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

ATLAS Contamination Control Plan

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Revision -

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**National Aeronautics and
Space Administration**

**Goddard Space Flight Center
Greenbelt, Maryland**

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

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CHANGE HISTORY LOG

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LIST OF TBDs/TBRs

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TBD-1	2.1	ATLAS Laser Safety Plan document		

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1.0 General Information

1.1 Objective

This document specifies the contamination controls necessary to deliver the ATLAS instrument to orbit at a cleanliness level that will preclude contamination induced damage or degradation.

1.2 Purpose

This is the instrument contamination control plan.

1.3 Scope

This document applies from design through launch and on-orbit operations of the ATLAS instrument. Where a conflict exists between this document and another requirement, the more stringent requirement shall be followed.

2.0 Documentation

2.1 Applicable Documents

None

2.2 Reference Documents

ISO 14644-1 Cleanrooms and associated controlled environments – Part 1:
Classification of Air Cleanliness

IEST-CC-1246D Product Cleanliness Levels and Contamination Control Program

3.0 Cleanliness Requirements

3.1 Surface Cleanliness

Surface cleanliness requirements are established as particulate and molecular non-volatile residue (NVR) levels. These levels are derived from optical and thermal performance requirements and from consideration of cross contamination during the life of the instrument. Initial cleanliness levels shall be verified prior to integration with the instrument bench or use within the cleanroom; final levels shall be verified prior to closeout or last access to the hardware.

Table 1 Surface Cleanliness Requirements

Hardware Type	IEST-CC-1246D Level, Initial (1)	IEST-CC-1246D Level, Final
Laser Assembly Window (2)	150 A/3	VCHS
Other Optical Surfaces	150 A/3	VCHS
Laser Assembly Enclosure	300 A/2	VCHS
Internal Mechanical and Structural Elements	300 A/2	350 A
Internal Harnesses	VCHS A	VCS A
External Surfaces (3)	300 A	400 B
Optical Fixtures and Tools	150 A/2	N/A
Purge Hardware, Interior (4)	25 A/5	N/A

Ground Support Equipment	(5)	N/A
Electrical Ground Support Equipment	VCHS B	N/A
Work Bench / Optical Table Surfaces	VCHS A	N/A

- (1) In addition to the NVR quantity limits, the residue for flight hardware elements shall be analyzed to verify that mid-IR absorption is less than 2%, and absorption is negligible at 532 nm (laser primary wavelength).
- (2) Laser window cleanliness will not be verified after delivery by the vendor. Packaging of the laser for delivery shall be consistent with maintaining this cleanliness level.
- (3) Painted surfaces will not have NVR levels verified.
- (4) Purge line interior surfaces shall be verified as volumetric cleanliness of a solvent flush sample.
- (5) Tools must match the cleanliness of the flight hardware they interface with, or be cleaned to level 400 B for entry into the clean room.

3.2 Outgassing

The integrated instrument shall be vacuum baked at 10^{-6} Torr to remove residual solvents, monomers, and NVR. The bakeout shall be performed at the warmest permitted temperature, and shall be maintained until the outgassing rate is less than TBD g/s as measured on a QCM with the crystal temperature set to 10°C below the coldest predicted temperature of any optical or thermal control surface.

Parts and subassemblies shall be baked out in accordance with the following table.

Table 2 Component Bakeout Requirements

Hardware Element	Bakeout Method	Comments
Wire	Pressure $< 10^{-3}$ Torr Temperature $100\pm 2^{\circ}\text{C}$ Time 44 +/- 4 hours	Unspool and coil in chamber
Connector inserts (1)	Pressure $< 10^{-3}$ Torr Temperature $150\pm 2^{\circ}\text{C}$ Time 44 +/- 4 hours	
Polymeric parts	Vacuum $< 10^{-5}$ Torr Temperature $80\pm 2^{\circ}\text{C}$ Time 44 +/- 4 hours	After solvent cleaning
Composite panels	Vacuum $< 10^{-5}$ Torr Temperature $60\pm 2^{\circ}\text{C}$ Time 44 +/- 4 hours	After inserts have been bonded
Painted parts	Vacuum $< 10^{-5}$ Torr	

	Temperature 80±2 °C Time 44 +/- 4 hours	
Internal Harnesses	Vacuum < 10 ⁻⁵ Torr Temperature 80±2 °C	QCM Temperature TBD °C Outgassing < TBD g/s
Other Subassemblies	Vacuum < 10 ⁻⁵ Torr Temperature and QCM criteria as directed by Contamination Control Engineer	As required to minimize time of instrument level bakeout.

3.3 Purge Gas Requirements

Purge gas shall be Grade B per Mil-P-2401.

3.4 Facility Requirements

Required air cleanliness is a function of surface cleanliness requirements and exposure duration. Air cleanliness levels shall be verified by the cleanroom facility engineer to meet the requirements in the following table on a weekly basis. Air quality shall be continuously monitored by a particle counter. The particle counter alarm threshold shall be set to 80% of the cleanliness limit.

Table 3 Facility Air Cleanliness Requirements, ISO-14644-1

Hardware Type (1)	Short Exposure < 15 minutes	Medium Exposure	Long Exposure > 1 hour
Laser Assembly Window	8	7	6
Other Optical Surfaces	8	7	6
Laser Assembly Enclosure	8	7	7
Internal Mechanical and Structural Elements	8	7	7
Internal Harnesses	8	7	6
External Surfaces	8	7	7

(1) When multiple hardware elements are exposed, the most stringent requirements shall be followed.

3.5 Materials Selection Requirements

3.5.1 Outgassing

Non-metallic materials used for flight hardware must be approved by the Contamination Engineer in addition to the Materials Engineer. The low outgassing screening criteria of 1% TML and 0.1% CVCM should be used when selecting design options, but are not sufficient to verify material acceptability. The hardware engineer shall provide the following information when seeking approval for use of a new material:

- Location on hardware
- Rough amount by weight
- Vendor and part number

If sufficient data is not available, the contamination engineer shall request a sample for testing. For materials to be used in proximity to the lasers and transmit optics, outgassing rates shall be established at source and receiver temperatures using the Molecular Kinetics (MOLEKIT) facility at GSFC, or an equivalent facility approved by GSFC.

3.5.2 General Guidelines

Certain design principles apply to the selection of materials for contamination sensitive spacecraft.

- Aluminum surfaces shall be treated to prevent particle generation; anodize is the preferred coating.
- Open cell foam shall be avoided. If a foam must be used, avoid silicone foams.
- Avoid silicone based organics in all applications.
- Avoid nonmetallics that crack, chip, flake, peel, etc.
- Materials which will be added to an assembly after vacuum certification will have more stringent selection requirements.

3.5.3 Prohibited Materials

The following materials are prohibited from use on ATLAS hardware.

- Chorlastic CHR-F12 Silicone Foam
- Chesterton Teflon Spray Lubricant (the carrier gas is unacceptable)
- Cadmium, zinc, or electroplated tin

4.0 Cleanliness Verification

The cleanliness requirements of Section 3 will be verified at critical points in the flow and as activities warrant. If not specified in the following sections, the verification methods and times shall be at the discretion of the contamination control engineer.

Prior to purging the instrument, a sample of the gas collected from the point of connection to the instrument shall be certified.

Cleanliness verification of surfaces and facilities will be performed using the following methods:

Table 4: Cleanliness Verification Methods

Visual Inspection	Inspection may be augmented by the use of ultraviolet (UV) light, which causes some molecular compounds to fluoresce, or by the use of magnification. The pass criterion is usually the absence of visible particles under specified lighting and viewing distance conditions.
Solvent Rinse	Surfaces are rinsed with a solvent, which is collected and analyzed. The solvent may be filtered, and the particles counted. The remaining solvent is evaporated, and the residue is weighed and analyzed to determine the composition.
Tapelift	A sample of the surface contaminants is collected using tape, which is subsequently evaluated under a microscope to determine the particle counts.
Optical Witness Sample	This is an indirect monitor of the condition of neighboring surfaces. The optical sample transmission or reflectance degradation is measured periodically.
Particle Fallout Sample	This is an indirect monitor of the condition of neighboring surfaces. The particle count on the fallout sample is measured with a microscope.
NVR Deposition Monitors	Quartz Crystal oscillators (QCMs or SAWs) detect mass changes as a change in frequency. Both devices have temperature and humidity responses, requiring the data to be evaluated in the context of the facility environmental conditions.
Air Particle Counter	An air particle counter records the particle concentration at specified particle diameters smaller than 25 micrometers.
Photo Ionization Detector	A photo ionization detector monitors the hydrocarbon content of the air using spectrographic methods.

4.1 Optical Surfaces

Initial cleanliness levels will be verified by microscopic inspection during optics characterization.

Cleanliness levels shall be verified by visual inspection with 10x magnification prior to optical bench integration, after integration with the optical bench, and as required by exposure or anomalous events.

After optical bench integration, the cleanliness of optical surfaces will be primarily inferred from optical witness samples. Witness samples shall be integrated onto the optical bench for as long as possible; when such integration poses a risk to the optical bench, placement shall be as close to the laser as possible. Optical witness samples shall be measured monthly or at an interval which produces a measurable response.

4.2 Painted Surfaces

Cleanliness levels will typically be verified by visual inspection. If a contamination anomaly requires NVR sampling, solvents shall be chosen to minimize interaction with the coating.

4.3 Non-Optical Surfaces

Initial cleanliness levels of flight hardware shall be verified after precision cleaning by solvent rinse analysis. After integration to the optical bench, cleanliness levels shall be verified by visual inspection with UV light used as an inspection aid.

Flight hardware surface cleanliness shall be verified by visual inspection before and after work is performed on or near exposed items. Prior to optical bench closeout, cleanliness of the bench shall be verified by tapelift sampling.

Tool and GSE cleanliness shall be verified by solvent rinse after precision cleaning. Tools and optical fixtures shall be re-cleaned after each shift of use. GSE and work surface cleanliness shall be verified by tapelift and solvent rinse weekly.

4.4 Outgassing

Where an outgassing criterion of g/s has been specified, a chamber model shall be used to establish the relationship between the hardware outgassing rate and the QCM requirement. The CCE shall prepare bakeout plans for these hardware items in which the chamber cleanliness, special operating constraints, and the hardware bakeout and certification temperatures and QCM requirements are specified. The use of a cold finger or scavenger plate to enable post-test identification of the contaminant species is preferred but not required.

4.5 Environment

4.5.1 Air Class

Air class shall be monitored by particle counters capable of counting particles between 0.3 and 10 micrometers in diameter.

- a. Particle counter inlets shall be located as close to the laser hardware as possible.

- b. The optics bonding flow bench shall be continuously monitored by a particle counter while optics are exposed.
- c. The optical bench integration area shall be continuously monitored by one or more particle counters.
- d. Air particle count data shall be recorded every TBD minutes. –tie to cleanup time constant
- e. Particle counter audible alarms shall be set to 80% of the target facility air class.

4.5.2 NVR Deposition

Facilities in which optics will be exposed shall use a QCM or SAW to monitor NVR deposition. All ATLAS clean areas shall use an NVR fallout sample to monitor NVR deposition.

- a. One QCM or SAW device is required per room.
- b. QCM or SAW data shall be recorded every TBD minutes.
- c. One NVR fallout sample shall be placed in each room.
- d. NVR fallout samples shall be measured monthly.

4.5.3 Particle Fallout

ATLAS clean areas shall be monitored by particle and NVR fallout samples.

- a. One particle fallout sample shall be placed on each work table.
- b. Particle fallout samples shall be measured every 2 weeks or as required to produce a measureable result.

5.0 Design Constraints

Materials and processes to be used in the manufacture, integration, and test of the lasers shall be reviewed by the Contamination Engineer.

6.0 Manufacturing Controls

Most of the hardware manufacturing will take place in areas exceeding a Class 8 cleanliness specification per ISO-14644-1.

For parts and components manufactured outside GSFC, the CCE shall provide a cleanliness specification as part of the procurement documentation. This specification will detail restrictions on materials and processes, and call out the cleanliness level at which the part is expected to be received by GSFC.

6.1 Mechanical Parts

For parts and components manufactured at GSFC, the following handling requirements shall be followed during manufacturing:

- a. During contamination generating operations such as drilling, welding, etc., contaminants (metal chips, dust, and so forth) shall be vacuumed off the hardware as they are generated or as soon as safety permits.
- b. When appropriate (drilling, cutting), alcohol shall be used as a cooling agent / lubricant.
- c. Lubricant deposits (grease/oil) shall be cleaned off immediately by using a clean wipe dampened with an alcohol solvent.
- d. Prior to applying coatings or paints, surfaces shall be cleaned and visually inspected in accordance with the coating application procedures.
- e. All areas which become inaccessible during the fabrication and assembly process shall be thoroughly cleaned using a solvent and then inspected by a project representative prior to becoming inaccessible. Areas which cannot be cleaned shall be sealed (e.g., placing flight approved tape over a crevice) to prevent later contamination of nearby surfaces.
- f. After manufacture is complete, the part shall be wiped with a clean wipe dampened with an alcohol solvent and blown dry with filtered, oil-free air, and/or shall be vacuumed until free of debris. Parts small enough to fit shall be placed in a polyethylene, RCAS 4200, Lumalloy, or other approved bag for handling. Larger parts shall be wrapped with approved bagging material; if required, cut-outs may be made for lifting points.

6.2 Harnesses

Harnesses are difficult to assemble and maintain clean. Because of the potential for contamination transfer between harnesses and other surfaces of the instrument, the following requirements shall be followed during harness construction.

- a. Harnesses shall be assembled in a good housekeeping environment. The Contamination Engineer shall develop protocols for maintaining the cleanliness of the area.
- b. The assembly shall be performed on a table/instrument mockup which is maintained free of grease, oil, flux, or other contaminating residues.
- c. Personnel working on the harness shall wear nitrile or latex gloves.
- d. Individual wires shall be wiped with alcohol prior to layup.
- e. Connector inserts shall be vacuum baked prior to assembly if the cable will be used in a vacuum chamber.
- f. Prior to use, the harnesses shall be certified to meet their cleanliness requirements, including outgassing if they are flight or to be used in a vacuum chamber.
- g. The harnesses shall be draped with clean bagging material over night.

6.3 Motors and Gear Assemblies

Many of the motor and gear assemblies will be provided by vendors not possessing adequate verification facilities. Because these parts cannot be internally cleaned after assembly, the piece parts shall be shipped to GSFC for cleaning and bakeout, then returned to the vendor for final assembly. Final assembly shall occur on a clean bench. A vacuum compatible lubricant or a dry lubricant shall be used if needed.

6.4 Clean Room Manufacturing Operations

Some manufacturing operations will occur within a cleanroom, and may interface with higher level assemblies. When this occurs, the following requirements shall apply:

- a. All hardware must be cleaned to the level of the cleanest part.
- b. During cutting, shaping, or drilling operations, a HEPA filtered vacuum shall be employed to collect particles as they are generated.
- c. Potting and staking operations shall minimize the amount of epoxy used; any drips or spills shall be immediately cleaned and the CCE shall be notified.
- d. All tools, including pens and markers, shall be approved and cleaned to the level of the most sensitive hardware.

7.0 Assembly Controls

All tools and parts must be cleaned prior to assembly. Unless otherwise specified by the CCE, hardware shall be cleaned to the requirements of Section 2.1. In most cases, assembly of subsystems will occur in a better than class 7 clean area. Air quality requirements are specified in Section 2.4.

During assembly, hardware will be cleaned and inspected at regular intervals to prevent violation of the contamination requirements. The following constraints shall apply during assembly:

- a. The cleanliness of optical components shall be measured using witness mirrors.
- b. Optical components shall be cleaned by trained optical personnel only.
- c. All other hardware shall be cleaned and verified by contamination control personnel.
- d. Surfaces shall be solvent wiped or vacuumed as contamination is generated.
- e. Hardware and the work area shall be inspected for accumulated contamination at the beginning and end of each task.
- f. The facility shall be inspected for accumulated contamination at the end of each shift.

- g. All non-optical surfaces shall be cleaned after assembly is complete, regardless of the visual cleanliness.

8.0 Optics Integration Controls

All tools and parts must be cleaned prior to assembly. Unless otherwise specified by the CCE, hardware shall be cleaned to the requirements of Section 2.1. Optical integration shall be performed in a Class 6 or better clean area. Air quality requirements are specified in Section 2.4.

8.1 Mounting

The following requirements apply to mounting of optics:

- a. Optics shall be mounted on a Class 5 flow bench.
- b. Potting and staking compounds shall be mixed on a separate bench.
- c. Optics shall not be covered for 24 hours after potting or staking.

8.2 Optical Bench Integration

Cleanliness certification for parts and tools to be used during integration of the optics onto the bench shall be confirmed prior to exposing the optics.

The following requirements apply to optical bench integration:

- a. Hardware and the work area shall be inspected for accumulated contamination at the beginning and end of each task.
- b. Hardware and the work area shall be inspected for accumulated contamination at the end of each shift.
- c. All non-optical surfaces shall be cleaned after assembly is complete, regardless of the visual cleanliness.
- d. Optical surfaces shall be covered when operations permit.

9.0 Testing Controls

During testing outside of a clean area, ATLAS hardware shall be double bagged. Access points and cutouts shall be prepared while in a clean area, then taped shut until needed. If the integrity of the bag is not sufficient to protect the hardware, the CCE may require that a nitrogen purge be used.

During vacuum testing outside a clean area, the hardware shall be exposed to the ambient air for a minimum period of time. Thermocouples shall be installed in a clean area before bagging the hardware.

10.0 Transportation and Storage

10.1 Optics

Prior to mounting, optical parts shall be stored in cleaned optics containers. These containers shall be stored in a desiccator or purged box. For transportation, the optic containers shall be double bagged.

After mounting, optical parts shall be stored in a desiccator or purged box. For transportation, the part shall be double bagged.

10.2 Non-optical Parts

After precision cleaning, non-optical parts shall be double bagged for storage and transportation.

10.3 Laser

The laser window shall have a red-tag cover installed for transportation and storage. The laser assembly shall be double bagged for transportation and storage.

11.0 Facility and Personnel Controls

A facility operations plan shall be developed for each ATLAS controlled clean area. The operations plan shall include facility maintenance and cleaning schedules, personnel gowning and access constraints, and controls on concurrent activities.

11.1 Training

Personnel requiring repeated access to ATLAS clean areas shall receive a contamination briefing by the CCE prior to being allowed access to the area. Personnel requiring one time access to ATLAS clean areas shall be escorted by trained project personnel.

11.2 Site Management

The CCE shall coordinate project activities with the Facilities Management Division to ensure that critical hardware is not exposed to risks from external activities. The following external activities are of particular concern:

- a. Roofing and roadwork within 0.5 km of the integration facility.
- b. Building maintenance and repair activities involving paint, caulk, sealants, or adhesives.
- c. Utility work (electrical, plumbing, fire suppression, etc.)

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