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Ice, Cloud, and Land Elevation Satellite (ICESat-2) Project

ATLAS Thermal Interface Control Document ICESat-2-THM-IFACE-0214

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Goddard Space Flight Center
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National Aeronautics and
Space Administration

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CHANGE RECORD PAGE

Document Version	Document Release Date	SCoRe Number	SCoRe Approval Date	Pages Affected	Description
Rev -	09/09/2010	0030	09/09/2010	All	Initial release of document.
Rev A	11/02/2010	0088	11/02/2010	3, 11, 15, 16, 17, 24, 38, 39	Interfaces added and level 3 upgraded
Rev A update	11/08/10	110	10/08/10	Title page	Doc # on title page was corrected

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LIST OF TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
01	TICD-008	MEB-to-Thermal MICD number	Vigneau	
02	TICD-009	PDU-to-Thermal MICD number	Vigneau	
03	TICD-010	Laser-to-Thermal MICD number	Vigneau	
04	TICD-011	DAA-to-Thermal MICD number	Vigneau	
05	TICD-012	DAA Electronics-to-Thermal MICD number	Vigneau	
06	TICD-013	Start Pulse Detector-to-Thermal MICD number	Vigneau	
07	TICD-014	LRS Optics-to-Thermal MICD number	Vigneau	
08	TICD-015	LRS Electronics-to-Thermal MICD number	Vigneau	
09	TICD-016, -17	LRS Sunshade-to-Thermal MICD number	Vigneau	
12	TICD-020	OFA-to-Thermal MICD number	Vigneau	
13	TICD-021	BSM-to-Thermal MICD number	Vigneau	
14	TICD-022	Telescope-to-Thermal MICD number	Vigneau	
15	TICD-023	Laser Pickoff-to-Thermal MICD number	Vigneau	
16	TICD-025	Fold Mirror-to-Thermal MICD number	Vigneau	
17	TICD-026	LSM-to-Thermal MICD number	Vigneau	
18	TICD-027	DOE-to-Thermal MICD number	Vigneau	
19	TICD-028	Beam Expander-to-Thermal MICD number	Vigneau	

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Item No.	Location	Summary	Ind./Org.	Due Date
20	TICD-029	Large Fold Mirror-to-Thermal MICD number	Vigneau	
21	TICD-030	LRS LTR-to-Thermal MICD number	Vigneau	
22	TICD-031	TAMS LTR-to-Thermal MICD number	Vigneau	
23	TICD-032	Aft Optics-to-Thermal MICD number	Vigneau	
24	TICD-034	LRS temperature limits, TBR	Correll & Garrison	
25	TICD-035	Laser setpoint control, TBR	Stephen & Garrison	
26	TICD-036	OFA setpoint control, TBR	Blagojevic & Garrison	
27	TICD-038	Thermal interface temporal gradient requirement, TBR	Garrison	
28	TICD-039	Temporal gradient measurement time, TBR	Garrison	
29	TICD-040	Thermal interface special gradient requirement, TBR	Garrison	
30	TICD-040	Structure gradient requirement, TBR	Garrison & Rossoni	
31	TICD-043	Cold plate heat flux limit, TBR	Garrison	
32	TICD-044	Heat pipe heat flux limit, TBR	Garrison	
33	TICD-045	Operational radiative environment on bench, TBR	Garrison	
34	TICD-046	Survival radiative environment on bench, TBR	Garrison	

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Item No.	Location	Summary	Ind./Org.	Due Date
35	TICD-047	Operational radiative environment in LTR tube, TBR	Garrison	
36	TICD-048	LRS Sunshade radiator backload	Garrison	
37	TICD-055	Temperature sensor accuracy	Garrison & Luers	
38	TICD-055	Temperature sensor range for accuracy	Garrison & Luers	
39	TICD-058	LRS Sunshade heat leak into bench	Garrison & Correll	
40	TICD-059	LRS Optics parasitic heat leak	Garrison & Correll	
41	TICD-060	Bus voltage range	Luers	
42	TICD-071	Survival heater bus size	Garrison	
43	TICD-072	ACS operational 1 heater bus size	Garrison	
44	TICD-073	LHP Shut-down heater bus size	Garrison	
45	TICD-074	LHP Control heater bus size	Garrison	
46	TICD-075	ACS operational 2 heater bus size	Garrison	
47	TICD-076	PWM heater bus size	Garrison	
48	TICD-077	LRS Optics heater bus size	Garrison	
49	TICD-078	OFA heater bus size	Garrison	
50	TICD-107	TAMS Light Source-to-Thermal MICD number	Vigneau	

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Table of Contents

1.0 GENERAL INFORMATION 3
1.1 Purpose and Scope 3
1.2 Applicability and Limitation 3
1.3 Definitions 3
1.4 Responsibility For Administration 4
1.5 Configuration Control and Distribution 5
2.0 DOCUMENTS 6
2.1 Applicable Documents 6
2.2 Reference Documents 6
3.0 TEMPERATURE LIMIT DEFINITIONS 7
3.1 Types of Temperature Limits 7
3.2 Thermal Interface Definitions 8
4.0 THERMAL INTERFACE REQUIREMENTS 15
4.1 Thermal Interface Temperature Requirements 15
4.2 Thermal Interface Temporal Gradient Requirements 17
4.3 Thermal Interface Spatial Gradient Requirements 18
4.4 Thermal Interface Flux Requirements 20
5.0 THERMAL RADIATION ENVIRONMENT 21
6.0 SURVIVAL CONDITIONS 22
7.0 COMPONENT-CONTROLLED FLIGHT THERMAL TELEMETRY 22
8.0 INSTRUMENT-CONTROLLED FLIGHT THERMAL TELEMETRY 23
9.0 THERMAL POWER 24
10.0 THERMAL HARDWARE 25
10.1 Heater Circuit Design 25
10.2 Thermistor, Heater and Thermostat Standards 25
10.3 Heater Flux Limits 26
10.4 Documentation 27
11.0 HEATER SERVICES 27
11.1 Spacecraft-Provided Heater Services 27
11.2 Instrument-Provided Heater Services 28
12.0 MULTI-LAYER INSULATION 30
13.0 THERMAL ANALYSIS 31
14.0 THERMAL MODEL DELIVERIES 32
14.1 Reduced Thermal Models Details 32
14.2 Reduced Thermal Model Correlation 34
14.3 Reduced Thermal Model Milestones 34
15.0 INTEGRATION AND TEST 35
15.1 Thermal Balance Testing 35
15.2 Thermal Test Documentation 35

CHECK https://icesat-2mis.gsfc.nasa.gov
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Released Version

15.3 Ambient Pressure Performance 36
15.4 In-Gravity Performance 36

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List of Figures

Figure Page

Figure 1: Coordinate Axis 38

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List of Tables

Table Page

Table 1: ATLAS Thermal Interface Temperature Limits 15
Table 2: ATLAS Thermal Interface Temporal Gradient Requirements 17
Table 3: ATLAS Thermal Interface Spatial Gradient Requirements 19
Table 5: ATLAS Thermal Environment Definitions 31

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1.0 GENERAL INFORMATION

1.1 Purpose and Scope

This document provides configuration control for all interfaces for the thermal control system of the Ice, Cloud, and Land Elevation Satellite-2 (ICESAT-2) Advanced Topographic Laser Altimeter (ATLAS) instrument. This document also details the ATLAS Thermal Control System requirements that are flowed down to instrument subsystems. It contains a baseline for demonstrating by test and analysis the satisfactory performance of hardware in the expected mission environments, and that minimum workmanship standards have been met. It elaborates on those requirements, gives guideline test levels, provides guidance in the choice of test options, and describes acceptable test and analytical methods for implementing the requirements.

The requirements within this document are level 3 interface controls within the mission architecture. Each requirement within this document must down up to one or more instrument level 4 requirements.

1.2 Applicability and Limitation

These requirements apply to the ATLAS thermal control system and all ATLAS components that interface to it.

1.3 Definitions

The following are level of assembly definition used in this document. For more information refer to Goddard Environmental Verification Standards (GEVS) (GSFC-STD-7000) Section 1.8.

Assembly: A functional subdivision of a component consisting of parts or subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and gyroscope.

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.

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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).

Module: A major subdivision of the payload that is viewed as a physical and functional entity for the purposes of analysis, manufacturing, testing, and recordkeeping. Examples include spacecraft bus, science payload, and upper stage vehicle.

Part: A hardware element that is not normally subject to further subdivision or disassembly without destruction of design use. Examples include resistor, integrated circuit, relay, connector, bolt, and gaskets.

Payload: An integrated assemblage of modules, subsystems, etc., designed to perform a specified mission in space. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are Laboratory, Observatory, Satellite and System Segment.

Spacecraft: See Payload. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

Section: A structurally integrated set of components and integrating hardware that form a subdivision of a subsystem, module, etc. A section forms a testable level of assembly, such as components/units mounted into a structural mounting tray or panel-like assembly, or components that are stacked.

Subassembly: A subdivision of an assembly. Examples are wire harness and loaded printed circuit boards.

Subsystem: A functional subdivision of a payload consisting of two or more components. Examples are structural, attitude control, electrical power, and communication subsystems. Also included as subsystems of the payload are the science instruments or experiments.

Unit: A functional subdivision of a subsystem, or instrument, 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.

1.4 Responsibility For Administration

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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 Manager (IM).

1.5 Configuration Control and Distribution

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

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2.0 DOCUMENTS

2.1 Applicable Documents

The ATLAS instrument and components will meet all requirements of the following documents. In cases of conflict between this document and the higher level documents, the higher level documents take precedence. Contractors will use the current version in effect at the time of procurement.

1. ICESat-2-SYS-REQ-0329, ATLAS Instrument Requirements Document
2. ICESat-2-SYS-REQ-0189, ATLAS Electrical Systems Requirements
3. ICESat-2-ATSYS-REQ-0517, ATLAS Component Environmental Requirements Document

2.2 Reference Documents

The following documents are referenced in this document. In cases of conflict, this document will take precedence.

1. ICESat-2-THM-SPEC-0217, ATLAS Thermal Hardware Specification
2. ICESat-2-THM-RPT-0212, ATLAS Thermal Model Delivery Report Template
3. ICESat-2-THM-LIST-0520, ATLAS Thermal Analysis Approved Optical Properties List
4. NASA GSFC S-311-P-079, Procurement Specification for Thermofoil Heaters
5. NASA GSFC S-311-641, Switches, Thermostatic, General Requirements
6. NASA GSFC S-311-P-018, Specification for Thermistor, Insulated and Uninsulated, Negative Temperature Coefficient
7. GSFC-STD-7000, General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects

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3.0 TEMPERATURE LIMIT DEFINITIONS

3.1 Types of Temperature Limits

TICD-001 Survival Limits will be defined as the minimum and maximum non-operating temperatures that may be experienced without inflicting damage or permanent performance degradation.

Rationale: Components may dwell at their survival temperature range when the instrument is unpowered.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-002 Qualification Limits will be defined as the minimum and maximum temperatures over which the responsible hardware manager has proven the components meet all performance requirements through qualification testing.

Rationale: Qualification testing provides margin on the system performance at extreme temperatures.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-003 Acceptance Limits will be defined as the minimum and maximum temperatures over which the responsible hardware manager has proven the components meet all performance requirements if the same design component has been qualified in a relevant environment to ATLAS.

Rationale: Qualification testing of non-flight units may reduce the testing burden on the flight component.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

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TICD-004 Flight Operational Limits will be defined as the minimum and maximum temperature range at the thermal interface that the component will see during flight.

Rationale: These provide the bounding design requirements for the instrument TCS.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-005 Flight Operational Limits will be at least 10C inside the qualification limits except for actively-controlled components, which will be at least 5C inside the qualification limits.

Rationale: These definitions are provided by GEVS. The laser thermal control system and the LRS Optics are the only components on the instrument that have an active thermal control system.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-006 Flight Operational Limits will be at least 5C inside the acceptance limits except for actively-controlled components.

Rationale: These definitions are provided by GEVS.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

3.2 Thermal Interface Definitions

TICD-007 All powered components will be designed to reject dissipated power through their conductive interface to the instrument TCS.

Rationale: The instrument TCS will not be designed to transport heat by radiation.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

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TICD-008 The thermal interface for the MEB will be the mounting interface to the radiator as shown in the MEB MICD (TBD01 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Avionics

TICD-009 The thermal interface for the PDU will be the mounting interface to the radiator as shown in the PDU MICD (TBD02 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Avionics

TICD-010 The thermal interface for the lasers will be the mounting interface to the heat pipes as shown in the Laser MICD (TBD03 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Transmitter

TICD-011 The thermal interface for the DAA will be the mounting interface to the structure as shown in the DAA MICD (TBD04 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Receiver

TICD-012 The thermal interface for the DAA Electronics will be the mounting interface to the radiator as shown in the DAA MICD (TBD05 document number).

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Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Receiver

TICD-013 The thermal interface for the start-pulse detector will be the mounting interface to the structure as shown in the Start-Pulse Detector MICD (TBD06 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Transmitter

TICD-014 The thermal interface for the LRS Optics will be the mounting interface to the radiator as shown in the LRS Optics MICD (TBD07 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, AMCS

TICD-015 The thermal interface for the LRS Electronics will be the mounting interface to the radiator as shown in the LRS Electronics MICD (TBD08 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, AMCS

TICD-016 The ATLAS TCS will provide a suitable view to space for the LRS Sunshade radiator as specified in the LRS Sunshade MICD (TBD09 document number).

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Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat. The backload on this surface is given in TICD-94.

Applicability: Thermal, AMCS

TICD-017 The thermal interface for the LRS Sunshade will be the mounting interface to the optical bench as shown in the LRS Sunshade MICD (TBD09 document number).

Rationale: The LRS Sunshade will be isolated from the optical bench, but this interface determines the magnitude of thermal isolation that must be provided by the LRS.

Applicability: Thermal, AMCS

TICD-018 Deleted

TICD-019 Deleted

TICD-020 The thermal interface for the OFA will be the temperature reference point on the exterior of the OFA oven as shown in the OFA MICD (TBD12 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Receiver

TICD-021 The thermal interface for the BSM will be the mounting interface to the structure as shown in the BSM MICD (TBD13 document number).

Rationale: Powered components require a thermal interface to the thermal control system to remove waste heat.

Applicability: Thermal, Transmitter

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TICD-022 The thermal interface for the telescope will be the mounting interface to the structure as shown in the Telescope MICD (TBD14 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Receiver

TICD-023 The thermal interface for the laser pickoff will be the mounting interface to the structure as shown in the Laser Pickoff MICD (TBD15 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Transmitter

TICD-024 The thermal interface for the optical fibers will be tie-down points of the optical fibers to the structure.

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Receiver

TICD-025 The thermal interface for the fold mirrors will be the mounting interface to the structure as shown in the Fold Mirror MICD (TBD18 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Transmitter

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TICD-026 The thermal interface for the laser select mechanism will be the mounting interface to the structure as shown in the Laser Select Mechanism MICD (TBD19 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Transmitter

TICD-027 The thermal interface for the DOE will be the mounting interface to the structure as shown in the DOE MICD (TBD20 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Transmitter

TICD-028 The thermal interface for the beam expander will be the mounting interface to the structure as shown in the Beam Expander MICD (TBD19 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: TRD-24

TICD-029 The thermal interface for the large fold mirror will be the mounting interface to the structure as shown in the Large Fold Mirror MICD (TBD20 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Transmitter

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TICD-030 The thermal interface for the LRS LTR will be the mounting interface to the LTR support tube as shown in the LRS LTR MICD (TBD21 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, AMCS

TICD-031 The thermal interface for the TAMS LTR will be the mounting interface to the LTR support tube as shown in the TAMS LTR MICD (TBD22 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, AMCS

TICD-032 The thermal interface for the aft optics will be the mounting interface to the structure as shown in the Aft Optics Assembly MICD (TBD23 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, Receiver

TICD-033 The thermal interface for the ATLAS primary structure will be defined as the exposed surface of the primary structure.

Rationale: The ATLAS structure temperature limits apply to the entire structure, but they will only be assessed and measured at areas that are exposed enough for temperature sensors to be installed.

Applicability: Thermal, Structure

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TICD-107 The thermal interface for the TAMS Light Source will be the mounting interface to the structure as shown in the TAMS Light Source MICD (TBD22 document number).

Rationale: Optical component temperatures must be maintained to ensure performance.

Applicability: Thermal, AMCS

4.0 THERMAL INTERFACE REQUIREMENTS

4.1 Thermal Interface Temperature Requirements

TICD-034 All instrument TCS thermal interfaces will meet the temperature limits given in Table 1.

Rationale: This provides the operational, survival, qualification and acceptance limits for all components listed in the above Thermal Interface Definition section.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

Table 1: ATLAS Thermal Interface Temperature Limits

Thermal Interface	Operational Limits (°C)	Survival Limits (°C)	Qualification Limits (°C)	Acceptance Limits (°C)
MEB	-10 to 40	-25 to 55	-20 to 50	-15 to 45
PDU	-10 to 40	-25 to 55	-20 to 50	-15 to 45
Laser 1	10 to 30	0 to 40	5 to 35	5 to 35
Laser 2	10 to 30	0 to 40	5 to 35	5 to 35
DAA	-10 to 17	-25 to 40	-20 to 27	-15 to 22
DAA Electronics	-10 to 40	-25 to 55	-20 to 50	-15 to 45
Start-Pulse Detector	-10 to 40	-25 to 55	-20 to 50	-15 to 45
LRS Optics	15 to 25 (TBR24)	-5 to 30 (TBR24)	10 to 30 (TBR24)	10 to 30 (TBR24)
LRS	-10 to 40	-25 to 55	-20 to 50	-15 to 45

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Thermal Interface	Operational Limits (°C)	Survival Limits (°C)	Qualification Limits (°C)	Acceptance Limits (°C)
Electronics	(TBR24)	(TBR24)	(TBR24)	(TBR24)
LRS Sunshade	-20 to 35	-40 to 50	-30 to 45	-25 to 40
OFA	20 to 40	-20 to 55	10 to 50	15 to 45
BSM	10 to 35	-5 to 50	0 to 45	5 to 40
Optical Fibers	-20 to 35	-40 to 50	-30 to 45	-25 to 40
Small Fold Mirrors	-20 to 35	-40 to 50	-30 to 45	-25 to 40
LSM	-20 to 35	-40 to 50	-30 to 45	-25 to 40
DOE	-20 to 35	-40 to 50	-30 to 45	-25 to 40
Beam Expander	-20 to 35	-40 to 50	-30 to 45	-25 to 40
Large Fold Mirror	-20 to 35	-40 to 50	-30 to 45	-25 to 40
LRS LTR	-20 to 35	-40 to 50	-30 to 45	-25 to 40
TAMS LTR	-20 to 35	-40 to 50	-30 to 45	-25 to 40
TAMS LS	-5 to 35	-20 to 50	-15 to 45	-10 to 40
Telescope	-20 to 35	-40 to 50	-30 to 45	-25 to 40
Aft Optics Assembly	-20 to 35	-40 to 50	-30 to 45	-25 to 40
Primary Structure	-40 to +40	-55 to +55	-50 to +50	-50 to +50

TICD-035 The thermal interface to the lasers will be capable of controlling to any temperature +/- 1C (TBR25) within its operational temperature range when the laser is operating.

Rationale: Laser operation requires that the lasers be adjusted to a temperature where they can meet all performance requirements.

Applicability: Transmitter, Thermal

TICD-036 The thermal interface to the OFA will be capable of controlling to any orbit-average temperature +/- 0.1C (TBR26) within its operational temperature range when the OFA is operating.

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Rationale: OFA wavelength is tunable by adjusting or maintaining the temperature of the etalon.

Applicability: Receiver, Thermal

TICD-037 Deleted

4.2 Thermal Interface Temporal Gradient Requirements

TICD-038 All instrument TCS thermal interfaces will have temporal gradients less than the values given in Table 2 while the instrument is operating.

Rationale: Some components may be sensitive to short-term variations in temperature.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

Table 2: ATLAS Thermal Interface Temporal Gradient Requirements

Thermal Interface	Temporal Gradient Requirement (°C/min)
MEB	3 (TBR27)
PDU	3 (TBR27)
Laser 1	3 (TBR27)
Laser 2	3 (TBR27)
DAA	3 (TBR27)
DAA Electronics	3 (TBR27)
Start-Pulse Detector	3 (TBR27)
LRS Optics	3 (TBR27)
LRS Electronics	3 (TBR27)
LRS Sunshade	3 (TBR27)
OFA	3 (TBR27)
BSM	3 (TBR27)
Optical Fibers	3 (TBR27)

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Thermal Interface	Temporal Gradient Requirement (°C/min)
Small Fold Mirrors	3 (TBR27)
LSM	3 (TBR27)
DOE	3 (TBR27)
Beam Expander	3 (TBR27)
Large Fold Mirror	3 (TBR27)
LRS LTR	3 (TBR27)
TAMS LTR	3 (TBR27)
TAMS LS	3 (TBR27)
Telescope	3 (TBR27)
Aft Optics Assembly	3 (TBR27)
Primary Structure	3 (TBR27)

TICD-039 All temporal gradient requirements will be assessed over a minimum time range of 6 minutes (TBR28).

Rationale: A minimum time window eliminates the need to analyze or test high-frequency temperature fluctuations, which will be damped by mass in the built system.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

4.3 Thermal Interface Spatial Gradient Requirements

TICD-040 All instrument TCS thermal interfaces will have spatial gradients less than the values given in Table 3.

Rationale: Spatial gradients can impact the thermal condition and pointing of some components.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

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Table 3: ATLAS Thermal Interface Spatial Gradient Requirements

Thermal Interface	Spatial Gradient Requirement (°C)
MEB	15 (TBR40)
PDU	15 (TBR40)
Laser 1	15 (TBR40)
Laser 2	15 (TBR40)
DAA	15 (TBR40)
DAA Electronics	15 (TBR40)
Start-Pulse Detector	15 (TBR40)
LRS Optics	15 (TBR40)
LRS Electronics	15 (TBR40)
LRS Sunshade	15 (TBR40)
OFA	15 (TBR40)
BSM	15 (TBR40)
Optical Fibers	15 (TBR40)
Small Fold Mirrors	15 (TBR40)
LSM	15 (TBR40)
DOE	15 (TBR40)
Beam Expander	15 (TBR40)
Large Fold Mirror	15 (TBR40)
LRS LTR	15 (TBR40)
TAMS LTR	15 (TBR40)
TAMS LS	15 (TBR40)
Telescope	See TICD-41, -42
Aft Optics Assembly	15 (TBR40)
Primary Structure, panel, in-plane	None (TBR41)
Primary Structure, panel, out-of-plane	None (TBR41)

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TICD-041 The instrument TCS will control the temperature gradient of the telescope secondary mirror tower to be no more than 2C, with a goal of 0.5C.

Rationale: Temperature gradients up the telescope tower can defocus the telescope mirrors.

Applicability: Receiver, Thermal

TICD-042 The instrument TCS will control the radial temperature gradient across the primary mirror to be no more than 1C.

Rationale: Temperature gradients across the primary mirror can defocus the telescope mirrors.

Applicability: Receiver, Thermal

4.4 Thermal Interface Flux Requirements

TICD-043 Components that have a thermal interface to a cold plate or panel will have a flux at that interface of no more than 1 W/in2 (0.000645 W/m2) (TBR31).

Rationale: Fluxes higher than this will require a thermal doubler.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-044 Components that have a thermal interface to a heat pipe will have a flux at that interface of no more than 25W (TBR32) per linear inch of pipe.

Rationale: Fluxes higher than this may dry out the heat pipe wick.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

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5.0 THERMAL RADIATION ENVIRONMENT

TICD-045 The TCS will provide an average thermal radiation environment for all components mounted to the –Z side of the optical bench between -15C and +35C (TBR33) when the instrument is operational except for surface that view space.

Rationale: Thermal radiation provides a secondary impact for component temperatures. The average thermal radiation environment is expected to be independent of direction.

Applicability: Transmitter, Receiver, AMCS, Thermal

TICD-046 The TCS will provide an average radiation environment for all components mounted to the –Z side of the optical bench between -30C and +40C (TBR34) when the instrument is not operational except for surface that view space.

Rationale: Thermal radiation provides a secondary impact for component temperatures. The average thermal radiation environment is expected to be independent of direction.

Applicability: Transmitter, Receiver, AMCS, Thermal

TICD-047 The TCS will provide an average thermal radiation environment for the LRS Optics laser window between -5C and +30C (TBR35).

Rationale: Thermal radiation provides a secondary impact for component temperatures.

Applicability: AMCS, Thermal

TICD-048 The total backload on the LRS Sunshade radiator will be between TBD36 and TBD36 W/m2.

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Rationale: This backload range will encompass the total environmental variability of the LRS sunshade radiator. This includes heat loads from the environment, the instrument and the spacecraft.

Applicability: AMCS, Thermal

6.0 SURVIVAL CONDITIONS

TICD-049 When powered off, each component will be capable of surviving indefinitely when its temperatures are within survival limits without damage or permanent performance degradation.

Rationale: Components must be able to dwell at a survival temperature when the instrument is unpowered. If necessary, the instrument TCS will use survival heater circuits to maintain the survival temperature range.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-050 When powered on, each component will be capable of surviving indefinitely when its temperatures are between the cold survival and hot qualification limits without damage or permanent performance degradation.

Rationale: The instrument TCS will not be designed to raise all components to their operational temperature range before component turn-on.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

7.0 COMPONENT-CONTROLLED FLIGHT THERMAL TELEMETRY

TICD-051 All temperature sensors internal to components accessible at instrument-level testing and their associated limits will be documented by diagram or figure in the end item data package prior to delivery of the component to instrument integration.

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Rationale: This will allow investigation into internal temperature anomalies at instrument-level thermal testing.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-052 All temperature limits internal to a component will be verified prior to delivery to instrument integration assuming that the thermal interface to the instrument TCS is held at the appropriate qualification or acceptance temperatures.

Rationale: Instrument-level thermal testing will not be intended to verify internal component temperatures.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

8.0 INSTRUMENT-CONTROLLED FLIGHT THERMAL TELEMETRY

TICD-053 All instrument-provided temperature sensors and their associated limits will be documented in the ATLAS Thermal Hardware Specification (ICESat-2-THM-SPEC-0217).

Rationale: Thermal hardware specification must include details of all the instrument thermal hardware.

Applicability: Thermal

TICD-054 All instrument-controlled temperature sensors will be capable of being read over all temperatures ranges specified.

Rationale: In-flight telemetry must be available for all temperatures expected in test and flight.

Applicability: Thermal, Avionics

TICD-055 All instrument-controlled flight temperature sensors will be accurate to within 1.0C (TBR37) over TBD38 temperature range.

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Rationale: Accuracy is important in knowing and controlling to a given temperature.

Applicability: Thermal, Avionics

TICD-056 All instrument-controlled temperature sensors will have a resolution of 0.5C between 0C and 40C, except those installed on the telescope and OFA, which will have a resolution of 0.1C between 0C and 40C.

Rationale: Resolution is important in verifying gradient requirements and providing tight heater control, especially proportional control.

Applicability: Thermal, Avionics

TICD-057 All instrument-controlled temperature sensors that are used as feedback for active heater control will be redundant.

Rationale: Redundant thermistors prevent a single failure from disabling a heater circuit.

Applicability: Thermal

9.0 THERMAL POWER

TICD-058 The TCS will accommodate a maximum of TBD39 W of heat transfer to or from the LRS Sunshade across the sunshade flexures.

Rationale: The LRS sunshade is to be thermally isolated from the instrument.

Applicability: Thermal, AMCS

TICD-059 In the hot case, the TCS will accommodate a maximum environmental parasitic heat from the LRS Optics of 2.4 Watts (TBR40) at beta angles below 16°, and 0.0 Watts at beta angles above 15°.

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Rationale: The LRS Optics will need to reject environmental heat that is absorbed through the aperture, which has a half-angle of 12°. This is in addition to the internal power dissipation given in TICD-34.

Applicability: Thermal, AMCS

10.0 THERMAL HARDWARE

10.1 Heater Circuit Design

TICD-060 All heaters will be able to operate at any bus voltage between 27 Vdc and 35 Vdc (TBR41).

Rationale: This is the expected voltage range of all primary power feeds on the spacecraft and instrument.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-061 All heaters will be sized for a maximum 70% duty cycle at the minimum bus voltage.

Rationale: Required margin defined in Gold Rules.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-062 All thermostats will be redundant in series.

Rationale: Series redundant thermostats protect against a full-on heater if a single thermostat fails closed.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

10.2 Thermistor, Heater and Thermostat Standards

TICD-063 All Kapton film heaters will comply with NASA GSFC S311-P-079.

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Rationale: All components must meet NASA standards.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-064 All Vishay Dale Ohm heaters will comply with Military/Established Reliability, MIL-R-39009 Qualified, Type RER, R Level, aluminum housed, and be standard (ERH).

Rationale: All components must meet NASA standards.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-065 All mechanical thermostats will comply with NASA GSFC S311-641.

Rationale: All components must meet NASA standards.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-066 All thermistors will comply with NASA GSFC S311-P-018.

Rationale: All components must meet NASA standards.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

10.3 Heater Flux Limits

TICD-067 All Kapton film heaters bonded with PSA and no aluminum over-tape will have a maximum watt density of 1 W/in2 at maximum bus voltage.

Rationale: Maximum watt densities reduce the chance of heaters lifting and over-heating.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-068 All Kapton film heaters bonded with PSA and with aluminum over-tape will have a maximum watt density of 3.5 W/in2 at maximum bus voltage.

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Rationale: Maximum watt densities reduce the chance of heaters lifting and over-heating.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-069 All Kapton film heaters bonded with Stycast or BN Arathane and with aluminum over-tape will have a maximum watt density of 10 W/in2 at maximum bus voltage.

Rationale: Maximum watt densities reduce the chance of heaters lifting and over-heating.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

10.4 Documentation

TICD-070 All heaters, including those internal to components, will be documented in the ATLAS Thermal Hardware Specification (ICESat-2-THM-SPEC-0217).

Rationale: Thermal hardware specification must include details of all the instrument thermal hardware.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

11.0 HEATER SERVICES

11.1 Spacecraft-Provided Heater Services

TICD-071 The TCS will include a survival heater service that receives unswitched power from the spacecraft with a maximum current of TBD42 amps at maximum bus voltage.

Rationale: This service will power all thermostatically-controlled survival heaters on the instrument. All heater services are redundant.

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Applicability: Thermal, Avionics, SC

TICD-072 The TCS will include an ACS operational heater service that receives switched power from the spacecraft with a maximum current of TBD43 amps at maximum bus voltage.

Rationale: This service will power the thermostatically-controlled operational heaters on the ACS components. All heater services are redundant.

Applicability: Thermal, Avionics, SC

TICD-073 The TCS will include a Loop Heat Pipe Shut-Down heater service receives switched power from the spacecraft with a maximum current of TBD44 amps at maximum bus voltage.

Rationale: This service will power the thermostatically-controlled shut-down heaters on the loop heat pipes. The loops cannot function while this heater is enabled, but the heater is required to maintain survival temperature limits on the lasers when they are unpowered. All heater services are redundant.

Applicability: Thermal, Avionics, SC

11.2 Instrument-Provided Heater Services

TICD-074 The TCS will include two loop heat pipe control heater services that receive software-controlled power from the PDU with a maximum current of TBD45 amps per service at maximum bus voltage.

Rationale: These services will actively control the temperature of the loop heat pipe compensation chamber. All heater services are redundant.

Applicability: Thermal, Avionics, SC

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TICD-075 The TCS will include one ACS heater services that receive software-controlled power from the PDU with a maximum current of TBD46 amps at maximum bus voltage.

Rationale: This service will provide warm-biased heater control for the ACS components to reduce transient gradients in the instrument bench. All heater services are redundant.

Applicability: Thermal, Avionics

TICD-076 The TCS will include three telescope heater services that receive pulse-width modulated power from the PDU with a maximum current of TBD47 amps per service at maximum bus voltage.

Rationale: These services will actively control the temperature gradients of the telescope. All heater services are redundant.

Applicability: Thermal, Avionics

TICD-077 The TCS will include one LRS Optics control heater services that receive software-controlled power from the PDU with a maximum current of TBD48 amps per service at maximum bus voltage.

Rationale: These services will actively control the temperature of the two VCHP reservoirs. All heater services are redundant.

Applicability: Thermal, Avionics

TICD-078 The TCS will include one OFA control heater services that receive software-controlled power from the PDU with a maximum current of TBD49 amps per service at maximum bus voltage.

Rationale: These services will actively control the temperature of the two VCHP reservoirs. All heater services are redundant.

Applicability: Thermal, Avionics

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TICD-079 The software-controlled heater services will be capable of switching power on and off based on temperature sensor feedback and programmable setpoints, with control provided by the MEB.

Rationale: This defines the expectations of the software-controlled heater services.

Applicability: Thermal, Avionics

TICD-080 The pulse-width modulated heater services will be capable of proportionally-controlling the average heater power based on temperature sensor feedback and programmable setpoints, with control provided by the MEB.

Rationale: This defines the expectations of the PWM heater services.

Applicability: Thermal, Avionics

12.0 MULTI-LAYER INSULATION

TICD-081 All MLI blankets will be mechanically constrained at a minimum of one point or mechanically captured by another blanket or mechanical component.

Rationale: Blankets must be constrained to prevent excess heat leaks.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-082 All MLI blankets that could interfere with the incoming or outgoing beam optical path will have redundant mechanical constraints.

Rationale: Blankets must be prevented from coming loose and impeding the science capability of the instrument.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

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TICD-083 All thermal hardware will be built so that the launch depressurization rate of 0.9 psi per second does not detach any thermal blankets or hardware.

Rationale: Depressurization is often the bounding load case for MLI.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

13.0 THERMAL ANALYSIS

TICD-084 The ATLAS TCS will meet all requirements in the thermal environment given in Table 4.

Rationale: The on-orbit thermal environment drives the design of the TCS.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

Table 4: ATLAS Thermal Environment Definitions

Parameter	Hot Case	Cold Case
Solar Flux (W/m2)	1420	1280
Albedo	0.35	0.25
Planetary IR (W/m2)	265	208

TICD-085 The ATLAS TCS will meet all requirements in a 481km circular polar orbit, with +Z pointing nadir, and the velocity vector pointing +X in positive beta angles and -X in negative beta angles.

Rationale: The on-orbit thermal environment drives the design of the TCS.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-086 MLI blankets will be analyzed using an effective emissivity equal to 0.005 or 0.03, case specific, that yields the worst case bounding thermal cases.

Rationale: Blanket variation must be accounted for in thermal analysis.

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Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-087 All thermal analyses will use only the optical properties documented in the ATLAS Thermal Analysis Approved Optical Properties List (ICESat-2-THM-LIST-0520).

Rationale: All optical properties must be verified by the NASA GSFC Coatings Committee.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-088 Hot case thermal analysis will assume maximum allocated power for the appropriate mode on all components.

Rationale: Hot case analysis should be done at the largest power possible.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-089 Cold case thermal analysis will assume the current best estimate of the minimum power dissipation for the appropriate mode on all components.

Rationale: Cold case analysis should be done at the lowest realistic power possible.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

14.0 THERMAL MODEL DELIVERIES

14.1 Reduced Thermal Models Details

TICD-090 All powered instrument components with internal temperature limits will provide a reduced thermal model for integration into the instrument thermal model.

Rationale: Reduced thermal model deliveries are expected from the lasers, detectors, MEB, and LRS.

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Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-091 Component reduced thermal models will have no more than 100 nodes.

Rationale: This is a large bound for the definition of a reduced model. Typical models are 20-40 nodes.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-092 Component reduced thermal models will be in either Thermal Desktop or SINDA/TSS formats.

Rationale: The models must be in a format usable to the instrument model. Thermal Desktop is preferred, but other formats can be negotiated with the Instrument Thermal Engineer if needed.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-093 Component reduced thermal model deliveries will be accompanied by a thermal model description document in the format and including all information listed in the ATLAS Thermal Model Delivery Report Template (ICESat-2-THM-RPT-0212).

Rationale: The model must include documentation that adequately describes the delivery.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-094 The component reduced thermal models will be capable of running upon delivery, and must include an analysis case to verify that the as-delivered model replicates the results obtained by the model developer.

Rationale: Thermal model deliveries must be fully-functional at the time of delivery.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

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TICD-095 Component reduced thermal models will reflect the latest known power levels and mechanical configuration.

Rationale: Models should represent the current design.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

14.2 Reduced Thermal Model Correlation

TICD-096 Component reduced thermal models will correctly represent the temperature of any internal temperature sensors.

Rationale: The goal of the reduced thermal models is to predict the temperature of internal components in the system-level model.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-097 After component-level thermal testing, component thermal models will be correlated to accurately represent the temperature of all internal temperature sensors to within 2C of the value measured in all thermal balance tests.

Rationale: The reduced models must be correlated prior to final delivery to the instrument.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

14.3 Reduced Thermal Model Milestones

TICD-098 Up-to-date component reduced thermal models will be delivered to the Instrument Thermal Engineer two weeks prior to the component CDR and delivery to instrument integration, and also any time that the Instrument Thermal Engineer requests a delivery due to a significant design change.

Rationale: Minimum delivery dates are required.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

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15.0 INTEGRATION AND TEST

15.1 Thermal Balance Testing

TICD-099 The target temperatures for thermal tests will be specified as a result of a test model analysis.

Rationale: Thermal test models are necessary to show that a test will not harm the hardware and to generate a correlated thermal model.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-100 Prior to delivery to instrument integration, all components that dissipate power will undergo a thermal balance test that simulates hot operational, cold operational and cold survival conditions.

Rationale: Thermal balance testing is necessary to show proper design margins and to correlate thermal models against observed performance.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-101 If the component is sensitive to orbital transient temperature changes, component performance will be monitored during test transitions at a rate similar to that expected in flight.

Rationale: Necessary to show performance in a flight-like condition.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

15.2 Thermal Test Documentation

TICD-102 Prior to a thermal test, a thermal analysis report will be released that gives the details of the test thermal model and shows the predicted performance for all conditions expected in the test.

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Rationale: This allows transparency into the test planning process and provides a reference for looking at results.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-103 After a thermal test, a thermal model correlation report will be released that shows the results against the initial predictions, what updates were made to the model, and how the updated model compares against the measured temperatures for each thermal balance.

Rationale: This is used to provide traceability in case the instrument-level thermal model does not perform as expected in the instrument thermal testing.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

15.3 Ambient Pressure Performance

TICD-104 All components will be capable of operating in ambient air, 15-25C, without active cooling or degradation of performance. This does not include the lasers.

Rationale: A GSE ground cooling system will be provided to cool the lasers. High-power electronics such as the PDU and MEB may not be able to dissipate their energy in air without the radiators installed.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

15.4 In-Gravity Performance

TICD-105 Heat pipes, if used, will be maintained at a slope of no more than 0.1 inches over their length when in thermal vacuum testing. This does not include heat pipes operating in reflux.

Rationale: CCHPs and VCHPs must be level to operate in a gravity environment.

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Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

TICD-106 All components will be capable of operating in the thermal vacuum configuration where gravity is in the -X direction at the instrument level or above.

Rationale: The TCS will be designed to operate in this orientation. The coordinate system is shown in Figure 1.

Applicability: Transmitter, Receiver, AMCS, Thermal, Avionics

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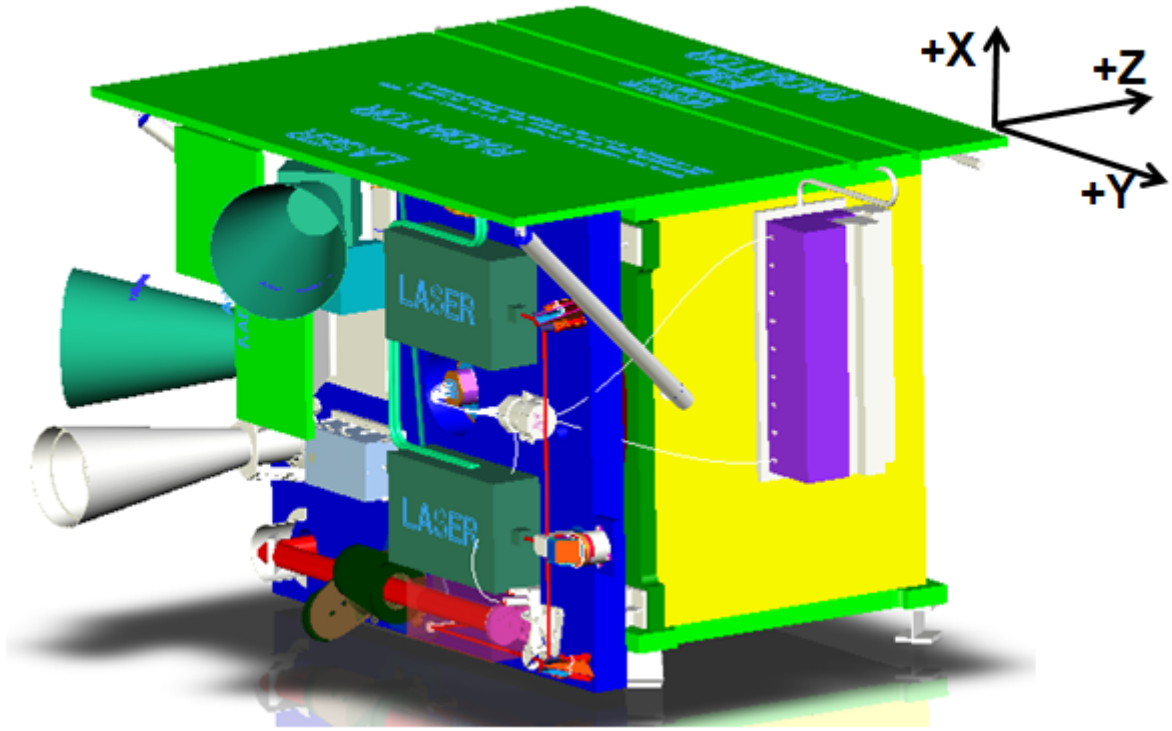

Figure 1: Coordinate Axis

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16.0 APPLICABILITY

TICD-200 Each ATLAS component will meet all applicable requirements contained within this document, the ATLAS Thermal Interface Control Document (ICESat-2-THM-IFACE-0214).

Rationale: Compliance is necessary for the instrument to function correctly in the anticipated thermal environments.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

TICD-201 Each ATLAS component shall provide a complete ATLAS Thermal Interface Control Document Verification Matrix showing proof of

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compliance with each of the applicable requirements in this document, the ATLAS Thermal Interface Control Document (ICESat-2-THM-IFACE-0214).

Rationale: A verification matrix is needed to show compliance with the applicable requirements contained within this document.

Applicability: Transmitter, Receiver, AMCS, Thermal, Structure, Avionics

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APPENDIX A: Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
A	Analysis
ATLAS	Advanced Togographic Laser Altimeter System
°C, C	Degrees Celsius
D	Design
DAA	Detector Array Assembly
DOE	Diffractive Optical Element
GCS	Ground Cooling System
GEVS	General Environmental Verification Specification
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HVPC	High Voltage Power Converter
I	Inspection
ICD	Interface Control Document
ICESat-2	Ice, Clound and Elevation Satellite 2
IEM	Instrument Electronics Module
LRS	Laser Reference System
LSM	Laser Select Mechanism
LTR	Lateral Transfer Retroreflector
M, m	Meters
MEB	Main Electronics Box
MICD	Mechanical Interface Control Document
MMOD	Micrometeoroid and Orbital Debris
OFA	Optical Filter Assembly
PDU	Power Distribution Unit
SC	Spacecraft
T	Test
TAMS	Telescope Alignment Monitoring System
TB	Thermal Balance
TBD	To Be Determined
TBR	To Be Revised
TCS	Thermal Control System
TV	Thermal Vacuum
Vdc	Volts, Direct Current
W	Watts

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