SOCIT4 collisional-breakup test data analysis: with shape and materials

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The Satellite Orbital-Debris Characterization Impact Test (SOCIT) series was a set of four hypervelocity impact tests conducted under a U.S. Department of Defense (DoD) program in 1991 through 1992. The common testing procedure of the set was to launch a small projectile, at hypervelocity, towards a large target in an impact chamber. The last of the four tests (SOCIT4) targeted a flight-ready, U.S. Transit navigation satellite, yielding collision fragments in the size regime of one millimeter through tens of centimeters. A subset of the fragments was weighed, measured, and tabulated. The derived area-to-mass vs. size distributions have been used in the NASA breakup models dated 1998 and 2001 (current model).

This paper revisits the SOCIT4 data set and explores, in detail, the fragment material, shape, and pickup position relationships. The intent of this study is not only to gain an understanding of the collisional-breakup process of this particular payload, but also to determine how these data may apply to other breakups.

What emerges from the study, first, is a clear distinction in fragment area-to-mass between primarily metal (heavy) and primarily non-metal (light) fragments. Metal fragments, which are dominated by aluminum, follow the characteristic curve of increasing area-to-mass with decreasing size: objects move from the character of large irregular chards to that of small solid spheroids. Non-metal fragments, dominated by phenolic/plastic, also move towards solid spheroids as their sizes decrease. But unlike the metals, their area-to-mass curve plateaus in the midsize region ($\sim$1 centimeter), coinciding with a peak in plate-like, non-metal fragments. The internal structure of the Transit payload, with its phenolic surface skin and packed arrays of plastic circuit-boards, certainly governs this behavior.

In the small fragment regime ($\sim$1 millimeter) phenolic/plastic ellipsoidal ‘nuggets’ display a melted and reformed character and dominate the population. They outnumber aluminum ‘nuggets’ by over four to one. This is of particular interest since space shuttle returned surfaces (windows, radiator panels) show little evidence of impacts by plastics at all. In fact, the main identifiable sources of debris hits in the sub-millimeter range appear to be aluminum and then steel.