considerations into fuel loading equipment selection/design. 3. Include propellant sampling and analysis requirements in GOWG discussions.	1. Analyze samples to demonstrate the propellant meets quality standards 2. Ensure adequate propellant flow through the entire propellant loading system to detect contamination sources within the loading system. 3. Draw samples at "point of use" after the propellant flows through loading equipment and as close as possible to spacecraft. 4. Include propellant sampling and analysis rqts for purity and particulate count in launch processing timelines prior to introduction to on-board flight hardware 5. Wait for acceptable analysis results before loading propellants into the flight system.	N/A	N/A
Verification:	N/A	1. Review summary documentation at MDR.	1. Review summary documentation at peer reviews and PDR.	1. Review summary documentation at peer reviews and CDR.	1. Review summary documentation at PSR.	N/A	N/A
Revision Status: Rev. F		**Owner:** Propulsion Branch (597)			**Reference:**		

1.40	**Maintaining Command Authority of a Passive Spacecraft**				**Systems Engineering**		
Rule:	All spacecraft shall be designed to prevent loss of command authority and command integrity.						
Rationale:	Mission control needs to be maintained.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Ensure that vehicle commanding scheme design is robust against failures that will result in loss of control. 2. Ensure that in the case of an encrypted primary command link, there is a backup with adequate command integrity.	1. Incorporate features, commensurate with mission class that facilitates restoration of command link in the case of loss.	1. Test scheme against likely command link loss scenarios.	1. Validate primary and backup command link, as applicable.	N/A	N/A
Verification:	N/A	1. Review summary documentation at MDR.	1. Review summary documentation at peer reviews and PDR.	1. Review summary documentation at peer reviews and CDR.	1. Review summary documentation at PSR.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G		**Owner:** Mission Systems Engineering Branch (599)				**Reference:**	

1.41	GSE Use At Launch Site					Systems Engineering
Rule:	All testing of flight systems at the launch site shall only use GSE and test configurations that have been previously demonstrated with the flight hardware. Proper operation of the spacecraft with umbilical length equal to or with similar impedance and circuit characteristics to that expected at the launch site shall be demonstrated. Note: Does not apply to launch site resident GSE.					
Rationale:	New test configurations introduce unknown variables that could possibly result in unexpected test results or damage flight hardware					

Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Develop preliminary list of planned launch site testing and GSE configuration.	1. Refine list of planned launch site testing and GSE configurations.	1. Develop final list of planned launch site test activities and GSE configurations to support those activities. 2. Develop and execute test procedures for the planned launch site test activities using the planned launch site GSE configurations.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. G	Flight Systems I&T Branch (568, Primary), Mission Systems Engineering Branch (599)	

1.42	Powering Off RF Command Receiver				Systems Engineering		
Rule:	The spacecraft RF Command Receiver shall not be powered off during nominal flight operations.						
Rationale:	Preserves spacecraft command receipt capability.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. As part of Fault Protection design, develop preliminary scenarios where Fault Protection will be allowed to power off the command receiver.	1. Finalize fault protection scenarios that result in command receiver power off. 2. Make Command Receiver power-off ground command a critical command.	1. Verify Fault Protection Command Receiver power-off scenarios. 2. Develop flight rules and contingency for powering off Command Receiver	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER. MOR	N/A	N/A
Revision Status: Rev. G		**Owner:** Mission Systems Engineering Branch (599, Primary), Flight Microwave and Telecommunication Systems Branch (567)				**Reference:**	

1.43	Flight Software Update Demonstration						Systems Engineering
Rule:	There shall be a pre-flight, end-to-end demonstration of code change, using the MOC and flight observatory, for any software which can be changed in flight. (If the system contains FPGAs that can be reprogrammed in-flight, the ability to do so from the MOC shall also be demonstrated.)						
Rationale:	Demonstration of this capability for software not hosted in the spacecraft primary computer is often overlooked prior to launch						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Identify preliminary list of reprogrammable flight processors in the system	1.Finalize list of reprogrammable processors in the flight system 2. Develop preliminary plans for demonstrating the ability to update code on each of the processors identified.	1. Demonstrate capability to update code on each of the flight system processors in the I&T environment. 2. Demonstrate the capability to update code on each of the flight system processors from the Mission Operations Center.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. G		**Owner:** Mission Engineering and System Analysis Division (590, primary) and Flight Software Systems Branch (582)				**Reference:**	

Note (1): This rule need not be enforced in the case of software systems that can not affect mission primary requirements.
Note (2): If the Integration and Test (I&T) Telemetry and Command (T&C) system is the same as the one used in the MOC, then a demonstration using the I&T T&C system is sufficient.

1.44	Early Interface Testing				Systems Engineering		
Rule:	Spacecraft-to-payload electrical interfaces, including protocol and software compatibility, shall be tested with breadboard or engineering unit hardware, as soon as the hardware is available, preferably before the instrument (or component) CDR.						
Rationale:	On multiple missions, it has been demonstrated that the time and effort to execute early interface tests reduces the overall mission cost and schedule by finding and correcting incompatibilities before they impact system-level I&T. While having well-written ICDs and/or the use of industry-standard interfaces, can minimize interface incompatibilities, there are often nuances that can only be uncovered via test.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Develop preliminary spacecraft-to-payload electrical interfaces 2. Ensure that Statements of Work for development of new or significantly modified components include provisions for interface tests	1. Develop preliminary spacecraft-to-payload ICDs. 2. Identify early interface test opportunities and configuration (i.e., breadboard versus ETU, etc.)	1. Execute interface testing using the configurations identified.	N/A	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. G	Mission Engineering and System Analysis Division (590, Primary) and Electrical Engineering Division (560)	

1.45	System Alignments				Systems Engineering		
Rule:	System alignment verifications shall be performed before and after exposure to system environmental testing to demonstrate alignment stability.						
Rationale:	Demonstrates stability of alignments through the environments which gives confidence that alignments will not shift due to launch vibro-acoustic environment or post-launch thermal environment						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Develop preliminary system alignment plan	1. Refine system alignment plan	1. Finalize system alignment plan and identify the points in the system-level test flow where alignments will be performed.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. G		**Owner:** Mission Engineering and System Analysis Division (590)				**Reference:**	

1.46	Use of Micro-Switches				Systems Engineering		
Rule:	Micro-switches shall be used for information only and shall not be used as the single means to initiate on-board autonomous activity or as an on-board interlock.						
Rationale:	Micro-switches have known reliability issues.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Assess applicability. 2. Complete initial compliance assessment, based upon applicability.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in draft technical requirements and Design-To specifications. 3. Define verification approach.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in technical requirements and Design-To specification baselines. 3. Update verification approach.	1. Reassess compliance. 2. Perform verification activity.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. G		**Owner:** Mission Engineering and System Analysis Division (590)				**Reference:**	

1.47	Design Deployables For Test				Systems Engineering		
Rule:	Whenever practical, appendages and other deployables shall be capable of deployment under 1G conditions without the use of g-negation ground support equipment. When it is not practical to design for unassisted 1G deployment, the design shall have provisions for interfacing to gravity off-load GSE.						
Rationale:	Numerous occasions where instrument doors, etc. are not designed for 1G deployment and don't have provisions built in for g-negation.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Identify deployable requirements	1. Preliminary design of deployables 2. Preliminary assessment of 1G deployment capability	1. Final design of deployables. 2. Final assessment of 1G capability. 3. Verify that design includes provisions for 1G off-load where applicable	1. Demonstrate deployments.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. G		**Owner:** Mission Engineering and System Analysis Division (590)				**Reference:**	

1.48	**Space Data Systems Standards**				**Systems Engineering**		
Rule	Data systems standards (e.g., CCSDS, OMG, commercial, international) shall be utilized by missions and implemented in all space communication systems.						
Rationale:	Standardization of space data system interfaces, formats, and protocols within the Agency reduces the cost of specification and implementation of data systems. It increases reliability through the use of proven interfaces and heritage software and tested vendor products. Space data systems standards enable easier and lower-cost data interoperability between systems within a local system, across a Center or Agency, and with external partners.						
Phase:	<A	A	B	C	D	E	F
Activities:	Examine all data interfaces and investigate applicable space data systems standards for those interfaces. Consult with the Center CCSDS Standards POC in identifying useful standards and provide feedback on any gaps or issues in the standards.	Perform trade studies to confirm the feasibility and benefits of the space data systems standards selected in pre-phase A. Incorporate the confirmed space data systems standards into system requirements and present at the SRR. Where CCSDS or OMG standards are planned provide feedback on any gaps or issues in standards to the Center CCSDS Standards POC.	Incorporate selected space data systems standards into the preliminary design and present at the PDR.	Finalize selected space data systems standards in the detailed design.	Implement and test for compliance with selected space data systems standards. Where CCSDS or OMG standards are planned report any issues or limitations with the selected space data systems standards to the Center CCSDS Standards POC.	Where CCSDS or OMG standards are planned, report any identified operational issues or limitations with the selected space data systems standards to the Center CCSDS Standards POC.	
Verification:	Verify that the proposal identifies space data systems standards where applicable.	Verify at SSR.	Verify at PDR.	Verify at CDR.	Verify at I&T and system readiness testing.		
Revision Status: Rev H	**Owner:** Electrical Engineering Division (Code 560)				**Reference:** www.ccsds.org www.ccsds.org/publications www.omg.org/space/		

Notes: 1) The Center CCSDS Standards Point of Contact (POC) is a recommended resource for learning the current breadth of standards to be considered and the status of CCSDS and OMG standards currently under development. 2) The Consultative Committee for Space Data Standards (CCSDS) publications span a wide range of technical areas which may be of benefit to missions, including both optical and RF communications, uplink and downlink messaging, file transfer protocols, delay-tolerant networking, navigation messages, service-oriented approaches to increase interoperability, data compression and security, and more. The Object Management Group (OMG) is an international, not-for-profit technology standards consortium. The OMG Space Domain Task Force (Space DTF) maintains standards specific to space applications, including common telemetry and command definition formats, scripting standards, and ground equipment interface definitions. Commercial or general use standards, including internet protocol or mobile device standards may also provide significant benefit to some missions and shall not be precluded.

2.01	**Flight Electronic Hardware Operating Time**				**Electrical**		
Rule:	One thousand (1000) hours of operating/power-on time shall be accumulated on all flight electronic hardware (including all redundant hardware) prior to launch. The last 350 hours of operating/power-on time shall be failure-free, of which at least 200 hours shall be in vacuum. For Class D and below, only the failure-free and vacuum requirements shall apply. For hardware expected to operate for less than 100 hours in-flight, proposed pre-launch operating hours shall be discussed with the rule owner.						
Rationale:	Accumulated power-on time that demonstrates trouble-free parts performance helps reduce the risk of failures after launch.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Draft test plan.	1. Approve test plan.	1. Update test plan.	1. Conduct 1000 hours of testing of all flight hardware and spares. The last 350 hours shall be trouble-free. At least 200 shall be in vacuum.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PSR that testing has been conducted. 2. Verify at PER that the test plan is sufficient for completion of required hours.	N/A	N/A
Revision Status: Rev. H		**Owner:** Electrical Engineering Division (560)				**Reference:** GEVS 2.3.4	

2.05	System Grounding Architecture				Electrical		
Rule:	For all missions, a system grounding design shall be developed and documented for flight and GSE test configurations. Except for coaxial interfaces, structure or shields shall not be used for the primary circuit current return path. A dedicated conductor shall be included to provide the current return path with the smallest loop area possible.						
Rationale:	Poor system grounding design will lead to grounding incompatibility between different systems during the integration phase, with potential degradation of end-to-end functional performance. Failure to consider GSE grounding could result in damage to flight hardware.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify a preliminary grounding concept.	1. Complete a preliminary grounding design and communicate it to all hardware developers.	1. State grounding requirements in all Electrical ICDs for the users.	1. Prepare a detailed System Grounding Document. 2. Implement the design.	1. Oversee implementation of the design. 2. Demonstrate safety, compatibility, and system performance.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at MDR.	1. Verify through peer review and at PDR.	1. Verify through peer review and at CDR.	1. Verify through peer review prior to TRR and at PER.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G		**Owner:** Avionics and Electrical Systems Branch (565)			**Reference:**		

2.06	System Fusing Architecture						Electrical
Rule:	A system fusing architecture shall be developed and documented for all missions, including the payloads. All circuit breakers that can't be reset by command (i.e., fuses) should be easily accessible for replacement and/or for integrity verification at any time prior to launch vehicle integration.						
Rationale:	Lack of a system fusing design may lead to fuse incompatibilities between the power source and the payloads, which could lead to the power source fuse being blown prior to the payloads. The system fusing design should maximize the reliability of the system.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Identify a preliminary system fusing architecture for the mission and communicate with all hardware developers.	1. Develop system fusing requirements for the mission and state requirements in all Electrical ICDs for the users, including transient requirements.	1. Prepare a detailed System Fusing Document.	1. Oversee correct implementation of design by all users.	N/A	N/A
Verification:	N/A	1. Verify through peer review and at MDR.	1. Verify all system fusing requirements (including the payloads) through peer review and at PDR.	1. Verify user implementation at electrical systems peer preview and at CDR.	1. Verify that design verification includes fusing design prior to TRR.	N/A	N/A
Revision Status: Rev. H		**Owner:** Avionics and Electrical Systems Branch (565)				**Reference:** EEE-INST-002	

2.13	Electrical Connector Mating					Electrical	
Rule:	All flight connectors where mating cannot be verified via ground tests, shall be clearly labeled and keyed uniquely, and mating of these connectors shall be verified visually to prevent incorrect mating. The design shall not use connectors that require a blind mating in system-level integration, test and launch operations.						
Rationale:	Error in mating of interchangeable connectors can result in mission degradation or failure.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Identify operations that cannot be tested on the ground.	1. Present plans to prevent error in mating of electrical connectors.	1. Verify by inspection & photo documentation that electrical connectors are mated correctly.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G		**Owner:** Avionics and Electrical Systems Branch (565)			**Reference:** Electrical Systems Design Guidelines		

2.14	Protection of Avionics Enclosures External Connectors Against ESD					Electrical
Rule:	All avionics enclosures shall be protected from ESD. All external connectors must be fitted with shorting plugs or appropriate caps during transportation between locations. Additionally, all test points and plugs must be capped or protected from discharge for flight.						
Rationale:	Capping open connectors provides protection from electrostatic discharge resulting from space charging.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Develop electrical systems requirements. 2. Identify the need for capping all open connectors and grounding the caps to chassis.	1. Develop electrical ICD stating requirement for capping open connectors. 2. Develop harness drawings.	1. Verify by inspection of build records (WOAs, traveler, etc.) that provisions for capping open connectors have been completed. 2. Verify final blanket closeout procedure includes check to verify connectors are capped.	N/A	N/A
Verification:	N/A	N/A	1. Verify through peer review and at PDR. 2. Ensure parts and materials list include connector caps.	1. Verify harness drawings include connector caps for any open connectors and their grounding provisions.	1. Inspect during pre-fairing, post fairing installation and final blanket closeouts.	N/A	N/A
Revision Status: Rev. F		**Owner:** Avionics and Electrical Systems Branch (565)		**Reference:** Electrical Systems Design Guidelines			

2.22	Corona Region Testing of High Voltage Equipment				Electrical		
Rule:	Assemblies containing a High Voltage (>150V) supply that is not tested through the Corona region shall undergo venting / outgassing analysis to determine when it is safe to turn on and operate after launch.						
Rationale:	Each High Voltage supply is different in its design and the voltage where coronal discharge may occur will vary by the construction and materials used. It will also be dependent on how clean the supply is and how well the outgassing products are vented to space.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Complete applicability assessment.	1. Reassess and update applicability. 2. Complete initial compliance assessment, based upon applicability.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in draft technical requirements and Design-To specifications. 3. Define verification approach.	1. Reassess compliance. 2. Ensure flow-down traceability to appropriate sub-system in technical requirements and Design-To specification baselines. 3. Update verification approach.	1. Reassess compliance. 2. Perform verification activity.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at SRR, MDR, and PNAR.	1. Verify at PDR and NAR.	1. Verify at CDR and SIR.	1. Verify at ORR, SMSR, and FRR.	N/A	N/A

Revision Status:	Owner:	Reference:
Rev. H	Power Systems Branch (563, Primary), Instrument Systems and Technology Division (550)	

2.23	RF Component Testing for Multipaction and Corona						Electrical
Rule:	Multipactor and corona margins for component of spacecraft RF communications subsystems shall be maintained at the mission frequencies. All components shall be vented. • If the RF transmitter is on during launch and ascent, all flight components in the transmit path shall be verified as corona free at all pressures from sea level to 1E-4 Torr. • Resonant passive flight components shall be verified as multipactor free by test on all units. • Non-resonant passive flight components shall be verified as multipactor free by test or analysis. • The test setup shall be verified with a known breakdown device. • Multipactor analysis shall show a 10dB margin. • Multipactor test level for the passive components shall be at least 6dB above the nominal power level in vacuum (<1E-5 Torr) during unit acceptance testing.						
Rationale:	Unless significant design margin is demonstrated, small unit-to-unit variations make it impossible to predict whether an RF component is susceptible to Multipaction or Corona. Testing/Analysis will ensure immunity to multipactor/corona at the component level.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Include the cost for meeting multipactor and corona requirements in basis of estimate.	1. Plan schedule to include milestones for activities necessary to verify absence of Multipactor or Corona effects.	1. Baseline system design using RF system components that are good candidates (low risk) based on whether they have been designed with sufficient margin to minimize possibility of Multipactor or Corona effects. 2. Complete analyses (to determine extent of design margin) and testing of RF Flight Components.	1. Complete RF component multipactor / corona analyses and testing prior to spacecraft I&T.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR	1. Verify at CDR.	1. Verify at ORR,	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. H	Microwave and Communication Systems Branch (567)	

2.24	Solar Arrays				Electrical		
Rule:	a. Solar arrays shall incorporate solar cells that have been qualified per AIAA-S-111A-2014, “Qualification and Quality Requirements for Space Solar Cells.” If a later revision of AIAA-S-111 has been released by the time of contract award for the mission, the later revision shall govern. b. Solar panels shall be qualified to the mission environment via qualification panels per AIAA-S-112A-2013 (or equivalent), “Qualification and Quality Requirements for Electrical Components on Space Solar Panels.” If a later revision of AIAA-S-112 has been released by the time of contract award for the mission, the later revision shall govern. c. Qualification and flight solar panels shall be tested at ambient temperature and at their highest predicted operating temperature including calibrated I-V curves (where practical) before and after panel-level environmental testing. d. Flight solar arrays shall be tested at wing level or array level at ambient temperature including calibrated I-V curves after all environmental testing (integrated to the spacecraft or not) is complete. Should the flight solar array be stored for a period of more than two years after the post-environmental array testing is complete, the calibrated I-V curve measurements at ambient temperature shall be repeated prior to launch.						
Rationale:	Space solar arrays must survive severe environments including particulate radiation, UV, and up to tens of thousands of very rapid temperature excursions between cold and hot. Incremental changes to parts and processes can have unexpectedly large consequences. Therefore, it is essential that the solar array for each mission be rigorously qualified and tested for that mission.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Design the array in accordance with mission requirements and established procedures.	1. Design the array in accordance with mission requirements and established procedures.	1. Revise the design of the array in accordance with mission requirements and established procedures.	1. Revise the design of the array in accordance with mission requirements and established procedures. Write an ICD.	1. Simulate the environment as accurately as possible. 2. Test q-panel(s) and flight array under illumination (including calibrated IV curves) at highest predicted operating temperature. 3. Qualify the solar panels to latest revision of AIAA S-112-2005 as tailored for the mission. 4. Fabricate the flight solar array in accordance with approved procedures.	1. Monitor array output on an hourly basis for 48 hours subsequent to launch and on a weekly basis thereafter. 2. Check output versus predictions and reconcile.	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Peer review the array design, applicable ICDs and test program.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. F, Updated Rev. H		**Owner:** Mechanical Systems Division (540) and Power Systems Branch (563, Primary)				**Reference:**	

2.25	**Electrical Interface Verification**				**Electrical**		
Rule:	Electrical Interface (i.e., copper-path) Verification Test (IVT) shall be performed on all flight connectors following final flight mating. This may be performed via powered testing and/or physical (e.g., resistance) measurements.						
Rationale:	Final verification of flight interfaces is required to ensure proper electrical integrity and function, thereby minimizing the probability of system failure and maximizing probability of mission success.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:		1. Identify electrical interfaces required for safety or mission success and define means by which interfaces will be verified. 2. Review/update the identified list of interfaces and tests. 3. Define success criteria for verification and incorporate into verification plan. 4. Review/update verification plan and schedule. 5. Identify facilities and other resources (e.g., GSE) required.	1. Review/update list of interfaces and tests identified in Phase A. 2. Review/update verification plan and schedule. 3. Identify test plans, facilities, and resources that need to be in place for IVT.	1. Draft final verification plan and IVT. 2. Sign off on plan and IVT and put under CM control.	1. Perform IVT. 2. Assess acceptability of interface verification. 3. Close verification plan and tracking log for interface.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at SDR or SRR, PDR.	1. Verify at CDR.	1. Verify at PSR and LRR.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G		**Owner:** Electrical Engineering Division (560, Primary) and Mission Engineering and Systems Analysis Division (590)				**Reference:**	

2.26	Power-On Reset Visibility				Electrical		
Rule:	A power-on reset occurrence shall be unambiguously identifiable via telemetry. Note: This does not imply real-time telemetry as the reset is occurring.						
Rationale:	An unexpected power-on reset could be an indication of a serious issue and should be able to be distinguished from resets that are indicative of less serious conditions.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Establish requirements (and flow-down) for being able to detect power-on reset occurrences.	1. Establish preliminary design of power-on reset monitoring capability including the routing of that telemetry to the spacecraft telemetry system.	1. Finalize power-on reset telemetry monitoring design.	1. Demonstrate the ability to detect and telemeter power-on reset occurrences.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A

Revision Status: Rev. G	**Owner:** Electrical Engineering Division (560, Primary) and Flight Software Systems Branch (582)	**Reference:**

2.27	Spacecraft Strip-Charting Capability				Electrical		
Rule:	A minimal set of hard-line spacecraft parameters, sufficient to establish spacecraft health and safety, shall be monitored and captured (stored), independent of the spacecraft telemetry system, by the EGSE whenever the spacecraft is powered. This data should be sampled at a rate sufficiently high to aid in diagnosis of abnormal power events.						
Rationale:	This capability is necessary to capture data for anomalous behavior on the spacecraft during I&T when spacecraft telemetry is not available.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Develop preliminary list of hard-line parameters required for monitoring. 2. Develop preliminary design of EGSE functions required for monitoring the hard-line parameters.	1. Finalize list of hard-line parameters. 2. Finalize design of EGSE hard-line monitoring functions	1. Employ hard-line functionality at start of system-level I&T	N/A	N/A
Verification:	N/A	1. N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. G	Flight Systems Integration and Test Branch (568, Primary) and Mission Systems Engineering Branch (599)	

3.01	**Verification and Validation Program for Mission Software Systems**				**Software**		
Rule:	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.						
Rationale:	Mission software, especially flight software, must be tested thoroughly to ensure a successful mission/project. The activities described below provide guidance on recommended software verification and validation activities at each lifecycle phase to supplement the requirements found in NPR 7150.2.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Develop first version of Operations Concept with customer. 2. Document SW functionality at high level. 3. Document SW verification and validation approach. 4. Document cost estimate for overall SW design.	1. Update Operations Concept. 2. Identify test tools to be used for software testing (i.e., fidelity, quality, etc.). 3. Update verification and validation approach and associated cost and schedule based on updated requirements.	1. Draft Software Test Plan. 2. Draft SW bi-directional traceability matrix showing SW requirements traced to parent requirements and to SW components and tests. 3. Plan SW test environment.	1. Complete Software Test Plan. 2. Identify verification and validation program risks. 3. Update SW bi-directional traceability matrix. 4. Set up FSW test environment. 5. Execute FSW tests.	1. Develop detailed test scenarios/cases. 2. Complete bi-directional traceability of requirements to SW design and SW test program. 3. Set up ground SW test environment. 4. Modify FSW test environment as necessary to increase fidelity. 5. Execute ground SW tests.	1. Develop detailed test scenarios/cases. 2. Complete bi-directional traceability of requirements to SW design and SW test program. 3. Set up ground SW test environment. 4. Modify FSW test environment as necessary to increase fidelity. 5. Execute ground SW tests	N/A
Verification:	1. Verify by inspection through peer reviews and at MCR.	1. Review by analysis the verification and validation approach for the mission through peer review and at MDR.	1. Verify SW development and test program by analysis and through peer review. 2. Verify that budget and schedule accommodate regressions and end-to-end mission testing at SDR and software PDR.	1. Verify by analysis at software CDR.	1. Verify by analysis through peer review and at Test Readiness Review.	1. Verify by analysis through peer review and at Test Readiness Review	N/A
Revision Status: Rev. E, Updated Activities in Rev. G		**Owner:** Software Systems Engineering Branch (581)				**Reference:** NPR 7150.2	

3.02	Elimination of Unreachable Software				Software		
Rule:	An analysis of unreachable code, as defined per Table 3.02-1, shall be performed on the intended software that is associated with space flight operation. The analysis shall identify all instances (areas) of unreachable code, the general functionality associated with the code, the reason each is intended to be left within the software, and the justification (e.g., mitigating action) that explains why the included code does not provide a risk to the mission. The focus is on technical risk to the long-term mission, not cost.						
Rationale:	There are significant benefits to re-using software from past missions, but each mission has different requirements and re-using heritage software often carries forward software not required by the current mission. Unreachable software can also occur within a mission's lifecycle as system and software requirements change during the software development process. Unreachable software is typically not verified or validated as part of the current mission test programs, as a mission is only required to verify its mission requirements. This creates the potential for negative side-effects, costs, and risks during the current mission's on-orbit life. Table 3.02-2 provides sample types of unreachable code.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Document that a software Reuse Plan and risk assessment of unreachable code will be developed.	1. Document the software Reuse Approach and the plan for managing unreachable code in the Software Mgt/ Development Plan(s). 2. Identify and document code capabilities/ requirements that are not required for the current mission but are intended to be included in the software product(s). 3. Provide initial risk identification, assessment & anticipated mitigation technique for each known type of unreachable code. 4. Present analysis at software reviews.	1. Analyze the potential risk of leaving the code in the flight product rather than removing it. 2. Remove unreachable software that creates risk. 3. Update software verification plans if justified to reduce risk. 4. Present analysis and risk mitigations at software reviews. 5. Update the documentation of unreachable code associated with the software.	1. Update and analyze the documentation of unreachable code from heritage and newly developed software. 2. Remove unreachable code that creates unacceptable risk. 3. Update software verification plans if justified to reduce risk. 4. Present analysis at SW reviews.	1. Update and analyze the documentation of unreachable code from heritage and newly developed. 2. Remove unreachable code that creates risk. 3. Update software test plans if justified to reduce risk. 4. Present analysis at SW reviews.	N/A
Verification:	N/A	Verify at MDR.	1. Verify at SW SRR and SW PDR. 2. Verify at SDR and PDR.	1. Verify at CDR. 2. Verify at SWCDR.	1. Verify at SW Acceptance Test Review. 2. Verify at PSR and FRR.	1.Verify at SW Acceptance Test Review and reviews of DRs. 2. Verify at TRR.	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. E, Updated Rev. H	Flight Software Systems Branch (582, Primary), Software Systems Engineering Branch (581), Ground Software Systems Branch (583)	

Table 3.02-1 Unreachable Software Definitions

Term	Definition
Unreachable Software	Code which cannot be properly exercised via demonstration during FSW or system level test.
Note	Well-known Commercial Off-the-Shelf (COTS) and Open-Source products with flight heritage and unnecessary and unreachable features are to be included in the analysis and will likely not require extensive mitigation actions. Source code is the description of a computer program that is translated into machine code by another program such as an assembler, compiler or interpreter. If the translator creates object code modules, then the modules are combined using a linker program. The end result of the process is a program or library of functions that is executable or a processing unit. Source code includes higher level languages, including visual languages, which are first translated into lower-level languages (e.g., C or Assembler) before translation to executable code.

Table 3.02-2 Example Areas To Consider For Analysis

Examples	Definition
Unused Design Capability	Application Program Interfaces (API) are developed to promote software reuse. For example, an Operating System (OS) API will have interface calls for dealing with semaphores (e.g., *create, give, take*, etc.). If a new mission does not require the use of semaphores, then these OS API functions will never be executed.
Unused Reuse Capabilities	A reused software component/library or set of reused software components/libraries will typically contain capabilities and features not required by a mission.
Debug/Test Features	Debug and test features, which are not a required part of the operational system, are often required to test the software system. For example, debug software is often used in conjunction with testing Error Detecting And Correcting (EDAC) memory. It is extremely difficult to inject correctable and uncorrectable errors into EDAC memory, whereas a test command can easily inject these erroneous conditions to verify that the application software handles and reports the EDAC errors correctly.

3.03	**High Fidelity Interface Simulation Capabilities**				**Software**		
Rule:	A high-fidelity software simulation capability for each external interface to FSW shall be provided in the FSW development/maintenance environments. Both nominal and anomalous data inputs to FSW shall be configurable in real-time using the procedure language of the FSW test workstation. The organization building the flight article being simulated shall also be responsible for the simulator. If this is not feasible, then the developing organization shall provide inputs for and participate in the requirements, design and development of the simulator.						
Rationale:	When adequate simulation capabilities aren't planned, there may be significant impact to FSW development/maintenance productivity and funds.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Describe functional and performance capabilities for each flight processor external interface in technical proposal. 2. Include cost estimate.	1. Update description of required simulation capabilities to reflect any changes in requirements since previous phase. 2. Document acquisition strategy for acquiring simulation capabilities, including responsible organizations.	1. Update requirements to reflect any changes since previous phase. 2. Deliver FSW external interface test tools to FSW team.	1. Maintain FSW external interface test tools.	1.Maintain FSW external interface test tools	N/A
Verification:	N/A	1. Verify by observation at MDR.	1. Verify by observation at SW SRR. 2. Verify flight simulation capability defined to accommodate test of all FSW data I/O, FSW modes, nominal and anomalous conditions, and load/stress tests for each flight CPU. 3. Verify simulator development and FSW schedules are consistent.	1. Verify by observation at software CDR.	1. Verify by observation at FRR/MRR.	1. Verify after maintenance or repair activities	N/A
Revision Status: Rev. H		**Owner:** Flight Software Systems Branch (582)				**Reference:**	

3.04	Independent Software Testing					Software	
Rule:	Software build testing, system testing, and acceptance testing shall be performed by qualified testers that are independent of the software designers and developers. NOTE: Members of the same development team can perform independent testing as long as the assigned testers have not been involved in any part of the design and development of the software components being tested.						
Rationale:	Ideally, an independent team should develop the software test plan and verification/validation test procedures and execute the tests. Frequently the software development team will be used to perform these functions as a means to reduce cost and schedule. Having authored the code, they already know how it should function and can quickly perform the testing activities. The independent test team approach is non-biased, with an end-user perspective, and specialized test teams frequently have greater expertise on various test tools and technologies; thus, providing a more thorough and comprehensive test program. An independent test team ensures adequate time for testing because there is a clear demarcation between development and testing. However, if utilizing an independent test team is not feasible, at a minimum, the use of independent testers who were not involved with the software design and development process allows alternate interpretations of requirements and multiple approaches to testing.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Project provides WBS for Test Team Lead. Test Team Lead is given signature authority on the Mission Flight Software Requirements document. 2. Test Team Lead reviews requirements for testability, plus compatibility with the Operations Concept. 3. Software Test Plan is written and approved.	1. Software Test Plan is updated as needed. 2. Requirements to Test Procedures Matrix is drafted.	1. Software Test Team staffed. Ensure members are independent from development team. 2. Continue to update Requirements to Test Procedures Matrix and begin drafting test procedures.	1. Test procedures drafted, reviewed, and executed.	1. Independent verification/validation testing completed.	N/A
Verification:	N/A	Verify at SRR.	Verify at PDR.	Verify at CDR.	Verify at TRR.	N/A	N/A
Revision Status: Rev. H		**Owner:** Software Engineering Division (580)				**Reference:**	

3.05	**Ground System/Operations Testing and Operations Team Readiness**				**Software**		
Rule:	Access to flight system interface and functional capabilities, provided either by the spacecraft or by spacecraft simulators, shall be negotiated with all stakeholders, including the ground system and operations teams. Schedules and agreements should address the spacecraft/spacecraft simulators/instrument(s)/instrument simulator(s) at all levels of fidelity.						
Rationale:	The ground system must be compatible with the S/C it is being designed to support, and this must be proven prior to launch via tests. Similarly, the operations team must be able to develop and validate a variety of operations products, such as procedures, databases, display pages, and launch scripts. The operations team must also have opportunities to learn about operating the S/C and prove this knowledge has been acquired prior to launch.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Develop plans for providing the flight system interfaces for use by the ground system and flight operations teams.	1. Develop preliminary simulation concepts.	1. Generate preliminary simulator requirements and identify long lead procurement items. 2. Establish preliminary agreements on simulator usage between all stakeholders. 3. Identify critical ground system and operations readiness tests along with estimated durations and equipment dependencies and incorporate into the mission I&T schedule.	1. Complete simulator requirements, design, and delivery plan/schedules. 2. Refine previously established agreements on simulator and spacecraft access times. 3. Ensure all ground system and operations readiness test details, including test durations and equipment dependencies, are incorporated into the detailed I&T plans and schedules.	1. Provide simulator and S/C hardware access for both ground system verification and validation, and for operations teams to prepare for launch.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at MDR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at FRR/MRR	N/A	N/A
Revision Status: Rev. H		**Owner:** Software Systems Engineering Branch (581, Primary), Mission Validation and Operations Branch (584)				**Reference:**	

3.06	**Dedicated Hardware Computing Platform Testbed for Flight Software and Reconfigurable FPGA Lifecycle Development**					**Software/Reconfigurable FPGA**	
Rule:	A data processing system testbed(s), representative of the flight hardware, shall be dedicated to FSW/FPGA product development teams specifically for development, integration and test. The quantity of f data system testbed units shall be sufficient to support the FSW/FPGA development schedule and the overall mission schedule.						
Rationale:	Early investment in dedicated flight computing system testbeds with high fidelity hardware saves costs and avoids significant schedule risks associated with FSW/FPGA development and downstream flight integration and test. Anything less than a dedicated hardware unit that is representative of the flight processing system (e.g., ETU, EDU, flight spare) will add to mission risk and threaten cost/schedule.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Define high-level testbed requirements (including quantity and fidelity of hardware) with clear and detailed rationale.	1. Update testbed requirements from Phase A. 2. Ensures that testbed development and delivery schedule is consistent with development team need dates. 3. Develop testbed acceptance criteria for hardware deliveries.	1. Review testbed design and verify that it is of sufficient fidelity to develop FSW/FPGA products. 2. Review/update testbed hardware delivery schedule 3. Ensure that a development/test processing platform is available for design work.	1. FSW/FPGA team verifies availability of testbeds to meet product development and test schedules. 2. FSW/FPGA team lead accepts testbed deliveries and verifies functionality.	1. FSW/FPGA team review and provides input on testbed long-term maintenance plan.	N/A
Verification:	N/A	1. Verify by observation at MDR that dedicated ETU-quality FSW/FPGA testbeds are clearly represented in the technical proposal.	1. Verify by observation at subsystem PDRs and Mission PDR that: a) Testbed(s) represent maturing flight architecture; b) Dedicated testbed with high-fidelity hardware is costed and delivery schedule is consistent with FSW needs; and c) Testbed is fully dedicated (i.e., not shared with I&T) for FSW/FPGA development.	1. Verify by observation at subsystem CDR that delivery plans for testbed(s) hardware is consistent with development needs. 2.	1. Verify by observation that: a) Testbed(s) have been delivered to FSW team; and, b) Testbed is confirmed to be adequate for development, testing, on-orbit maintenance and operations support.	1. Verify by observation at FRR/MRRR that: a) Testbeds have been moved to their long-term environment for FSW/FPGA maintenance & operations support; and b) system administration, facility, and hardware support are in place.	N/A

Revision Status:	Owner:	Reference:
Rev. H	Flight Software Systems Branch (582, Primary); Electrical Engineering Division (560)	**500-PG-8700.2.8B**

Notes:

1) In Rev H, this rule has been expanded to cover systems that also include reconfigurable FPGAs that will change throughout the lifecycle.
2) Projects that have a complex computing platform (multiple reconfigurable FPGAs, many-core or distributed processors, dynamic reconfiguration processing, Machine Learning applications, etc) may require multiple testbeds and/or testbeds with higher fidelity components that interface with the data processing system.
3) The testbed fidelity must include flight-like processors, supporting chips (memory, power delivery, etc.), FPGAs, and interfaces. An EDU or ETU typically meet the fidelity intent.
4) Agreement on testbed quantity must be made between FSW/FPGA leads, Systems, and Project Management.

3.07	Flight Software Margins					Software	
Rule:	Flight software resource margins shall be maintained in accordance with Table 3.07-1 and presented at Key Decision Point (KDP) milestone reviews.						
Rationale:	Early and repeated attention by flight software teams to resource utilization will improve resource margins for future phases of the mission.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Establish clear rationale for FSW resource estimates using the proposed hardware.	1. Update software margins based on updated requirements. 2. Coordinate with S/C and instrument procurement and hardware development teams to ensure margins can be maintained.	1. Design FSW within defined design margins. 2. Continue coordination with S/C and instrument hardware development teams. 3. If margins are below guidelines at PDR, provide rationale as to how mission requirements can still be met and necessary mitigation and/or corrective actions needed.	1. Track development to design margins. If margins are below guidelines at CDR, provide rationale as to how meeting mission requirements are not at risk.	N/A	N/A
Verification:	N/A	1. Verify by observation at MDR.	1. Verify by observation at FSW PDR and Mission PDR.	1. Verify by observation at FSW CDR and Mission CDR.	1. Verify by observation at SIR and ORR.	N/A	N/A
Revision Status: Rev. H		**Owner:** Software Systems Engineering Branch (581, Primary), Flight Software Systems Branch (582)				**Reference:** Table on next page	

Resource Margins for Flight Software Development

The numbers provided in the table below are margins for different mission phases and maturity levels. These do not represent hard limits, but levels where the software development team should open a dialog with the GOLD Rule owner to assess the anticipated projection of excessing the limits and any potential risks associated with future development and sustainability that could impact science and/or flight requirements.

Table 3.07-1. Flight Software Margins

	Mission Phase (with Method)			
	FSW SRR	**FSW PDR**	**FSW CDR**	**Ship/Flight**
Resource	Estimate	Analysis	Analysis/ Measured	Measured
Average CPU Usage	50%	50%	40%	30%
Deadlines	50%	30%	20%	10%
Non-Writeable NVM	50%	30%	20%	0%
Writeable NVM	50%	50%	40%	30%
RAM	50%	50%	40%	30%
Data Interfaces	40%	30%	20%	10%

Margin is calculated using the formula: (total allocated resource – used resource)/total allocated resource

Total allocated resource = the total magnitude of the resource allocated for use by flight software.

Used resource is estimated, analyzed and/or measured.

Note: Selecting which column to use at a particular time is not always obvious. Generally, one should pay more attention to the “Method” row rather than the “Mission Phase” row. For example, if there is a lot of re-use of heritage code and you have actual measured code sizes for most modules, your PROM could be 80% full at PDR without causing concern. Different resource elements can be at different maturity levels at any given point in a project. The right-most column should only be used when the code is fully integrated and tested. Those are the margins we want to save for in-flight maintenance.

Average CPU Usage: This is the percentage of time the CPU is doing non-background processing work. Background processing may include tasks such as memory scrubbing, memory validation (such as memory checksum), or any process that is interruptible or has very loose timing requirements. This average should be estimated/measured over an interval that exceeds the longest real-time event rate under normal worst-case operating conditions.

Deadlines: This row usually represents the interrupt timing requirements of the system. For example: How quickly does the processor need to re-fill that FIFO after the HW interrupt is asserted? If you have a 50 ms deadline for an ISR and you estimate the processor can meet it in 20ms, your usage (margin) is 40% (60%). All deadlines in the system should be considered and compared individually to the recommended margin.
Also, consider which deadlines can occur simultaneously to calculate the worst-case timing.

Non-Writeable NVM: Non-Volatile Memory (NVM) that cannot be modified in flight. Typical technologies include PROM, EEPROM, and MRAM. While EEPROM and MRAM are both reprogrammable technologies, if the underlying processing platform locks out ability to write once in flight, it is considered non-writeable for this rule.

Writeable NVM: Non-Volatile Memory that can be modified in flight. Typical technologies include EEPROM, NOR Flash, NAND Flash, and MRAM. Used resources should include memory space allocated for code updates.

RAM: Volatile memory where the executing code and data are stored. This memory is always on the processor's local bus. Typical technologies include SRAM, SDRAM and DDR SDRAM. Note: Bulk memory used for storage of housekeeping and science data has been removed from this table. The amount of bulk memory is driven more by mission parameters (data rates, number of ground contacts, etc.) than software design. So, systems engineers should track the bulk memory margin. However, some systems have the "bulk" memory on the processor card, indistinguishable from regular RAM (or writeable NVM). In this case, the software team should track margins on this combined RAM/NVM/bulk memory space.

Data Interfaces: Any external interface used by the processing system to exchange data. Typical examples include PCI, PCIe, 1553, UART, SpaceWire, SerDes, Ethernet. Usage calculations should include 1 retry for each transaction, where applicable (if protocol allows), unless mission requirements specify otherwise. If the scheduling of bus traffic is segmented into slots or channels, the usage should be calculated based on the number of slots used (rather than actual bus time).

For software resources that do not appear in the table, use an analogous resource that does appear or work with the project systems engineer to define acceptable margins for that unique resource.

3.10	Flight Operations Preparations and Team Development	Software
Rule:	Experienced operations personnel shall participate as early as possible during mission development, preferably during the mission operations concept phase and the development of specifications for the spacecraft and/or instruments which impact operations. Ideally, the Flight Operations Team (FOT) will supply Test Conductors to support Observatory I&T, which will serve to prepare and train the FOT. As a minimum, the FOT shall participate in flight operations readiness tests that are specified in Table 3.10. Note that these serve as guidelines and are not intended to be prescriptive.	
Rationale:	Involving experienced operations personnel early in the mission helps ensure that the mission design will be considerate of operational requirements and practicalities. It will allow the operations team to become intimately familiar with the mission design, including design rationale, spacecraft limitations, and operating constraints. Involving FOT members during mission operations readiness tests gives them a great deal of hands-on experience with the observatory prior to launch thereby enhancing their training; and the FOT will be able to assume their responsibility with a reasonable degree of skill and knowledge for conducting on-orbit spacecraft operations.	

Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Assess the flight operations team's role throughout the mission lifecycle. Flight operations experts develop preliminary operations concepts.	1. Flight operations and software experts support the development of more detailed operations concepts, and flight/ground architecture. 2. Update mission design estimates.	1. Identify roles and responsibilities for FOT members. 2. Review and update operations concepts and identify details on approach to operations team support. 3. Conduct peer review of flight/ground architecture. 4. Develop test plans (see Table 3.10).	1. Involve FOT and Test Conductor(s) in test plan development. 2. Support the completion of the operations concepts.	1. Ensure all FOT members and Test Conductor(s) gain knowledge and experience on ground systems during I&T. 2. Conduct tests (see Table 3.10). 3. Complete flight operations plan. 4. Assess the number of available FOT personnel against peak needs for conducting operations and managing anomalies at the same time.	1. Conduct Tests or Re-Tests of critical events using available simulation and flatsat resources.	N/A
Verification:	1. Verify at MCR: a) Ensure flight development experts were consulted during mission formulation. b) Ensure that operations concept covers flight operations team's role during entire mission lifecycle.	1. Verify at MDR: a) Flight operations concepts are sound.	1. Verify at PDR: a) Flight operations roles are defined and personnel identified. b) Flight and ground system interfaces to all mission support elements are well defined and documented.	1. Verify at CDR: a) Flight operations experts have been consulted on the overall ground system design. b) The project has completed full mission lifecycle design to include extended mission and mission termination phases.	1. Verify at FRR/MRRR and ORR: a) MRT items completed by MRR.	1. Verify at an associated readiness review (such as Critical Event Readiness Review, CERR).	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. E, Updated Rev. H	Flight Systems Integration and Test Branch (568) Software Systems Engineering Branch (581, Primary) Mission Validation & Operations Branch (584)	

Table 3.10 Simulation Types and Minimum Number of Successful Simulations/ Test Hours versus Mission Class

Simulation Type	Class A	Class B	Class C	Class D
End-to-end	5 tests	4 tests	3 tests	3 tests
Day-in-the-life (focused on instrument)	3 tests/simulations	2 tests/simulations	1 test/simulation	1 test/simulation
Day-in-the-life (focused on spacecraft)	3 tests/simulations	2 tests/simulations	1 test/simulation	1 test/simulation
Launch & early-orbit phase	4 tests/simulations	3 tests/simulations	2 tests/simulations	2 tests/simulations
Critical operations	each planned critical operation included in at least 2 simulations, 1 of which is in LE&O phase	each planned critical operation included in at least 2 simulations, 1 of which is in LE&O phase	each planned critical operation included in at least 1 simulation	each planned critical operation included in at least 1 simulation
Contingency operations	each contingency/critical operation included in at least 2 simulations, one of which is in LE&O phase	each contingency/critical operation included in at least 2 simulations, one of which is in LE&O phase	each contingency/critical operation included in at least 1 simulation	each contingency/critical operation included in at least 1 simulation
Flight system operation with spacecraft	400 hours	300 hours	250 hours	200 hours

Note: Simulations and tests may be performed in parallel or in combination, if appropriate, to satisfy above goals. End-to-end test implies spacecraft-to-Control Center interface and includes all supporting elements, i.e., Science Data Center, communications network, etc. Ground Readiness Tests (GRTs) are not included in this table.

3.11	Long Duration And Failure Free System Level Test of Flight and Ground System Software			Software			
Rule:	Ground test of the fully integrated FSW and ground system shall include demonstration of error free operations-like scenarios over an extended time period. The minimum duration of uninterrupted FSW system-level test (on the highest fidelity FSW testbed) and ground system operations is 72 hours for Class A and B missions; 48 hours for Class C missions; and, 36 hours for Class D missions, respectively. Planetary missions should consider test durations longer than the above guidance commensurate with the planned ConOps.						
Rationale:	Frequent restart of FSW and the ground system during ground tests may mask problems which will only occur following extended execution of these systems. Also, ground system stress testing is needed to ensure reliable operation. The number of hours specified is based on discussion with senior-level engineers, and reflect best practices accumulated over a period of 15 years.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Complete Draft FSW and Ground System Test Plans.	1. Complete Final FSW and Ground System Test Plans.	1. Complete and execute test plans, to include long duration FSW and ground system testing.	N/A	N/A
Verification:	N/A	N/A	N/A	1. Verify at CDR that FSW and Ground System Test Plans are baselined and that they include long-duration testing.	1. Verify at FRR/MRR: a) The longest duration, uninterrupted FSW system-level test (on the highest fidelity FSW testbed), and ground system testing have been completed. b) Verify at FRR/MRR that realistic post-launch science operations and safehold operations were represented by the long duration test(s).	N/A	N/A
Revision Status: Rev. E		**Owner:** Software Systems Engineering Branch (581) Flight Software Systems Branch (582, Primary)				**Reference:**	

3.13	**Maintaining Adequate Resources for Mission Critical Components**				**Software**		
Rule:	The updating of mission critical components during the mission operations phase (including any combination of hardware platforms, hardware devices, and software code) shall not compromise the capability of the system to meet mission requirements. Missions shall provide sufficient quantities of flight and ground resources to allow development, test, and operations activities to be conducted without compromising mission availability requirements.						
Rationale:	Missions should provide sufficient resources to allow updates to mission critical/high availability components, such as flight software and ground system components directly supporting space-ground communications, to be developed and tested without compromising operations. Missions should also ensure against inadvertent updates or deliberate concurrent updates of mission critical/high availability components. For example, under no circumstances should prime and redundant components, such as prime and backup flight software code images, be modified/updated concurrently, before the operational performance of the change is properly verified in a single unit.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Ensure preliminary flight and ground system design contains adequate strings or quantities of equipment to satisfy both maintenance and mission availability requirements during Phase E.	1. Ensure flight and ground system level design does not allow modification of software between one CPU and its redundant elements. 2. Ensure final flight and ground system design contains adequate strings or quantities of equipment to satisfy both continuing maintenance and mission availability requirements during Phase E.	1. Ensure flight and ground system maintenance plans define approach and required resources for development and test of changes to mission critical functions before committing to operations. 2. Declare and enforce Ground S/W Freeze and Change Control for all Mission Critical Components"	1. Enforce change control for all Mission Critical Components 2. Verify all changes to Mission Critical Components on non-operational strings	N/A
Verification:	N/A	N/A	Verify at PDR.	1. Verify at CDR.	Verify at FRR/MRR.	N/A	N/A
Revision Status: Rev. F, Updated Rev. G	**Owner:** Software Systems Engineering Branch (581, Primary) and Mission Engineering and Systems Analysis Division (590)				**Reference:**		

3.14	**Command Procedure Changes**				**Software**		
Rule:	Command procedures and/or scripts, and mission databases (onboard and ground) shall be controlled (treated with the same rigor as changes to 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 command loads to perform nominal operations may require less test rigor based on experience of senior engineers.)						
Rationale	Changes in command procedures and critical database areas that are not tracked, controlled, and fully tested can cause loss of science and/or the mission.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Ensure draft CM plans address items defined in this rule.	1. Ensure that the final CM and test plans address the items defined in this rule. 2. Ensure that operations and sustaining engineering plans address the items defined in this rule.	1. Implement CM plans. Make changes to procedures and databases as necessary based on changing mission needs/requirements.	1. Enforce CM plans and Change Control. Maintain command procedures, scripts, and mission databases as necessary based on changing mission needs/requirements (i.e., aging S/C, etc.).	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	N/A	N/A	N/A
Revision Status: Rev. E		**Owner:** Software Systems Engineering Branch (581) Flight Software Systems Branch (582) Mission Validation & Operations Branch (584, Primary)				**Reference:**	

4.01	**Contamination Control, Planning, and Execution**				**Mechanical**		
Rule:	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.						
Rationale:	Contamination sensitive components are often critical elements that directly affect system performance. It is essential that critical component performance be preserved and not allowed to degrade due to contamination exposure & accumulations. Early attention to pinpointing susceptibilities to contamination degradation in the design as well as iterating allowable degradation due to contamination in the science performance requirements allows project management to identify risks and mitigations with the least impact to cost and schedule. Monitoring early on-orbit performance and documenting lessons learned benefits all future GSFC missions.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Provide within the conceptual study the preliminary contamination control requirements that will drive mission cost, schedule, and design.	1. Define Level 2 requirements in collaboration with MSE and science team or PDLs as applicable, 2. Derive EOL contamination levels required to meet the above Level 2 requirements. 3. Create contamination accumulation budget and use budget to identify potential risks and any recommended early modeling effort.	1. Update contamination accumulation budget, include verifications points, 2. Derive Level 3 and 4 requirements as applicable, 3. Create initial CCP and release in project CM	1. Baseline Accumulation Budget and verification steps 2. Update requirements in level 3 and 4. 3. Release update to CCP with all TBD and TBRs resolved. 4. Implement appropriate elements of CCP for procurements and early fabrication.	1. Implement all elements of the CCP.	1. Monitor system performance for evidence of contamination related degradation and prepare mitigation plans if necessary.	N/A
Verification:	1. Verify above at MCR and via Branch review of the proposal content.	1. Verify through peer review, proposal team, and at MRR and/or SRR as applicable. Requirements entered in project requirement tracking system.	1. Verify through peer review and at MDR.	1. Verify through peer review and at PDR and CDR.	1.Verify through verification matrix for requirements tracking system	1.Verify mitigation plan at ORR	N/A
Revision Status: Rev H		**Owner:** Contamination and Coatings Engineering Branch (546)				**Reference:** GEVS 2.8.1	

4.03	Factors of Safety for Structural Analysis and Design, and Mechanical Test Factors & Durations			Mechanical		
Rule:	Structural analysis and design factors of safety shall apply to all systems in accordance with GEVS Section 2.2.5. The project shall employ the mechanical test factors and durations in accordance with GEVS Section 2.2.4.					
Rationale:	This will provide confidence that the hardware will not experience failure or detrimental permanent deformation under test, ground handling, launch, or operational conditions.					

Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Employ design factors of safety in accordance with GEVS 2.2.5.	1. Employ design factors of safety in accordance with GEVS 2.2.5.	1. Employ design factors of safety in accordance with GEVS 2.2.5. 2. Formulate test plans for all structural elements incorporating the requirements described in the rule.	1. Employ design factors of safety in accordance with GEVS 2.2.5. 2. Write Test plans and execute tests.	N/A	N/A
Verification:	N/A	1. Verify that factors of safety are defined at MDR.	1. Verify that factors of safety are defined at SDR and PDR.	1. Verify these factors of safety, test factors, and test durations at CDR.	1. Verify these factors of safety, test factors, and test durations at EPR, PER, and PSR.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. E	Mechanical Systems Analysis and Simulation Branch (542, Primary) and Mechanical Engineering Branch (543)	GEVS 2.2.4 & 2.2.5

4.06	Validation of Thermal Coatings Properties				Mechanical		
Rule:	All thermal coatings properties that drive thermally significant performance shall be determined, measured and validated to be accurate for materials and mission flight parameters over the lifecycle of the mission. All thermal analysis shall employ these properties. The GSFC Coatings Committee (chaired by Code 546) shall review and approve the coatings properties.						
Rationale:	Thermal coatings properties directly affect Mission success through S/C or instrument thermal design. Early assessment of thermal coating ensures the mission objectives will be met.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Assess proposed thermal coatings for the mission design parameters.	1. Assess proposed thermal coatings for mission design parameters.	1. Determine appropriate BOL and EOL coatings properties to be used in the thermal analysis. 2. Determine mission specific thermal coating requirements.	1. Update thermal coatings properties as coatings selection matures.	1. Update thermal coatings properties as coatings selection matures. 2. Measure coatings properties when appropriate as determined by the Thermal Engineer/Coatings Engineer 3.Develop notional plan for assessing in flight	1. Assess thermal coatings performance through flight data as appropriate.	N/A
Verification:	1. Specify needed environmental tests on thermal coatings.	1. Specify needed environmental tests on thermal coatings.	1. Verify through peer review/GSFC Coatings Committee, test results, analysis and at PDR.	1. Verify through peer review/GSFC Coatings Committee, test results, analysis and at CDR.	1. Verify at PER as determined by the Thermal Engineer/Coatings Engineer	1. Confirm performance with available flight data as appropriate.	N/A
Revision Status: Rev. E, Updated Rev. H			**Owner:** Contamination & Coatings Engineering Branch (546)			**Reference:** NASA/TP-2005-212792	

4.10	**Minimum Workmanship**				**Mechanical**		
Rule:	All electrical, electronic, and electro-mechanical components shall be subjected to minimum workmanship test levels as specified in GEVS Section 2.4.2.5.						
Rationale:	The workmanship levels defined in GEVS Section 2.4.2.5 have been found to be the minimum input level necessary to adequately screen the hardware types above for workmanship flaws.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Envelop minimum workmanship levels when deriving component random vibration test levels.	1. Envelop minimum workmanship levels when deriving component random vibration test levels.	1. Envelop minimum workmanship levels when deriving component random vibration test levels.	N/A	N/A
Verification:	N/A	N/A	1. Verify that component test levels envelop minimum workmanship.	1. Verify that component test levels envelop minimum workmanship.	1. Verify that components have been adequately screened for workmanship.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. E	Mechanical Systems Analysis and Simulation Branch (542, Primary) and Electrical Engineering Division (560)	GEVS Section 2.4.2.5

4.11	Testing in Flight Configuration				Mechanical		
Rule:	Mechanical environmental testing (sine, random, & acoustic, shock, etc.) of flight hardware shall be performed with the test article in the flight like configuration. Mechanisms shall be configured for flight, and the flight (or flight like) blankets and harness shall be present for test. The flight optical system shall also be present for the test and configured for flight.						
Rationale:	Testing in-flight configuration ensures that hardware which is difficult to analyze (i.e., blankets, harnesses, mechanisms) will be adequately screened by environmental testing for design or workmanship flaws. The presence of the optical system in this testing enables verification that the performance stability of the as-built opto-mechanical configuration is compliant to requirements (e.g., wave-front error, alignment, etc.) before and after testing.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	N/A	1. Develop plans necessary to allow testing of hardware in flight configuration.	1. Perform testing in flight configuration.	N/A	N/A
Verification:	N/A	N/A	N/A	1. Verify that appropriate planning has been performed to conduct test in flight configuration.	1. Verify that testing has been performed with the test article in flight configuration.	N/A	N/A
Revision Status: Rev. E, Updated Rev. G		**Owner:** Mechanical Systems Analysis and Simulation Branch (542, Primary), Electrical Engineering Division (Code 560), and Optics Branch (Code 551)				**Reference:** GEVS Sections 2.4	

4.12	Structural Proof Testing				Mechanical		
Rule:	Primary and secondary structures fabricated from nonmetallic composites, beryllium, or containing bonded joints, bonded inserts, or critical welds shall be proof tested in accordance with GSFC-Std-7000 Section 2.4.1.4.1. The following definitions should be used to interpret this GOLD Rule: Primary Structure – Structure in the primary load path that carries the operational or test loads of the system to the structural boundary and whose failure would result in loss of structural integrity. Secondary Structure – Structure that is not in the primary load path and whose failure would not result in loss of structural integrity but would result in an unacceptable loss of capability for the system to meet functional requirements. Secondary structure includes structure whose failure could result in damage to other hardware critical to meeting the functional requirements of the system. Tertiary Structure – Structure not in the primary load path whose failure would not affect structural integrity or the ability of the system to meet functional requirements. Note: Classification of structures should be evaluated at each level of assembly as defined in GEVS (system, subsystem, component).						
Rationale:	The mechanical strength of the above items is dependent on workmanship and processing and can only be verified by proof testing.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Identify structure requiring proof testing.	1. Develop test methods and plans for performing proof testing.	1. Perform proof testing to verify mechanical strength.	N/A	N/A
Verification:	N/A	N/A	1. Verify that all structural elements requiring proof testing have been identified.	1. Verify that approach for proof testing appropriate structural elements has been defined.	1. Verify that proof testing has been performed.	N/A	N/A
Revision Status: Rev. E, Updated Rev. H		**Owner:** Mechanical Systems Analysis and Simulation Branch (542)				**Reference:** GEVS 2.4.1.4.1	

4.14	Structural and Mechanical Test Verification				Mechanical		
Rule:	Structural and Mechanical Test Verification program shall comply with GEVS-Table 2.4-1, Structural and Mechanical Verification Test Requirements.						
Rationale:	Demonstration of structural requirements is a key risk reduction activity during mission development.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Develop outline of structural qualification methodology.	1. Update structural qualification methodology and develop preliminary strength qualification plan.	1. Develop draft structural qualification methodology and plan.	1. Finalize structural qualification plan. 2. Implement plan.	1. Demonstrate that flight hardware supports expected mission environments and complies with specified verification requirements.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at MDR.	1. Verify that plan is under configuration control. 2. Verify through Engineering Peer Review and at PDR.	1. Verify through CDR, and Engineering Peer Review and at CDR.	1. Verify at PER, Engineering Peer Review, and PSR.	N/A	N/A
Revision Status: Rev. E		**Owner:** Mechanical Engineering Branch (543, Primary), Mechanical Systems Analysis and Simulation Branch (542)				**Reference:** GEVS Sections 2.4.1	

4.15	Torque/Force Margin					Mechanical	
Rule:	The Torque/Force Margin (TM) requirement defined in NASA-STD-5017, Section 4.3 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. Note: use higher safety factors as appropriate for immature mechanism designs with no engineering test data to significantly substantiate resistive torque/force loads. See GEVS Section 2.4.5.3 for suggested factors to be considered by mission phase.						
Rationale:	The torque or force margin needs to be sufficiently large to guarantee system-performance under worst-case conditions throughout its life by fully accommodating the uncertainty in the resisting forces or torques and in the source of energy.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Identify and create a plan for determination and implementation for Torque Margin verification.	1. The Torque Margin (TM) shall be calculated per the guidelines in NASA-STD-5017, Section 4.3. Identify basis for input to analysis.	1. The Torque Margin (TM) shall be calculated per the guidelines in NASA-STD-5017, Section 4.3. Identify basis for input to analysis. 2. Present all available engineering test data used for these analyses.	1. The Torque Margin (TM) shall be Calculated per the guidelines in NASA-STD-5017, Section 4.3.	1. Monitor system performance for evidence of mechanism degradation. Use this data to improve future design approaches. 2. Prepare mitigation plan to extend the life of the mission if degradation becomes evident.	N/A
Verification:	N/A	1. The Torque Margin Plan shall be presented at MDR as part of the analysis and verification process.	1. Present TM analysis at PDR.	1. Present TM analysis at CDR.	1. Present final test verified TM analysis at PSR. Identify basis for input to analysis. Present all available hardware verification test data used for these analyses.		N/A

Revision Status:	**Owner:**	**Reference:**
Rev. E, Updated in Rev H	Electro-Mechanical Systems Branch (544, Primary), Mechanical Engineering Branch (543)	NASA-STD-5017, Section 4.3

4.18	**Deployment and Articulation Verification**				**Mechanical**		
Rule:	All flight deployables, movable appendages, and mechanisms shall demonstrate full range of motion and articulation under worst-case conditions, when being driven by the flight avionics (i.e., not EGSE) prior to flight.						
Rationale:	Environmental factors such as temperature, gravity, acceleration fields, wire bundle stiffness, and others can adversely affect successful deployment. Additionally, initiation of mechanism release with EGSE could result in masking system-level design issues. Verification of these systems under worst-case conditions will improve on-orbit success.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	1. Include articulation in the verification plan and verification matrix.	1. Analyze design and use environment to determine worst case deployment conditions. 2. Demonstrate that all deployable system test plans include provisions to verify deployment under worst case conditions.	1. Update worst case analysis and test plans. 2. Write test procedure(s). 3. Conduct tests.	N/A	N/A
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify worst case condition analysis and test plans/procedures through engineering peer review and at CDR.	1. Verify test procedures and test results through engineering peer reviews, and at PER and PSR.	N/A	N/A
Revision Status: Rev. E, Updated Rev. G		**Owner:** Mechanical Engineering Branch (543, Primary and Electrical Engineering Division (560)				**Reference:**	

4.20	Fastener Locking				Mechanical		
Rule:	All threaded fasteners shall employ a minimum of one locking feature that does not depend on fastener preload to function. Exception: Swagelock compression fittings are not required to have a locking feature, but it is recommended. See Code 543 for best practices/approaches for adding a secondary locking feature.						
Rationale:	If not locked in the torqued, preloaded position, threaded fasteners subjected to vibration and thermal cycling loads may experience a reduction in preload and fully back out potentially jeopardizing the mission.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	N/A	1. Review all design drawings and specifications to assure all fasteners employ an appropriate locking feature.	1. Inspect all threaded fastener related assemblies to verify that the specified locking feature has been properly applied.	N/A	NA
Verification:	N/A	N/A	N/A	1. Verify at CDR.	1. Verify at PER and PSR.	N/A	N/A
Revision Status: Rev. F, Updated in Rev H		**Owner:** Mechanical Engineering Branch (543 Primary), Electromechanical Systems Branch (544)				**Reference:** **NASA-STD-5020**	

4.21	**Brush-type Motor Use Avoidance**				**Mechanical**		
Rule:	Designs shall avoid brush-type motors for critical applications with very low relative humidity or vacuum operations. Intentionally excluded from this rule are contacting sensory and signal power transfer devices such as potentiometers and electrical contact ring assemblies (slip rings, roll rings), etc.						
Rationale:	The operating life of the brush-type motors can be significantly decreased in extremely dry or vacuum conditions. Critical components relying on brush-type motors could be rendered inoperable due to excessively worn brushes or brush particulate contamination.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Identify all motor applications and motor types.	1. Mechanisms and Controls shall be designed to avoid the use of brush-type motors. If Brush-type motor is used, it shall be carefully scrutinized, and an alternative motor design and selection trade study shall be seriously considered.	1. Finalize motor and control design.	1. Trending Motor Performance during Integration and Test activities.	N/A	NA
Verification:	N/A	1. Verify at EPR & MDR.	1. Verify at EPR and PDR.	1. Verify at EPR and CDR. Conducted Life Test consistent with Gold Rule 4-23, Life Test Verification.	1. Verify at EPR, PER and PSR.	N/A	N/A
Revision Status: Rev. E		**Owner:** Electromechanical Systems Branch (544)				**Reference:**	

4.22	Precision Component Assembly						Mechanical
Rule:	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.						
Rationale:	When in the domain of arc-sec to sub-arc-sec location requirements, the use of pinning or similar non-friction reliant method will help ensure alignment is maintained through all expected stresses.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Begin to identify potential high precision interfaces.	1. Refine identification of high precision interfaces.	1. Identify methodology for precise location attachment.	1. Design and document attachment methods.	1. Inspect assemblies to assure specified attachment techniques are properly applied.	N/A	N/A
Verification:	N/A	N/A	1. Verify through peer review and at PDR.	1. Verify through peer review and at CDR.	1. Verify through peer review and at PER.	N/A	N/A
Revision Status: Rev. E		**Owner:** Electromechanical Systems Branch (544)				**Reference:**	

4.23	Life Test				Mechanical		
Rule:	Once requirements and design are stabilized to a high degree of certainty, 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. The differences between the life-test drive electronics and the flight drive electronics (e.g., voltage, current, duty cycle, etc.) could affect mechanism operating life and should be considered in the life-test.						
Rationale:	Degradation in repetitive motion devices from wear, fatigue, lubrication degradation, etc., can have serious negative impacts on mission success. Continuing the life test post-launch, if required, provides valuable information of potential anomalous conditions that could be used to modify mechanism flight operations to meet minimum mission requirements.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Develop a life test outline for all repetitive motion devices.	1. Develop draft life test plan.	1. Finalize plan and implement.	1. Present life test conclusions and compare to mission performance requirements.	N/A	N/A
Verification:	N/A	1. Verify at MDR.	1. Verify that plan has been drafted at PDR.	1. Verify plan and any existing life test data.	1. Verify life test results at PER and PSR.	N/A	N/A
Revision Status: Rev. H		**Owner:** Electromechanical Systems Branch (544, Primary), Mechanical Engineering Branch (543)				**Reference:** GEVS 2.4.5.1 and NASA-STD-5017, Section 4.22.1	

4.24	Mechanical Clearance Verification					Mechanical	
Rule:	Verification of mechanical clearances and margins (e.g., potential reduced clearances after blanket expansion) shall be performed on the final as-built hardware.						
Rationale:	Proper mechanical clearances are often critical to successful on-orbit performance (e.g., free-movement area, thruster impingement, FOV, etc.). Verification through analysis and drawing checking alone is not sufficient to properly demonstrate adequate clearance.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	N/A	N/A	1. Demonstrate that mechanical integration plans include provisions for verifying mechanical clearances at appropriate integration milestones. 2. Conduct inspections and measurements.	1. Demonstrate that mechanical integration plans include provisions for verifying mechanical clearances at appropriate integration milestones. 2. Conduct inspections and measurements.	N/A	N/A
Verification:	N/A	N/A	N/A	1. Verify at CDR.	1. Verify at PER and PSR.	N/A	N/A
Revision Status: Rev. E		**Owner:** Electromechanical Systems Branch (544)				**Reference:**	

4.25	Thermal Design Margins				Mechanical		
Rule:	Thermal design shall provide adequate margin between stacked worst-case flight predictions and component allowable flight temperature limits per GEVS 2.6 Note: This applies to normal operations and planned contingency modes. This does not apply to cryogenic systems.						
Rationale:	Positive temperature margins are required to account for uncertainties in power dissipations, environments, and thermal system parameters.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Thermal design concept produces minimum 5C margins, except for heater controlled elements which have a maximum 70% heater duty cycle, and two-phase flow systems which have a minimum 30% heat transport margin. For Pre-A, larger margins advisable.	1. Thermal design concept produces minimum 5C margins, except for heater controlled elements which have a maximum 70% heater duty cycle, and two-phase flow systems which have a minimum 30% heat transport margin. For Phase A, larger margins advisable.	1. Thermal design concept produces minimum 5C margins, except for heater controlled elements which have a maximum 70% heater duty cycle, and two-phase flow systems which have a minimum 30% heat transport margin.	1. Thermal design concept produces minimum 5C margins, except for heater controlled elements which have a maximum 70% heater duty cycle, and two-phase flow systems which have a minimum 30% heat transport margin.	1. System thermal balance test produces test-correlated model. Test and worst-case flight thermal analysis with test-correlated model demonstrate minimum 5C margins, except for heater controlled elements which demonstrate a maximum 70% heater duty cycle, and two-phase flow systems which demonstrate a minimum 30% heat transport margin.	1. Thermal analysis with flight-correlated model shows minimum 5C margins for mission trade studies, except for heater controlled elements which have a maximum 70% heater duty cycle, and two-phase flow systems which have a minimum 30% heat transport margin.	1. Thermal analysis with flight-correlated model shows minimum 5C margins for mission disposal options, except for heater controlled elements which have a maximum 70% heater duty cycle, and two-phase flow systems which have a minimum 30% heat transport margin.
Verification:	1. Verify at MCR.	1. Verify worst-case thermal analysis of concept through peer review and at SRR and MDR.	1. Verify worst-case thermal analysis of design through peer review and at PDR.	1. Verify worst-case thermal analysis of detailed design through peer review and at CDR.	1. Verify through peer review and at PER and PSR.	1. Verify thermal analysis of flight system using flight-correlated thermal model through peer review.	1. Verify thermal analysis of flight system using flight-correlated thermal model through peer review.
Revision Status: Rev. E, Updated Rev. G		**Owner:** Thermal Engineering Branch (545)				**Reference:** GEVS 2.6	

4.27	Test Temperature Margins				Mechanical		
Rule:	Components and systems shall be tested beyond allowable flight temperature limits, to proto-flight or acceptance test levels as specified in GEVS section 2.6.3.2 Note that at levels of assembly above component, full specified margins may not always be achievable for all components due to test setup limitations. In these cases, the expected test levels shall be approved by the GSFC Project, and shall be presented at the earliest possible formal review, no later than PER.						
Rationale:	The test program shall ensure that the flight hardware functions properly (meets performance requirements) at temperatures more severe than expected during the mission to demonstrate robustness to meet its mission lifetime requirements. (Note: This rule does not apply to cryogenic systems.)						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities: Revalidate	N/A	N/A	1. Component proto-flight thermal vacuum test temperatures shall be specified with the required margin as stated in the Reference (GEVS 2.6.3.2).	1. Component, subsystem, and system proto-flight thermal vacuum test temperatures shall be specified with the required margin as stated in the Reference (GEVS 2.6.3.2).	1. Components and systems shall undergo proto-flight thermal vacuum testing with the required margin as stated in the Reference (GEVS 2.6.3.2a). Yellow and Red limits for flight temperature telemetry database shall be consistent with actual proto-flight system thermal vacuum (TV) test temperatures.		
Verification:	N/A	N/A	1. Verify at PDR.	1. Verify at CDR.	1. Verify results of component and subsystem thermal vacuum (TV) tests, and present plans for system TV test at PER. 2. Verify results of system thermal vacuum test at PSR. 3. Verify flight database limits at MRR and/or FRR.		
Revision Status: Rev. H		**Owner:** Thermal Engineering Branch (545, Primary) and Electrical Engineering Division (Code 560)				**Reference:** GEVS 2.6.3.2	

4.28	Thermal Design Verification				Mechanical		
Rule:	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 2.6.4.						
Rationale:	This test shall provide an empirical verification of the subsystem/system's thermal design margin. In addition, steady state temperature data from this test shall be used to validate subsystem/system thermal math models (TMMs).						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify thermal balance test concepts.	1. Include thermal balance test in environmental test plan.	1. Identify preliminary thermal balance test architecture and scope.	1. Identify specific thermal balance test architecture and cases.	1. Implement test.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at MDR.	1. Verify at SDR and PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A
Revision Status: Rev. E		**Owner:** Thermal Engineering Branch (545)				**Reference:** GEVS 2.6.4	

4.29	Thermal-Vacuum Cycling				Mechanical		
Rule:	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. For an instrument, a minimum of four (4) of these eight (8) Thermal Vacuum cycles shall be performed at the instrument level of assembly. For units where there is an institutional or organizational delivery to an interim level of assembly, pre-delivery testing should include a minimum of 4 cycles.						
Rationale:	This provides workmanship and performance verifications at lower levels of assembly where required environments can be achieved and reduces the risk to cost during spacecraft Integration and Test (I&T).						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Identify environmental test concept.	1. Develop preliminary environmental test plan.	1. Update environmental test plan and put under configuration control.	1. Update plan.	1. Implement test cycles.	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at MDR.	1. Verify at SDR and PDR.	1. Verify at CDR.	1. Verify that all components have seen required testing prior to spacecraft I&T at PER.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. F, Updated Rev. G	Mission Systems Engineering Branch (599, Primary) and Thermal Engineering Branch (545)	GEVS 2.6.3.2.2

4.30	Materials Engineering Implementation				Mechanical		
Rule:	Materials and processes intended for use in flight designs shall be validated by Materials Engineering to be appropriate for the flight configuration, from concept through delivery of hardware. Materials properties testing and verification needed to inform engineering analyses as well as Non-Destructive Evaluation (NDE) of hardware, shall be identified in the early stages of the project.						
Rationale:	Improper materials selection and usage, inadequate materials properties information, insufficient review of manufacturing processes, can increase cost late in the project timeline, impact schedule, and elevate technical risk. The project's ability to ensure performance and environmental stability of materials is dependent on materials engineering involvement in design and testing activities, from concept through development.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1.Materials Engineering discipline is established within the project engineering team. 2. Mission-specific materials and processes engineering support, testing, and verification are identified	1. Prepare a mission-specific Materials & Processes implementation Plan that tailors the requirements in NASA-STD-6016 2. Identify engineering analyses requiring Materials verification or testing, and coordinate Materials Engineering support of engineering reviews (peer, milestone, review boards, etc.)	1. In coordination with project engineering team, assess and validate materials and processes according to Materials & Processes implementation Plan 2. Conduct materials laboratory testing, analyses, and inspections to support engineering design, and provide reports as project deliverables	1. In coordination with project engineering team, finalize materials deliverables according to Materials & Processes implementation Plan 2.Conduct materials laboratory testing, analyses, and inspections to support hardware design and fabrication, and provide reports as project deliverables	1.Deliver complete as-built materials lists, and approved materials usage agreements 2.Conduct materials laboratory testing, analyses, and inspections to support hardware assembly, integration & testing activities, and provide reports as project deliverables	N/A	N/A
Verification:	1. Verify at MCR.	1. Verify at SRR.	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PSR	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. H	Materials Engineering Branch (541)	GEVS 2.4 NASA-STD-6016

5.04	Instrument Testing for Multipaction				Instruments		
Rule:	Active RF components, such as radars, that develop significant RF power shall be designed and tested for immunity to multipaction. If multipaction immunity is demonstrated by test alone, the test shall be performed at least 6dB above the nominal power level. If satisfied by analysis and test, the analysis shall show at least 10dB of margin above the nominal power level and the test shall be performed at least 3dB above the nominal power level. Due to the inherent uncertainty in the analysis at these power levels, satisfaction by analysis alone is not allowed.						
Rationale:	Multipaction on RF components that carry large amounts of RF power can degrade overall performance and cause damage. Unless significant design margin is demonstrated, small unit-to-unit variations make it impossible to predict whether an RF component is susceptible to multipaction.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Determine the likely maximum power levels that components are going to see and determine if multipaction could be an issue.	1. Further refine power requirements and for components that are likely to have multipaction issues. 2. Begin vendor research to determine the extent of the issues.	1. Down select vendor and finalize component performance and power requirements. 2. Develop multipaction immunity verification plan.	1. Build engineering models of all components that could experience multipaction and perform testing on these components before and after environmental testing.	1. Build flight models and perform multipaction testing on all flight components before and after environmental testing.	1. Monitor instrument performance to determine if component damage or degradation is occurring due to multipaction.	N/A
Verification:		1. Gather data from multiple vendors to have several points of comparison.	1. Verify design and verification plan at PDR.	1. Verify results of EM testing at CDR.	1. Verify results of testing at PSR.	1. Track long-term performance of instrument for trends in overall performance and compare to expectations.	N/A
Revision Status: Rev. E, Updated Rev. G		**Owner:** Microwave Instrument Technology Branch (555)				**Reference:**	

5.05	Fluid Systems GSE				Instruments		
Rule:	Fluid systems GSE used to pressurize flight systems shall be compliant with the fault tolerance requirements of Rule 1.26.						
Rationale:	Fluid systems GSE is usually at a pressure significantly above the flight systems final pressure and therefore poses a risk of over-pressurizing the flight system.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Recognize the need for this specialized GSE.	1. Determine if candidate GSE exists and availability (versus a new build).	1. Secure agreement for existing GSE. 2. Design new GSE and procure components.	1. Recertify existing GSE before use. 2. Assemble and certify GSE.	1. Use GSE to test flight system (and components if necessary).	N/A	N/A
Verification:	1. Verify inclusion in proposal write-up and cost estimate.	1. Present GSE assessment at MDR.	1. Verify through peer review and at PDR.	1. Present certification at CDR.	1. Verify that procedures for GSE are approved by PER.	N/A	N/A
Revision Status: Rev. E		**Owner:** Cryogenics and Fluids Branch (552)				**Reference:** NPR 8715.3	

5.06	**Flight Instrument Detector Characterization Standard**				**Instruments**		
Rule:	Instrument detector systems (and associated components) shall demonstrate performance via test over the expected operating temperature range before the Pre-Environmental Review (PER) to establish a performance baseline and provide a provisional verification of performance prior to exposure to non-operational environments, such as vibration, acoustics, non-operational temperatures, or other conditions required to demonstrate survival. At the conclusion of environmental testing, performance shall again be characterized via test and the results compared to the baseline results.						
Rationale:	Detector performance falls off rapidly as a function of temperature for both increasing and decreasing temperature. Additionally, structural-thermal and optical performance models need to be correlated against tests.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Test mission-enabling parts and components at room temperature (extrapolate performance at other than room temperature).	1. Test critical parts and components over the flight operation temperature range, plus margin (no extrapolations) beyond intended operating range.	1. Test flight-like subsystem and components over the flight operation temperature range, plus margin beyond intended operating range.	1. Test flight-like systems and components operating temperature range, plus margin beyond intended operating range.	1. Test flight system over operating temperature range, plus margin beyond intended operating range. Show results of pre-environmental baseline tests in the operating environment.	N/A	N/A
Verification:	1. Test result reviewed by principal investigator.	1. Test result reviewed by principal investigator and science working group.	1. Review summary of results at PDR.	1. Review summary of results at CDR.	1. Verify through peer review and at PER.	N/A	N/A
Revision Status: Rev. E, Updated Rev. G		**Owner:** Instrument Systems and Technology Division (550)				**Reference:**	

5.10	Early Demonstration of Instrument Opto-Mechanical System Alignment and Test				Instruments		
Rule:	For instrument opto-mechanical systems without significant flight heritage, an early demonstration of the capability to fabricate, assemble, align, and test the opto-mechanical system shall be performed. Optics, mechanisms, structures, and other components relevant to the instrument system, including all opto-mechanical features and interfaces, using components of the approximate fit, form, and function of the flight hardware should be part of the early demonstration. The hardware configuration for the demonstration shall be agreed to by all stakeholders and phased with the flight unit to ensure that demonstration occurs early enough to be valuable.						
Rationale:	Early demonstration of the capability to fabricate, assemble, align and test opto-mechanical systems saves cost and mitigates schedule risks.						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Develop preliminary opto-mechanical demonstration configuration.	1. Finalize demonstration configuration and procure parts.	1. Build and test the demonstration hardware.	N/A	N/A	N/A	N/A
Verification:	1. Present plan at MCR	1. Review design at SRR	1. Review test results at PDR.	N/A	N/A	N/A	N/A
Revision Status: Rev. G		**Owner:** Optics Branch (551)			**Reference:**		

5.11	Instrument System Performance Margins				Instrument Systems	
Rule:	Instrument performance budgets shall be developed for instrument systems and their sub-systems. The performance budgets shall account for uncertainties including, but not limited to, fabrication, assembly, stability and test/verification. The project must have justification for the adequacy of their margins; test demonstration of predicted on-orbit performance with margins against the performance budgets is the preferred justification.					
Rationale:	Failure to properly allocate uncertainties in the fabrication, assembly, stability and test/verifications of instrument systems can result in an instrument that does not meet its performance requirements on orbit.					

Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Develop preliminary allocations based on top-level instrument performance requirements.	1. Perform analysis to develop error budgets. Identify any driving requirements that impact technical risk, schedule and cost.	1. Develop detailed budgets for fabrication, assembly, stability, and test/verification uncertainties.	1. Demonstrate that hardware meets its requirements with allocated margins.	1. Demonstrate that hardware meets its requirements with allocated margins by test.	N/A	N/A
Verification:	1. Verify at MCR	1. Verify at SRR	1. Verify at PDR.	1. Verify at CDR.	1. Verify at PER.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. G	Mission Engineering and Analysis Division (590, Primary) and Instrument Systems and Technology Division (550)	

5.12	Instrument Alignment, Integration and Test			Optics		
Rule:	Instruments containing optical systems shall develop an alignment plan in Phase A which will be refined and tracked throughout the project life cycle. The alignment plan should address such considerations as: alignment philosophy including the number of datasets required for appropriate statistics to verify requirements; cross-checks for critical data; leveling the instrument to gravity during metrology as appropriate; fiducials and other references; and authority to proceed before breaking an alignment configuration. In addition, consideration must be given to likely failure modes during testing to ensure that the hardware and test design is adequate to determine test failure causes and corrective action.					
Rationale:	Projects that do not incorporate assembly/integration, alignment and test planning early into the concept and design phases increase risk to cost and schedule, alignment efficiency, alignment requirement feasibility, and overall instrument performance.					

Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	1. Develop preliminary alignment and test concept flow chart.	1. Develop preliminary alignment and test plan.	1. Finalize alignment and test plan.	1. Develop draft alignment and test procedures.	1. Develop final alignment and test procedures.	N/A	N/A
Verification:	1. Verify at MCR	1. Verify at SRR	1. Verify at PDR.	Verify at CDR.	Verify at PER.	N/A	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. G	Optics Branch (551)	

5.13	**Laser Life Testing**				**Instruments**		
Rule:	There shall be a project-approved and peer-reviewed plan, consistent with the mission risk profile, for life-testing a laser prototype to a minimum of 1x of the mission lifetime requirement. The life-test unit should be a high-fidelity representation of the flight laser and any differences between the life test unit and the flight laser should be delineated in the plan. The plan should include system and component-level testing and/or analysis. Any components that have a wear-out or failure mechanism need to be addressed in the plan either by testing or with justification for why testing is unnecessary. Accelerated tests are permitted (and even encouraged) if the acceleration factors are understood and justified. The plan should include technical, budget, schedule and resource assumptions upon which the plan is based.						
Rationale:	There are unique requirements for laser life testing that differ significantly from those of electro-mechanical life-testing (GR 4.23)						
Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	N/A	1. Identify any components that have a wear-out or failure mechanism. 2. Develop draft plan and identify if risk is addressed either by testing or with justification for why testing is unnecessary. 3. If appropriate start testing of high-risk components.	1. Finalize plan and hold peer review. 2. Accelerated tests are permitted (and even encouraged) if the acceleration factors are understood and justified. 3. Perform testing of components and/or subsystems.	1. Perform testing of subsystems or ETU as appropriate.	1. Present life test conclusions and compare to mission performance requirements.	N/A	N/A
Verification:		1. Verify at MDR	1. Verify that plan has been drafted at PDR. 2. Review results of any available data	1. Review plan updates and any existing life test data at CDR.	1. Verify life-test results at PER and PSR.	N/A	N/A
Revision Status: Rev. G		**Owner:** Laser and Electro-Optics Branch (554)				**Reference:**	

5.14	Cryogenic Thermal Margins				Instruments	
Rule:	The Cryogenic Thermal Design shall provide adequate margin to account for increased heat load or decreased cooling capability from conceptual design to implementation. This is applicable to passive systems operating below 120K and actively cooled systems below 200K.					
Rationale:	Knowledge of heat loads can be very uncertain at early design stages, so cryogenic thermal design should be done with appropriate amount of margin to ensure a viable design.					

Phase:	**<A**	**A**	**B**	**C**	**D**	**E**	**F**
Activities:	The cryogenic thermal design shall have a 100% design margin on the current best estimate of the heat loads on the cryogenic subsystem.	The cryogenic thermal design shall have a 100% design margin on the current best estimate of the heat loads on the cryogenic subsystem.	The cryogenic thermal design shall have a 80% design margin on the current best estimate of the heat loads on the cryogenic subsystem.	The cryogenic thermal design shall have a 50% design margin on the current best estimate of the heat loads on the cryogenic subsystem.	The cryogenic thermal design shall have a 40% design margin on the current best estimate of the heat loads on the cryogenic subsystem.	The cryogenic thermal design shall have a 33% design margin on the current best estimate of the heat loads on the cryogenic subsystem.	N/A
Verification:	At MCR, Cryogenic, Thermal, and Systems Engineering organizations shall verify.	At SRR, Cryogenic, Thermal, and Systems Engineering organizations shall verify.	At PDR, Cryogenic, Thermal, and Systems Engineering organizations shall verify.	At CDR, Cryogenic, Thermal, and Systems Engineering organizations shall verify.	At PER, Cryogenic, Thermal, and Systems Engineering organizations shall verify.	At PSR, Cryogenic, Thermal, and Systems Engineering organizations shall verify.	N/A

Revision Status:	**Owner:**	**Reference:**
Rev. H	Cryogenics and Fluids Branch (Code 552, Primary) and Thermal Engineering Branch (Code 545)	NASA-GSFC Cryogenics and Fluids Branch/552

Notes:
1) Margin% = (Cooling Capability – Current Best Estimate) / Current Best Estimate
2) Parasitic load margins are applied at the location in which they are incurred.

5.15	**Stray Light Modeling and Mitigation**	**Instruments/Optical**
Rule:	All optical systems shall have an end-to-end stray light modeling and test campaign performed at the system level to identify background due to stray light effects and develop appropriate mitigation strategies to keep stray light effects within documented requirements. Throughout the life cycle, the model and test configuration shall be continually updated to reflect the current state of the design, ultimately accurately capturing the as-built flight hardware*. "End-to-end" is defined as the entire path from the observed target to the detecting surface. "Optical systems" include, but are not necessarily limited to scientific instruments, guiders, cameras or other vision-type systems, lidar instruments, star trackers, and sun sensors.	
Rationale:	Stray light is a system issue that requires early awareness and continual coordination among various disciplines to ensure mitigation and system performance. End-to-end stray light modeling provides accurate estimates of background due to sources such as scattering from optical and hardware surfaces and background due to thermal self-emission, and guards against unintended optical paths, hardware glints and vignetting that may not be accurately identified or quantified through modeling of individual subsystems. Testing provides model validation and the ultimate requirement verification. Mitigation involves proactive modification of design as well as inspection of as-built hardware to assure that the hardware reflects the design intent. *Note: In this text, "as-built" refers to the extent that properties of mechanical, optomechanical, and optical surfaces are relevant to stray light performance of the system. An example of a relevant properties is coatings selection whereas a mechanical deviation within tolerance would not be relevant.	
Phase:	**<A A B C D E F**	

Activities:	1.Perform a feasibility study from a stray light perspective. E.g.: a."Does the architecture sufficiently shield the system from unintended light paths or is it over-engineered?" b."Are preliminary optical surface roughness, cleanliness, and coating specifications realistic and achievable?" c."Is the proposed mechanical conceptual design feasible and achievable?" (e.g., is there room for appropriate baffling?) d."Identify likely stray light characteristics of proposed concepts, including the mechanical/structural design."	1.Generate a rough estimate of top-level system stray light "goals" as a budget precursor, e.g., 10% of zodiacal background for astronomical observing systems. 2.Develop an optomechanical (i.e., "stray light") model based on the current optical and mechanical designs, including initial definition of the physical apertures of each optical element. "Current" is defined as at least as up-to-date as any Integrated Modeling effort. 3.Validate the optical portion of the optomechanical model by comparing relevant metrics against those from the optical design model, e.g., compare chief raytrace data between stray light and optical design programs. 4.Assess the feasibility of incorporating appropriate baffling based on the current optical and mechanical designs. 5.Identify any unintended paths (e.g., specular skip paths, glint paths, diffracted paths, etc.) that reach the optical model detector surface(s) and draft a plan for how to handle the risks of each. 6.Assign surface roughness and particulate contamination scattering models to optical surfaces that are consistent with those that the science, optical, and contamination teams are using, and assess background at relevant field points due to these assignments. 7. Assign mechanical surface characteristics to hardware elements that are consistent with those of the mechanical and thermal designs. 8. For optical and mechanical design iterations/changes, verify that modifications do not impact optical design requirements (e.g., introduce unexpected vignetting) 9. Create/update an optical keep-out volume for incorporation into the system CAD model. 10. Flow down (or understand) the system requirements to quantities that can be determined with the optical model. 11. Establish a configuration management plan for the optomechanical model including scatter models and associated data, coating models and associated data, hardware (particularly hardware that will be evolving during the stray light analysis), etc. used for stray light analysis. Establish rules for how model is to be updated, who can update model, responsibility for model upkeep, etc. Strongly suggest that all analyses be scripted so that they can be rerun under the same conditions.	1. Continue development of stray light model based on the current optical and mechanical designs. "Current" is defined as being at least as up-to-date as any Integrated Modeling effort. 2. Identify hardware surfaces that could result in scatter paths to the detector and assign scatter models to at least those surfaces in the stray light model. Scatter models should be based on relevant past history or measurement of witness samples whenever possible. 3. Develop a stray light background budget and allocate terms to relevant sources including, but not limited to, optical and mechanical surface scattering, thermal self-emission, diffraction, non-sequential paths, volume effects in lenses (i.e., bulk scatter, radiation darkening, etc), ghosting, and susceptibility mapping to the target object (sky, ground, etc.) 4. Determine current best estimates for terms in the stray light budget. 5. Update the official optical keep-out volume due to any relevant changes in the optical design. 6. Flow down subsystem and component requirements using language, units, and forms of data that are testable and verifiable in the lab. Have a plan to compare the model results to actual physical measurements in order to verify the stray light model. 7. Inform plans for subsystem and system-level stray light tests in support of either stray light requirement verification or stray light model validation	1. Update the stray light model to include changes to the optical model and any relevant current hardware designs around the optical path(s). 2. Update the stray light background budget and allocate terms to relevant sources including, but not limited to optical and mechanical surface scattering, thermal self-emission, diffraction, non-sequential paths, volume effects in lenses (i.e., bulk scatter, radiation darkening, etc), ghosting, and susceptibility mapping to the target object (sky, ground, etc.) 3. Determine current best estimates for terms in the stray light background budget. 4. Complete a stray light test plan and execute subsystem stray light tests as appropriate. Update models based on subsystem test results accordingly.	1. Update the model to include final flight hardware designs. Visually inspect as-built hardware, thermal blankets, and closeouts to verify model consistency. e.g., perform "flashlight" tests to inspect closeouts and interfaces for gaps. 2. At a minimum, the stray light model shall reflect the expected on-orbit optical and hardware design. 3. Execute system-level stray light tests as technically appropriate. Update models based on system-level test results accordingly 4. (Prior to launch) Prepare tools for quick-look analyses to support commissioning.	1. Support commissioning with assessment of system background compared to CBEs and diagnosis of unidentified artifacts. 2. Document and pass on any lesson's learned for subsequent missions and/or instrumentation development.	N/A

Verification:	1. Verify at MCR	1. Verify at MDR	Verify at SDR and PDR	Verify at CDR	Verify at PER	Verify at ORR (post-launch, after commissioning is complete)	N/A
Revision Status: Rev. H		**Owner:** Optics Branch (551)				**Reference:**	

GLOSSARY AND ACRONYM GUIDE

AIAA	American Institute of Aeronautics and Astronautics
Anomaly	An unexpected event that is outside of certified design/performance specification limits. NOTE: Certified design limits are those identified in approved design-level documents
Assembly	A functional subdivision of a component consisting of parts or subassemblies that perform functions necessary for the operation of a component as a whole (Ref: GEVS 1-6)
ACS	Attitude Control System
API	Application Program Interfaces
BOL	Beginning of Life
Breadboard	A model used to test hardware at TRL 4 or 5 (See TRL levels.)
Catastrophic Hazard	A hazard, condition or event that could result in a mishap causing fatal injury to personnel and/or loss of spacecraft, launch vehicle or ground facility
CCP	Contamination Control Plan
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CM	Configuration Management: A management discipline applied over the product's life cycle to provide visibility and to control performance and functional and physical characteristics (Ref: NPR 7120.5)

Component	A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation (Ref: GEVS 1-6)
COTS	Commercial Off-The-Shelf
CPU	Central Processing Unit
Critical Hazard	A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, or flight hardware
Debug Features	With the best of intentions of helping to debug software and/or hardware problems, there exists a feature that is not needed by the operation software but was accidentally or intentionally left in the code for debug purposes. (May be advertised or unadvertised; May be documented or undocumented; May be tested or untested)
DR	Decommissioning Review
EDAC	Error Detecting and Correcting
EEE	Electrical, Electronic, and Electromechanical
EEPROM	Electrically Erasable Programmable Read-Only Memory
EGSE	Electrical Ground Support Equipment
Element	A portion of a hardware or software unit that is logically discrete
End-to-end test	A test performed on the integrated ground and flight system, including all elements of the payload, its control, stimulation, communications, and data processing (Ref: GEVS 1-4)
ESD	Electro-Static Discharge

Established Reliability	Demonstrated operation (of a standard product or COTS assembly, component, or spacecraft) over years and production over multiple units by the same vendor, including possible changes due to obsolescence and modernization. May be quantified by risk classification using the Inherited Standard Products row in Table 1 along with Appendix D from GPR 8705.4A.
ETU	Engineering Test Unit
EOL	End of Life
FDAC	Failure Detection and Correction
FIFO	First-In / First-Out
FOR	Flight Operations Review
FOS	Factors of Safety
FOV	Field of View
FPGA	Field Programmable Gate Array
FRR	Flight Readiness Review
FSW	Flight Software
GEVS	General Environmental Verification Standard
GN&C	Guidance, Navigation, and Control
GOLD	Goddard Open Learning Design
GPR	Goddard Procedural Requirement

GRT	Ground Readiness Test
GSE	Ground Support Equipment
Heritage hardware	Hardware from a previous project, program, or mission
High fidelity	Addresses form, fit, and function. Equipment that can simulate and validate all system specifications within a laboratory setting (Ref: Defense Acquisition University)
HW	Hardware
I&T	Integration and Test
ICD	Interface Control Document
I/F	Interface
I/O	Input / Output
ISR	Interrupt Service Routine
ITU	Integrated Test Unit
IVT	Interface Verification Test
KDP	Key Decision Point. The event at which the Decision Authority determines the readiness of a Program/project to progress to the next phase of the life cycle (or to the next KDP)
L&EO	Launch and Early Orbit
LRR	Launch Readiness Review

OS	Operating System
Margin	The amount by which hardware capability exceeds requirements (Ref: GEVS 1-7)
MDR	Mission Definition Review
MCR	Mission Concept Review
MEL	Mission Exceptions List
Mission-critical	Item or function that must retain its operational capability to assure no mission failure (See Mission success) (Ref: MSFC SMA Directorate)
Mission Success Reqs	Level 1 Mission Requirements or minimum mission success criteria for a project or program.
MOR	Mission Operations Review
MRR	Mission Readiness Review
MRT	Mission Readiness Test
ms	milliseconds
M&P	Materials and Processes
MSPSP	Missile System Prelaunch Safety Package
NDE	Non-Destructive Examination
NPR	NASA Procedural Requirements
ORR	Operational Readiness Review

OS	Operating System
Payload	An integrated assemblage of modules, subsystems, etc., designed to perform a specified mission in space (Ref: GEVS 1-6)
PCI	Peripheral Component Interconnect
PDR	Preliminary Design Review
PER	Pre-Environmental Review
Performance Verification	Determination by test, analysis, or a combination of the two that the payload element can operate as intended in a particular mission (Ref: GEVS 1-7)
POC	Point Of Contact
PROM	Programmable Read-Only Memory
Prototype hardware	Hardware of a new design. It is subject to a design qualification test program; it is not intended for flight (Ref: GEVS 1-5)
PSR	Pre-Ship Review
RAM	Random Access Memory
RF	Radio Frequency
Safe Hold Mode	A control mode designed to provide a spacecraft with a mode to preserve its health and safety while recovery efforts are undertaken
Safety	Freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment (Ref: NPR 7120.5)

SAR	System Acceptance Review
S/C	Spacecraft
SDR	System Design Review
SEMP	Systems Engineering Management Plan
Simulation	The imitation of the behavioral characteristics of a system, entity, phenomenon or process. (Ref: NASA-STD-7001)
SORR	Science Operations Readiness Review
Spare (part)	A replacement part (reparable or expendable supplies) purchased for use in the maintenance of systems such as aircraft, launch vehicles, spacecraft, satellites, ground communication systems, ground support equipment, and associated test equipment. It can include line-replaceable units, orbit-replaceable units, shop-replaceable units, or piece parts used to repair subassemblies
SRR	System Readiness Review
Subsystem	A functional subdivision of a payload consisting of two or more components (Ref: GEVS 1-6)
System	The combination of elements that function together to produce the capability required to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose (Ref: NPR 7120.5, NASA Space Flight Program and Project Management Requirements)
SW	Software
TBD	To Be Determined

Test Features	With the best of intentions of helping to test and validate the software, there exists a feature that is not needed by the operational software but is desirable to have for testing purposes. (May be advertised or unadvertised; May be documented or undocumented; May be tested or untested)
TAYF	Test As You Fly
TM	Torque Margin
TRL	Technology Readiness Level - A systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology. NASA recognizes nine technological readiness levels:
Traceability Matrix	A matrix demonstrating the flow-down of requirements to successively lower levels
UART	Universal Asynchronous Receiver / Transmitter
Validation	Proof that Operations Concept, Requirements, and Architecture and Design will meet Mission Objectives, that they are consistent, and that the “right system” has been designed. May be determined by a combination of test or analysis. Generally accomplished through trade studies and performance analysis by Phase B and through tests in Phase D
Verification	Proof of compliance with requirements and that the system has been “designed and built right.” May be determined by a combination of test, analysis, and inspection

DOCUMENT HISTORY LOG

Revision	Effective Date	Description
-	10-Dec-04	Baseline
A	30-May-05	[P. 10] User's Guide: removed text examples, replaced with bullets explaining what general information goes into each rule section.
		Addition of Change History page (against 12/10 baseline rulebook).
		[P. 7] Revised Front Matter Graphics (architectural diagram - Figure 2).
		[Rule 1.17, Glossary] 1. Added "credible" to Principle, Phase B, and Phase C; 2. Added "credible" definition to Glossary.
		[Rule 1.22] Phase C revision - Replaced existing language with: "Demonstrate that the method for drying the wetted system has been validated by test on an equivalent or similar system."
		[Rule 1.14] Revision to the Principle and Rationale. Revised Principle: Telemetry coverage shall be acquired during all mission-critical events. *Continuous telemetry and command capability shall be maintained during launch and until the spacecraft has been established on-orbit in a stable, power-positive mode."*
		[Rule 1.06] Added table 1.06-1 to website rule set.
		[Rule 3.07] Added table 3.07-1 to website rule set.
		[Rules: 2.01, 2.07, 2.11, 4.01, 4.03, 4.09, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15, 4.23, 4.25, 4.27, 4.28, 4.29] 1. Corrected GSFC-STD-7000 (GEVS) references in GSFC-STD-1000. 2. Created reference PDFs. 3. Added reference links.
		[Rule 3.09] Added web links to source material (NPR 7150.2, GPG 8700.5).

Revision	Effective Date	Description
B	**30-June-06**	[P. 6] Updated Introduction.
		[P. 9] Revised Figure 3 Lifecycle Chart - Removed "from SMO"
		[P. 10] Updated User's Guide.
		New Systems Engineering Rule: 1.04 – System Modes.
		New Systems Engineering Rule: 1.08 – End to End Testing.
		[Rule 1.14] Revised Principle, Rationale, Activities (Phase E), and Verification (Phases pre-A, A, C → E). Revised Principle: *Continuous telemetry and command 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.* Revised Rationale: *With continuous telemetry and command capability, operators can prevent anomalous events from propagating to mission loss. Also, flight data will be available for anomaly investigations.*
B.1	**29-Sept-06**	Formatting changes to Rules 1.17, 2.02, 2.17, 3.03, 3.06, 3.07, 3.09, 3.10, 3.14, 3.15, 4.07, 4.15, 4.20, 4.28, Page 2, Table 307-1 and Glossary "Space Part"
		Typographical errors corrected on Rule 1.28, 3.10, 4.08, 4.18, 4.23, 4.26
		Replaced Page 2 and 3 of Table 3.07-1
C	**30-Oct-06**	Rule 1.14 – Revised Language in "Principle" Statement
		Rule 1.26 – Major Revision
		New Systems Engineering Rule: 1.29 Leakage of Hazardous Propellant
		Glossary – Added definitions for critical and catastrophic hazards
		Table of Contents – Updated to Reflect Changes for Rules 1.26, 1.29
C.1	**12-Dec-06**	New Systems Engineering Rule: 1.09 Test Like You Fly
		New Software Rule: 3.02 Elimination of Dead Software Code
		Table of Contents – Updated to Reflect Changes/Insertion for Rules 1.09, 3.02
		Glossary – Added Definitions for Dead Software/Code & Acronym for "Test Like You Fly"
		Table of Contents – Typographical error in Rule 1.08 title corrected
		[Rule 1.14] Revised Verification for Phases pre-A → E.
C.2	**12-Dec-06**	Introduction – Corrected language for GPR 8070.4
		Table 1.06-1 – Deleted "RF Link" Margin

Revision	Effective Date	Description
D	01-March-08	Table of Contents – Revised to Reflect Rev D Changes
		Rule 1.03 – Revised “Principle” Statement
		Rule 1.11 – Revised “Principle” Statement
		Rule 1.16 – Revised “Principle” Statement
		Rule 3.07 – Revised “Title” and “Principle” Statement
		Rule 5.05 – Revised “Principle” Statement
		Rule 5.09 – Revised “Principle” Statement
		New Systems Engineering Rule: 1.18 Physically Co-Located Redundant Elements
		New Systems Engineering Rule: 1.23 Spacecraft “OFF” Command
		New Systems Engineering Rule: 1.25 Redundant Systems
		New Electrical Engineering Rule: 2.08 Secondary Circuit Failures
		New Electrical Engineering Rule: 2.18 Redundant Functions
		New Electrical Engineering Rule: 2.19 Multiple Circuit Power Bus Loss
		New Electrical Engineering Rule: 2.20 Single Control Line Dependency
		New Electrical Engineering Rule: 2.21 Gross Failure of Integrated Circuits
		New Electrical Engineering Rule: 2.22 Corona Region Testing of High Voltage Equipment
		Table 3.07-1 – Revised first paragraph
E	07-July-09	Major Revision / Rewrite
E	03-Aug-09	Administrative Changes Only - Rule 1.06 (pages 12 thru 16) and associated tables, modified throughout for clarity, regarding system margin.
E	21-Feb-12	Administrative Changes Only – Rule 1.06 (pages 12 - 13); reverts to previous version, in its entirety, for immediate near-term efficiency of mission application.
		Glossary and Acronym Guide – changed definition of Catastrophic Hazard (ref. Rule 1.26), for consistency with NASA-STD 8719.24.
F	10-Dec-12	New Rules 1.39, 2.23, 2.24, 2.25; Added Rule 4.01 Introduction and elsewhere as needed: Removed Rev. E delineation between Rules and Principles to identify all rules; rule = requirement Updated all GEVS references to align with latest version (TBD) of GEVS Updated owner organization throughout. Glossary – corrected definitions of anomaly and EEE CCR-D-0047
F	22-Jan-13	Administrative Change Only – Table 1.06-1: Phase B in Power line changed from 15% to 20%
F1	8-Feb-2013	Administrative Change Only – Table 1.09: Note corrected to “not a global approval to waive TAYF for all elements”. Acronym TYF corrected to TAYF.

G	**6-Nov-2015**	Rev G is an extensive revision **Deleted The Following Rules:** 1.34 Close-out Photo Documentation Of Key Assemblies 2.02 EEE Parts Program For Flight Missions 2.03 Radiation Hardness Program 2.12 Printed Circuit Board Analysis 2.15 Flight and Ground Electrical Hardware 4.07 Solder Joint Intermetallics Mitigation 4.08 Space Environments Effects on Material Selection **Merged the Following "duplicate" Rules:** 2.07 End-to-End Test of Release Mechanism For Flight Deployable) merged with 4.18 (Deployment and Articulation Verification) and 2.07 removed 2.18 (Implementation of Redundancy) merged with 1.25 (Redundant Systems) and 2.18 removed **Revised The Following Rules (not a complete list):** 1.05 Single Point Failures – Clarified Wording 1.06 System Margins – Revised calculation to be consistent with industry practices; clarified margin and contingency to remove double bookkeeping 1.08 End-To-End Testing – Clarified Wording 1.23 Spacecraft "Off" Command – Simplified and clarified wording 1.40 Maintaining Command Authority of a Passive Spacecraft – significant rewrite 2.05 System Grounding Architecture – Added requirement to include GSE 2.24 – Solar Arrays – Significant Rewrite to give more detail on cell qualification and panel testing 3.07 Flight Software Margins – Rewrite of Table 3.07-1 to define verification methods 4.06 Validation of Thermal Coatings Properties – added detail on how to validate 4.23 Life Test – Added consideration for differences between drive electronics used in the life test versus the flight drive electronics 5.04 Instrument Testing for Multipaction – Significant rewrite 5.06 Flight Instrument Detector Characterization Standard – Added detector to title since that was the intent of the rule; added detail **Added The Following New Rules:** New Systems Engineering Rule 1.41 GSE Use At Launch Site New Systems Engineering Rule 1.42 Powering Off RF Command Receiver New Systems Engineering Rule 1.43 Flight Software Update Demonstration

		New Systems Engineering Rule 1.44 Early Interface Testing New Systems Engineering Rule 1.45 System Alignments New Systems Engineering Rule 1.46 Use of Micro-Switches New Systems Engineering Rule 1.47 Design Deployables for Test New Systems Engineering Rule 1.48 Space Data Systems Standards New Electrical Rule 2.26 Power-On Reset Visibility New Electrical Rule 2.27 Spacecraft Strip-Charting Capability New Instrument Rule 5.10 Early Demonstration of Instrument Opto-Mechanical Alignment and Test New Instrument Rule 5.11 Instrument System Performance Margins New Instrument Rule 5.12 Instrument Alignment, Integration and Test New Instrument Rule 5.13 Laser Life Testing
H	**15-Mar-2023**	Rev H is an extensive revision **Deleted the Following Rules:** 1.26 Safety Inhibits and Fault Tolerance – Covered by Safety Requirements 1.33 Polarity Checks of Critical Components – Merged with 1.07 1.35 Maturity Of New Technologies – Covered by NPR7123.1 5.08 Laser Development Contamination Control – Covered by 4.01 5.09 Cryogenic Pressure Relief – Covered by Safety Requirements **Revised The Following Rules (not a complete list):** 1.06 Resource Margins – Revised to Align with AIAA S-120A-2015 1.09 Test As You Fly – Added option to document via an Engineering Peer Review 2.22 Corona Region Testing Of High Voltage Equipment – Defined High Voltage 2.23 RF Component Testing For Multipaction and Corona – Rewrite For Clarity 3.05 Flight/Ground System Test Capabilities – 3.06 Dedicated Engineering Test Unit For Flight Software Testing – 4.15 Torque Margin – Revised with additional guidance **Added The Following New Rules:** 4.30 Materials Engineering Implementation 5.14 Cryogenic Thermal Margins 5.15 Stray Light Modeling and Mitigation