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CALCULATING DAMAGE FROM ASTEROID IMPACTS

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ABSTRACT

Large bolides that penetrate the Earth's atmosphere are may cause a wide range of destruction, depending on the size, velocity and composition of the asteroid. The rarest and largest impacts, such as the ca. 15 km diameter K/Pg impactor that extinguished the dinosaurs and created the 170 km diameter Chicxulub crater, owe their destructive ability to global effects such as ejecta reentry and injections of harmful chemicals into the upper atmosphere. However, the damage from smaller (and more probable) impacts of objects 1 km or less in diameter is more local. These local effects range from airblast and thermal radiation from objects that do not actually reach the Earth's surface, to seismic shaking, ejecta deposition and actual excavation from larger objects that crater the surface. Oceanic impacts may generate tsunami that can propagate destructive energy great distances from the impact site.

G. Collins, R. Marcus and I (Collins, 2003) quantitatively evaluated these aspects of impact damage and incorporated these (and more recent unpublished estimates of tsunami effects) into a website now hosted at www.purdue.edu/**impactearth**/ and at http://impact.ese.ic.ac.uk/. The computer program begins by evaluating the asteroid entry into the Earth's atmosphere, its potential for fragmentation and the dispersion of the fragments should it break up. When this occurs for a weak impactor, as it did at Tunguska in 1908, most of the original kinetic energy of the impactor is deposited in the atmosphere and a strong airblast is the result. On the other hand, if the impactor is strong, as was the ca. 3 m diameter object that struck at Carancus, Peru in 2007, the result is only a small crater whose principal damage was to dig out a

crater 13 m in diameter and scorch the surrounding soil, while the airblast shattered windows 0.6 km away (in this case there were no injuries, although if this event were to occur in a city, some fatalities would be inevitable).

Asteroids large enough to reach the surface at high speed dig out craters, create hot fireballs and generate strong seismic shaking, all of which may cause damage ranging from scorching, ignition of fires, collapse of structures and burial by hot debris, in addition to destruction from the airblast. Oceanic impacts displace volumes of water much larger than that of the impacting asteroid and can potentially initiate destructive tsunami.

Although our website represents a start on reliable computation of the hazardous effects of impacts, many uncertainties exist and there is an urgent need for better estimates of these various effects. For example, our estimates of airblast and thermal radiation effects come largely from the study of above-ground nuclear blasts, which are similar to impacts in many ways, but which also differ in important respects. Seismic effects depend upon a poorly known coupling factor that relates the elastic energy radiated from an impact to the total energy invested in opening the crater. Tsunami are probably the most poorly understood of the various impact effects and have themselves been the object of a heated controversy (Melosh 2003).

The very largest (ca. 1 km diameter) impacts considered to be a serious hazard to civilization may have additional consequences for the composition of the upper atmosphere, consequences that could result in ozone loss, acid rain and global effects from aerosol injection (Birks, 2007).

A balanced program for asteroid hazard mitigation must include further, more realistic, studies of the damage that might be caused by asteroid impacts over a range of sizes, energies and the likely nature of the impacting body (eg. Rubble piles vs monolithic asteroids). Is it worse if an asteroid is fragmented in small pieces by some mitigaton scheme and would it be better to allow it to strike in a single, compact, body (perhaps in a well-defined region that could be evacuated)? Questions like this have been asked, but do not yet have clear answers. The study of impact effects is hardly complete and much remains to be done before we can say that we can really anticipate the effects of a given asteroid or comet impact on our Earth.

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