ICESat-2 Controlled Document
Released by: N. Brown 10/3/2011

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

Advanced Topographic Laser Altimeter System (ATLAS)

Transmitter Optics Requirements

ICESat-2-OPT-REQ-0552

Revision (-)

Effective Date: September 29, 2011

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

CM FOREWORD

This document is an Ice, Cloud, and Land Elevation (ICESat 2) Project signature-controlled document. Changes to this document require prior approval of the applicable Product Design Lead (PDL) or designee. Proposed changes shall be submitted in the ICESat-2 Management Information System (MIS) via a Configuration Controlled Request (CCR), along with supportive material justifying the proposed change.

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:

ICESat-2 Configuration Management Office
Mail Stop 425
Goddard Space Flight Center
Greenbelt, Maryland 20771

***** All Signatures are available on-line at: https://icesat-2mis.gsfc.nasa.gov *****

DOCUMENT CHANGE RECORD

Document Version	Document Release Date	SCoRe Number	SCoRe Approval Date	Pages Affected	Description
Rev -	10/3/2011	0236	09/29/2011	All	Initial release of baseline.

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
OPT1	Transmitter Optics Mission Lifetime	The ATLAS Transmitter Optics shall be designed to meet all mission requirements for an on orbit duration per TRANS34.	BDA, PBC, Fold Mirror, BE, DOE	The ATLAS instrument needs the Transmitter Optics to operate and meet mission lifetime requirements.	3	A	Object Identifier:TRANS34 Object Text:The ATLAS transmitter shall comply with IRD1.
OPT2	Transmitter Optics Ground Storage	The ATLAS Transmitter Optics shall meet all mission requirements after exposure to a ground storage phase per TRANS36.	BDA, PBC, Fold Mirror, BE, DOE	The ATLAS instrument needs the Transmitter Optics to meet environmental requirements and prepare for launch delays.	3	A	Object Identifier:TRANS36 Object Text:The ATLAS transmitter shall comply with IRD3.
OPT3	Transmitter Optics Autonomous Operation	The ATLAS Transmitter Optics shall operate in nominal science mode autonomously (without ground intervention) without damage or degradation of performance per TRANS79	BDA, PBC, Fold Mirror, BE, DOE	Specifies the duration of autonomous instrument performance.	5	A	Object Identifier:TRANS79 Object Text:The ATLAS transmitter shall comply with IRD49.
OPT4	Transmitter Optics Coordinate System	The ATLAS Transmitter Optics shall utilize the coordinate system per TRANS132	BDA, PBC, Fold Mirror, BE, DOE	Utilize a common coordinate system for the spacecraft subsystems.	3	I	Object Identifier:TRANS132 Object Text:The ATLAS transmitter shall comply with IRD156.
OPT5	Transmitter Optics Contamination Control	The ATLAS transmitter shall comply with TRANS133.	BDA, PBC, Fold Mirror, BE, DOE	All Transmitter Optics must follow common contamination control practices to minimize cross contamination issues and maintain integrity of the system.	5	I	Object Identifier:TRANS133 Object Text:The ATLAS transmitter shall comply with IRD191.
OPT6	Transmitter Optics Clear Field of View	The ATLAS Transmitter Optics shall have unobstructed optical fields of view contained within the field of view envelopes per TRANS134	BDA, PBC, Fold Mirror, BE, DOE	The transmitted laser beam must have clear fields of view.	5	I	Object Identifier:TRANS134 Object Text:The ATLAS transmitter shall comply with IRD62.
OPT9	Transmitter Optics	The ATLAS Transmitter Optics shall be grounded per ERS134	BDA, PBC, Fold Mirror, BE, DOE	Unpowered electrically conductive matericals and Transmitter Optics need to be grounded	3	T	Object Identifier:ERS134 Object Text:Unpowered electrically conductive materials and components shall be grounded with straps or wires and connected to instrument ground by a resistance of <10 kohms.
OPT14	Transmitter Optics Operational Temperature limits	The ATLAS Transmitter Optics shall meet the Flight Temperature Acceptance Limits per TICD9	BDA, PBC, Fold Mirror, BE, DOE	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.	5	T	Object Identifier:TICD9 Object Text: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
OPT15	Transmitter Optics Thermal Interface	The Thermal Interface for the ATLAS Transmitter Optics shall be the mounting interface to the structure per TICD272, 29, 28, 31 and 30	BDA, PBC, Fold Mirror, BE, DOE	Optical component temperatures must be maintained to ensure performance.	5	T	Object Identifier:TICD28 Object Text:The thermal interface for the fold mirrors will be the mounting interface to the structure as shown in the Fold Mirror MICD (drawing 2153302). Object Identifier:TICD29 Object Text:The thermal interface for the polarizing beam combiner (PBC) will be the mounting interface to the structure as shown in the PBC MICD (drawing 2153303). Object Identifier:TICD30 Object Text:The thermal interface for the DOE will be the mounting interface to the structure as shown in the DOE MICD (drawing 2153306). Object Identifier:TICD31 Object Text:The thermal interface for the beam expander will be the

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							mounting interface to the structure as shown in the Beam Expander MICD (drawing 2153305). Object Identifier:TICD272 Object Text:The thermal interface for the Beam Dump will be the mounting interface to the structure as shown in the Beam Dump MICD (drawing 2153315).
OPT113	Transmitter optics thermal interface temperature limits	All transmit optics TCS thermal interfaces shall meet the temperature limits given in TICD42.	BDA, PBC, Fold Mirror, BE, DOE	This provides the operational, survival, qualification and acceptance limits for all the transmitter optics.	5	I	Object Identifier:TICD42 Object Text:All instrument TCS thermal interfaces will meet the temperature limits given in Table 1. **Table 1: ATLAS Thermal Interface Temperature Limits**
OPT16	Transmitter Optics	The ATLAS Transmitter Optics shall have a Thermal Interface Temporal Gradient per TICD046, and TICD47.	BDA, PBC, Fold Mirror, BE, DOE	All ATLAS Transmitter Optics TCS thermal interfaces shall have temporal gradients less than the values given in Table 2 while the instrument is operating.	5	T	Object Identifier:TICD46 Object Text:All instrument TCS thermal interfaces will have temporal gradients less than the values given in Table 2 while the instrument is operating. **Table 2: ATLAS Thermal Interface Temporal gradient Requirements** Object Identifier:TICD47 Object Text:All temporal gradient requirements will be assessed over a minimum time range of 6 minutes (TBR28).
OPT17	Transmitter Optics	The ATLAS Transmitter Optics shall have a flux at a cold plate interface per TICD53	BDA, PBC, Fold Mirror, BE, DOE	Fluxes higher than this will require a thermal doubler.	5	T	Object Identifier:TICD53 Object Text: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).
OPT18	Transmitter Optics	The ATLAS Transmitter Optics Heater Circuit Design shall be able to operate throughout the voltage range specified in TICD77	BDA, PBC, Fold Mirror, BE, DOE	This is the expected voltage range of all primary power feeds on the spacecraft and instrument.	5	T	Object Identifier:TICD77 Object Text:All heaters will be able to operate at any bus voltage between 27 Vdc and 35 Vdc.
OPT19	Transmitter Optics	The ATLAS transmit optics heaters shall be sized for a maximum 70% duty cycle at the minimum bus voltage.	BDA, PBC, Fold Mirror, BE, DOE	Required margin defined in Gold Rules.	5	T	Object Identifier:TICD78 Object Text:All heaters will be sized for a maximum 70% duty cycle at the minimum bus voltage.
OPT20	Transmitter Optics	The ATLAS Transmitter Optics Heater Circuit Thermostats shall be redundant in series per TICD79	BDA, PBC, Fold Mirror, BE, DOE	Series refundant thermostats protect against a full-on heater if a single thermostat fails closed.	5	T	Object Identifier:TICD79 Object Text:All thermostats will be redundant in series.
OPT21	Transmitter Optics	The ATLAS Transmitter Optics Kapton film heaters shall comply with NASA GSFC S311-P-079. per TICD81	BDA, PBC, Fold Mirror, BE, DOE	All Transmitter Optics Kapton film heaters shall meet NASA standards	5	T	Object Identifier:TICD81 Object Text:All Kapton film heaters will comply with NASA GSFC S311-P-079.
OPT22	Transmitter Optics	The ATLAS Transmitter Optics Vishay Dale Ohm heaters shall comply with Military/Established Reliability, MIL-R-39009 Qualified per TICD82	BDA, PBC, Fold Mirror, BE, DOE	All Transmitter Optics must meet NASA standards	5	T	Object Identifier:TICD82 Object Text: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).
OPT23	Transmitter Optics	The transmit optics mechanical thermostats shall comply with NASA GSFC S311-641 per TICD83	BDA, PBC, Fold Mirror,	All Transmitter Optics must meet NASA standards	5	T	Object Identifier:TICD83 Object Text:All mechanical thermostats will comply with NASA GSFC

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
			BE, DOE				S311-641.
OPT24	Transmitter Optics	The ATLAS transmit optics thermistors shall comply with NASA GSFC S311-P018 per TICD84.	BDA, PBC, Fold Mirror, BE, DOE	All Transmitter Optics must meet NASA standards	5	T	Object Identifier:TICD84 Object Text:All thermistors will comply with NASA GSFC S311-P-018. Additional testing will be done to qualify certain flight parts to operate with a minimum temperature of -70C.
OPT25	Transmitter Optics	The ATLAS Transmitter Optics Kapton film heaters bonded with PSA and no aluminum over-tape shall have a maximum watt density per TICD86	BDA, PBC, Fold Mirror, BE, DOE	Maximum watt densities reduce the chance of heaters lifting and over-heating.	5	T	Object Identifier:TICD86 Object Text: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.
OPT26	Transmitter Optics	The ATLAS Transmitter Optics Kapton film heaters bonded with PSA and with aluminum over-tape shall have a maximum watt density per TICD087	BDA, PBC, Fold Mirror, BE, DOE	Maximum watt densities reduce the chance of heaters lifting and over-heating.	5	T	Object Identifier:TICD87 Object Text: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
OPT27	Transmitter Optics	The ATLAS Transmitter Optics Kapton film heaters bonded with Stycast or BN Arathane and with aluminum over-tape shall have a maximum watt density per TICD088	BDA, PBC, Fold Mirror, BE, DOE	Maximum watt densities reduce the chance of heaters lifting and over-heating.	5	T	Object Identifier:TICD88 Object Text: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.
OPT28	Transmitter Optics	The ATLAS Transmitter Optics Heaters, including those internal to Transmitter Optics, shall be documented per TICD90	BDA, PBC, Fold Mirror, BE, DOE	Thermal hardware specification must include details of all the instrument thermal hardware.	5	T	Object Identifier:TICD90 Object Text:All heaters, including those internal to components, will be documented in the ATLAS Thermal Hardware Specification (ICESat-2-THM-SPEC-0217).
OPT29	Transmitter Optics	The ATLAS Transmitter Optics MLI blankets shall be mechanically constrained per TICD105	BDA, PBC, Fold Mirror, BE, DOE	Blankets must be constrained to prevent excess heat leaks.	5	T	Object Identifier:TICD105 Object Text:All MLI blankets will be mechanically constrained at a minimum of one point or mechanically captured by another blanket or mechanical component.
OPT30	Transmitter Optics	The ATLAS Transmitter Optics MLI blankets that could interfere with the incoming or outgoing beam optical path shall have redundant mechanically constraints per TICD106	BDA, PBC, Fold Mirror, BE, DOE	Blankets must be prevented from coming loose and impeding the science capability of the instrument.	5	T	Object Identifier:TICD106 Object Text:All MLI blankets that could interfere with the incoming or outgoing beam optical path will have redundant mechanical constraints.
OPT31	Transmitter Optics	The ATLAS Transmitter Optics Thermal hardware shall be built per TICD107	BDA, PBC, Fold Mirror, BE, DOE	Depressurization is often the bounding load case for MLI.	5	A	Object Identifier:TICD107 Object Text: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.
OPT32	Transmitter Optics	The ATLAS Transmitter Optics Target Temperatures for thermal tests shall be specified per TICD129	BDA, PBC, Fold Mirror, BE, DOE	Thermal test models are necessary to show that a test will not harm the hardware and to generate a correlated thermal model	5	A	Object Identifier:TICD129 Object Text:The target temperatures for thermal tests will be specified as a result of a test model analysis.
OPT33	Transmitter Optics	If The ATLAS Transmitter Optics Transmitter Optics are sensitive to orbital transient temperature changes Transmitter Optics performance shall be monitored per TICD132	BDA, PBC, Fold Mirror, BE, DOE	Necessary to show performance in a flight-like condition	5	T	Object Identifier:TICD132 Object Text: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.
OPT34	Transmitter Optics	The ATLAS Transmitter Optics Transmitter Optics shall be capable of operating in ambient air per TICD136	BDA, PBC, Fold Mirror, BE, DOE	Would not require an active ground cooling system.	5	T	Object Identifier:TICD136 Object Text: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.

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
OPT35	Transmitter Optics	The ATLAS Transmitter Optics Heat pipes, if used, shall be maintained per TICD137	BDA, PBC, Fold Mirror, BE, DOE	CCHPs and VCHPs must be level to operate in a gravity environment	5	T	Object Identifier:TICD137 Object Text: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.
OPT36	Transmitter Optics	The ATLAS Transmitter Optics components shall be capable of operating in the Thermal Vacuum configuration per TICD141, TICD6, TICD7, TICD8 and TICD10.	BDA, PBC, Fold Mirror, BE, DOE	The TCS will be designed to operate in this orientation.	3	T	Object Identifier:TICD6 Object Text: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. Object Identifier:TICD7 Object Text: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. Object Identifier:TICD8 Object Text:Flight Operational Limits will be defined as the minimum and maximum temperature range at the thermal interface that the component will see during flight. Object Identifier:TICD10 Object Text:Flight Operational Limits will be at least 5C inside the acceptance limits except for actively-controlled components. Object Identifier:TICD141 Object Text:Survival Limits will be defined as the minimum and maximum non-operating temperatures that may be experienced without inflicting damage or permanent performance degradation.
OPT37	Transmitter Optics	Metallic structure in the Transmitter Optics qualified by analysis shall show positive margins of safety per CERD1	BDA, PBC, Fold Mirror, BE, DOE	Metallic structure with high margins of safety may verify strength by analysis.	3	A	Object Identifier:CERD1 Object Text:Metallic structures, excluding Beryllium, qualified by analysis with approval of the ATLAS instrument manager (IM), shall show positive margins of safety using factors of safety of 2.0 on yield and 2.6 on ultimate.
OPT38	Transmitter Optics	Beryllium, glass and composite materials of the Transmitter Optics shall not be qualified by analysis per CERD2.	BDA, PBC, Fold Mirror, BE, DOE	Brittle materials must be tested to verify strength.	5	A	Object Identifier:CERD2 Object Text:Beryllium, glass and composite materials shall not be qualified by analysis alone.v
OPT39	Transmitter Optics	The weight of each Transmitter Optics shall be measured to within limits set per CERD3.	BDA, PBC, Fold Mirror, BE, DOE	The ATLAS component weight measurement shows compliance with specified component requirements and provides accurate data for the observatory mass properties control program.	5	T	Object Identifier:CERD3 Object Text:The weight of each ATLAS flight component shall be measured to within $\pm$ 0.2%.
OPT40	Transmitter Optics	The center of gravity (CG) of each Transmitter Optics, referenced to the ATLAS spacecraft	BDA, PBC, Fold Mirror,	The Transmitter Optics CG measurement shows compliance with specified component	5	A	Object Identifier:CERD4 Object Text:The center of gravity (CG) of each ATLAS flight component,

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
		mounting plane, shall be verified to levels set by CERD4. The CG may be analytically derived.	BE, DOE	requirements and provides accurate data for the observatory mass properties control program.			referenced to the ATLAS to spacecraft mounting plane, shall be verified to within ± 0.15 centimeters (cm). The CG may be analytically derived.
OPT41	Transmitter Optics	The fundamental frequencies of the Transmitter Optics shall be per CERD5	BDA, PBC, Fold Mirror, BE, DOE	ATLAS component fundamental frequencies should avoid instrument assembly and observatory induced excitation frequencies	5	A	Object Identifier:CERD5 Object Text:The fundamental frequencies of the ATLAS components shall be greater than or equal to 100 Hertz (Hz).
OPT42	Transmitter Optics	Transmitter Optics shall undergo a low-level sine survey, measuring all modes up to the component's specified frequency per CERD8, CERD9.	BDA, PBC, Fold Mirror, BE, DOE	A low-level sine sweep determines compliance with fundamental frequency requirements.	5	T	Object Identifier:CERD8 Object Text: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. Object Identifier:CERD9 Object Text: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.
OPT43	Transmitter Optics	The Transmitter Optics shall undergo structural analysis per CERD10.	BDA, PBC, Fold Mirror, BE, DOE	Show compliance with the mechanical/structural design and test requirements.	5	A	Object Identifier:CERD10 Object Text: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** **Table 4.4-2 - Minimum Design and Test Factors for Glass** Source: NASA-STD-5001A Section 5.1.4
OPT44	Transmitter Optics	The Transmitter Optics shall undergo sine burst protoflight testing per CERD12	BDA, PBC, Fold Mirror, BE, DOE	Sine burst testing verifies the structural strength of ATLAS Transmitter Optics.	5	T	Object Identifier:CERD12 Object Text: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

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							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.
OPT46	Transmitter Optics	The Transmitter Optics shall show positive margins of safety for ultimate and yield failures in a structural analysis per CERD14.	BDA, PBC, Fold Mirror, BE, DOE	Show compliance with the mechanical/structural design and test requirements.	5	A	Object Identifier:CERD14 Object Text:Each ATLAS component, including the instrument structure, 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
OPT47	Transmitter Optics	The Transmitter Optics shall meet performance requirements after sine vibration testing per CERD 15.	BDA, PBC, Fold Mirror, BE, DOE	Verify workmanship quality and to simulate launch vehicle loading conditions.	5	T	Object Identifier:CERD15 Object Text: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: 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.
OPT48	Transmitter Optics	The Transmitter Optics, 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 per CERD16.	BDA, PBC, Fold Mirror, BE, DOE	Purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirement.	5	A	Object Identifier:CERD16 Object Text: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
OPT50	Transmitter Optics	The Transmitter Optics shall meet performance requirements after undergoing random vibration testing per CERD18.	BDA, PBC, Fold Mirror, BE, DOE	Random vibration test demonstrates workmanship quality and simulates launch vehicle environmental levels due to vibro-	5	T	Object Identifier:CERD18 Object Text:Each ATLAS component, with the exception of the structure, shall meet performance requirements after undergoing random vibration

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
				acoustics.			testing to the following specifications: 1. Test to protoflight levels specified in Table 4.6-1 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 IM approval.
OPT51	Transmitter Optics	An acoustic loads analysis of the Transmitter Optics shall be perform showing positive margins of safety for ultimate and yield failures per CERD20.	BDA, PBC, Fold Mirror, BE, DOE	Structural analysis of ATLAS flight Transmitter Optics may wring out design problems before flight hardware testing.	5	A	Object Identifier:CERD20 Object Text: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
OPT52	Transmitter Optics	All transmitter optics shall meet CERD32	BDA, PBC, Fold Mirror, BE, DOE	Ensures the component will withstand the acoustic environment of the launch phase.	5	T	Object Identifier:CERD32 Object Text: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.
OPT53	Transmitter Optics	All Transmitter Optics shall perform a shock loads analysis showing positive margins of safety for ultimate and yield failures per CERD22.	BDA, PBC, Fold Mirror, BE, DOE	Evaluating shock sensitivity of ATLAS flight Transmitter Optics may wring out design problems before flight hardware testing.	5	A	Object Identifier:CERD22 Object Text: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

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							2. Glass – Table 4.4-2 3. Glass bonds - Table 4.4-3
OPT54	Transmitter Optics	Any Transmitter Optics, if shown by shock analysis to be susceptible to the shock environment shall undergo shock testing per CERD23.	BDA, PBC, Fold Mirror, BE, DOE	Verify that flight hardware will survive expected shock events.	5	T	Object Identifier:CERD23 Object Text: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. 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)
OPT56	Transmitter Optics	The Transmitter Optics, carrying the maximum allowable payload and IMSC masses, shall be designed to operate at a pressure per CERD25.	BDA, PBC, Fold Mirror, BE, DOE	The instrument will operate at standard room temperature and pressure.	5	T	Object Identifier:CERD25 Object Text: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).
OPT57	Transmitter Optics	The Transmitter Optics, carrying the maximum allowable payload and IMSC masses, shall survive exposure to a maximum depressurization rate per CERD26.	BDA, PBC, Fold Mirror, BE, DOE	The instrument will operate after being exposed to de-pressurization during launch and ascent	5	A	Object Identifier:CERD26 Object Text: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.
OPT58	Transmitter Optics	Venting analyses of The Transmitter Optics, susceptible to pressure loading shall show positive margins of safety for ultimate and yield failures per CERD27.	BDA, PBC, Fold Mirror, BE, DOE	This analysis verifies that ATLAS Transmitter Optics (such as thermal blankets and contamination enclosures) susceptible to pressure loadings will survive exposure to the launch pressure profile.	5	A	Object Identifier:CERD27 Object Text: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 CERD21 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
OPT59	Transmitter Optics	All Transmitter optics shall meet CERD28.	BDA, PBC, Fold Mirror, BE, DOE	This analysis verifies structures will survive on orbit stresses due to temperature loading and coefficient of thermal expansion mismatches.	5	A	Object Identifier:CERD28 Object Text:Each ATLAS component, including 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 maximum on-orbit temperature gradients predicted by the thermal analysis specified in CERD25, and the appropriate factor of safety specified below: 1. Metallic, Beryllium, Composite – Table 4.4-1 2. Glass - Table 4.4-2

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							3. Glass bonds - Table 4.4-3
OPT60	Transmitter Optics	The Transmitter Optics shall show in a thermal analysis that parts and materials maintain the minimum temperature margin required per CERD29.	BDA, PBC, Fold Mirror, BE, DOE	The thermal analyses will show that parts and materials do not exceed temperature limits during the operational and test environment	5	A	Object Identifier:CERD29 Object Text: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)
OPT61	Transmitter Optics	ATLAS Transmitter Optics requiring life-cycle thermal testing shall undergo additional thermal cycling concurrent with performance testing at ambient pressure on qualification units per CERD33.	BDA, PBC, Fold Mirror, BE, DOE	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.	5	T	Object Identifier:CERD33 Object Text:Delete per deletion of IRD255 in CCR106
OPT62	Transmitter Optics	The Transmitter Optics shall undergo thermal bake-out tests per CERD34.	BDA, PBC, Fold Mirror, BE, DOE	Thermal bake-out tests reduce out gassing of contaminants to acceptable levels.	5	T	Object Identifier:CERD34 Object Text:All ATLAS components, including the instrument structure, shall undergo thermal bake-out tests per the ATLAS Contamination Control Plan (ICESat-2-ATSYS-PLAN-0297).
OPT63	Transmitter Optics	ATLAS Transmitter Optics shall meet all performance requirements during and after exposure to relative humidity levels per CERD35. These tests shall be done on witness samples to prove compliance after coating.	BDA, PBC, Fold Mirror, BE, DOE	Humidity levels are also important to reduce or eliminate the possibility of an ESD event which could damage flight hardware	5	A	Object Identifier:CERD35 Object Text: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.
OPT66	Transmitter Optics	The ATLAS instrument Transmitter Optics shall not exceed the allocated misalignment values as defined per TAR11.	PBC	The Beam Steering Mechanism (BSM) can correct for misalignments over a range of at least 1000 micro-radians, however, a larger range will increase complexity of the LRS laser side optical design to accommodate large off-axis misalignments.	5	A	Object Identifier:TAR11 Object Text:The ATLAS instrument components shall not exceed the allocated misalignment values as defined in table 7-3, during nominal science mode. **Table 7-3 Allocation of Correctable Misalignment**
OPT68	Transmitter Optics	Post-test reviews of ATLAS component testing shall be held wherein test data are reviewed to determine conformance with test requirements per CERD53	BDA, PBC, Fold Mirror, BE, DOE	Post test reviews verify requirements were met.	5	T	Object Identifier:CERD53 Object Text:Post-test reviews of ATLAS component testing shall be held wherein test data are reviewed to determine conformance with test

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							requirements.
OPT75	DOE Requirements	Design Wavelength:The ATLAS Transmitter Diffractive Optical Element shall diffract in first and third order at 532 nm	DOE	ATLAS operating wavelength	5	T	Object Identifier:TRANS30 Object Text:The ATLAS transmitter shall comply with IRD199.
OPT76	DOE Requirements	Spot Pattern:The ATLAS Transmitter Diffractive Optical Element shall diffract six spots in a 2 x 3 rectanguluar pattern in first and third order at 532 nm	DOE	The ATLAS Instrument is required to illuminate 6 spots on the ground	5	T	Object Identifier:TRANS18 Object Text:The ATLAS transmitter shall transmit 6 laser beams. Object Identifier:TRANS19 Object Text:The ATLAS transmitter shall emit pulses in all 6 beams simultaneously. Object Identifier:TRANS21 Object Text:The ATLAS transmitter shall comply with IRD13.
OPT77	DOE Requirements	The ATLAS Transmitter Diffractive Optical Element diffractive first order spots shall have an angular resolution of 3.05 mrad by 2.5 mrad and third order angular resolution of 9.915 mrad by 2.5 mrad for a full diffraction pattern of angular size 13.22 mrad by 5 mrad for first and third order	DOE	The ATLAS Instrument is required to illuminate a rectangular pattern on the ground spaced 3.3 km at 496 km range	5	T	Object Identifier:TRANS21 Object Text:The ATLAS transmitter shall comply with IRD13.
OPT78	DOE Requirements	The ATLAS Transmitter Diffractive Optical Element shall transmit three weak beams 25 % ± 5 % of the three strong beams as defined in OPT76.	DOE	Meet link budget and accommodate uncertainty in path loss	5	T	Object Identifier:TRANS45 Object Text:The ATLAS transmitter shall transmit in each weak beam, per shot, 25% ± 5% of the average energy of the strong beams.
OPT79	Beam Expander	Magnification:The ATLAS Transmitter Beam Expander shall have a Magnification 4.4	BE	Derived from Spot size on ground. Assumes laser output size and beam divergence; magnification needed to achieve 10-meter diameter spots on ground.	5	A, T	Object Identifier:TRANS32 Object Text:The ATLAS transmitter shall have the far-field divergence that complies with IRD13.
OPT80	Beam Expander	Input Clear Aperture:The ATLAS Transmitter Beam Expander shall have an Input Clear Aperture at least 10% larger than the laser beam size at the entrance to the Beam Expander	BE	Beam expander must transmit full unvignetted beam for the largest laser beam size possible, 15 mm beam diameter input	5	I	Object Identifier:TRANS32 Object Text:The ATLAS transmitter shall have the far-field divergence that complies with IRD13.
OPT81	Beam Expander	Output Clear Aperture:The ATLAS Transmitter Beam Expander shall have an Output Clear Aperture at least 10% larger than the laser beam size at the exit from the Beam Expander	BE	Beam expander must transmit full unvignetted beam for the largest laser beam size possible, 66 mm beam diameter output	5	I	Object Identifier:TRANS32 Object Text:The ATLAS transmitter shall have the far-field divergence that complies with IRD13.
OPT82	Beam Expander	Wavefront Error: The ATLAS Transmitter Beam Expander shall have a transmitted wavefront error of < 0.071 RMS at 633 nm	BE	Minimizes diffraction effects to preserve spot size on ground	5	A, T	Object Identifier:TRANS32 Object Text:The ATLAS transmitter shall have the far-field divergence that complies with IRD13.
OPT84	Beam Expander	Laser Fluence: The ATLAS Transmitter Beam Expander shall survive, without damage a Laser Fluence >10 MW/cm^2	BE	Coating survival has x 5 Margin; Derived from laser energy and pulse length, adjustable from 45 +/- 5 microjoules to 150 +/- 10 microjoules per shot in each strong beam	5	A	Object Identifier:TRANS44 Object Text:The ATLAS transmitter shall transmit energy adjustable from 45 ± 5 microjoules to 155 ± 10 microjoules**,** per shot, in each strong beam.
OPT85	Beam Expander	Mass Allocation: The ATLAS Transmitter Beam Expander shall not exceed the mass allocation of	BE	Derived from total instrument mass allocation budget. Traces to ICESat-2-SYS-REQ-0329	5	A, I	Object Identifier:TAR1 Object Text:The ATLAS components shall not exceed the allocated

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
		TAR 1		(IRD7), reference ICESat-2-ATSYS-LIST-0293			masses in Table 2-1. **Table 2-1 Component Mass Allocations**
OPT86	Beam Throughput	The ATLAS Transmitter Beam Expander shall meet or exceed the optical throughput per TAR 8	BE	Derived from available laser output energy and power specified in the ATLAS Laser Specification, ICESat-2-ATSYS-SPEC-099	5	A, T	Object Identifier:TAR8 Object Text:The components in the ATLAS transmitter system shall have optical throughput values greater than or equal to the allocations in Table 6-2. **Table 6-2 ATLAS Transmitter Estimated Optical Throughput**
OPT87	Beam Misalignment	The ATLAS Transmitter Beam Expander shall not exceed the Misalignment allocation of TAR 11	BE	The Beam Steering Mechanism can correct for misalignments over a range of at least 1000 microradians, however a larger range will increase complexity of the LRS laser side optical design to accommodate large off-axis misalignments.	5	A	Object Identifier:TAR11 Object Text:The ATLAS instrument components shall not exceed the allocated misalignment values as defined in table 7-3, during nominal science mode. **Table 7-3 Allocation of Correctable Misalignment**
OPT88	Beam Expander de-collimation	The ATLAS Transmitter Beam Expander shall not exceed the allocated misalignment values per TAR10.	BE	The Beam Steering Mechanism cannot correct for de-collimation. Allocation is needed to achieve beam size specified in ICESat-2-ATREQ-REQ-0487 TRANS32	5	A	Object Identifier:TAR10 Object Text:The ATLAS instrument components shall not exceed the allocated misalignment values as defined in table 7-2 during nominal operations. **Table 7-2 ATLAS Alignment Monitoring and Control System (AMCS): Unmeasured, Noise, Residuals and Uncorrectable Alignment Allocations**
OPT89	Beam Expander	The Transmitter Optics shall be designed to accept the laser wavelength range as defined in TRANS30.	BE, PBC	This requirement is levied on the lasers in the ATLAS transmitter subsystem, but other subsystems must accept this requirement to meet their performance requirements, 532 +/- 1 nm, ICESat-2-SYS-REQ-0329, IRD199	5	A, T	Object Identifier:TRANS30 Object Text:The ATLAS transmitter shall comply with IRD199.
OPT90	Fold Mirror Alignment	Alignment Stability: The ATLAS Transmitter Fold Mirror shall not exceed the allocated Alignment	Fold Mirror	Bore sight allocation	5	T, A	Object Identifier:TAR11 Object Text:The ATLAS instrument components shall not exceed the

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
	Stability	Stability in TAR11.					allocated misalignment values as defined in table 7-3, during nominal science mode. **Table 7-3 Allocation of Correctable Misalignment**
OPT91	Fold Mirror	Surface Wavefront Error:The ATLAS Transmitter Fold Mirror shall have < surface figure error of 0.03 waves RMS at 633 nm	Fold Mirror	This applies to the laser used in testing and manufacture of the optical components	5	A	Object Identifier:TAR10 Object Text:The ATLAS instrument components shall not exceed the allocated misalignment values as defined in table 7-2 during nominal operations. **Table 7-2 ATLAS Alignment Monitoring and Control System (AMCS): Unmeasured, Noise, Residuals and Uncorrectable Alignment Allocations**
OPT92	Fold Mirror	The ATLAS Transmitter Fold Mirror shall survive, without damage a Laser Fluence >10 MW/cm^2.	Fold Mirror	Coating survival has x 5 Margin; Derived from laser energy and pulse length, adjustable from 250 microjoules to 900 microjoules per shot.	5	T	Object Identifier:TRANS44 Object Text:The ATLAS transmitter shall transmit energy adjustable from 45 ± 5 microjoules to 155 ± 10 microjoules**,** per shot, in each strong beam.
OPT93	Fold Mirror Reflectance	The ATLAS Transmitter Fold Mirror shall meet or exceed an optical Reflectance according to TAR8	Fold Mirror	Optical Throughput Budget Allocation	5	T	Object Identifier:TAR8 Object Text:The components in the ATLAS transmitter system shall have optical throughput values greater than or equal to the allocations in Table 6-2. **Table 6-2 ATLAS Transmitter Estimated Optical Throughput**
OPT94	Fold Mirror λ	The ATLAS Fold Mirror shall operate at the wavelength of 532 nanometers plus or minus 1 nanometer.	Fold Mirror	The ATLAS instrument needs the fold mirror to operate and meet mission requirements.	5	T	Object Identifier:TRANS30 Object Text:The ATLAS transmitter shall comply with IRD199.
OPT95	Fold Mirror Clear Aperture	The ATLAS Transmitter Fold Mirror shall have a Clear Aperture at least 10% larger than the base beam size at 45 degrees AOI on the mirror's surface.	Fold Mirror	Derived from laser specification ICESat-2-ATSYS-SPEC-0099, paragraph 3.9 assumes laser output size and beam divergence needed to achieve 10 meter diameter spots on ground.	5	A	Object Identifier:TRANS32 Object Text:The ATLAS transmitter shall have the far-field divergence that complies with IRD13.
OPT101	Polarizing Beam Combiner	The ATLAS transmitter shall comply with TRANS34.	PBC	The ATLAS instrument needs the transmitter to operate and meet mission lifetime requirements.	5	T	Object Identifier:TRANS34 Object Text:The ATLAS transmitter shall comply with IRD1.

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
OPT103	Polarizing Beam Combiner	The ATLAS transmitter shall have the far-field wave front error of <0.04 w RMS for L1 and <0.03 w RMS for L2 at 6328Å	PBC	The ATLAS instrument is required to illuminate on ground 10 meter diameter spots at 496 kilometers.	5	T	Object Identifier:TRANS32 Object Text:The ATLAS transmitter shall have the far-field divergence that complies with IRD13.
OPT104	Polarizing Beam Combiner Output Polarization	Output polarization:The ATLAS Transmitter Polarizing Beam Combiner Optical Output shall be circular polarized	PBC	Polarization sensitivity of other components can affect the throughput for ATLAS	5	T	Object Identifier:TAR8 Object Text:The components in the ATLAS transmitter system shall have optical throughput values greater than or equal to the allocations in Table 6-2. **Table 6-2 ATLAS Transmitter Estimated Optical Throughput**
OPT105	Polarizing Beam Combiner Waveplate Adjustability	Wavelplate adjustability: The ATLAS Transmitter Polarizing Beam Combiner Waveplate rotation shall be adjustable	PBC	Polarization sensitivity of other components can affect the throughput for ATLAS	4	I	Object Identifier:TAR8 Object Text:The components in the ATLAS transmitter system shall have optical throughput values greater than or equal to the allocations in Table 6-2. **Table 6-2 ATLAS Transmitter Estimated Optical Throughput**
OPT106	Polarizing Beam Combiner Back Reflectance	The ATLAS Transmitter Optics shall reflect less than TBD% of the laser output directed back toward the laser within a 0.5 mrad cone.	BDA,PBC Fold Mirror, BE, DOE	Optical Ghost can be optically traced to laser and cause damage	5	T	
OPT112	BDA Requirements Stray Light	The Beam Dump Assembly shall not re- emit any of the original laser light to a level greater than 1 x 10 E-04 Watts (TBR)	BDA	RE-emitted stray light degrades signal to noise performance			Object Identifier:OPT106 Object Text:The ATLAS Transmitter Optics shall reflect less than TBD% of the laser output directed back toward the laser within a 0.5 mrad cone.
OPT114	Thermal Balance Test Temporal gradient requirements	The transmitter optics shall meet TICD47	BDA, PBC, Fold Mirror, BE, DOE	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	5	T	Object Identifier:TICD47 Object Text:All temporal gradient requirements will be assessed over a minimum time range of 6 minutes (TBR28).
OPT115	Thermal Balance Test Spatial Gradient Requirements	The transmitter optics shall meet TICD49	BDA, PBC, Fold Mirror, BE, DOE	Spatial gradients can impact the thermal condition and pointing of some components	5	T	Object Identifier:TICD49 Object Text:All instrument TCS thermal interfaces will have spatial gradients less than the values given in Table 3. **Table 3: ATLAS Thermal Interface Spatial Gradient Requirements**
OPT116	Thermal Balance Test Thermal Radiation Environment	The transmitter optics shall meet TICD56	BDA, PBC, Fold Mirror, BE, DOE	Spatial gradients can impact the thermal condition and pointing of some components	5	T	Object Identifier:TICD56 Object Text: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.
OPT117	Thermal Balance Test Thermal Radiation	The transmitter optics shall meet TICD57	BDA, PBC, Fold Mirror, BE, DOE	Thermal radiation provides a secondary impact for component temperatures. The average thermal radiation environment is expected to	5	T	Object Identifier:TICD57 Object Text:The TCS will provide an average radiation environment for all components mounted to the -Z side of the optical bench between -30C

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
	Environment			be independent of direction			and +40C (TBR34) when the instrument is not operational except for surface that view space.
OPT118	Thermal Balance Test Survival	Thr transmitter optics shall meet TICD61	BDA, PBC, Fold Mirror, BE, DOE	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.	5	T	Object Identifier:TICD61 Object Text:When powered off, each component will be capable of surviving indefinitely when its temperatures are within survival limits without damage or permanent performance degradation.
OPT119	Thermal Balance Test Survival	The transmitter optics shall meet TICD62	BDA, PBC, Fold Mirror, BE, DOE	The instrument TCS will not be designed to raise all components to their operational temperature range before component turn-on.	5	T	Object Identifier:TICD62 Object Text: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.
OPT120	Heater Circuit Design	The transmitter optics shall meet TICD78	BDA, PBC, Fold Mirror, BE, DOE	Required margin defined in Gold Rules.	5	T	Object Identifier:TICD78 Object Text:All heaters will be sized for a maximum 70% duty cycle at the minimum bus voltage.
OPT121	Heater Circuit Design	The transmitter optics shall meet TICD79	BDA, PBC, Fold Mirror, BE, DOE	Series redundant thermostats protect against a full-on heater if a single thermostat fails closed	5	T	Object Identifier:TICD79 Object Text:All thermostats will be redundant in series.
OPT127	Transmitter Optics	Transmitter optics shall meet CERD30	BDA, PBC, Fold Mirror, BE, DOE	Pre-test reviews verify readiness for flight testing.	5	A	Object Identifier:CERD30 Object Text: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 (HYPERLINK "javascript:%20viewDoc('492',%20'0',%20'1')"IC Sat-2-ATSYS-REQ-0479) through a therm l balance test: 1. Maximum hot operating temperatures 2. Minimum cold operating temperatures 3. Minimum survival temperatures 1. Operational heater duty cycle less than 70% in worst cold case, including minimum voltage as established by the project. 2. Survival heater duty cycle less than 70% in worst cold case, including minimum voltage as established by the project 3. Interface heat flows are within requirements. 4. Internal power dissipations and line losses, 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

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							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.
OPT128	Transmitter Optics	Transmitter optics shall meet CERD31	BDA, PBC, Fold Mirror, BE, DOE	Pre-test reviews verify readiness for flight testing.	5	A	Object Identifier:CERD31 Object Text: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 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.

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							3. Test Temperature Soak Criteria - Temperature soaks will begin when the "control" temperature is within ± 2°C of the proposed test temperature. 4. Test Margins - 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. 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 X 10^{-3} Pa. (1 X 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

CHECK https://icesat-2mis.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.
Released: October 3, 2011

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							Performance Tests. Figure 5-1 - Qualification/Protoflight and Acceptance Levels Thermal Vacuum Temperatures Object Identifier:CERD32 Object Text: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.
OPT129	Transmitter Optics	Transmitter optics shall meet CERD32	BDA, PBC, Fold Mirror, BE, DOE	Pre-test reviews verify readiness for flight testing.	5	A	Object Identifier:CERD32 Object Text: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.
OPT130	Transmitter Optics	Transmitter optics shall meet CERD33	BDA, PBC, Fold Mirror, BE, DOE	Pre-test reviews verify readiness for flight testing.	5	A	Object Identifier:CERD33 Object Text:Delete per deletion of IRD255 in CCR106
OPT131	Transmitter Optics	Transmitter optics shall meet CERD34	BDA, PBC, Fold Mirror, BE, DOE	Pre-test reviews verify readiness for flight testing.	5	A	Object Identifier:CERD34 Object Text:All ATLAS components, including the instrument structure, shall undergo thermal bake-out tests per the ATLAS Contamination Control Plan (ICESat-2-ATSYS-PLAN-0297).
OPT132	Transmitter Optics	Transmitter optics shall meet CERD35	BDA, PBC, Fold Mirror, BE, DOE	Pre-test reviews verify readiness for flight testing.	5	A	Object Identifier:CERD35 Object Text: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.
OPT133	DOE Requirements Throughput	The Diffractive Optical Element shall have optical throughput values greater than or equal to the allocations in TAR8.	DOE	The ATLAS Instrument is required to illuminate a rectangular pattern on the ground spaced 3.3 km at 496 km rangerectangular pattern on the ground spaced 3.3 km at 496 km range	5	T	Object Identifier:TAR8 Object Text:The components in the ATLAS transmitter system shall have optical throughput values greater than or equal to the allocations in Table 6-2.

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							Table 6-2 ATLAS Transmitter Estimated Optical Throughput
OPT134	DOE Requirements Mass	The DOE and its mount shall not exceed the mass allocation in TAR1	DOE	Complete instrument mass allocation must not exceed the predetermine maximum mass of the payload.	5	I	Object Identifier:TAR1 Object Text:The ATLAS components shall not exceed the allocated masses in Table 2-1. **Table 2-1 Component Mass Allocations**
OPT135	Beam Expander Thermal Interface	The thermal interface for the beam expander will be the mounting interface to the structure as shown in the Beam Expander MICD (drawing 2153305).	Beam Expander	Optical component temperatures must be maintained to ensure performance.	5	I	Object Identifier:TICD31 Object Text:The thermal interface for the beam expander will be the mounting interface to the structure as shown in the Beam Expander MICD (drawing 2153305).
OPT136	Fold Mirror Mass	The Fold Mirror optics, and its mounts shall not exceed the mass allocation in TAR1	Fold Mirror	Complete instrument mass allocation must not exceed the predetermine maximum mass of the payload.	5	I	Object Identifier:TAR1 Object Text:The ATLAS components shall not exceed the allocated masses in Table 2-1. **Table 2-1 Component Mass Allocations**
OPT137	Fold Mirror thermal Interface	The thermal interface for the fold mirrors will be the mounting interface to the structure as shown in the Fold Mirror MICD (drawing 2153302).	Fold Mirror	Optical component temperatures must be maintained to ensure performance.	5	I	Object Identifier:TICD28 Object Text:The thermal interface for the fold mirrors will be the mounting interface to the structure as shown in the Fold Mirror MICD (drawing 2153302).
OPT138	Polarizing Beam Combiner Mass	The Polarizing Beam Combiner optics, and its mounts shall not exceed the mass allocation in TAR1	PBC	Complete instrument mass allocation must not exceed the predetermine maximum mass of the payload.	5	I	Object Identifier:TAR1 Object Text:The ATLAS components shall not exceed the allocated masses in Table 2-1. **Table 2-1 Component Mass Allocations**
OPT139	Polarizing Beam Combiner Thermal Interface	The transmitter optics shall meet TICD29	PBC	Optical component temperatures must be maintained to ensure performance.	5	T	Object Identifier:TICD29 Object Text:The thermal interface for the polarizing beam combiner (PBC) will be the mounting interface to the structure as shown in the PBC MICD (drawing 2153303).
OPT140	BDA Requirements Mass	The Beam Dump Assembly shall not exceed the mass allocation in TAR1	BDA	Complete instrument mass allocation must not exceed the predetermine maximum mass of the payload.	5	I	Object Identifier:TAR1 Object Text:The ATLAS components shall not exceed the allocated masses in Table 2-1. **Table 2-1 Component Mass Allocations**
OPT141		The DOE assembly shall not exceed the mislalignment allocations in TAR10	DOE	DOE must meet suballocated pointing requirement for ATLAS to stay aligned	5	T	Object Identifier:TAR10 Object Text:The ATLAS instrument components shall not exceed the allocated misalignment values as defined in table 7-2 during nominal operations.

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							Table 7-2 ATLAS Alignment Monitoring and Control System (AMCS): Unmeasured, Noise, Residuals and Uncorrectable Alignment Allocations
OPT142	DOE	The DOE assembly shall not exceed the mislalignment allocations in TAR10	DOE	DOE must meet suballocated pointing requirement for ATLAS to stay aligned			Object Identifier:TAR10 Object Text:The ATLAS instrument components shall not exceed the allocated misalignment values as defined in table 7-2 during nominal operations. **Table 7-2 ATLAS Alignment Monitoring and Control System (AMCS): Unmeasured, Noise, Residuals and Uncorrectable Alignment Allocations**
OPT143	Waveplate	Transmit optics shall meet RAD19	Optics				Object Identifier:RAD19 Object Text:No effect due to displacement damage dose shall cause permanent damage to, or performance degradation of the flight system.
OPT144	Optics	Transmit optics shall meet RAD20	Optics				Object Identifier:RAD20 Object Text:Displacement damage dose degradation of individual components, to include electrical, electronic, and electromechanical parts, light emitting diodes, bulk optical materials, and fiber optics, shall be included in appropriate worst case analyses.
OPT145	Optics	Transmit optics shall meet RAD21	Optics				Object Identifier:RAD21 Object Text:Displacement damage dose requirements for electrical, electronic, and electromechanical parts, light emitting diodes, bulk optical materials, and fiber optics are material dependent and shall be evaluated for an equivalent 10 MeV proton fluence.
OPT146	Optics	Transmit optics shall meet RAD22	Optics				Object Identifier:RAD22 Object Text:All silicon electrical, electronic, and electromechanical parts shall be able to tolerate either a minimum 10 MeV equivalent proton fluence of 7.0×10^{9} protons/cm^{2}, a radiation design margin of 2, or the equivalent fluence obtained from the table of silicon values in ICESat-2-SYS-REQ-0277, Table A5a.
OPT147	Optics	Transmit optics shall meet RAD23	Optics				Object Identifier:RAD23 Object Text:All gallium arsenide EEE parts shall be able to tolerate either a minimum 10 MeV equivalent proton fluence of 7.6×10^{9} cm^{-2} or the

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							equivalent fluence obtained from the table of gallium arsenide values in section 3.3.1, whichever fluence is greater.
OPT148	Optics	Transmit optics shall meet RAD24	Optics				Object Identifier:RAD24 Object Text:Displacement damage test and analysis using energies other than those listed in RAD22 shall be scaled according to the non-ionizing energy loss practices described in section 3.3.1 of “Summers, G.P., et. al., IEEE Trans. Nuc. Sci., vol. 40, no. 6, pp. 1372-1379, 1993”, whenever requirement RAD22 cannot be met.
OPT149	Optics	Transmit optics shall meet RAD25	Optics				Object Identifier:RAD25 Object Text:For displacement damage dose evaluations, the use of equivalent proton fluences below the maximum equivalent proton fluence in the box shall require approval by-the Parts Control Board.
OPT150	Optics	Transmit optics shall meet RAD26	Optics				Object Identifier:RAD26 Object Text:The use of displacement damage dose spot shielding shall be approved by the Parts Control Board.
OPT151	Optics	Transmit optics shall meet RAD29	Optics				Object Identifier:RAD29 Object Text:Flight lot displacement damage dose testing shall be mandatory if test data (same part number, same manufacturer, and same process) do not exist for parts susceptible to displacement damage dose.
OPT152	Optics	Transmit optics shall meet RAD30	Optics				Object Identifier:RAD30 Object Text:Flight lot testing shall be mandatory for commercial (i.e., not audited by Defense Logistics Agency - Land & Maritime) parts, even if generic data exist..
OPT153	Optics	Transmit optics shall meet RAD31	Optics				Object Identifier:RAD31 Object Text:Generic displacement damage dose data for a part or material with the same part number, manufacturer and process shall be submitted to the Parts Control Board for evaluation.
OPT154	Optics	Transmit optics shall meet RAD65	Optics				Object Identifier:RAD65 Object Text:Acceptable displacement damage dose data from 3 or more lots shall have a radiation design margin of 4 assigned to the application.
OPT155	Optics	Transmit optics shall meet RAD32	Optics				Object Identifier:RAD32 Object Text:Displacement damage dose testing on the flight procurement lot or a Defense Logistics Agency - Land & Maritime audited radiation guarantee shall be required in order to use the minimum radiation design margin of 2 specified in RAD22.
OPT156	Optics, Thermal	All ATLAS Transmit optics shall comply with TICD141, TICD6, TICD7 TICD8, TICD9, and TICD10	Transmit, Optics				Object Identifier:TICD6 Object Text:Qualification Limits will be defined as the minimum and maximum temperatures over which the responsible hardware manager has

ID	Section Title	Initial	Applicability	Rationale	VL	VM	Parents
							proven the components meet all performance requirements through qualification testing. Object Identifier:TICD7 Object Text: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. Object Identifier:TICD8 Object Text:Flight Operational Limits will be defined as the minimum and maximum temperature range at the thermal interface that the component will see during flight. Object Identifier:TICD9 Object Text: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 Object Identifier:TICD10 Object Text:Flight Operational Limits will be at least 5C inside the acceptance limits except for actively-controlled components. Object Identifier:TICD141 Object Text:Survival Limits will be defined as the minimum and maximum non-operating temperatures that may be experienced without inflicting damage or permanent performance degradation.