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NEW RISK ASSESSMENT AND EARLY WARNING OF AIRBURSTS FROM SMALL NEOs

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We present a new risk analysis of airbursts, which we define as events in which small (meters to tens-of-meters in diameter) asteroids deposit most of their energy in the atmosphere as large bolides and where the total energy is comparable to or greater than small nuclear explosions (>0.1 kilotons of TNT). The risk from airbursts is higher than previous assessments for two reasons. First, they are more frequent than previously thought. Our Tunguska-class (~40 meters) population (and impact frequency) estimate has doubled, and Chelyabinsk-class (~20 meters) has increased by a factor of 2.6. Second, asteroid airbursts are significantly more damaging than previously assumed. In most cases, they more efficiently couple energy to the surface than nuclear explosions of the same yield.

NEO risk assessments published in the 1990s concluded that the largest asteroids (> 1 km) dominated the hazard. Even though large NEOs represent only a tiny fraction of the population because of a power-law size distribution, the potential for global catastrophe means that the contribution from low-probability, high-consequence events is large. This conclusion led to the Spaceguard survey, which has now catalogued nearly 90% of these objects, none of which is on a collision course. The survey has reduced the assessed near-term statistical risk from this fraction by more than an order of magnitude because completion is highest for the largest and most dangerous. The relative risk from objects in the tens-of-meters size range would therefore be increasing even if their absolute assessed risk were not.

Uncertainty in the population of airburst-class NEOs remains quite large, and can only be unambiguously reduced by expanded surveys focused on objects in the tens-of-meters size range to improve the population estimates. One strategy would be to design surveys to count small NEOs making close passes in statistically significant numbers. The uncertainty in NEO population is greatest for Chelyabinsk and Tunguska-scale objects, which are tens of meters in diameter, because they are too small and numerous for good optical counting, but still too rare for statistically-significant bolide counting. After the current survey is complete, they will dominate the risk. We argue that future surveys should address this uncertainty and reduce the associated risk.

It has long been a working assumption of the planetary defense community that the appropriate risk metric is the long-term “actuarial” estimate measured in fatalities per year, and that the primary goal should be aimed at reducing this risk. However, it could be argued that another goal of planetary defense would be to maximize the probability of preventing any fatalities over some prescribed time period. From a political and social perspective, one decade would be a realistic time scale. Short-warning surveys and a civil defense (evacuation and shelter-in-place) would provide the best means. Statistically, the probability of an airburst disaster in the next decade is about 1%, whereas the probability that surveys will discover an object on a collision course that is greater than 140 meters in diameter in the next decade is only about 0.1%. To save lives on a socially-relevant timescale, inclusion of small, short-warning impactors should be an additional survey goal.

The NRC report *Defending Planet Earth* stated in its findings that “It is highly probable that the next destructive NEO event will be an airburst from a <50-meter object, not a crater-forming impact.” This finding led to the following recommendation: “Because recent studies of meteor airbursts have suggested that near-Earth objects as small as 30 to 50 meters in diameter could be highly destructive, surveys should attempt to detect as many 30- to 50-meter objects as possible. This search for smaller-diameter objects should not be allowed to interfere with the survey for objects 140-meters in diameter or greater.”

This reinforces the notion that, in addition to pursuing the current survey goal, it would be appropriate to augment capability to provide early warning (days or weeks) of objects on their “death plunge” into Earth’s atmosphere rather than only discovering large objects with sufficient time (many years or decades) to launch a deflection mission. Early warning of an imminent impact would give authorities time to issue evacuation or take-cover instructions in circumstances for which there would be no time the prevent the impact. An early-warning system, such as the ATLAS project, which has plans to come online in 2015, would have many additional benefits optimized to discover imminent impactors.

First, it would provide an additional means to improve the population estimates of airburst-scale objects (tens of meters in diameter) allowing NEOs making close passes to be counted in statistically significant numbers. For example, there are about 25 times as many objects of a given size that pass within the distance of geosynchronous orbit than collide with the earth, and 2000 times as many pass within a lunar distance (accounting for gravitational focusing). An asteroid the size of the Cheylabinsk impactor (~20 m) could potentially be observed within geosynchronous orbit every two years and within lunar orbit nearly once a week. A Tunguska-sized asteroid (~40 m) passes within a lunar distance several times a year. A survey optimized to discover and count these objects would rapidly reduce the uncertainty in these intervals, and therefore in their populations. The following table lists the mean time intervals of impacts and close passages of impactors with various diameters, using the definitions:

D > = NEA diameter (larger than given amount)
N = Total population of NEAs for given diameter D >
T_c = Mean time interval between Earth collisions (in years)
T_{ld} = Mean time interval between NEA passages within a lunar distance
$T_{ld} = T_c/(2000)$

D >	N	T_c	T_{ld}
5 km	20	25,000,000	12,500 years
1 km	990	480,000	240 years
500 m	3,300	150,000	75 years
300 m	7,500	63,000	32 years
200 m	15,000	32,000	16 years
100 m	50,000	9,500	5 years
50 m	430,000	1,100	7 mo
20 m	10,000,000	50	9 days

Second, short warning survey would also discover non-threatening imminent impactors like 2008 TC3 and 2014 AA. The ability to observe asteroids in space and predict the time and place of their atmospheric entry would provide opportunities for research, meteorite recovery, and even for adventure tourism. This suggests a financial incentive for private enterprise to support short-warning surveys. Advance warning surveys would potentially allow outfitters to operate tourist-funded expeditions that could also carry scientific instruments and devices such as high-resolution stereoscopic video cameras, radiometers, spectrometers, seismometers, barographs, radar, infrared trackers, infrasound, and dust collectors. High-fidelity observational data collected from airbursts would provide information on the dynamic properties of asteroids that would be useful for impulsive deflection design, as well as for better understanding of the physics of airbursts for improved risk assessment and to further our knowledge of meteoritics by linking meteorite types to astronomical asteroid observations and orbits.

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