Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx)

Mission Contamination Control Plan

OSIRIS-REx-PLAN-0011

Revision -

December 2013

Prepared by: Charles Lorentson
NASA - Goddard Space Flight Center

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CONFIGURATION MANAGEMENT (CM) FOREWORD

This document is a ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH Explorer mission (OSIRIS-REx) Project CM-controlled document. Changes to this document require prior approval of the applicable configuration control board (CCB) chairperson or designee. Proposed changes shall be submitted to the OSIRIS-REx Configuration Management Office, along with supportive material justifying the proposed change. Changes to this document will be made by complete revision. This document will expire once a Launch Vehicle Interface Control Document (LV-ICD) has been signed.

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:

OSIRIS-REx Configuration Management Office
Mail Stop 433
Goddard Space Flight Center
Greenbelt, Maryland 20771

OSIRIS-REx
Mission Contamination Control Plan

Signature Page

Prepared by:

12/16/13

Chris Lorentson Date
OSIRIS-REx Project Contamination Control Manager
NASA/GSFC, Code 433

Reviewed by:

David F. Everett 12/16/13

David Everett Date
OSIRIS-REx Project Systems Engineer
NASA/GSFC, Code 599

Arlin Bartels 2013/12/16

Arlin Bartels Date
OSIRIS-REx Flight Mgr.
NASA/GSFC, Code 433

Mary Walker 12/18/13

Mary Walker Date
OSIRIS-REx Instrument Systems Mgr.
NASA/GSFC, Code 433

Ronald Perison 12/12/13

Ron Perison Date
OSIRIS-REx Chief S&MA Officer
NASA/GSFC, Code 323

Approved by:

12/17/13

Mike Donnelly Date
OSIRIS-REx Project Manager
NASA/GSFC, Code 433

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OSIRIS-REx Mission Contamination Control Plan
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OSIRIS-REx Mission Contamination Control Plan

1.0 Introduction

The Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) will characterize the surface features and spectra of near-Earth asteroid Bennu and return a pristine sample of the surface of the asteroid to Earth. Asteroids are the direct remnants of the original building blocks of the terrestrial planets. Knowledge of their nature is fundamental to understanding planet formation and the origin of life. The return to Earth of pristine samples with known geologic context will enable precise analyses that cannot be duplicated by spacecraft-based instruments, revolutionizing our understanding of the early Solar System.

The OSIRIS-REx project is led by the Principle Investigator (PI) at the University of Arizona, and managed by the NASA Goddard Space Flight Center (GSFC). The prime contractor for the OSIRIS-REx spacecraft is Lockheed Martin Space Systems Company (LMSSC) in Denver, CO, which is responsible for spacecraft design, integration of science instruments, the Touch-And-Go Sample Acquisition Mechanism (TAGSAM), the Sample Return Capsule (SRC), launch operations support, SRC recovery, and support of mission operations.

The OSIRIS-REx instruments payload consists of the OSIRIS-REx Camera Suite (OCAMS), the OSIRIS-REx Laser Altimeter (OLA), the OSIRIS-REx Visible and IR Spectrometer (OVIRS), the OSIRIS-REx Thermal Emission Spectrometer (OTES), and a student experiment: the Regolith X-ray Imaging Spectrometer (REXIS). These instruments are provided by the University of Arizona, Canadian Space Agency, GSFC, Arizona State University, and Massachusetts Institute of Technology/Harvard University, respectively. OSIRIS-REx is also composed of the previously mentioned TAGSAM which will collect the sample, and the SRC which will carry the TAGSAM sampler head back to a safe landing on Earth after separation from the OSIRIS-REx spacecraft.

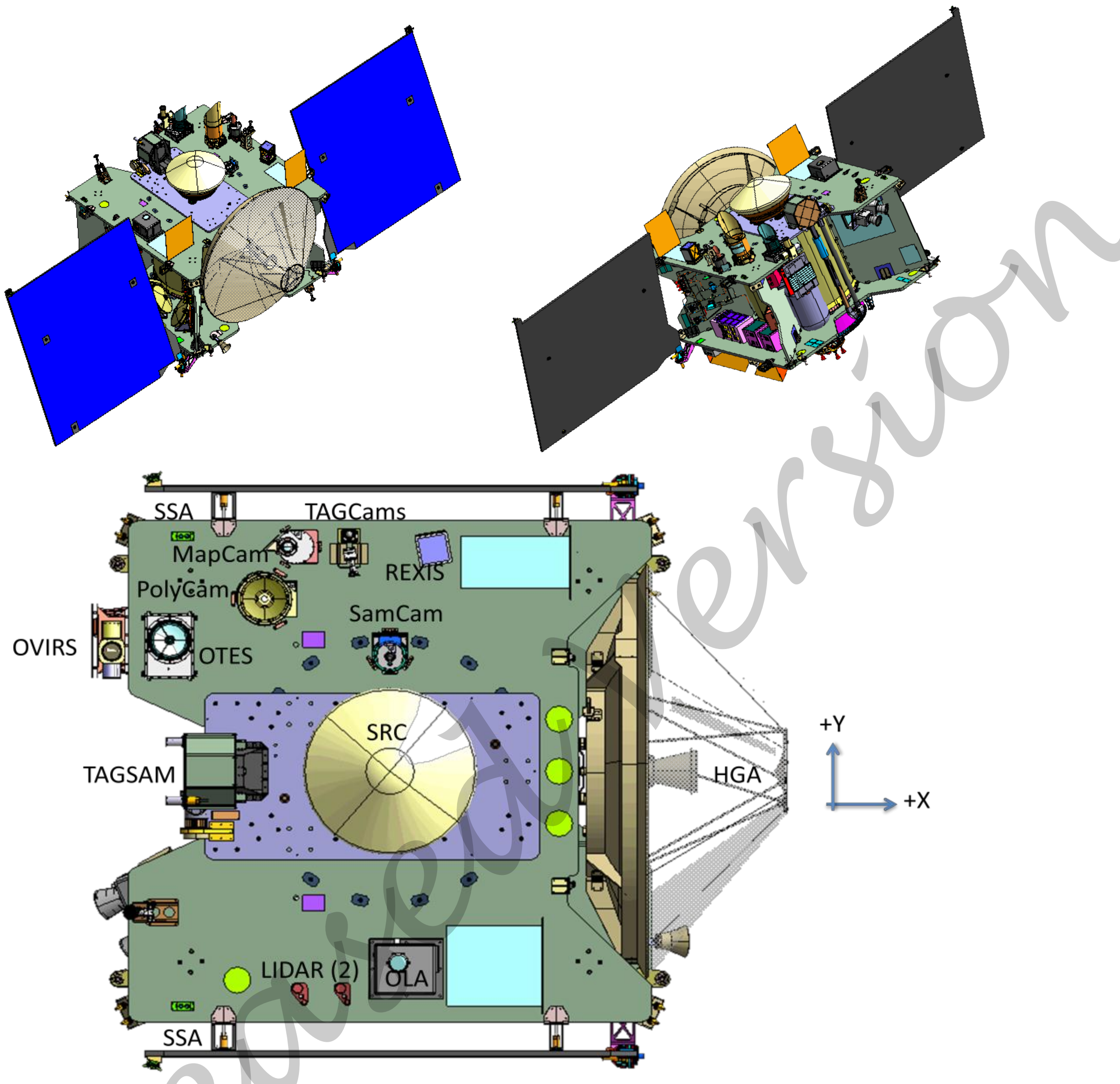


Figure 1-1 OSIRIS-REx S/C and Instrument Suite

OSIRIS-REx will be launched on a NASA Launch Services-II provided Atlas 411 Launch Vehicle (LV) during what is anticipated to be a 39-day planetary launch window opening on or about September 3, 2016. OSIRIS-REx will launch to a C3 of at least 29.3 km^2/s^2, perform an Earth flyby about 1 year after launch, capture in the vicinity of asteroid Bennu in October 2018, sample the asteroid in mid 2019, and depart the asteroid in March of 2021. The samples will be returned to Earth via releasing the SRC for landing at Utah Test and Training Range (UTTR) on or about September 24, 2023.

While planetary protection requirements are Category II outbound and Category V, Unrestricted Earth Return, the organic contamination control requirements will drive Mars-like cleanliness protocols.

The addition of Earth based materials into the sample returned from the asteroid would complicate analysis of the environment and composition of the asteroid. This could hinder the scientific study of the returned sample. For this reason a primary goal of the mission is to return a "pristine" sample of the asteroid for study. Knowledge of what materials we may have added to the sample through flight and ground activities is absolutely critical. For this reason, contamination control is even more essential for this mission than for most. Limiting what terrestrial materials may be integrated with the sample as well as understanding what those materials are is a crucial element to providing a successful completion of this mission.

In order to obtain the most accurate data, the instrument and spacecraft must also operate at peak performance. Adverse particulate and molecular contamination can degrade the analysis of the mission asteroid sample as well as instrument and spacecraft performance. Through a carefully planned contamination control program, the sample acquisition and return hardware, instruments, and spacecraft can be protected from harmful contamination effects.

1.1 Scope of Document

This document defines the OSIRIS-REx contamination requirements necessary for mission success. Methods of contamination control with respect to materials and processes during design, fabrication, assembly, integration, test, and launch for the flight system and its instruments are addressed in this document. Sources of contamination for OSIRIS-REx will be identified and contamination allowances and budgets will be defined. In addition, contamination controls for OSIRIS-REx development and cleaning requirements for OSIRIS-REx hardware will be established. Furthermore, the plan will outline cleanliness monitoring and verification techniques.

This plan also covers transportation of the flight system to the launch site, contamination requirements on the launch vehicle, and contamination requirements during launch site operations. These will be covered in the appendix of this OSIRIS-REx Contamination Control Plan as well as the OSIRIS-REx Launch Services Support Plan (LSSP). Contamination control for OSIRIS-REx at the Payload Processing Facility and at the Launch Pad facilities will also be covered in the appendix.

The use of witness plates and other forms of Contamination Knowledge will be used to limit the impact of contamination transfer to the sample acquisition hardware. This plan will also address methods to develop contamination knowledge and materials archiving to lessen the impacts of stringent contamination control procedures where practical.

1.2 Responsibilities

GSFC is responsible for the cleanliness and overall contamination control program for the OSIRIS-REx mission.

GSFC subcontractor contamination control should be consistent with the approach contained in this document and ensure that necessary contamination control requirements are met.

Lockheed Martin is the OSIRIS-REx spacecraft vendor and shall be responsible for generating a spacecraft contamination control plan consistent with this mission contamination control plan for all spacecraft hardware and flight system integration activities. This spacecraft contamination control plan shall also be consistent with all instrument Interface Requirements Control Documents (IRCD). GSFC will review and approve the spacecraft Contamination Control Plan.

The instruments shall generate an instrument-specific contamination control plan per the OSIRIS-REx Mission Assurance Requirements (MAR) Document. In addition, the instruments shall meet the instrument and spacecraft compatibility requirements referred to in the MAR, the instrument Interface Requirements Control Documents (IRCD), and defined in this contamination control plan, in order to avoid spacecraft to instrument contamination and instrument cross contamination. GSFC will review and approve the instrument Contamination Control Plans. Instrument cleanliness shall be verified upon delivery to OSIRIS-REx flight system.

Instrument cleaning from delivery to launch shall be the responsibility of the Instrument Provider unless a detailed procedure is provided to GSFC and/or LM and negotiated in the hardware element to flight system Interface Control Document (ICD).

Any questions about this document should be directed to the GSFC OSIRIS-REx Contamination Control Manager, Code 546 or the OSIRIS-REx Project Office.

1.2.1 Implementation of Requirements

The following table describes how contamination control and the requirements of this plan are implemented. Referenced manager/engineer is the responsible party at the relevant level of hardware development (Instrument/Spacecraft/Flight system):

Table 1.2.1-1: Implementation

Activity	Responsibility	Verification
Flow down of requirements to subcontractors	Subsystem Engineer	Contamination Engineering
Implement compatibility requirements (i.e. surface cleanliness, outgassing certification, and venting)	Instruments, subsystem engineers, Flight system Manager, ATLO Manager	Contamination Engineering, Quality Assurance
Inspections/Cleaning	ATLO Manager, Contamination Engineering	Contamination Engineering, Quality Assurance
Implementation of facility requirements and appropriate control of work area	ATLO manager	Contamination Engineering
Incorporate requirements into work order authorizations (WOA)	ATLO manager, Subsystem Engineer	Contamination Engineering, Quality Assurance
Incorporate requirements into plans and procedures	Instruments, subsystem engineers, Flight system Manager, ATLO Manager, Contamination Engineering	Contamination Engineering, ATLO Manager
Material lists	Instruments, Subsystem Engineer	Materials Engineer
Facility certification and maintenance	Facilities Contractor	Contamination Engineering, Quality Assurance
Hardware cleaning (GSE and Flight)	Facilities Contractor, Contamination Engineering	Contamination Engineering, Quality Assurance
Facility monitoring	Facilities Contractor	Contamination Engineering, Quality Assurance
Facility Maintenance Restrictions	Environmental Test Engineering and Integration, Contamination Engineering, Facilities Management	Contamination Engineering, Quality Assurance
Purge cart and implementation of instrument purge	ATLO manager	Contamination Engineering
Purge manifold and purge lines on flight system	Mechanical Engineering	Contamination Engineering, ATLO manager
Purging procedure	Contamination Engineering	ATLO manager
Bagging Concept	Mechanical Engineering and Contamination Engineering	ATLO manager
Molecular adsorber mounting and frame hardware	Mechanical Engineering	ATLO manager
Molecular adsorbers	Contamination Engineering	ATLO manager

Activity	Responsibility	Verification
Molecular adsorber and vent close-outs	Mechanical Engineering, Blanket Shop	Contamination Engineering
Verification of Surface Cleanliness Requirements during ATLO	Facilities Contractor , Contamination Engineering	Contamination Engineering, Quality Assurance
Implementation of bake-outs	Subsystem Engineers, Test engineer	Contamination Engineering
Contamination Knowledge Witnesses	Contamination Engineering	Science Team Representative
Materials Archiving	Instrument Manager, Subsystem Engineers	Curation Team

1.3 Applicable and Reference Documentation

The following documents become part of this document to the extent referenced in this document. When a specific version is specified for a referenced document, only that version applies. For undated references, the latest edition of the referenced document applies.

1.3.1 Precedence of OSIRIS-REx Documents

The following applicable documents are in order of precedence. Reference numbers for these documents are listed in Section 1.3.2

OSIRIS-REx Mission Requirements Document
OSIRIS-REx Mission Assurance Requirements
OSIRIS-REx Mission Contamination Control Plan
OCAMS/OVIRS/OLA/OTES/REXIS/Spacecraft Contamination Control Plans
Flight system to Instrument ICD's

1.3.2 OSIRIS-REx Applicable and Reference Documents

OSIRIS-REx-SYS-RQMT-0001	OSIRIS-REx Mission Requirement Document (MRD)
OSIRIS-REx-SYS-RQMT-0003	OSIRIS-REx Mission Assurance Requirements (MAR)
OSIRIS-REx-PLAN-0021	OSIRIS-REx Materials and Process Selection, Implementation, and Control Plan (MPCP)
OSIRIS-REx-ICD-0001	Spacecraft to OCAMS Interface Req. Control Document
OSIRIS-REx-ICD-0002	Spacecraft to OVIRS Interface Req. Control Document
OSIRIS-REx-ICD-0003	Spacecraft to OTES Interface Req. Control Document
OSIRIS-REx-ICD-0004	Spacecraft to OLA Interface Req. Control Document

OSIRIS-REx-ICD-0005	Spacecraft to REXIS Interface Req. Control Document
OSIRIS-REx-SYS-SPEC-000X	OSIRIS-REx Purge System Specification
OSIRIS-REx-SYS-ANYS-000X	Initial Flight system Level Direct Flux Analyses
OSIRIS-REx-SYS-ANYS-000X	Initial Thruster Impingement Analyses
OSIRIS-REx-I&T-PLAN-000X	OSIRIS-REx Spacecraft and Flight system Integration and Test Plan
OREX-DOC-05.01-00005	OCAMS Instrument Contamination Control Plan
OVIRS-PLAN-0018	OVIRS Contamination Control Plan
OTES-CD-0005	OTES Contamination Control Plan
MDA-OLA-PLN-12364 A	OLA Contamination Control Plan
OSIRIS-REx-SYS-PLAN-000X	REXIS Contamination Control Plan
NFP3-PN-11-MA13-1	Spacecraft Contamination Control Plan

1.3.3 Federal Specifications

TT-I-735	Isopropyl Alcohol
FED-STD-209E	Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

1.3.4 Military Specifications

MIL-D-16791	Detergents General Purpose (Liquid, Non-ionic)
MIL-PRF-27401D	Propellant Pressurizing Agent, Nitrogen
MIL-STD-1246C	Product Cleanliness Levels and Contamination Control Program

1.3.5 NASA Specifications

Web site for replacement of NASA Reference Publication 1124	Outgassing Data for Selecting Spacecraft Materials [http://outgassing.nasa.gov]

JSC-SN-C-0005C	Contamination Control Requirements for the Space Shuttle Program
GSFC-TLS-PR-7324-01	Contamination Control Procedures for the Tape Lift Sampling of Surfaces
KTI-5212	KSC Material Selection List for Plastic Films, Foams, and Adhesive Tapes

1.3.6 ISO Documents

ISO-14644-1	Cleanrooms and associated controlled environments - Part 1: Classification of air cleanliness [Replacement for FED-STD-209E - Clean Room and Work Station Requirements, Controlled Environment]
ISO-14644-2	Cleanrooms and associated controlled environments - Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1 [Replacement for FED-STD-209E - Clean Room and Work Station Requirements, Controlled Environment]
ISO-14644-4	Cleanrooms and associated controlled environments - Part 4: Design, construction and start-up
ISO-15859-3	Nitrogen [Alternative to MIL-P-27401 Propellant Pressurizing Agent, Nitrogen]

1.3.7 Other Specifications

AIAA 91-1977	Cleanliness considerations in the Design, Manufacturing, and Testing of Satellite Surface Tension Propellant Tanks
ASTM E-595	Methods of Test, Total Mass and Controlled Volatile Condensable Materials from Outgassing in a Vacuum Environment
ASTM F-50	Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Cleanrooms Using Instruments Capable of Detecting Single Sub-Micrometer and Larger Particles
IEST-RP-CC-006	Testing Cleanrooms
IEST-RP-CC-018	Cleanroom Housekeeping -Operating and Monitoring Procedures
IEST-STD-CC1246D	Product Cleanliness Levels and Contamination Control Program [Replacement for MIL-STD-1246C]

2.0 Contamination Control Requirements

The OSIRIS-REx driving contamination requirements are based on the acquired sample contamination control requirements specified in the MRD. While this is the primary driver for the mission requirements, the instrument contamination requirements, spacecraft contamination requirements, and on-orbit contamination transfer also impact the overall contamination environment. The sample contamination requirements are derived based on the maximum amount of contamination in the acquired sample which will still allow the measurement and evaluation of scientific elements necessary to achieve mission success criteria. Contamination transfer to the sample or associated sample acquisition or return hardware will drive the contamination control requirements when the hardware performance does not establish a more sensitive contamination requirement.

The instrument contamination requirements consist of internal and external requirements that help minimize performance degradation and take into account requirements for instrument optics, instrument detectors, instrument filters, and thermal control surfaces. Spacecraft contamination requirements other than the sample hardware are based on star tracker contamination requirements, allowable thermal control surface degradation, coarse sun sensor performance requirements, and to a lesser extent, solar array performance requirements. In addition, the on-orbit contamination transfer and environmental concerns are also considered in deriving the OSIRIS-REx contamination control approach. Those concerns include: outgassing of materials, venting and vent paths, electrostatic return of molecular contaminants, propulsion effluent from thruster firings, polymerization effects, solar activity, and environments of asteroid orbits.

Design, fabrication, assembly, integration, testing, packaging, transportation and launch site activities will be performed in a manner that minimizes the probability of contaminating contamination sensitive surfaces and samples.

2.1 Overall Contamination Control Requirements

Cleanliness for the OSIRIS-REx instruments and the spacecraft will follow the standards outlined in ISO-14644 [formerly FED-STD-209E], IEST-STD-CC1246D [formerly MIL-STD-1246C], and JSC-SN-C-0005. During all project phases, an active contamination monitoring and verification program will be in effect for flight hardware, using black light and white light inspections, tape lift particulate measurements, image analysis particulate counting, non-volatile residue swab samples, molecular washes, in-situ molecular monitors, and/or witness samples. All instruments, subsystems, and/or components shall meet outgassing certification requirements prior to integration with the flight system. Techniques such as Black and White light inspections, image analysis, tape lift samples, and/or wash samples will be performed on a schedule, as defined in Section 8.2, such that the Flight system will be sustained at the specified levels in section 2.4. Cleanliness levels may be measured using an equivalent Percent Area Coverage [PAC] level as described in Table B-6 if desired.

2.2 OSIRIS-REx Instrument Contamination Requirements

The OSIRIS-REx Instruments mission cleanliness levels are specified in Table 2.2-1. These levels are required to ensure instrument to instrument, and instrument to sample hardware compatibility. This compatibility requirement can be verified via tape lift samples, image analysis, visual inspections, and/or wash samples on representative instrument surfaces. Black and white light inspections if performed should be performed to the criteria of JSC-SN-C-0005 or an equivalent procedure. Some instruments will have stricter requirements on their respective contamination sensitive surfaces than other hardware. Where these requirements are in conflict, the more stringent requirement must prevail where contamination transfer may occur in order to provide the necessary operating environment for all hardware elements.

Table 2.2-1 lists the instrument sensitivity levels as specified by the instrument vendors. These instrument sensitivity levels are taken from the individual instrument contamination control plans and will be included here as a relative estimate of the instrument contamination control requirements necessary for adequate performance of each instrument. Actual mission budgeted cleanliness levels may be more stringent than these requirements in order to restrict harmful contamination transfer to more sensitive surfaces or hardware elements. This budget, including contamination levels at hardware delivery, will be presented later in this plan. Actual instrument sensitivity levels should be verified in the configuration management version of the instrument's Contamination Control Plan if there are any discrepancies.

Table 2.2-1: OSIRIS-REx Instrument Sensitivity Levels.

Note: The instrument sensitivity levels here have been taken from the individual instrument contamination control plans and are to be included here as a relative estimate of the instrument contamination control requirements. Current required cleanliness levels should be verified in the configuration management version of the instrument's Contamination Control Plan.

INSTRUMENT	COMPONENT	BEGINNING-OF-LIFE		END-OF-LIFE	
		Particulate	Molecular	Particulate	Molecular
OCAMS	Internal Surfaces	Level 400	Level D	Level 400	Level D
	External Surfaces	Level 800	Level D	Level 800	Level D
OVIRS	Internal Surfaces	Level 400	Level A/2	Level 400	A
	External Surfaces	Level 400	Level A/2	Level 400	A
OTES	All Surfaces	Level 800	Level B	Level 800	Level D
OLA	External Surfaces	VC-HS	VC-HS	VC-HS	VC-HS
REXIS	All Surfaces	Level 400	Level D	Level 400	Level D
Sample Hardware (for comparison)	All surfaces contacting sample	Level 50 (at final cleaning)	Level A/3 (at final cleaning)	Level 100 (measured at launch)	Level A/2 (measured at launch)

2.2.1 Instrument Outgassing Certification Requirements

The instruments shall meet an outgassing certification requirement during thermal vacuum testing or at the end of the instrument bakeout, prior to delivery to the flight system, as defined in Table 2.2.1-1. The bake-out/outgassing certification performance shall be measured using a temperature-controlled Quartz Crystal Microbalance (TQCM) at chamber pressures below **$1x10^{-5}$** torr. This device provides information to enable a determination of the duration and effectiveness of the thermal vacuum bakeout as well as measures compliance to the outgassing certification requirements. During certification, the flight hardware shall be maintained at **10** ^{o}C above the maximum allowable flight temperature (AFT) and the TQCM shall be controlled at –**20** ^{o}C or lower throughout the test to measure the total outgassing of volatile outgassed condensables. The TQCM must be mounted within the chamber such that the TQCM has a representative view of the flight hardware or is monitoring the hardware vent. The outgassing certification is required to demonstrate compliance with outgassing levels specified in this document. The purpose of this certification is not only to measure the impact of the instrument on other flight system contamination sensitive hardware, but also to insure that each component will not self contaminate its own sensitive hardware. Any outgassing above the levels specified in this plan may degrade the science and effective performance of one or more components of this flight system. While a bakeout is not strictly required prior to certification, the higher temperatures used in a bakeout phase typically remove contaminants in a more speedy and more efficient manner than an extended certification vacuum period.

The outgassing certification test will be deemed successful when the outgassing rates in Table 2.2.1-1 are achieved for at least **5** consecutive hours during the certification phase. It is also required that a cold finger or scavenger plate shall be used to provide a qualitative assessment of the instrument outgassing effluent at the end of the certification test. The results of the thermal vacuum bakeout / outgassing certification test shall be verified and provided to the OSIRIS-REx Project for approval. The data set shall be recorded at least once every **30** minutes during testing and shall contain, as a minimum, TQCM data, temperature of hardware, chamber/shroud temperature, TQCM temperature, and chamber pressure. In addition, the chamber configuration and cold finger data (qualitative contamination measurement) shall be delivered with the results. All instruments unable to satisfy the outgassing certification requirement must obtain a waiver.

Table 2.2.1-1: Outgassing Requirements for Instruments.

*****Note**: The final molecular transport analysis will be completed after CDR. Current values may change following the final revision of this analysis.

Instrument	Component	TQCM temperature	Outgassing Certification Rate
OCAMS	Instrument level	-20C	$\leq 1 \times 10^{-12}$ g/cm^2-s
OVIRS	Instrument level	-20C	$\leq 1 \times 10^{-12}$ g/cm^2-s
OTES	Instrument level	-20C	$\leq 1 \times 10^{-12}$ g/cm^2-s
OLA	Instrument level	-20C	$\leq 1 \times 10^{-12}$ g/cm^2-s
REXIS	Instrument level	-20C	$\leq 1 \times 10^{-12}$ g/cm^2-s
Sample Hardware	Hardware contacting sample	-20C	$\leq 1 \times 10^{-12}$ g/cm^2-s

If the instrument is unable to adequately analyze the chamber configuration to meet these requirements, the OSIRIS-REx project may be able to analytically convert the outgassing certification requirement to an equivalent TQCM rate given the instrument unique test configuration. If this analysis is desired, the instrument will submit the unique test configuration and chamber data to GSFC at least **30** days prior to the outgassing certification test in order to allow adequate time for GSFC to calculate the equivalent TQCM rate. Required data includes: test configuration, chamber dimensions, pumping efficiency, shroud and hardware temperature, location of scavenger plates, cold plates, and cold finger, and location of the TQCM relative to the hardware.

2.2.2 General Instrument Integration and Test Requirements

The instruments shall be integrated to the Flight system in an operational ISO Class **7** (formerly Fed-STD-209 Class **10,000**) cleanroom. If the room is not meeting ISO Class 7 conditions, work shall be delayed until Class 7 conditions can be restored, or the instrument and/or sample return hardware can be suitably protected from enhanced contamination exposure.

Doors, Apertures, Covers

Instrument protective covers will remain on unless integration and test activities prohibit this. Instrument use of protective covers is defined in the Contamination Control Requirements Section of the respective instrument's OSIRIS-REx Flight system to Instrument ICD. Instrument doors, if any, should be opened within a cleanroom determined and approved by the instrument contamination engineer, with the possible exception of thermal vacuum testing.

Bagging

The instruments will be bagged whenever possible. Instrument doors may be opened within a cleanroom determined and approved by the instrument contamination engineer.

Purge

A nitrogen purge shall be available to the instruments during integration, test (except during thermal vacuum testing), and storage. Nitrogen or clean, dry air will be provided during transportation to the launch site. Purge requirements are discussed in Section 8.4. Purge interface requirements can be found in the Contamination Control Requirements Section of the respective instrument's OSIRIS-REx Flight system to Instrument ICD. Purge System descriptions and requirements will also be found in the OSIRIS-REx Purge System Specification. A quick summary is presented below.

Table 2.2.2-1: Purge Requirements for Instruments/Sample Hardware

Component	Purge Required	Purge Rate	Purge Notes
OCAMS	Yes	5 SCFH	N/A
OVIRS	Yes	5 SCFH aperture closed 20 SCFH aperture open	Primarily for Moisture Reduction 1 hour max interruption per incident
OTES	Yes	5 SCFH	1 hour max interruption per incidence
OLA	No	N/A	He purge may be necessary for calibration purposes only during testing
REXIS	No	N/A	N/A
Sample Hardware	Yes	5 SCFH	Purge is to maintain knowledge of contamination exposure

2.3 OSIRIS-REx Spacecraft Subsystem Requirements

Some spacecraft subsystem surfaces are considered to be contamination sensitive. In fact, the sample acquisition and return hardware developed as part of the spacecraft contract are the most contamination sensitive elements on the flight system. These surfaces and their respective contamination sensitivity levels are listed in Table 2.3-1. To prevent cross contamination, the subsystem components listed in the table will be cleaned to the flight system contamination levels or the contamination levels listed in Table 2.3-1, whichever, is cleaner.

In general, the flight system will be maintained at a level **500A/2** per IEST-STD-CC1246D during assembly. During spacecraft integration, all mating surfaces will be cleaned to and verified to level **500A/2** per IEST-STD-CC1246D equivalent using a VC-HS inspection by a person trained in contamination control inspection techniques before becoming inaccessible. All box exterior surfaces, interior to the spacecraft bus, will also be cleaned and verified to IEST-STD-CC1246D level **500A/2** equivalent using the same VC-HS inpsection prior to Flight system integration. Upon completion of integration, all exterior surfaces on the flight system and subsystems not requiring a more stringent cleaning will be cleaned and verified to an IEST-STD-CC1246D level **500A/2.** Tape lifts, image analysis, and wash samples can be taken at regular intervals. Black and white light inspections can also be made frequently during integration to maintain these levels. A detailed cleaning and monitoring schedule can be found in Table 11.2-1.

Table 2.3-1: OSIRIS-REx Subsystem Sensitivity Levels

Sub-System	At Launch			End-of-Life (or sample safely stowed for sample return hardware)	
	Particulates	Molecular	Amino Acid	Particulates	Molecular
Sample acquisition Hardware	Level 100	Level A/3	180 ng/cm^2	Level 100*	Level A/2
SRC Canister (internal)	Level 100	Level A/3	180 ng/cm^2	Level 100*	Level A/2
Instrument Deck	Level 300	Level A/2	N/A	Level 400*	Level A
TAGSAM Hardware not directly contacting sample (rest of SARA)	Level 300	Level A/2	N/A	Level 400*	Level A
Propulsion (Internal)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Propulsion (External)	VC-HS	VC-HS	N/A	Level 550	Level A
Spacecraft Radiators	Level 500	Level A/2	N/A	Level 550	Level A
Solar Arrays	Level 500	Level A/2	N/A	Level 550	Level A
Star Trackers	Level 500	Level A/2	N/A	Level 550	Level A
Sun Sensors (Coarse)	Level 500	Level A/2	N/A	Level 550	Level A

* NOTE: Neglecting regolith particles from sample collection of the asteroid and those particle generating activities previously anticipated and identified to the science team

2.3.1 Spacecraft Subsystem Outgassing Certification Rates

All flight hardware shall meet outgassing certification rates prior to integration to the flight system per Table 2.3-2. Outgassing rates shall be measured with a TQCM, set at the temperature requirements of -20C, at chamber pressures below **$1x10^{-5}$** torr. All bakeouts will be conducted at the maximum hardware temperature with appropriate safety margin. Outgassing certification shall be done at 10°C above the maximum operational on-orbit temperature. The TQCM shall be mounted within the chamber such that the TQCM has a representative view of the flight hardware or is monitoring the hardware vent. The hardware outgassing certification shall be deemed successful when the outgassing requirements are achieved for at least **5** consecutive hours. For all bake-outs, an 8 hour cold finger (or scavenger plate) sample shall be taken at the end of the certification test prior to vent-back for a qualitative assessment of hardware outgassing effluent at the end of the certification test.

Table 2.3-2: Outgassing Requirements for Spacecraft Components.

*****Note**: The final molecular transport analysis will be completed after CDR. Current values may change following this analysis.

Subsystem	Outgassing rate (g/cm2/sec)	TQCM Temperature (deg C)
High Gain Antenna reflector (Backside is considered MLI)	5×10^{-12} g/cm^2-s	-20
Sample Return Capsule (top surface)	5×10^{-12} g/cm^2-s	-20
Radiators	5×10^{-11} g/cm^2-s	-20
Solar Array Holding Fixtures	5×10^{-12} g/cm^2-s	-20
Solar Array Backside	2.5×10^{-12} g/cm^2-s	-20
Solar Array Cellside	3×10^{-11} g/cm^2-s	-20
TAG Boom ends	5×10^{-12} g/cm^2-s	-20
MLI (Bus and instrument deck)	2.5×10^{-12} g/cm^2-s	-20
Electronic boxes	2.5×10^{-11} g/cm^2-s	-20
Apertures and closeout nodes	1×10^{-12} g/cm^2-s	-20

Support equipment used in the vacuum chamber must meet the minimum flight hardware material requirements (CVCM 1%, TML 0.1%). It is also required that a pre-test chamber bake-out, with ground support equipment and cables, and an outgassing background measurement, with a TQCM, be performed prior to loading the flight hardware in the chamber. This assures that the chamber and ground support equipment will not contaminate the flight system flight hardware and will provide a TQCM background measurement to be subtracted from the TQCM measurements recorded during the actual test. Without the background measurements, the outgassing background in the chamber is assumed to be negligible during the certification test. The pre-test chamber bake-out requirement may be waived by the OSIRIS-REx contamination engineer if chamber cleanliness can be verified by other means.

The results of the thermal vacuum bakeout / outgassing certification test shall be verified and provided to the OSIRIS-REx Project for review. The data set shall be recorded at least once every **30** minutes during testing and shall contain, as a minimum, TQCM data, temperature of hardware, chamber/shroud temperature, TQCM temperature, and chamber pressure. In addition, cold finger and scavenger plate data shall be delivered with the results. All subsystems unable to satisfy the outgassing certification requirement must obtain a waiver. Contact the Contamination Engineer for more test details.

As stated above, OSIRIS-REx Contamination Engineering can analytically convert the outgassing certification requirement to an equivalent TQCM rate given the instrument unique test configuration if the spacecraft vendor is unable to perform this analysis. If this analysis is desired, the subsystem will submit the unique test configuration and chamber data to OSIRIS-REx Contamination Engineering at least **30** days prior to the outgassing certification test in order to allow adequate time for OSIRIS-REx Contamination Engineering to calculate the equivalent TQCM rate. Required Data includes: test configuration, chamber dimensions, pumping efficiency, shroud and hardware temperature, location of scavenger plates, cold plates, and cold finger, and location of the TQCM relative to the hardware

2.4 OSIRIS-REx Flight system Requirements

All flight system surfaces not having a more stringent requirement shall meet an exterior contamination cleanliness level of **500A/2** per IEST-STD-1246C during final assembly and integration. [redacted] (For this mission a trained contamination specialist shall be someone familiar with IEST contamination control procedures who has cleaned and verified highly contamination sensitive hardware in the past. Not simply someone who has cleaned flight or lab hardware at some previous time.) All internal spacecraft surfaces will be cleaned to a level **VC-HS**. Upon completion of integration, all exterior surfaces will be cleaned and verified to level **500A/2** and maintained at that level through testing until launch. Table 11.2-1 contains a detailed cleaning and monitoring schedule.

2.4.1 Flight system Bagging

Because of contamination sensitivities, when the Flight system is outside of an ISO Class **7**/8 (Fed-STD-209 Class **10,000/100,000)** cleanroom, it must be bagged. The only exception is when I&T activities would prohibit bagging. This reason for this exception will included on the work order authorization and shall require OSIRIS-REx Project approval. Additionally, when the flight system is not being worked on in the cleanroom, for an extended period of time, it must be protected with a bag, cover, or drape, if possible, to protect from particulate fallout and minimize required cleanings. During any type of transportation outside the facilities, as in the case of launch site transportation, or during storage, the flight system should be bagged in approved bagging film and stored in a shipping container.

OSIRIS-REx shall be bagged using a contamination and ESD acceptable film. The bags will be designed especially to accommodate the configuration of OSIRIS-REx with special attention to required lifting points. The film may be purchased in a verified clean condition or may be precision cleaned to better than the flight system levels it will contact prior to final assembly in the cleanroom environment (Class 100A/3 is a typical bagging material delivery cleanliness verification level when verified by the vendor). The assembly of the bag will be implemented in the cleanroom. A designated number of bags (minimum of 2 for an additional "double bag" is required, but for "risky" bagging schemes, additional bags may be warranted in case of additional tears during installation) will be made to assure that rupture of a bag being used will not interrupt OSIRIS-REx bagging for a prolonged period.

The bagging concept will be formulated by LM Mechanical Engineering (if support structures are needed) and Contamination Engineering prior to the OSIRIS-REx Flight system Critical Design Review. Final determination of the bagging material and purchased cleanliness condition will be made by LM and approved by the mission CCE.

Individual instrument bags shall be provided by the instrument provider, unless a detailed design analysis is provided to and negotiated with the OSIRIS-REx project prior to integration. These bags will protect the instrument prior to and after integration to the flight system.

The following bagging materials are options to be approved for use on OSIRIS-REx: **Llumalloy** (If still available), Dun-shield 200 by DunMore Corp, or other like material approved by the OSIRIS-REx CCE. Other materials meeting the selection criteria may be approved for use. Selection criteria include ESD, hypergolic compatibility, cleanliness, flammability, and non-shedding. Test methods for evaluating flammability, ESD, and hypergolic compatibility are referenced in KSC document, Material Selection List for Plastic Films, Foams, and Adhesive Tapes. Additional ESD requirements can be found in the OSIRIS-REx Electrical System Specification.

2.4.2 OSIRIS-REx Cleanliness Levels from Assembly to End-of-Life

The following contamination budget table defines internal and external surface cleanliness levels for instruments, spacecraft subsystems and the integrated flight system from instrument delivery to end-of-life. While these levels are the expected contamination levels for the specified hardware, not all budget points will require specific tape lift/NVR rinse verification. These verifications will be required at hardware subsystem deliveries, at the end of integration, and prior to launch. Other budget points may be verified by inspection unless a contamination event has been observed. Additional verifications may be required if deemed necessary by the Project CCE or Flight system CCE with project concurrence. Cleanliness levels presented after launch are detemined by analysis and are verified by analysis only. These analytical values are dependent on well verified hardware cleanliness at launch.

Table 2.4.2-1: OSIRIS-REx Surface Cleanliness Level Budget from Instrument/Subsystem Delivery through Sample Acquisition

Event	External Surfaces	Internal Surfaces
Instruments delivered to Flight system	Level 300A/2	As specified by the specific Instrument CCP unless surface has direct contribution to external surfaces, then Level 300A/2
SRC delivery to SARA	Level 300A/2, 180 ng/cm^2 of amino acids	Level 50A/3, 180 ng/cm^2 of amino acids
Sample Acquisition Hardware delivery to SARA	Level 50A/3, 180 ng/cm^2 of amino acids	Level 50A/3, 180 ng/cm^2 of amino acids
SARA delivery to Flight system	Level 300A/2, 180 ng/cm^2 of amino acids	Level 50A/3, 180 ng/cm^2 of amino acids
Spacecraft Subsystems delivery to Integration	Level 300A/2	Level 300A/2 (instrument deck)
Flight system at start of Integration	Level 300A/2	Level 300A/2 (interior to bus)
Flight system at end of Integration and Test (Instrument deck)	Level 300A/2	Level 300A/2
Flight system at end of Integration and Test (Non Instrument Deck)	Level 500A/2	Level 500A/2
Flight system during Launch Site Preps	Level 500A/2	Level 300A/2 (Instrument Deck)
Flight system at Encapsulation	Level 500A/2	Level 300A/2 (Instrument Deck)
Flight system at Launch	Level 525A/2	Level 325A/2 (Instrument Deck)
Instruments at Launch	Level 325A/2	Level 325A/2
Sample Acquisition and Return Hardware at Launch	Level 50A/3	Level 50A/3
Flight system at Orbit Insertion	Level 575A	Level 400A (Instrument Deck)
Flight system at Sample Acquisition	Level 575A	Level 400A (Instrument Deck)
Instruments at Sample Acquisition	Level 400A	Level 400A
Sample Hardware at Sample Acquisition	Level 100A/2	Level 100A/2

2.4.3 OSIRIS-REx Flight system Thermal Vacuum Testing/ Outgassing Certification

The OSIRIS-REx Flight system will be subjected to flight system level thermal vacuum testing. The OSIRIS-REx Flight system level thermal vacuum test will be performed in a LM approved thermal vacuum chamber. The chamber shall be maintained as an ISO Class **8** or better clean environment. Full cleanroom garments will be worn while working within the chamber.

The thermal vacuum test will be monitored with a series of temperature controlled quartz crystal microbalances (TQCMs) and the following instrumentation: passive fallout coupon samples, cold finger, scavenger plates and optical coupon plates. The outgassing certification portion of the OSIRIS-REx flight system thermal vacuum test will be used to verify the on-orbit contamination analyses. All temperature transitions will be controlled to minimize contamination. In addition, cold plates will be used, as required, to minimize contamination from known high outgassing sources. An analysis will be performed prior to the thermal vacuum test to verify no subsystem or instrument will be susceptible to contamination and so that precautions can be taken to minimize contamination to problem areas.

Support equipment used in the vacuum chamber must meet flight hardware material requirements. A pre-test chamber bake-out, with ground support equipment and cables, and an outgassing background measurement, with a TQCM, shall be performed prior to loading the flight hardware in the chamber. This assures that the chamber and ground support equipment will not contaminate the flight hardware. The pre-test outgassing levels shall be measured and verified to meet the chamber certification levels defined in OSIRIS-REx Flight system Thermal Vacuum Plan.

Outgassing certification rates shall be verified during a hot cycle of thermal vacuum testing. The last hot cycle of the thermal vacuum testing is preferred. During certification, the flight hardware shall be maintained at its maximum on-orbit operation temperature. The hardware outgassing rate shall be measured with a series of TQCMs for at least **5** consecutive hours. The TQCMs must be mounted within the chamber such that each TQCM has a representative view of the flight hardware or is monitoring a hardware vent. The TQCM temperatures shall be defined in the OSIRIS-REx Flight system Thermal Vacuum Plan. If the flight hardware does not meet the outgassing certification requirements, the flight system shall be subjected to a contingency bakeout.

3.0 Contamination Sources and Analyses

Possible sources of contamination must be identified in order to protect OSIRIS-REx from contamination and to effectively clean contaminated components. Table 3.0-1 is a listing of typical possible contamination sources at various development stages.

Quantitative estimates of contamination sources and deposits will be made for critical surfaces through the analyses as listed below. A physical description of the contamination environment (molecular/particulate) of the surrounding critical surfaces will be provided by OSIRIS-REx Contamination Engineering. The analyses will consider the locations, geometry, and operation of sensitive surfaces relative to potential contamination sources.

Table 3.0-1: Contamination Sources for OSIRIS-REx

Mission Phase	Molecular	Particulate
Fabrication	Machining oils, fingerprints, air fallout	metal chips, filings, air fallout, personnel
Assembly and Integration	air fallout, outgassing, personnel, cleaning, solvents, soldering, lubricants, bagging material	air fallout, personnel, soldering, drilling, bagging material
Test	air fallout, outgassing, personnel, test facilities, purges	air fallout, personnel, test facilities, purges, redistribution
Storage	bagging material, purges, containers	bagging material, purges, containers
Transport	bagging material, purges, containers	bagging material, purges, containers, vibration
Launch Site	bagging material, air fallout, outgassing, personnel, purges	bagging material, air fallout, personnel, checkout activities, other payload activities, purges
Launch	Outgassing, venting, launch vehicle	vibration and/or redistribution, launch vehicle
OSIRIS-REx On-Orbit	Outgassing, atomic oxygen, propulsion effluent, glow, electrostatic return, polymerization effects	OSIRIS-REx cloud, micrometeoroid and debris impingement, material erosion

3.1 Thruster Impingement

The spacecraft should be designed to minimize thruster impingement on contamination sensitive surfaces. These surfaces include the sample acquisition site. Thruster firing impacting the acquisition site may degrade the species in the returned sample. Impingement of the thrusters with the actual acquisition sight should be minimized as much as possible. The spacecraft propulsion system will be using ultra-pure hydrazine as a propellant. A preliminary analysis was performed indicating the effects of plume analysis on sample site during the mission phase A period. A follow-up analysis will need to be performed to determine the thruster effluent deposition levels on the sample hardware and instrument exterior surfaces through sample acquisition and mission end of life. The deposition levels shall be no more than **180** ng/cm^2on TAGSAM surfaces. The effects from orbit insertion burns, attitude correction burns, TAG events, and any required special maneuvers are to be included in the analyses.

3.2 Atomic Oxygen Effects

The duration of OSIRIS-REx at altitudes that would generate appreciable atomic oxygen erosion of exposed materials is **negligible**. No atomic oxygen erosion requirements are specified for this mission.

3.3 In-Flight Analyses

Contamination mass transport analyses of in-flight contamination will be performed by the GSFC Contamination Engineering for the OSIRIS-REx mission. The molecular impingement rate on sensitive surfaces as well as the total amount of contaminants depositing on those surfaces will be calculated over the life of the mission. The contaminant flux to each instrument aperture, as well as other contamination sensitive surfaces, will be provided to each instrument provider. The mass transport analyses will take into account in-flight outgassing, electrostatic return mechanisms, instrument and spacecraft venting, and propulsion plume impingement. The analyses are to be documented and available for review.

The subsystem and spacecraft outgassing requirements (Tables 2.2.1-1 and 2.3-2) will be derived from the in-flight analyses, based on sample hardware and instruments contamination requirements. In addition, the analyses to be used will verify the effects of the propulsion system and choose the optimal flight system vent locations.

An additional analyzed effect will be to determine those non line-of-sight materials which may impact the sample acquisition hardware and will need to be archived for potential future study.

Mass transport analyses should also be performed for each instrument to determine their acceptable contamination accumulation as well as to determine the potential benefits of any in-flight decontamination procedures.

3.4 Particle Redistribution Analysis

A particle redistribution analysis will be performed by the GSFC Contamination Engineering for the OSIRIS-REx Flight system, if necessary. The analysis will predict particle redistribution on the Flight system due to launch forces, launch vibration, and launch vehicle cleanliness. The change in exterior particulate cleanliness levels on sensitive surfaces during launch will be calculated. This analysis is performed by the launch vendor for each mission. If this analysis is deemed to be adequate, no further analysis will be performed. However, if this analysis is not of sufficient detail, a more refined analysis will be performed as instructed above.

3.5 Venting Analyses

OSIRIS-REx will be using directional venting to aid in contamination control procedures. Since this process does not allow free flow of entrapped air volume, Mechanical Engineering will need to perform an OSIRIS-REx de-pressurization analysis to size the spacecraft vent paths with respect to bus volume. The vents will be sized to keep the maximum delta-pressure on the spacecraft below the allowable pressure differential. Spacecraft vent placement on the spacecraft bus will be determined by the results of this analysis and the output from the molecular mass transport analysis mentioned above. The size and efficiency, if any, of the molecular getters, located in the spacecraft bus, will be calculated as well. Section 4.1.1 provides the details for the spacecraft vent.

In addition, venting analyses will be used to verify instrument and subsystem vent locations to prevent spacecraft to instrument, instrument to sample hardware, spacecraft to sample hardware, and instrument to instrument cross contamination.

A separate venting analysis must also be performed on the Sample Return Canister (SRC) as it must survive not only a depressurization on ascent, but also a re-pressurization event on sample return. This analysis should consider contamination concerns when placing volume vent locations and blanket placement to limit contamination cross transfer.

3.6 Miscellaneous Analyses

A number of other analyses will be performed by either GSFC or LM Contamination Engineering for the OSIRIS-REx program to include:

The OSIRIS-REx thruster impingement analyses will be performed to verify thruster placement with respect to effluent impingement, pressure, and heating effects. Trade study results can be requested from the OSIRIS-REx Contamination Engineer.

Contaminant polymerization studies will be performed by GSFC, if needed, based on the need of the instruments.

4.0 Design, Materials and Processing Requirements

4.1 Venting

The Flight system exterior components, spacecraft vents, and Instruments must be designed such that all outgassing and propulsion plume products are vented away from instruments, sample acquisition hardware, and sensitive parts of the Flight system. Sensitive components include apertures, thermal control surfaces, star trackers, sun sensors, sample hardware, and solar arrays. Correct venting design may require the use of directional venting, baffles, filters and/or labyrinth seals.

Venting analyses will be performed by LM Contamination Engineering and/or Mechanical Engineering to verify instrument and subsystem vent locations in order to prevent cross contamination from improper venting. Details of the instrument vent locations should be defined in the Instrument Mechanical Interface Control Drawings (Mechanical Implementation Details) of each Flight system to Instrument ICD. As much of this spacecraft has an open design, blanket locations will often dictate the location of these vents and should be verified in all ICD documentation.

4.2 Materials

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. The materials should be chosen from the following web site: http://outgassing.nasa.gov which is a replacement for NASA Reference Publication 1124. Manufacturing materials not listed in the reference publication shall be tested by Code 541, Materials Branch, in accordance to ASTM E595; "Methods of Test, Total Mass and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment".

Materials shall meet the CVCM level of 0.1% and TML of 1.0% by weight, in order to be used in fabrication and assembly. If a material does not meet these standards, it must be discussed with the Contamination Engineer (GSFC 546) and Materials Engineer (Code 541) for a possible waiver.

Additional materials requirements not related to contamination control must also be met. These requirements are specified in the OSIRIS-REx Materials and Processes Selection, Implementation, and Control Plan (MPCP).

4.2.1 Material Restrictions

Materials for flight system design may be limited for a number of reasons. Two primary reasons are general contamination produced and mission specific contamination concerns. For OSIRIS-REx, both concerns are present and may limit the acceptable materials which may be used. This CCP is the primary source for contamination related materials restrictions. Materials restrictions for non-contamination related reasons will be addressed by the OSIRIS-REx Materials Identification and Usage Lists (MIUL) maintained by materials engineering.

4.2.1.1 General Contamination Materials Restrictions

The following materials are known to cause outgassing or surface contact contamination problems and shall be prohibited or the quantity used shall be tightly controlled and demonstrated to not pose a threat to contamination sensitive surfaces.

- Silicones shall be prohibited/limited in areas where mass transport modeling demonstrates that they may be transported to contamination critical surfaces unless specifically approved by the OSIRIS-REx Contamination Engineer and the OSIRIS-REx Materials Engineer. Silicones are difficult to remove using either chemical or vacuum baking cleaning techniques. Silicones may creep due to low surface tensions. Silicones also polymerize into a dark highly absorbing contaminant deposit.
- Silicones used in other areas shall be limited and minimized in quantity. Those used will have the lowest TML and CVCM outgassing properties available for the application.
- Foams
- Non-flight adhesives (in masking tapes, temporary bonding activities, and other fabrication and test activities) for ground operations shall be generally prohibited. Where use is unavoidable, the quantity used will be minimized and all residues shall be removed from flight hardware surfaces as well as any surfaces where there is a possibility of transfer to a flight surface.

In addition, some materials are known particle generators and usage of such materials shall be controlled and monitored, particularly near contamination sensitive surfaces.

- Paints which can become particle generators when improperly applied (e.g., over spray or excessive thickness) or cured (insufficient humidity or temperature or insufficient or excessive curing of a base layer prior to application of second layer). Silicates may present particle

generating hazards.
- Some surfaces become particle generators when over-handled -- e.g., painted surfaces and surfaces with flexible substrates with metallic or paint coatings.
- Paints containing large pigment particles.
- Some dry lubricants
- Surfaces prone to corrosion or oxides.
- Fabrics with brittle constituents (e.g., composites, graphite or glass).
- Perforated materials when insufficient post-cleaning is performed or material is highly susceptible to tear propagation (e.g., MLI).
- Metal oxides (bare (untreated) aluminum and magnesium, iron, non-corrosion resistant steel, etc.).
- Materials containing fabric or fabric scrim (these materials must have all edges sealed with tape if used in optic cavities or near optic cavities.
- Braided metallic or synthetic wires, ropes, slings, etc. (these must be sheathed entirely).
- Woven materials especially cut or unfinished ends (metal braid, EMI shielding, lacing cord, expando sleeving).
- Materials with thin films that might erode or crack and flake (ITO Teflon MLI, metallized packaging materials).

4.2.1.2 Mission Specific Materials Restrictions

Due to the sensitivity of this mission to the contamination environment, several materials have been deemed unacceptable for use on this particular mission. Aside from the materials issues mentioned above, materials which would produce amino acid like materials have also been restricted. Because amino acids are one of the primary focal points of the science data, materials producing these species would degrade the mission science. These materials include Latex, Nylon, and poly**a**mide materials. Poly**i**mides (like Kapton) are acceptable for use however.

4.3 Mechanisms and Deployments

Mechanisms and hardware deployments shall not generate particulate debris or molecular contaminants that will cause adjacent external surfaces or other external contamination sensitive surfaces to exceed their allotted cleanliness levels. Design of internal mechanisms shall restrict or prohibit the venting of lubricant via a labyrinth seal, if possible. In addition, effluent from vents in mechanisms will not impinge upon external contamination sensitive surfaces. Particulate debris generation and molecular contamination generation of mechanisms and hardware deployments will be verified via test data or analyses.

4.4 Processing Requirements

Contamination control measures should be used during all manufacturing phases and storage/transportation. Surfaces should be kept clean, and if any debris is generated during the manufacturing process it should be immediately vacuumed with an ESD compatible vacuum or wiped off with solvent dampened extracted wipes. Some surfaces cannot be wiped with a solvent. ITO is such a surface. Germanium surfaces may be wiped, but require gentle handling. Kapton can be wiped with a solvent dampened extracted wipe without excessive concern for the surface. Black Kapton can be wiped with an extracted wipe dampened with a solvent, but excessive solvent use is not advisable. Detailed information and cleaning procedures for OSIRIS-REx surfaces will be found in the OSIRIS-REx Cleaning and Verification Procedure.

All ground support equipment should be cleaned and inspected to **VC** (visibly clean) per JSC-SN-C-0005 before it enters the cleanroom. Cables should be bagged and all suspect equipment should be precision cleaned. Equipment with cooling fans must remain downstream from sensitive hardware or remain outside of the cleanroom. Support equipment used in the vacuum chamber must meet flight hardware material requirements and will be subjected to a bakeout prior to hardware bakeout and thermal vacuum testing. Whenever hardware is not being worked on for an extended period of time, it should be covered or bagged. Covering materials and drapes must be contamination and electrostatic discharge (ESD) approved. Protective bagging and covering materials at the launch site must also be hypergolic compatible and pass flammability acceptance levels as per KSC requirements. Additional bagging requirements can be found in Section 2.4.1.

All work order authorizations involving hardware-related work on the flight system (including mechanical operations, blanket installation, electrical mating and/or rework, subsystem installation, etc.) must include steps to verify all tools and materials are clean prior to work and are accounted for when work is complete. In addition, a visual inspection for molecular and particulate contamination must be performed and the area cleaned in accordance to the appropriate hardware or facility Cleaning and Verification Procedure.

To prevent electrostatic discharge (ESD) damage to any of the electronic components, precautions beyond contamination control measures will be required. This may mean using antistatic packaging films that also meet the contamination requirements of Section 2.4.1, ESD approved garments, and grounded wrist straps. Additionally, the temperature and humidity of the work environment will have to be controlled. Concerns pertaining to ESD should be brought to the attention of Quality Assurance.

5.0 Contamination Knowledge Requirements

Unlike many other contamination sensitive missions, the particular type and species of contaminant are of significant importance to the OSIRIS-REx mission. For this reason, knowledge of what contaminants and contaminant sources are present is a critical element of the contamination control plan for this mission. These Contamination Knowledge (CK) requirements involve three primary areas. Flight witness plates which will measure the contamination environment in-flight. Ground contamination monitoring plates which will measure the contamination environment while processing during ground operations. And material archiving which will preserve material species for later study should a need arise to study the source of particular contaminating elements which effect the returned sample. Use of the CK element has enabled the contamination requirements presented in this plan to be, while highly stringent, at least achievable.

The CK elements listed above allow the science team for this mission to essentially calculate a contamination "background". This background would show what species and how much of each contaminant was likely present within the sample. This background can then be subtracted from the sample during analysis much like a dark field measurement is usually subtracted from other types of detectors. Knowledge of this background allows a practical level of contamination, to be present and still achieve mission requirements, reducing the cost of contamination implementation of highly stringent cleanliness levels.

5.1 Contamination Knowledge Flight Witness Plates

During the flight portion of the OSIRIS-REx mission, CK data will be accumulated through the use of flight witness plates. To provide representative data, **Flight witness plates** are located by the sample acquisition hardware (TAGSAM head and SRC canister). These plates accumulate species which may be **transferred TO or FROM the sample** and which may hinder future measurements by the science team. The witness plates are composed of two materials (Aluminum, and Sapphire) in order to best collect a representative sample of the CK background. Since each of these materials can be analyzed by different methods, this gives more flexibility to the background calculation.

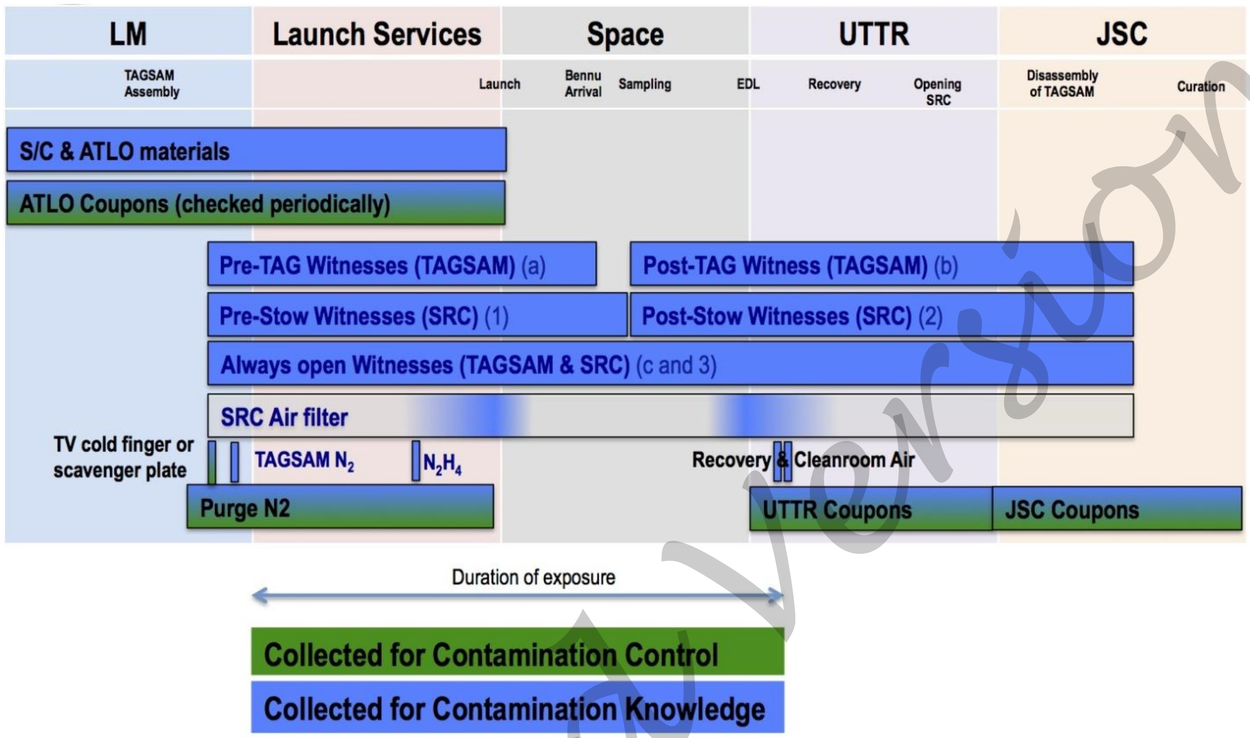
Obtaining CK with a single flight witness plate would be the easiest method, but is not adequate to obtain the most useful background knowledge. Contaminant species accumulated on the witness plate could have been from the spacecraft, from the sample itself, or from a source to which the witness was exposed, but the sample was not. More witness definition is required to separate the effects of these different accumulations. Multiple plates allow the science team to subtract accumulation from different phases in order to better identify contamination sources. Flight witness plates will be required for three time periods of the mission. Each period has a distinct focus and increases the CK of that time period. The comparison of these plates in conjunction with the other plates provides the most complete picture of what the sample has experienced, however any CK developed from any number of these plates has value. If a particular plate is compromised, the others still provide valuable CK as well as some redundancy.

Each of the three time periods is represented on both the TAGSAM and the SRC hardware. These time periods are:

1) Before the mission sample has been acquired.
2) After the mission sample has been acquired.
3) The period between these two is required due to the timing of the Design Reference Mission (DRM).

Table 5.1-1 shows the timeline of exposure for each of these plates. The witness plates located on the TAGSAM head are labeled a, b, and c. The witness plates located on the SRC are labeled 1, 2, and 3. The witness materials and witness exposure period are paired between the two groups. The SRC Air Filter may provide some additional CK to assist with the study of these plates.

Table 5.1-1: Flight Witness Plate Exposure Timeline.



The first time period (1,a) is of general outgassing and molecular transfer from elements of flight hardware **TO** TAGSAM sample sensitive hardware (TAGSAM head, Launch container, and SRC canister (TLS) hardware). These plates show contaminants sources prior to acquisition which may be transferred to the sample. These plates are exposed from encapsulation through sample acquisition. These plates are intended to demonstrate any material which could have accumulated on the TLS hardware, but did not leave via changing environmental conditions and may transfer to the sample by direct contact.

The second period (2,b) is after sample acquisition through recovery. These plates measure contamination which may be transferred **TO** the sample via outgassing **after** the sample has been acquired. These species may also react with the sample directly due to environmental conditions. These plates will also demonstrate any species that may have outgassed **FROM** the sample after acquisition. The combination of these plates with the first period plates can separate out the species lost from the sample from those accumulated from general contamination transfer.

A third set of plates (3,c) is exposed for the entire duration as a "total" accumulated contaminant mass measurement. These plates fill in the gaps in witness exposures 1a and 2b. Gaps arise since the opening and closing of witness plates is driven by other s/c operations (e.g. removing the TAGSAM from the launch container). These plates also provide information on any interactions between the contaminants in group 1 with those from group 2.

5.2 Contamination Knowledge Ground Contamination Monitoring Plates

A series of **ground contamination monitoring plates** will be exposed throughout ATLO to capture the contaminant species to which the hardware was exposed from both known and unknown sources during ground processing. To avoid confusion with the plates used in section 5.1, the plates used for this ground based contamination monitoring and archiving will be referred to as contamination monitoring plates rather than witness plates as is common. These plates will be collected on a regular basis and archived at the mission archive site for potential future analysis. These plates are in addition to the normal facility monitoring plates used to insure proper performance of the clean area. These archived plates will typically be exposed and exchanged on the same schedule and same location as the facility contamination monitoring plates

The contamination monitoring plates will typically be exposed on a monthly basis, but may be exposed for lesser time periods to distinguish critical events. The archived plates will not be cleaned and reused as many contamination monitoring plates are used, but will be stored in as used condition until archived. Both types of plates should be positioned in the cleanroom to accumulate representative samples of what the flight hardware will experience. They should be placed in locations where they will not be touched, handled, or need significant movement during ATLO operations.

These plates will also be used during the recovery phase at UTTR and at the JSC archiving site. Table 5.1-1 lists periods of exposure times for these monitoring plates as well. The green contamination control monitoring plates at UTTR and JSC will be the standard plates used to monitor these facilities for proper cleanroom operation since they will be housing the returned sample and must be adequately controlled.

5.3 Materials Archiving for Contamination Knowledge

Materials which are in direct line of sight to the sample TLS sensitive hardware will need to be archived for later analysis. These materials contain contaminating species which may transfer to the sample and obscure the science data collected via contact transfer or molecular outgassing. This will include all TAGSAM, TAGSAM arm, SRC, and launch container hardware. While much of the science deck of the spacecraft will have a direct line of site to sample hardware during integration operations, transfer from non SARA hardware should be limited to outgassing/offgassing and should be archived by use of the flight witness and ground contamination monitoring plates. Spacecraft hardware archiving lists and specific requirements will be detailed in the OSIRIS-REx spacecraft CCP. A sample of these materials of at least 1 gram shall be saved from the specific material type and lot at the JSC Curation facility. A separate archived sample is required for each unique set of hardware manufacturing conditions. If the hardware was processed at a different time, on a different machine, or using different materials, a new archive sample shall be acquired. Sample archiving acquisition, storage and transport details are given in the OSIRIS-REx Materials Archiving Plan presented as appendix D of this CCP.

Materials which are not direct line of sight but may be transferred to the sample hardware by other means may also need to be archived. This would include any materials which would display significant shedding of particulate material (ie. velcro, foam, or paints with flaking concerns). Lubricants will also need to be archived due to the specific nature of these materials. Lubricant are easily transferred by contact transfer and creep mechanisms. Transfer techniques which are not as present in most other materials. As each of these transfer mechanisms could cause transfer of contaminants to the sample which are not collected on the flight or ground plates, these materials will need to be archived.

For materials that are not line of sight, but may outgas, the archiving of potentially transferred materials is covered by the use of ground and flight contamination monitoring plates and witness samples. For most instrument, and non science deck spacecraft hardware no archiving of these materials is required other than the specific exemptions listed above.

5.4 Contamination Knowledge Requirements for Gases

Gaseous materials used on both the flight system as well as during ATLO activities which encounter the sampler return hardware will also need to be archived. This would include a sample of the purge gas used during ATLO, the nitrogen used in sample acquisition, and the purge gas used during retrieval and archiving at the curation facility. A sample of these materials of at least 1 gram shall be saved from the specific material type and lot at the JSC Curation facility. Sample archiving acquisition, storage and transport details are given in the OSIRIS-REx Materials Archiving Plan portion of this document (Appendix D).

5.5 Materials Archiving of the Hydrazine Thrusters

Due to the reactive nature of the hydrazine material, keeping a sample of this gas for archiving will not adequately represent the material as used during either flight or fabrication. The material is likely to react with the environment and may pose a risk to the curation facility personnel. For this reason a detailed analysis of the gas will be archived, and a fired thruster will be archived as well. These will be the representative sample of the thruster environment experienced by the sample. Sample archiving acquisition, storage and transport details are given in the OSIRIS-REx Materials Archiving Plan portion of this document (Appendix D).

5.6 Archiving of Contamination Monitoring Solvent rinse/washes

Because the solvent rinses used in cleaning the flight hardware are a good representative sample of the materials on the surface, a sample of these rinses will also need to be archived for potential future study. While not every rinse needs to be archived, the primary and final cleaning of sample hardware acquisition components should be archived. In addition, a sample of the scavenger plate rinse from thermal vacuum testing of the sample hardware, or flight system hardware should also be archived. A sample of these materials of at least 1 gram shall be saved from the specific material type and lot at the JSC Curation facility. Sample archiving acquisition, storage and transport details are given in the OSIRIS-REx Materials Archiving Plan portion of this document (Appendix D).

5.7 Coordination with Science Team CK Plan

As scientific study is always a changing process, the details laid out for contamination knowledge in this plan may need to be changed based on future analysis. As this plan is intended more as a definition of how to implement the processes needed to collect contamination knowledge information rather than the study of the CK itself, all requirements must be coordinated with the OSIRIS-REx Contamination Knowledge Plan provided by the mission Science team. If these plans are in conflict, the Contamination Knowledge Plan shall take precedence for CK collection activities.

6.0 Cleanroom Facilities and Operational Requirements

Integration of OSIRIS-REx shall occur in both an ISO Class 7(Fed-Std-209 Class 10,000) as well as an ISO Class8(Fed-Std-209 Class 100,000) or cleaner facility. When the TLS sample acquisition hardware or sensitive instrument hardware must be exposed, the facility must be a Class 7 facility. During periods when the sensitive hardware is being protected or the TLS hardware is not present, a Class 8 facility may be used. The facility shall provide a HEPA filtered bank at the ISO certified flow rate for the specified cleanroom class. Air flow shall be vertical, from top to bottom whenever possible. The most sensitive hardware will be placed closest to the HEPA filters in the cleanroom and less sensitive hardware will be kept downstream from the more sensitive hardware. Typical cleanroom temperature should be maintained at 72 +5/-10°F and the relative humidity should be maintained at 30 to 50%.

Spacecraft hardware and ground support equipment shall be cleaned to the required levels by Contamination Control Technicians in a precision cleaning room. All hardware cleaned in the precision cleaning room shall be double bagged for transportation to the cleanroom facility if not within the cleanroom facility. For convenience, a precision cleaning station may be set up outside the cleanroom facility where appropriate.

The following subsections detail the typical operations of this type of cleanroom for this class of mission. Following the specific techniques in these sections will insure the proper operation of the cleanrooms used to house mission hardware at acceptable levels. While the specific techniques in these sections are more guidelines than specific requirements, the areas covered must be addressed in all cleanrooms used on this mission. Providing a method to address the proper operations specified in these sections is a requirement and if the following techniques are not used, an approved alternate method must be presented and approved by the mission CCE.

6.1 Cleanroom Garments

Personnel entering the cleanroom are required to use a shoe cleaner, walk on a series of tacky mats, and use the air shower if available. Cleanroom type garments will be worn in the cleanroom at all times. The best garments are usually made of polyester and are efficient particulate filters to human generated contamination. In addition, garments must meet ESD standards. Full cleanroom garments, including bunny suits, face masks, hoods, boots, and gloves shall be worn on the OSIRIS-REx program when in an ISO Class 7 (Class 10K) cleanroom or when the TLS hardware is exposed. This garmenting is highly recommended in all other cleanroom environments as well. Details on gowning and personnel operation procedures will be found in the specific facility Personnel Operations Procedure.

6.2 Non Volatile Residue Levels in the Facility

Monitoring of the molecular cleanliness level (typically NVR level) of the cleanroom is necessary to insure the cleanroom does not adversely contaminate the OSIRIS-REx hardware. Molecular contamination monitoring plates (or foils) are typically used to monitor the molecular contamination level in the facility. At least **2** plates will be exposed at any given time. The plates will be analyzed **once** per month, staggered so one plate is measured every **60** days. The acceptable level of NVR on the plate after 2 months is **Level A** per IEST-STD-CC1246D, **1 mg/0.1m^{2}.**

Amino acid specific residue testing shall also be performed once the SARA hardware is present in the facility. Prior to SARA being in the facility, no amino acid testing is required as all hardware shall be cleaned prior to integration with the flight system. This residue is measured on foils specially prepared for this use. The foils will be provided by the GSFC science team, or may be prepared by the vendor if the appropriate preparation techniques can be implemented on site with the approval of the GSFC science team. These monitoring foils shall be placed within the facility for exposure of a minimum of 60 days and shall not exceed 180 ng/cm^{2} when analyzed. These foils will need to be analyzed by GSFC science team either at the LM facility or via shipment of the foil samples to GSFC. The vendor is NOT required to perform this analysis.

6.3 Particle Counts in the Facility

The facility environments will be continuously monitored with a particle counter near the personnel work area. If the particle counts exceed the room specification (Class 7 or 8), personnel will leave the facility and/or contamination-generating operations will stop, as directed by the Integration and Test Manager, the Integration and Test Manager's representative, or Quality Assurance. If facility in house monitoring is not available, a suitable portable particle counter placed near the hardware is also adequate. If continuous monitoring cannot be made available, a well defined regular schedule of monitoring shall be provided for approval. Non continuous monitoring shall require more frequent inspections of the hardware be performed to insure no contamination events have occurred. The less frequent the monitoring, the more frequent the inspections must be performed. Initial calibration of the cleanroom alone is not adequate to monitor the proper operation of the cleanroom. This would allow the cleanroom to operate out of spec without any indication of a contamination event until it has already caused a significant disruption and possible damage to the hardware.

6.4 Cleanroom Maintenance

A properly maintained facility will be cleaned a minimum of twice per week or more often as necessary. The cleanroom will be vacuumed, than mopped with deionized water and low-residue, non-ionic detergent. Scaffolding and other work fixtures will be cleaned at that time. **LM** will perform the facility cleaning operations during flight system integration using the procedures outlined in the facility Personnel Operations Procedure at all LM facilities. Launch site facility cleaning schedules and responsibilities will be detailed in the launch site contamination control plans listed in appendix C of this document.

6.5 Support Materials

Tools, GSE, and any other items containing materials that shed, slough, or flake particles or outgas molecular contaminants at room temperature are prohibited from the clean room. The cleanliness requirements for tools and GSE are given in Section 8.1.

In addition, only non-retractable ball point pens should be used for writing in the cleanroom. Documents needed in the cleanroom will be on lint-free cleanroom paper, cleaned, and bagged for transport. If this practice is not possible, the documents shall be bagged and sealed in clean bagging material and remained bagged while in the cleanroom. All documents shall be kept downstream of flight hardware.

Additional material and personnel regulations will be found in the facility Personnel Operations Procedure. Where there is any conflict with these requirements, the more stringent requirement will prevail.

6.6 Facility/Maintenance Restrictions During ATLO

The following table describes the facility and maintenance restrictions while OSIRIS-REx is in the ATLO complex. While these restrictions are not specifically imposed on the instrument vendors, the restrictions posted in this table can help prevent contamination events and should be followed whenever possible.

Table 6.6-1 Facility/Maintenance Restrictions

Activity	Restrictions	Restriction Time Period
Combustion Engine Operation Standard Operations (Mowing Grass, normal deliveries)	No restrictions	From OSIRIS-REx assembly to shipping date
Combustion Engine Operation (Buses, idling trucks, etc)	Not permitted outside near air intakes	From OSIRIS-REx assembly to shipping date
Combustion Engine Operation Non-standard Operations (cranes, forklifts, trucks, construction, generators, etc)	Need Approval. May be allowable depending on location of flight hardware	From OSIRIS-REx assembly to shipping date

Activity	Restrictions	Restriction Time Period
Herbicides / Pesticides	Not permitted outside/inside ATLO Complex.	From 1 months prior to OSIRIS-REx assembly to shipping date
Painting (exterior)	Ask for approval prior to painting outside ATLO Complex	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Painting (interior)	Ask for approval, some complex locations acceptable.	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Roofing / Roofing Repairs	None within ½ mile of ATLO Complex	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Paving	None within ½ mile of ATLO Complex	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Facility floor cleaning/stripping/waxing	Ask for approval. Not permitted within building housing OSIRIS-REx flight hardware.	From OSIRIS-REx assembly to shipping date
Facility Floor Maintenance (Pouring/replacing/repairing floors)	Ask for approval within complex	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Solvent usage in ATLO high bay	Non typical solvent use (i.e. IPA, Acetone, Freon) requires approval	From OSIRIS-REx assembly to shipping date
Sealants, caulks (Windows, bathrooms, ceiling tiles, HEPA filters, etc)	Ask for approval within ATLO Complex	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Adhesive bonding, gluing (installation of carpets, base board molding, flooring, etc)	Restricted in ATLO complex; Ask for permission based on specific location within building	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Sandblasting, sanding, grinding, jack hammering	Not permitted near air intakes in ATLO Complex	From 2 weeks prior to OSIRIS-REx assembly to shipping date
Repair, replacement, or lubricant of cleanroom equipment (Air handling equipment, cranes, doors, etc)	Ask for approval. Not permitted within building housing OSIRIS-REx flight hardware.	From 2 weeks prior to OSIRIS-REx assembly to shipping date

Activity	Restrictions	Restriction Time Period
Use of equipment with air bearing	Notify project to allow protection of critically sensitive operations if in same facility	From OSIRIS-REx assembly to shipping date
Fluorescent lamps	Lamp tubes must be encapsulated and cannot be handled within the cleanroom environment	From 2 weeks prior to OSIRIS-REx assembly to shipping date

7.0 Contamination Control during Fabrication and Assembly

7.1 OSIRIS-REx Instruments during Fabrication and Assembly

The Instrument Providers are responsible for the Contamination Control of their instruments during instrument fabrication and assembly at the instrument facilities. The Instrument Providers are also responsible for instrument transportation to LM per the instrument contamination control plan and other applicable instrument documentation. Instruments shall be delivered to the flight system meeting the cleanliness compatibility requirements specified in Section 2.2.

The Instrument Providers shall supply an instrument Contamination Control Plan to detail the contamination requirements and contamination control procedures necessary to insure proper performance of the instrument hardware. This document shall be the guiding document during instrument fabrication and assembly operations.

7.2 OSIRIS-REx Spacecraft during Fabrication and Assembly

OSIRIS-REx spacecraft will be provided by LM-Denver. The Spacecraft Provider shall provide a spacecraft contamination control plan (CCP) which will be the guiding document during spacecraft fabrication and assembly operations. The spacecraft and all subsystems shall be delivered to the flight system meeting the cleanliness compatibility requirements specified in Section 2.3-1 and Section 2.4.2-1.

To facilitate the ability to maintain these levels, the spacecraft shall generally be maintained at level **500A/2** per IEST-STD-CC1246D throughout the fabrication process where more stringent cleanliness requirements are not specified for sensitive hardware elements (ie SARA, SRC, and sample TLS hardware). This cleanliness level may be verified at most times by meeting VC-HS inspection by a contamination trained individual. The cleanliness level must be verified prior to delivery for integration and following the completion of integration operations. As surfaces become inaccessible they must pass an inspection to VC-HS and be cleaned if necessary to level **500A/2** per IEST-STD-CC1246D or better prior to final closeout. VC-HS inspection by a contamination trained individual shall be deemed equivalent to, or better than level 500 A/2 for these periods.

The following guidelines apply during spacecraft and subsystem fabrication and assembly.

Internal electronic box level and board level fabrication and assembly shall be governed by the proven cleanliness practices of the box vendor.

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, the surface should be cleaned free of particulate or molecular deposits and be inspected to VC-HS as an equivalent for level **500A/2** per IEST-STD-CC1246D. If an area becomes inaccessible during fabrication, it must be cleaned and inspected to this same level before becoming inaccessible. Upon completion of a fabrication operation, the components will be subjected to a gross cleaning procedure involving solvent washes and particulate removal. The clean fabricated components will then be bagged.

Assembly of fabricated components will take place in an ISO Class8(FED-STD-209 Class 100,000) facility. During assembly, parts will be inspected and cleaned to **VC-HS,** unless required to be cleaner, prior to becoming inaccessible. The following guidelines should be adhered to in the assembly process.

Parts, surfaces, holes and so forth must be cleaned with isopropyl alcohol (IPA) moistened wipes or swabs. Only approved wipes, that are low in particulate generation and low non-volatile residue, shall be used. Wiping should be in one direction only and each pass should be with a new clean area on the existing wipe or using a new wipe. In some instances, wipes will be ineffective and extracted swabs moistened with alcohol may be used. Cleaning will continue until all surfaces are visibly clean, highly sensitive upon inspection. Any cleaning of painted surfaces will be done according to the procedure recommended by the manufacturer or be performed by the responsible hardware vendor. Prior to any final assembly, all surfaces must be vacuumed and wiped with the appropriate solvent, giving special attention to holes, crevices and riveted regions. Assemblies will be inspected for oil or grease deposits, and if any are found, the areas will be wiped with IPA moistened wipes or other appropriate solvent, using a clean wipe area for each pass and wiping in one direction.

7.3 OSIRIS-REx Flight system during Fabrication and Assembly

The Flight system integration will occur in the LM ATLO complex in both an ISO Class7(FED-STD-209 Class 10,000) facility as well as an ISO Class8(FED-STD-209 Class 100,000) facility operated as an ISO class 7 facility at various times. Parts from a less controlled fabrication and assembly area will be cleaned to VC-HS or the required levels defined in Tables 2.3-1 and 2.4.2-1, prior to entry into the cleanroom.

Accessible areas of the [redacted] Parts that have been machined, welded, or riveted will be inspected to a general **VC-HS** level with white and black lights, or to the required more stringent IEST-STD-CC1246D level prior to entering the cleanroom.

Solar panels, coarse sensors and radiators will be cleaned according to the OSIRIS-REx Spacecraft CCP approved procedure. Instrument providers are responsible for instrument cleaning during flight system operations, unless permission and a detailed cleaning procedure are provided to OSIRIS-REx, or LM contamination control engineering.

8.0 Contamination Control during Integration and Test

OSIRIS-REx will be integrated at LM in the ATLO Complex. Integration will occur in both ISO Class 7 (FED-STD Class 10,000) and Class 8(FED-STD Class 100,000) facilities. Room temperatures will be in the 72 +5/-10°F range and typical humidity requirements are 30 to 50%. Personnel working in the cleanroom will wear full cleanroom outfits, booties, hoods, masks and approved gloves. When working with solvents, polyethylene or low NVR Nitrile gloves should be worn. Latex gloves shall not be used on the OSIRIS-REx mission. Detailed gowning procedures and personnel operating procedures will be posted if different than standard operating procedures for the facility. The approved bagging materials for the OSIRIS-REx mission are listed in Section 2.4.1.

8.1 Ground Support Equipment

Tools and Ground support equipment (GSE) required for testing will be cleaned to **VC** per JSC-SN-C-0005C with IPA and prior to entry into the cleanroom. If the precision clean area is not attached to the cleanroom, the tools shall be bagged for transport to the cleanroom. Large pieces of GSE may be cleaned and inspected outside the facility roll up door and immediately taken into the cleanroom after cleaning and inspection, without being bagged. In addition, tools and GSE that comes into contact with flight hardware must be inspected to **VCHS** level under black light and white light per JSC-SN-C-0005 prior to entering the cleanroom. If at any time, the tools or GSE become visibly contaminated, the hardware will be re-cleaned and inspected. Any GSE that will come into direct contact with the sample acquisition TLS hardware must be be more thoroughly cleaned to insure these highly sensitive parts are not contaminated. These tools shall be cleaned as detailed above, but this inspection must performed by a contamination trained individual whose cleaning technique has been verified to meet IEST-STD-CC1246D Level 300 prior to allowing these tools contact with this hardware.

Tools and GSE containing materials that shed, slough, or flake particles or transfer or outgas molecular contaminants at room temperature are prohibited from the clean room. Critical ground support equipment containing fans must be positioned downwind from the instrument module, spacecraft, and/or flight system with respect to the HEPA filters. Printers are not allowed in the cleanroom. Additional material restrictions can be found in Section 4.2.1.

8.2 Contamination Control Flow

The Contamination Control Flow throughout integration and test can be found in Figure 8.2-1 TBD. Figure 8.2-1 will be a simplified OSIRIS-REx integration and test flow and is intended to show cleanliness inspections and cleanings with respect to activities, not detailed integration and test activities. Detailed integration and test flow can be found in the OSIRIS-REx Assembly, Test, and Launch Operations (ATLO) Plan.

Figure 8.2-1 Contamination Control Flow throughout the I&T process

TBD

8.3 OSIRIS-REx Instruments during Integration and Test

Prior to delivery to the flight system, all OSIRIS-REx Instruments must pass the outgassing certification requirement as defined in Section 2.2.1. If the instrument outgassing requirements are not met, the instrument must obtain a waiver from the OSIRIS-REx Project/Contamination Engineer or be baked-out to the required levels. Upon delivery to the flight system the instrument exterior cleanliness level will be inspected to the levels in Section 2.2. Instruments not meeting the cleanliness requirements must be cleaned by their instrument support team and then re-inspected.

Instrument bench acceptance testing will be performed in an ISO Class **7**(Fed-Std-209 Class **10,000**) clean tent or cleanroom environment for the contamination sensitive instruments. The instrument will be purged per the requirements in the respective Spacecraft to Instrument IRCD. Following these inspections and testing, the instrument will be bagged and delivered to the appropriate cleanroom facility for integration.

If needed, the instruments will be continuously purged with dry, filtered nitrogen throughout integration and test, as required and defined in the instrument to spacecraft ICD. If the purge must be interrupted, the duration of the interruption shall not exceed instrument requirements. Instrument personnel will inspect instruments to the cleanliness levels in Section 2.2, per the schedule in Section 11.2. If an instrument does not meet the required cleanliness level, the instrument shall be cleaned until it meets the requirement. The instruments will be bagged and purged(if required) during all periods of inactivity, or if the hardware is outside of the cleanroom. If an instrument or hardware is removed from the cleanroom for testing in an unbagged condition, or some other reason such as calibration, it must be re-verified to the external cleanliness requirements in Section 2.2 or 2.3, before it can reenter the cleanroom. **The instrument support team** is responsible for cleaning and maintaining their respective instruments during flight system integration and testing. Flight system personnel will only clean external instrument surfaces with specified direction and permission as well as a detailed written procedure from the instrument provider.

8.4 Purging Requirements

A nitrogen purge will be available for OSIRIS-REx instruments as required, during integration and test until launch. The nitrogen purge will be filtered to **0.5** microns or smaller and shall conform to MIL-PRF-27401D, Grade **C** and ISO 15859-3 or an approved equivalent standard. It may be necessary to switch the purge gas from nitrogen to clean, dry air for instrument purging during transportation to the launch site for safety reasons. At the launch site the use of a t-0 purge line will be necessary.

The purge interfaces and purge rates will be defined in the Flight system to Instrument Interface Control Documents. The purge system, purge panel, and associated safety requirements will be defined in the OSIRIS-REx Purge System Specification or equivalent LM purge specification document.

8.5 Integration of Subsystems and the Flight system

All subsystems and/or components must meet an outgassing certification requirement prior to integration per Section 2.3.1. At the time of integration, components or subassemblies will be inspected to their required cleanliness levels. All spacecraft hardware and ground support equipment shall be cleaned, by the appropriate support personnel, prior to the hardware entering the designated integration facility.

Oils, greases and other similar agents that may be contamination hazards will not be used during integration without the permission of the Contamination Engineer. Joints or crevices will be covered during integration to minimize the build up of contaminating debris. Rivets, bolts, nuts and so forth must be cleaned to remove any type of contamination such as lubricants and machining oils prior to integration and test.

Frequent white light and black light inspections will be made during integration to ensure that the flight system is maintained at the levels specified in Sections 2.3 and 2.4. All fluorescent and "black" lamps used to perform inspections must be adequately encapsulated for use around the OSIRIS-REx hardware.

The completed flight system will be cleaned to the levels as specified in Sections 2.2, 2.3, and 2.4. Direct sampling of the flight system surfaces can involve taking tape lifts, solvent wash samples, swab samples, image analysis, and black/white light inspections. Particular attention should be given to areas, which will become inaccessible during integration. All areas as they become inaccessible will be cleaned to the required cleanliness levels defined in Section 2.3. The cleaning procedures may entail vacuuming, CO_2 snow cleaning, and/or solvent wiping.

The flight system (except attach points) should be bagged per Section 2.4.1 with approved bagging film during crane operations.

8.6 Test Facilities

Following integration, OSIRIS-REx will be subjected to environmental testing. Figure 8.2-1 will be a simplified flowchart of the environmental testing sequence. In the testing facilities, the instruments will be bagged individually when possible and continuously purged with nitrogen where required. If an instrument has an aperture cover, these covers should be installed whenever possible. In addition, the flight system will also be bagged, when possible. Testing facilities will be held at 72 +5/-10°F temperature and 30 to 50% humidity conditions. If a particular test requires the removal of bagging, the facility will be cleaned and the personnel who come in contact with the flight system and instruments must be wearing cleanroom bunny suits, booties, hoods, masks and gloves. If solvents are used, polyethylene or low NVR nitrile gloves (often blue) must be worn. Latex gloves (often yellow), or rubber (black), etc shall not be used with OSIRIS-REx.

8.6.1 EMC/EMI Facility

At LM, the EMC/EMI facility is an ISO Class 8 (Class 100,00) Clean Zone (TOCZ) operated with Class 7 (Class 10,000) protocols. Personnel requiring access to the facility may need additional cleanroom training. The facility has humidity and temperature control. The instruments and spacecraft shall remain bagged as much as possible, unless integration and test activities in the EMC/EMI room prohibit bagging. The instruments will be purged continuously where required.

8.6.2 Vibration Cell

The vibration cells are not cleanroom facilities; however, they will be operated as a Class 8 clean area through facility cleanings, materials restrictions, and implementation of personnel cleanroom protocol. Full cleanroom garments will be worn. Personnel in the facility will be limited. The cell will be cleaned prior to flight system arrival and maintained clean while the flight system is in the facility. The doors to the cell will remain closed to maintain the room cleanliness, unless operations require temporary door opening. The instruments will remain bagged and purged at all times while in the vibration cell. The flight system will be bagged as much as possible, unless prohibited by test activities.

8.6.3 Acoustic Facility

The Acoustics Facility is classified as a Class 8 clean area through facility cleanings, materials restrictions, and implementation of personnel cleanroom protocol. All personnel working in the acoustics facility will wear full cleanroom garments. The room shall be cleaned prior to flight system arrival and maintained clean while the flight system is in the facility. The instruments will remain bagged and purged at all times. The flight system will be bagged as much as possible, unless prohibited by test activities.

8.6.4 Thermal Vacuum Chamber

The **SSL 65'** thermal vacuum chamber will be operated as a Class **7** cleanroom due to the requirement for exposure of sensitive hardware elements during this test. Additional cleanroom training may be required by personnel working in the chamber, to become familiar with unique chamber protocol and restrictions. All personnel will enter the chamber through a gowning area. Full cleanroom garments will be worn. Personnel will be kept to a minimum inside the chamber. A ground support equipment, tool, and hardware cleaning station will be set up outside the gowning area. Care must be taken to account for all materials, tools, and equipment brought in and out of the chamber. The chamber will be cleaned and inspected prior to loading OSIRIS-REx into the chamber. A crane may be used to load OSIRIS-REx into the chamber. The flight system must be draped with clean bagging film anytime the chamber lid is opened during thermal vacuum preparations. The chamber will be inspected and re-cleaned, if necessary, after all work is completed prior to closing the doors. The red tag covers on contamination sensitive components shall be removed at the last possible moment. The instruments will remain bagged and purged until the last possible moment prior to closing the chamber doors.

Contamination monitoring during the flight system thermal vacuum test is addressed in Section 2.4.3. As specified in that section, the chamber must have a pre-test certification of the outgassing rate, including GSE, prior to loading the OSIRIS-REx flight system into the chamber. All test instrumentation shall be installed on the flight system in an ISO Class 7 facility or comparable clean area prior to moving the spacecraft to the thermal vacuum chamber. After installation of instrumentation is complete, the flight system will be double bagged and transported to the chamber.

9.0 Contamination Control during Transportation and Storage

After delivery, all instruments will be bagged and purged during storage or transportation. Subsystems and subassemblies, which do not have any special requirements for handling and storage prior to integration, will be cleaned to their respective cleanliness requirement and bagged unless integration or test activities prohibit it. All systems will be stored in an air-conditioned area with controlled access. The flight system will be bagged with approved bagging material per Section 2.4.1 when outside of the cleanroom, unless integration and test activities prohibit it.

For transportation outside the LM ATLO complex, the flight system shipping container will be used for protection. The flight system shipping container will be pre-cleaned, prior to use, to Level **VCHS per** JSC-SN-C-0005C**.** Nitrogen or dry, filtered ultra high purity air will be used to purge the shipping container per the OSIRIS-REx Purge System Specification and the instrument interface control documents. Temperature and humidity will be controlled and monitored in the shipping container to meet OSIRIS-REx flight system requirements. In addition, particulate contamination monitoring plates and NVR monitors will be mounted inside the shipping container to monitor the contamination environment during transportation.

10.0 Contamination Control at the Launch Site

The details of the contamination control procedures to be used during launch site processing will be added as Appendix C of this plan. The OSIRIS-REx launch site contamination control requirements for the flight system, the facilities, and the launch vehicle will be delineated in this Appendix. The OSIRIS-REx Contamination Engineer, launch vehicle team, and the launch vehicle and facilities staff will coordinate the launch site activities to be presented in the Appendix. Further details will also be provided in the Launch Services Support Plan (LSSP) which focuses more on what materials are supplied by each mission group.

The launch site plan will minimize contamination generation whenever possible. Instrument soft/hard covers will remain in place during Launch Site operations whenever possible. The current baseline is to remove these covers immediately prior to fairing encapsulation.

T-0 purges will remain in place whenever possible in order to meet the purge requirements of the instruments and mission hardware.

11.0 Implementation of Contamination Control Requirements

The Integration and Test Manager, Quality Assurance, and Contamination Engineer will be responsible for ensuring that contamination control measures are implemented throughout the design, fabrication, assembly, integration, testing, storage and transportation of the OSIRIS-REx mission.

11.1 Cleanliness Inspection and Monitoring Methods

Cleanliness inspection and monitoring methods, which will be used for the OSIRIS-REx mission, are contamination monitoring plates; optical witness samples (OWS), black and white light inspections, washes, swab sampling, tape lifts, and a real time Non-Volatile Residue monitor. Descriptions of these techniques are as follows:

Contamination Monitoring Plates (or foils):

Contamination Monitoring Plates are used to determine particulate levels, particle fallout rates, amino acid residue levels, and Non-Volatile Residue (NVR) levels. Contamination Monitoring plates collect particulates passively during cleanliness monitoring procedures. Contamination Monitoring plates should be placed as close as possible to contamination sensitive areas, to obtain the most accurate particulate readings. The spacecraft particle monitoring plates at GSFC are generally silicon wafers because of the image analyzer's ability to process the wafers and determine pretest cleanliness. Occasionally, Teflon grids are used. Facility fallout plates are usually 1 ft^2 stainless steel plates that are washed and analyzed for molecular or particulate contamination. Amino acid plates are typically pyrolyzed (500^oC > 12 hrs in air) aluminum foil. The foils are usually a 4 cm^2 area cut out of a larger foil area in order to avoid adhesives on the edge surfaces. These foils are typically placed into tared glass tubes and mailed to GSFC for analysis.

Optical Witness Samples:

Optical Witness Samples (OWS) consist of quartz glass with a thin film of aluminum and a magnesium fluoride coating to represent an optical surface. Molecular contamination is allowed to deposit on the samples during cleanliness monitoring. After monitoring, the reflectance degradation of the optical witness samples is measured.

Light Inspections:

Visual Inspection is done periodically using black (UV) light or white light. Visibly clean, using white light is the absence of all particulates and non-particulates visible to the normal unaided eye (except corrected vision). The three levels of visibly clean and observational distances are listed in Table B-1. UV inspection light sources are no less than 100 watts and located no more than 50cm from the inspected item. During UV inspection, light from other sources should not be more than 5 ft-candles. If visual contamination is evident, the hardware must be cleaned and then re-inspected 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.

Washes:

A surface, which is to be inspected, is washed with alcohol or an appropriate solvent and the solvent and residue is collected. This rinse is then subjected to quantitative and qualitative analyses and the type of contaminant residue is chemically identified.

Tape Lifts:

Tape lift samples are taken of the inspection surface to determine the surface particulate cleanliness level according to IEST-STD-CC1246D. The tape lift samples are prepared, taken and read by an approved tape lift procedure. Tape lifts can not be taken on painted surfaces, ITO coated surfaces, or on other delicate coatings.

Real Time Non-Volatile Residue Monitor:

A real time non-volatile residue monitor can be utilized on the OSIRIS-REx Program. The monitor can measure NVR build up over time. The NVR is measured electronically with a surface acoustic wave sensor. This monitor can be placed in the vicinity of the flight system.

11.2 Verification and Cleaning Schedules

Cleanliness verification and monitoring will occur as listed below at a minimum and more frequently if the OSIRIS-REx Contamination Control Manager deems that extra cleanliness monitoring is necessary. The hardware surfaces will be inspected for compliance to the cleanliness requirements in Table 11.2-1. If the contamination levels on the hardware exceed the cleanliness requirements, a cleaning will be scheduled. Each cleaning will be conducted under a work order authorization developed for the specified cleaning or as a step in a more extensive procedure. The cleanings shall be performed by Contamination Control Technicians or by the OSIRIS-REx Contamination Engineering Group. The detailed cleaning procedures can be found in the hardware approved cleaning and verification procedure. The instrument providers will be notified for cleanliness inspections and hardware cleanings affecting or in the vicinity of their instrument. Results from the inspection methods and cleanliness verification on the flight system will be provided to the instrument providers. Instrument unique cleanliness verification and contamination monitoring plate change-out will occur per the requirements in the respective Flight System to Instrument ICD. The instrument providers are responsible for cleaning the instruments unless permission is given and a detailed cleaning procedure is provided.

Table 11.2-1: Verification and Cleaning Schedule

Reason for Inspection or Cleaning	Item to be inspected or cleaned	Cleanliness Requirement	Method
Instrument Delivery	Instrument	300 A/2	Tape Lift/NVR Rinse
Sub-System Delivery	Sub-Systems	300 A/2	Tape Lift/NVR Rinse
Integration	Instrument, Sub-Systems, Flight system	VC-HS	Inspection
Post Integration	Flight system	VC-HS	Inspection
Vibration Testing	Flight system	VC-HS	Inspection

Post Vibration Testing	Flight system	VC-HS	Inspection
Acoustics Testing	Flight system	VC-HS	Inspection
Post Acoustics Testing	Flight system	VC-HS	Inspection
Pre-Thermal Vac	Flight system	VC-HS	Inspection
Thermal Vac	Flight system	VC-HS	Inspection
Post Thermal Vac	Flight system	VC-HS	Inspection
Post Mass Properties	Flight system	VC-HS	Inspection
Pre-Ship	Flight system	500 A/2	Tape Lift/NVR Rinse
Shipping	Flight system	VC-HS	Inspection
Transportation	Flight system	VC-HS	Inspection
Launch Site	Flight system	500 A/2	Tape Lift/NVR Rinse

12.0 Employee Training

Contamination Control and Cleanroom Practices training should be conducted for all personnel involved in the fabrication, assembly, integration, testing, transportation, storage, and launch site activities of the OSIRIS-REx instruments, subsystems and flight system. Areas which can be studied in the training sessions are as follows: Definition of contamination and how it affects the OSIRIS-REx mission; the importance of maintaining contamination control from fabrication through launch; reviewing instrument and subsystem sensitivities; knowledge of the instrument and spacecraft contamination control plans and related contamination documents; specific techniques for cleaning, inspection, and packaging; monitoring techniques in the cleanroom and in the shipping containers; and cleanroom dressing procedures and rules for working in a controlled cleanroom area.

APPENDIX A: Acronyms and Definitions

A.1 Acronyms

BOL	Beginning of Life
CCM	Contamination Control Manager
CPT	Comprehensive Performance Test
CVCM	Collected Volatile Condensable Materials
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
ESD	Electrostatic Discharge
FED-STD	Federal Standard
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HEPA	High Efficiency Particulate Air
ICD	Interface Control Document
IPA	Isopropyl Alcohol
I & T	Integration and Test
ITO	Indium Tin Oxide
LM	Lockheed Martin
MAR	Mission Assurance Requirements
MIL-STD	Military Standard
MLI	Multi-Layer Insulation
NASA	National Aeronautic and Space Administration

NVR	Non-Volatile Residue
OSIRIS-REx	Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer
OWS	Optical Witness Sample
PAC	Percent Area Coverage
QA	Quality Assurance
TML	Total Mass Loss
T/B	Thermal Balance
TBD	To Be Determined
TBR	To Be Resolved
TLS	TAGSAM head, Launch Canister, SRC Canister
T/V	Thermal Vacuum
TQCM	Temperature-Controlled Quartz Crystal Microbalance
UHP	Ultra High Purity
UV	Ultraviolet
VC	Visibly Clean
VC-HS	Visibly Clean – Highly Sensitive
WOA	Work Order Authorization

A.2 Definitions

Action Level	The Maximum allowable contamination level set by the user in the context of controlled environments and cleanliness, which, when exceeded, requires immediate intervention, including investigation of cause, and corrective action.
Alert Level	The contamination level set by the user in the context of controlled environments and cleanliness, giving early warning of a potential drift from normal conditions. NOTE: When alert levels are exceeded, this should result in increased attention to the process.
Cleanroom	Room in which the concentration of airborne particles is controlled to specified limits.
Cold Finger	A cold finger is used in vacuum tests to provide qualitative and quantitative information about the molecular environment of the vacuum chamber at the end of the test. It is a stainless steel cylinder of known surface area, typically 1 ft^2, which is flooded with LN_2 during the last 8 hours a test. When flooded, the cylinder resides at ~80 K and collects any molecules that hit the cylinder and are condensable at that temperature. When the chamber is brought back to ambient, the cold finger is rinsed with a solvent, and the residue is analyzed to determine its mass and constituents. The results from cold finger analyses are used to determine if any unexpected molecular contamination is present.
Contamination	Any unwanted material that causes degradation in the desired function of an instrument or flight hardware.
Contamination Control	Organized action to control the level of contamination.
Fiber	A fiber is 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.
Molecular Adsorber	A zeolite-coated ceramic honeycomb used to adsorb outgassed molecular contaminants. It is also known as a molecular sieve.
Nitrogen Purge	Pressurized flow of clean, dry nitrogen through a system in order to displace impurities and reactive species.

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.
Flight system	The flight system consists of the complete OSIRIS-REx flight assembly, all OSIRIS-REx instruments, and all subsystem hardware and bus components.
Particle	A particle is a small quantity of solid or liquid material which has a definable shape or mass with a length to width ratio less than 10:1.
Particle Size	(1) The apparent maximum linear dimension of a particle in the plane of observation, as observed with an optical microscope; (2) The equivalent diameter of a particle detected by automatic instrumentation. The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured; (3) The diameter of a circle having the same area as the projected area of a particle, in the plane of observation, observed by image analysis; (4) The size defined by the measurement technique and calibration procedure.
Percent Area Coverage	An alternative method of specifying particle concentration levels on a surface. PAC is the fraction of the surface that is covered by particles. Percent area coverage is reported as the sum of the projected areas of the particles divided by the total surface area.
Precision Cleaning	Precision cleaning is 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 IEST-STD-CC1246D molecular cleanliness levels by measuring molecular contamination in a solvent, which was washed over a surface and collected.
Spacecraft	The spacecraft refers to all bus components, structure, electronic boxes, communication hardware, propulsion hardware, and attitude control subsystem hardware in an integrated assembly, not including instruments.

Surface Cleanliness Level	An established level of maximum allowable particulate and/or NVR contamination ranging from visibly clean to specific IEST-STD-CC1246D levels (e.g., Level 100A, etc. as shown in Figure B-1 and Tables B-4 and B-5).
Swab Sample	A qualitative method of identifying contaminants by analyzing the residue on a solvent-soaked swab that was wiped over a surface.
Tape Lifts	A quantitative method of verifying IEST-STD-CC1246D particulate cleanliness levels by measuring particulate contamination on a sample of tape that has come in contact with the surface one wishes to examine.
Vapor Degrease	Item to be cleaned is exposed to heated solvent vapors that condense on the part and wash away contaminant.
Visibly Clean	The achievement of a clean surface as seen without optical aids (except corrected vision) as measured by a specified method.

APPENDIX B: Reference Tables and Figures

Table B-1: Visibly Clean Levels and Inspection Criteria
(from JSC-SN-C-0005C)

VC Level	Incident Light Level (1)	Observation Distance	Remarks
Standard	≥ 50 foot-candles	5 to 10 feet	(2) (3) (5)
Sensitive	≥ 50 foot-candles	2 to 4 feet	(2) (3) (5)
Highly Sensitive	≥ 50 foot-candles	6 to 18 inches	(3) (4)

NOTES:

(1) One foot-candle (lumens per square foot) is equivalent to 10.76 lumens per square meter.

(2) Cleaning is required if the surface in question does not meet VC under the specified incident light and observation distance conditions.

(3) Exposed and accessible surfaces only.

(4) Initial cleaning is mandatory; Note (2) applies thereafter.

(5) Areas of suspected contamination may be examined at distances closer than specified for final verification.

Table B-2: Cleanroom Class limits (from ISO 14644-1)

Selected airborne particulate cleanliness classes for cleanrooms and clean zones

ISO Classification Number (N)	Maximum concentration limits (particles/m^3 of air) for particles equal to and larger than the considered sizes shown below (concentration limits are calculated in accordance with equation (1) in 3.2*)				
	0.1µm	0.2 µm	0.3 µm	0.5 µm	1 µm	5 µm
ISO Class 1	10	2				
ISO Class 2	100	24	10	4		
ISO Class 3	1 000	237	102	35	8	
ISO Class 4	10 000	2 370	1 020	352	83	
ISO Class 5	100 000	23 700	10 200	3 520	832	29
ISO Class 6	1 000 000	237 000	102 000	35 200	8 320	293
ISO Class 7				352 000	83 200	2 930
ISO Class 8				3 520 000	832 000	29 300
ISO Class 9				35 200 000	8 320 000	293 000

NOTE: Uncertainties related to the measurement process require that concentration data with no more than three significant figures be used in determining the classification level.

* $C_n = 10^N \times [0.1/D]^{2.08}$

Where:

C_n is the maximum permitted concentration (in particles per cubic meter of air) of airborne particles that are equal to or larger than the considered particle size. C_n is rounded to the nearest whole number, using no more than three significant figures.

N is the ISO classification number, which shall not exceed a value of 9. Intermediate ISO classification numbers may be specified; with 0.1 the smallest permitted increment of N.

D is the considered particle size, in micrometers.

0.1 is a constant, with a dimension of micrometers.

Table B-3: Cleanroom Class limits (from Fed-STD-209)

AIRBORNE PARTICULATE CLEANLINESS CLASSES

Class limits are given for each class name. The limits designate specific concentrations (particles per unit volume) of airborne particles with sizes equal to and larger than the particle sizes shown*

Class Name**		Class limits									
		0.1 µm		0.2 µm		0.3 µm		0.5 µm		5 µm	
		Volume units		Volume units		Volume units		Volume units		Volume units	
SI	English***	(m^3)	(ft^3)	(m^3)	(ft^3)	(m^3)	(ft^3)	(m^3)	(ft^3)	(m^3)	(ft^3)
M 1		350	9.91	75.7	2.14	30.9	0.875	10.0	0.283	–	–
M 1.5	1	1 240	35.0	265	7.50	106	3.00	35.3	1.00	–	–
M 2		3 500	99.1	757	21.4	309	8.75	100	2.83	–	–
M 2.5	10	12 400	350	2 650	75.0	1 060	30.0	353	10.0	–	–
M 3		35 000	991	7 570	214	3 090	87.5	1 000	28.3	–	–
M 3.5	100	–	–	26 500	750	10 600	300	3 530	100	–	–
M 4		–	–	75 700	2140	30 900	875	10 000	283	–	–
M 4.5	1 000	–	–	–	–	–	–	35 300	1 000	247	7.00
M 5		–	–	–	–	–	–	100 000	2 830	618	17.5
M 5.5	10 000	–	–	–	–	–	–	353 000	10 000	2 470	70.0
M 6		–	–	–	–	–	–	1 000 000	28 300	6 180	175
M6.5	100 000	–	–	–	–	–	–	3 530 000	100 000	24 700	700
M 7		–	–	–	–	–	–	10 000 000	283 000	61 800	1 750

*The class limits shown in Table I are defined for classification purposes only and do not necessarily represent the size distribution to be found in any particular situation.

**Concentration limits for intermediate classes can be calculated, approximately, from the following equations:

$$\text{particles}/m^3 = 10^M(0.5/d)^{2.2}$$

where M is the numerical designation of the class based on SI units, and d is the particle size in micrometers, or

$$\text{particles}/ft^3 = N_C(0.5/d)^{2.2}$$

where N_C is the numerical designation of the class based on English (U. S. customary) units, and d is the particle size in micrometers.

***For naming and describing the classes, SI names and units are preferred; however, English (U.S. customary) units may be used.

Figure B-1: Cleanliness Levels (from IEST-STD-CC1246D)

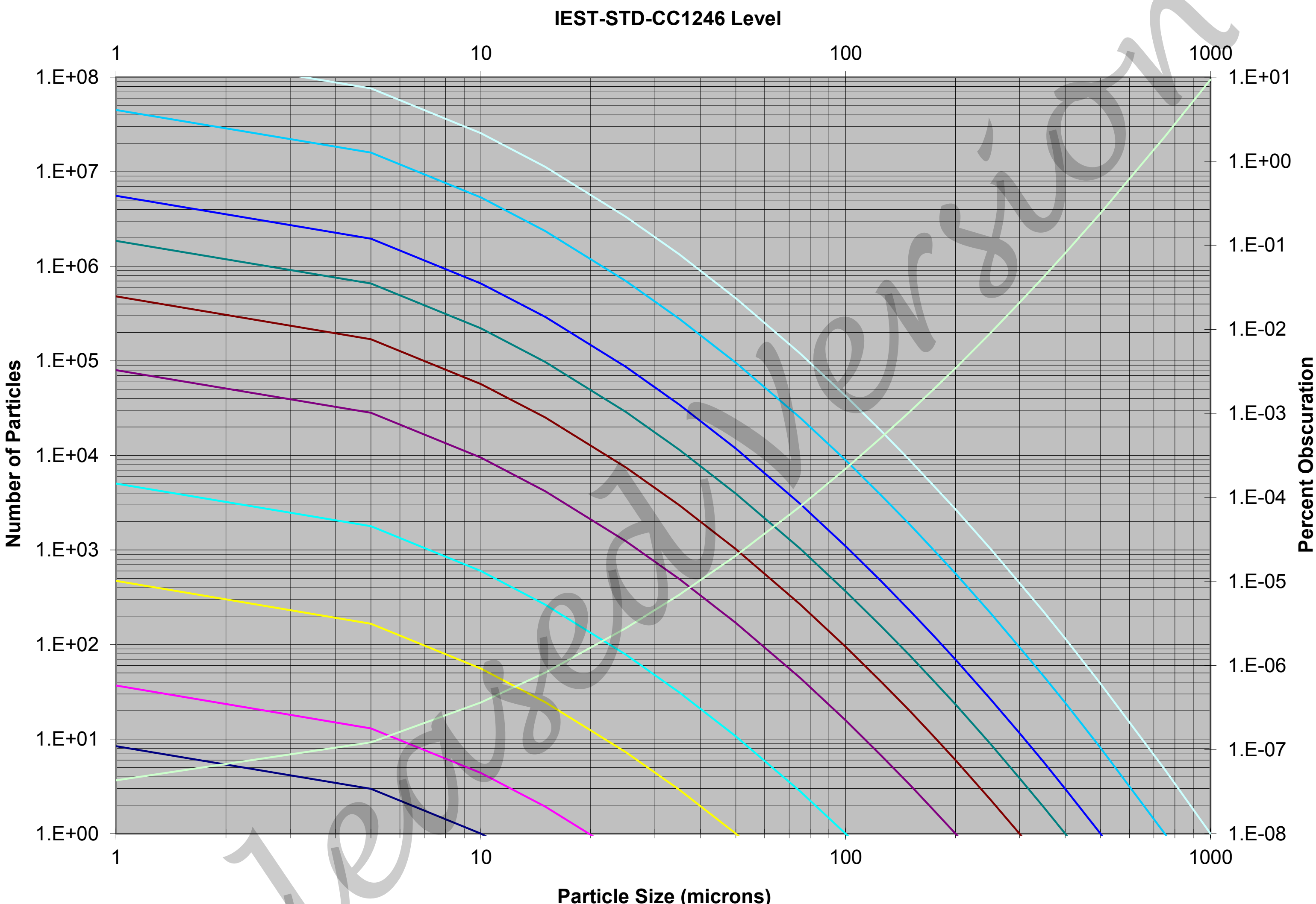


Table B-4: Classification of Levels (from IEST-STD-CC1246D)

Particulate Cleanliness Levels

Level	Particle Size, µm	Count per 1 ft^2	Count per 0.1 m^2	Count per liter
1	1	1.0	1.08	10
5	1	2.8	3.02	28
5	2	2.3	2.48	23
5	5	1.0	1.08	10
10	1	8.4	9.07	84
10	2	7.0	7.56	70
10	5	3.0	3.24	30
10	10	1.0	1.08	10
25	2	53	57	530
25	5	23	24.8	230
25	15	3.4	3.67	34
25	25	1.0	1.08	10
50	5	166	179	1660
50	15	25	27.0	250
50	25	7.3	7.88	73
50	50	1.0	1.08	10
100	5	1785	1930	17850
100	15	265	286	2650
100	25	78	84.2	780
100	50	11	11.9	110
100	100	1.0	1.08	10
200	15	4189	4520	41890
200	25	1240	1340	12400
200	50	170	184	1700
200	100	16	187.3	160
200	200	1.08	10	1.0
300	25	7455	8050	74550
300	50	1021	1100	10210
300	100	95	103	950
300	250	2.3	2.48	23
300	300	1.0	1.08	10
500	50	11817	12800	11817
500	100	1100	1190	11000
500	250	26	28.1	260
500	500	1.0	1.08	10
750	50	95807	105000	958070
750	100	8919	9630	89190
750	250	214	231	2140
750	500	8.1	8.75	81
750	750	1.0	1.08	10
1000	100	42658	46100	426580
1000	250	1022	1100	10220
1000	500	39	42.1	390
1000	750	4.8	5.18	48
1000	1000	1.0	1.08	10

Table B-5: Classification of Cleanliness Levels (from IEST-STD-CC1246D)

Non-volatile Residue Cleanliness Levels

Level	Limit, NVR mg/0.1m^2 1/ (or µg/cm^2)	Limit, NVR Mg/liter
A/100	0.01	0.1
A/50	0.02	0.2
A/20	0.05	0.5
A/10	0.1	1.0
A/5	0.2	2.0
A/2	0.5	5.0
A	1.0	10.0
B	2.0	20.0
C	3.0	30.0
D	4.0	40.0
E	5.0	50.0
F	7.0	70.0
G	10.0	100.0
H	15.0	150.0
J	55.0	250.0

1/ Limits on non-volatile residue (NVR, mg) for surface, liquid, or gas to meet the level of cleanliness.

(One square foot = 0.0929m^2)

Table B-6: Cleanliness Levels versus PAC

Cleanliness Level *	Percent Area Coverage
100	0.00022
200	0.0035
300	0.020
350	0.044
400	0.080
450	0.14
500	0.24
550	0.4
600	0.6
650	0.9
700	1.4
750	2.0

* Per IEST-STD-CC1246D

APPENDIX C: Launch Site Contamination Control Procedures

TBD

APPENDIX D: Materials Archiving Plan

Instructions for archiving items for contamination knowledge during ATLO
JSC will provide pre-cleaned Teflon bags (or other container), Teflon tape, and forms to fill out and include with the items to be archived. Bags range in size from 6"x6" to 12"x12" to 18"x18" to 24"x24". If a bag is an inappropriate container, pre-cleaned glass vials, aluminum or stainless steel containers can be sent. Please contact Righter and/or Nakamura-Messenger to discuss and identify the appropriate container and size.
The form will include the following information, which will ultimately be entered into the JSC database:

Date: Location: Person:

Item and location on spacecraft or SRC:

MEL#:

Material:

Size and/or weight:

Reason for archiving:

Manufacturer: Lot#:

Manufacturer URL or other contact information:

Bag type: Bag size:

Vial type: Vial size:

Photographs attached? Y N

Any special handling required?:

Specific comments to add to the database:

Item should be handled with nitrile gloves, placed in the bag (or container), bag sealed with Teflon tape, labeled clearly, and then sent along with the form to JSC:

Kevin Righter
Mailcode KT
NASA Johnson Space Center
2101 NASA Parkway
Houston, TX 77058
281-483-5125

The originator of the form and item to be archived should also email Kevin Righter (Kevin.righter-1@nasa.gov) and Keiko Nakamura-Messenger (Keiko.nakamura-1@nasa.gov) to notify them that the item(s) has(have) been sent to JSC so they can anticipate their arrival.