



ICE & STONE 2020

WEEK 27: JUNE 28-JULY 4

Presented by The Earthrise Institute

#27

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THIS WEEK IN HISTORY



JUNE 28, 1911: A meteorite falls to the ground near the village of El Nakhla El Bahariya, Egypt. The Nakhla meteorite was one of the first-known meteorites determined to have come from Mars. A fragment of the Nakhla meteorite supposedly struck and killed a dog, although there has been no independent confirmation of this. "Martian meteorites" are discussed in a future "Special Topics" presentation.

JUNE 28, 2011: A team of astronomers led by Mark Showalter discovers Pluto's fourth known moon, Kerberos, in images taken with the [Hubble Space Telescope](#). Pluto and its system of moons are discussed in a future "Special Topics" presentation.



JUNE 30, 1861: Comet Tebbutt 1861 II passes 0.133 AU from Earth, in the process becoming one of the brightest and most spectacular comets of the 19th Century. It is this week's "Comet of the Week."

JUNE 30, 1908: An object, perhaps 50 to 80 meters in diameter, enters Earth's atmosphere over northeastern Asia and explodes several km above the ground near the Stony Tunguska River in central Siberia, creating widespread devastation for hundreds of square km around. The "Tunguska Event," as this has come to be called, is the largest impact event on Earth in recent history, and it, together with some smaller more recent events, is the subject of this week's "Special Topics" presentation.

JUNE 30, 2024: Comet 13P/Olbers is expected to pass through perihelion at a heliocentric distance of 1.176 AU. This return is discussed as a part of the "[Comet of the Week](#)" presentation on Comet 12P/Pons-Brooks (which passes through perihelion two months earlier).



JULY 1, 1770: Comet Lexell 1770 I (new style: D/1770 L1), discovered two weeks earlier by French comet hunter Charles Messier, passes 0.015 AU from Earth, the closest confirmed cometary approach to Earth in recorded history. Comet Lexell – which has not been seen since 1770 and is now considered "lost" – and this encounter are discussed in a previous "[Special Topics](#)" presentation.

JULY 1, 2020: The main-belt asteroid (544) Jetta will [occult](#) the 7th-magnitude star HD 143114 in Scorpius. The [predicted path](#) of the occultation crosses the southwestern Pacific Ocean and mostly lies over water, but does cross the northern tip of the South Island of New Zealand and western New Britain Island in Papua New Guinea.



JULY 2, 1737: A Jesuit missionary, Ignatius Kegler, discovers a comet from near Beijing, China. This is now known to have been a previous return of Comet 109P/Swift-Tuttle, the parent comet of the Perseid meteor shower, and a future “Comet of the Week.”

JULY 2, 1985: ESA's [Giotto](#) mission is launched from Kourou, French Guiana. Giotto passed just 600 km from the nucleus of Comet 1P/Halley in March 1986 and then went on to encounter Comet 26P/Grigg-Skjellerup in July 1992. The Giotto mission as a whole is discussed in next week's “Special Topics” presentation, and the encounter with Comet Halley, and some of its scientific results, are discussed in that comet's “[Comet of the Week](#)” presentation.



JULY 3, 1819: French scientist Francois Arago observes Comet Tralles 1819 II (new style: C/1819 N1) with a polarimeter that he had invented, and discovered that some of the light in the comet's tail was polarized, indicating that it was shining by reflected sunlight. This was the first such observation made of a comet.

JULY 3, 2020: Comet NEOWISE C/2020 F3 will pass through perihelion at a heliocentric distance of 0.295 AU. This comet, which was discussed in a previous “[Comet of the Week](#)” presentation, has the potential of becoming a naked-eye object for the northern hemisphere later this month. Current information about it can be found at the [Comet Resource Center](#).

JULY 3, 2020: The main-belt asteroid (128618) 2004 QH25 will [occult](#) the 7th-magnitude star HD 173854 in Sagittarius. The [predicted path](#) of the occultation crosses the south central Pacific Ocean, central Queensland and the north-central Northern Territory in Australia, and eastern Java and southern Sumatra in Indonesia.



JULY 4, 1997: Comet 2P/Encke passes 0.190 AU from Earth, the closest approach it has made to our planet since its original discovery in 1786. Comet Encke, which passed through perihelion last week and was last week's “[Comet of the Week](#),” should become visible in the southern hemisphere's evening sky by the end of this week. Current information about it can be found at the [Comet Resource Center](#).

JULY 4, 2005: NASA's [Deep Impact](#) mission passes by Comet 9P/Tempel 1, firing a projectile at the comet's nucleus and thereby creating a cloud of debris from the resulting impact, from which chemical information about the nucleus' internal composition could be determined. Comet 9P/Tempel 1 is next week's “Comet of the Week” and the Deep Impact encounter will be discussed in detail in that presentation.

COVER IMAGE CREDIT:

Front and back cover: As part of the global effort to hunt out risky asteroids and comets, ESA is developing an automated telescope, nicknamed ‘Flyeye’, to conduct nightly sky surveys. Artist's impression courtesy of ESA/A. Baker

COMET OF THE WEEK: TEBBUTT 1861 II

Perihelion: 1861 June 12.01, $q = 0.822$ AU



Comet Tebbutt on June 30, 1861, as sketched by Austrian astronomer Edmund Weiss. [Capella](#) is the bright star to the comet's right, and Cassiopeia is in the upper right.

Two of the brighter comets of the latter half of the 19th Century were discovered by an Australian amateur astronomer, John Tebbutt, who for four decades essentially ran a one-man astronomical clearinghouse from his private observatory near Windsor, New South Wales. In addition to numerous astrometric observations of asteroids and comets, he also maintained detailed studies of the weather as well as a local time service, and also wrote prodigiously on scientific topics for the general public. His scientific contributions were such that the Australian government placed his portrait on the back of the AUS\$100 banknote from 1984 to 1996.

Tebbutt discovered his first, and brighter, comet – and, indeed, one of the brightest and most spectacular comets of the entire 19th Century –

on May 13, 1861, at which time it was about 4th magnitude, and located at a declination of -30 degrees in the constellation Eridanus and traveling very slowly northward. Such was the state of communications at the time that Tebbutt was the only observer of the comet for a few more weeks, but during the second week of June it began to be picked up by other observers as a relatively bright object of 2nd magnitude with a distinct tail that some reported as being close to 40 degrees long. Although the comet passed through perihelion on the 12th it continued to approach Earth and to brighten, and by the last week of June was close to magnitude 0.

Comet Tebbutt passed 0.133 AU from Earth on June 30, passing almost directly between Earth and the



Back side of the AUS\$100 banknote from 1984 to 1996, featuring a portrait of John Tebbutt.

sun at that time, thus briefly exhibiting a phase angle in excess of 165 degrees and accordingly a dramatic brightness enhancement due to forward scattering of sunlight. It was traveling northward at over 10 degrees per day at the time, and right around the 30th suddenly became visible from the northern hemisphere as a brilliant object of magnitude -2 or brighter. Because of the viewing geometry the tail was broad and structured, and according to several observers stretched over 90 degrees on the sky. Several observers reported the comet as being bright enough to cast shadows. It appears that Earth might actually have passed through part of the comet's tail around the time of closest approach.

During the first few days of July Comet Tebbutt entered northern circumpolar skies, and for the first week of that month remained a bright and spectacular object of 1st magnitude with its tail extending for a length of 60 degrees or more. It began fading after that, although it was still close to 3rd magnitude, with a tail over 10 degrees long, around mid-July, and was close to 4th magnitude by the end of that month. The comet dropped below naked-eye visibility around the middle of August and remained telescopically detectable until the beginning of May 1862, by which time its heliocentric distance had increased to 4.4 AU and it was located within 13 degrees of the North Celestial Pole.

Being as bright and spectacular as it was, and especially with its dramatic and sudden appearance in the northern hemisphere's sky at

the end of June 1861, Comet Tebbutt appeared in numerous popular writings of the time. Its appearance came only 2½ months after the start of the American Civil War, and Commander Raphael Semmes, Captain of the Confederate Navy's commerce raider CSS Sumter, wrote of viewing the comet while that vessel made its escape from the Union blockade of New Orleans on the evening of June 30. Meanwhile, on July 6 the British explorer of Africa David Livingstone, while in present-day Malawi commanding the Second Zambezi Expedition, independently discovered the comet while it was traversing Ursa Major north of the Big Dipper.

Orbital calculations, based in part upon some of the astrometric measurements that Tebbutt himself collected, suggest that Comet Tebbutt has an orbital period of slightly over 400 years, in turn suggesting that it might have returned sometime around the mid-15th Century. In 1995 Japanese astronomers Ichiro Hasegawa and Syuichi Nakano [proposed](#) that a comet observed from China, Japan, and Korea in May and June 1500 might be identical to Comet Tebbutt, and successfully linked the orbits of the two comets mathematically. If the two comets are indeed one and the same object, Hasegawa and Nakano predict that it will return to perihelion again in December 2265. At that time it will be on the opposite side of the sun from Earth and thus would be nowhere near as spectacular as it was in 1861, although with its near-perpendicular orbit (inclination 85 degrees) it would presumably still be visible after perihelion without too much difficulty.

SPECIAL TOPIC: THE TUNGUSKA EVENT AND OTHER RECENT IMPACTS



Photograph of the Tunguska Event's impact site taken by Leonid Kulik's expedition in 1927. Most of the trees are knocked flat, radially extending outward from "ground zero."

During the early morning hours on Tuesday, June 30, 1908, at around 7:17 A.M. local time, "something" entered the earth's atmosphere near the Pacific coast of Asia, traveling northwestward. A few km above the surface of a largely uninhabited region of central Siberia, near the Stony Tunguska River some 90 km north-northwest of the village of Vanavara, this object exploded with a force that is presently estimated to have been approximately 10 to 30 megatons, and according to eyewitness accounts was as bright as, perhaps even brighter than, the sun.

The region over which this event occurred is very sparsely inhabited, the only people in the area at the time being nomadic reindeer herders. The camps of some of these herders were completely destroyed, with some of the herders themselves being sent airborne by the force of the blast, resulting in some serious injuries and apparently three fatalities.

People 100 km away were knocked off their feet, and windows were blasted out of buildings. At Vanavara the sky was said to have "split apart," and the sound of the explosion was heard 1000 km away.

Even far away from the event its effects were felt. The force from the explosion created atmospheric pressure waves that circled the earth twice, and seismographs thousands of km away recorded waves from earthquakes – as powerful as 5.0 on the Richter scale – produced by the blast. Particles deposited in the atmosphere created light scattering so intense that on subsequent nights in eastern Europe newspapers could be read at night without the need of any lights, and astronomers around the world detected a significant decrease in the sky's transparency.

In part because of the region's inaccessibility and



Artist's conception of the Tunguska Event, as viewed from the town of Kirlensk (60 km distant) two seconds before the explosion. Courtesy [William Hartman](#).

inhospitableness – it is a mosquito-infested wilderness, with much of its being marshland – in part because of political events such as the Bolshevik Revolution, and in part because of local taboos concerning the event itself, it was almost two decades before any scientific expeditions to the site were conducted. The first such expedition was led in 1927 by Leonid Kulik from the Soviet Academy of Sciences. After an arduous overland journey Kulik and his group reached the site in the late spring of that year and witnessed an incredible sight of devastation: over an area constituting approximately 2000 square km around the site trees has been uprooted and knocked to the ground, with their trunks pointing back toward “ground zero.” Forest fires resulting from the heat of the explosion had burned much of the surrounding vegetation.

This and three additional expeditions to the site over the next ten years were the only significant examinations of the area for some time, with World War II being a major contributing factor in

the curtailing of this exploration. The next major expeditions weren't conducted until the late 1950s, but thereafter the then-Soviet Union sent expeditions to the site on a fairly regular basis. Expeditions continue to be conducted to the site today, and it and the surrounding region has been designated a protected area, the [Tunguska Nature Reserve](#). Much of the vegetation has since grown back, and the site is once again pretty much the dense Siberian wilderness that it was prior to 1908.

Much has been written about the “Tunguska Event,” as this event has come to be called, during the over a century that has elapsed since it took place, including a lot of speculation as to what caused it. Some of the explanations have bordered on the fanciful, but the majority consensus all along has been that it was caused by the impact of an object from space. Kulik himself believed this, although he was surprised by the lack of any impact crater at the site.

In 1930 a British astronomer, Francis Whipple – no



The daylight fireball of August 10, 1972, over Jackson Lake and the [Grand Teton](#) Mountains in western Wyoming. Photograph courtesy James Baker of Omaha, Nebraska; his wife Linda is in the left foreground.

apparent relation to American comet scientist Fred Whipple, of the “icy conglomerate” comet nucleus [model](#) – proposed that the Tunguska Event was caused by a small comet that entered Earth’s atmosphere and disintegrated. Then, in 1969 Russian scientist I.T. Zotkin proposed that the Tunguska Event was caused by an inert fragment of [Comet 2P/Encke](#), an idea that was subsequently championed and expanded upon by Lubor Kresak in then-Czechoslovakia during the late 1970s – an idea reinforced by the fact that the impact date coincides with the peak of the daytime Beta Taurid meteor shower that is associated with that comet. During the early 1980s, however, astronomer Zdenek Sekanina pointed out that a comet would not have the internal strength to have survived passage through the atmosphere to that low a level, and proposed instead that the Tunguska Event was caused by a stony asteroid. More recent research, including by Jack Hills at the Los Alamos National Laboratory and Chris Chyba (then at the Goddard

Space Flight Center in Maryland) have reinforced this idea, which has been further supported by examination of cosmic dust particles found in tree resins at the Tunguska site that are consistent with origin within a stony asteroid.



Commemorative stamp issued by the Soviet Union in 1957 marking the 10th anniversary of the Sikhote-Alin impact event. The painting was made by Russian artist P.I. Medvedev, who was sitting at his window starting a sketch when the meteor appeared.

The current consensus is that the Tunguska Event was caused by a stony asteroid, 50 to 80 meters in diameter, that entered the atmosphere traveling at 15 km per second. The atmospheric shocks that it encountered as it made its plunge through the atmosphere soon overcame its internal strength, and it disintegrated in an airburst explosion some 10 to 14 km above the surface. The explosion released an energy equivalent to 10 to 30 megatons, with much of the blast force being focused downward toward the surface, in turn creating the devastation and other effects that were witnessed.

We know from the ongoing comprehensive sky survey programs that objects in the size range of the Tunguska impactor pass by Earth



The Chelyabinsk meteor of February 15, 2013. Photograph courtesy Alex Alishevskikh, licensed by [Creative Commons](#).

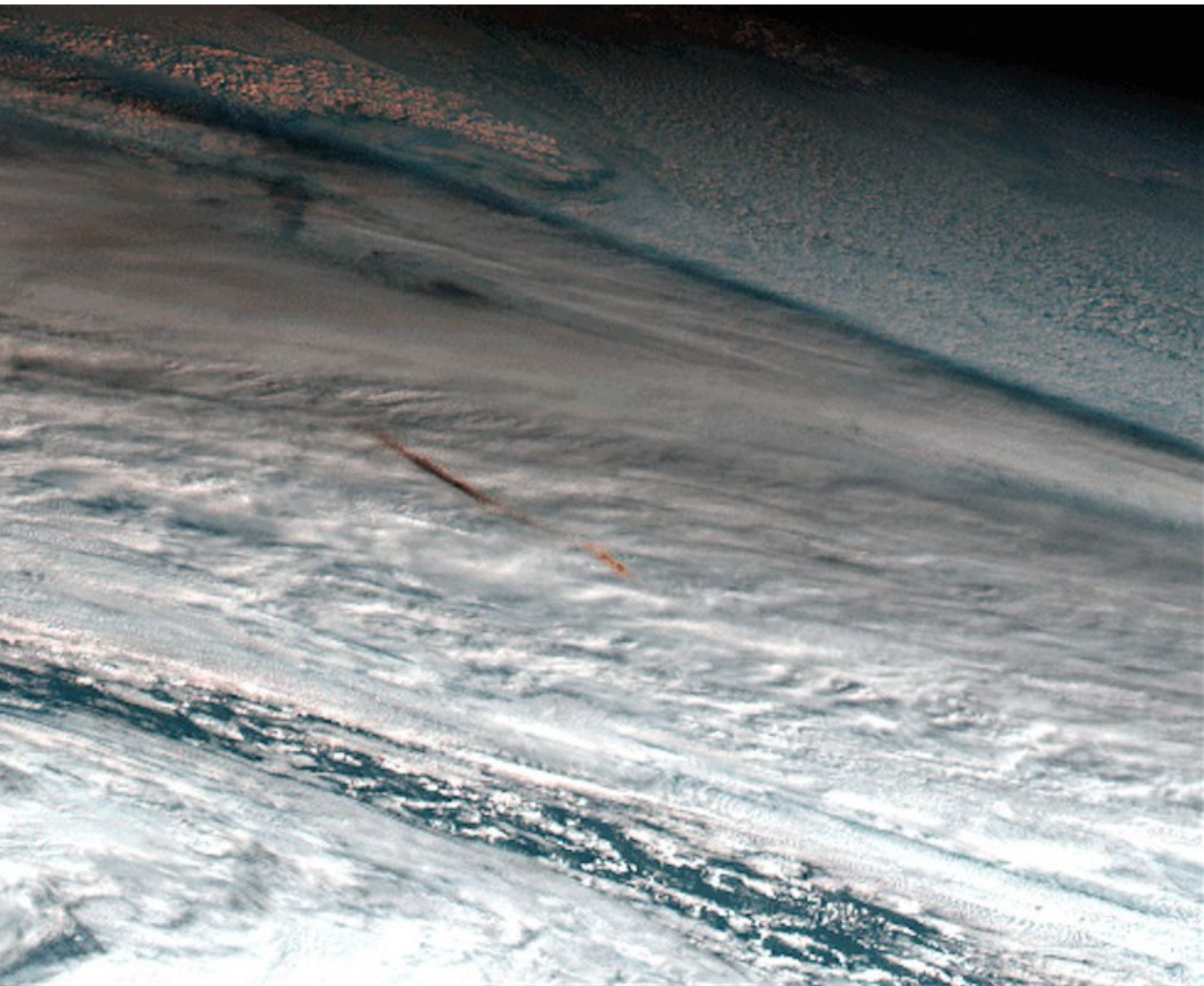
on a rather frequent basis. Estimates for the average frequency of impacts of Tunguska-size objects have ranged from once every few centuries to once every few millennia, with most recent estimates favoring the longer-time range of that timespan. At the same time, there are even larger numbers of smaller objects, and consequently we might expect that these will impact Earth (or, at least, Earth's atmosphere) with an even higher frequency. Since 1908 there have been at least two such events, and via an interesting coincidence both of these, as well as the Tunguska Event itself, have all taken place within present-day Russia.

The first of these took place at around 10:30 A.M. local time on February 12, 1947, when an object entered the atmosphere and exploded above the Sikhote-Alin Mountains in far southeastern Russia, some 440 km northeast of Vladivostok. According to eyewitness accounts the Sikhote-Alin object was brighter than the sun and approached from the north; the explosion created a deafening sound that was heard for hundreds of km and left a smoke tail in the atmosphere that persisted for several hours. Several meteorite fragments have been recovered from the Sikhote-Alin impactor which show that it was originally a metallic asteroid, with a pre-impact mass of approximately 23 tons.

The largest impact event since Tunguska took place

at 9:20 A.M. local time on February 15, 2013, over the city of Chelyabinsk in southwestern Russia. (By a most remarkable coincidence, the small asteroid (367943) Duende passed just 0.00028 AU from Earth – within the orbit of geosynchronous satellites, and the closest predicted approach of an asteroid to Earth to date – on that very same day, although the two events are completely unrelated.) The Chelyabinsk impactor exploded some 30 km above the surface and released 400 to 500 kilotons of energy, with the resulting blast wave damaging thousands of buildings and shattering windows throughout the city and thereby injuring hundreds of people in the area, although there were apparently no fatalities. Several meteorite fragments of the Chelyabinsk impactor have since been found, the largest of these being retrieved from the bottom of the nearby Lake Chebarkul and having a mass of 654 kg. Overall, the various data including information from the retrieved meteorite fragments indicates that the original object was a stony asteroid some 20 meters in diameter.

Other significant airburst explosions from incoming objects include one that took place over far western Brazil near the Curuca River on August 13, 1930, although this occurred over largely uninhabited wilderness and very little information has been ascertained about it. With the advent of the Space Age and the placement of detectors in space several



Plume and shadow of the December 18, 2018 impact event over the southwestern Bering Sea, as imaged by NASA's [Terra](#) satellite. Image courtesy NASA.

other significant events have been detected that were not observed, or at best poorly observed, from the ground; these include an event that occurred near the Prince Edward Islands off the coast of South Africa on August 3, 1963; one that occurred some 300 km southeast of the south Pacific island of Kusaie on February 1, 1994, that was detected by several U.S. Defense Department satellites and also seen by two fishermen on the ground; and, more recently, one that took place over the southwestern Bering Sea off the east coast of Russia's Kamchatka Peninsula on December 18, 2018.

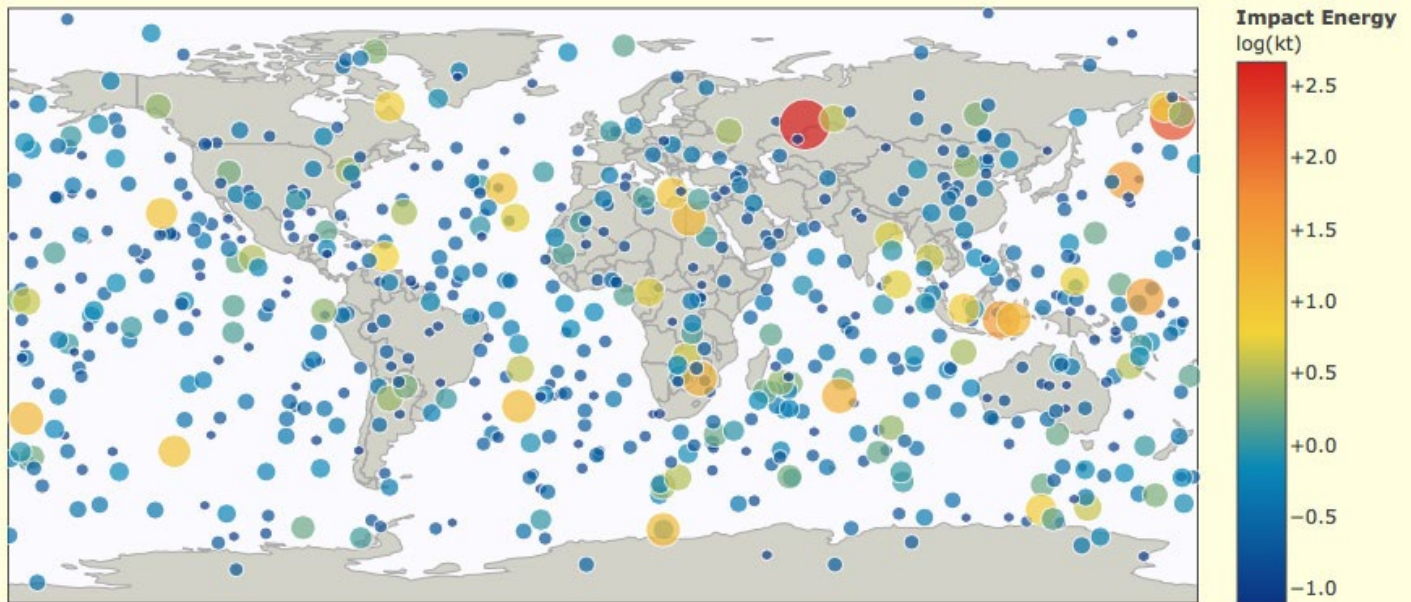
The primary rationale for the comprehensive survey

programs is the detection of threatening objects before they hit Earth. In October 2008 Richard Kowalski with the [Catalina Sky Survey](#) in Arizona discovered a tiny asteroid, designated 2008 TC3, that less than 24 hours later entered Earth's atmosphere above Sudan and exploded. Three more such events have occurred within the relatively recent past, and these are collectively discussed in more detail in a future "Special Topics" presentation.

A slight variation on this overall theme is provided by an object that entered the atmosphere above Utah in the southwestern U.S. on the early afternoon of August 10, 1972, and traveled almost directly northward

Fireballs Reported by US Government Sensors

(1988-Apr-15 to 2020-May-27)



Fireballs recorded by U.S. Government spaceborne sensors between April 1988 and May 2020. The Chelyabinsk event is obvious to right of top center; other notable events are the Bering Sea event of December 18, 2018 and the Kusaie event of February 1, 1994. Courtesy Alan Chamberlin/JPL-CalTech.

for the next 100 seconds before disappearing over Alberta. The object was widely photographed from the ground and was also detected from space, and studies indicate that it entered the atmosphere at such a shallow angle that it reached a minimum distance of approximately 60 km above the surface in Montana and then returned back into space. Size estimates are problematical given the lack of available physical information, but most estimates place it in the range of 10 to 20 meters in diameter, roughly comparable to that of the Chelyabinsk impactor.

It has become apparent over the past couple of decades that the largest danger that humanity faces from space comes from objects in this size range. While the damage is not global, events like Tunguska and Chelyabinsk demonstrate that they can cause damage and casualties over a local to regional area. For example, had the Tunguska impactor entered Earth's atmosphere some four hours later the airburst would have occurred over Moscow and, in the words of acclaimed science fiction writer Arthur C. Clarke, "changed the course of history." It should also be kept in mind that these events occur with enough frequency such that the chances of one's occurring within a person's lifetime are non-negligible. Furthermore, these objects are small enough that they are difficult to detect until they are already in Earth's vicinity, and thus there may be little if any lead time before an impact event occurs. The Chelyabinsk

impactor approached Earth from the daytime side, and although there is no direct evidence one way or the other, the Tunguska impactor may have done so as well, so absent any survey telescopes placed interior to Earth's orbit there was no way these objects could have been detected ahead of time to begin with.

Another danger arises from the fact that, at first glance, the effects of an airburst explosion from an impacting asteroid mimic those of the explosion of a nuclear device. Indeed, for a time the 1963 event off South Africa was believed to be due to the testing of a clandestine nuclear device by that nation until more detailed examination revealed it as having been due to the impact of a small stony asteroid. According to unconfirmed reports then-U.S. President Bill Clinton was woken up by his defense staff after the February 1994 Kusaie event. Meanwhile, if the 1972 object, instead of skipping back into space had instead actually impacted the western U.S., which was at that time locked in the Cold War with the then-Soviet Union, it might have at first been mistakenly attributed to a "first strike" nuclear attack and consequently could have triggered a retaliatory strike, with resulting effects that none of us like to think about. Fortunately, the world has retreated from that Cold War stance, and as one result the Chelyabinsk impact was in short order recognized as being what it was. Still, the danger from these objects is obvious, and it behooves us to remain vigilant.

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