Modeling Asteroid Impact Dynamics: Catastrophic Disruption of Three Distinct Structure Types. S. D. Hart[1], E. Asphaug[1], D. Durda[2], and G. J. Flynn[3], [1]University of California Santa Cruz, Santa Cruz, Ca. 95064, [2]Southwest Research Institute, 1050 Walnut Street, Boulder, CO 80302, [3]State University of New York Plattsburgh, NY 12901.

Introduction. This paper reports the outcome of high-speed collision experiments in three distinct structure types. The purpose was to make qualitative and quantitative comparisons of possible asteroid structure types, specifically aggregates (to simulate a "rubble pile" body), fractured bodies and solid bodies. The benefits of such a study are numerous and will help to demonstrate the types of processes that form the space environment that surrounds the Earth. Helping to shed light on the collision history of our solar system, these experiments could also help us to predict future impact events. There have been numerous impact experiments in the past, but relatively few have dealt with the comparison of impacts of similar energy into distinct structure types. All of the bodies consisted of a porphorytic basalt with olivine phenocrysts, in order to best simulate the consistency of a chondritic meteorite [1]. The experiments were conducted at the Ames Vertical Gun Range (AVGR) in October 2001 and June 2002. Qualitatively, it was observed that there was much more localization of the impact area in the collisions with the fractured and aggregate bodies than was observed in the solid body collision. Quantitatively, projectile speeds were measured to be similar to the average in the asteroid belt, and the impact energies were measured to be between $4.96 \times 10^{3}\ ^{J}/_{kg}$ and $1.20 \times 10^{4}\ ^{J}/_{kg}$. The percentages of intact mass of the target bodies that were not directly impacted were 42.09%, 79.38% and 98.74% for the solid, fractured, and aggregate bodies respectively. These numbers give us a good insight into the propagation of shock waves in the different solids. This information also supports some of the current theories concerning rubble pile asteroids, and their ability to survive comparatively large impact events [2]. In this study, structure type appears to be the most influential factor concerning the disruption event's outcome.

Impact Experiments. 1/8 in. aluminum projectiles impacted three specimens of porphorytic basalt with speeds of up to $5.59\ ^{km}/_{s}$. These speeds were achieved with the use of the Ames Vertical Gun Range (AVGR) gas chamber gun, and took place in a vacuum chamber in order to best approximate the environment of the main asteroid belt. Each specimen was suspended in the middle of the chamber by string and was impacted at an angle of 15^{o} from the horizontal. In order to record the impact events of shots 020511 and 020512, two cameras were positioned around the impact chamber and were approximately 75^{o} apart. One camera recorded the events at 250fps while the second camera recorded at 1000fps. Using these cameras it was possible to constrain the qualitative differences in the separate impacts, and helped us to observe the relative paths of the resulting ejecta. For shot 011006 one camera was used and recorded the event at 500fps. Upon further analysis, the data from these cameras may also help to constrain the speeds of large ejecta and thus help to find the energy partitioning for the individual impacts. The current results for each impact are summarized below.

Solid Body Impact This shot actually occurred in October 2001 and as part of the set of experiments chronicled in Durda et. al. [1].The shot was catalogued as shot 011006 and the target body for this shot was a 219.9 g piece of Hawaiian porphorytic basalt. The target was impacted at a speed of $4.55\ ^{km}/_{s}$ and the impact had a resulting E/M_T of $2.13 \times 10^{3}\ ^{J}/_{kg}$. Upon review of the video footage, it was found that the body underwent disruption throughout, and the largest surviving piece was weighed to be 140.4 kg.

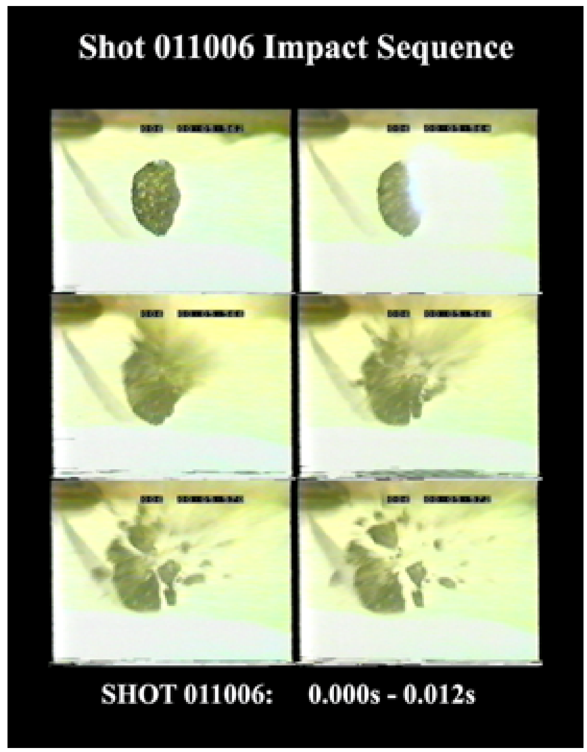

Figure 1. Impact sequence of shot 011006

Figures 1, 2, and 3 show still frames of the footage taken immediately after each impact event, and help to exemplify the differences between the impacts.

Fractured Body Impact The body targeted in this shot was that of a fractured piece of basalt and was cataloged as shot 020511. The fractures throughout the target were extensive, and the area that was impacted was a fragment that was completely separated from the rest of the body by a fracture plane. It was thus possible to weigh this fractured piece separately, which allowed us to calculate the mass of the target that was not directly impacted. The target body was measured to be 137.48 kg, and was impacted by a projectile traveling at $5.49\ ^{km}/_{s}$. This led to an E/M_T of $4.96 \times 10^{3}\ ^{J}/_{kg}$. Inspecting the video footage, and resulting still frames, it was possible to witness the localization of the

Figure 3. Impact sequence for shot 020511

impact to the fractured piece. In the video, the ejecta of smaller fragments almost completely originates from this smaller fractured piece. Upon collection of the debris, it was found that 98.71% of the original mass was retrieved. By then weighing the largest surviving piece of the target at 92.552 g, we were able to establish that 79.38% of the specimen that had not been directly impacted had remained intact.

Rubble Pile Impact The last specimen to be impacted was that of the aggregate, and was catalogued as shot 020512. This body consisted of six individual pieces of porphorytic basalt that were each attached by strings and held together by a small contact force induced by the displacement of the strings from a vertical axis. Each piece was weighed separately, with the total weight coming out to be 56.40 g. The speed of the projectile was measured to be 5.46 $^{km}/_{s}$, giving the impact an E/M_T of $1.2x10^4$ $^{J}/_{kg}$. The projectile was aimed at the largest of the individual fragment pieces. Again the video footage demonstrates the containment of the disruption to the fragment that was directly impacted. The footage is similar to that seen for shot 020511, with an even larger accentuation

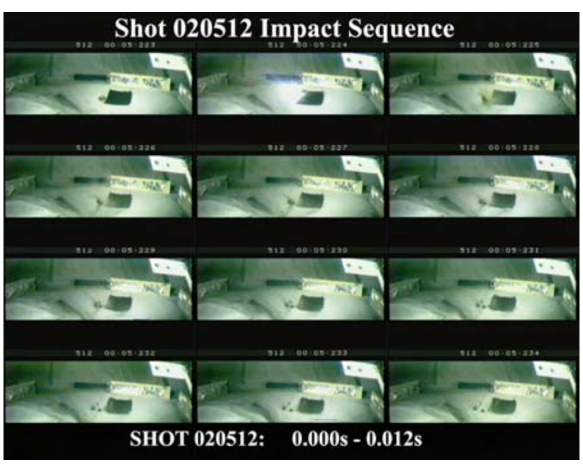

Figure 2. Impact sequence of shot 020512

of the localization effect. Collecting the debris from the impact, we were able to collect 96.54% of the original specimen. The remaining pieces were collected and weighed; leaving us with a mass of 36.944 g for the fragments that had not been directly impacted. Surprisingly, this led to 98.741% of the mass, that had not been directly impacted, staying intact.

References: [1] Durda D. D. et. Al. (2002) LPS XXXIII, abs. No.1535 [2] Asphaug E. & Melosh, H. J. *Icarus* 101, 144 – 164 (1993)