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ICE, CLOUD, and Land Elevation Satellite (ICESat-2) Project

Advanced Topographic Laser Altimeter System (ATLAS) Component Environmental Requirements Document (CERD)

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

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CM FOREWORD

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In this document, a requirement is identified by “shall,” a good practice by “should,” permission by “may” or “can,” expectation by “will,” and descriptive material by “is.”

Questions or comments concerning this document should be addressed to:

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CHANGE RECORD PAGE

Document Version	Document Release Date	SCoRe Number	SCoRe Approval Date	Pages Affected	Description
Rev -	09/24/10	0027	09/24/10	All	Initial release of baseline.
Rev A	11/16/10	0114	11/16/10	All	Updated for iSRR
Rev B	04/06/11	0168	03/23/11	Requirements Section	Update requirements flowdown
Rev C	08/02/2011	0212	07/19/2011	Requirements Section	Changes made to allocations, rationale, requirements, etc.
Rev D	08/11/2011	CCR-0101	08/10/2011	Pg. 22	Waiver for CERD31 to allow the LRS TRL6 prototype thermal vacuum test to be run at a chamber pressure of up to 5 x 10^-3 Torr. See CCR-0101 for details.

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1 GENERAL INFORMATION

1.1 PURPOSE AND SCOPE

This document provides specifications for the operating environment and requirements for the environmental verification program of components of the Ice, Cloud, and Land Elevation Satellite-2 (ICESAT-2) Advanced Topographic Laser Altimeter System (ATLAS) instrument. This document describes methods for implementing those requirements. It contains a baseline for demonstrating by test and analysis the satisfactory performance of hardware in the expected mission environments. It elaborates on those requirements, gives test levels, provides guidance in the choice of test options, and describes acceptable test and analytical methods for implementing the requirements.

This document was adopted from the ICESAT-2 Environmental Requirements Document (ERD).

1.2 APPLICABILITY AND LIMITATION

These requirements apply to ATLAS component flight hardware and associated flight software that is to be launched on an Expendable Launch Vehicle (ELV).

1.3 DEFINITIONS

The following are definitions of flight hardware used in this document. These definitions are taken directly from GSFC-STD-7000, General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects.

Component: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. For the purposes of this document, "component" and "unit" are used interchangeably.

Instrument: A spacecraft subsystem consisting of sensors and associated hardware for making measurements or observations in space. For the purposes of this document, an instrument is considered a subsystem (of the spacecraft).

1.4 THE ATLAS COMPONENT VERIFICATION APPROACH

The ATLAS components will be verified under conditions that simulate the launch operations, flight operations and flight environment as realistically as possible.

Units powered on for launch, will be powered on and their performance monitored during test. However, it is recognized that there may be unavoidable exceptions, or conditions which make it preferable to perform the verification activities at other levels of assembly.

The total verification process also includes the development of models representing the

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hardware, tests to verify the adequacy of the models, analyses, alignments, calibrations, functional/performance tests to verify proper operation, and finally end-to-end tests and simulations to show that the total system will perform as specified.

1.5 RESPONSIBILITY FOR ADMINISTRATION

The responsibility and authority for decisions in waiving or deviating from the requirements of this document are subject to review and approval by the ATLAS Instrument Lead Systems Engineer (ISE).

1.6 CONFIGURATION CONTROL AND DISTRIBUTION

This document is controlled and maintained by the GSFC ICESAT-2 Project Office.

2 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents provide information Applicable (i.e., binding/required) to the ATLAS instrument. These documents are applicable in the sections referenced in the text of this document. Since these documents are subject to periodic revisions, the user should refer to the latest available version. In the event of a conflict between this document and the documents referenced herein, this document takes precedence. Contractors will use the current version in effect at the time of procurement.

1. GSFC-STD-1000-E, Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems
2. GSFC-STD-7000, General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects
3. ICESat-2-SYS-REQ-0329, ATLAS Instrument Requirements Document (IRD)
4. ICESat-2-ATSYS-PLAN-0297, ATLAS Contamination Control Plan
5. ICESat-2-ATSYS-REQ-0479, ATLAS Resource Allocations
6. ICESat2-SYS-REQ-0518, ICESAT-2 Environmental Requirements Document (ERD)
7. ICESat-2-THM-IFACE-0214, ATLAS Thermal ICD
8. MIL-STD-461C Part 2, as amended by Notice 1
9. MIL-STD-462, as amended by Notice 1
10. NASA-STD-5001A, Structural Design and Test Factors of Safety for Space Flight Hardware

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3 ATLAS COMPONENT REQUIREMENTS VERFICATION M ATRIX

CERD998: Deleted. Verification matrix no longer used.

CERD999: Deleted. Verification matrix no longer used.

4 MECHANICAL ENVIRONMENT AND VERIFICATION

All testing is to protoflight levels unless otherwise specified.

ID : CERD1
Section 4.1
Title : Qualification by Analysis
Metallic structures, excluding Beryllium, qualified by analysis with approval of the ATLAS instrument lead systems engineer (ISE) shall show positive margins of safety using factors of safety of 2.0 on yield and 2.6 on ultimate.
Rationale : Metallic structure with high margins of safety may verify strength by analysis.
Traceability : IRD243
Verification Method: Analysis, if applicable.
Verification Level: Component.
Allocation: Laser, Laser Sampling Assembly (LSA), Start Pulse Detector (SPD), Fold mirrors, Fiber optics, Beam expander, Diffractive Optical Element (DOE), Polarizing Beam Combiner (PBC), Thermal Control System (TCS), Laser Reference System (LRS), Transmitter Alignment Monitoring System (TAMS), Beam Steering Mechanism (BSM), Lateral Transfer Retro-reflector (LTR), Telescope, Aft Optics, Optical Filter Assembly (OFA), Detector Array Assembly (DAA), Structure, Main Electronics Box (MEB), Power Distribution Unit (PDU).

ID : CERD2
Section : 4.1
Title : Qualification by Test
Beryllium, glass and composite materials shall not be qualified by analysis alone.
Rationale : Brittle materials must be tested to verify strength.
Traceability : IRD244
Verification Method: Test, if applicable.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD3
Section : 4.2.1
Title : Weight Verification
The weight of each ATLAS flight component shall be measured to within ± 0.2%.
Rationale : The ATLAS component weight measurement shows compliance with

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specified component requirements and provides accurate data for the observatory mass properties control program.

Traceability : IRD86

Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, Electrical Harness

ID : CERD4
Section : 4.2.1
Title : Center of Gravity Verification
The center of gravity (CG) of each ATLAS flight component, referenced to the ATLAS to spacecraft mounting plane, shall be verified to within ± 0.15 centimeters (cm). The CG may be analytically derived.
Rationale : The ATLAS component CG measurement shows compliance with specified component requirements and provides accurate data for the observatory mass properties control program.
Traceability : IRD87
Verification Method: Test or Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD5
Section : 4.3.1
Title : Component Fundamental Frequency Specification
The fundamental frequencies of the ATLAS components shall be greater than or equal to 100 Hertz (Hz).
Rationale : ATLAS component fundamental frequencies should avoid instrument assembly and observatory induced excitation frequencies.
Traceability : IRD89, IRD241
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD6
Section : 4.3.1
Title : Structure Axial Fundamental Frequency Specification
The fundamental frequency of the ATLAS structure, carrying the maximum allowable payload and instrument mounted spacecraft component (IMSC) masses, shall be greater than or equal to 50 Hz in the axial direction.
Rationale : The ATLAS structure carries the entire mass of the instrument and the

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IMSC. The fundamental frequency of this entire assembly (the instrument assembly) should avoid observatory induced excitation frequencies.

Traceability : IRD241
Verification Method: Analysis.
Verification Level: Subsystem.
Allocation: Structure

ID : CERD7
Section : 4.3.1
Title : Structure Lateral Fundamental Frequency Specification

The fundamental frequency of the ATLAS structure, carrying the maximum allowable payload and IMSC masses, shall be greater than or equal to 35 Hz in the lateral axes.

Rationale : The ATLAS structure carries the entire mass of the instrument and the IMSC. The fundamental frequency of this entire assembly (the instrument assembly) should avoid observatory induced excitation frequencies.

Traceability : IRD89
Verification Method: Analysis.
Verification Level: Subsystem.
Allocation: Structure

ID : CERD8
Section : 4.3.2
Title : Fundamental Frequency Testing

Each ATLAS component, including the structure carrying the maximum allowable payload and IMSC masses, shall undergo a low-level sine survey, measuring all modes up to the component's specified frequency.

ATLAS components having mass less than 2 kilograms (kg) may supply analytically-derived frequencies.

Rationale : A low-level sine sweep determines the modal signature of the flight item which verifies compliance with fundamental frequency requirements.

Guideline test parameters are shown below.

1) Frequency: 5 – 2000 Hz
2) Acceleration: 0.25 g
3) Sweep Rate: 2 octaves/minute

Traceability : IRD200
Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

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ID : CERD9
Section : 4.3.2
Title : Fundamental Frequency Testing
Each ATLAS component, including the structure carrying the maximum allowable payload and IMSC masses, shall undergo a low-level sine sweep performed immediately preceding the sine/random vibration tests and repeated after the sine/random vibration tests.
Rationale : A low-level sine sweep determines the modal signature of the flight item, which verifies the instrument structure did not shift during loads testing.
Guideline test parameters are shown below.

1) Frequency: 5 – 2000 Hz
2) Acceleration: 0.25 g
3) Sweep Rate: 2 octaves/minute

Traceability : IRD242
Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD10
Section : 4.4.1
Title : Component Quasi-Static Loads Analysis
Structural analysis of ATLAS components, excluding the structure, shall show positive margins of safety (MS) for ultimate and yield failures verified by a detailed stress analysis that assesses all primary and secondary structure, joints, and fasteners for the limit loads defined in Figure 4-1 and the appropriate factor of safety (FS) specified below:

1. Metallic, Beryllium, Composite - Table 4.4-1
2. Glass - Table 4.4-2
3. Glass bonds – Table 4.4-3

Table 4.4-1 - Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads for Non-glass and Non-pressurized ATLAS Components

Type	Static	Sine	Random/ Acoustic[1]
Metallic Yield	1.25	1.25	1.6
Metallic Ultimate	1.4	1.4	1.8
Stability Ultimate	1.4	1.4	1.8
Beryllium Yield	1.4	1.4	1.8
Beryllium Ultimate	1.6	1.6	2
Composite Ultimate	1.5	1.5	1.9
Bonded Inserts/Joints Ultimate	1.5	1.5	1.9

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Table 4.4-2 - Minimum Design and Test Factors for Glass
Source: NASA-STD-5001A Section 5.1.4

Verification Approach	Loading Condition	Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
Protoflight	Nonpressurized	3.0	NA	1.2
	Pressurized	3.0	NA	2.0
Analysis Only	Nonpressurized	5.0	NA	NA

Table 4.4-3 - Minimum Design and Test Factors for Glass Bonds

Source: NASA-STD-5001A Section 5.1.5

Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
2.0	1.4	1.2

Figure 4-1 - ATLAS Component Mass Acceleration Curve (MAC) [1,2]

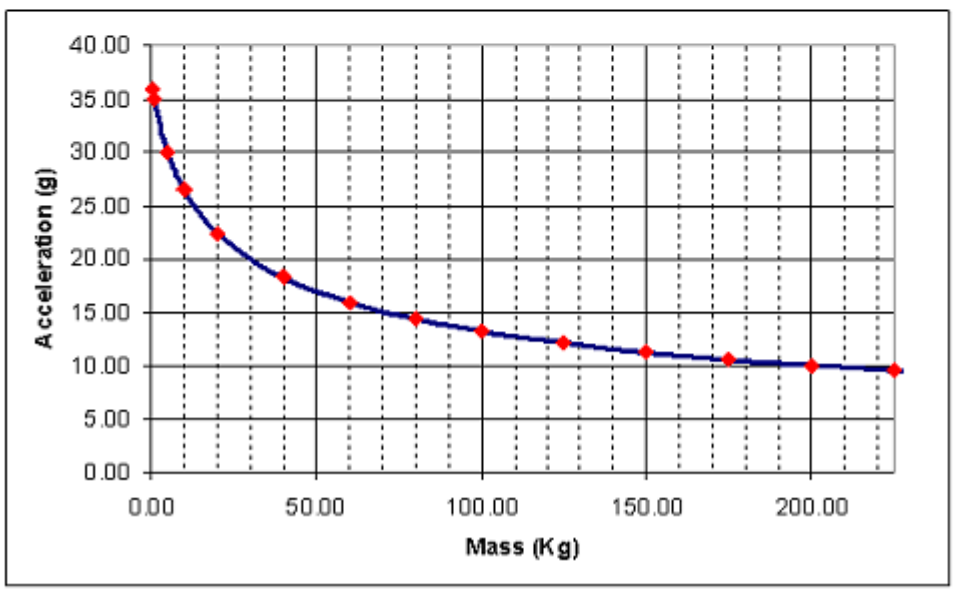

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Table 4.4-4 - ATLAS Component Design Loads (Break Points)

ATLAS Component	Limit Load
Mass (Kg)	(G, Any Direction)
0.5	35.9
1	35
5	30.1
10	26.5
20	22.4
40	18.2
60	15.9
80	14.3
100	13.2
125	12.1
150	11.2
175	10.6
200	10
225	9.5

Rationale : Quasi-static acceleration represents the combination of steady-state accelerations and the low frequency mechanically transmitted dynamic accelerations that occur during launch. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements. Component loads, excluding the structure, are covered using the MAC in the figure below.

The margin of safety is defined as follows:

MS = {Allowable Stress (or Load) ÷ (Applied Limit Stress (or Load) x FS)} – 1

The limit loads used in the static analysis are defined in the mass-acceleration curve (MAC) shown in Figure 4-1. MAC loads are single axis loads that can occur in any direction relative to the ATLAS component.

The breakpoints for the MAC are given in Table 4.4-4. The design loads shown in the MAC will be updated based on the results of coupled loads analysis.

Traceability : IRD92

Verification Method: Analysis.

Verification Level: Component.

Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, MEB, PDU.

ID : CERD11

Section : 4.4.1

Title : Structure Quasi-Static Loads Analysis

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Structural analysis of the ATLAS instrument structure shall show positive margins of safety (MS) for ultimate and yield failures verified by a detailed stress analysis that assesses all primary and secondary structure, joints, and fasteners subjected to limit loads equal to 10 g's applied to each axis separately, and the appropriate factor of safety specified in Table 4.4-1.

Rationale : Quasi-static acceleration represents the combination of steady-state accelerations and the low frequency mechanically transmitted dynamic accelerations that occur during launch. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements. The structure design loads are specified by the loads on the instrument assembly, since it is the backbone of this assembly, and not the loads from the MAC.
The margin of safety is defined as follows:
MS = {Allowable Stress (or Load) ÷ (Applied Limit Stress (or Load) x FS)} – 1
The limit loads will be updated based on the results of coupled loads analysis.
Traceability : IRD92
Verification Method: Analysis.
Verification Level: Component.
Allocation: Structure

ID : CERD12
Section : 4.4.2
Title : Component Quasi-Static Loads Testing - Sine Burst
Each ATLAS component, excluding the structure, shall undergo sine burst protoflight testing to the following specifications:
1) Test performed in each of three orthogonal axes
2) Test to limit loads defined in Figure 4-1 times a test factor of 1.25.
3) Test frequency less than one-third of the resonant frequency of the ATLAS component to avoid dynamic amplification during test.
4) Test to at least 5 cycles at maximum level.
5) All structural elements fabricated from composite materials must be proof tested even if previously strength qualified on valid prototype or protoflight hardware.
Rationale : Sine burst testing verifies the structural strength of ATLAS components.
Traceability : IRD246
Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, MEB, PDU.

ID : CERD13
Section : 4.4.2
Title : Structure Quasi-Static Loads Testing - Sine Burst

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The ATLAS instrument structure, carrying the maximum allowable payload and IMSC masses, shall undergo sine burst protoflight testing to the following specifications:

1) Test performed in each of three orthogonal axes
2) Test to limit loads equal to 10 g's times a 1.25 test factor.
3) Test frequency less than one-third of the resonant frequency of the ATLAS instrument to avoid dynamic amplification during test.
4) Test to at least 5 cycles at maximum level.
5) All structural elements fabricated from composite materials must be proof tested even if previously strength qualified on valid prototype or protoflight hardware.

Rationale : Sine burst testing verifies the structural strength of ATLAS.
Traceability : IRD246
Verification Method: Test.
Verification Level: Component.
Allocation: Structure

ID : CERD14
Section : 4.5.1
Title : Sine Vibration Analysis

Each ATLAS component, including the instrument structure carrying the maximum allowable payload and IMSC masses, shall show positive margins of safety for ultimate and yield failures in a structural analysis using the loads specified in Table 4.5-1and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite – Table 4.4-1
2. Glass – Table 4.4-2
3. Glass bonds – Table 4.4-3

Rationale : Sine vibration loads simulate launch vehicle loading conditions. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements.
The margin of safety is defined as follows:
MS = {Allowable Stress (or Load) ÷ (Applied Limit Stress (or Load) x FS)} – 1
These levels will be updated using a combination of coupled loads results and base-drive analysis.
Traceability : IRD93
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD15
Section : 4.5.2
Title : Sine Vibration Testing

Each ATLAS component, including the instrument structure carrying the maximum allowable payload and IMSC masses, shall meet performance requirements after sine vibration testing to the following specifications:

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1) Test to protoflight levels specified in Table 4.5-1 times a 1.25 test factor.
2) Test in each of three mutually perpendicular axes.
3) Test with the unit attached to the vibration table using the same configuration, attachment points, preloads, and attachment hardware that will be used during launch and flight.
4) If required during testing, reduce (notch) the test input level at critical frequencies to limit the vibration loads and/or acceleration responses to the protoflight levels specified in Table 4.5-1. Notching will require the approval of the ATLAS IM.

Table 4.5-1 - Sinusoidal Vibration Levels for ATLAS Components

Test	Axis	Frequency (Hz)	Level (peak)	Sweep Rate (octaves/min)
Acceptance	Thrust	5 – 20 20 – 50	0.5 inches D.A. 10.0 g	4
	Lateral	5 – 20 20 – 50	0.5 inches D.A. 10.0 g	4
Proto-flight	Thrust	5 – 20 20 – 50	0.63 inches D.A. 12.5 g	4
	Lateral	5 – 20 20 – 50	0.63 inches D.A. 12.5 g	4
Qualification	Thrust	5 – 20 20 – 50	0.63 inches D.A. 12.5 g	2
	Lateral	5 – 20 20 – 50	0.63 inches D.A. 12.5 g	2

Note: These vibration levels apply in the stowed configuration

Rationale : Sine vibration testing is intended to verify workmanship quality and to simulate launch vehicle loading conditions. These levels will be updated using a combination of coupled loads results and base-drive analysis.
Traceability : IRD94
Verification Method: Test.
Verification Level: Component/Instrument.
Allocation:
Component Level Test: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.
Instrument Level Test: Electrical harness.

ID : CERD16
Section : 4.6.1
Title : Component Random Vibration Analysis

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Each ATLAS component, with the exception of the structure, shall show positive margins of safety for ultimate and yield failures in a structural analysis using the protoflight loads specified in Table 4.6-1, and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite - Table 4.4-1
2. Glass - Table 4.4-2
3. Glass bonds - Table 4.4-3

Table 4.6-1 - Random Vibration Levels for ATLAS Components (GEVS Table 2.4-3)

Random Levels for Components Weighing Less Than 22.7 kg (50 lbs.)			
Frequency (Hz)	**Acceptance ASD (g^2/Hz)**	**Proto-flight ASD (g^2/Hz)**	**Qualification ASD (g^2/Hz)**
20	0.013	0.026	0.026
20-50	+6 dB/Octave	+6 dB/Octave	+6 dB/Octave
50-800	0.08	0.16	0.16
800-2000	-6 dB/Octave	-6 dB/Octave	-6 dB/Octave
2000	0.013	0.026	0.026
Overall (g_{rms})	10.0	14.1	14.1
Duration (minutes)	1	1	2

Rationale : The random vibration environment results from the coupling of structure-borne random vibration with the acoustic noise inside the payload fairing. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements. The margin of safety is defined as follows:

MS = {Allowable Stress (or Load) ÷ (Applied Limit Stress (or Load) x FS)} – 1

Random vibration loads will be statistically derived peak responses based on RMS level from the specification in Table 4.5-1. As a minimum, the peak responses will be calculated as 3-sigma value.

Traceability : IRD95
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, MEB, PDU.

ID : CERD17
Section : 4.6.1
Title : Structure Random Vibration Analysis

Released

The ATLAS structure carrying the maximum allowable payload and IMSC masses, shall show positive margins of safety for ultimate and yield failures in a structural analysis using the protoflight loads specified in Table 4.6-2, and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite - Table 4.4-1
2. Glass - Table 4.4-2
3. Glass bonds - Table 4.4-3

Table 4.6-2 - ATLAS Instrument Structure Random Vibration Levels

Levels Derived from GEVS Table 2.4-3

Frequency (Hz)	Acceptance ASD (g^2/Hz)	Proto-flight ASD (g^2/Hz)
20	0.005	0.01
20-50	+2.28 dB/Octave	+2.28 dB/Octave
50-800	0.01	0.02
800-2000	-2.28 dB/Octave	-2.28 dB/Octave
2000	0.005	0.01
Overall (g_{rms})	3.99	5.65
Duration (minutes)	1	1

Rationale : The random vibration environment results from the coupling of structure-borne random vibration with the acoustic noise inside the payload fairing. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements. The margin of safety is defined as follows:

MS = {Allowable Stress (or Load) ÷ (Applied Limit Stress (or Load) x FS)} – 1

Random vibration loads will be statistically derived peak responses based on RMS level from the specification in Table 4.5-1. As a minimum, the peak responses will be calculated as 3-sigma value.

Traceability : IRD95
Verification Method: Analysis.
Verification Level: Component.
Allocation: Structure.

ID : CERD18
Section : 4.6.2
Title : Component Random Vibration Testing

Each ATLAS component, with the exception of the structure, shall meet performance requirements after undergoing random vibration testing to the following specifications:

1. Test to protoflight levels specified in Table 4.6-1

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2. Test in each of three orthogonal axes.
3. Attach the unit to the vibration table using the same configuration, attachment points, preloads, and attachment hardware that will be used during launch and flight.
4. During the test, monitor cross-axis responses of the fixture to preclude unrealistic levels.
5. The test input level may be reduced (notched) according to the following:
    a. Notch input at the fundamental modes of the test article such that the interface loads do not exceed 1.25 times design limit levels.
    b. Additional input notching at critical frequencies of the test article may be allowed based on force-limiting techniques or based on response limiting if flight or test responses at higher levels of assembly are known.
    c. Limit notching to –12 dB of the original input and to a bandwidth of less than 100 Hz.
    d. Notching will require ATLAS instrument lead systems engineer (ISE) approval.

Rationale : The random vibration test demonstrates workmanship quality and simulates launch vehicle environmental levels due to vibro-acoustics. Guidelines for developing appropriate force-limiting criteria can be found in NASA-HDBK-7004.
Traceability : IRD96
Verification Method: Test.
Verification Level: Component/Instrument.
Allocation:
Component Level Test: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, MEB, PDU.
Instrument Level Test: Electrical harness.

ID : CERD19
Section : 4.6.2
Title : Structure Random Vibration Testing

The ATLAS instrument structure carrying the maximum allowable payload and IMSC masses, shall meet performance requirements after undergoing random vibration testing to the following specifications:
1. Test to protoflight levels specified in Table 4.6-2.
2. Test in each of three orthogonal axes.
3. Attach the unit to the vibration table using the same configuration, attachment points, preloads, and attachment hardware that will be used during launch and flight.
4. During the test, monitor cross-axis responses of the fixture to preclude unrealistic levels.
5. The test input level may be reduced (notched) according to the following:
    a. Notch input at the fundamental modes of the test article such that the interface loads do not exceed 1.25 times design limit levels.
    b. Additional input notching at critical frequencies of the test article may be allowed based on force-limiting techniques or based on response limiting if flight or test responses at higher levels of assembly are known.

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c. Limit notching to –12 dB of the original input and to a bandwidth of less than 100 Hz.
d. Notching will require ATLAS instrument lead systems engineer (ISE) approval.

Rationale : The random vibration test demonstrates workmanship quality and simulates launch vehicle environmental levels due to vibro-acoustics. Guidelines for developing appropriate force-limiting criteria can be found in NASA-HDBK-7004.
Traceability : IRD96
Verification Method: Test.
Verification Level: Component.
Allocation: Structure.

ID : CERD20
Section : 4.7
Title : Acoustic Loads Analysis

All ATLAS components, including the instrument structure, shall perform an acoustic loads analysis showing positive margins of safety for ultimate and yield failures using the loads specified in Table 4.7-1 and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite – Table 4.4-1
2. Glass – Table 4.4-2
3. Glass bonds - Table 4.4-3

Rationale : Acoustic noise occurs during launch, at lift-off and in the transonic region. Structural analysis of ATLAS flight components may wring out design problems before flight hardware testing.
The margin of safety is defined as follows:
MS = {Allowable Stress (or Load) ÷ (Applied Limit Stress (or Load) x FS)} – 1
Acoustic loads will be statistically derived peak responses based on RMS level from the specifications in Table 4.7-1. As a minimum, the peak responses will be calculated as 3-sigma value.
Traceability : IRD247
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD21
Section : 4.7.2
Title : Acoustic Testing

Any ATLAS component, including the instrument structure carrying the maximum allowable payload and IMSC masses, meeting either of the two criteria below with strength protoflight loads that do not cover acoustic loading, shall undergo acoustic testing to the loads in Table 4.7-1 without damage or degradation of performance.

1. Shown by analysis to be sensitive to the acoustics environment

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2. Having an area to mass ratio of greater than 50 in^2/ lb. (0.072 m^2 / kg)

Table 4.7-1 - Observatory Acoustic Levels (Composite with Taurus-II)

1/3 Octave Band Center Frequency (Hz)	Max. Predicted Environment (dB)	Proto-flight Test Level (dB)	Qualification Test Level (dB)
	126	129	129
	127	130	130
32	126	129	129
40	129	132	132
50	132	135	135
63	134	137	137
80	135	138	138
100	135.5	138.5	138.5
125	136	139	139
160	135	138	138
200	133	136	136
250	132	135	135
315	132	135	135
400	131	134	134
500	130	133	133
630	128.5	131.5	131.5
800	127	130	130
1000	124	127	127
1250	122	125	125
1600	120.5	123.5	123.5
2000	121	124	124
2500	118	121	121
3150	117.5	120.5	120.5
4000	115.5	118.5	118.5
5000	114.5	117.5	117.5
6300	113.5	116.5	116.5
8000	114	117	117
10000	114.5	117.5	117.5
OASPL	141.2	144.2	144.2
Duration	60 sec	60 sec	120 sec

Rationale : Ensures the component will withstand the acoustic environment of the launch phase.

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Traceability : IRD248
Verification Method: Test if necessary.
Verification Level: Component/Instrument
Allocation:
Component Level Test: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.
Instrument Level Test: Electrical harness.

ID : CERD22
Section : 4.8.1
Title : Shock Analysis
All ATLAS components, including the instrument structure carrying the maximum allowable payload and IMSC masses, shall perform a shock loads analysis showing positive margins of safety for ultimate and yield failures using the loads specified in Table 4.8-1 and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite – Table 4.4-1
2. Glass – Table 4.4-2
3. Glass bonds - Table 4.4-3

Rationale : Certain ATLAS components may be sensitive to shock loads, such as such as observatory separation, boom deployment, etc. Evaluating shock sensitivity of ATLAS flight components may wring out design problems before flight hardware testing.
The shock levels given in Table 4.8-1assume that ATLAS is located at least 60 cm (2 ft) from a shock source. If ATLAS is farther than 2 ft from a shock source the methods specified in General Environmental Verification Specification (GEVS), GSFC-STD-7000, Appendix A-5 to A-12 can be used to calculate shock levels from pyrotechnic devices
Traceability : IRD249
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD23
Section : 4.8.2
Title : Shock Testing
Any ATLAS component, including the instrument structure carrying the maximum allowable payload and IMSC masses, shown by shock analysis to be susceptible to the shock environment shall undergo shock testing to one of the levels specified below, without suffering damage or degradation of performance.

1. Shock testing performed by firing the actual device, consisting of two actuations, for internally induced shocks.

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2. Simulated shock testing performed to 1.4 times the levels specified in Table 4.8-1, for externally induced shocks, performing 2 tests per axis for protoflight testing.

Table 4.8-1 - ATLAS Component Shock Response Spectrum (Q = 16)

Frequency (Hz)	Shock Level Protoflight/Qualification (g)
100	70
1000	2400
10000	2400

Rationale : Shock testing is designed to verify that flight hardware will survive expected shock events such as observatory separation, boom deployment, etc.
The shock levels given in Table 4.8-1assume that ATLAS is located at least 60 cm (2 ft) from a shock source. If ATLAS is farther than 2 ft from a shock source the methods specified in General Environmental Verification Specification (GEVS), GSFC-STD-7000, Appendix A-5 to A-12 can be used to calculate shock levels from pyrotechnic devices
Traceability : IRD250
Verification Method: Test if necessary.
Verification Level: Component/Instrument
Allocation:
Component Level Test: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.
Instrument Level Test: Electrical Harness

ID : CERD25
Section : 4.9.1
Title : Ambient Pressure
All ATLAS components, including instrument structure carrying the maximum allowable payload and IMSC masses, shall be designed to operate at a pressure of 1.01×10^5 N/m^2 (760 Torr).
Rationale : The instrument will operate at standard room temperature and pressure.
Traceability : IRD251
Verification Method: Test (as part of any ambient performance testing).
Verification Level: Component.

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Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, Electrical Harness, BCE.

ID : CERD26
Section : 4.9.1
Title : Depressurization
All ATLAS components, including instrument structure carrying the maximum allowable payload and IMSC masses, shall survive exposure to a maximum depressurization rate of 6.2 kiloPascal (kPA)/second (s), 0.9 pounds per square inch (PSI)/s, experienced during launch and ascent, without any damage or degradation of performance.
Rationale : The instrument will operate after being exposed to de-pressurization during launch and ascent.
Traceability : IRD273
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, Electrical Harness.

ID : CERD27
Section : 4.9.2
Title : Pressure Profile Verification Analysis
Venting analyses of all ATLAS components, including instrument structure carrying the maximum allowable payload and IMSC masses, susceptible to pressure loading shall show positive margins of safety for ultimate and yield failures using the loads equal to twice those induced by the maximum pressure differential specified in **CERD26** and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite – Table 4.4-1
2. Glass - Table 4.4-2
3. Glass bonds - Table 4.4-3

Rationale : This analysis verifies that ATLAS components (such as thermal blankets and contamination enclosures) susceptible to pressure loadings will survive exposure to the launch pressure profile.
Traceability : IRD252, **CERD26**
Verification Method: Analysis if necessary.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD28
Section : 4.10
Title : Thermal Loads Analysis
Each ATLAS component, including instrument structure carrying the maximum allowable payload and IMSC masses, shall show positive margins of safety for ultimate and yield

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failures in a structural analysis using the maximum on-orbit temperature gradients predicted by the thermal analysis specified in **CERD29**, and the appropriate factor of safety specified below:

1. Metallic, Beryllium, Composite – Table 4.4-1
2. Glass - Table 4.4-2
3. Glass bonds - Table 4.4-3

Rationale : This analysis verifies structures will survive on orbit stresses due to temperature loading and coefficient of thermal expansion mismatches.
Traceability : IRD253, CERD29
Verification Method: Analysis.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, BCE.

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5 THERMAL REQUIREMENTS

All testing is to protoflight levels unless otherwise specified.

ID : CERD29
Section : 5.1
Title : Thermal Analysis

Each ATLAS component, including instrument structure, shall show in a thermal analysis that parts and materials maintain the minimum temperature margin required as shown in Table 5.1-1 for the temperatures specified in ICESat-2-THM-IFACE-0214, ATLAS Thermal ICD, and do not exceed allocated heater powers specified in the ATLAS resource allocations document (ICESat-2-ATSYS-REQ-0479).

Table 5.1-1 - ATLAS Thermal Design Margins
Source: Gold Rule 4.25 (GSFC-STD-1000-E, Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems)

4.25	Thermal Design Margins						Mechanical
Rule: R	Thermal design shall provide adequate margin between stacked worst-case flight predictions and component allowable flight temperature limits per GEVS 2.6 and 545-PG-8700.2.1A. 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		Owner: Thermal Engineering Branch (545)					Reference: GEVS 2.63 545-PG-8700.2.1A

Rationale : The thermal analyses will show that parts and materials do not exceed temperature limits during the operational and test environment.
Traceability : IRD100
Verification Method: Analysis.
Verification Level: Component.

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Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, Electrical Harness, BCE.

ID : CERD30
Section : 5.2
Title : Thermal Balance Qualification Testing

It is preferable that the thermal balance test precede the thermal vacuum test so that the results of the balance test can be used to establish the temperature goals for the thermal vacuum test.

All ATLAS components that dissipate power and/or contain internal temperature sensors, shall verify the following list of temperatures, as specified in ICESat-2-THM-IFACE-0214, ATLAS Thermal ICD, and allocated heater powers, as specified in the ATLAS resource allocations document (ICESat-2-ATSYS-REQ-0479) through a thermal balance test:

1. Maximum hot operating temperatures
2. Minimum cold operating temperatures
3. Minimum survival temperatures
4. Operational heater duty cycle less than 70% in worst cold case, including minimum voltage as established by the project.
5. Survival heater duty cycle less than 70% in worst cold case, including minimum voltage as established by the project
6. Interface heat flows are within requirements.
7. Internal power dissipations and line loses, if possible.

The following specifications apply:

1. Power dissipation of individual components are measured to an accuracy of 1% at voltage and temperature extremes.
2. For each case, stabilization is considered to have been achieved when the control sensors change less than a calculated rate, for a period of not less than six hours, and exhibit a decreasing temperature slope over that period. The rate shall be determined so that the change in bulk temperature of the component does not account for more than 3% of the power dissipated in the component.

Rationale : The thermal balance test verifies and correlates the thermal model and thermal design margins.
Traceability : IRD102
Verification Method: Test/ Test if necessary.
Verification Level: Component.
Allocation:
Test: Laser, LSA, SPD, TCS, LRS, TAMS, BSM, Telescope, OFA, DAA, MEB, PDU.
Test If Necessary: Fold mirrors, Fiber optics, Beam expander, DOE, PBC, LTR, Aft Optics.

ID : CERD31
Section : 5.3
Title : Thermal Vacuum Protoflight Testing

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All ATLAS components, including instrument structure, shall meet all performance requirements during and after exposure to the thermal vacuum protoflight test environment specified below (see GEVS Section 2.6.2 for more details).
Note: The laser subsystem will test to a modified GEVS specification. The ATLAS lasers must work over their entire qualification temperature range, however, will meet performance requirements over a TBD 2C temperature range for optimum laser performance. A waiver to the GEVS requirement will be acquired.

The thermal vacuum protoflight test environment includes the following:

1. 4 cycles of thermal vacuum testing.
    a. 1 cycle between survival limits.
        i. Soak for 4 hours at each extreme.
        ii. ATLAS component is off at temperatures past the operating limits.
        iii. ATLAS component performs turn on after exposure to each of the survival limits at its cold survival limit or a start temperature agreed upon by both the component and instrument. Test turn-on temperatures should be at either the survival/safehold or qualification/protoflight temperature conditions, whichever is more extreme.
        iv. After turn on, ATLAS component undergoes functional testing and meets all performance requirements.
    b. 3 cycles between operating limits
        i. Soak for 4 hours at each extreme.
        ii. Functional tests will be performed at each hot and cold soak plateau. A comprehensive performance test (CPT) will be performed at least once during hot plateau(s) and once during cold plateau(s).
        iii. ATLAS component is operating during transitions between the operating limits. Functional tests will be performed during the transitions.
    c. Over the range of possible survival flight voltages

The thermal vacuum protoflight test specification includes the following:

1. <u>Temperature Limits</u> - Temperature limits are specified in the ATLAS Thermal ICD (ICESat-2-THM-IFACE-0214). Thermal vacuum temperature limit envelopes are shown in Figure 5-1.
2. <u>Maximum rate of temperature change</u> - Maximum rates of temperature change will not exceed the limits defined in the ATLAS Thermal ICD (ICESat-2-THM-IFACE-0214). The limits are based on hardware characteristics or orbital predictions.
3. <u>Test Temperature Soak Criteria</u> - Temperature soaks will begin when the "control" temperature is within ± 2°C of the proposed test temperature.
4. <u>Test Margins</u> - For actively controlled systems such as those using heaters, thermo electric coolers (TECs), loop heat pipes (LHPs), or other devices with selectable/variable set points, a test temperature margin of no less than 5°C will be imposed on the respective set point band that is under control. For all passively-controlled systems, a test temperature margin of no less than 10C will be imposed.

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5. Avoiding Contamination -Elements of a test item can be sensitive to contamination arising from test operations or from the test item itself. In all cases, every effort should be made to keep the test article warmer than its surroundings during testing.
6. Durations – The thermal soaks will be of sufficient duration to allow time for functional tests for all modes of operation, and will be no less than 4 hours.
7. Pressure – The chamber pressure will be less than 1.33×10^{-3} Pa. (1×10^{-5} Torr).
8. Test Environment - For ATLAS components that have been shown by analysis to be insensitive to vacuum effects relative to temperature levels and temperature gradients, the requirements may be satisfied by temperature cycling at normal room pressure in an air or gaseous-nitrogen environment. However, the recommended approach is to test in the expected environment (vacuum). If testing at ambient pressure is implemented, GSFC project approval is required based on the results of a rigorous thermal analysis.
9. Profile – Figure 5-2 shows a typical thermal vacuum testing profile for ATLAS components.
10. Comprehensive Performance Test (CPT) - Used to verify full compliance of each flight unit to all of its performance requirements, within the limitations of the environment and facilities. This test is also defined in Section 6.0 Performance Tests.
11. Functional Test (FT) - Also known as a Limited Performance Test (LPT). The FT is a subset of the Performance Test and is designed to verify functionality of the flight unit under nominal input/output conditions. The FT will be used to verify unit operation when it is not practical to use the CPT. Typically, it is used to during and after certain environmental tests to demonstrate that the functional capability of the ATLAS component has not been degraded due to environmental exposure, handling, and transportation. It is also commonly used during some of the hot and cold plateaus during thermal vacuum testing. This test is also defined in Section 6.0 Performance Tests.

WAIVER:
LRS TVAC Pressure Waiver for CERD31 will allow the LRS TRL6 prototype thermal vacuum test to be run at a chamber pressure of up to 5 x 10^-3 Torr. This waiver is approved and documented in CCR-0101 on MIS.

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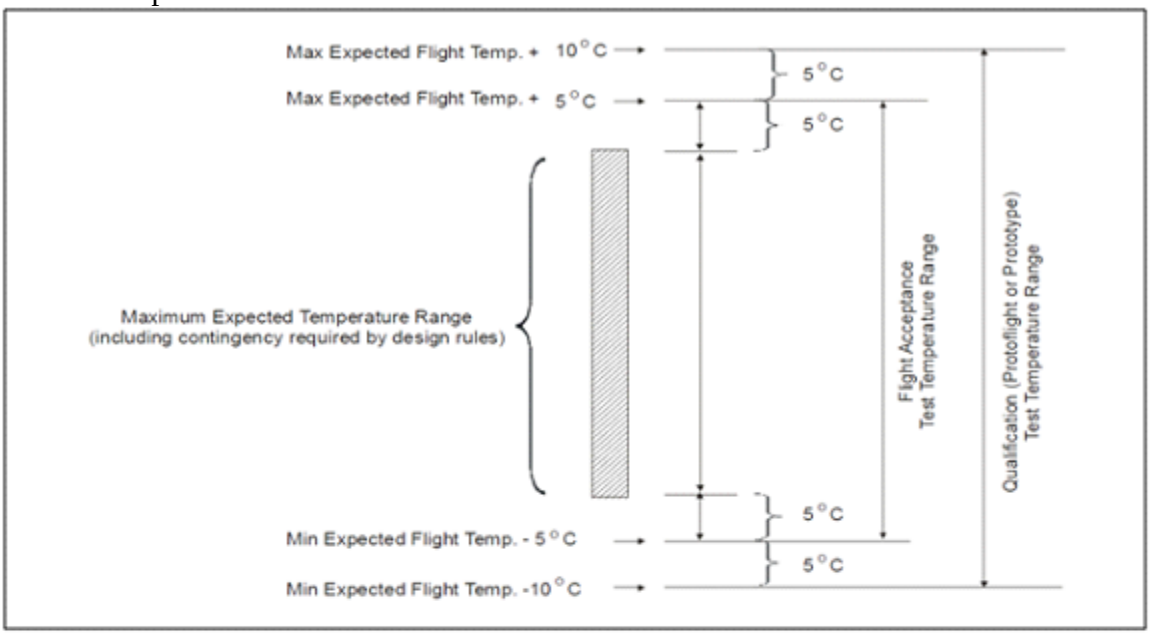
Figure 5-1 - Qualification/Protoflight and Acceptance Levels Thermal Vacuum Temperatures



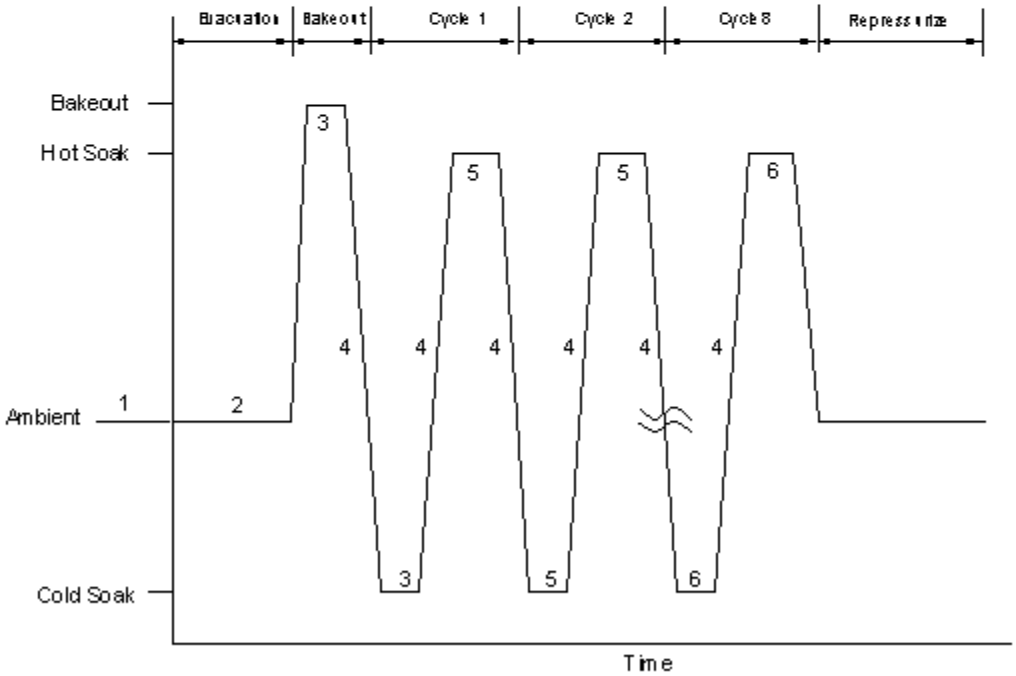


Figure 5-2 - Typical ATLAS Component Thermal Vacuum Cycle Profile
(Note: ATLAS Components required cycles is 4)

Rationale : The thermal vacuum protoflight test verifies ATLAS components for the mission thermal environments.

Traceability : IRD103
Verification Method: Test/ Test if necessary.
Verification Level: Component.
Allocation:
Test: Laser, LSA, SPD, TCS, LRS, TAMS, BSM, Telescope, OFA, DAA, Structure, MEB, PDU, Electrical Harness.
Test If Necessary: Fold mirrors, Fiber optics, Beam expander, DOE, PBC, LTR, Aft Optics.

ID : CERD32
Section : 5.3
Title : Non-Vacuum Thermal Protoflight Testing
ATLAS components that meet all of the following criteria may satisfy the thermal environment requirements by temperature cycling at normal room pressure in an air or gaseous-nitrogen environment:

1. Have been shown by analysis to be insensitive to vacuum effects relative to temperature levels
2. Have been shown by analysis to be insensitive to vacuum effects relative to temperature gradients
3. Acquired GSFC project approval is required based on the results of a rigorous thermal analysis.

Rationale : Some ATLAS components may be insensitive to the vacuum environment and so standard pressure is a sensible test environment.
Traceability : IRD103
Verification Method: Test if allowable.
Verification Level: Component.
Allocation:
Test If Allowable: Fold mirrors, Fiber optics, Beam expander, DOE, PBC, LTR, Aft Optics.

ID : CERD33
Section : 5.4
Title : Life Cycle Thermal Test
ATLAS components, including instrument structure, requiring life-cycle thermal testing shall undergo additional thermal cycling concurrent with performance testing at ambient pressure on qualification units.
Rationale : Some ATLAS components may require life-cycle thermal testing to qualify the design. Since it is not practical to perform very large number cycles in vacuum, additional thermal cycling at ambient pressure may be used on qualification units to increase the total number of cycles.

Prior to ambient-pressure thermal cycling, the units are still required to undergo thermal vacuum cycling as called out in Section 4.3. Performance tests will be performed periodically during these cycles to

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detect problems early.
Traceability : IRD255
Verification Method: Test if necessary.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

ID : CERD34
Section : 5.5
Title : Thermal Bake-Out
All ATLAS components, including the instrument structure, shall undergo thermal bake-out tests per the ATLAS Contamination Control Plan (ICESat-2-ATSYS-PLAN-0297).
Rationale : Thermal bake-out tests reduce out gassing of contaminants to acceptable levels.
Traceability : IRD256
Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, Electrical Harness, BCE.

ID : CERD35
Section : 5.6
Title : Humidity
ATLAS components, including instrument structure, shall meet all performance requirements during and after exposure to relative humidity levels of 35% to 70% (TBR).
NOTE: A lower humidity level may be required to not condense dew when the ground cooling system is operating if the laser operational temperature is below the dew point. A dry nitrogen purge may be required for this operation.
Rationale : Humidity levels are also important to reduce or eliminate the possibility of an ESD event which could damage flight hardware.
Traceability : IRD257
Verification Method: Test (when subjected to ambient environmental conditions in a lab).
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU, Electrical Harness.

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6 ELECTROMAGNETIC ENVIRONMENT AND REQUIREMENTS

All testing is to protoflight levels unless otherwise specified.

ID : CERD36
Section : 6.1.1
Title : Spurious Signal Elimination
Spurious signals generated in electromagnetic interference (EMI) testing that lie above specified testing limits shall be eliminated.
Rationale : Removing spurious signals protects observatory components from the possibility of interference that could hinder the system's operation.
Traceability : IRD259
Verification Method: Test if necessary.
Verification Level: Component.
Allocation: Laser, LSA, SPD, LRS, TAMS, BSM, OFA, DAA, MEB, PDU, Electrical Harness.

ID : CERD37
Section : 6.1.1
Title : Spurious Signal Elimination
Spurious signals generated in EMI testing that lie below specified testing limits shall be eliminated, unless analysis shows a subsequent change in frequency or amplitude is possible to move the signals to within limits.
Rationale : Removing spurious signals protects observatory components from the possibility of interference that could hinder the system's operation.
Traceability : IRD260
Verification Method: Test if necessary.
Verification Level: Component.
Allocation: Laser, LSA, SPD, LRS, TAMS, BSM, OFA, DAA, MEB, PDU, Electrical Harness.

ID : CERD38
Section : 6.1.1
Title : Spurious Signal Re-test
Retest will be performed to verify that spurious signals generated in EMI testing were eliminated.
Rationale : Removing spurious signals protects observatory components from the possibility of interference that could hinder the system's operation.
Traceability : IRD261
Verification Method: Test if necessary.
Verification Level: Component.
Allocation: Laser, LSA, SPD, LRS, TAMS, BSM, OFA, DAA, MEB, PDU, Electrical Harness.

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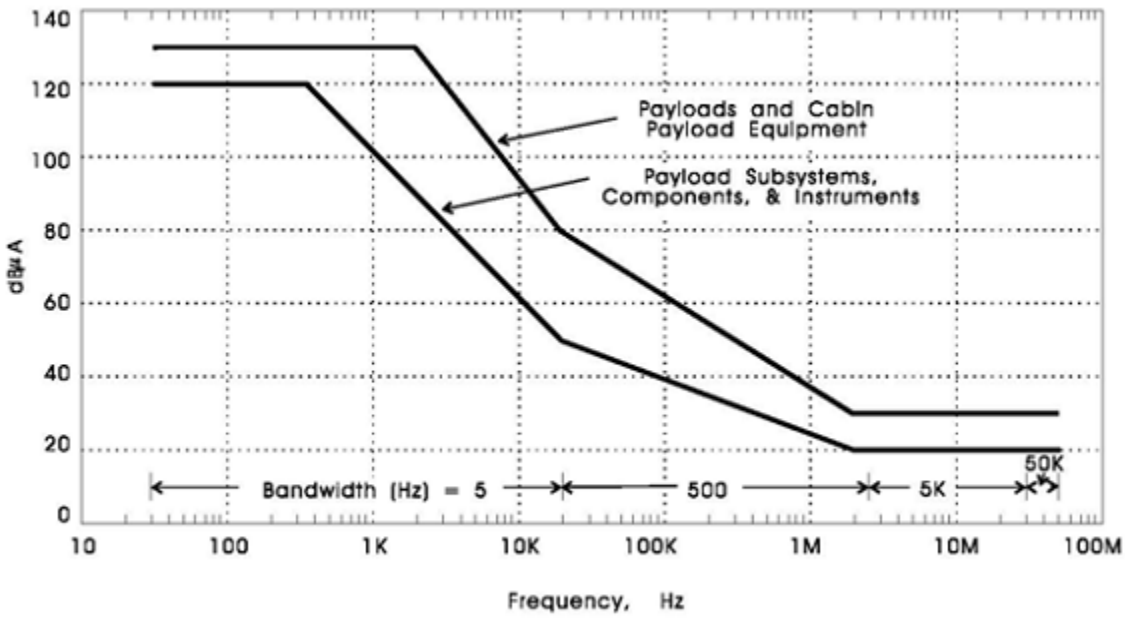
ID : CERD39
Section : 6.1.2.1
Title : Narrowband Conducted Emissions Test

ATLAS components with power and power return leads shall demonstrate an operating margin of 6 dB between the component emissions and susceptibility specifications in a narrowband conducted emissions test to the levels specified in Figure 6-1, in accordance with MIL-STD-461C, Part 2, Paragraphs 2.0 and 3.0, and MIL-STD-462, test numbers CE01 and CE03.

Figure 6-1 - Narrowband Conducted (CE01 & CE03) Emission Limits on Payload Power Lines



Rationale : Conducted emission limits and requirements on power leads verify that ATLAS components are electromagnetically compatible with other systems and do not generate conducted signals that could hinder the operation of other systems.
Traceability : **IRD258**, IRD104
Verification Method: Test.
Verification Level: Component/Component with MEB/Component with PDU.
Allocation:
Component test: Laser, LRS, MEB, PDU.
Component with MEB test: LSA, SPD, TAMS, BSM, OFA, DAA.
Component with PDU test: TAMS.

ID : CERD40
Section : 6.1.2.2
Title : Common Mode Noise (CMN) Conducted Emissions Test

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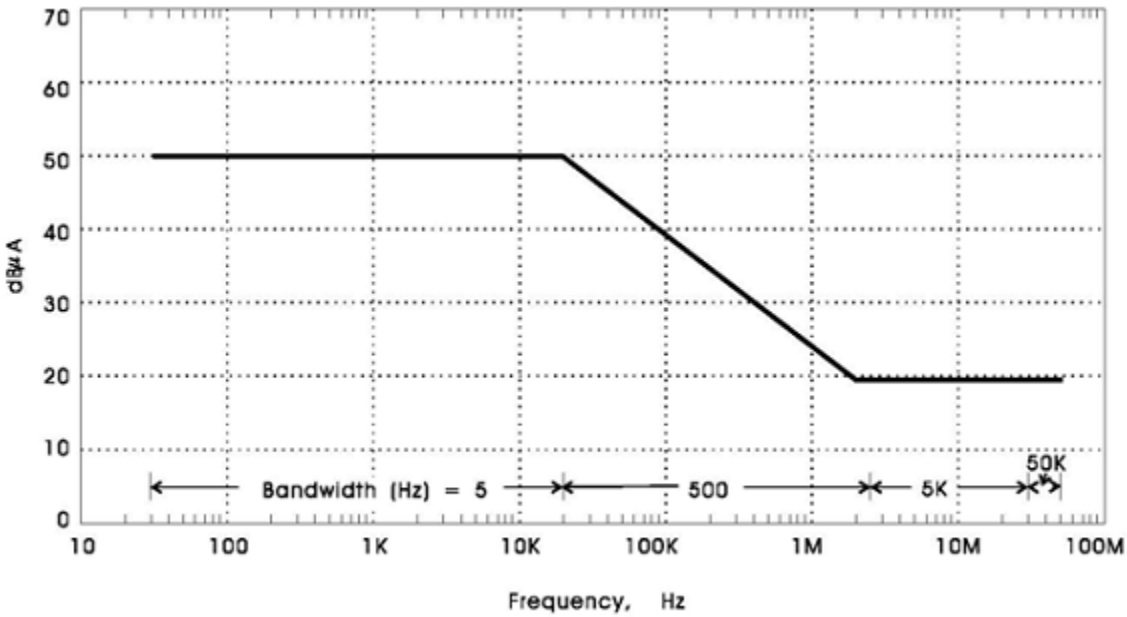
Each ATLAS non-passive component with power and return leads shall demonstrate an operating margin of 6 dB between the component emissions and susceptibility specifications during a Conducted Emissions (CE) frequency domain current test to the limits of Figure 6-2, in accordance with MIL-STD-461C, Part 2, Paragraphs 2.0 and 3.0, and MIL-STD-462, test numbers CE01 and CE03.

Figure 6-2 - Common Mode (CMN) Conducted Emission Limits on Primary Power Lines



Rationale : The purpose of the test is to limit CMN emissions that flow through the spacecraft structure and flight harness which result in the generation of undesirable electrical currents, and electro-magnetic fields at the integrated system level.
The CMN test procedure is the same as narrowband CE01/03 except that the current probe is placed around both the plus and return primary wires together.
Traceability : **IRD258**, IRD105
Verification Method: Test.
Verification Level: Component/Component with MEB/Component with PDU.
Allocation:
Component test: Laser, LRS, MEB, PDU.
Component with MEB test: LSA, SPD, TAMS, BSM, OFA, DAA.
Component with PDU test: TAMS.

ID : CERD41
Section : 6.1.2.3
Title : Single-Event Switching Transient Conducted Emissions Test (CE07)
Each ATLAS component with AC or DC leads which obtain power from or provide power to other equipment or subsystems shall demonstrate an operating margin of 6 dB between the

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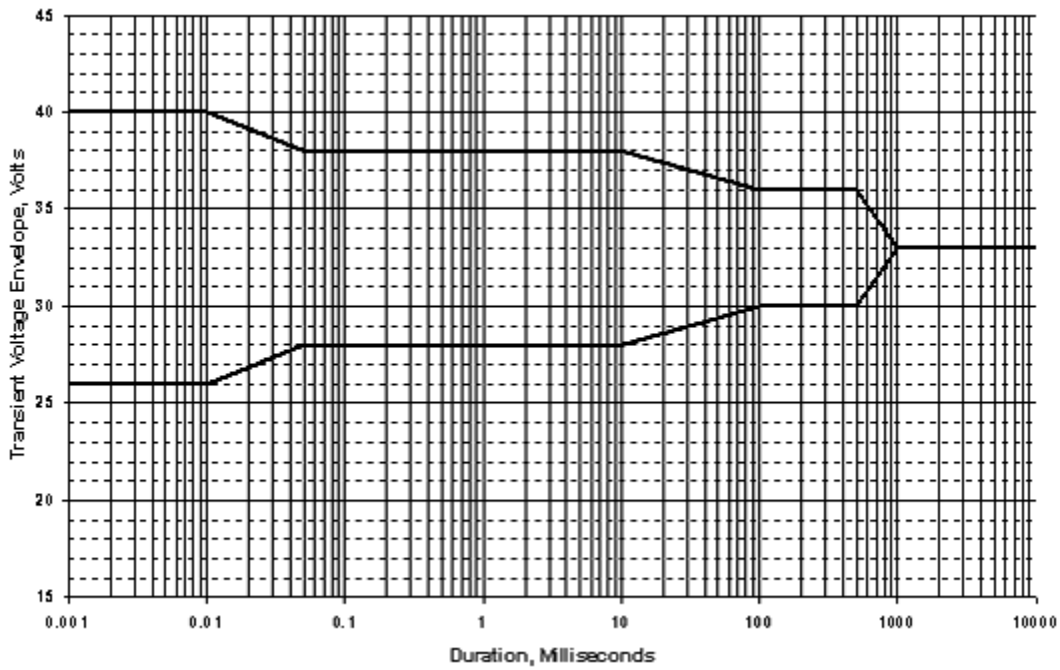
component emissions and susceptibility specifications during testing to verify transient voltage excursions are within the envelope shown Figure 4-1, in accordance with MIL-STD-461C, Part 2, Section 5.0.

The requirement applies to turn-on, turn-off, and operational mode transients.

Spike duration is the time interval between the 50% amplitude points on the transient leading and trailing edges.

Figure 6-3 - CE07Conducted Emission Limits



Rationale : The purpose of the test is to limit transient voltage emissions which result in the generation of undesirable electrical currents, and electro-magnetic fields at the integrated system level.
Traceability : **IRD258**, IRD262
Verification Method: Test/Test if necessary
Verification Level: Component.
Allocation:
Test: Laser, LRS, MEB, PDU.
Test if necessary: LSA, SPD, TAMS, BSM, OFA, DAA.

ID : CERD42
Section : 6.1.2.4
Title : Radiated AC Magnetic Field Test (RE04)
Each ATLAS component with a radiated alternating current (AC) magnetic field shall demonstrate an operating margin of 6 dB between the component emissions and susceptibility specifications during testing to verify that the field levels produced at distances

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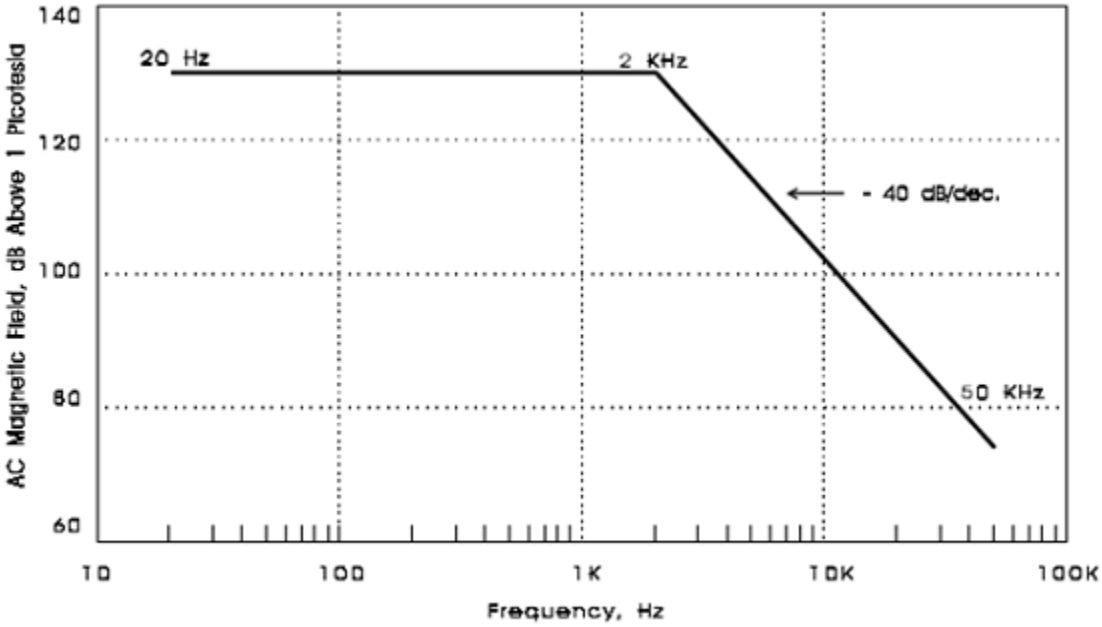
of 1 meter from the component shall not exceed the limits shown in Figure 6-4, and in accordance with MIL-STD-462, radiated emissions (RE) test number RE04.

Figure 6-4 - Limits of ATLAS Component Radiated AC Magnetic Field at 1 Meter from the Component



Rationale : Radiated emission limits and requirements on ac magnetic fields verify that ATLAS components are electromagnetically compatible with other systems and do not generate conducted signals that could hinder the operation of other systems.
Traceability : **IRD258**, IRD107, IRD108
Verification Method: Test if necessary.
Verification Level: Component
Allocation: Laser, LSA, SPD, LRS, TAMS, BSM, DAA, MEB, PDU.

ID : CERD43
Section : 6.1.2.5
Title : Radiated Narrowband Electric Field Test (RE02)
Each ATLAS component with radiated emissions shall undergo tests to show that the unintentional radiated narrowband electric field levels produced by the component demonstrate an operating margin of 6 dB between the component emissions and susceptibility levels specified in the lower curve labeled “Payload Subsystems, Components, and Instruments” in Figure 6-5, in accordance with MIL--STD 461C Part 2, Section 17.0, and MIL-STD-462, test number RE02.
NOTE: The notching shows an example of how the limits for RE02 testing should be adjusted to accommodate spacecraft, instrument, launch vehicle and tracking radars.

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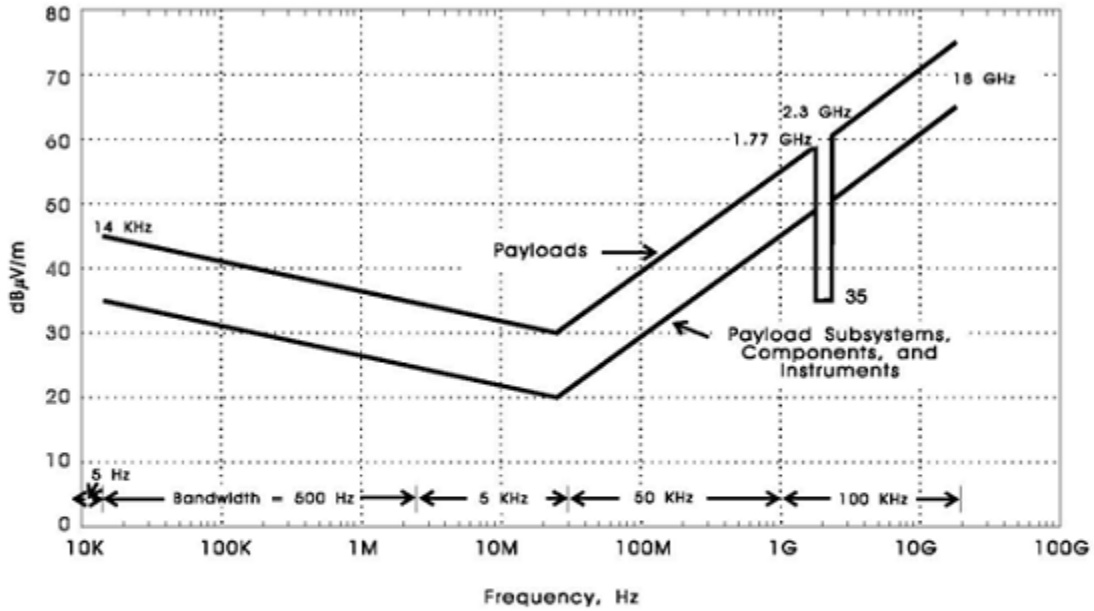
Figure 6-5 - Unintentional Radiated Narrowband (RE02) Limits for Electric Field Emission Produced by Payloads and Payload Systems



Notes:

1. The lower curve is to be used for ATLAS Components
2. The notching shows an example of how the limits for RE02 testing should be adjusted to accommodate spacecraft, instrument, launch vehicle and tracking radars.

Rationale : Radiated emission limits and requirements on electric fields verify that ATLAS components are electromagnetically compatible with other systems and do not generate conducted signals that could hinder the operation of other systems.
Traceability : **IRD258**, IRD109, IRD110
Verification Method: Test/Test if necessary
Verification Level: Component
Allocation:
Test: Laser, LSA, SPD, LRS, BSM, OFA, DAA, MEB, PDU, Electrical Harness.
Test if necessary: TAMS.

ID : CERD44
Section : 6.2.1.1
Title : Conducted Susceptibility CS01 Test (Power lines)

All ATLAS components that contain DC/DC converters or power regulation devices shall meet all performance requirements during and after being subjected to a ripple voltage of N volts RMS (where N=10% of the nominal bus voltage) from 30 Hz to 50kHz as applied in accordance with conducted susceptibility (CS) CS01 testing defined in MIL-STD-461C, Part 2, Paragraph 6.0, MIL-STD-462, test number CS01, and shown in Figure 6-6.

Rationale : Conducted susceptibility requirements verify that ATLAS components will operate properly if subjected to conducted or radiated emissions

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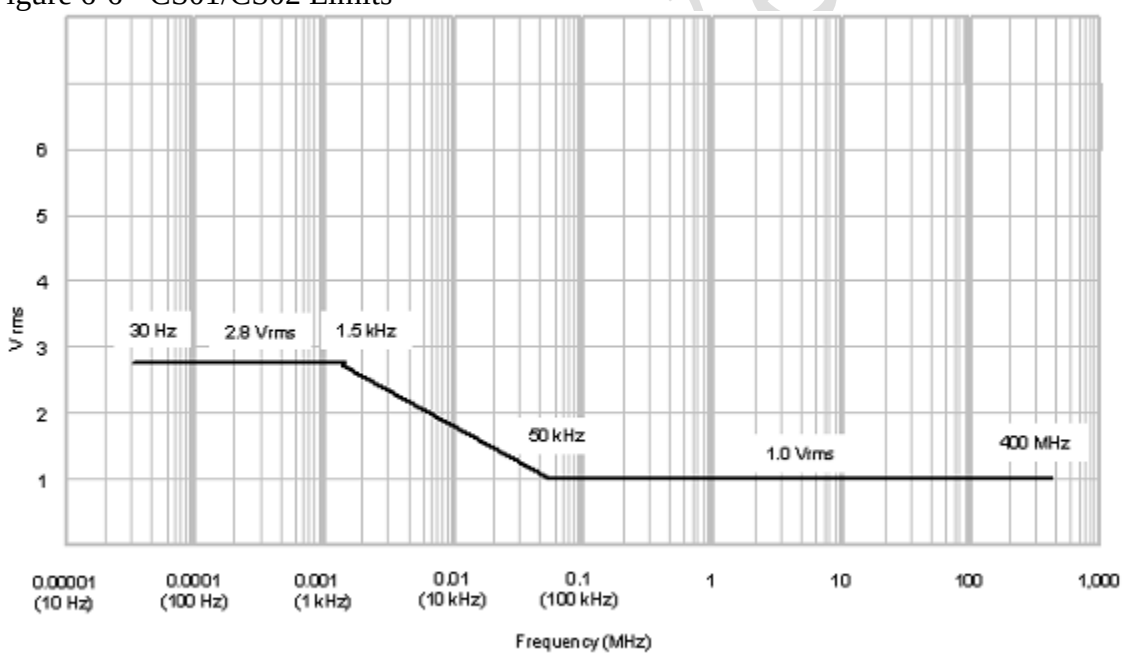
from other sources that could occur during launch or in orbit.
Traceability : IRD111
Verification Method: Test/Test if necessary
Verification Level: Component.
Allocation:
Test: Laser, LRS, MEB, PDU.
Test if necessary: LSA, SPD, BSM, DAA.

ID : CERD45
Section : 6.2.1.1
Title : Conducted Susceptibility CS02 Test (Power lines)
All ATLAS components that contain direct current (DC)/DC converters or power regulation devices shall meet all performance requirements during and after being subjected to a ripple voltage of 1.0V RMS from 50 kHz to 400 MHz on the power bus as applied in accordance with conducted susceptibility CS02 testing defined in MIL-STD-461C, Part 2, Paragraph 7.0, MIL-STD-462, test number CS02, and shown in Figure 6-6.

Figure 6-6 - CS01/CS02 Limits



Rationale : Conducted susceptibility requirements verify that ATLAS components will operate properly if subjected to conducted or radiated emissions from other sources that could occur during launch or in orbit.
Traceability : IRD263
Verification Method: Test/Test if necessary
Verification Level: Component.
Allocation:
Test: Laser, LRS, MEB, PDU.
Test if necessary: LSA, SPD, BSM, DAA.

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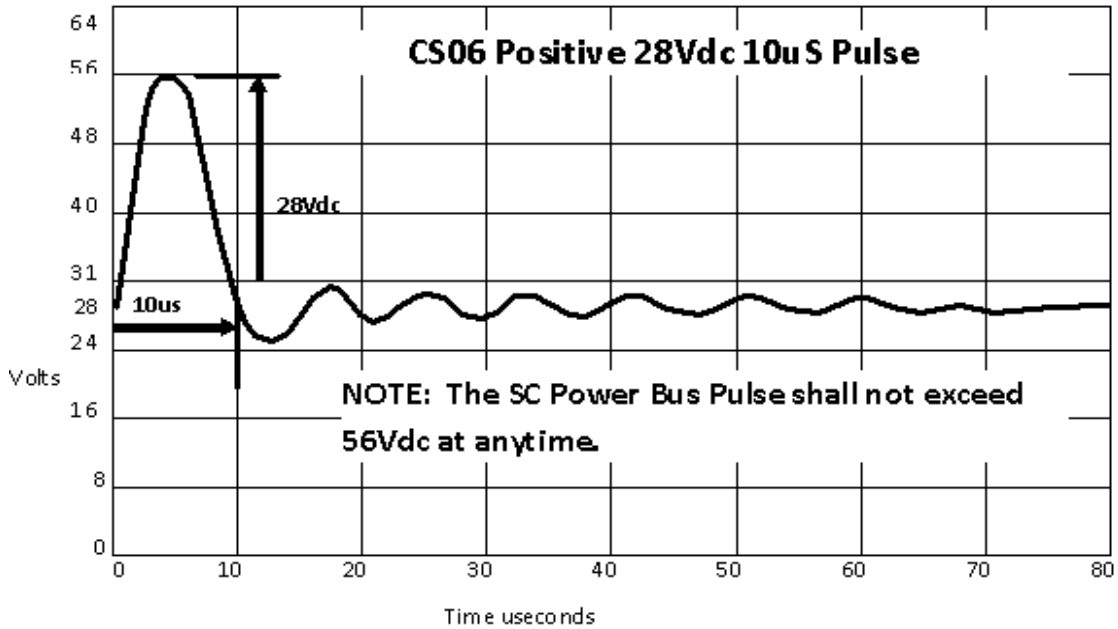
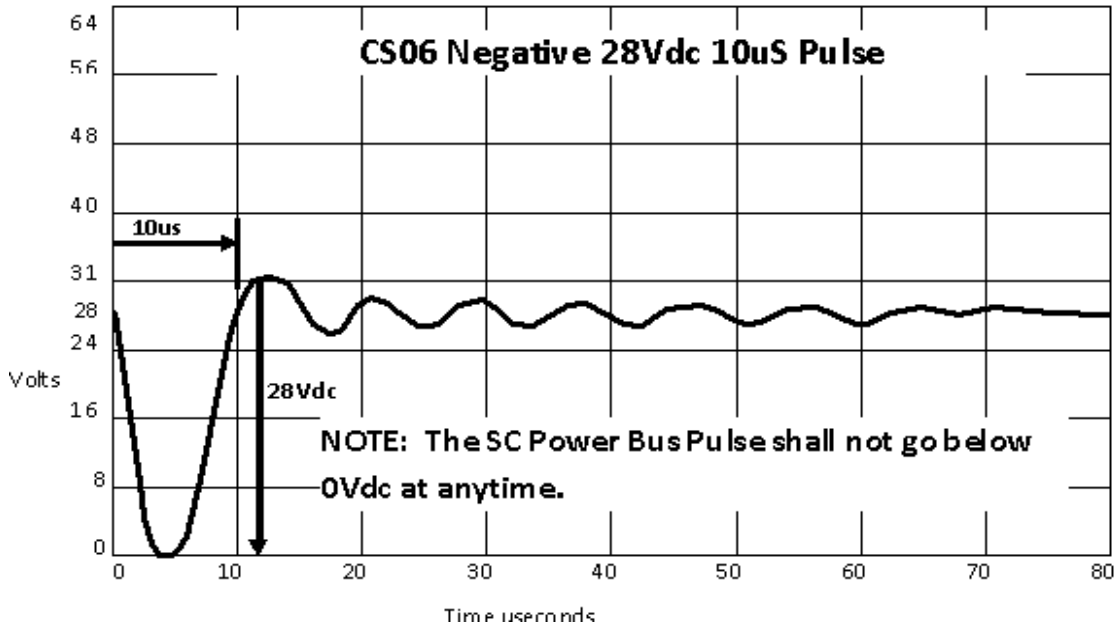
ID : CERD46
Section : 6.2.1.2
Title : Conducted Susceptibility CS06 Test (Power line Transient)

All ATLAS components that contain the DC/DC converters or power regulation devices shall meet all performance requirements during and after being subjected to positive and negative voltage spikes, 2 times the nominal bus voltage not to exceed 56V, injected on the positive power lead to the limits shown in Figure 6-7, in accordance with CS06 testing defined in MIL-STD-461C, Part 2, Paragraph 4.0 and as specified in MIL-STD-462, test number CS06**.**

Figure 6-7 - CS06 Limits





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Rationale : Conducted susceptibility requirements verify that ATLAS components will operate properly if subjected to conducted or radiated emissions from other sources that could occur during launch or in orbit.
Traceability : IRD112
Verification Method: Test/Test if necessary
Verification Level: Component.
Allocation:
Test: Laser, LRS, MEB, PDU.
Test if necessary: LSA, SPD, BSM, DAA.

ID : CERD47
Section : 6.2.2.1
Title : Radiated Susceptibility Test RS03 (E-field)
Any ATLAS component that contains power leads shall meet all performance requirements during and after being subjected to the following radiated test signals, appropriately tailored to account for intentional radiation from spacecraft and LV sources such as S-band, C-band, X-band and other transmitters as well as launch site tracking radars, in accordance with the requirements and test methods of radiated susceptibility (RS) test RS03 per MIL-STD-461, Part 2, Paragraph 21, and MIL-STD- 462:

Electric-Field	Frequency Range
1. 20 V/m	14 kHz to 30 MHz
2. 20 V/m	30 MHz to 30 GHz
3. TBD V/m	Other radio frequency (RF) sources: Launch Vehicle (LV) transmitter, etc

Rationale : Radiated susceptibility requirements verify that ATLAS components will operate properly if subjected to radiated emissions from other sources that could occur during launch or in orbit.
Traceability : IRD113
Verification Method: Test/Test if necessary
Verification Level: Component.
Allocation:
Test: Laser, LRS, MEB, PDU, Electrical Harness.
Test if necessary: LSA, SPD, BSM, DAA.

ID : CERD48
Section : 6.3.1
Title : Magnetic Field Limits
The maximum magnetic field produced by any ATLAS component shall not exceed TBD Gauss.
Rationale : Magnetic field limits ensure that ATLAS components are electromagnetically compatible with other systems and do not generate signals that interfere with spacecraft attitude control.
Traceability : IRD115
Verification Method: Analysis
Verification Level: Component.

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Allocation: Laser, LSA, SPD, TCS, LRS, TAMS, BSM, BCE, DAA, MEB, PDU, Electrical Harness.

ID : CERD49
Section : 6.3.2
Title : Magnetic Field Environment
All ATLAS components shall meet all performance requirements during and after exposure to a magnetic field environment of 650 microteslas or 6.24 Gauss, as measured at the spacecraft to instrument interface plane
Rationale : The magnetic field specification ensures that ATLAS components are designed to operate in the magnetic environment generated by other ICESat-2 systems.
Traceability : IRD115
Verification Method: Test if necessary.
Verification Level: Component.
Allocation: Laser, LSA, SPD, TCS, LRS, TAMS, BSM, DAA, MEB, PDU, Electrical Harness.

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7 PERFORMANCE TESTS

ID : CERD50
Section : 7.1
Title : Comprehensive Performance Test
All ATLAS components shall undergo a Comprehensive Performance Test (CPT) to verify full compliance of each flight unit to all of its performance requirements, in all modes and configurations and under varying input/output conditions, within the limitations of the environment and facilities.
Rationale : The CPT verifies that components meet requirements after exposure to the flight environments. It also verifies initial performance then provides a baseline which can be subsequently compared to see if performance has degraded after significant events.
Traceability : IRD118
Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, LRS, TAMS, BSM, DAA, MEB, PDU.

ID : CERD51
Section : 7.2
Title : Functional Test
All ATLAS components shall undergo a Functional Test (FT), also known as a Limited Performance Test (LPT), to verify unit operation when it is not practical to use the CPT. An Abbreviated Functional Test (AFT) may be used when it is necessary to monitor the performance of the flight unit over a very short period of time. The AFT is typically used when a unit is being subjected to vibration testing.
Rationale : The FT is a subset of the Comprehensive Performance Test and is designed to verify functionality of the flight unit under nominal input/output conditions. Typically, it is used during and after certain environmental tests to demonstrate that the functional capability of the ATLAS component has not been degraded due to environmental exposure, handling, and transportation. It is also commonly used during some of the hot and cold plateaus during thermal vacuum testing.
Traceability : IRD116, IRD117
Verification Method: Test.
Verification Level: Component.
Allocation: Laser, LSA, SPD, LRS, TAMS, BSM, DAA, MEB, PDU.

ID : CERD53
Section : 7.4
Title : Post-Test Reviews
Post-test reviews of each ATLAS component test shall be held wherein test success criteria and verification data as specified in the test procedure are reviewed to determine successful verification of the test requirements.

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Rationale : Post test reviews verify requirements were met.
Traceability : IRD265
Verification Method: Inspection.
Verification Level: Component.
Allocation: Laser, LSA, SPD, Fold mirrors, Fiber optics, Beam expander, DOE, PBC, TCS, LRS, TAMS, BSM, LTR, BCE, Telescope, Aft Optics, OFA, DAA, Structure, MEB, PDU.

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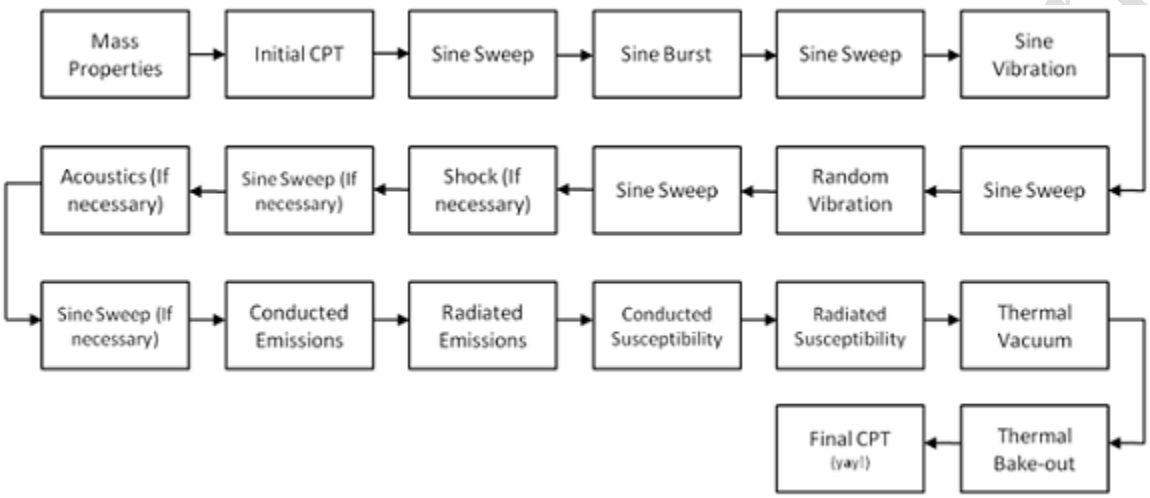
8 TEST SEQUENCE

ID : 59
Section : 8.0
Title : Test Sequence

Figure 8-1 Baseline ATLAS Component Environmental Test Sequence



9 ATLAS COMPONENT VERIFICATION MATRIX

The ATLAS Component Requirements Verification Matrix is attached as a separate document.

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10 ACRONYMS AND ABBREVIATIONS

Abbreviation/ Acronym	DEFINITION
A	Ampere
A	Analysis
AC	Alternating Current
AFT	Abbreviated Functional Test
ASD	Acceleration Spectral Density
ATLAS	Advanced Topographic Laser Altimeter System
ATSYS	Atlas Systems
BTU	British Thermal Unit
C	Celsius
CE	Conducted Emissions
CERD	Component Environmental Requirements Document
CG	Center Of Gravity
cm	Centimeter
CMN	Common Mode Noise
CPT	Comprehensive Performance Test
CS	Conducted Susceptibility
DA	Direct Amplitude
dB	Decibel
DC	Direct Current
Dec	Decibel
deg	Degree
ELV	Expendable Launch Vehicle
EMI	Electromagnetic Interference
ERD	Environmental Requirements Document
ESD	Electrostatic Discharge
F	Fahrenheit
FS	Factor Of Safety
FT	Functional Test
Ft	Foot
G	Giga
G	Gravitational Constant
g	Acceleration Due To Gravity At The Earth's Surface
GEVS	General Environmental Verification Specification
GHz	Gigahertz

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Abbreviation/ Acronym	**DEFINITION**
grms	G's Root Mean Square
GSFC	Goddard Space Flight Center
HDBK	Handbook
Hz	Hertz
I	Inspection
ICD	Interface Control Document
ICESat-2	Ice, Cloud, And Land Elevation Satellite 2
IFACE	Interface
IM	Instrument Manager
IMSC	Instrument Mounted Spacecraft Components
in	Inches
Ind	Individual
IR	Infrared
IRD	Instrument Requirements Document
I&T	Integration And Test
K	Kilo
Kg	Kilogram
kHz	Kilohertz
kPa	Kilopascal
Lb	Pound
LHP	Loop Heat Pipe
LPT	Limited Performance Test
LV	Launch Vehicle
M	Mega
m	Meter
MAC	Mass-Acceleration Curve
MHz	Megahertz
MIL	Military
Min	Minute
MLI	Multilayer Insulation
MOI	Moment Of Inertia
MS	Margin Of Safety
MSE	Mission System Engineer
N	Newton
NA	Not Applicable
NASA	National Aeronautics And Space Administration

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Abbreviation/ Acronym	**DEFINITION**
No.	Number
OASPL	Overall Sound Pressure Level
Org.	Organization
Pa	Pascal
PDR	Preliminary Design Review
PFR	Problem Failure Report
PMT	Photomultiplier Tube
PR	Problem Report
PSI	Pound Per Square Inch
Q	Attenuation Factor
RE	Radiated Emissions
REQ	Requirement
RF	Radio Frequency
RFW	Request For Waiver
RMS	Root Mean Square
RS	Radiated Susceptibility
s	Second
Sec	Second
STD	Standard
SYS	Systems
T	Test
TBD	To Be Determined
TBR	To Be Resolved
TEC	Thermo Electric Cooler
THM	Thermal
V	Volt
Vrms	Volts Root Mean Square
W	Watt
μ (u)	Micro
μ A	Microampere
μ s	Microsecond
μ V	Microvolt

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