Micrometeoroid Impact Risk Assessment for Interplanetary Missions

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ABSTRACT

Meteoroids are solid particles of interplanetary or interstellar origin. Hypervelocity impacts of micrometeoroids (with typically velocities of tens of km/s) pose a significant environmental hazard to spacecraft and/or astronauts conducting EVAs. Repeated impacts of micron-sized particles or smaller lead to the gradual degradation of spacecraft surfaces and materials by erosion/cratering, affecting for example mirrors, lenses and sensors. Larger particles can perforate insulation layers and optical baffles. A micrometeoroid with sufficient kinetic energy can puncture pressurized vessels (manned habitats, propulsion tanks), batteries, coolant lines or spacesuits, as well as sever cables, tethers and springs. Millimetre-sized grains are able to cause structural damage, leading to the potential failure of components or subsystems up to the complete destruction of the spacecraft or loss of crew in the worst case.

ESABASE2/Debris, developed by etamax space, is ESA's tool to analyse the effects of space debris and meteoroid impacts on spacecraft in the near-Earth environment, i.e. on Earth and lunar orbits, on transfer orbits to the Moon, and around the Sun-Earth Lagrangian points L_1 and L_2. ESABASE2/Debris allows reading in or building 3D spacecraft models, setting damage and failure equations/laws, and incorporates the latest models of the Near-Earth space debris and meteoroid environments. The software computes impact fluxes, distributions for mass, size and velocities of the impactors as functions of time and spacecraft surface area, as well as risk assessments (e.g. probability-of-no-penetration values) over the complete mission.

In light of upcoming interplanetary missions, and extension of the ESABASE2's Debris analysis capabilities is required to be able to assess the risk of meteoroid impacts during the entire mission. The capabilities of the ESABASE2/Debris software tool need to be enhanced to implement existing interplanetary meteoroid models, like IMEM, MEMR2, or Divine-Staubach and IMEM2. Furthermore the software shall be able to ingest and process trajectory files in various common formats, e.g. SPICE or CCSDS/OEM, and allow user-defined spacecraft attitudes.

This paper will provide an overview of the main software development activities towards the ESABASE2/Debris interplanetary mission analysis capability. These are the handling of trajectory formats, interfacing to interplanetary meteoroid models, and post-processing functionalities. Our approach for verification, validation and testing will be outlined. The paper will conclude with an outlook on possible future extensions and enhancements of the ESABASE2/Debris impact risk assessment tool.