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ASSESSMENT OF THREAT OF SMALL IMPACTS

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ABSTRACT

Relatively small asteroids strike the Earth more frequently and represent real hazards the man can confront in the nearest future. We consider impact effects of cosmic objects with diameters 5-10 m, 50-100 m, and 200-300 m. 5-10-m-diameter asteroids often decelerate high in the atmosphere and, despite their appreciable energy of several tens of kilotons, their impacts might be classified in general as meteor phenomena, as they mostly do not produce any significant effect on the Earth surface. The famous Tunguska event has been caused by the fall of an asteroid with a diameter in the range 50-100-m. The final airburst with energy of 10-20 Megatons at altitudes 5-10 km undoubtedly bears real threat because it can destroy a big city. Larger asteroids can produce an aerial burst at the surface, and 200-300-m-diameter asteroids typically collide with the surface at high speed and, in the case of a land impact, produce a crater.

Despite hazardous impact effects in general grow with the mass and size of an impacting object, the risk, or danger, depends on the frequency of impacts and can be conventionally determined as the impact probability times the damage produced by an impact. According to data derived from lunar craters, bolide observations and astronomical observations of asteroids, the average frequency of the impacts of 5-10-m-diameter objects is from 2 to about 15 years while the frequency of the impacts of 50-100-m-diameter asteroids is from about 1,800 to 13,000 years. (Under frequency, we mean the average time between the impacts.) If we assume that a 5-10-m-diameter asteroid decelerates at an altitude of 500 m and a 50-100-m diameter asteroid decelerates at 5 km, the areas of devastation by aerial shock waves will be approximately proportional to the asteroid radii squared, that is, the ratio of these areas will be about 100. Strength of small bodies is higher. If ten percent of 50-100-m asteroids are strong enough to reach low altitudes (iron or strong stony) or have a

good aerodynamic shape, the risk from impacts of 5-10-m bodies is the same as from 50-100-m bodies because small impacts happen about 1000 times more often. Note that some 50-m bodies can be substantially different from the Tunguska cosmic body which was roughly of this size. These stronger or weaker bodies can produce smaller effects than in the Tunguska event of 1908.

The frequency of the impacts of 200-400-m-diameter asteroids is from about 40,000 to 140,000 years. The area of damage by aerial shock waves from these impacts is somewhat smaller than that from 50-100-m-diameter asteroids times 16 (the ratio of asteroid diameters squared) because some energy goes to the ground and produce a crater and some energy goes to the plume which expands to the upper atmosphere. Therefore, the risk (frequency times damage) of devastation by shock waves of both impactors with different sizes is roughly the same.

In this work we have made numerical simulations of the land impacts of 200-400-m-diameter asteroids and compared their mechanical and thermal impact effects with the effects of smaller bodies (we have studied the Tunguska event in detail by numerical simulations earlier). The simulations were based on the numerical method SOVA and included the stage of the flight through the atmosphere with ablation, formation of a crater and ejecta cloud. The results of simulations have confirmed the suggestion that the risk (frequency times damage) from these bodies is not higher than the risk from smaller bodies. However, we have not considered electromagnetic disturbances in the atmosphere and generation of acoustic gravity waves which are poorly studied and can prove to be dangerous after the impacts of large asteroids.

Most of hazardous asteroids larger than 100 m in size are to be detected in the future by astronomical observations, and the threat from these objects can be removed or mitigated in advance. But it is unlikely to detect most of asteroids some tens of meters in size in due time. So the threat from these smaller asteroids becomes substantially higher. Composition and structure of small bodies substantially influence the impact concequences. As we do not know mechanical properties of these bodies and, therefore, cannot predict the airbust altitude exactly, to eliminate the risk, the man must be ready to quickly destroy or deflect any small body with a trajectory aimed at any important object on the Earth. It is very important to study the falls of 10-kiloton-energy objects which happen roughly every two years. Unfortunately we have only some very restricted data on atmospheric flashes and infrasound waves created by these objects. In addition, numerical simulations of the impacts of these bodies present a problem because they are substantially smaller than the atmospheric scale height and their way in the atmosphere measured in their diameters is very long.