Atomic Oxygen Interactions and the Design of MISSE-9 and MISSE-10 Experiments

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Extended Abstract

Spacecraft in low Earth orbit (LEO) are subjected to harsh environmental conditions, including radiation (cosmic rays, ultraviolet, x-ray, and charged particle radiation), micrometeoroids and orbital debris, temperature extremes, thermal cycling, and atomic oxygen (AO). These environmental exposures can result in erosion, embrittlement and optical property degradation, threatening spacecraft performance and durability. While all of these environmental exposures can cause degradation to spacecraft components, AO is a particularly serious structural, thermal, and optical threat, to exterior oxidizable spacecraft components.

Atomic oxygen is formed in the LEO environment through photodissociation of diatomic oxygen (O_2). In LEO, between the altitudes of 180 and 650 km, AO is the most abundant species. Atomic oxygen can react with polymers, carbon, and many metals to form oxygen bonds with atoms on the exposed surface. For most polymers, the oxidation product is a gas. Therefore, polymers and other materials with volatile oxidation products can be eroded away through reaction with LEO AO. In order to design durable high-performance spacecraft systems that will survive exposure to an AO environment, it is essential to know the AO erosion yield (E_y, the volume loss per incident oxygen atom (cm^3/atom)) of materials being considered for spacecraft applications. In addition to the structural degradation, AO erosion can also cause optical and thermal property degradation. Even materials with AO protective coatings can be susceptible to AO erosion as a result of AO undercutting erosion at protective coating defect sites. Also, materials not in direct line-of-sight of AO can be affected by AO scattering and subsequent erosion.

To further our understanding of AO erosion of spacecraft materials, NASA Glenn Research Center has developed and flown a series of experiments as part of the Materials International Space Station Experiment (MISSE) missions on the exterior of the International Space Station (ISS). In continuing these studies, two new Glenn experiments have been proposed, and accepted, for flight on the new MISSE-Flight Facility (MISSE-FF). The first experiment is the Polymers and Composites Experiment (PCE), which is being flown as part of the MISSE-9 inaugural mission of MISSE-FF. The MISSE-9 PCE is a passive experiment with 138 samples being flown in ram, wake and zenith orientations. Figure 1 shows the MISSE-9 PCE samples loaded in the MISSE Sample Carrier (MSC) trays ready for flight. The second experiment is the Polymers and Composites Experiment-2 (PCE-2), and it is being flown as part of the MISSE-10 mission, the second mission of the MISSE-FF. The MISSE-10 PCE-10 is a passive experiment with 43 samples being flown in ram, zenith and nadir orientations.

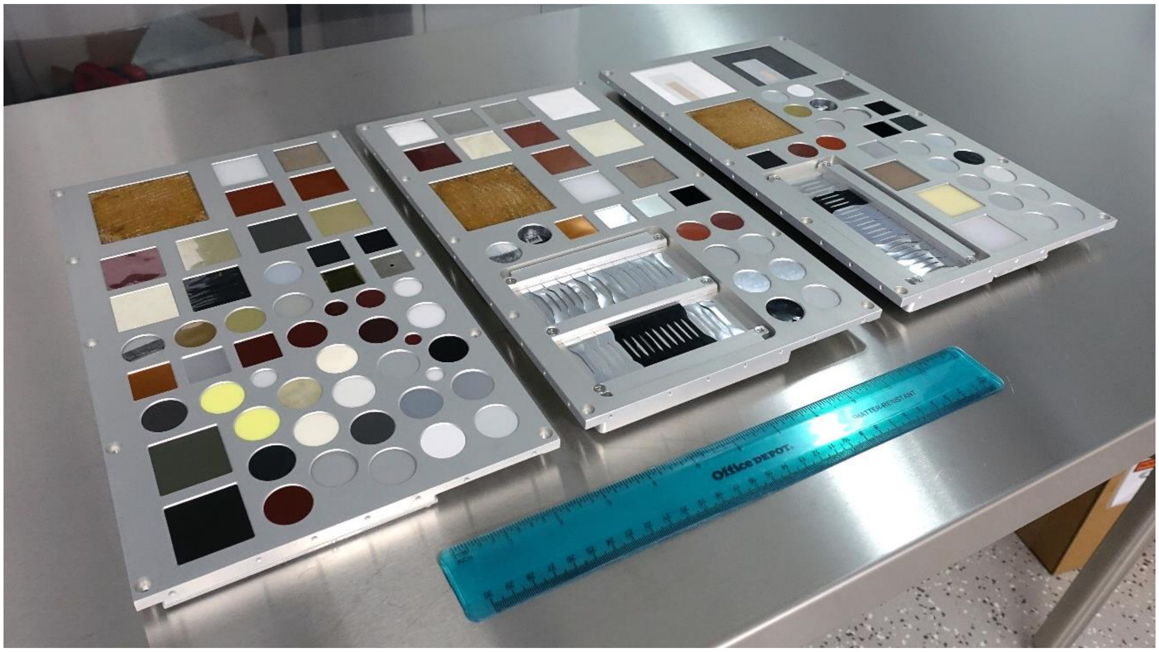

Figure 1. MISSE-9 Polymers and Composites Experiment samples loaded in three MSC decks, from left to right: R2 (ram), W3 (wake), and Z3 (zenith).

This paper provides an overview of the ISS flight experiments including the objectives and the implications of the expected spaceflight results. Although there are numerous objectives, both experiments are designed to address consequences of AO interactions. For example the rate of AO reaction with materials can vary by orders of magnitude causing large variations in spacecraft component structural durability. In addition, the changes in surface morphology caused by AO erosion can result in increased solar heating due to changes in optical and thermal properties of materials. Therefore, numerous samples are being flown for E_y, optical and thermal characterization. In some cases similar samples are being flown in both ram and zenith flight orientations to determine the effect of solar exposure on E_y. Also, small changes in polymers, such as the addition of inorganic filler materials, can cause large increases in AO durability. Therefore, epoxy samples with varying fill levels of AO durable ZnO powder are being flown to study the effect of filler fraction on AO erosion. And, a variety of samples are being flown to characterize AO scattering and its effect on erosion. For example, several AO scattering chambers are included along with flight holders with varying scattering angles. The results from these ISS flight experiments will provide spacecraft designers with LEO AO interaction and consequence data, which can be used to assure the development of durable spacecraft components.