An Approach to Shape Parameterization Using Laboratory Hypervelocity Impact Experiments

John H. Seago[(1)], Heather Cowardin[(2)], Phillip Anz-Meador[(3)], Alyssa Manis[(2)], Joshua Miller[(4)], and Eric Christiansen[(5)]

[(1)] ERC, Jacobs JETS II Contract, NASA Orbital Debris Program Office, NASA Johnson Space Center, MC XI5-9E, 2101 NASA Parkway, Houston, TX 77058, USA
[(2)] NASA Orbital Debris Program Office, NASA Johnson Space Center, MC XI5-9E, 2101 NASA Parkway, Houston, TX, 77058, USA
[(3)] Jacobs, NASA Orbital Debris Program Office, NASA Johnson Space Center, MC XI5-9E, 2101 NASA Parkway, Houston, TX 77058, USA
[(4)] University of Texas at El Paso, 500 West University Avenue, El Paso, TX 79968, USA
[(5)] NASA Hypervelocity Impact Technology, NASA Johnson Space Center, MC XI5-9E, 2101 NASA Parkway, Houston, TX, 77058, USA

ABSTRACT

NASA's Orbital Debris Program Office relies on laboratory-based impact tests to supplement the measurement data of on-orbit events that defines the orbital debris environment. These experiments provide information that is essential to interpreting the radar and optical measurements of orbital fragmentation events into useful metrics, such as characteristic size of the debris, and to providing a better understanding of the distributions of fragment populations in terms of their masses, material constituents, fragment densities, cross-sectional areas, area-to-mass ratios, shapes, *etc*.

The Satellite Orbital Debris Characterization Impact Test (SOCIT) was a notable laboratory impact experiment conducted in 1992 using a surplus U.S. Navy Transit navigation satellite of the 1960s. The data from this ground-based experiment were combined with on-orbit measurements to develop the NASA Standard Satellite Breakup Model (SSBM). To account for advancements in satellite design and construction since, a new impact test series – DebriSat – was conducted in 2014. This test utilized a high-fidelity mock-up spacecraft that better represents the materials and construction techniques used to design and manufacture modern spacecraft. Together, these tests offer valuable data to model an orbital debris environment composed of legacy and modern spacecraft.

This paper presents an overview of the two laboratory impact tests, comparing their fragment parameter distributions with each other and with relevant distributions from the NASA SSBM. The categorization and descriptions of fragment shapes are of significant interest for future work, yet there are marked differences in the definitions of shape categories between each dataset. The categorizations of constituent materials, and the measurement techniques employed to populate these two datasets, are also different. New rubrics simplify and equate the categorizations between datasets to aid comparative analyses and to facilitate the potential use of both datasets in tandem with future environmental debris models.

A preferred approach to classifying shape across disparate datasets uses the characteristic-length dimensions, and a simplified shape classification based on physical, solid-body dimensions, to mathematically construct an encapsulating right-circular cylinder that represents the fragment. The ratio of cylinder length-to-diameter (L:D) then provides a single continuum value for shape that is strongly correlated with its designated shape and size. This metric can then be used to further assess the distribution of shape with populations of other fragment characteristics within these datasets. The shape parameterization using the L:D ratios of right-circular cylinders is discussed.