PANAMETRICS

Contamination Control Plan

for the

Solar X-Ray and EUV Sensor (XRS/EUV), the Energetic Particle Sensor (EPS), and the High Energy Proton and Alpha Detector (HEPAD) for GOES NO/PQ

prepared for

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1.0 Reference Documents

Documents listed in **bold** are applicable to items in this Contamination Control Plan, and will be implemented as part of this plan. All other documents are provided for reference purposes only. In the case of conflicts, the Hughes Space & Communications Product Specifications take precedence over all documents.

1.1 Government Documents and Standards

ASTM

ASTM E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ASTM E1234	Standard Practice for Handling, Transporting, and Installing Nonvolatile Residue (NVR) Sample Plates Used in Environmentally Controlled Areas for Spacecraft
ASTM E1559-93	Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials
ASTM E1560	Method for Gravimetric Determination of Nonvolatile Residue from Cleanroom Wipers

Federal

FED-STD-209E	Federal Standard Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

Military

MIL-STD-1246C	Product Cleanliness Levels and Contamination Control Program
MIL-P-27401C	Propellant Pressuring Agent, Nitrogen

NASA

JSC SP-R-0022A	Vacuum Stability Requirements of Polymeric Materials for Spacecraft Application – General Specification
NASA Reference	Outgassing Data for Selecting Spacecraft Materials, ONLINE at http://misspiggy.gsfc.nasa.gov/og/
NASA MAPTIS	Materials and Process Technical Information System Database Center
MSFC-HDBK-527	Material Selection List for Space Hardware Systems -JSC 09604, Rev. E or later
GSFC S-415-22	Performance Specification for the Geostationary Operational Environmental Satellites, GOES-N,O,P,Q
SN-C-0005	Contamination Control Requirements for the Space Shuttle Program

1.2 Government Contractor Documents

Hughes

CDRL SDA-CCP Hughes Space and Communications Company -Contamination Control Plan for GOES NO/PQ

Panametrics

GOESN-RTP-190	Thermal Vacuum Bakeout Procedures
GOESN-RTP-197	Handling, Storage, Packaging, and Transportation Procedures for the XRS/EUV
GOESN-RTP-198	Handling, Storage, Packaging, and Transportation Procedures for the EPS/HEPAD
GOESN-ENG-005	Controlled Area Practices; 'Cleanroom Buyer's Guide' is Appendix A of this document
GOESN-SPL-001	SCDRL # 16, Summary of Parts List and Part Specifications
GOESN-M&P-001	SCDRL # 17, Materials and Processes List and Specifications

2.0 Introduction & Overview

Strict control of molecular contamination is paramount to maintaining the performance of the XRS/EUV on the GOES NO/PQ Satellites. The entrance-filters and sensors are so highly sensitive to contamination that a molecular contaminant deposition layer of only 10 angstroms (just over one molecule in thickness) can seriously degrade the on-orbit performance. This kind of extreme sensitivity to contamination is typical in ultraviolet and low-energy x-ray optics. Many ultraviolet and x-ray satellites have experienced performance degradation prior to their end-of-life; some had crippling losses as early as 1 to 2 months into the mission. The EPS and HEPAD do not have the same strict contamination requirements and thus will not be handled with the same precautionary care as the XRS/EUV. However, since those instruments will be fabricated and tested alongside the XRS/EUV, care must be exercised to avoid contaminating the XRS/EUV. Separating the XRS/EUV from the other instruments during storage and assembly will avoid cross-contamination.

Maintaining such low levels of on-orbit contamination is very difficult, and it becomes even more difficult when the effects of UV light from the Sun or the earth's albedo are taken into account. Studies have shown that ultraviolet light interacts in complex ways with the materials that outgas from satellites, their outgassing by-products, and the surfaces upon which these by-products deposit. This results in dramatic increases in deposition rates beyond those rates predicted by using standard molecular transport software based on thermally driven, diffusion, evaporation, and condensation processes.

Since particulate contamination is not as important to sensor degradation as is molecular contamination, much of this document focuses on the latter. Every practical and reasonable attempt possible must be made to reduce the risk of molecular contamination. This includes careful selection and placement of all organic materials, directed venting of outgassing by-products, very thorough thermal-vacuum bakeouts, and strict control of all ground operations from assembly through launch. Attention must also be paid to the control of particulate contamination, especially for the inner instrument surfaces. Particulate contamination not only absorbs and/or blocks light if attached to sensors, but more importantly, it provides a scattering surface for the intense EUV solar radiation. Radiation normally falling on internal baffles, for instance, may be scattered into the EUV optics. The particulate contamination requirements are given in Section 4.0, 'Contamination Budget and Requirements.'

In addition to contamination control practices, careful instrument design is a very important aspect of maintaining low levels of molecular and particulate contamination. Optimized placement of internal baffles, Zeolite molecular absorbers, and entrance slits will minimize the FOV to the sensitive instrument surfaces (from contaminating surfaces). Internal baffles and Zeolite absorbers also provide sticking surfaces that inhibit the transfer of molecular contaminants towards the sensors. Finally, careful design of GN2 purge-flow is important in controlling particulates, as turbulent-flow purges can actually increase the particulate contamination within certain areas of the instrument. GN2 purges can also contaminate the instrument they were designed to protect, by carrying molecular contaminants with the flow if the purge tubing is not clean.

Contamination monitoring is an important aspect of contamination control. At all practical stages of instrument assembly and test, contamination monitoring will be performed in order to understand, and to minimize the sources of molecular and particulate contamination.

Contamination control practices for the Panametrics XRS/EUV, the EPS, and the HEPAD, shall be as detailed herein. For each project phase, pro-active and comprehensive contamination control and monitoring programs are required in order to assure and verify that the contamination requirements are met. The goal of these programs is to deliver instruments that meet the surface and outgassing contamination requirements contained herein. Panametrics will evaluate several possible methods of achieving this goal to determine the most effective (and cost-effective) approaches. For example, it is often more cost-effective to use protective covers and/or nitrogen purging than to upgrade a facility to a higher cleanroom classification or to place costly requirements on satellite-level integration and testing. Panametrics will design for cleanliness through careful selection and location of materials and by minimizing exposure to contaminating environments. They will also assist in the design and placement of the instruments on the satellite to minimize cross-contamination from those other instruments. Documentation of contamination control and monitoring for each phase of development will be performed as described herein. This plan conforms to the Performance Specification for the Geostationary Operational Environmental Satellites, GOES -N, O, P, and Q, as listed in Section 1.0, 'Reference Documents.'

3.0 Control Plan Summary

The following is a brief summary of the contamination control practices described in this document. The list describes many of the more important aspects of successful contamination control for UV instruments. Refer to the appropriate sections of this document for more complete information, and to the Approved Parts and Materials Lists. The following apply fully to the XRS/EUV, but may be applied only in part to the EPS/HEPAD units.

Clean, handle, and assemble parts according to these general practices:

- Clean mechanical parts ultrasonically to remove cutting oils, etc.

- This applies fully to the XRS/EUV parts
- The EPS/HEPAD parts may use a lower level of cleaning

- Use only Methyl and/or Isopropyl alcohol, and/or diluted Simple Green Solution for cleaning or wiping (see Section 9.0, 'Cleaning Procedures')
  - PCBs will be cleaned using Asahi AK225T, 1,1,1-Trichloroethane and/or an approved automatic cleaning system
- Use approved Latex or Nitrilite gloves during all levels of assembly and test. (Finger cots are not to be used when handling XRS/EUV hardware.)
- Use only non-particulating cleanroom wipes and swabs
- Use black lights to enhance particulate visibility for cleaning
  - This applies to the XRS/EUV, and all exterior surfaces prior to delivery
- Use only approved epoxies, adhesives, conformal coatings, and sealant
  - The XRS/EUV will use a special set of items chosen for EUV non-contamination considerations
  - The EPS/HEPAD units will have an expanded set of approved items
- Double- or triple- bag assemblies for transportation
- Use only low-outgassing materials for flight and GSE shipping and transport containers (Stainless Steel, Surface-treated Aluminum, Teflon, Delrin, Viton, Llumalloy, *etc.*)
- Avoid use of 'dissimilar metals', which can corrode contact surfaces
- Use only approved low-outgassing bagging and packaging materials
- Generally, materials are acceptable if the Total Mass Loss (TML) is < 1.0%, and the Collected Volatile Condensable Material (CVCM) is < 0.1%

Inevitably, it is unforeseen circumstances that lead to instrument contamination. Only those materials listed in the Approved Materials and Parts Lists should contact flight hardware; however, contamination sources have blinded instruments with even the most thorough contamination control programs and well-defined parts lists (the Hubble Space Telescope Wide-Field Planetary Camera is the most infamous example). The best way to avoid this scenario is to avoid use of the most common contamination sources altogether:

- Silicone adhesives, sealers, and lubricants. (This is an absolute requirement for the XRS/EUV. Some low outgassing silicones are approved for use with the EPS/HEPAD.)
- Non-approved conformal coatings, epoxies, and staking compounds
- Dioctylphthalate (DOP), an aerosol used to challenge HEPA filters (filters can be tested by other means)
- Cutting oils from machined parts
- Finger oils and molecular transfers from handling parts without approved gloves
- Powder and residues from some Latex gloves
- Cadmium or Zinc plated 'D'-connector shells

4.0 Contamination Budget and Requirements

The contamination budget during ground operations is based upon accepting a certain level of accumulation during instrument-level assembly and test PRIOR TO CALIBRATION, knowing that the low levels of contaminants accumulated in the assembly phase can be removed by bakeout prior to delivery. It is not practical to define a 'budget' for fractions of the total allowable molecular contamination (10 Å in some cases, which is barely within measurement range). Rather, the full budget will be applied at instrument delivery. Verification of these levels will be handled in various ways, including periodic NVR rinses and swabs followed by FTIR/Mass Spec, and other techniques (see Section 6.0, 'Contamination Monitoring'). Meanwhile, the on-orbit contamination allowance is based upon a requirement of less than 5% degradation in the EUV channels over 2-years' on-orbit storage and 5-years' on-orbit operation. These requirements are drawn from **CDRL SDA-CCP**, the Hughes Contamination Control Plan for GOES NO/PQ.

The contamination requirement for all exterior surfaces (and the goal for the interior surfaces) of the EPS/HEPAD is MIL-STD-1246C Level 500 C, visibly clean highly sensitive plus UV light per SN-C-0005. The requirement for the exterior of the XRS/EUV and the interior of the XRS is MIL-STD-1246C Level 500 B, visibly clean highly sensitive plus UV light per SN-C-0005. The particulate goal for the XRS/EUV telescope interiors is Level 200; however, even Level 500 does not pose a significant loss of throughput, since grating and sensor efficiencies are simply reduced by that fraction of blocked light. If both the gratings and the EUV sensors are clean to Level 500, the total instrument throughput is only degraded by 0.6% ($1.0 - 0.997^2$) due to particulates.

The molecular requirement for the interior of the EUV telescopes is more stringent than stated above, and is Level 500 A (with a goal of Level 200 A), and visibly clean highly sensitive plus UV light per SN-C-0005. Molecular deposits of only a few nanometers (C, CH, or SiO) will result in 5% degradation in the EUV-C, -D, and -E channels. Those channels therefore define the contamination requirements for the rest of the instrument. Most of the molecular contamination is expected to evaporate in vacuum, so the residual effect on the EUV response should be well below the 5% degradation requirement. The levels will be verified in several ways, including inspections and black-lighting prior to final cover installation, periodic tape-lifts (tape-lift areas will be solvent cleaned immediately after lift to remove any tape residue), witness sample monitoring, NVR rinses and swabs, and TQCM certification following instrument bakeout. Detailed contamination results will be made available upon delivery of the Engineering Model (EM), which is the pathfinder for all contamination practices and monitoring. Lessons learned from contamination control on the EM and Protoflight Units will be incorporated into the plan for the flight units. The proposed plan for monitoring of the EM is detailed in Section 6.5.

4.1 Cross-contamination

The contamination budget must account for the risk of particulate and molecular cross-contamination from the other instruments delivered by Panametrics, namely the EPS and HEPAD, as well as Satellite molecular outgassing (in particular, epoxies and adhesives used on the Solar Panel Arrays, Thermal Radiators, and other instruments). The cross-contamination of these instruments must be minimized in order to meet the performance requirements on orbit. It is often more difficult to contain contaminants from without than from within an instrument. This is because stringent care is normally taken in the development of the contamination-sensitive sensors, while it is not often a high priority for other instrument packages. The XRS/EUV has been designed to minimize the effects of this external cross-contamination.

5.0 Contamination Control

Contamination control is multi-faceted, beginning with careful consideration of the instrument design. A high degree of care must be exercised to control the materials and parts used within the instrument (and other instruments), in cleaning and baking components prior to assembly, and in maintaining thorough contamination control practices throughout assembly and test. Finally, handling and packaging for shipment, storage, and integration and test are essential to delivering an instrument that meets the specifications.

The XRS/EUV has the most severe contamination control requirements, so all of the requirements in this document apply to that instrument. The EPS/HEPAD does not have the severe contamination limitations of the XRS/EUV, and some materials and practices that are unacceptable for the XRS/EUV are permitted for the EPS/HEPAD instruments.

All cleaning and assembly procedures and storage/work areas will be reviewed, inspected, and approved by the Contamination Control Engineer prior to flight hardware assembly. Periodic walkthroughs of controlled-areas will be made by the CCE to verify that appropriate procedures are in place and being implemented. Specific handling instructions with regard to contamination control will be incorporated in the process route-sheets and test procedures.

5.1 Instrument Design

Careful instrument design, with contamination control as the driver, can save countless man-hours in contamination control, monitoring, and mitigation. Design features based upon contamination modeling can often provide a simple and cost effective means of ensuring that the on-orbit performance requirements will be satisfied. Strategic placement (based upon modeling) of internal baffles, Zeolite molecular absorbers, and entrance slits will minimize the FOV from contaminating surfaces to the sensitive instrument surfaces. Internal baffles and Zeolite absorbers also provide sticking surfaces that inhibit the migration of molecular contaminants toward the sensors. Careful design of GN2 purge-flow is also an important aspect of the instrument design, as turbulent-flow purges can actually increase the particulate contamination in some areas of the instrument due to eddy-current flows, and can transport molecular contamination if non-approved purge tubing is used. The purge-ports are further described in Section 5.4, 'Purging and Venting.' Protective caps or covers provide significant isolation from contaminating environments (as long as low-outgassing materials are used), and will be used wherever practical. The general design of the EUV telescope, including the purge port location, is shown in Figure 5-1.

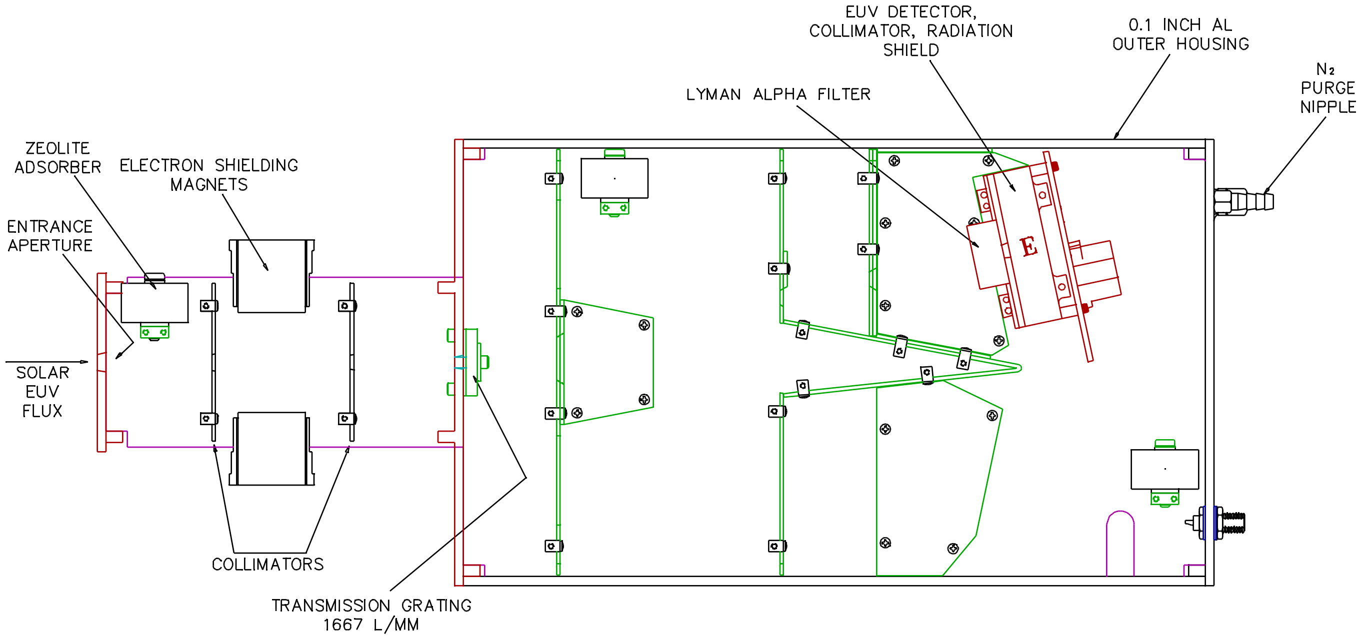

Figure 5-1, General layout of one EUV telescope (EUV-E channel shown).

5.2 Inspection, Parts Cleaning, and Assembly

The following procedures apply in full for the XRS/EUV, but some items may be only partially applied to the EPS/HEPAD instruments, which have much more relaxed contamination requirements. In general, the EPS/HEPAD instruments do not require handling on a Class 100 laminar flow bench, and some handling requirements are eased if the part can be cleaned at a later stage. Detailed controlled area operations and monitoring procedures are provided in a separate document, the 'Controlled Area Practices', (GOESN-ENG-005). Cleaning procedures are summarized below, but all specific parts-cleaning requirements will be provided in the assembly route sheets or travelers for the individual parts or assemblies. In addition, individual test routines and procedures will call-out all special handling and assembly requirements with regard to contamination control.

XRS/EUV flight-component receiving and inspection shall be performed in a safe, controlled area. Assembly shall be performed on a Class 100 laminar flow bench, located within a class 10,000 cleanroom, in order to minimize the transfer of particulate and molecular contaminants to the parts during handling. Approved gloves must be used whenever incoming parts or components are inspected or otherwise handled. Cleaning of incoming parts and components will be performed in a separate controlled area, with final cleaning being done in the cleanroom. The cleaning processes described in Section 9.0, 'Cleaning Procedures' are particularly geared towards removing molecular and organic residues from manufactured or machined parts. Electronic components (including ICs, resistors and capacitors, PC boards, connectors, connector shells, etc.) do not require cleaning prior to assembly, as these components are cleaned appropriately during and after board-level assembly. Wires and harnesses, and other hard-to-clean parts will be solvent-wiped as part of the assembly process.

All other manufactured piece-parts for the XRS/EUV shall be cleaned in ultrasonic baths as per Section 9.0, 'Cleaning Procedures', or according to the individual route sheets as stated above, unless those parts are received in a condition that precludes cleaning. Freshly anodized or iridited aluminum parts need not always be cleaned ultrasonically if received in approved, non-particulating packaging, but a solvent wipe may be prudent. Solvent wipes shall be performed using non-particulating clean-room wipes (see below), and will be done frequently during assembly to remove particles and residue. Any component/item that is suspected of being contaminated will be solvent-wiped before it is used in the XRS/EUV. Approved cleaning agents and solvents for all parts and components are given below. (See the Approved Materials List for grades). For hard to remove oils and silicones, a solution of de-ionized water and Simple Green™ Solution (a surfactant) can be used.

Additional cleaning agents may be used (in PC board cleaning, for example), but must be approved (grade HPLC) and included on the Materials List (see Section 8.0, 'Parts and Materials Lists'). In addition, very low residue gloves must be worn during all stages of inspection, cleaning, and assembly. It is important that finger oils and other molecular contaminants not be transferred to flight components (or to GSE components which come into contact with flight components during inspection and assembly). This is an absolute requirement for the XRS/EUV; the EPS/HEPAD units may be excluded from this requirement if the contaminants can be removed at a later time by surface wiping. The use of Nitrilite gloves at all times is strongly recommended, and they are available from Ansell Edmont as noted in the Cleanroom Buyer's Guide (Appendix A of GOESN-ENG-005).

Gloves must be changed frequently when working with both 'clean' and 'dirty' parts simultaneously, or during transitions from mixing epoxies, to working with flight hardware, for instance. Small amounts of contaminants may be removed from gloves by wiping with IPA-soaked clean room wipes. Non-particulating, Class 100 (or lower) wipes, and ESD compatible swabs must be used during all stages of inspection, cleaning, and assembly. Solvent-extracted wipes will not routinely be used, but may be used to assay molecular contamination levels prior to final cover installation. A complete line of cleanroom products is available from Texwipe (also noted in the Cleanroom Buyer's Guide, Appendix A of GOESN-ENG-005).

Standard practices to be used during assembly include the use of ESD-safe vacuum cleaners, ionizing N2 guns, and non-particulating alcohol wipes or swabs to remove particles generated during assembly. Inner surfaces must always be treated with extreme care to avoid transferring molecular sources from the assembly area to the clean surfaces.

5.2.1 Solvent Use

All solvents used for cleaning vacuum-GSE or flight hardware shall conform to the Materials and Parts List (GOESN-M&P-001). Use only Panametrics approved Isopropyl Alcohol (IPA) and Panametrics approved Methyl Alcohol. Solvents used in the controlled areas will be kept in approved polyethylene or Teflon squeeze bottles that will not leech molecular contaminants into the solvent or otherwise degrade the solvent. Wipes/swabs will not be dipped into solvent containers as this practice contaminates the solvent. Instead, the approved squirt bottles will be used to wet the wipes/swabs. Appropriate care must be taken to properly vent these solvents during use.

5.3 Material Selection Criteria

The general selection criteria (with respect to cleanliness level, outgassing potential, constituent materials, shedding, etc.) for materials used in the assembly, packaging, and transport of flight hardware are given below. This includes verification of the suitability of materials used in the construction of containers, carts, lifting devices, packaging materials, etc. Recommended sources of such materials are provided in the Cleanroom Buyer's Guide, Appendix A of GOESN-ENG-005. Where required, testing will be performed according to ASTM E595 to verify that outgassing levels are acceptable for certain materials. At a minimum, materials selection criteria shall conform to the following requirements:

- Materials that outgas molecular contamination shall not be used unless approved for use on the program, and contained in the Approved Materials List. Also, see Table 5-1, 'Restricted Materials' below.
- Materials generating particulate contamination shall not be used. Common problem areas in the past have been plastic, metal-laminated, or coated-plastic films that shed particles when abraded. This is especially true at contact points, oxidized aluminum surfaces, corroded surfaces, and improperly applied paints. See the Table 5-1, 'Restricted Materials' below.
- Surface cleanliness of all materials that come in contact with flight hardware shall be equal to the required cleanliness level of the flight hardware being contacted.
- Wood, silicones, and PVC are prohibited, as they pose serious molecular contamination threats. Very often, materials that violate the outgassing requirements will have a noticeable 'smell' or will feel 'slippery'. Use of such materials shall always be avoided.
- Metals shall be finished so that they do not generate particles. All flight hardware shipped in metal containers shall be bagged prior to installation into the container.
- Lubricants, coatings, sealants, adhesives, and epoxies, must be carefully selected for low TML and CVCM, and must be used as indicated in the Materials List. Acceptable vacuum stability levels are:

  Total Mass Loss (TML) < 1.0%
  Collected Volatile Condensable Material (CVCM) < 0.1%

All materials and parts used in the inspection, assembly, and testing of the XRS/EUV must be included in the detailed inspection, assembly, and/or testing instructions, as approved by the CCE, and must conform to the general requirements stated above, and in Table 5-1, 'Restricted Materials.' Vacuum outgassing tests will be made according to **ASTM E595**. The EPS/HEPAD instruments need not adhere to the same requirements, although they must adhere to the TML and CVCM limits. The 'Materials and Processes List and Specifications,' GOESN-M&P-001, identifies all approved M&P items with conditional applicability statements.

5.3.1 Table of Restricted Materials

Only those parts and materials on the Approved Parts and Materials Lists shall be used in the assembly of the XRS/EUV. However, contamination problems often occur during those instances where the use of a special tool, a new assembly area, or some other unforeseen circumstance results in contaminating material coming in contact with flight hardware. The following table of restricted materials, Table 5-1, is included in order to develop an awareness level for all personnel who work with the instruments, that these materials are known to be common causes of such contamination. The table applies fully to the XRS/EUV, and the EPS/HEPAD instruments will follow the restrictions to the extent that they are reasonably applied. The EPS/HEPAD units will be assembled and tested in a Controlled Area, with wooden workbenches covered with an accepted conductive layer. Standard office-flooring tiles are acceptable, with conductive mats being used as necessary. The XRS/EUV will be assembled and tested on a laminar flow bench located in a class 10,000 cleanroom.

Table 5-1, Restricted Materials

Restricted Materials	Problems, Workarounds, Comments
Wood, wood by-products, paper: Laminates, pressed woods, wooden handle tools, crates, harness fixtures, cardboard cartons, common paper	Outgas for long periods of time (wood smell). Shed particles, cannot be thoroughly cleaned. Rough porous surfaces trap contaminants. No direct contact with the XRS/EUV allowed; sealed surfaces (conductive surface covered wooden workbenches) acceptable; isolated work areas acceptable; only partly applicable to the EPS/HEPAD units.
Silicone: Adhesives, adhesive tapes, hand creams, oils, lubricants, gaskets, seals, release agent for many processes (esp. plastic molding)	Very difficult to remove once on a surface, creeps due to low surface tension, migrates easily and quickly. Contaminated surfaces must be cleaned with Simple Green. Use of silicone in the XRS/EUV is prohibited.
Vinyl, PVC, Rubber: Tubing, electrical wire insulation, films, packaging, gloves, pipes, tool handles, substrates for adhesive tapes, floor tiles, toteboxes, connector covers	Tend to outgas or transfer molecular contamination. Not all are a problem, but the cost of verifying is prohibitive. Easily attacked by solvents – including IPA. May be used in the cleanroom, provided the XRS/EUV are suitably isolated (laminar flow bench; bagging). May require CCE approval and taping or bagging around material for certain uses in assembly areas or in Controlled Areas.
ESD Materials: Pink polyethylene and other polymers with surfactants, certain carbon loaded materials, topical surface treatments, and Velcro ESD wrist straps	Carbon particles in some products shed (connector covers, and conductive foams). Surfactants and topical treatments are either volatile or easily transferred upon contact. Certain metal coatings can shed particles. May require CCE approval for certain uses.

Restricted Materials	Problems, Workarounds, Comments
Non-vacuum-stable Oils, Lubricants: Mechanical GSE, (dollies, wheels, bearings, *etc.*), mechanisms, moving joints, cutting and drilling oils	Molecular contaminant hazards. Replace non-vacuum materials with Apiezon L or M, Braycote 600 or 601, or other lubricant approved by CCE. Apiezon is preferred for non-vacuum GSE. For cases where this is not easily accomplished, the XRS/EUV must be protected by suitable bagging.
Particulating Surface Finishes: Flaking paint, chipped, cracked, or corroded surfaces, aluminum-oxide, black oxide, moly-disulfide, Velcro	Shed particles. Use of these requires CCE approval. May be able to tape and/or bag affected areas. Surfaces may have to be recoated.
Common Plastics:	Most molded plastics use silicone as release agents, so must be cleaned with Simple Green. Acceptable plastics for use with the XRS/EUV are: clear polyethylene, polycarbonate, polypropylene, and Teflon. ABS and acrylics may be acceptable.
Foams, Sponges, etc.	Shall not be used unless approved by the contamination engineer. They shed particles, trap contaminants, and can't be easily cleaned.
Brushes:	Verify materials: handle, bristles, ferrule, adhesives. Prefer all-polypropylene construction with mechanically held bristles.
Packaging Materials:	Only materials on the Parts and Materials Lists, and identified for packaging applications, may be used for shipping and storage. (See Section 5.5, 'Handling, Storage, Packaging, and Transportation')

5.3.2 Epoxy, Staking, Sealant, Potting, and Conformal Coat

All of the epoxies, staking compounds, sealers, potting, and conformal coats used throughout the program will meet the outgassing requirements of TML < 1.0% and CVCM < 0.1% (as shown on the Materials List). However, excessive use of these organic compounds can still result in high total outgassing rates. It is good practice to use only the minimum amount of material required to perform the task. Additionally, extreme care must be exercised in mixing and applying these materials, since deviating from the approved mixing ratios and cure times can greatly affect the outgassing properties. Surprisingly large amounts of such organic materials find their way into instruments. These materials are often used in late stages of satellite integration, and must therefore be carefully handled prior to use (since hard bakeouts are no longer possible).

5.4 Purging and Venting

The XRS/EUV instrument will be nearly hermetically sealed. This will permit the use of dry-nitrogen purge to flush the instrument of particulate contamination, and to reduce the influx of molecular contaminants through the input apertures. Such a nitrogen purging system must deliver nitrogen of a purity that does not compromise the cleanliness of the sensors. Liquid nitrogen boil-off is the most desirable purge gas. Vacuum chambers used for T/V, bakeout, calibration, and test will also be vented according to the requirements below. Instrument-specific purge requirements are detailed in the 'Handling, Storage, Packaging, and Transportation Procedures for the XRS/EUV' (GOESN-RTP-197) and 'Handling, Storage, Packaging, and Transportation Procedures for the EPS/HEPAD' (GOESN-RTP-198).

Whenever possible, the instruments will remain under GN2 purge, or in dry N2 or vacuum storage. This includes all levels of instrument and satellite-level environmental testing. Flow-rates through the XRS/EUV will be determined upon initial testing, but are expected to be only a few SCFH. The policy for instrument purge at satellite-level is described below.

The XRS/EUV is designed to vent through the input apertures on vacuum-test and launch-ascent depressurization. The purge-port is located on the anti-sun-side of the instrument (near the sensors). The purge-port is described in the XRS/EUV ICD (nominal location is shown in Fig. 5.1). Whenever practical the apertures will remain covered with red-tagged caps to minimize the risk of cross-contamination. An additional 'shower-cap' cover may be used to protect the XRS/EUV apertures during Satellite I&T.

The completed EUV telescope assembly will be kept under continuous nitrogen purge at a rate of 1 to 10 SCFH, or sealed off with near-hermetic seals at all times. These seals shall be tight enough to maintain an internal relative humidity of less than 5 percent when the exterior humidity level is 45%, and they are under nitrogen purge. The instrument can remain un-purged for periods of no longer than 7 days, if properly sealed, at which point, the purge must be reinstated for 24 hours. Following this purge, the instrument must be resealed. There is no requirement for fairing purge (when the cover seals have been removed) other than reasonable attempts to minimize exposure to moisture and contaminants during this period. Again, these requirements are described in the'Handling, Storage, Packaging, and Transportation Procedures for the XRS/EUV' (GOESN-RTP-197) and 'Handling, Storage, Packaging, and Transportation Procedures for the EPS/HEPAD' (GOESN-RTP-198), which take precedence over this document for said purposes.

5.4.1 Nitrogen Requirements

Liquid nitrogen boil-off (0.5 micron filtering) or Class C or better (per MIL-P-27401C) research-grade bottled nitrogen shall be used for purging the XRS/EUV, back-filling vacuum chambers, and for drying parts after cleaning.

Plumbing used for purging, back-filling, and blow-guns shall be fabricated from non-contaminating materials that shall not degrade the cleanliness of the nitrogen. Panametrics dry nitrogen consists of filtered LN2 boil-off, and is plumbed into each room via stainless-steel tubing, and filtered prior to use.

Approved flexible teflon or Frelin-Wade tubing may be used for the XRS/EUV purge. Prior to attachment to flight hardware, all flexible tubing will be flushed with dry nitrogen for 12 hours.

5.5 Handling, Storage, Packaging, and Transportation

General practices for storage, packaging, and transportation of the XRS/EUV and EPS/HEPAD are shown below. Specific procedures are described in detail in the Handling, Storage, Packaging, and Transportation Procedures for the XRS/EUV' (GOESN-RTP-197) and in the 'Handling, Storage, Packaging, and Transportation Procedures for the EPS/HEPAD' (GOESN-RTP-198) (see Section 1.0 Reference Documents). For long-term storage, instruments and sensitive subassemblies shall be stored either under clean vacuum (<100 mTorr), in a container purged continuously with dry GN2, in a sealed bag which has been purged with dry GN2, or in clean dry boxes (EPS/HEPAD units only). In addition, whenever an assembly is in temporary storage, anti-static ESD shielded shrouds or covers will be used to protect the assembly from particle fallout.

Instruments must be triple-bagged prior to shipping or transporting. For the inner 2 (two) bagging layers, use only Courtaulds Llumalloy ESD bagging material (HSC-50%, 2-mil is recommended. See the Controlled Area Buyer's Guide). Whenever the XRS/EUV flight instruments are being transported outside of the facilities, an outer moisture barrier (sealed bag) must also be used. The outer bagging material can be found in the 'Cleanroom Buyer's Guide', Appendix A of GOESN-ENG-005. In addition, Permacell 224 Kapton and 3M 850 tapes are approved for packaging and bagging.

5.6 Environmental and Functional Testing

Typically, the instrument-level test-phase is where most of the molecular contamination occurs. This is partly due to the fact that environmental testing is more time-consuming than assembly, but is also due to the lack of control over the local environment during certain testing. Instrument covers and shrouds must be removed for some of this testing, and certain environments (EMI/EMC and vibration, for example) are particularly dirty. Extra care will be taken during these phases to minimize the level of contamination. For example, prior to exposing flight hardware to a 'dirty' area, the area will be prepared and cleaned as well as practical. In addition, extra layers of bagging material will be used, and/or portable clean-hoods or tents will be built-up around exposed hardware. Whenever sub-components are being tested outside of a controlled area or cleanroom, that area will be prepared according to procedures within the process route sheets, and the hardware will be protected as well as is practical from the environment, typically by layers of bagging material.

Thermal vacuum is another likely place for contaminants to be thermally transferred into the instrument's inner surfaces. Prior to thermal vacuum testing of any instrument, the thermal vacuum chamber will be baked out and verified per GOESN-RTP-190, 'Thermal Vacuum Bakeout Procedures'. Since the thermal vacuum chamber uses a cryopump, the cold surfaces of the cryopump will trap most of the outgassing contaminants during thermal vacuum, and these will be contained during chamber bleed-up, since the cryopump will be valved off. This is more desirable than the use of an in-chamber cold plate, which must be warmed up during chamber bleed-up, thus releasing much of the condensed contaminants. Calibration of the XRS/EUV at the BNL NSLS is not expected to be a problem, since cleanliness requirements on the XRS/EUV are very high in order to prevent contaminating the NRL beam-line. The instrument must be able to maintain a vacuum of <3 x 10^{-7} Torr before calibration at the NSLS can begin. Whenever possible, the instruments will be maintained in well-controlled environments such as:

- Under GN2 purge, with aperture covers installed
- Bagged in ESD protective shrouds
- Stored in vacuum or dry N2. Note instruments containing solid state detectors should not be stored in vacuum for extended time periods without standby bias applied.

Satellite integration and test (I&T) is relatively more benign, because the instrument environment can normally be well maintained during this period. The highest concern from the XRS/EUV standpoint is with satellite T/V. Several approaches are being considered in order to minimize contamination of the XRS/EUV during T/V, including using GSE covers, and/or aperture-plates and/or cold-plates, which will permit operation of the instruments, but reduce the risk of organic cross-contamination.

All mechanical, electrical, and vacuum GSE that must be used to test flight hardware will be appropriately cleaned or prepared prior to contacting flight hardware. Relevant instructions will be incorporated into the process route sheets and test procedures for such occasions.

Expected contamination allowances will be verified at each phase of EM and protoflight testing, and the results will be used to refine the control procedures used for the flight instruments.

5.7 Contamination Awareness Training

All personnel who work with flight components will be given ongoing training sessions in standard contamination control practices and procedures. The first of these training sessions will be conducted prior to assembly of the Engineering Model, and subsequent 'spot-training' will be performed during all stages of hardware inspection, cleaning, assembly, and test. The objective of the personnel training will be to raise the awareness level as to the risks, concerns, causes, and consequences of mishandling, and to provide a level of self-discipline. Certain facilities will be under development during early EM work, including the thermal vacuum and bakeout chambers. Experience gained in the development of the EM is expected to result in some changes to the facilities plan as well as the assembly procedures.

6.0 Contamination Monitoring

Contamination control processes alone are not sufficient to deliver an instrument which meets the performance specification through end-of-life. Periodic monitoring of the levels of particulate and organic contamination is also necessary. Once established, a simple, yet thorough contamination-monitoring program can provide:

- Evidence that effective contamination control practices have been used, and
- Confidence that requirements for on-orbit performance will be met

Unfortunately, however, there are large uncertainties associated with the direct measurement of molecular contamination within the XRS/EUV instrument. The molecular requirement as shown in Section 4.0 for the interior surfaces is less than 1.0 μg/cm^2 and less than 5% post-calibration degradation. Only the absolute calibration of the sensors, themselves, can approach this measurement sensitivity. NVR rinses of the interior surfaces, for example, would require very large rinse areas in order to detect such low levels. The 'background' in pre-extracted swab measurements is far too high for such verification. Other indirect measurement techniques such as reflectivity or FTIR on witness plates also suffer from such uncertainties, and the results don't necessarily apply to the surfaces of interest. Due to the large measurement uncertainties, these techniques can identify only the most severe contamination events. For this reason, there will not be an extensive contamination-monitoring plan for the internal XRS/EUV surfaces. Periodic measurements will be made, however, with the intent to verify that such large contamination events have not taken place. Careful attention shall also be paid to contamination control during all stages of assembly and test, and very thorough vacuum bakeouts will ensure that contaminants have been removed prior to calibration. Only the final sensor calibration will verify that molecular contamination budgets have been met (the gratings and sensors will be measured prior to assembly, and large discrepancies in sensitivity will be investigated as contamination losses). The above mentioned monitoring approaches are further described in "Section 6.3, Monitoring Processes and Techniques."

6.1 Controlled Area Monitoring

All XRS/EUV assembly operations will be performed in a controlled area. The controlled area environment is 70±10°F, 30% to 60% RH, and ≥0.05 inch water overpressure. The detailed controlled area procedures are described in the 'Controlled Area Practices' document (GOESN-ENG-005), which provides the temperature, humidity, and particulate monitoring schedules. Particulate levels for 0.5 micron particles will be checked at roughly 6 month intervals, but will not be monitored continuously. Special care shall be exercised to assure that the Dew Point is avoided at all times when flight hardware is present.

6.2 Cleanroom Monitoring

All XRS/EUV assembly operations will be performed in a class 10,000 cleanroom. The cleanroom environment is 70±10°F, 30% to 60% RH with HEPA filter air. The detailed cleanroom procedures are described in the 'Controlled Area Practices' document (GOESN-ENG-005), which provides the temperature, humidity, and particulate monitoring schedules. Particulate levels for 0.5 micron particles shall be continuously monitored, whenever flight hardware is present. Monitoring units shall be located as specified in the 'Controlled Area Practices' document (GOESN-ENG-005). Corrective action shall be implemented when the requirements for the cleanroom are exceeded or large excursions from the norm occur and persist. If the particulate level for a cleanroom is exceeded (as indicated via set-point alarms on the particle fallout monitor) for more than 30 minutes, or by more than 10%, immediate action shall be taken to protect the flight hardware from excessive fall-out. The general practice shall be to observe the particle readings continuously and to log hourly. Data will only be logged in a single location due to the small size of Panametrics cleanroom. These measurements will be provided to the contamination engineer on a monthly basis.

Cleanroom molecular levels will be monitored continuously, using witness samples which are checked at roughly 3 month intervals. During periods of significant activity this may be reduced to 2 weeks (minimum), as recommended by the CCE (see GOESN-ENG-005). Special care shall be exercised to assure that the Dew Point is avoided at all times when flight hardware is present.

6.3 Monitoring Processes and Techniques

As mentioned earlier, the large uncertainties associated with molecular monitoring techniques preclude the use of such measurement for all but the most severe contamination events, or very long-term exposures. For this reason, molecular monitoring of the internal surfaces of the XRS/EUV will not be routinely carried out. The use of witness foils is required in the assembly/storage area for the XRS/EUV; as specified in GOESN-ENG-005. In addition:

- Residual Gas Analyzers (RGAs) will be used during instrument-level T/V to monitor and quantify outgassing levels, and to provide molecular species identification (MID)
- TQCMs will be used during instrument-level T/V to monitor outgassing rates (no MID), and to verify cleanliness certification levels
- Periodic NVR rinses will be performed according to ASTM E1234 along with FTIR and Mass Spectrometry to quantify deposition levels and provide MID. (This applies to the XRS/EUV only.)
- Periodic wipes and swabs will be performed according to ASTM E1560 in order to quantify NVR and provide MID. (This applies to the XRS/EUV only.)
- Surface Acoustic Wave (SAW) monitoring is up to 200 times more sensitive than TQCMs, and may be investigated as a means of providing outgassing rates near the EUV sensors
- Tape lifts done for particulate monitoring will have the tape lift area solvent cleaned immediately after the lift to remove any possible tape residue

6.4 Control Documentation

All data that are recorded to quantify particulate or molecular contamination levels will be logged according to standard practices (specified in the 'Controlled Area Practices' document, GOESN-ENG-005), and will be readily available for inspection. It is expected that most of the monitoring and data analysis will be done early in the program (for the EM and protoflight). This will lead to refinement of the assembly and handling processes used for the flight units.

6.5 Engineering Model and Protoflight Monitoring Plan

The monitoring plan for the XRS/EUV instruments will use the EM as a 'pathfinder' as follows:

- Monitor cleanroom particulate levels during all stages of assembly (cleanroom witness foils are also used).

- Measure transmission and sensitivity of individual gratings and sensors prior to assembly. This process will lead to the selection of gratings and sensors. At instrument calibration, the measured sensitivities should approach the theoretical values based upon the individual measurements.
- Measure the sensitivity of the most sensitive channel (EUV-E band) using a Lyman-α source at Panametrics. This measurement can be done periodically, and will provide quantitative data on any sensor degradation.
- Assay the molecular and particulate baseline prior to final installation of covers. Various techniques will be employed at this phase, as stated in Section 6.3, 'Monitoring Processes and Techniques.'
- Monitor and log TQCM and/or RGA data during flight and GSE H/W bakeouts, as required by the appropriate route sheets.
- Calibrate instruments at the BNL NSLS.
- Following calibration and environmental testing (vibration, EMI/EMC, and thermal/vacuum), re-measure molecular and particlulate levels where possible.
- Log TQCM and RGA data during final bakeout and outgassing verification prior to instrument delivery.
- Periodically re-measure the EUV-E channel with the Lyman-α source.
- Respond to special circumstances during above flow, which may require additional levels of monitoring (such as implementing witness samples or SAWs).

7.0 Thermal Vacuum and Bakeout

The following thermal vacuum and bakeout requirements apply fully to the XRS/EUV. The EPS/HEPAD instruments will only be subjected to portions of the bakeouts as necessary to achieve the GOES spacecraft cleanliness requirements, as stated in Section 4.0.

Thermal-vacuum bakeout reduces outgassing rates of organic materials. A bakeout consists of exposing materials, subassemblies, and higher-level assemblies to thermal vacuum conditions. A cost-effective thermal vacuum bakeout program will be developed to assure that sensor surfaces are not degraded by contamination. Higher bakeout temperatures accelerate the outgassing process, and can result in time and cost savings. Also, baking out components at the lowest assembly level possible often results in the lowest costs and risks because higher bakeout temperatures can be used, and the chambers are often smaller and less expensive to operate. The use of efficient venting designs also reduces the amount of thermal vacuum bakeout-time required to meet the deposition requirements as given in Section 4.0.

The vacuum stability (outgassing) characteristics of all organic materials, including those used in subcomponents (connectors and potted devices,) will be determined prior to assembly. This verification may be accomplished through test (e.g., Nusil Technologies), or by using existing data. Records of this verification will be kept in sufficient detail to permit timely verification of the vacuum stability of any materials used within the instruments upon request by HSC. Outgassing data on materials can be found in the Materials and Processes Technical Information Service (MAPTIS) database at the NASA Marshall Space Flight Center, and in the latest revisions of the MSFC-HDBK-527 (JSC 09694) and NASA Reference Publication 1124. The online outgassing database is very useful, and is available at http://misspiggy.gsfc.nasa.gov/og/.

While NASA qualified parts normally meet minimum vacuum stability requirements there are some parts (connectors, for example) which only meet these requirements after extensive pre-conditioning (air-bake or vacuum bakeout). Special care shall be taken to verify that parts and materials have been preconditioned in the same way as those that have passed the tests (this preconditioning information is provided in the references mentioned above.) This is especially true for two-part epoxies, etc. (see Section 5.3.2).

Thermal vacuum bakeout, curing at elevated temperatures, and air-bake are all efficient means of reducing unacceptable material outgassing rates to acceptable levels. It is also sometimes possible to justify the use of materials that do not meet the outgassing requirements by performing a controlled outgassing rate test (ASTM E1559-93 or equivalent). In such a case, the following guidelines can be used: the source should be 10°C above the maximum expected on-orbit temperature for the material, and the TQCM should be 10°C below the minimum orbit temperature for the instrument.

A comprehensive 'Thermal Vacuum Bakeout Procedure' (GOESN-RTP-190) is provided (see Section 1.0 Reference Documents) and contains:

- Thermal vacuum chamber setup and certification including:
  - Chamber and GSE certification
  - TQCM setup and use
  - Bakout support equipment
- Thermal vacuum bakeout
  - Flight hardware bakeout Procedure
  - Special bakeout cases and circumstances
- Data sheets for logging of all relevant bakeout parameters (time, pressure, temperature, RGA readings, TQCM rates, etc.)

Following bakeout, the instruments outgassing rates will be verified according to the maximum change in TQCM values of:

Delta delta = 5%, over 8 hours at T_{op}° C with the TQCM at –10° C,

where T_{op} is the maximum on-orbit operating temperature of the XRS/EUV. The outgassing goal is 1 x 10^{-7} g/cm^2/hr.

8.0 Parts and Materials Lists

The SCDRL numbers listed in Section 1.0, 'Reference Documents', control all parts and materials to be used on this program. Materials that are not on the Materials List must not be used until a formal review has been done, and the material has been added to the list via official channels. These lists shall be reviewed by the CCE, and once approved by the SID and HSC shall become the Baseline Materials and Processes List and Specification Document, SCDRL #17. Any changes to the list shall be made via formal ECOs, waivers, and/or deviations.

9.0 Cleaning Procedures

For all specific cleaning requirements, individual route sheets must be consulted. Detailed cleaning procedures will be provided with the route sheets, as well as with all test procedures that require cleaning or special handling. Most precision cleaning jobs require only the use of Panametrics approved 50/50 Methyl/IPA baths and pure IPA rinses. All XRS/EUV parts and components will be precision cleaned, most of them ultrasonically; the EPS/HEPAD parts and components do not require ultrasonic cleaning. Most manufactured parts and components shall be cleaned as follows:

- Use clean glassware or stainless steel containers to clean parts
- Ultrasonic for 10-15 minutes in 50/50 Methyl/IPA (repeat as necessary)
- Localized brushing or agitation may be required
- Ultrasonic rinse for 10-15 minutes in IPA (repeat as necessary)
- Replace IPA, and final ultrasonic rinse for 10-15 minutes in IPA
- Air-bake or vacuum bake at warmest allowable temperatures, for longest practical duration (typically 1-2 hour air-bake at 100°C for screws, etc.) (note cure times and temperatures on Materials List)

DI Water with Simple Green is used for certain plastics and for very persistent oils and residues, or when silicone contamination is suspected.

- Use clean glassware or stainless steel containers to clean parts
- Ultrasonic for 10-15 minutes (or until visibly clean) in 10% Simple Green / 90% de-ionized water (repeat as necessary)
- Localized brushing or agitation may be required
- Rinse and agitate very thoroughly with DI water (repeat cleaning/rinsing steps as necessary)
- Ultrasonic for 10-15 minutes in 50/50 Methyl/IPA (repeat as necessary)
- Ultrasonic rinse for 10-15 minutes in IPA (repeat as necessary)
- Replace IPA, and final ultrasonic rinse for 10-15 minutes in IPA
- Air-bake or vacuum bake at warmest allowable temperatures, for longest practical duration (typically 1-2 hour air-bake at 100°C for screws, etc.) (note cure times and temperatures on Materials List)

PCB cleaning may be accomplished by using some of the above procedures, including use of 1, 1, 1-Trichloroethane, or by using an approved PCB cleaning system.

For large or unwieldy assemblies that cannot be cleaned using the above techniques, the Contamination Engineer shall be consulted regarding the appropriate cleaning method. Typically, such parts are wiped until visibly clean with non-particulating cleanroom wipes that have been wetted with IPA.

10.0 List of Acronyms

ABS	Acrylonitrile-butadiene-styrene
BNL	Brookhaven National Laboratory
CCE	Contamination Control Engineer
CVCM	Collected Volatile Condensable Materials
DI	Deionized (water)
DOP	Di-Octyl Phthalate
DPU	Data Processing Unit
EM	Engineering Model
EMI/EMC	Electromagnetic Interference/Electromagnetic Compatibility
EPS	Energetic Particle Sensor
ESD	Electrostatic Discharge
ETU	Engineering Test Unit
EUV	Extreme Ultraviolet (Sensor)
FED-STD	Federal Standard
FOV	Field Of View
FTIR	Fourier Transform InfraRed
GN2	Gaseous Nitrogen
GOES	Geostationary Operational Environmental Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HEPA	High Efficiency Particulate Air
HEPAD	High Energy Proton and Alpha Detector
HPLC	High Performance Liquid Chromatography
HSC	Hughes Space and Communications Company
I&T	Integration and Test
IPA	Isopropyl Alcohol
IRD	International Radiation Detectors
M&P	Materials and Processes
MID	Molecular Identification
MIL-STD	Military Standard
MLI	Multi-Layer Insulation
NASA	National Aeronautics and Space Administration
NRL	Naval Research Laboratory
NSLS	National Synchrotron Light Source
NVR	Non-Volatile Residue
PCBs	Printed Circuit Boards

PPA	Panametrics Product Assurance
PVC	Polyvinyl Chloride
RGA	Residual Gas Analyzer
SCDRL	Subcontract Data Requirements List
SCFH	Standard Cubic Feet per Hour
SID	Space Instrumentation Division (of Panametrics)
SPA	Solar Panel Array
TBC	To Be Confirmed
TBD	To Be Determined
TML	Total Mass Loss
TQCM	Temperature-controlled Quartz-Crystal Monitor
T/V	Thermal Vacuum
UV	Ultraviolet
XRS	X-Ray Sensor