



# ICE & STONE 2020

WEEK 38: SEPTEMBER 13-19

*Presented by The Earthrise Institute*

*Authored by Alan Hale*

#38

# THIS WEEK IN HISTORY



**SEPTEMBER 13, 1959:** The then-Soviet Union's [Luna 2](#) spacecraft impacts the lunar surface slightly to the east of the Mare Imbrium. This was the first human spacecraft to reach the moon and the first spacecraft to impact another object in the solar system.

**SEPTEMBER 13, 1985:** The U.S. Defense Department's [P78-1](#) satellite is deliberately destroyed during the course of an Anti-Satellite (ASAT) weapon test. Among P78-1's complement of instruments was the SOLWIND coronagraph – still functioning at the time of destruction – which discovered ten comets between 1979 and 1984, nine of these being Kreutz sungrazers (discussed in a future "Special Topics" presentation). The first of these comets – the first comet ever discovered from a satellite – is a previous "[Comet of the Week](#)."



**SEPTEMBER 14, 2006:** The [Catalina Sky Survey](#) program in Arizona discovers the tiny asteroid designated 2006 RH120. No more than a few meters in diameter and probably a piece of the lunar surface ejected during an impact event, 2006 RH120 spent approximately one year orbiting Earth as a temporary second moon before escaping into orbit around the sun. It is discussed in more detail in a previous "[Special Topics](#)" presentation.

**SEPTEMBER 14, 2020:** The main-belt asteroid (373) Melusina will [occurt](#) the 7th-magnitude star HD 21483 in Aries. The [predicted path](#) of the occultation passes south to north and crosses east-central Australia (eastern South Australia, including just west of Adelaide, and western Queensland), western Papua New Guinea, open waters of the western Pacific Ocean, and the southern tip of the Kamchatka Peninsula in Russia.

## COVER IMAGE CREDIT:

*Front and back cover: Results from NASA's Wide-field Infrared Explorer, or WISE, reveal that the Jovian Trojans -- asteroids that lap the sun in the same orbit as Jupiter -- are uniformly dark with a hint of burgundy color, and have matte surfaces that reflect little sunlight. The results are illustrated in this artist's concept, showing both the leading and trailing packs of Trojans in orbit with Jupiter. Observations from WISE also confirmed the previous suspicion that there are more asteroids in the leading pack of Trojans (seen in the distance) than the trailing bunch. The data for this research come from the asteroid-hunting portion of the WISE survey, called NEOWISE.*

*Courtesy NASA/JPL-Caltech*



**SEPTEMBER 15, 1682:** Comet 1P/Halley passes through perihelion at a heliocentric distance of 0.583 AU. Among those who observed the comet on that return was the British astronomer Edmond Halley, who later would correctly deduce that it was identical to earlier-seen comets and that it returns approximately every 76 years, and would return in 1758. After the comet was recovered that year it was named in Halley's honor. Comet Halley is the subject of a previous "[Special Topics](#)" presentation.

**SEPTEMBER 15, 2027:** NASA's [Lucy](#) mission is scheduled to fly by the "Jupiter Trojan" asteroid (15094) Polymele. Lucy is discussed in a previous "[Special Topics](#)" presentation, and Trojan asteroids are discussed in a future "[Special Topics](#)" presentation.

**SEPTEMBER 15, 4479:** According to a study [published](#) in 1995 by British astronomer John Chambers, Comet 109P/Swift-Tuttle will pass so close to Earth that "it is not possible to make accurate predictions of its future motion beyond that point." Comet Swift-Tuttle is the parent comet of the Perseid meteor shower and is a future "Comet of the Week."



**SEPTEMBER 17, 1882:** The Great Comet of 1882 – one of the brightest comets of the entire 2nd Millennium – passes through perihelion at a heliocentric distance of 0.008 AU. The Great Comet of 1882 was a Kreutz sungrazer and is a future "Comet of the Week."



**SEPTEMBER 18, 1965:** Two Japanese amateur astronomers, Kaoru Ikeya and Tsutomu Seki, independently discover Comet Ikeya-Seki 1965f. This comet was a Kreutz sungrazer and became the brightest comet of the 20th Century; it is a future "Comet of the Week."



**SEPTEMBER 19, 2020:** The main-belt asteroid (24743) 1992 NF will [occurt](#) the 7th-magnitude star HD 49909 in Gemini. The [predicted path](#) of the occultation crosses northern Mexico, far southern Texas, the very southern tip of Louisiana, northwestern Florida, far southern Georgia, and the west-central Atlantic Ocean.

# COMET OF THE WEEK: 21P/GIACOBINI-ZINNER 1984E

Perihelion: 1985 September 5.21,  $q = 1.028$  AU



Comet 21P/Giacobini-Zinner during its 1959 and 2018 returns. Left: Comet 21P/Giacobini-Zinner on October 26, 1959, as photographed by Elizabeth Roemer at the [U.S. Naval Observatory's](#) station near Flagstaff, Arizona. Official U.S. Navy image. Right: The comet on September 11, 2018, when near the open star cluster M37 in Auriga. This image approximates the comet's appearance in binoculars or a small telescope. Courtesy Monika Landy-Gyebnar in Hungary.

The last comet discovered in the 19th Century was found on December 20, 1900 by the French astronomer Michel Giacobini from Nice Observatory, the fifth of twelve comets he discovered between 1896 and 1907. The comet was around 10th magnitude and was followed for two months, with orbital calculations showing it to be a periodic object with an orbital period somewhat less than seven years. It was unfavorably placed for viewing in 1907 and wasn't recovered, and was likewise expected to be unfavorably placed in 1914, however on October 23, 1913 the German astronomer Ernst Zinner – who would later become a renowned science historian – accidentally re-discovered it while examining variable stars. The revised orbital calculations indicated that it has an orbital period close to 6.6 years, and it has been



Comet Giacobini-Zinner at my “bachelor party” on the morning of September 14, 1985, from the mountains east of San Diego, California. Courtesy Bob Lunsford.

recovered on almost every return since that time. Comet Giacobini-Zinner is, intrinsically, one of the brighter Jupiter-family periodic comets, and with a perihelion distance close to 1 AU it can pass close to Earth on occasion and become somewhat bright. In 1946 it passed 0.26 AU from Earth and, following a small outburst, briefly reached naked-eye visibility at 6th magnitude. It had other favorable returns in 1959, 1985, and 2018 and reached 7th magnitude during each of those.

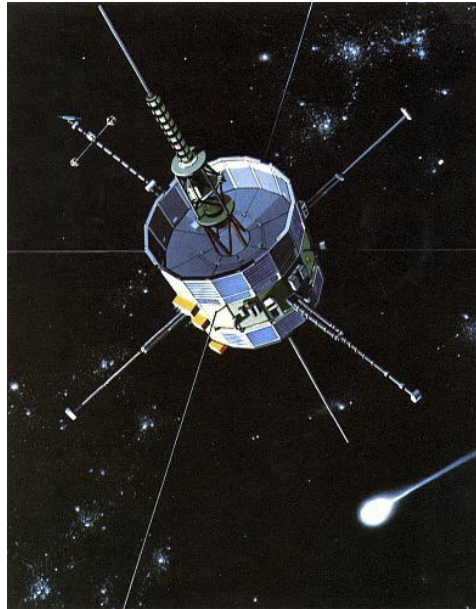
The comet's descending node is very close to Earth's orbit, and Comet Giacobini-Zinner is the parent comet of the Draconid meteor shower, that peaks around October 8-9 each year. Normally the shower is quite weak, however in 1933 a strong Draconid “storm” was witnessed from Europe, when rates momentarily reached

somewhere between 3000 and 30,000 meteors per hour. A similar Draconid “storm” occurred in 1946, when despite a full moon and widespread cloudy weather several locations within the U.S. recorded rates as high as 3000 to 6000 meteors per hour. This shower, incidentally, marks the first time that meteors were observed via radar; a meteor passing through the atmosphere ionizes molecules in the air around it, and these ions leave a radar-detectable echo. Several World War II-era radars were specially adapted for use in detecting meteors from this Draconid shower and were successful in recording them.

Gravitational perturbations from Jupiter have changed the comet’s orbit enough such that the Draconid meteor stream no longer passes so close to Earth, and thus we no longer experience Draconid “storms” like these. Observers in Japan recorded a brief Draconid shower with a peak rate of about 200 meteors per hour in 1985, and a weaker shower with rates between 50 and 100 meteors per hour was recorded from Japan and parts of eastern Europe in 1998. During the comet’s most recent return in 2018 several observers, including within the U.S., observed a Draconid shower lasting a couple of hours with a peak rate of slightly over 100 meteors per hour.

Comet Giacobini-Zinner achieved a new claim to fame during its favorable return in 1985. Comet scientists in the U.S. were dismayed by the failure of the U.S. Congress to fund a spacecraft mission to [Comet 1P/Halley](#) (then en route to its 1986 perihelion passage), but planetary scientist Robert Farquhar at

NASA’s Goddard Space Flight Center in Maryland proposed an alternate idea: utilizing the already-existing International Sun-Earth Explorer 3 ([ISEE-3](#)) spacecraft, launched in 1978 and presently located at the sun-Earth L1 Lagrangian point 1.6 million km directly sunward of Earth, and send it on a series of lunar flybys that would propel it towards Giacobini-Zinner. The idea was approved, and following the final



Artist's conception of the International Cometary Explorer (ICE) encounter with Comet Giacobini-Zinner on September 11, 1985. Courtesy NASA.

lunar flyby – only 120 km above the lunar surface – on December 22, 1983 the spacecraft was renamed the International Cometary Explorer (ICE). This entire mission is discussed more thoroughly in a previous [“Special Topics”](#) presentation.

On September 11, 1985 ICE passed through Giacobini-Zinner’s ion tail some 7700 km “downwind” from the nucleus, becoming the first spacecraft mission to encounter a comet. ICE did not carry any cameras, but did carry several scientific instruments that were able to record measurements of the electrical environment around the comet and of its interaction with the solar wind. Among its findings were that the comet’s magnetic field reversed polarity directly at the

ion tail – fulfilling a prediction made in the late 1950s by the Swedish physicist Hannes Alfvén – along with a thick “bow wave” 130,000 km sunward of the nucleus (produced by the solar wind encountering charged particles within the comet’s environment) and a large proportion of ionized water molecules – consistent with the “dirty snowball” model of a comet’s nucleus [proposed](#) in 1950 by Fred Whipple (and the subject of a previous [“Special Topics”](#) presentation). The goings-

on within a comet’s ion tail are discussed more thoroughly in next week’s [“Special Topics”](#) presentation.

Comet Giacobini-Zinner’s most recent return, in 2018 – during which it passed perihelion on September 10 and passed 0.39 AU from Earth – turns out to be the most favorable return of the entire 21st Century. An approach to Jupiter of 0.36 AU in early 2029

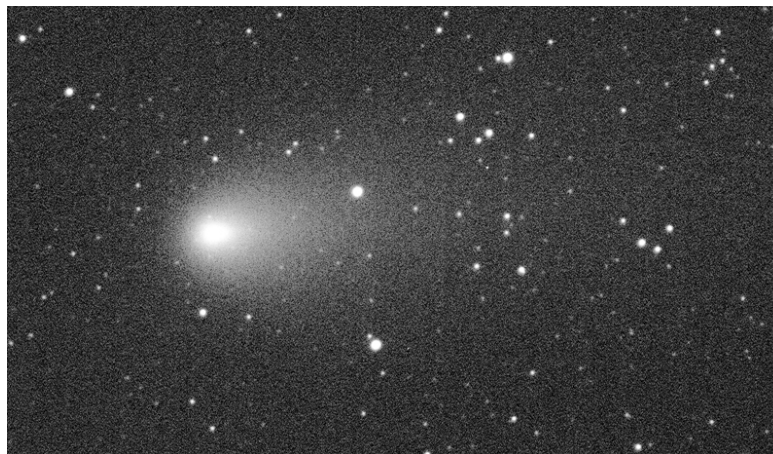


Image 1 took of the comet on September 7, 2018, from the [Las Cumbres Observatory](#) facility at [Teide Observatory](#) in the Canary Islands.

increases the perihelion distance and orbital period to 1.07 AU and 6.7 years, respectively, although a somewhat closer approach to Jupiter in 2076 will drop the perihelion distance back down to near its present value. The return in 2031, with a perihelion passage on August 30 and a closest approach to Earth of 0.55 AU, is quite favorable, and the comet should reach a peak brightness between 8th and 9th magnitude.

# SPECIAL TOPIC: DEFLECTION STRATEGIES



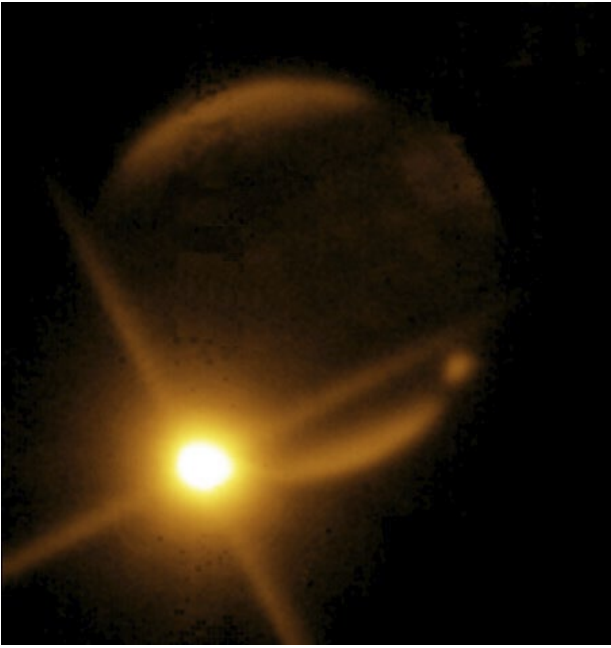
Artist's conception of a large asteroid striking Earth. Courtesy NASA.

A common and persistent theme throughout "Ice and Stone 2020," and indeed one of the primary reasons the "small bodies" of the solar system are of such high interest in the first place, is the threat they pose to Earth – or, at least, to our civilization and way of life here on Earth – via impacts. I have witnessed the growing awareness of this threat over the past few decades, which has included the ever-increasing number of discoveries of Earth-approaching objects; the realization that the major [mass extinction](#) at the end of the Cretaceous Period 66 million years ago (and perhaps other mass extinctions as well) was very probably the result of an impact – with the likely identification of the resulting crater off the north coast of the Yucatan Peninsula of Mexico; and events such as the impacts of the fragments of [Comet Shoemaker-Levy 9](#) into Jupiter in 1994 and the airburst explosion and impacting meteorite over [Chelyabinsk, Russia](#) in 2013. (All of these are discussed in previous "Ice and Stone 2020" presentations.) This threat has also made its way into the popular psyche as well, which is reflected in various forms of [literature and entertainment](#) – not always necessarily accurately – that have come out within the fairly recent past.

This growing awareness is also reflected in the increased number of [spacecraft missions](#) to these objects and in the comprehensive [survey programs](#) that started becoming operational at the very end

of the 20th Century – these again being discussed in previous "Ice and Stone 2020" presentations. As of now the survey programs have likely identified well in excess of 90% of the large potentially threatening objects, i.e., those that could produce a global catastrophe and end civilization, and most of the remainder should be detected within the not-too-distant future. Smaller objects, i.e., those that can cause damage on a regional scale, are also starting to be identified, although these will continue to be an area of concern, as are also objects that can cause local damage such as those that caused the [Tunguska event](#) in 1908 and the Chelyabinsk event in 2013. The one other type of object that will always remain a cause of concern for at least the near- to intermediate term foreseeable future are the long-period comets, since these are not discoverable until a relatively short period of time before a potential impact, and many of these are in retrograde orbits that, should they hit, will do so at a high relative velocity and thus liberate very large amounts of kinetic energy. Fortunately, these objects are quite rare compared to the asteroids and short-period comets that inhabit the inner solar system.

The identification of a potentially threatening object is just the first step in the overall process of mitigating the threat any such object might pose, of course. The next step, quite obviously, is determining what



Recent events that have helped spur the recent awareness of the threat posed by impacting objects from space. Left: Infrared image of the impact of nucleus "G" of [Comet Shoemaker-Levy 9](#) into Jupiter on July 18, 1994. The image was taken by Peter McGregor from Siding Spring Observatory in New South Wales, provided courtesy Mount Stromlo and Siding Spring Observatories. Right: The [Chelyabinsk meteor](#) of February 15, 2013. Photograph courtesy Alex Alishevskikh, licensed via [Creative Commons](#).

to do once that object has been found. In practice, it is very unlikely that any large threatening object will be found that is already certain to impact Earth; rather, as was covered in a previous "[Special Topics](#)" presentation, additional astrometric measurements and refined orbital calculations will constrain the probability of an impact – and, in the vast majority of cases, eventually eliminate the possibility. For the very rare cases where that does not happen and the likelihood of an impact is confirmed, the process then turns towards what physical actions to take to reduce and, hopefully, eliminate the threat. Additional data gathering, both to identify the time and location of the impact, as well as to collect information about the physical nature of the impacting object, will continue to be a part of this process.

A common practice in popular fiction on this subject involves the usage of nuclear explosives to destroy the incoming object. In reality, however, this is not an especially effective way to neutralize the threat from such an object. Many asteroids are "rubble piles," i.e., aggregates of small pebble-size particles loosely held together by the object's combined self-gravity. A nuclear device might disrupt part of such an aggregate but, depending upon the overall size of the incoming object, might leave the rest relatively untouched. Even the disrupted regions might start to re-coalesce. For a more solid object, the nuclear explosion would not destroy it but rather would fragment it into several pieces. People on Earth would then face the decision whether to have one very devastating impact by a large object, or instead a series of slightly less devastating impacts by several somewhat smaller objects. In any event, such an approach could only properly be considered as a last resort, to be utilized only after other mitigation attempts have failed.

The entire point of the comprehensive survey programs is to identify any potentially threatening objects well in advance of any possible impact. Indeed, for any objects large enough to pose any kind of global or regional threat we should have at least a couple of decades of advance notice. It helps to remember that, for an impact to occur, an object must have one of its "nodes," i.e., the two points where it crosses the plane of Earth's orbit, right at Earth's orbit, and must arrive at that node at the same time that Earth is at that same point. Since Earth's orbital motion causes it to travel its own diameter in just over seven minutes, delaying (or advancing) and impacting object's arrival at the node by that amount of time can prevent an impact. A tiny change in an object's orbital motion twenty years in advance can accordingly create a non-trivial change in its location twenty years later.

A number of potential strategies for introducing such changes and deflecting a threatening object's later trajectory have been devised and are being studied, both by governmental agencies from various nations – for example, NASA's [Planetary Defense](#) office – and national coalitions, and by private organizations such as the [B612 Foundation](#) that was co-founded by former Apollo astronaut Russell Schweickart. The particular strategy and technique that might be most appropriate for a specific object can depend upon that object's size and physical make-up as well as the amount of lead time that is available.

The exploding of a nuclear device, not on an object after impacting it but rather close to its surface, could deflect it slightly by means of its resulting shock wave. Such an approach could be effective against a "rubble pile" asteroid since the particle aggregate would not be split apart by the explosion. The heat



Schematic of NASA's planned Double Asteroid Redirection Test (DART) mission, scheduled for launch in July 2021. Courtesy NASA.

produced by such an explosion could vaporize particles near the surface and eject them in the same manner as the thrust of a rocket engine, thereby giving the asteroid a soft "nudge."

Impacting an object, not with an explosive device but instead with an inert massive projectile, can make a small deflection in that object's path. Indeed, the impacting projectile of the [Deep Impact](#) mission – discussed in [previous](#) "Ice and Stone 2020" presentations – introduced tiny changes in the orbital motion of its destination, [Comet 9P/Tempel 1](#). This approach is the rationale for NASA's upcoming Double Asteroid Redirection Test (DART) mission planned for launch in July 2021. DART's destination is the near-Earth asteroid (65803) Didymos, or more correctly its small moon that has recently been [named](#) Dimorphos; the objective is for DART to impact Dimorphos and attempt to deflect its orbit. An accompanying CubeSat from the [Italian Space Agency](#) dubbed Light Italian CubeSat for Imaging of Asteroids (LICIA), a later ESA mission, [Hera](#), and ground-based observations will hopefully be able to detect any changes in Dimorphos' orbit.

In some cases it might even be possible to impact an

asteroid with a smaller asteroid and deflect the larger object's orbit via the same principle. Although this wasn't its primary objective, NASA's since-cancelled [Asteroid Redirect Mission](#) would have tested the potential feasibility of such an approach. Should such an approach prove feasible at some point in the future, the list of "Easily Retrievable Objects" [produced](#) in 2013 by Daniel Garcia Yarnoz and colleagues – referenced in previous "Special Topics" presentations – includes some asteroids that could potentially be utilized in such an endeavor.



Comet 109P/Swift-Tuttle during its most recent return, on December 15, 1992. Courtesy Michael Jaeger in Austria.

In principle, a rocket engine could be attached to an asteroid, with its orbital trajectory then being affected via application of Newton's Third Law. In practice, this would be quite difficult to implement; among other things, many Earth-approaching asteroids are rapid rotators, which creates issues with not only the landing and placement of such an engine, but also its overall effectiveness. (Perhaps the placing of an engine at one of the rotational poles

could alleviate these issues in part, although there is evidence that at least some objects exhibit a complex rotational pattern involving precession as well as rotation.) There is also the issue of providing enough fuel to power the rocket.



A variation of this idea is the so-called "mass driver," which is analogous to a rocket engine in that it utilizes ejection of material and application of Newton's Third Law, however it utilizes the asteroid's own material as its "fuel." Such a device might be reasonably effective with a "rubble pile" asteroid, although the above issues involving the asteroid's rotation would still create difficulties.

Another approach is the "gravity tractor," wherein a massive object, for example a large unmanned spacecraft or perhaps even one of the aforementioned "Easily Retrievable Objects," is maneuvered close to the incoming object. The two objects would then be gravitationally attracted to each other, and if the introduced object could be slowly moved – perhaps by means of an attached low-thrust rocket engine – the two-object system as a whole would accordingly be moved. Such an approach would take a long time – many years – to yield results, but if we had a significant amount of lead time with which to work this type of approach may ultimately be the most effective. It also has the advantage that it can be used with both "rubble pile"-type asteroids and more "solid" objects.

A somewhat more exotic approach involves using the energy contained within light to slow down incoming objects – something that could be especially effective against the low-mass particles making up "rubble pile" asteroids. Large orbiting lasers could potentially do this, but the deployment and usage of such devices is not economically feasible at this time. Large orbiting mirrors which could redirect and strongly focus sunlight on these objects could also be effective, and at least theoretically could be developed and deployed within the not-too-distant future if circumstances warrant.

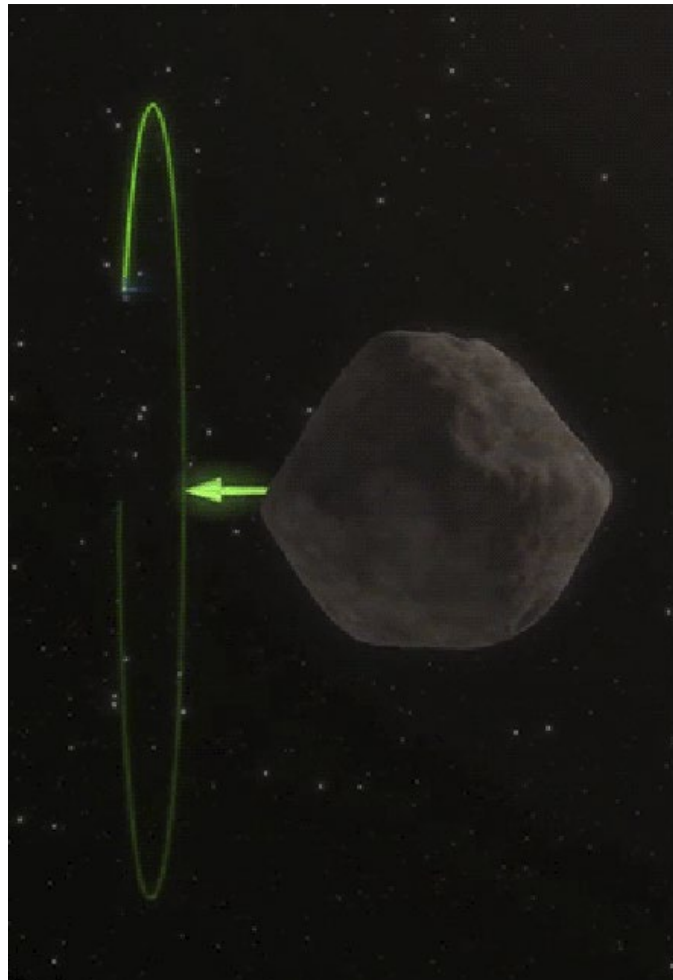
Most of the aforementioned techniques are meant for utilization on somewhat large objects where we have sufficient advance warning for the necessary

devices to be deployed. However, as previously mentioned for the foreseeable future there will remain a threat from the smaller objects which can cause damage over a substantial local area and which cannot be detected until they are close by – at best, we may have a few days' warning. Some small-scale version of a few of the above methods might work in such instances, although on the other hand some of the ASAT systems that have been developed could perhaps be refocused and might at the very least alleviate some of the potential damage. In any event, we may at least have enough lead time

to implement effective evacuation plans, and it should be kept in mind that, since over 70% of Earth's surface area is open ocean, a similar percentage of impacts would occur there as well, which creates the potential for tsunamis.

One of the items in this week's "This Week in History" events involves Comet 109P/Swift-Tuttle, the parent comet of the Perseid meteor shower and a future "Comet of the Week." In a 1995 study British astronomer John Chambers calculated that on September 15, 4479, Comet Swift-Tuttle will pass so close to Earth that "it is not possible to make accurate predictions of its future motion past that point," and he estimated the possibility of a collision as being one in a million. This comet's nucleus is apparently quite large, as comet nuclei go, with most estimates being in the range of 30 km, and since the comet's orbit is

retrograde the relative velocity would be very large, over 55 km per second; the energy liberated during any impact would dwarf that of the K-T impact event 66 million years ago that destroyed the dinosaurs. Our descendants still have almost 2½ millennia to keep track of the comet and refine the circumstances of the 4479 close approach; if it becomes necessary, that should hopefully be enough time for them to develop whatever techniques they might need – perhaps based on some of the above ideas, or perhaps something we have no conception of now – to deal with the threat.



Graphical representation of the utilization of a "gravity tractor." The large asteroid is gravitationally attracted to the spacecraft placed in a nearby orbit. Courtesy NASA.

[www.halebopp.org](http://www.halebopp.org)

[www.iceandstone.space](http://www.iceandstone.space)

