Abstract
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International Space Station External Contamination Environment for Space Science Utilization

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The International Space Station (ISS) is the largest and most complex on-orbit platform for space science utilization in low Earth orbit. Multiple sites for external payloads, with exposure to the associated natural and induced environments, are available to support a variety of space science utilization objectives. Contamination is one of the induced environments that can impact performance, mission success and science utilization on the vehicle. The ISS has been designed, built and integrated with strict contamination requirements to provide low levels of induced contamination on external payload assets. This paper addresses the ISS induced contamination environment at attached payload sites, both at the requirements level as well as measurements made on returned hardware, and contamination forecasting maps being generated to support external payload topology studies and science utilization.

The ISS system level requirement limits contaminant deposition to 130 Å/year on contamination sensitive surfaces (contained in the System Specification for the International Space Station, SSP 41000). In contrast, the Hubble Space Telescope Program had an outgassing requirement measured at the scientific instrument aft vent could not exceed an equivalent rate of 1.56 x 10^{-9} g/(cm^2 hr) based on the exterior surface area of the instrument (measured with the scientific instrument 10°C above the worse case predicted hot operational temperatures and the collector at -20°C). The Hubble requirement is equivalent to 350Å/year with time-decay and assuming a contaminant deposit density of 1 g/cm^2.

Validation of the requirement is accomplished through analyses performed to integrate all ISS hardware elements and verify that the system level contamination control requirement is maintained for ISS payloads. Predicted contamination levels at ISS payload sites have typically been lower than the system level specification for select surfaces and many contamination sensitive payloads have relied on predicted levels in operational planning.

Currently, the ISS does not have active on-orbit monitoring of contamination deposition. The program has been relying on returned hardware to obtain measurements of contamination deposition and to evaluate performance against predictions. One set of early measurements came from the Materials International Space Station Experiment (MISSE) program which has been deploying materials

experiment trays on ISS since 2001. The MISSE trays are exposed to the natural and induced environment on ISS and subsequently retrieved for return and analysis. MISSE-1 and 2 trays were deployed on the U.S. airlock in August 2001 and had 4 years of on-orbit exposure on ISS prior to being retrieved in August 2005.

Two MISSE 2 gold mirror samples were analyzed by Boeing with X-Ray Photoelectron Spectroscopy (XPS) to determine the composition and thickness of contaminant layer after 4 years of exposure. Contamination measurements on the ram-facing mirror show a contaminant deposit layer of approximately 50 Å (Fig. 1) composed of carbon, oxygen, silicon, and traces of selenium and magnesium.

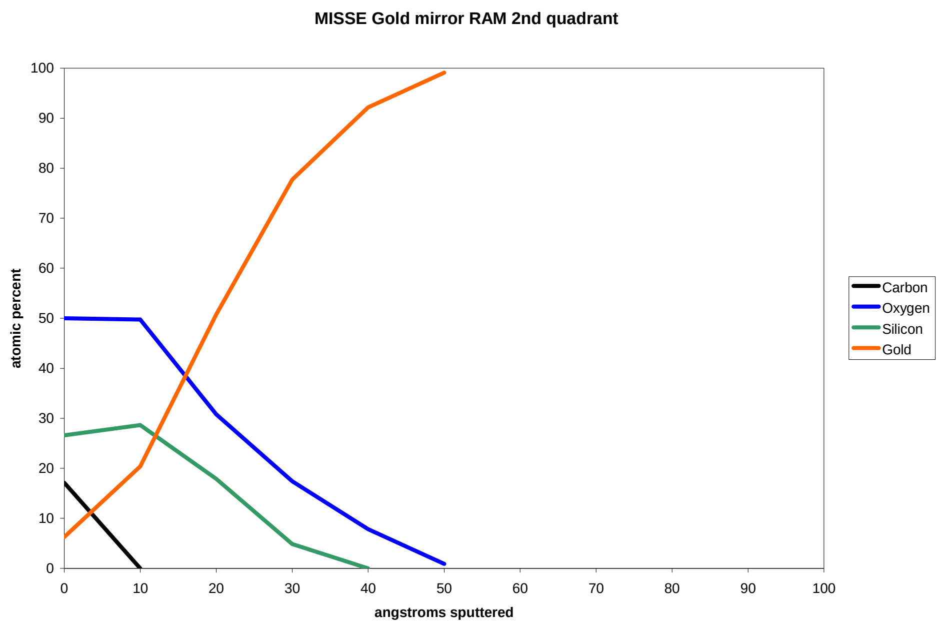

Figure 1. MISSE 2 Ram Facing Mirror XPS Results

The wake-facing mirror was shown to have a contaminant deposit layer of approximately 500 Å (Fig. 2) composed of carbon, oxygen, silicon.

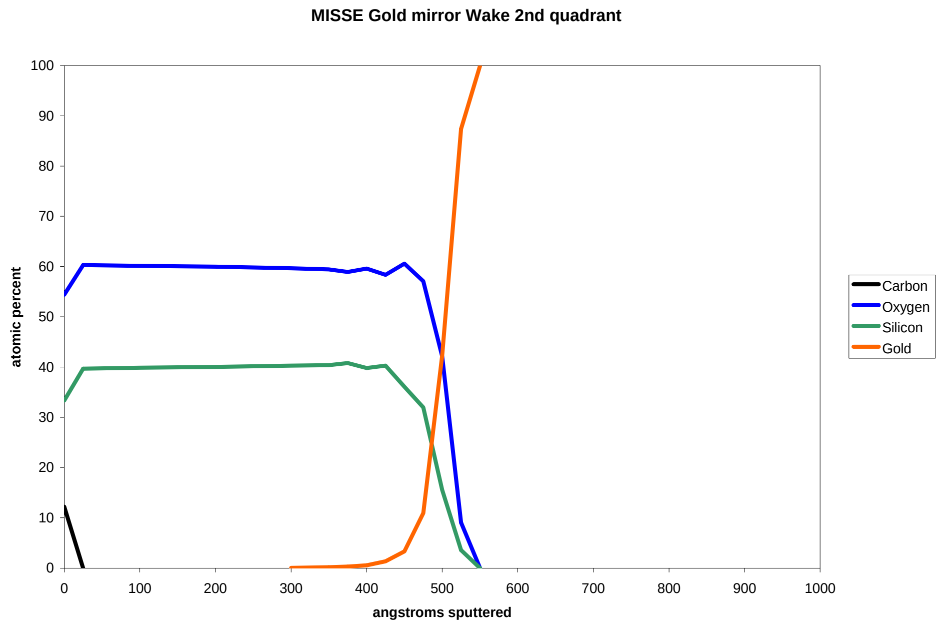

Figure 2. MISSE 2 Wake Facing Mirror XPS Results

A comparison of the MISSE 2 ram and wake-facing samples with analysis predictions (Table 1) showed excellent agreement in contaminant deposition values. Measured values were within a factor of 1.6 of predictions.

Table 1. Comparison of Predicted and Measured Contamination Levels on MISSE-2

MISSE-2	*Predicted Contamination*	*Measured Contamination*
Ram	80 Å	50 Å
Wake	730 Å	500 Å

Additionally, the ram facing measurements are significantly lower (almost one order of magnitude) than the ISS system level specification limit (equivalent to 520 Å for four years of exposure). Wake facing measurements were close to the 520 Å limit (for 4 years of exposure) and a result of contamination sources on the Russian Segment that were deployed prior to MISSE 2 installation on the U.S. Airlock. It should be noted that the MISSE-1 and 2 locations on the Joint Airlock were not originally planned for external payload deployment on ISS and hence, not tracked and protected as contamination sensitive locations.

Observations from external payloads on ISS have been positive. Several payloads (e.g., MISSE and CANARY) have reported no signs of significant performance degradation from induced contamination. A single payload, the European SOLACES experiment (part of SOLAR which is on the Columbus module), observed a significant reduction in counts from its channel electron multipliers (channeltrons) and initially listed contamination as a potential cause. ISS Space Environments Team conducted an investigation on the causes of the observed degradation and concluded that aging of the SolACES channel electron multipliers was the cause of the degradation (channeltrons have a limit on accumulated counts over their lifetime).

As part of ISS payload integration activities, contamination forecast maps are being generated for U.S. attached payload sites to support payload feasibility, topology and placement studies. An example of a contamination forecast map for ExPRESS Logistics Carrier 4 (ELC-4) on the starboard side of the ISS truss is shown in Figure 3. ELC-4 will host two highly sensitive Earth science payloads, SAGE-III and MUSES. This forecast map covers 2015 annualized contamination from all sources of materials outgassing. Similar forecast maps are being generated for future timeframes to support payload manifesting decisions.

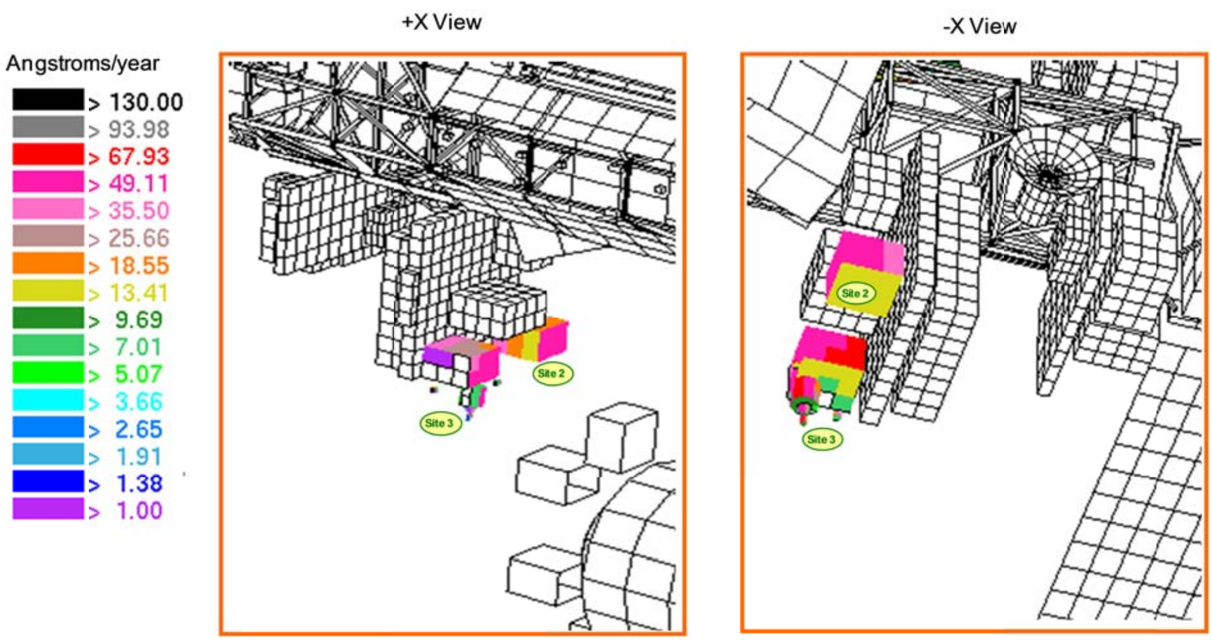

Figure 3. 2015 Contamination Forecast Maps for ELC-4

The ISS has been designed to offer low levels of contamination to its external payload complement. Unique analytical capabilities have been developed for the Program to support requirements validation, integration and to forecast contamination on the vehicle. These activities ensure success of ISS as a platform for space science payloads in low Earth orbit.