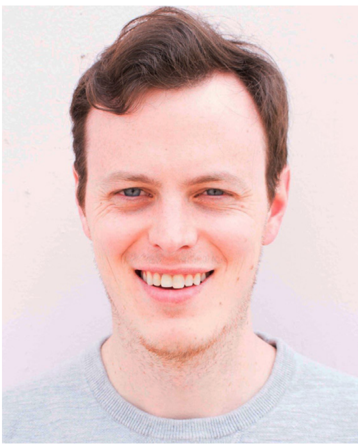
UNIVERSITY OF MARYLAND

THE BURGERS PROGRAM FOR FLUID DYNAMICS
FLUID DYNAMICS REVIEWS SEMINAR SERIES

AERODYNAMIC SEPARATION OF FRAGMENTED BODIES IN HIGH-SPEED FLOW



Friday, October 1, 2021 | 11am

DeWalt Seminar Room
2164 Glenn L. Martin Hall

Speaker

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ABSTRACT

Atmospheric entry of meteoroids poses danger to humans in the form of blast-wave overpressure, impact craters, tsunamis, and other assorted threats. The relative risks of each are highly dependent on the details of the unavoidable structural disruption that occurs and the subsequent aerodynamic separation sequence, so accurate prediction of fragment trajectories is required for threat mitigation. However, the physics of aerodynamic separation immediately following meteor fragmentation are virtually uncharacterized, allowing for only low confidence in threat assessment projections.

The present work endeavors to constrain the separation behavior of fragmenting bodies by examining the model problem of close-packed sphere clusters and, to a lesser extent, clouds of dusty debris. Free-flight experimentation in UMD HyperTERP, a Mach-6 shock tunnel, is conducted to provide a foundation for both statistical and aerodynamic analyses, while coupled inviscid CFD/FEA provides complementary insight into the mechanisms driving fragment separation. First, computations of equal-sized sphere pairs reveal a previously unidentified phenomenon wherein two bodies in continual mechanical contact oscillate about a stable angle-of-attack equilibrium and achieve anomalously high lateral velocities. At intermediate equal-sphere cluster populations ($2 < N < 20$), separation procedure can be divided into two stages: mutual repulsion from a common center and subsequent subcluster interactions dictated by the influence of an upstream body. The degree of repulsion induced by the former demonstrates close correlation with the initial angular position of a fragment, whereas the lateral velocities resulting from the latter appear to be normally distributed about a slightly positive value. The transverse separation characteristics of equal-sphere clusters numbering from 2 to 115 bodies are used to constrain a power-law fit between the lateral extent of a disrupted swarm and its population, providing a significant improvement to existing models of aerodynamic separation following fragmentation. Furthermore, experiments of unequal-sphere clusters, whose compositions are governed by realizations of truncated power laws, reveal a systematic underestimate in the equal-sphere correlation, resulting largely from massive subclusters suppressing high expulsion. A unified model of fragment separation, based on both the aforementioned power-law fit and a combined Rayleigh—exponential distribution, is then proposed. Finally, the dynamics of dusty debris clouds are discussed, with implications for mass depletion and energy deposition of rubble-pile-type impactors highlighted.

BIO

Tom Whalen is a NASA Space Technology Research Fellow and Ph.D. student in Aerospace Engineering under Stuart Laurence at the University of Maryland, College Park. His research interests include free-flight aerodynamics, meteor airbursts, hypersonic fluid-structure interactions, shock-wave boundary-layer interactions, and development of diagnostic techniques.

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