Contamination Control Plan
for the
CRaTER Project
32-01203
Rev 06

Record of Changes

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Purpose

The purpose of this Contamination Control Plan (CCP) is to define the overall contamination control requirements for the design, fabrication, assembly, integration, testing and operation of CRaTER Instrument onboard the LRO spacecraft.

1. Scope

Contamination control requirements during all phases of the mission will be addressed. Allowable contamination requirements will be presented along with the planned methods for limiting contamination throughout all phases. Plans for analyses, laboratory investigations, cleanroom and hardware monitoring will also be addressed.

2. Applicable and Reference Documents

The following applicable and reference documents are mentioned in this CCP.

- FED-STD-209 Clean Room and Work Station Requirements, Controlled Environment
- MIL-STD- 1246 Product Cleanliness Levels and Contamination Control
- JSC SP-R-022A Specification Vacuum Stability Requirements of Polymeric Materials for Spacecraft Applications
- JSC SN-C-005C Contamination Control Requirements for the Space Shuttle Program
- NASA Materials Outgassing Data for Selecting Spacecraft Publication 1124 Materials
- ASTM E-595 Methods of Test, Total Mass and Controlled Volatile Condensable Materials from Outgassing in a Vacuum Environment

3. Contamination Control Requirements

The CRaTER instrument itself is not very contamination sensitive. Most of the instrument consists of conformal-coated circuit boards, connectors, harnesses and aluminum housing. The closest items in the instrument that can be considered critical surfaces are the six silicon particle detectors buried inside the instrument. Even though they are completely enclosed inside the instrument housing, these detectors and their bond wires are not hermetically sealed and are therefore exposed to the internal environment of the instrument housing. Unlike some photon detectors, buildup of passive contamination on these detectors doesn't have a noticeable impact on their scientific function (degradation in quantum efficiency for example). Contamination concerns with these detectors are related to such things as bond wire corrosion or chemical reaction with the detector surface. However, experience with these types of detectors has shown them to be quite robust in the typical environments we expect them to be exposed too, if some basic precautions are taken. These precautions include the selection of low outgassing materials[1] in the instrument, vacuum bakeout of subassemblies such as printed circuit boards and regular nitrogen purging of instrument once assembled.

The overall Contamination Control program has been developed based on the sensitivities and performance goals of the CRaTER Instrument on LRO. This section will present baseline contamination sensitivities and requirements. All design,

[1] At this time the A-150 Tissue Equivalent Plastic planned for use in this experiment is still having it's outgassing properties analyzed to determine if any contamination mitigation will be necessary.

fabrication, assembly, integration, testing, packaging, transportation and integration must be performed in a manner that will minimize the probability of contaminating CRaTER critical surfaces. During many project phases, an active contamination monitoring program will be in effect, using a number of methods including visual inspections, black light and white light measurements. All subsystems and/or components through proper selection of materials and appropriate vacuum bakeout of parts, components, and subsystems will meet outgassing requirements.

Generally, assembly and integration will take place in a class 100,000 or better clean room environment at MIT and Aerospace Corp. When the instrument is outside of the class 100,000 clean room it will be bagged. The only exception is when I&T activities prohibit bagging. Additionally, when flight hardware is not being worked on in the clean room it must be protected with a cover or drape. During any type of transportation or storage the instrument will be bagged in approved cleanroom bagging material. Visual inspections will also be carried out after any recleaning activities.

4. Surface Cleanliness

CRaTER shall be delivered *Visibly Clean to the Standard Level* per JSC-SN-C-0005C.

5. Contamination Sources For CRaTER

Possible sources of contamination must be identified in order to protect the instrument from contamination and to effectively clean contaminated components. Table 1 is a listing of possible contamination sources at the various development stages.

Table 1 Contamination Sources

Mission Phase	Molecular	Particulate
Fabrication	Materials outgassing, machining oils, fingerprints, air fallout and personnel	Shedding, flaking, metal chips, filings, air fallout, personnel
Assembly & Integration	Air fallout, outgassing, personnel, cleaning solvents, soldering, lubricants, bagging material	Air fallout, personnel, soldering, drilling, bagging material, shedding, flaking
Test	Air fallout, outgassing, personnel, test facilities, purges	Air fallout, personnel, test facilities, purges, shedding, flaking, redistribution
Storage	Bagging material, outgassing, purges, containers	Bagging material, purges, containers, shedding, flaking
Transport	Bagging material, outgassing, purges, containers	bagging material, purges, containers, vibration, shedding, flaking
Launch Site	Bagging material, air fallout, outgassing, personnel, purges	Bagging material, air fallout, personnel, shedding, flaking, checkout activities, other payload activities

Launch/Ascent	Outgassing, venting, engines, payload separation and maneuvers	Vibration and/or redistribution, venting, shedding, flaking
On-Orbit	Outgassing, UV interactions, propulsion systems and attitude control systems	Spacecraft cloud, micrometeoroid & debris Impingement, material erosion, redistribution, Shedding, flaking, operational events

6. Design Phase Contamination Control

Contamination prevention is a basic design consideration and will be examined throughout the development process.

6.1 Materials Selection

In order to control contamination and protect sensitive surfaces, the use of minimal contaminating materials and the use of covers and protective shields must be considered. Manufacturing materials should be low outgassing, non-shedding and non-flaking. Generally, materials must meet ASTM E595 "Methods of Test, Total Mass and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment" outgassing requirements. Efforts will be made to select low outgassing materials (CVCM level of 0.1% and TML of 1.0% by weight) for all applications. For questionable materials, or materials where data does not exist, it may be necessary to test outgassing characteristics at the NASA-GSFC Materials Engineering facilities, in accordance with the ASTM E595 procedure.

7. Fabrication And Assembly Phases Contamination Control

Fabrication of CRaTER parts will generally take place in uncontrolled environments (> Class 100,000 environments); assembly of the instrument will take place in a Class 100,000 cleanroom or better. During all fabrication and assembly phases and associated storage/transportation periods, contamination control measures will be instituted. Surfaces will be kept clean, and if any debris is generated during the manufacturing process it will be cleaned/vacuumed off. During assembly, mating surfaces will be cleaned to visibly clean standard level prior to attachment. All interior volumes will be cleaned thoroughly prior to final assembly and attachment. All ground support equipment will be kept visibly clean during assembly. When necessary cables, harnesses, etc. will be cleaned and vacuum baked before attachment to flight hardware.

Instrument subsystems will be maintained at a visibly clean standard level throughout the fabrication process. Trained personnel will perform inspections. Cleanliness requirements during subsystem fabrication are as follows:

- During manufacturing operations such as machining, welding and soldering, contaminants should be cleaned off of the hardware by wiping and/or vacuuming. Lubricants and cutting oils (i.e. oils and greases) should be cleaned off as soon as possible after the manufacturing operation using appropriate solvents.
- Prior to priming or painting a surface it should be free of particulate or molecular deposits and be inspected at a visibly clean level.
- If an area becomes inaccessible during fabrication it must be cleaned and inspected to a visibly clean level before becoming inaccessible.

- Upon the completion of a fabrication operation, the components will be subjected to a gross cleaning procedure involving solvent washes and particulate removal, yielding a visibly clean standard product. The fabricated components will then be bagged to negate contamination effects.
- Parts, surfaces, holes and so forth must also be cleaned. Cleaning will continue until all surfaces are visibly clean upon inspection.
- Any cleaning of painted surfaces will be done with the approval of the instrument mechanical engineer.
- Prior to any final assembly, all surfaces must be vacuumed giving special attention to holes, crevices and riveted regions.
- Assemblies will be visually inspected with a blacklight for external oil or grease deposits.

8. Test Phase Contamination Control

Prior to spacecraft integration, the instrument will be subjected to a number of testing operations.

8.1 Vibration Testing

The instrument will be bagged during vibration testing except at the interface to the shake table. The shake fixture adapter plate will be visibly cleaned to standard level at the instrument interface.

8.2 Thermal Vacuum Testing

The instrument will undergo a thermal vacuum test sequence. The instrument level thermal vacuum test will be performed at TBD. Cleanliness requirements for the TV chamber itself are TBD.

Periodic purges, using TBD grade nitrogen, of the instrument will be implemented after the final phase assembly of the instrument and thru the test phase.

9. Spacecraft Integration Phase Contamination Control

Integration of the instrument with the spacecraft is assumed to occur in a class 100,000 environment or better at NASA-GSFC. After spacecraft integration, the CRaTER project assumes the goal will be to keep the instrument in class 100,000 environment or better.

During downtimes when hardware is not actively being worked on, or for weekends and other non-operational times, flight hardware, not yet mounted on the spacecraft will be kept covered with an approved clean room certified, anti-static bagging material. Bagging materials and drapes must be contamination and electrostatic discharge (ESD) approved. Additionally the temperature and humidity of the work environment will be controlled.

Weekly purges, using TBD grade nitrogen, of the instrument will be required during the spacecraft integration phase.

10. Venting Design Requirements

The number of vents shall be limited to facilitate thermal vacuum testing. The venting design shall be adequate to provide for launch-ascent depressurization. There are no requirements for the instrument to direct outgassing products in a certain direction.

11. Clean Room and Operational Requirements

The following list highlights the assumed contamination procedures to be implemented during assembly activities:

- Parts, such as assembly tools, from a less controlled fabrication and assembly area will be cleaned to a visibly clean standard level prior to entry into the clean room.
- All surfaces will be cleaned to visibly clean standard level throughout integration activities.
- Parts, such as assembly fixtures, , which are machined, welded or riveted, will be inspected and re-cleaned, if necessary to meet the Visibly Clean Sensitive levels.
- Personnel working in the cleanroom will wear appropriate cleanroom clothing, shoe coverings, etc. and latex or nitrilite gloves. When working with solvents appropriately rated clean gloves should be worn.
- Ground support equipment (GSE) required for testing will be cleaned to a visibly clean standard level, and bagged before going into the cleanroom.
- Oils, greases and other similar agents, which may be contamination hazards, will not be used during integration without the permission of the mechanical engineer.
- Rivets, bolts, nuts and so forth must be cleaned to remove any type of contamination such as lubricants and machining oils prior to I & T. Fasteners, which are lubricated, will be cleaned with an appropriate solvent prior to being used during integration. Areas which become inaccessible for cleaning must be cleaned and inspected prior to that time
- If an instrument or hardware is removed for testing, or some other reason, it must re-verified to a cleanliness level visibly clean standard level before it can reenter the cleanroom.
- The NASA-GSFC instrument support team is responsible for cleaning and maintaining the instruments during satellite integration and testing.

12. Contamination Control During Transportation and Storage

The instrument will be bagged during storage or transportation. The instrument will be bagged with approved bagging material at all times unless integration and test activities prohibit it.

The bagged instrument will be transported in a shipping container. The shipping container will be pre-cleaned, prior to transportation, to a visibly clean standard level. Temperature and humidity will not be monitored in the shipping container.

13. Vacuum Bakeout Requirements

Along with the selection of low outgassing materials for the instrument, a thermal vacuum bakeout program at the subassembly level is planned. All structure, materials and sub-assemblies will be evaluated on a case-by-case basis to assess the need for vacuum bakeout.

14. Roles And Responsibilities

The Fabrication Manager, Mechanical Engineer, Project Engineer and Mission Assurance Manager will be responsible for ensuring that contamination control measures are implemented throughout the design, fabrication, assembly, integration, testing, storage and transportation, and all other phases.

15. Cleanliness Inspection and Monitoring Methods

Cleanlines Inspection methods to be used are black and white light inspections, and wipes. Descriptions of these techniques are as follows:

Light Inspections

Visual Inspection is done periodically using black (UV) light or white light, per JSC-SNC005C. If visual contamination is evident, the hardware must be cleaned and then reinspected under the same light conditions. If during UV inspection there is any evidence of fluorescence the item/surface must be re-cleaned. If re-cleaning does not reduce the fluorescence, it must be determined whether the fluorescing material is a contaminant or the substrate surface.

Wipes

A surface, which is to be inspected, is wiped with reagent grade isopropanol alcohol or an appropriate solvent. The collected residue is then subjected to a visual inspection to determine if further cleaning is necessary.

16. Cleaning and Monitoring Schedules

Cleaning of flight hardware shall occur as required by the assembly work order. Cleaning of the assembly area cleanroom shall occur prior to the start of the flight unit assembly activities and monitored during the period of flight unit assembly. GSE will be cleaned prior to first use with flight equipment and monitored thereafter, with recleaning as necessary.

17. Employee Training

Personnel involved in the design, fabrication, assembly, integration, testing, and transportation of the instrument will review the CRaTER Contamination Control Plan. Any necessary additional training will be provided as needed.

18. Contamination Documentation Requirements

There are a number of contamination-related documents, which must be produced and periodically updated throughout the development process. These include:

- Contamination Control Plan
- Cleanroom History Logs
- Hardware Assembly Work Orders with cleaning and inspection points

19. Acronyms and Definitions

19.1 Acronyms

- CCE Contamination Control Engineer
- CCM Contamination Control Manager
- CCP Contamination Control Plan
- CVCM Collected Volatile Condensable Materials
- ESD Electrostatic Discharge
- FED-STD Federal Standard
- GSE Ground Support Equipment
- GSFC Goddard Space Flight Center
- HEPA High Efficiency Particulate Air
- IPA Isopropyl Alcohol

- I&T Integration and Test
- MIL-STD Military Standard
- MLI Multi-Layer Insulation
- NASA National Aeronautics and Space Administration
- NVR Non-Volatile Residue
- PAR Performance Assurance Requirements (Document)
- QA Quality Assurance
- QCM Quartz Crystal Microbalance
- TML Total Mass Loss
- TQCM Temperature-Controlled Quartz Crystal Microbalance
- TV Thermal Vacuum
- VCS Visibly Clean Sensitive

19.2 Definitions

- ***Cleanroom*** - Room in which the concentration of airborne particles is controlled to specified limits.
- ***Clean Zone*** - Defined space in which the concentration of airborne particles is controlled to specified limits. Clean zones are classified by a number such as 1, 100, 1000, etc., in accordance with FEDSTD- 209, which describes the maximum number of particles, 0.1 microns and larger, permitted per cubic foot of air.
- Contamination - Any unwanted material that causes degradation in the desired function of a instrument or flight hardware.
- ***Contamination Control*** - Organized action to control the level of contamination.
- ***Fiber*** - A particle whose length-to-width ratio exceeds 10:1 with a minimum length of 100 microns.
- ***Gross Cleaning*** - Cleaning hardware surfaces to visual inspection standards.
- ***Level x per Mil-Std 1246*** - The cleanliness level defined by a number and/or letter designating the particle distribution and molecular cleanliness as described in Table 2 and Table 3.

Table 2 Particulate Levels

Mil Std 1246 Particle Level	***Percent Obscuration by Cylinder- Hemisphere***
400	0.08
500	0.24
600	0.61
700	1.35
800	2.76
900	9.33

Table 3 Molecular Levels

Mil Std 1246 Molecular Level	***mg/ft2 NVR***
A	1.0
B	2.0
C	3.0
D	4.0
E	5.0
F	6.0

- ***Non-Volatile Residue*** - Soluble material remaining after evaporation of a volatile liquid which usually causes degradation in the desired function of an instrument or flight hardware.
- ***Particle*** - A small quantity of solid or liquid material with definable shape or mass with a length to width ratio less than 10:1.
- ***Particle Size*** - Expressed as the apparent maximum linear dimension or diameter of the particle.
- ***Precision Cleaning*** - A cleaning procedure done in a controlled environment to attain a specific level of cleanliness. This procedure follows gross cleaning.
- ***Sensitive Surface*** - Any surface of flight hardware that must meet a specified cleanliness level to assure the minimum performance levels.
- ***Solvent Flushing*** - Method of cleaning surfaces with a stream of filtered solvent under pressure, which is directed against a surface to dislodge and rinse away any foreign material.
- ***Solvent Washes*** - A quantitative method of verifying MIL-STD-1246 molecular cleanliness levels by measuring molecular contamination in a solvent, which was washed over a surface and collected.
- ***Surface Cleanliness*** Level - An established level of maximum allowable particulate and/or NVR contamination ranging from visibly clean to specific MIL-STD-1246 levels (e.g., Level bOA, Level 300B, etc.).
- ***Visibly Clean*** - The achievement of a clean surface as seen without optical aids (except corrected vision) as measured by a specified method. Three levels of visibly clean (VC) requirements are defined in JSC-SN-C-0005C. Visibly clean is the absence of particles as seen by the unaided eye at the distance and light level specified in Table 4.

Table 4 Visually Clean Levels

VC Level	*Incident Light Level (Note 1)*	*Observation Distance*	*Remarks*
Standard	>50 ft-candles	5-10 feet	Notes 2, 3, 4
Sensitive	>50 ft-candles	2-4 feet	Notes 2, 3, 4
Highly Sensitive	>100 ft-candles	6-18 inches	Notes 3, 4, 5

NOTES

Note 1: One foot-candle (lumens per square foot) is equivalent to 10.76 lumens per square meter.
Note 2: Cleaning is required if the surface in question does not meet VC under the specified incident light and observation distance conditions.
Note 3: Surfaces other than diffuse white may require additional cleaning to achieve these levels.
Note 4: Exposed and accessible surfaces only.
Note 5: Initial cleaning is mandatory; Note 2 applies thereafter.