PREFERRED
RELIABILITY
PRACTICES

CONTAMINATION CONTROL PROGRAM

Practice:

Apply a Contamination Control Program to those spacecraft projects involving scientific instruments which have stringent cleanliness level requirements.

Benefits:

This practice enables spacecraft to meet these stringent cleanliness level requirements of state-of-the-art scientific instruments. It also serves to maintain the inherent efficiency and reliability of the instrument by minimizing degradation of critical surfaces and sensors due to undesired condensation of molecular and accumulation of particulate contamination layers.

Programs That Certified Usage:

Cosmic Background Explorer (COBE)
Extreme Ultraviolet Explorer (EUVE)

Center to Contact for More Information:

Goddard Space Flight Center (GSFC)

Implementation Method:

General

This Contamination Control Program and a number of its supporting technologies were developed to meet the stringent cleanliness specifications of the COBE state-of-the-art scientific instruments. These instruments operated at temperatures below 2 degrees Kelvin inside a dewar and required the most stringent surface level cleanliness specifications ever attempted by GSFC and perhaps NASA. These low temperatures required innovative contamination control measures to prevent condensation of outgassing materials on critical cold optical and non-optical surfaces. This program as defined in the following begins with the early design phases where cleanliness specifications are established and continues through the entire flight program where contamination of flight hardware is monitored and controlled from fabrication through integration and testing, transportation to and handling at the launch site, and the launch and early orbit phases as appropriate. The COBE stringent cleanliness specifications were initially

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met and maintained. Early observations from COBE show that the instruments are operating nominally. Optical scattering, principally caused by particulate and molecular contamination, is an order of magnitude smaller than originally budgeted with the spacecraft's contamination specifications.

Cleanliness Specifications

Establish cleanliness specifications during the early design phases. The most stringent cleanliness specifications are established as required for critical surfaces, usually cold surfaces such as optical surfaces, apertures, forebaffles, detectors, etc. These specifications are usually based on theoretical instrument performance degradation studies, contamination data from previous spacecraft missions, and in some cases from the space environment where cold optics can be coated with molecular layers of contamination from high-energy atomic oxygen bombardment or particulate contamination from micrometeoroid collisions with the spacecraft. Less stringent contamination specification requirements are established for less critical spacecraft and instrument surfaces and components.

Stringent cleanliness specifications usually require the design of special contamination control domes and covers to protect critical surfaces during spacecraft qualification testing, transportation to and preparations for launch at the launch site, and during the launch and early orbital outgassing period. These domes and covers are deployed or detached from the spacecraft during the early orbits. Where appropriate, special instrumentation such as scatterometers or quartz crystal microbalances (QCM) are incorporated into the design of instruments to monitor contamination of critical surfaces or areas generated during spacecraft testing and launch activities.

Selection and Testing of Materials

Material selected for use in flight hardware is tested for its outgassing properties in accordance with ASTM E-595-77/84. Only materials that meet the criteria of ASTM E-595-77/84 [i.e., have a total mass loss (TML) < 1.0% and a collected volatile condensable mass (CVCM) <0.10%] are approved for use in a space environment. Instruments with more stringent contamination control specifications may require more stringent material selection criteria. Refer to related Practice NO. PT-TE-1410 for additional information on material selection and supporting vacuum outgassing data.

Maintaining Clean Surfaces

Spacecraft surface cleanliness levels are maintained throughout fabrication, integration, environmental qualification, and launch operations. These cleanliness levels are achieved through initial component level cleaning in a precision cleaning facility along with routine cleaning of the entire spacecraft. The cleaning facility is a 10,000 or better laminar-flow clean tent or clean-room equipped with an exhaust bench for chemical cleaning, an ultrasonic cleaning station, and contamination inspection stations. Standard cleaning procedures include a combination of thermal bakeouts, solvent rising, vacuuming, gaseous nitrogen blasting, vibration testing, and ultrasonic techniques. Flight components are required to undergo a thermal bakeout to reduce potential contamination due to outgassing. The following three inspection techniques are used to verify levels of cleanliness of flight hardware. First, the component is visually inspected using a minimum 100 footcandle intensity white light and a long wave black light to determine the presence of molecular and particular contamination. Second, tape lift samples are taken and analyzed to provide a statistical estimate of the total number and size distribution of particles per square foot present on the test sample. Third, molecular contamination levels are verified by analyzing a solvent wash using infrared and mass spectrometry techniques. These analyses verify that contaminants are within specified limits and provide data to help pinpoint the source of contaminant and whether material substitutions should be made.

Contamination Control Procedures

Special contamination control procedures are followed during component, subsystem, and spacecraft level flight environmental qualification test programs. These tests include thermal vacuum cycling, three axis vibration, acoustic bombardment, microphonics, and electromagnetic compatibility. Each test presents its own challenge for cleanliness control. An additional challenge is the transportation of the flight hardware from one test chamber or test facility to the next one. Each test chamber or test facility should be capable of maintaining a Class 10,000 or better environment and all test equipment and test fixturing brought into the test chamber or test facility is cleaned according to strict project procedures. During moves between test chambers or test facilities, the flight hardware is double bagged in clean antistatic nylon film. Once inside the clean area, the outer bag is removed and the environment is stabilized prior to removing the inner bag and exposing the flight hardware. If the test chamber or test facility is not a cleanroom, the bags remain on the flight hardware throughout the test. The bags are purged with Class 100 air conditioned atmospheric air to maintain thermal specifications on the flight hardware.

A primary contamination control objective during thermal vacuum testing is to determine the possibility of the spacecraft self-contaminating its instruments during either launch or on-orbit. Secondary objectives are to (1) bake out the entire spacecraft during the first three days of hot-soak conditions, (2) measure the amount of condensed contamination throughout each phase of the test, and (3) determine the chemical makeup of the residue collected on cold surfaces in the chamber. This data is combined with a statistical on-orbit outgassing model of the

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spacecraft to determine an optimum outgassing period prior to deploying or removing contamination control covers from critical hardware. Contamination monitoring techniques used in the thermal vacuum testing include (1) the placement of quartz crystal microbalances around the spacecraft to provide a real-time means of measuring the quantity of outgassing contaminates throughout the testing, (2) the use of a residual gas analyzer to measure the types and quantity of gas molecules and their outgassing rates. Cold fingers, scavenger plates, and witness mirrors are used to collect contaminates that will condense on critical surfaces. The contaminates are analyzed using infrared and spectrometer techniques to identify the outgassing materials and their quantities.

Primary contamination control objectives during vibration/acoustic testing are (1) to measure the generated debris and spacecraft self-contamination, (2) to analyze the effectiveness of contamination control covers, and (3) to assess the possibility of debris created during the launch reaching critical instrument surfaces. Contamination is monitored by placing witness plates containing nylon disks coated with transfer adhesive at critical locations usually at the same locations as the witness mirrors used in the thermal vacuum testing. The witness plates collect debris which is analyzed to identify the type and quantity of debris at the various locations of interest. In addition many tape-lift samples are taken at various locations. These samples can show the source and migration of debris. One source of debris generation that has been identified by this technique is scraping interaction between hardware. The problem is corrected by either separating the hardware or by installing an isolating layer of nylon or teflon material to provide a smooth surface that will not shed during launch.

Contamination Control During Transport

The spacecraft is transported to the launch site in a specially designed and built trailer to control the temperature, pressure, humidity, and cleanliness of the environment while protecting it from induced vibrations and stresses. The filtration system used in the transporter enables the pressure to stabilize at equilibrium during both takeoff and landing of transport aircraft. The spacecraft is completely covered and sealed inside two specially constructed Llumalloy-HSC bags prior to mounting the spacecraft inside an outer hard box which is a part of the transporter system. The acceptance tests of the bags include particle counts, tapelift samples, and rinse residue tests to ensure that the bags meet the project contamination specifications. A breathable air purge line equipped with a desiccant and a 2 micron particulate filter is inserted into the inner bag to provide positive pressure between the inner bags and the outer box. A thick outer bag equipped with three High Efficiency Particle Air (HEPA) filters is then placed around the double-bagged spacecraft and supported by a cage to add further weather protection. The HEPA filters protect the spacecraft from the incoming air supplied by a HVAC system which consists of dual air conditioner and heaters powered by diesel generators. The HEPA filter system and the outer bag

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ensure a less than Class 1000 environment around the spacecraft during transportation. Contamination measurements are again taken when the spacecraft is unbagged at the launch site to verify surface cleanliness levels.

Contamination Control at the Launch Site

At the launch site the spacecraft is placed inside a laminar-flow clean room or tent ranging between Class 100 to Class 1000 for final integration and launch preparations. The launch gantry which may have normal contamination levels of Class 100,000 must be carefully cleaned so as to lower the contamination levels to Class 10,000. The fairing of the launch vehicle is submitted to the same contamination levels and inspection techniques as the external surfaces of the spacecraft. The spacecraft is double bagged and purged with Grade C gaseous nitrogen during transportation to the gantry. The purge is then changed to conditioned air. The clean bags and the purge remain until just before the fairing is installed. A "shower" cap can be installed over the spacecraft to protect exposed instruments and dewars until the second half of the fairing is installed. Once the fairing is installed, an air-conditioned line containing a HEPA filter to maintain Class 100 air is connected. The air flow inside the fairing is sampled for 20 minute time periods to measure the air quality around the exposed spacecraft.

Technical Rationale:

A variety of instruments including the three state-of-the-art instruments flown on the COBE spacecraft require stringent surface level cleanliness control to protect critical surfaces and components from particulate and molecular contamination. The diffuse infrared background experiment (DIRBE) and the differential microwave radiometer experiment (FIRAS) flown on COBE operate at temperatures below 2 degrees Kelvin (-456.07^{0}F) inside the dewar. This requires stringent contamination control to prevent condensation of outgassing materials on critical cold optical components. The FIRAS is a modified Michelson interferometer that operates in the wavelength range from 0.1 to 10 mm to determine the spectrum of the cosmic background radiation. It utilizes a polished aluminum input skyhorn to direct cosmic radiation into the optical system. Particulate or molecular contamination in excess of level 300A would decrease off-axis rejection performance of the skyhorn and possible destroy tiny elements inside the bolometer detectors. The DIRBE measures diffuse galactic radiation in the wavelength range from 1 to 300 microns. The first optical element in this off-axis Gregorian system is a super polished, gold-coated aluminum parabolic mirror that was cleaned and maintained at level 100A to minimize radiation scattering. The differential microwave radiometer instrument (DMR) flown on COBE has three individual receiver heads positioned around the periphery of the dewar to determine whether the cosmic background radiation is equally bright in all directions. The DMR

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antennas operate at wavelengths of 3.3, 5.7, and 9.6 millimeters, respectively to map the entire sky. The internal surfaces of the corrugated horns were protected from particulate contamination at all times to preserve the cleanliness of the horn throats and the switching mechanism that is used to calibrate each receiver on orbit. A particle of 80 microns in length would cause blockage in the horns and interrupt signal throughput.

Impact of Nonpractice:

Instruments may not be capable of meeting their sensitivity, resolution, and other performance requirements if critical surfaces and components are not adequately protected from particulate and molecular contamination that can condense on cold optics and other components.

Related Practices:

"Selection of Spacecraft Materials & Supporting Vacuum Outgassing Data," PT-TE-1410.

References:

1. Barney, Richard D., "Contamination Control Program for the Cosmic Background Explorer", Journal of the IES, March/April 1991