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BREACHING THE SUB-CM TO CM GAP WITH IN-SITU SPACE DEBRIS OBSERVATIONS: LESSONS LEARNT FROM PAST MISSIONS & ON-GOING EFFORTS AT THE EUROPEAN SPACE AGENCY

Abstract

With the increasing number of satellites in orbit and the efforts to mitigate the risk space assets are facing, comprehensive modelling and understanding of the artificial space environment and its evolution is becoming ever more imperative. Space environment models such as ESA's MASTER and NASA's ORDEM provide a validated representation of the debris population and can be used for spacecraft risk assessment and compliance analyses against mitigation standards, such as ESA's Space Debris Mitigation standard and "Zero Debris" policy.

As the space debris environment is dynamic, the models must be periodically updated and validated against independent, up-to-date sources. While catalogues are maintained for objects which can be routinely observed by ground telescopes and radars (sizes ¿10cm in LEO and 30-40cm in GEO), the knowledge of small objects comes from statistical sampling using large remote sensing systems, in-situ detectors, or returns of space-exposed hardware. With few large remote sensing systems available worldwide, strict data sharing policies, and the limited availability of vehicles to return hardware to Earth, focus is put on in-situ observations.

In the frame of the modelling and validation efforts at ESA, measurements from the longest operating in-situ sensor, DEBIE-1 on PROBA-1, were analysed. The statistical value of the data, the capability of the sensor to capture debris generating events and its compatibility with the particle density predicted by MASTER were studied.

In view of the challenges such datasets pose e.g. small detector size, sophisticated post-processing, limited size range sensitivity and orbital coverage, ESA has also been running studies for mission concepts to decisively address the MASTER data gap. In 2022, a pre-phase A activity studied the concept of employing large areas to collect a dataset of sub-mm to cm objects. In 2024, phase A/B1 aims at demonstrating the concept by designing a mission which shall expose to the environment two large-area thin foils inspected by a camera system, presenting an alternative to sample return missions and impact detectors.

Two instrument development activities are additionally presented: (1) a feasibility study on the use of laser sheets to detect particles crossing an instrumented volume by either static laser sheets or a LiDAR

illuminated volume and (2) a breadboarding activity to assess the performance of a combination of sensor technologies to reconstruct the velocity vector of impacting particles.

The study summarises results and lessons learned from the DEBIE-1 and instrument development activities and introduces the status of the debris monitoring activity.