Air and Space this Week

Item of the Week

TUNGUSKA AND IMPACT HAZARDS

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The Earth is bombarded by extraterrestrial material on a regular basis, but most meteoroids are tiny and at most make a nice "falling star." But there are some larger bodies out there, such as the meteor that came in over Chelyabinsk, Russia a decade ago. We know that the Earth has been hit by even larger objects in the past, including the iron meteorite that formed Meteor Crater in Arizona. Just how much are we at risk from such events? An important event to consider when assessing impact risk is the multi-megaton event over the Podkamennaya Tunguska River region of Siberia, 114 years ago on ***June 30****, 1908.*

TUNGUSKA BEFORE 1908

The Tunguska region is extremely remote today, and was even more so 114 years ago. It's located well north of Lake Baikal, just above 60° N, in the central part of the Central Siberian Plateau. The area has some deeply-incised river valleys, including that of the Podkamennaya Tunguska River, and is mostly covered by a taiga (boreal forest). Swampy land is common, especially in the valleys during summer, and the region supports a population of elk, bears, caribou, and smaller animals. Archeological sites in the region date from the Neolithic Period.

The indigenous population, the Evenki people, was very sparse. They ranged over the Russian North, and into what is now the PRC and Mongolia. There were some minor Russian settlements in the area, especially in its southern reaches near Lake Baikal. Their presence, and the Tsar's demand for taxes, caused the Evenki considerable grief. Many moved eastward, some all the way to Sakhalin, and only a few remained in the Baikal region by 1900.

THE EVENT

That morning, local natives and Russian settlers near the lake saw a very bright object pass overhead, then a bright flash to their northwest. A strong shock wave swept the area, breaking windows many miles away. A man 40 miles from the explosion site was knocked to the ground, feeling an intense heat. The air pressure wave was detected thousands of miles away, and the sky above the area glowed for days following.

Something big had happened in Siberia, but what was it? There was little communication with the region, and it was very difficult to get to. The Tunguska "Event," as it came to be known, was a mystery. Many thought it had to be some sort of impact event, but nobody knew for sure.

INVESTIGATIONS

The first attempt to conduct a scientific expedition to the region was not mounted until 19 years after the Event. Leonid Kulik, the Chief Curator of the meteorite collection at the St. Petersburg Museum, put together an attempt to reach the site. It failed due to the harsh climate and difficult terrain, and lack of supporting infrastructure. He tried again six years later, and this time managed to get near enough to the impact site that he encountered eye witnesses to the great event two decades-plus earlier.

The locals were not very willing to discuss what they saw/experienced with an outsider. To them, the explosion that had knocked over their forest and killed their reindeer was the act of a vengeful god, and talking about it risked further outbursts. The land, however, spoke volumes.

Kulik found that 800 square miles of pine forest had been flattened, with over 80 million trees were knocked flat in a radial pattern. The trees at the center of the devastated area were still standing, but they had been stripped of every one of their branches. Whatever its source, the explosion had been well above the surface of the ground, blasting the trees in a radial pattern away from the epicenter, whose trees suffered debranching from the blast directly overhead.

Kulik found no impact crater, the aerial burst had spent itself laterally and upward.

Kulik would make a third expedition to the region, and this time he had better luck talking with witnesses. They described vividly the "sky splitting in two" and the whole "northern part of the sky covered with fire" along with an account of strong shock waves and extremely loud noises.

The astronomical community was now convinced that an extra-terrestrial object had struck Tunguska, but was it an asteroid? Was it a comet? The lack of an obvious impact crater proved it wasn't an iron body that fell (as in the case of Meteor Crater), because the iron would have resisted aerodynamic forces better. The object had to be a stony meteor, but it could have contained a fair number of volatile components.

Subsequent investigations and modeling give an idea of the magnitude of this event.

Depending on its exact composition and structural integrity, the impacting object would have been ~40 meters in diameter with a mass of a supertanker, moving at 30,000+ MPH. The object exploded at about 30,000 feet altitude. The equivalent impact energy was that of a hydrogen bomb of a few megatons yield.

The ground effects of both the Meteor Crater and Tunguska Event were similar – they would have killed pretty much everything within a radius of a few tens of miles. The Tunguska explosion was bigger, but it was more spread out because it occurred at altitude; the Meteor Crater meteoroid hit pretty much intact. Either would have annihilated a mid-size town and its surrounding area.

Tunguska is the largest impact event on Earth during recorded history. But it was by no means the largest impact event recorded in ***geologic*** history!

One of the biggest impacts since life arose on Earth was the Chicxulub impact that marked the end of the Mesozoic Era, ~65 million years ago. I wrote about it in the May 2, 2022 A+StW, as part of the set up for the PBS *Dinosaur Apocalypse* show that aired on May 11. Numerous books and articles have been written about this impact and how its nature was uncovered, so I won't go into more detail here, apart from pointing out that ~75% of the species alive at the moment of impact were rendered extinct. The mass die-off that marks the end of the Paleozoic may have been even more extreme.

Planetary scientists find huge numbers of craters on the Moon and other planets/moons. The Earth would have that many, too, if it didn't have active geological processes that quickly erase the surface features associated with impacts. Only a few, like Meteor Crater, are young enough to have retained their original shape. Most of the several hundred impact sites now known are the eroded roots of the long-gone surface crater.

The relative absence of smaller craters on Earth due to erosion makes assessing the rate of Earth being hit by impactors, especially those smaller than that at Tunguska.

THE RISKS

Planet (near) sterilization events occur once or so in a geologic age. Events the size of Tunguska occur every few centuries or so. A megaton-scale blast would cause relatively little damage at sea (depending on exact site), but could easily wipe out a whole city.

And what about smaller, but more common impacts, the ones that are more akin to Hiroshima in size? They'd badly damage a populated area, too. How can we best assess the risk involved, and what, if anything, could we do about it?

Many scientists are working on mitigating the potential threat of a large asteroid impact. One tool they use in explaining the threat to the public is the "Torino Scale," a 1-10, color-coded, threat roster. A mathematically more-sophisticated version of this scale is the "Palermo Scale," which is also 1-10, but logarithmic, which gives a better range of potential damage for smaller, more common, impacts. Such scales are useful in assessing the threat, but by themselves do nothing to mitigate potential damage.

Another way of understanding the risks associated with asteroid impact is to graph the frequency of occurrence of an impact event against the energy of such an event, for example, see here. Note that there are only two hard data points on the graph, one at the high end for Chicxulub, and the other for Tunguska. Small changes in the position of those two points on the graph could cause large changes in the number of impacts of a given size/energy. This shows just how important understanding the 1908 event really is in assessing impact risk!

WHAT IS BEING DONE

Both NASA and the European Space Agency have set up departments that are responsible for assessing and defending against impact events.

NASA's Near-Earth Object Observation Program is under congressional direction to "find, track, and characterize at least 90% of the predicted number of NEOs that are 140 meters and larger in size." The Program has several projects that allow it to reach the directive, including NASA Observatories (NEOWISE and IRTF); the Minor Planet Center, which is the international clearinghouse for NEO discoveries and initial orbit computation; the Center for Near-Earth Object Studies, which makes precise orbit determinations and impact probability assessments; and various sky surveys. Ground-based planetary radar data are acquired of asteroids of interest to determine their shape and other physical characteristics. The NEOOP also supports the collection of meteorites in Antarctica (ANSMET) and conducts a variety of mitigation studies under the auspices of the NASA Ames Asteroid Threat Assessment Project (ATAP).

The ATAP team used computer modeling of: asteroid composition and how that would affect an impact; impact location (land, shallow water, deep water); and how the shock wave from the blast would affect various objects.

Asteroid composition: As was the case with Meteor Crater and Tunguska, the composition of the impacting body affected the damage the resulted; an iron body caused more damage than a rocky/icy body of similar size, IF the latter exploded aloft.

Impact location: Impact in water poses a different threat than impact on land. Modeling by the Ames group reveals the danger posed by impact-generated tsunamis to coastal areas far from the impact site.

Understanding the consequences of a potential impact is important, but learning what is going to happen just prior to impact is of little comfort. What could be done to prevent or lessen the impact?

A Hollywood solution would be to send courageous retired astronauts to "blow up" the impactor and save the day. But physically disrupting the incoming body would do little or nothing to divert the material coming in. Would you rather get hit by a speeding bullet or a shotgun blast at short range? *Macht nichts*; in fact, disruption could spread catastrophic damage more widely than if the impactor were not disrupted.

A more effective approach might be to see the impacting body far enough out to take action, then send a spacecraft that could actually alter the trajectory of the impactor. A very slight nudge to the side, if taken at great enough distance, can make a big difference in the path of the impactor near Earth. NASA is actually in the process of testing the feasibility of doing just that, with the Double Asteroid Redirection Test mission (*DART*), launched on November 23, 2021.

DART

When we first started sending spacecraft to fly by asteroids close enough to image their surfaces, we were surprised to find that some asteroids had smaller asteroids orbiting them.

Our Earth-based observation capabilities have increased to the point where we can identify such pairs without the fly-by. One such is the binary asteroid named “Didymos,” from the Greek for “twin.” It’s about a half-mile across in size (780 meters).

Didymos’ “moon” is the smaller asteroid named, “Dimorphos.” It’s only about 160 meters across, and orbits Didymos in just under 12 hours.

The idea behind the DART mission is simple. It will be guided to strike Dimorphos head-on at high speed, and then the effect of the impact on Dimorphos’ orbit will be determined to see how much deflection was obtained.

The only scientific instrument *DART* will carry is the Didymos Reconnaissance and Asteroid Camera of Optical navigation (DRACO), a high-resolution imager derived from the LORRI camera on board the *New Horizons* spacecraft that flew by Pluto. Its images will help guide *DART* to its impact, and will stream live images of the final approach to allow scientists to understand the characteristics of the impact site.

Since DRACO will be destroyed in the impact, *DART* will also carry a CubeSat called the *Light Italian CubeSat for Imaging of Asteroids* (*LICIACube*), contributed by the Italian Space Program. *LICIACube* will be released by *DART* a few days prior to impact, and will provide a ringside seat of the impact itself.

DART also carries several technologies being tested/demonstrated. One of the most important is NASA’s Evolutionary Xenon Thruster - Commercial (NEXT-C), an ion engine developed at NASA’s Glenn Research Center.

By the way, you can become a DART Planetary Defender; see: https://dart.jhuapl.edu/Planetary-Defender!

ONE MORE WORRY

If the prospect of rocks falling on you from the sky isn’t enough to worry you, consider this. The USSR delayed the launch of an early Mars probe, scheduled to go aloft around the time of the Cuban Missile Crisis, because they were concerned that the U.S. would detect the launch and, thinking it was a missile aimed at us, respond with a nuclear strike. Monitoring capabilities back then were quite primitive, and the speed of the missiles required an immediate “use or lose” approach to defense.

We are watching the skies closely today for asteroids and external interlopers that might hit the Earth, but the Chelyabinsk impactor came in from a direction we couldn’t monitor closely, and surprised us.

The Chelyabinsk event came almost exactly 50 years after the Cuban Missile Crisis, and Chelyabinsk is only a few hundred miles from Moscow. Fifty years and a few hundred miles are extremely small on the astronomical time/distance scales. A slight variation in trajectory could have caused the impact to occur 50 years earlier and closer to Moscow, and who knows how the Russians would have reacted in that case?

The odds of a sizable body hitting Earth with being detected on the way in are getting smaller, but aging nuclear defense systems might not be robust enough to separate a celestial event from a nuclear first strike.

Therefore, the threat of impact is not just the damage caused by the impact, it includes the potential human responses to the impact.

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