**JETTING DURING THE VERTICAL IMPACT OF A SPHERICAL PROJECTILE.** B. C. Johnson[1] and H. J. Melosh[1,2], [1]Department of Physics, Purdue University, 525 Northwestern Avenue West Lafayette, IN 47907, USA (johns477@purdue.edu), [2]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN 47907, USA.

**Introduction:** Early in the contact stage of an impact, highly shocked luminous material is ejected at low angles forming an impact flash [1]. The impact flash forms when a jet of material squirts from the contact point of the target and the projectile. This jetted material reaches velocities greater than the impact velocity. Although jetting during the oblique convergence of two thin plates (often driven by shaped charges) [2] is well studied, the process of jetting in bolide and planetesimal impacts has received little attention [3,4]. Here we present the first numerical models that resolve jetting during impacts of spherical projectiles on flat targets.

**Methods:** We use the axisymmetric iSALE hydrocode to simulate a 10 km diameter impactor striking a half space target. We study impact velocities ranging from 2-20 km/s, stepping by 2km/s. For this preliminary study, we use the Tillotson equation of state for Aluminum to represent both the target and the projectile [5]. As we are only interested in the most highly shocked high velocity material, we do not consider any material strength.

To best resolve the jetting process, our models require the unprecedented resolution of 6.35 m or 800 cells per projectile radius. Although we include the gravitational acceleration of Earth and use a fixed impactor size, the high velocities of jetted material allow us to scale our results using hydrodynamic similarity.

**Results:** In the oblique convergence of thin plates, jetting occurs when the shock velocity is greater than the velocity at which the collision point moves along the plates [2]. Using the Hugoniot for the material of interest, this jetting criterion yields a critical impact angle, below which jetting does not occur, where the impact angle is the angle between the free surfaces of the impacting plates. During the impact of a spherical body on a flat target, the impact angle ranges from 0 to $\pi/2$ from the time that the sphere contacts the surface to the time that the sphere is buried halfway into the target. Thus, as the impact progresses the impact angle will inevitably reach and surpass the critical angle and jetting should initiate [4].

The critical angle increases monotonically with impact velocity. For this reason the most impressive example of jetting occurs in our 2 km/s impact. As **Figure 1** shows, material is ejected at velocities up to ~7 km/s, almost 3.5 times the impact velocity. The highest velocity material comes from 1828 m from the symmetry axis implying a critical angle of 21.4 degrees. This is somewhat larger than the critical angle of 16.5 degrees, calculated using the simple geometric relation of Ang (1990) and the Hugoniot for Aluminum. This discrepancy likely implies that we do not have high enough resolution to resolve the exact moment of jet initiation. Although the initiation of jetting is abrupt, the transition between the jet and the normal ejecta curtain is smooth. Rarefactions propagating from the free surface of both the projectile and the target are probably responsible for this smooth transition.

We define jetted material as any material ejected at a velocity greater than the impact velocity. With this definition, the 2 km/s impact velocity yields the highest mass of jetted material at $3.4 \times 10^{-2}$ projectile masses. Although jetting is an extreme process where melting and vaporization can occur at very low impact velocities, in terms of mass involved, jetting does not play a major role in the process of impact cratering.

**References:** [1] Eichorn G. (1975) *Planet. Space. Sci., 23*, 1519-1525. [2] Walsh J. M. et al. (1953) *J. Appl. Phys., 24*, 349-359. [3] Ang J. A. (1990) *Int. J. Impact. Engng., 10*, 23-33. [4] Melosh H. J. and Sonnet C. P. (1986) *Origin of the moon, conference proceedings* 621-642. [5] Tillotson J. H. (1962) General Atomic Report GA-3216.

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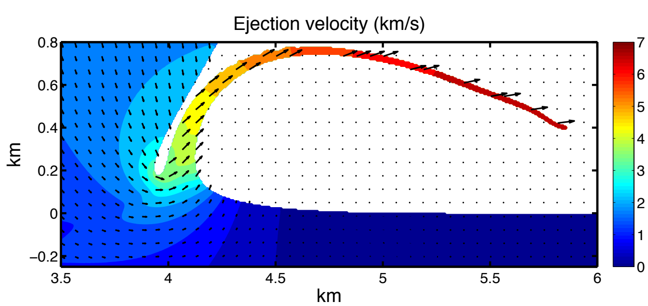


**Figure 1:** Material colored according to velocity 0.75 s after a 10 km diameter aluminum impactor strikes an aluminum half space at 2 km/s. The vectors show the direction of the material velocity. Note that the x-axis starts 3.5 km from the symmetry axis.