Simulating Armageddon on Your PC: Asteroid Impacts with Earth

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Millions of non-catalogued space rocks careen through interplanetary space, and Earth is one of the many sitting ducks in the cosmic shooting gallery.

Although centuries can pass on Earth without a catastrophic strike, waiting impassively to be hit is seen by many experts as a clear and possibly deadly gamble. But what are the odds? And what would happen under different types of impacts?

As with almost anything that can be simulated, the odds and consequences of an asteroid strike are now programmed into a computer software package.

I ran some scenarios on the new software, created by planetary scientist John Lewis from the University of Arizona. The results, described below, are not official predictions. But they do present some frightening possibilities that put the threat of rocks from space into tangible terms, while at the same time pointing to the need to search for the uncharted asteroids and comets (known as Near Earth Objects or NEOs) that threaten our civilization.

Lewis' software uses a Monte Carlo analysis to calculate the human fatalities resulting from impacts. This works by generating random numbers for the size and type of NEO and the human population density at the impact site. The process is based on the actual distribution of these factors. It includes fatalities from "airbursts," where the NEO explodes in a devastating fireball several miles from the ground.

The consequences are similar to those from a nuclear bomb and estimates of fatalities are based mainly on research with nuclear weapons. Another danger modeled by the program is the risk of a tsunami swamping coastal cities hundreds or thousands of miles from the site of an ocean impact.

A million years of bombardment

In one run I simulated a total of one million years, looking at the worst event in each of 10,000 centuries.

I want to stress that these are not predictions and that no known NEOs are on a collision course with Earth.

Although one million years seems a very long time, bear in mind that impacts do not run like clockwork -- they could occur at any time. An event that happens once in one million years of the simulation has a one-in-a-million chance of happening in the next twelve months. This should not be dismissed as unimportant, particularly if it could involve billions of deaths and the end of civilization. After all, many optimistic people around the world regularly buy lottery tickets where the chance of winning first prize is one in 30 million or less.

The chance of being dealt a royal flush in 5-card poker is about one in half a million.

In my simulation the total death toll during one million years was 7.5 billion. This represents an average of 7,500 fatalities per year and is higher than the 3,000 fatalities per year generally quoted by scientists. However, nearly half of these

fatalities occurred in one devastating event that wiped out half of the world's population -- a possible outcome in the real-life gamble with rocks from space.

To put the NEO death toll in perspective, it lies somewhere between that of airline crashes (700 per year) and earthquakes (10,000 per year).

Fatalities by size of NEO in the simulation

Asteroid/Comet Diameter (yards)	Annual Fatalities	Fatal Events	% Fatal (for group)*
25 to 99 yards	236	2,664	31%
100 to 199	231	736	69%
200 to 499	532	295	95%
500 to 1000	618	44	98%
1000 yards to 1 mile	788	10	100%
1 mile to 1.3 miles	2,064	5	100%
More than 1.3 miles	3,060	1	100%
Total			38%

*Percentage of events in this size group that cause fatalities.

Looking at the results

Fatalities topped 1 million in 2% of the centuries. Nearly two-thirds of centuries had no fatalities.

In another 5 percent of centuries, the worst event happened in a remote location and caused less than one thousand fatalities. Such events would probably not been blamed on NEOs, for lack of being spotted. An additional 5 percent of centuries had only had tsunami fatalities, with an average of 100,000 fatalities per tsunami event. Many of these tsunami events would not have been linked to a NEO since the ocean impact happened well away from eyewitnesses.

Overall, some 70 percent of centuries may have had no reported fatalities from NEOs. This may help to explain the general lack of awareness of the NEO threat by the public and politicians.

Surprisingly, 1,207 fatal impacts involved NEOs with a diameter less than 50 yards. Most did their damage in an airburst of around 10 megatons -- like that of a "small" H-bomb.

There were several sobering impact events in the simulation. They are described below. Geographic names are arbitrary and are intended to give an indication of the population density and landforms of the impact site (as well as dramatic effect).

Big blasts

First the really big ones -- asteroids or comets a mile or more across. These are civilization-destroying events that leave little opportunity for disaster recovery. Estimates of the NEO population suggest that, over a period of one million years, about 5 such impacts can be expected. By chance, this is the number produced in the simulation.

- During the 133rd Millennium a 1.3-mile-wide comet hits the American Midwest at a speed of 100,000 mph. The blast, equivalent to 3 million megatons of TNT or 60,000 H-bombs, kills 7 million instantly and makes a crater 20 miles across. Within days the skies around the globe darken from the dust injected into the atmosphere. Sunlight is blocked. Crops fail and, over the next year, half of the Earth's human population dies, mainly from starvation.
- In the 621st Millennium a mile-wide comet slams into Mongolia. "Only"

300,000 people die instantly, but the dust from a crater 13 miles across darkens the skies around the globe. Some 900 million die from starvation.
- In the 952nd Millennium a 1.2-mile-wide comet hits central Africa. About 3 million people are killed instantly. An 11-mile-wide crater is formed. Later, 500 million starve to death around the globe.
- During the 11th Millennium a 1.2-mile asteroid hits the southern Atlantic Ocean 400 miles off the coast of southern Argentina. A tsunami 250 yards high sweeps 50 miles inland and kills 300,000. The climatic effects are less severe than with a land impact, but 400 million still die from starvation due to these effects.
- An almost identical event, this time off the northern coast of Russia, occurs in the 699th Millennium.

Quirky blasts

There were several events that were unusually deadly -- a matter of bad luck for 54 million people:

- 136th Millennium: A 200-yard-wide asteroid hits the South China Sea just 300 miles from Hong Kong. A 40-yard-high tsunami sweeps the coast and kills 18 million people.
- 20th Millennium: An asteroid just 70 yards across explodes in the skies 14 miles above London. 10 million are killed in the 80-megaton blast and firestorm.
- 273rd Millennium: A 50-yard-wide comet travelling at an unusually fast 150,000 mph explodes in the atmosphere 25 miles above Mexico City. 14 million are killed by the 110-megaton blast and firestorm.
- 721st Millennium: An almost identical event occurs over Manila, killing 12 million.

The lessons from the simulation

Comets accounted for three-quarters of the fatalities, due mainly to the event in the midwestern United States. That event was caused by a long-period comet that spent tens of thousands of years out beyond the orbit of Neptune before diving into the inner solar system.

The simulations show that unusual events can be killers. In his book, Lewis points out that the simulations generally produce a greater number of casualties from small NEOs than would be expected from calculations involving "typical" values. Unfortunately, it would be extremely difficult for current technology to reliably detect such small, but deadly, objects.

The situation is very different for the civilization-destroying giants because most can be easily spotted from Earth using existing technology. Given decades of warning, we can develop the space technology to nudge them into a non-threatening orbit. But the current odds are that a large NEO will strike with little or no warning because the world-wide search for NEOs is grossly under-funded and under-staffed (as one frustrated scientist put it -- less than the number of staff at a typical McDonald's restaurant).

Lewis sums up the situation succinctly: "Of all the natural hazards facing Earth, impacts are the most dangerous. Unlike native hazards of the Earth's surface, impacts know no size limit. Their effects can be devastating over the entire surface of the planet. They are the only credible natural threat to human civilization. But impacts, especially those of large bodies, are both predictable and avoidable.

"The Near Earth Object (NEO) population constitutes both an unprecedented hazard and an unparalleled opportunity," Lewis said. "It is sometimes said that there is a fine line that separates a threat from an opportunity. The near-Earth asteroids present us with just this dilemma. They present us with an intelligence test of the highest order, with the highest possible stakes for the human race."

Notes about the computer program

The computer program is available on diskette distributed with the book "Comet and Asteroid Impacts on a Populated Earth" by John S. Lewis, Academic Press. It was released late in 1999.

Due to its random nature, each time the program is run it generates a completely different set of results. The overwhelming influence of a few horrendous events means that the total number of fatalities can vary considerably between successive runs.

Only the worst event in each century was considered in my simulation. Other fatal events may occur but are not included in the death toll.

The original program uses a tsunami runup factor of 30 (the height of the wave at the shoreline was assumed to be 30 times the height of the wave in deep water). A more conservative runup factor of 5 was used in the simulation.

The program is mainly intended for runs covering several thousand years. In these time periods, impacts massive enough to cause global climatic trauma are extremely rare and the program did not fully account for these effects. Lewis and others suggest an explosion equivalent to one million megatons of TNT would be sufficient to cause over a billion human fatalities, mainly due to global starvation. A typical asteroid about 1 mile across would do the trick. Global climatic effects probably become insignificant for asteroids smaller than 500 yards across, with a typical explosion of 10,000 megatons of TNT (some 200 times larger than an H-bomb). The potential fatalities from these climatic effects have been included in the above fatality estimates.

A constant world population of 5 billion people is assumed. It is also assumed that impacts occur without warning (the current situation) and that there is no time for evacuation or preparation, such as stockpiling of food supplies.

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