

Spacecraft Materials in the Space Flight Environment: International Space Station - May 2002 to May 2007

John Golden^{(2)*}, Mary J. Lorenz⁽²⁾, John Alred⁽¹⁾, Steven L. Koontz⁽¹⁾, Michael Pedley⁽¹⁾, Eric Christiansen⁽⁴⁾

Abstract

The performance of ISS spacecraft materials and systems on prolonged exposure to the low-Earth orbit (LEO) space flight is reported in this paper. In-flight data, flight crew observations, and the results of ground-based test and analysis directly supporting programmatic and operational decision-making are presented. The space flight environments definitions (both natural and induced) used for ISS design, material selection, and verification testing are shown, in most cases, to be more severe than the actual flight environment accounting for the outstanding performance of ISS as a long mission duration spacecraft. No significant ISS material or system failures have been attributed to spacecraft-environments interactions. Nonetheless, ISS materials and systems performance data is contributing to our understanding of spacecraft material interactions in the spaceflight environment so as to reduce cost and risk for future spaceflight projects and programs.

Orbital inclination (51.6°) and altitude (nominally near 360 km) determine the set of natural environment factors affecting the functional life of materials and systems on ISS. ISS operates in an electrically conducting environment (the F2 region of Earth's ionosphere) with well-defined fluxes of atomic oxygen, other charged and neutral ionospheric plasma species, solar UV, VUV, and x-ray radiation as well as galactic cosmic rays, trapped radiation, and solar cosmic rays (1-4). The LEO micrometeoroid and orbital debris environment is an especially important determinant of spacecraft design and operations (5, 6).

The magnitude of several environmental factors varies dramatically with latitude and longitude as ISS orbits the Earth (1-4). The high latitude orbital environment also exposes ISS to higher fluences of trapped energetic electrons, auroral electrons, solar cosmic rays, and galactic cosmic rays (1-4) than would be the case in lower inclination orbits, largely as a result of the overall shape and magnitude of the geomagnetic field (1-4). As a result, ISS exposure to many environmental factors can vary dramatically along a particular orbital ground track, and from one ground track to the next, during any 24-hour period.

The induced environment results from ISS interactions with the natural environment as well as environmental factors produced by ISS itself and visiting vehicles fleet. Examples include ram-wake effects, hypergolic thruster plume impingement, materials out-gassing, venting and dumping of fluids, and specific photovoltaic (PV) power system interactions with the ionospheric plasma (7-11). Vehicle size (**L**) and velocity (**V**), combined with the magnitude and direction of the geomagnetic field (**B**) produce operationally significant magnetic induction voltages ($\mathbf{V} \times \mathbf{B} \cdot \mathbf{L}$) in ISS conducting structure during flight through high latitudes ($> \pm 45^\circ$) during each orbit (7-11). Finally, an induced ionizing radiation environment is produced by cosmic ray interaction with the relatively thick ISS structure and shielding materials (12-14).

Characterizing the interactions between a spacecraft and the space flight environment depends on the details of spacecraft configuration and spacecraft operations (15). The exposure of any specific material or system to any of the various natural and induced environment factors depends on the location of the specific material in or on the spacecraft (shielding effects) as well as the spacecraft trajectory and flight attitude (15). Spacecraft configuration effects are especially important for assessment of: 1) atomic oxygen (16), 2) trapped radiation dose (17), thruster plume impingement (18), spacecraft contamination (19), and 3) spacecraft charging (7-11) effects. ISS must fly in a very limited number of approved flight attitudes, so that exposure of a particular material or system to environmental factors depends upon: 1) location on ISS (shielding effects) 2) ISS flight configuration (shielding and wake effects), 3) ISS flight attitude (shielding, shadowing, and wake effects), 4) variation of solar exposure (β angle) with time, and 5) levels of solar and geomagnetic activity (space weather).

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