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SPH Simulation of Atmospheric Effects on Bolide Entry

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ABSTRACT

In this paper, we apply smoothed particle hydrodynamics to model the atmospheric entry and break-up of the PDC exercise body. Such bodies rapidly release large quantities of energy into the atmosphere and the resulting shock wave can present a hazard to local communities. Ground overpressures can be used to gauge the risk to infrastructure and human life, and as such, their accurate prediction could better inform civil defense strategies. One current strategy for predicting ground effects involves estimating the energy deposit along the trajectory using a reduced-order model such as the pancake model or fragment-cloud model. The estimated deposit is then used as an initial condition for hydrodynamic simulation of the shock wave.

Reduced-order models, however, require tuning parameters to be set, which at present, limit predictive capabilities. Full-scale hydrodynamic simulation of the atmosphere’s interaction with the bolide has the potential to further our understanding of the break-up process and better inform computational expedient reduced-order models. Full simulation of the atmospheric entry is particularly relevant for rubble-piles, with the potential for irregular geometries and heterogenous compositions to influence the break-up process.

In this paper, we use the meshless smoothed particle hydrodynamics method to model the atmospheric entry of the PDC exercise body, focusing on the bounds of the size uncertainty range: 35-700m. We estimate the energy deposition and strength of the resulting shock wave. Results from a preliminary 2D simulation of a spherical granite body with a radius of 35m, vertical entry of 15km/sec, and constant yield strength of 15MPa, are shown in Figure 1 and 2.

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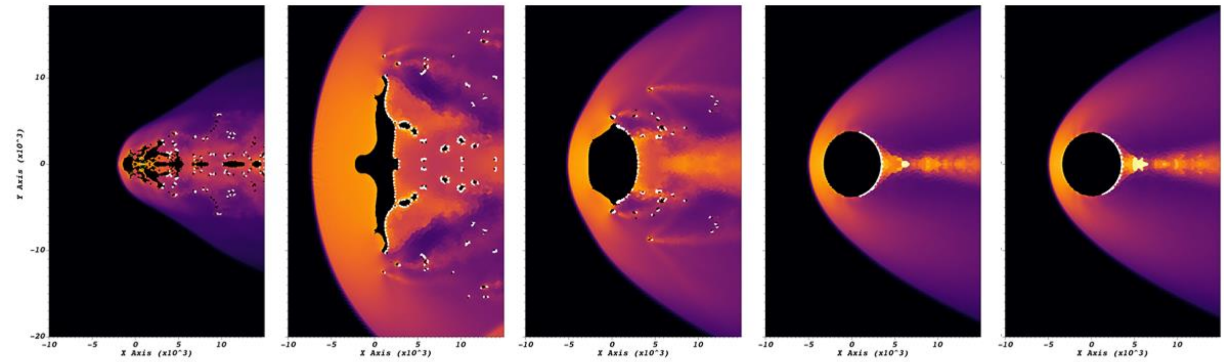

Figure 1: Specific thermal energy field showing the deformation of the bolide and break-up under the atmospheric loading. The simulation began at an altitude of 30km. Image from right to left show the development of Rayleigh-Taylor and Kelvin-Helmholtz instabilities which eventually tear the asteroid apart producing a debris cloud.

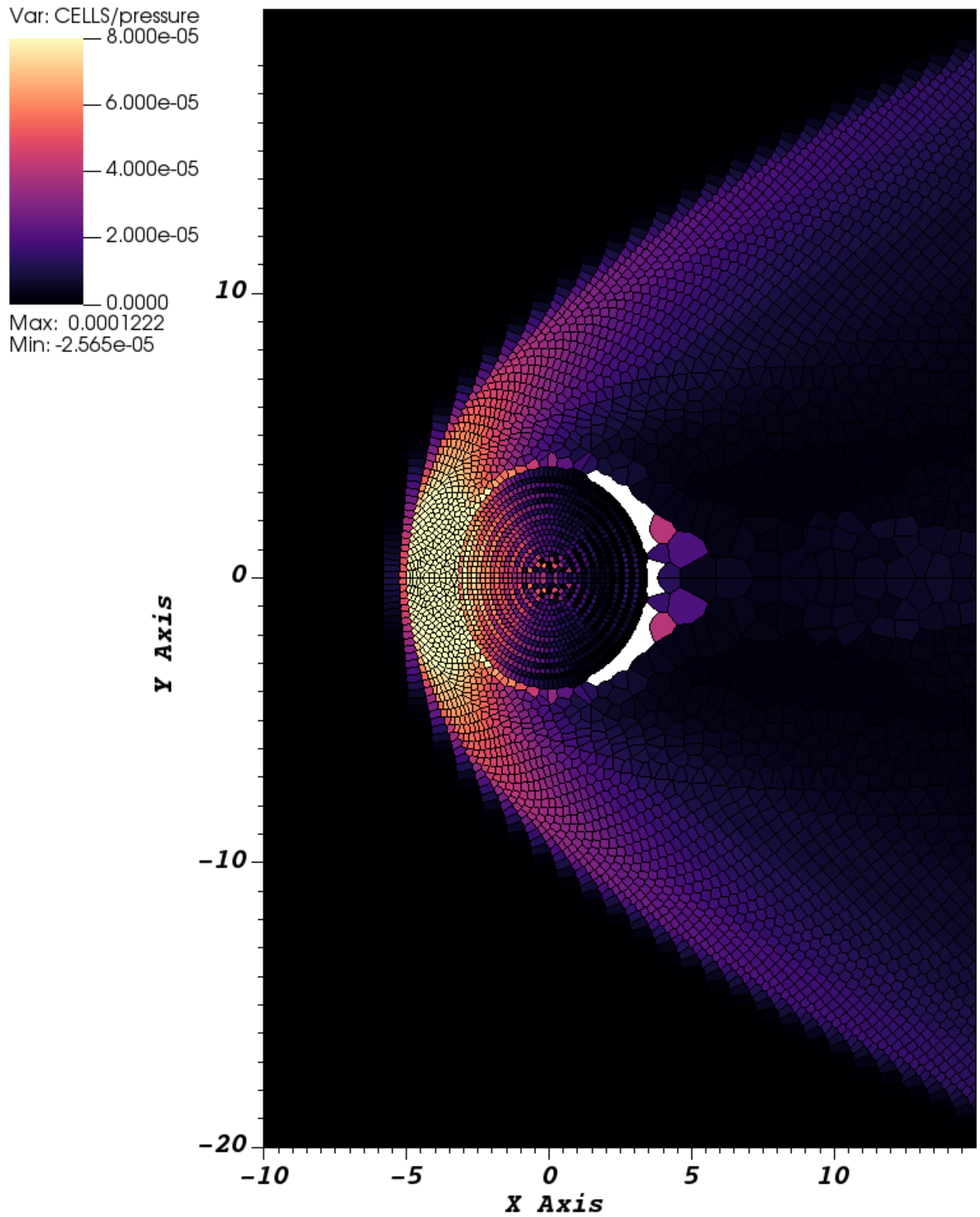

Figure 2: Contour plot of pressure showing the transfer of the aerodynamic load into the solid as the bolide begins to pancake at an altitude of approximately 23km. The contour is in units of 10^5MPa and axes are in 10s of meters. The SPH particle distribution is visualized as a Voronoi tessellation.

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