International Space Station Columbus Payload SoLACES Degradation Assessment

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SOLAR is a European Space Agency (ESA) payload deployed on the International Space Station (ISS) and located on the Columbus Laboratory. It is located on the Columbus External Payload Facility in a zenith location. The objective of the SOLAR payload is to study the Sun. The SOLAR payload consists of three instruments that allow for measurement of virtually the entire electromagnetic spectrum (17 nm to 2900 nm). The three payload instruments are SOVIM (SOlar Variable and Irradiance Monitor), SOLSPEC (SOLar SPECctral Irradiance measurements), and SolACES (SOLar Auto-Calibrating Extreme UV/UV Spectrophotometers).

The SolACES payload has been developed for a mission period of 18 months. It includes a set of 4 spectrometers that measure the solar extreme ultraviolet (EUV) flux from 17 nm to 220 nm. One of these 4 spectrometers failed early on (before deployment). EUV data is important in understanding the solar dynamo. Also, EUV flux is the source of most of the ionization that produces the ionosphere plasma. Plasma production is important in understanding the ionosphere environment. The ionosphere conditions affect many subjects including spacecraft charging, dynamo processes, instabilities, and communications. The 3 remaining spectrometers have collected valuable data during the historically low solar cycle 24. Some of this data will be presented.

After the nominal mission period a significant trend in degradation of the remaining SolACES spectrometers was observed towards the end of CY2010 (GMT 310) through mid CY 2011 (GMT 132). The Principle Investigators of SolACES initiated a Mission Evaluation Room (MER) Chit to request an investigation of the degradation in CY 2011 (GMT 230). The Boeing Space Environments team was asked to respond to the ESA initiated MER Chit request to investigate the cause of the degradation. This paper will discuss the findings of that investigation.

The spectrometers function by photons reflecting off of a grating and mirror separating the wavelengths and then being counted by a pulse rate channel electron multiplier. It was determined that the spectrometer count rate on the 3 functioning instruments within the SolACES began significantly decreasing in an almost identical manner at the end of 2009 and was heading towards instrument failure in late 2011. Now the instrument is still in operation.

Two possible sources of count rate degradation were identified for investigation. They were contamination on the spectrometer grating, parabolic mirror, and channeltron electron multiplier, and/or degradation of the channel electron multiplier. Both of these sources of degradation were explored.

Contamination on the grating and mirror were found to be a possible cause for the observed count rate degradation. Though the plume contamination levels on the outside of the SolACES site are inconsistent with the inferred levels of contamination which would be needed to produce the observed degradation, and additionally, the SolACES payload has limited paths from the external plume sources to inside the experiment. It was determined that the ISS external contamination environment remains very clean. Also, based on the SolACES instrument bakeout, internally induced contamination is highly unlikely. However, these considerations may not be representative for the internal instrumental conditions, because the outer environment such as the vacuum, the cosmic radiation, atomic oxygen interaction, and the solar EUV radiation with photon energies up to 100 eV are acting as 'surface cleaners'.

Channel electron multipliers (CEM) are used to convert a photon into a measurable current pulse. The amount of electrons produced by each photon is called the gain. The performance of a CEM depends on many variables. The Space Environments Team focused mainly on gain recovery, total accumulated counts, applied voltage, count rates, and total accumulated charge. Gain recovery occurs when a CEM is inactive. Gain recovery was a regular occurrence in the count rate data from 2009 to 2010. CEMs are known to require higher voltage levels over time in order to sustain a particular gain level. Most CEMs require this voltage increase after 1e10 counts. The SolACES was found to have exceeded this total accumulated counts threshold. Also, the gain depends on the rate the photons are collected. If the electrons are collected at a faster rate than the electrons in the CEM can replenish then the gain can drop below measurable levels. The measurable counts were found to drop for very intense spectral emissions at times when the solar EUV flux increased. – The ability to apply high voltage increase was not given at the time of SolACES fabrication, because the mission period was planned for 18 months at that time. During that 18 month period in space the channeltrons were neither reaching the critical integrated count nor was degradation was an issue.

The SolACES payload count rate degradation was also compared to the count rate degradation on the CEM located on the Remote Atmosphere and Ionosphere Detection System (RAIDS) experiment. The RAIDS experiment has not experienced the same count rate degradation seen on the SolACEs. The contamination levels at the SolACES payload site were compared with the contamination levels at the RAIDS site. The RAIDS contamination levels were higher, but contamination was found to not cause the degradation observed on that spectrometer. The RAIDS degradation only occurred at times when the CEM was on. The RAIDS degradation was found to be caused by the total accumulated counts affecting the CEM. Unlike the SoLACES experiment, the RAIDS payload was able to increase the voltage on the CEM in order to deal with this degradation.

The analysis of the SolACES came to the same conclusion: total accumulated counts are an important issue to understand the degradation with time. In addition two special aspects should to be taken into account, too: First, inter-comparing spectral recordings of high count rate levels followed by low count rates levels. During this period solar radiation changed at a negligible rate. However, the change in intensity by up to three orders of magnitude within a relatively short period is not explained by channeltron degradation. Second, there is a strong correlation of count rates of the three spectrometers with time. If the degradation resulting from the total accumulated counts was the only issue there is no explanation for the strong correlation at different amplitude levels. Since spectrometer S2 is close to the always open venting holes, the SolACES team concludes that thruster material did intrude into the spectrometer S2 most directly. Since spectrometer S1 is located further away from the venting holes than S2, less thruster material is deposited. From this point of view P3 is located most advantageously.

Understanding the causes of instrument degradation and data reliability is important in planning experiments. Based on both studies, it was determined that the ISS external contamination environment remains clean for external payload experiments at some locations. In addition, it is believed that the SoLACES payload's degradation was caused by the total accumulated counts, and the inability to increase the CEM voltage as well as by contamination from thruster events. It is recommended that future CEM devices include the ability to increase the CEM voltage when feasible as well as including shutters to protect optical parts sensitive to the deposition of exhausted thruster materials.