Columbus Crater Survey – Analyzing the small particle environment in low Earth orbit via impact craters on the European Columbus module of the International Space Station

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Detailed knowledge about the space debris and micrometeoroid environment in Earth orbit is paramount to spaceflight safety. Surfaces exposed to space have already been retrieved and evaluated for the particle flux density in their respective orbits, with the Long-Duration Exposure Facility (1984 – 1990) and the Hubble Space Telescope solar array panels as notable examples. The Columbus module on the International Space Station has been exposed to the particle environment since February 2008, and thus provides data on the oriented particle flux integrated over more than 10 years. This study aims to determine cumulative particle flux densities from video material acquired from Columbus' surface.

To analyze crater diameters, the video material was stitched to composite images by two-dimensional translation stitching with manual key point detection. Edge detection based on image gradient information by Sobel derivatives, and manual edge definition by three points on crater rims have been used to measure the diameter and area of craters. The pixel dimensions of craters are matched to reference objects of known size, allowing to determine physical crater dimensions. Five different equations to calculate impactor diameters from crater diameters have been used. Information on the cratered area and exposure time allows to calculate particle flux densities. All results have been compared to expected flux densities of the MASTER-2009 debris and micrometeoroid model, and the Grün micrometeoroid model.

On the analyzed surfaces, a total of 1299 craters have been identified. Image resolution was a limiting factor in the survey, as many craters were only 3 – 5 pixel in diameter. The resulting flux density functions generally yield results 0.5 – 1.5 orders of magnitude higher than the reference models. The analyzed craters were generated by particles with estimated masses in the order of 10^(-6) g and 10^(-5) g. Data on the lower particle masses were acquired from close-up scans. To examine the possibility of a systematic under- or overestimation of crater diameters, flux densities have been calculated for a constant crater diameter offset, propagated through the entire evaluation chain. Flux densities calculated with crater diameters which are 2 pixels smaller move the flux densities closer to the reference data. A systematic deviation of 1 pixel on each side of the crater is considered possible, given the manual influence on the detection methods.

In conclusion, the entire chain to determine cumulative particle fluxes from debris shield video data has been successfully established and demonstrated. To increase confidence in the present data, a possible experimental campaign and complementing high-resolution photographs would be next logical steps for the study.