PROTECTING THE EARTH FROM NEO IMPACTS: NASA PERSPECTIVE

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NASA takes the threat of impacts by comets and asteroids very seriously. We have a long–standing research program to understand more about comets and asteroids, including those that come close to the Earth (Near Earth Objects, or NEOs). While this research program is motivated primarily by a desire to understand the scientific aspects of these small bodies, it is also designed in part to provide the information that will be essential for planning a defense program against hazardous impacts. NASA currently spends about $1 million per year for research related to the impact threat, and we have also carried out two detailed studies of the impact hazard mandated by the U.S. Congress. The report of the first of these studies (The Spaceguard Survey Report) was released in 1992, and a second Report of the NEO Survey Working Group was released in 1995. The complete texts of both of these reports, together with other supporting information on the impact hazard, is available on the internet at the Asteroid and Comet Impact Hazard homepage: http://ccf.arc.nasa.gov/sst/.

One essential element for any program of asteroid defense is an analyses of the nature of the hazard. This aspect of the problem is addressed in The Spaceguard Survey Report and (in more detail) in a 1992 paper by C.R. Chapman and D. Morrison published in Nature. The hazard depends very strongly on the size (energy) of the impacting bodies. For kinetic energy of less than approximately 10 megatons, the object (expect for rare iron meteorites) will disintegrate in the upper atmosphere without doing any harm. The hazard from these objects, with diameters generally less than 50 meters, is near zero. Incoming projectiles with energy from 10 megatons to approximately 1 million megatons will either strike the surface or explode in the lower atmosphere with a capability to do great harm. We expect that the Earth as a whole is struck by an object of 10 megatons or more energy about once per century. Although the force of such explosions is considerable, it is easy to show that the total statistical risk of such impacts on land is rather small, substantially less than that of many other natural hazards such as earthquakes or severe storms. In fact, at this impact rate we would not expect more than one city to have been hit by such an object over the past 10,000 years of recorded history. The danger is substantially greater than the global average, however, for coastal populations. Objects with energy greater than 1000 megatons, striking the ocean, are capable of generating tsunamis with the potential for disaster of a nearly global scale. Persons living in coastal regions run a risk from impact–generated tsunamis as much as two orders of magnitude greater than that from land impacts.

The most important distinction among impacts occurs when the consequences of the impact become truly global, disrupting the environment on a planet–wide scale. Studies have shown that the most important environmental problem following such an impact is injection of dust into the upper atmosphere, causing an “impact winter” similar to the so–called nuclear winter. It is estimated that this threshold for global catastrophe occurs at an energy of about 1 million megatons, corresponding to a hit about once per million years on average. Such an environmental disaster could kill 25 percent or more of the human population. The hazard posed by such impacts is about 100 times greater than that of local, Tunguska–class impacts. The corresponding size threshold for such bodies is between 1 and 2 km diameter.

The primary conclusion from such hazard analysis is that the magnitude of the hazard increases with the size of the impacting body, at least up to about 2 km diameter. The greatest risk corresponds to NEOs with diameters of about 1 km and larger. There is a much smaller risk from objects in the size between about 200 m and 1 km, and the risk from objects less than 200 m is so small that there is little justification for considering a defense against such objects. Aside from the numerical size of the hazard, it is also important to note the qualitative distinction between global catastrophes and the smaller impacts. Impacts above this global threshold are the only known natural disasters capable of killing a large fraction of humanity and threatening the survival of civilization. Any defense program should thus concentrate on objects greater than 1 km in diameter.

Because such impacts are statistically rare, we have time to consider how best to defend against them. Certainly the first task is to search for NEOs of 1 km or greater diameter and determine whether, in fact, any is expected to strike the Earth in the next few decades or centuries. A comprehensive survey (called the Spaceguard Survey) of NEOs is justified. A considerable part of the NASA studies have been devoted to analysis of how to carry out such a survey. At current discovery rate, the survey will be completed in about one century. With any of a variety of proposed new programs, the timescale for a complete survey can be reduced to about one decade. The Spaceguard Survey can be carried out with ground–based telescopes specially equipped for the purpose. There is no advantage in making the survey from space. It should be emphasized that the purpose of Spaceguard is to discover all potentially threatening asteroids and to predict any impact decades or even centuries before it happens. It is not a short–range, quick–response program. We conclude that there is little or no justification for such a short–term program. The proper approach is to carry out a complete sky survey over a period of years and to provide decades of warning of any future impact catastrophe.

While we carry out the Spaceguard Survey we also need to improve our knowledge of the physical properties of NEOs. Our current knowledge indicates that the Earth–approaching objects have a wide variety of size, composition, shape, and spin state. In particular, of the three NEOs that have been imaged by radar, only one (Geographos) appears to be a single coherent object. Castalia is bifurcated and dumbbell shaped, and Toutatis is extremely elongated with the suggestion of three separate components. Toutatis has also been shown to have a rotation state that does not correspond to equilibrium solid–body rotation. We need a great deal more information on the nature of these objects in order to plan a defense program.

In this short paper I will not attempt to describe, even in outline, what the nature of the defense system should be. Fortunately, we are likely to have a long warning time for any future impact in order to work out the details of the system. It is perhaps worth noting, however, that there exists skepticism about the need to develop such a system in advance of the actual discovery of a threatening object. It seems reasonable for any defensive system to address the issue of what the unintended consequences of deployment might be, and to show that the risks to society of developing such a system are less than the impact risks it is intended to defend against.