

## Coupling a Particle Trajectory Capability to the US3D CFD Flow Solver

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**Brief Presenter Biography:** Amal Sahai received a Bachelor of Technology in Mechanical Engineering from the Indian Institute of Technology Guwahati in 2012 and a Master of Science in Aerospace Engineering from the University of Illinois at Urbana-Champaign in 2015. He graduated with a PhD from University of Illinois at Urbana-Champaign in 2019 and is currently a Research Scientist with AMA, Inc. at NASA Ames Research Center.

**Introduction:** One of the unique aspects of designing a spacecraft that will enter the Martian atmosphere is that the vehicle will encounter dust during atmospheric entry. Small dust particles are present even under quiescent conditions, and the level of dust significantly increases when a major dust storm occurs. During or after a dust storm, the dust can extend to altitudes as high as 80 km. Because planetary missions to Mars take years from initial design to arrival at Mars, and because of the unpredictability of major global dust storms, the design of the thermal protection system (TPS) of a Mars entry vehicle requires an estimation for the potential damage caused by dust particle impacts on the heatshield. Dust particle erosion can increase the required TPS thickness and/or increase risk due to leaner margins.

Palmer, et al. [1] provided an overview of the equations and modeling assumptions that go into an analysis of heatshield erosion due to dust particle impacts during a Martian entry. The equations for determining the size distribution and number density of dust particles as a function of altitude based on observations taken at Mars were presented as well as the governing particle trajectory equations using the Lagrangian framework. These equations were implemented into a 2-D standalone particle trajectory code and applied to estimate the heatshield erosion due to dust particle impacts for a hypothetical case of the ExoMars Schiaparelli capsule entering the Martian atmosphere during a major regional and global dust storm.

The purpose of the current research effort is to take the equations presented in Ref. [1] and incorporate them into the US3D CFD flow solver [2]. The integrated code will allow higher-fidelity modeling of particle-fluid interactions and allow for the simulation of physical effects such as surface heating augmentation due to particle impacts. The key elements underpinning the current work are a robust tracking algorithm that can identify the encompassing mesh elements for individual particles and a point to point MPI framework. These developments combined with accurate property models and

high-order time-stepping deliver realistic simulations on larger computational grids for a wide range of particle mass loadings. The coupled US3D-particle code will be applied to the Schiaparelli capsule and Earth-based experimental test cases.

### References:

[1] Palmer, G., Ching, E., Ihme, M., Allofs, D. and Gulhan, A. (2020) "Modeling Heatshield Erosion due to Dust Particle Impacts for Martian Entries," AIAA Paper 2020-0254.

[2] Candler, G., Johnson, H., Nompelis, I., Subbareddy, P., Drayna, T., Gidzak, V., and Barnhardt, M., (2015) "Development of the US3D Code for Advanced Compressible and Reacting Flow Simulations," AIAA Paper 2015-1893.