

THE PLANETARY REPORT

JUNE
SOLSTICE 2021

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**ASTEROIDS HAVE BEEN
HITTING EARTH
FOR BILLIONS OF YEARS.
IT'S TIME TO
HIT BACK.**

Disasters Aren't Inevitable

Planning Ahead to Protect Our World

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OUR WORLD IS fragile. The COVID-19 pandemic reminds us that we are all in this together on our planet. When trouble started in one part of the world, it quickly touched every one of us.

The analogy from pandemic to asteroid impact is compelling. A major impact anywhere in the world would have enormous consequences. It would affect every single person on Earth, either directly or indirectly. Lives would be lost. Some people would be forced to migrate. Economies would slow or even collapse depending on the impact's size and location.

If a potentially disastrous incoming object were identified—one that would impact here, say, 20 years hence—would we work together? Would governments cooperate or be paralyzed by mistrust? Would science deniers and contrarians carry the day and prevent significant action? After the catastrophe, would we lend a hand to one another, or would rivalries and inequities be amplified? No matter the eventual outcome, we would once again be painfully reminded that as Earthlings, we are all affected by forces of nature, whatever they may be.

A global pandemic is akin to a massive asteroid impact in yet another way. Both could be prevented if we were to put in enough time, effort, and energy—and if we have the right systems in place. For most of us, contemplating the effects of an asteroid or comet impact

often brings to mind apocalyptic images from science fiction, but by studying distant objects that might threaten us, we can indeed prepare for a potential orbital collision. The threat is real, and we are the first generation of humans able to get ready and be set to deflect an incoming asteroid. Fundamentally, it will require investment by governments around the world. Here at The Planetary Society, we've been advocating for those investments for many years, and thanks to the support of members like you, we've made progress.

If there's one thing we can learn from the enormous challenges created by the pandemic, it's that we have to work together to protect our species. Our world is fragile. We aren't invincible, but when we pool our considerable talents, we humans are a force to be reckoned with. Let's not let an asteroid prove otherwise.

This issue of *The Planetary Report* highlights the important things we should all know about the threat of incoming asteroids along with the work we're doing to defend Earth from such impacts. We also celebrate the impact (pun very much intended) that your membership has already made on planetary defense efforts and share new ways that you can get involved to help defend Earth. Let's go! 🚀



BILL NYE is chief executive officer of The Planetary Society.

ON THE COVER: NASA's DART mission will intentionally crash into the small asteroid Dimorphos in 2022, changing Dimorphos' orbit around a larger asteroid named Didymos. The mission will demonstrate a technique that could be used if a future asteroid is found on course to hit Earth. Credit: NASA/Johns Hopkins APL
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A dashcam caught these stills as a meteor exploded over the city of Chelyabinsk, Russia in February 2013.

YOUTUBE

Our Members Kick Asteroid

“Someone Is Doing Something About This”

by Ellen McSorley

IN FEBRUARY 2013, an asteroid blasted through the air over Chelyabinsk, Russia. Thousands of buildings were damaged, and hundreds of people were injured. I asked myself, “How did this go undetected?”

In 2017, I was reading an article about Bill Nye, CEO of The Planetary Society, and asked my good friend Google, “What’s The Planetary Society?” Searching through the website and reading about different projects in which the Society was involved, I came upon a page about defending Earth from asteroid impacts. “Wow,” I thought, “someone is doing something about this.” Reading further, I discovered that the Society has the Shoemaker NEO (near-Earth object) Grant program to help amateur astronomers find and track potentially dangerous asteroids.

Soon after my discovery, the Society held a fundraiser through Kickstarter for planetary defense. I had the opportunity to be involved in a project that could very well save the world! Asteroid impacts are the one natural disaster about which we can actually do something.

Since then, I’ve been hooked on planetary defense. In 2020, I attended the Day of Action in Washington, D.C., and planetary defense was my favorite talking point. I had the opportunity to educate members of Congress about this important mission.

I’m hoping that at this year’s Day of Action, I can spark interest in the funding of the NEO Surveyor space telescope so that a disaster like the one in Chelyabinsk won’t happen again.

Want to know more? I highly recommend the video series by Dr. Bruce Betts on defending Earth from asteroids, available on The Planetary Society’s website at planetary.org/asteroid-video. Hey, it has dinosaurs! Who could ask for more? 🦕

ELLEN MCSORLEY is a Planetary Society member and donor from Monmouth County, New Jersey.



Contents

JUNE SOLSTICE 2021

2 Your Place in Space

CEO Bill Nye explains how we can defend Earth from asteroids.

3 Members on Deck

A member recalls how she got hooked on planetary defense.



4 In Context

What two famous 1998 asteroid movies got right and wrong.



6 Feature Story

Will the world rise to the challenge of asteroid defense?

19 Get Involved

How you can help defend our planet.

20 Your Impact

Our annual Day of Action connected 145 members and supporters with their political representatives.

23 What’s Up?

Get ready for a supermoon and meteor shower.

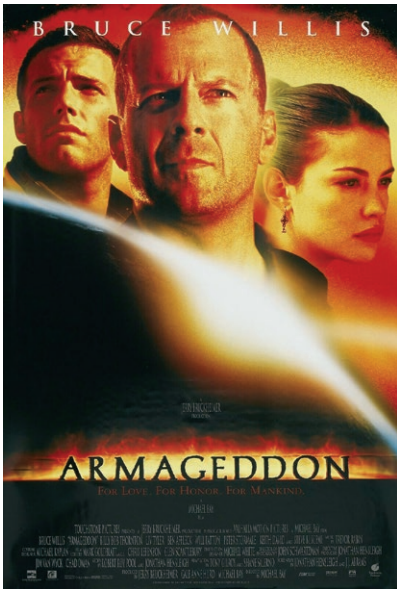
24 Space Art

An artist captures the scene from a 1908 asteroid impact.

“Just Nuke ‘Em!”

Planetary Defense in the Movies

by Kate Howells



THIS PAGE: TOUCHSTONE PICTURES/WALT DISNEY

THE THREAT OF asteroids or comets is something most people have only seen in movies. To get a sense of the public's potential misconceptions about planetary defense, we're taking a look at the two most iconic films in the deadly-rocks-from-space genre: *Armageddon* and *Deep Impact*. Here's what they got right, what they got wrong, and why it matters.

Armageddon

In *Armageddon*, an asteroid the size of Texas is detected only 18 days away from a collision with Earth. NASA's solution is to send a team of experienced oil drillers to land on the asteroid, drill a deep hole, plant nuclear bombs inside it, and blast it into two halves that will pass safely on either side of Earth. Much drama ensues, but eventually, they succeed at blowing the asteroid in two, vaporizing every smaller asteroid that was traveling with it, and returning safely to Earth (minus a few heroic casualties).

WHAT IT GOT RIGHT

Basically, the only things *Armageddon* got right are that it's possible for an asteroid to hit Earth and that what looks like a single asteroid may actually be a group of asteroids bound together gravitationally.

WHAT IT GOT WRONG

So, so much. The movie confuses asteroids, comets, and meteors. The Russian Mir space station conveniently has artificial gravity. One character gets “space dementia.” The list goes on. But in terms of depicting planetary defense, these aren't the most important inaccuracies.

The main problem is that the timing of the events depicted is extraordinarily unrealistic. The asteroid is detected only 18 days from impact, and within that time frame, NASA is able to precisely determine its composition, map its surface, calculate exactly how much force would be needed to split it neatly in half with neither half impacting Earth, train oil drillers to operate in space, send spacecraft to intercept the asteroid, and blow it up.

ARMAGEDDON

Released **May 8, 1998**

Worldwide Gross **\$554 million**

Starring **Bruce Willis, Billy Bob Thornton, Ben Affleck, Liv Tyler, Will Patton, Steve Buscemi, Owen Wilson, Michael Clarke Duncan, Peter Stormare**

DEEP IMPACT

Released **July 1, 1998**

Worldwide Gross **\$349 million**

Starring **Robert Duvall, Téa Leoni, Elijah Wood, Vanessa Redgrave, Morgan Freeman, James Cromwell, Jon Favreau, Mary McCormack, Richard Schiff, Leelee Sobieski, Blair Underwood, Dougray Scott**



Deep Impact

In *Deep Impact*, a comet the size of New York City is on a trajectory to impact Earth in two years. After a year spent developing a plan and building an enormous spacecraft in collaboration with Russia, the U.S. government informs the public and other world governments. The plan is familiar: plant a nuke inside the comet to blow it apart.

The plan to nuke the comet fails, only splitting a smaller chunk off the main comet. Plan B (exploding nuclear warheads next to the comet to change its course) also fails. People start rioting and looting in desperation. The secondary chunk of comet strikes the Atlantic Ocean, creating tsunamis that kill millions. At the last moment, NASA astronauts manage to blow up the main comet, and an extinction-level impact is averted.

WHAT IT GOT RIGHT

Deep Impact is a breath of fresh air next to *Armageddon*, and if you only watch one, we recommend this one. The timescale is slightly more believable, and the technologies depicted make a bit more sense. It also acknowledges that blowing up a comet would create debris that could still impact Earth. *Deep Impact* also gets points for addressing the fact that society would probably have a less than peaceful reaction to impending doom.

WHAT IT GOT WRONG

Although it too is riddled with minor inaccuracies, *Deep Impact*'s main shortcoming is that the U.S. government manages to keep the comet a secret for a year, builds a large space station in Earth orbit without anyone noticing, and saves the day without much help (financial, technological, or otherwise) from other countries.

So What?

The inaccuracies highlighted here matter because they convey the idea that one country can more or less independently deal with an impending impact on relatively short notice.

The reality is that humanity's only chance of avoiding a devastating impact is to find the threat many years in advance, study it extensively, coordinate a global response, prepare multiple strategies for deflection, and carry out these tactics while the object is still very far away. Blowing up an asteroid at the last second is great fodder for Hollywood but isn't a solid plan for an actual impact threat.

Here at The Planetary Society, we work to raise public awareness of the asteroid threat; help observers find, track, and characterize near-Earth objects; support the development of asteroid mitigation technology; and help decision-makers develop global response strategies. If only we had the reach of a blockbuster film! Who knows, maybe Bruce Willis would give us a nonprofit discount. 🦁



KATE HOWELLS is communications strategy & Canadian space policy adviser for The Planetary Society.



THIS PAGE: PARAMOUNT PICTURES

An aerial photograph of Meteor Crater, also known as Barringer Crater, in Arizona. The crater is a large, circular impact feature with a distinct rim and a central peak. The surrounding landscape is arid and rugged, with various shades of brown and tan. A winding road or path is visible in the upper left, and a small, dark, irregularly shaped feature is visible in the lower left. The overall scene is captured from a high altitude, providing a clear view of the crater's structure and its surroundings.

ABOVE Astronauts aboard the International Space Station captured this image of Meteor Crater northeast of Phoenix, Arizona. The crater is roughly a kilometer wide and 170 meters (560 feet) deep. An asteroid impact formed it roughly 50,000 years ago.

NASA

Risky Business

Will the World Rise to the Challenge of Asteroid Defense?

by Jason Davis

EARTH HAS BEEN stuck in a cosmic shooting gallery since its formation. About 4 billion years ago, the orbits of Jupiter and Saturn shifted, barreling through a dense ring of asteroids and comets left over from the solar system's formation. Some of these ancient worlds slammed into Earth, possibly carrying water and organic materials here that kick-started life.

But what the universe giveth, it can taketh away. Sixty-six million years ago—long after life had taken hold—a 10-kilometer-wide (6.2-mile-wide) asteroid struck Earth, snuffing out the dinosaurs.

The dinosaurs didn't have a space program. Fortunately, we do.

This November, NASA will launch the world's first mission to test a method of deflecting an asteroid. DART, short for Double Asteroid Redirection Test, will spend a year cruising through space to asteroid Didymos and its small moon, Dimorphos. (Neither are on course to hit Earth; this is only a test.)

As it approaches Didymos and Dimorphos in September 2022, DART will lock onto Dimorphos. The washing-machine-sized spacecraft won't slow down, intentionally smashing into Dimorphos at a speed of 6.6 kilometers (4.1 miles) per second.

There won't be much of the probe left, says Andy Rivkin, a planetary astronomer and DART investigation lead at the Johns Hopkins University Applied Physics Laboratory in Baltimore, Maryland.

"Psychologically, we have been trying to remind ourselves that DART is a tool we're using to get some data, to do a job," Rivkin tells The Planetary Society. "We try not to anthropomorphize it too much, in the way people don't have a favorite nail or screw."

DART's impact will be akin to detonating several tons of TNT, creating a crater as wide as a bowling lane. Dimorphos, which weighs almost 5 million metric tons, will absorb the blow like a lumbering giant, wobbling enough to drop its orbital period around Didymos from about 11.9 to 11.8 hours—a difference of roughly 10 minutes.

But that will be enough. From Earth, Dimorphos and Didymos look like a single point of light that brightens and dims at regular intervals as Dimorphos passes behind and in front of Didymos. Astronomers watching through telescopes will see that interval change. While Dimorphos and Didymos aren't on course to hit Earth, DART will confirm that we have the capability to change the trajectory of an asteroid if we need to do so.

The mission is a turning point for the world's nascent planetary defense efforts, but there is still much work to be done. Tens of thousands of city-killer-sized asteroids must still be found, tracked, and studied. Future missions need to test other methods of deflecting space rocks. And countries must work together to coordinate global response strategies if we find an asteroid on course to hit Earth.

"This is part of a much bigger strategy—understanding what's out there and making a plan," Rivkin says.

VERMIN OF THE SKY

Our brains like to categorize things. This has historically been a problem for asteroids, which defy simple categorization.

Astronomer Giuseppe Piazzi discovered the first asteroid, Ceres, by accident in 1801

RIGHT A resident 200 kilometers (120 miles) north of Chelyabinsk, Russia snapped this photo of the trail left by a small asteroid that exploded over the city in February 2013.

ALEX ALISHEVSKIKH



while making a star map. Ceres and three other asteroids discovered around the same time were often called planets until the mid-1800s, when astronomers began to discover a flood of similar small worlds between Mars and Jupiter.

So, what should these worlds be called? Astronomers veered between planets, small planets, minor planets, and asteroids—the latter an imprecise Greek word that means “star-like.” The debate on what to call small worlds like Pluto has arguably raged for more than 170 years.

In 1898, astronomers discovered Eros, an asteroid that veers unnervingly close to Earth. Like its predecessors, this near-Earth asteroid was initially an outlier before scientists learned there were many more like it.

The early to mid-20th century was a boon for learning our place in space, as astronomers realized that the spiral smudges of light in their telescopes were entire galaxies separate from our own, set in an ever-expanding, mind-bogglingly large universe.

Asteroids, meanwhile, got downgraded to party-crasher status. They frequently showed up as streaks of light that ruined long-exposure photographs of gorgeous deep-sky objects.

This earned them an infamous nickname that you can imagine being uttered in tandem with a shaking fist: “vermin of the sky.”

IT CAN HAPPEN HERE

You don’t have to look far to see the impact—no pun intended—that asteroids can have on other worlds. All it takes is a pair of binoculars to get a close-up look at the Moon’s craters, formed over time mostly by volcanic eruptions and asteroid impacts.

Nevertheless, it has been an uphill battle for scientists to show that asteroids have previously wreaked large-scale destruction on our own planet and that they can still do so today.

“We got laughed at a lot,” says Lindley Johnson, the head of NASA’s planetary defense program, remembering the reactions he and his colleagues received just a couple decades ago. “People didn’t believe it was a real threat that anybody needed to worry about.”

About a three-hour drive northeast from Phoenix, Arizona lies a giant hole in the desert named Barringer Crater that’s a kilometer wide and 170 meters (560 feet) deep. In 1960, planetary scientist Gene Shoemaker and his colleagues

found a mineral called coesite at Barringer. Coesite only forms under high pressure—the kind of pressure you’d expect from an asteroid impact. Shoemaker’s discovery was clear evidence that Barringer was created by something smashing into Earth, incinerating plants and animals up to a couple dozen kilometers away in all directions.

Twenty years later, a team of researchers including the father-son duo Luis and Walter Alvarez announced they’d found high concentrations of iridium in the worldwide band of rock that marks the end of the Cretaceous period—the reign of the dinosaurs—66 million years ago. Levels of iridium that high don’t show up naturally on Earth, but they do in meteorites that fall from the sky.

By 1990, scientists had found a candidate dinosaur-killer crater at the tip of Mexico’s Yucatán Peninsula. Half of the massive indentation, which measures 150 kilometers (93 miles) across, lies buried beneath the Gulf of Mexico.

It took two decades for most of the scientific community to agree that the Yucatán crater was caused by the asteroid that did in the dinosaurs. Among the groups that helped collect evidence was The Planetary Society, which led a series of expeditions to Belize to study debris from the impact. Society members also collected rock samples in Italy corresponding to the same time period.

Today, most of the public seems convinced that asteroid impacts should be taken seriously. Opinion polls consistently show that most U.S. residents believe defending our planet should be one of NASA’s top priorities.

Johnson isn’t surprised. “Who else are they going to turn to if such a threat appeared other than their space program?” he says.

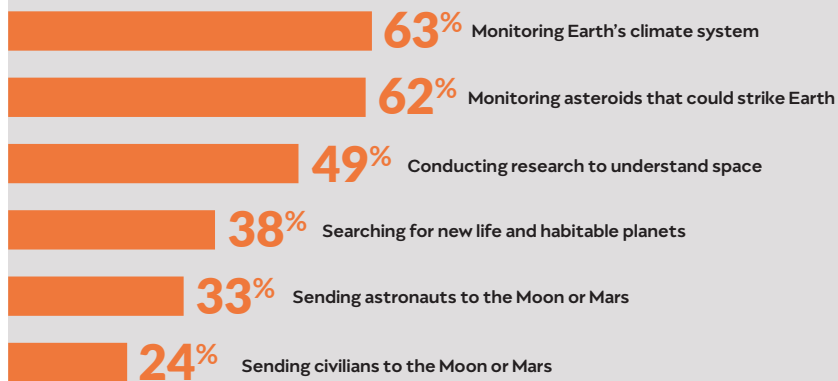
THE RISK IS NOT ZERO

Looking at NASA’s budget, you wouldn’t infer that the public feels so strongly about stopping dangerous asteroids. Less than 1% of the agency’s \$23 billion budget for 2021 went toward planetary defense, and that’s almost 40 times more than what the agency spent on asteroid defense 15 years ago.

In 2005, Congress passed a law directing NASA to find at least 90% of all near-Earth objects—that is, objects that come close to Earth orbit—that are

CONCERNED ABOUT EARTH

Opinion polls consistently show that most U.S. residents believe defending our planet from asteroids should be one of the government’s top space priorities. This chart shows the percentage of 2,200 adults surveyed in February 2021 who ranked each issue a top or important priority.



DATA: MORNING CONSULT, MARGIN OF ERROR ±2%

140 meters (459 feet) or larger. There was just one problem: Congress didn’t give the space agency the money it needed to fulfill the goal, and NASA didn’t request it either. The original 2020 deadline came and went, and today, fewer than 40% of asteroids that size and larger have been found.

It doesn’t even take a 140-meter-wide asteroid to cause serious damage. According to the Torino Scale, a tool that ranks the severity of asteroid threats, just a 20-meter-wide object can cause “localized destruction for an impact over land or possibly a tsunami if close offshore.” The scale notes these events can occur as frequently as every 50 years.

Fortunately, Earth is vast, with two-thirds of it covered in water. The risk of an asteroid scoring a direct hit on a major metropolitan area is low but not zero.

Russia, with its large land mass, often bears the brunt of small asteroid impacts. In 1908, an object roughly 50 to 80 meters wide (160 to 260 feet wide) exploded over a remote region of Siberia, flattening 2,000 square kilometers (770 square miles) of forest. More recently, in 2013, a 20-meter-wide asteroid exploded near the





THE GREAT DYING

The extinction of the dinosaurs 66 million years ago is just one of five known major extinction events. The largest occurred about 250 million years ago, when a whopping 96 percent of all life on Earth died. Scientists aren't sure what caused the event, known as "the Great Dying." In 2017, three scientists, including Max Rocca, who has received funding from The Planetary Society to look for and study Earth impacts, published a peer-reviewed paper showing evidence for a 250-kilometer-wide (155-mile-wide) crater near the Falkland Islands that may be linked to the event. Learn more at planetary.org/falklands

OPPOSITE Near-Earth asteroids come in a variety of shapes and sizes. Pictured here to scale with one another are the only five near-Earth asteroids that have ever been visited by a spacecraft. From top to bottom: Eros, Toutatis, Ryugu, Bennu, and Itokawa. Eros measures roughly 33 kilometers (21 miles) across, while Bennu and Itokawa measure just a half kilometer across.

NASA/GSFC/JHUAPL/CNSA/JAXA/UNIVERSITY OF ARIZONA

Russian city of Chelyabinsk, damaging buildings and sending more than 100 people to area hospitals.

The good news is that with missions like DART, we can theoretically stop asteroids from impacting Earth. But first, we have to find them in time.

THE ASTEROID HUNTERS

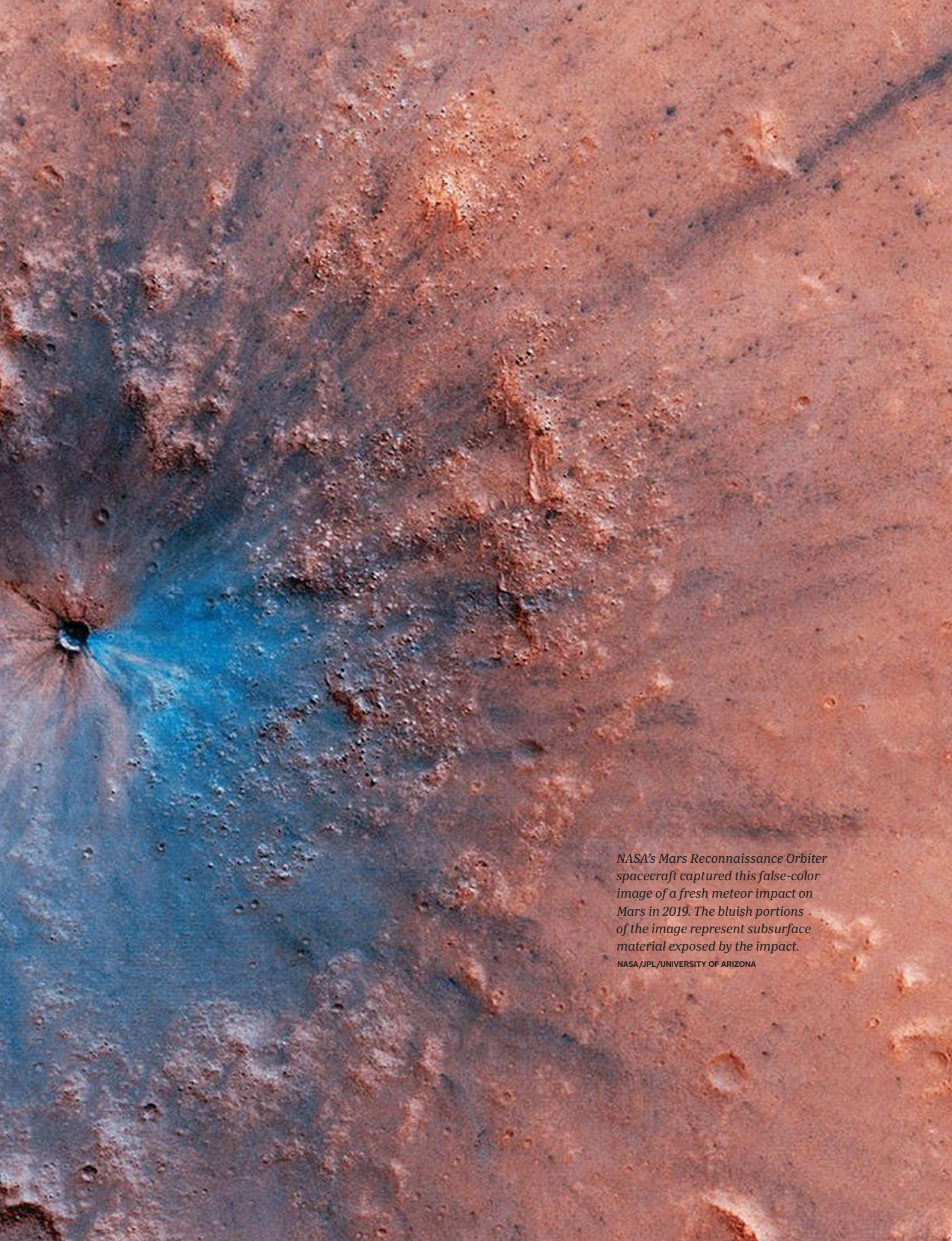
Until the early 1970s, most asteroid discoveries were still being made by telescopic sky surveys dedicated to cataloging stars, galaxies, and other deep-sky objects—a tradition started by Giuseppe Piazzi when he stumbled upon Ceres in 1801.

"Asteroids and comets were not considered cutting edge," says Linda Schweizer, an astronomer and the author of *Cosmic Odyssey: How Intrepid Astronomers at Palomar Observatory Changed Our View of the Universe*. "They were a byproduct of sky surveys, not the target."

That changed around 1973 when Gene Shoemaker and planetary scientist Eleanor Helin started a search for near-Earth objects based out of Palomar Observatory in Southern California.

Helin would go on to become a prolific asteroid hunter, discovering 515 objects and codiscovering





NASA's Mars Reconnaissance Orbiter spacecraft captured this false-color image of a fresh meteor impact on Mars in 2019. The bluish portions of the image represent subsurface material exposed by the impact.

NASA/JPL/UNIVERSITY OF ARIZONA

388 more from 1973 to 1995. She cobbled together funding from various sources to secure asteroid-hunting time on telescopes around the world.

Among her donors are members of The Planetary Society, who began funding her work in 1982.

"I certainly don't want to frighten anyone or cause great alarm," Helin told the *Los Angeles Times* in 1993. "It's not that I'm rattling any cage saying, 'Tomorrow we will die.' But we have been impacted before, and we will be

so you need a team—a network of people."

SPACE TELESCOPES

Mainzer knows a thing or two about planetary defense. Since 2005, she's been trying to get NASA to launch a space telescope that would specifically hunt for near-Earth objects.

Ground-based telescopes can only search for asteroids at night, which leaves our planet vulnerable to any flying at us from the Sun's

Who else would the public turn to if an asteroid threat appeared other than their space program?

OPPOSITE Five known asteroids larger than 20 meters—the threshold at which an asteroid impact could under the right circumstances cause citywide damage—have passed or will pass closer to Earth than our geostationary communications satellites. The largest, Apophis, is roughly four times wider than the International Space Station and will make its closest approach to Earth in 2029.

THE PLANETARY SOCIETY

impacted again. We need to be prepared."

Following the death of Gene Shoemaker in 1997, The Planetary Society established a grant program in his name to fund astronomers who find, track, and study near-Earth asteroids. Since then, the Society has awarded 62 grants to observers in 19 countries on six continents.

Initially, the program was focused on discovery; today, that's mostly the domain of professional sky surveys. But because survey telescopes are focused on sweeping the sky, they can't always stop to study newly discovered objects.

It can take dozens of observations of a newly discovered asteroid to determine whether or not it will hit Earth. Those follow-ups often fall to a tightly knit community of amateur and professional astronomers around the world, including the Society's Shoemaker grant winners.

"One thing I have learned from working in this field is that it's a team effort," says Amy Mainzer, a planetary scientist and professor at the University of Arizona. "If you play a team sport like soccer, you know this. The ball is moving,

direction. Furthermore, asteroids are often as dark as charcoal briquettes, reflecting very little light against the blackness of space.

A space telescope can overcome the charcoal briquette problem by observing in infrared light, where the heat asteroids absorb from the Sun makes them easy to pick out against the cold backdrop of space.

To solve the sunlight problem, you have to place your telescope between Earth and the Sun, where it can look at the region of space ahead of and behind our planet's orbital path.

Mainzer's telescope, which was originally named NEOCam and is now known as NEO Surveyor, will do both of those things. In 2020, after years of congressional prodding from groups including The Planetary Society, NASA finally moved the mission into its formulation phase.

NEO Surveyor could be ready to fly as soon as 2026, but NASA has been reluctant to request funding for the mission, citing other science priorities and the COVID-19 pandemic. Earlier this year, Congress asked NASA to lay

APOPHIS
32100 KM



COMMS SATELLITES
35800 KM



36000 KM

ASTEROID 2014 RC
32100 KM



ASTEROID 2018 PD20
28200 KM



DUENDE
28200 KM



ASTEROID 2016 EF195
24400 KM



24000 KM

GPS SATELLITES
20000 KM



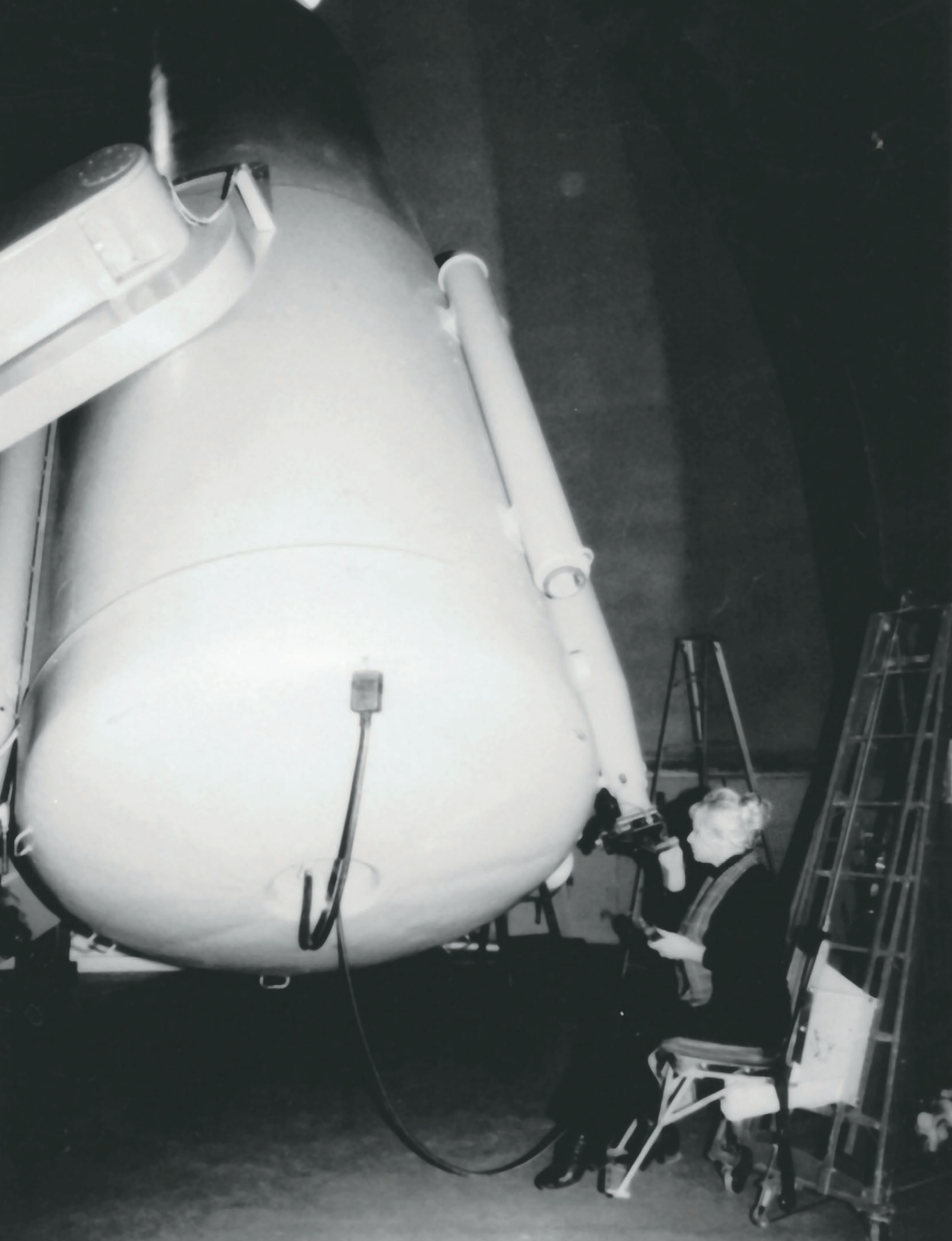
ASTEROID CLOSE CALLS

FIVE CLOSEST CITY-KILLER SIZE FLYBYS

12000 KM

INTERNATIONAL
SPACE STATION
400 KM





out a plan for a mid-2020s launch, signaling an intent to support the program. U.S. Planetary Society members pressed their congressional representatives to fund the mission during the Society's annual Day of Action in March.

Until NEO Surveyor launches, NASA's only space-based asteroid hunter is a telescope that wasn't specifically designed for the job in the first place.

WISE, the Wide-field Infrared Survey Explorer, launched in 2009 on a mission to scan the sky for nearby cool stars and faraway bright galaxies. The scientists behind WISE figured its infrared detectors would allow it to find asteroids as well, but there was no computer pipeline in place to process the telescope's images specifically for that purpose.

So, Mainzer and other team members built one. "It turned out to be a fun challenge," she says.

After WISE's supply of frozen hydrogen that kept its instruments cool ran out as expected in 2010, NASA deactivated the telescope and left it adrift in Earth orbit. Three years later, the agency revived it as an asteroid hunter called NEOWISE thanks to the data processing work done by Mainzer and her colleagues.

As of early 2021, NEOWISE has surveyed the entire sky 15 times, observing roughly 40,000 solar system objects including 1,400 near-Earth asteroids. This is in addition to the more than 100,000 small worlds observed during the prime WISE mission.

NEOWISE has worked in a pinch, but it's not optimized for asteroid hunting nor is it located between the Sun and Earth. Atmospheric drag is slowly pulling it back toward our planet, and its mission will end no later than 2025.

THE GOD OF CHAOS

On April 13, 2029—Friday the 13th if you're superstitious—a new point of light will appear in Earth's night sky. Looking like a moderately bright star, the dot will be visible from Europe, Africa, and western Asia as it glides across the horizon. The dot will be asteroid Apophis, named for the Egyptian god of chaos.

During its visit to Earth, Apophis will come as close as 30,600 kilometers (19,000 miles)—closer than our geostationary communications satellites, making it by far the closest-known flyby for an object of its size. The 450-meter-wide (1,500-foot-wide) asteroid won't hit Earth, but if it did, the energy released would be comparable to a blast from tens to hundreds of nuclear weapons.

There is perhaps no better way to visualize the potential threat from near-Earth asteroids than to see with your own eyes one that could instigate a global catastrophe and possible civilizational collapse.

No missions to Apophis are currently scheduled, but with the flyby less than eight years away, NASA's Lindley Johnson says now is the time to plan.

"It's not too early to talk about these types of missions," he says. "When you're talking budget, you can't just wait until an asteroid gets close to Earth."

Late last year, a worldwide group of scientists and engineers participated in a virtual workshop titled "Apophis T-9 Years: Knowledge Opportunities for the Science of Planetary Defense." Topics included the latest radar models of Apophis, analyses of how Earth's gravity will strain the asteroid in 2029, and what science instruments an Apophis mission should carry.

The Planetary Society participated in the workshop and called for missions to study Apophis in its submission to the planetary science decadal survey, a community-authored report that helps NASA plan its next 10 years of space missions.

The Apophis flyby is the perfect chance to show the cosmos how far Earthlings have come since the dinosaurs.

Whether or not the world will rise to the challenge remains to be seen. 🌌



JASON DAVIS is the editorial director for The Planetary Society.

OPPOSITE *The Planetary Society supported near-Earth object research conducted by Eleanor "Glo" Helin for more than a decade starting in 1982.*

THE PLANETARY SOCIETY

A large, dark, cratered asteroid is shown in the foreground, slightly to the right. In the background, the Earth is visible as a blue and white sphere on the left side of the frame. The background is a deep black space filled with numerous small, distant stars.

THE THREAT IS REAL.
THE ANSWER IS SCIENCE...
POWERED BY **YOU**.



Last September, Brazilian amateur astronomer Leonardo Amaral discovered a kilometer-wide, near-Earth asteroid that would create global devastation if it hit our home planet. Thankfully, the asteroid QU6 was of no risk to us due to its distance from Earth.

But the fact that a near-Earth object (NEO) large enough to destroy a major city had gone undetected until Leonardo's discovery proves we must work urgently to defend Earth from deadly asteroids! This is where you come in...

Thanks to funding from members like you, Leonardo received a Shoemaker NEO grant from The Planetary Society in 2019 for a new telescope mount that allows him to observe dimmer objects.

His work underscores the immense value of our grants, given every two years to fund equipment upgrades for passionate astronomers who spend countless hours working to find, track, and characterize near-Earth objects.

Will you please power this important work with your contribution? Act now and your gift will be matched dollar for dollar up to a total of \$25,000!

DONATE NOW AT [PLANETARY.ORG/NEO](https://planetary.org/neo)

How Can I Help Defend the Planet?



ADVOCATE

U.S. residents can sign a petition to Congress advocating for the NEO Surveyor mission to rapidly detect and characterize hazardous near-Earth objects. Find the petition at planetary.org/action-center.



SPREAD THE WORD

Help raise awareness about the asteroid threat by giving a presentation to a local astronomy club, student group, or even just your friends and family. Check out our planetary defense presentation kit at planetary.org/outreach-toolkits.



GET EDUCATED

Brush up on asteroid impacts and how to prevent them with our free Asteroid Defense 101 course at courses.planetary.org.



Celebrate Asteroid Day With Us!

June 30 is Asteroid Day, a UN-sanctioned global awareness campaign that takes place every year on the anniversary of the Tunguska event in 1908, the most harmful known asteroid-related event in Earth's recent history. Asteroid Day's mission is to inspire, engage, and educate the public about asteroid opportunities and risks. The Planetary Society is a proud partner and is helping to develop *Asteroid Day LIVE*, a free live broadcast that mixes education and entertainment. Go to asteroidday.org to learn more and tune in on June 30 to join the celebration.



Make Your Mark on The Planetary Society

There are so many ways to honor your heroes and loved ones. As a Planetary Society member, we invite you to do so while also supporting our mission to advance space science and exploration. By buying a custom-inscribed brick that paves the front of our headquarters in Pasadena, California, you can leave a permanent mark on the future of our organization while helping us achieve our mission. Learn more at planetary.org/brick.



Bringing the Cosmos to You Every Week

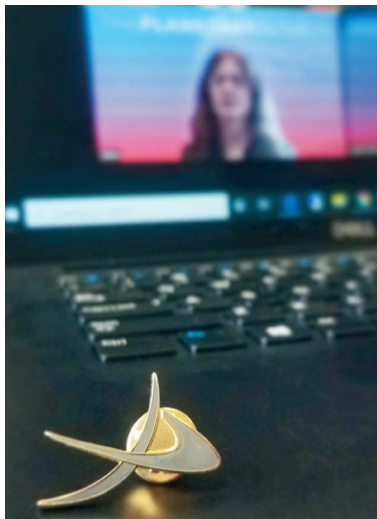
If you aren't already subscribed to our weekly email newsletter, *The Downlink*, sign up today! Every Friday, we send you the latest space news, amazing space images, inspiring artwork, updates on The Planetary Society's work, and ways that you can get involved. There's no better way to stay connected to our global community of space advocates. Sign up at planetary.org/connect.

Members Make Impact on Congress, Prevent Impacts From Asteroids



Planetary Society member Travis Vazansky paused to take this cheeky photo between meetings with his elected officials in Colorado during The Planetary Society's 2021 Day of Action.

TRAVIS VAZANSKY



A Day of Action participant shows off their Planetary Society membership pin.

ADAM BRUNNER

The Day of Action

On March 31, 2021, we held our annual Day of Action, connecting Planetary Society members directly with Congress to advocate for space. This year, because of the ongoing pandemic, we did things a little differently, setting up virtual meetings between 145 members and their congressional representatives and staffers.

Our priorities included a renewed commitment to NASA's science missions, the continuation of the Artemis program to send humans to the Moon and on to Mars, and support for the NEO Surveyor mission to accelerate asteroid detection efforts.

We asked our members throughout the United States to lend their voices to the chorus, and nearly 1,000 additional messages were sent to Congress echoing these same advocacy messages. Internationally, we provided our members with advocacy talking points to share with their governments. To spread the word even further, we gave our members key advocacy messages to share on social media.

Concurrently, we submitted a statement to the government of Canada in response to its call for input on the future of the country's space program. We advocated for increased investment in planetary science, greater support for Canada's space science communities, and a more ambitious vision for independent Canadian missions to explore worlds. Our Canadian members also wrote letters to the government in support of this message.

All in all, this year's Day of Action had the most widespread participation we've ever seen. With the support of members like you, we're looking forward to doing even more next year.

Fueling Our Advocacy Work

In March, our members showed enormous support for our Space Policy and Advocacy program. In a month-long fundraising effort, we raised \$75,000 to directly fund activities like the Day of Action, policy research, and efforts to educate and encourage policymakers to invest in space science and exploration. In addition to contributing financial gifts, our members sent 8,651 messages asking the new U.S. administration and Congress to support continued growth in NASA's science and exploration missions. We are very grateful to all of our members for helping us work toward a better future for everyone.



The Planetary Defense Conference was held virtually this year.
THE PLANETARY SOCIETY

Spreading the Word About Planetary Defense

In April, planetary defense experts from around the world gathered virtually for the biannual Planetary Defense Conference. As a primary sponsor, The Planetary Society hosted a free virtual event for the public to complement the conference's more technical programming. Our chief scientist, Bruce Betts, and *Planetary Radio* host, Mat Kaplan, were joined by some of the world's foremost experts for a discussion of the asteroid threat and the latest developments in the effort to defend our planet. Watch it at planetary.org/live.

Shoemaker NEO Grant Winners Advance Their Work

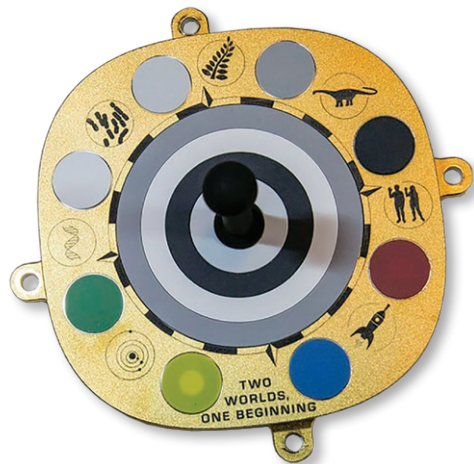
The Planetary Society awarded our last batch of Shoemaker NEO grants in 2019, and since then, that funding has helped researchers around the world to conduct important research to find, track, and characterize near-Earth objects.

All of this work makes a real difference to the efforts to prevent impacts on Earth, and it is thanks to the support of members like you that it's all possible. We have announced the latest round of Shoemaker NEO grants, with proposals due July 28, 2021.



This image shows the primary calibration target for the Mastcam-Z cameras on NASA's Perseverance rover, containing a motto, graphics, and a sundial.

NASA/JPL-CALTECH/ASU/UNIV. COPENHAGEN

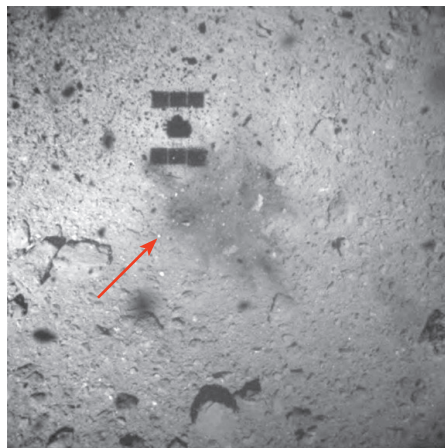


Hearing Sounds on Mars

Thanks to the longtime support of our members, The Planetary Society is celebrating major milestones in our efforts to explore Mars. After 25 years of advocating for a Mars microphone and flying our own microphone on the failed Mars Polar Lander, we were delighted to hear the first sounds recorded from another planet using the microphones aboard NASA's Perseverance rover. And as the rover's Mastcam-Z camera instrument got ready to image Mars, it calibrated its camera using a target designed with the help of The Planetary Society that includes a motto, graphics, and a sundial.

Hayabusa2 snapped this picture while ascending from its sample grab. The red arrow points to one of the target markers it dropped.

JAXA ET. AL.

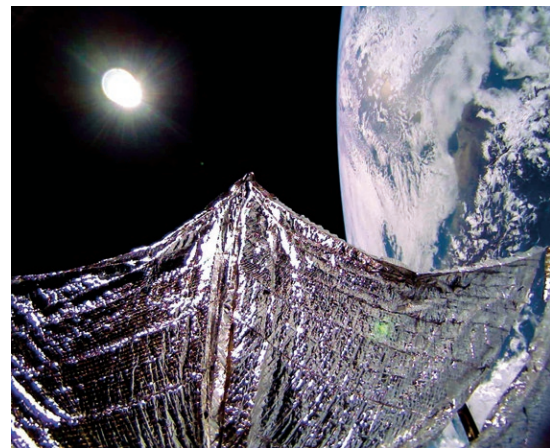


Names Sent to Ryugu and Back Again

The names Planetary Society members sent to asteroid Ryugu and back via Japan's Hayabusa2 spacecraft survived their journey. Hayabusa2 mission officials successfully extracted and accessed the names, which were stored on two microSD memory cards—the same type commonly used in cameras and other small electronic devices. The Planetary Society helped Japan's space agency collect the names in 2013 as part of our Messages From Earth program. The names were also etched into a set of baseball-sized target markers that were dropped on Ryugu to help the spacecraft navigate.

This image taken by The Planetary Society's LightSail 2 spacecraft on October 14, 2020, shows the coast of northern Peru and clouds over the Pacific Ocean. North is at the upper right. The image has been color-adjusted and some fisheye lens distortion has been removed.

THE PLANETARY SOCIETY



LightSail 2 Paves the Way Forward

The member-funded LightSail 2 mission hasn't only succeeded by successfully demonstrating controlled solar sailing for CubeSats: Three new NASA missions will build on LightSail 2's legacy. The first is NEA Scout, which will use a solar sail to visit a near-Earth asteroid. NASA has also greenlit Solar Cruiser, a mission launching in 2025 to test a giant sail measuring 1,650 square meters (17,800 square feet) at an artificial orbit between Earth and the Sun. A third mission called ACS3, short for Advanced Composite Solar Sail System, will test a new type of sail boom in Earth orbit. Our chief scientist Bruce Betts recently gave a presentation about LightSail 2 to NASA solar sail mission teams, helping advance our goal to communicate the results of this mission to the technical community to feed forward what we've learned. LightSail 2 continues its operations in Earth orbit.

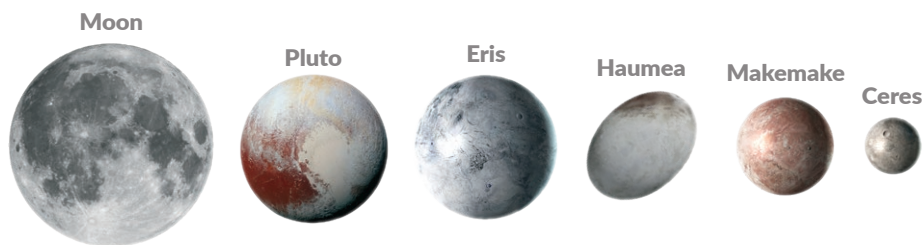
A Supermoon and Meteor Shower

In the Sky

On June 24, look for a supermoon, which is when the Moon looks extra large and bright. This happens whenever the Moon is on the opposite side of Earth from the Sun, fully illuminating its face while closest to Earth in its elliptical orbit. Reddish Mars will be sinking lower in the west soon after sunset through June and July. Super-bright Venus will be low in the west soon after sunset through September. Venus and Mars grow closer in the sky until July 12/13, when they will be as close as the width of a full Moon (about half a degree). Bright Jupiter and yellowish Saturn are in the same region of the sky, rising in the east in the late evening in June and the early evening by September. The Perseid meteor shower peaks August 12/13, with increased activity several days before and after. The most meteors will occur after midnight, and the Moon will have set by then, leaving a darker sky. For more night sky tips, you can always check out planetary.org/nightsky.

Random Space Fact

The Moon, with a diameter of 3,474 kilometers (2,159 miles), is larger than each of the dwarf planets, the largest being Pluto, with a diameter of 2,377 kilometers (1,477 miles).



Trivia Contest

Our December solstice contest winner is Jim Derivera of Oxnard, California.

Congratulations! The question was: **What was the only Apollo spacecraft call sign named after a single star?** The answer: **The Apollo 14 Lunar Module call sign was Antares, named after the star that would be used to orient the Lunar Module during landing.**

Try to win a copy of *Astronomy for Kids* by Bruce Betts and a *Planetary Radio* T-shirt by answering this question: **What is the largest asteroid considered to be a near-Earth object (NEO)?**

Email your answer to planetaryreport@planetary.org or mail your answer to *The Planetary Report*, 60 S. Los Robles Ave., Pasadena, CA 91101. Make sure you include the answer and your name, mailing address, and email address (if you have one). By entering this contest, you are authorizing *The Planetary Report* to publish your name and hometown. Submissions must be received by September 1, 2021. The winner will be chosen in a random drawing from among all the correct entries received. For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science-fiction guests, listen to *Planetary Radio* at planetary.org/radio.



Please contact Terri or Taunya at Betchart Expeditions for brochures and updated information on COVID and travel. Call 1-800-252-4910 or go to betchartexpeditions.com.

There are wonderful travel adventures ahead for you in 2021 and 2022 with The Planetary Society! A magnificent eclipse awaits you in Antarctica. You can watch the aurora borealis dance across the Alaskan sky in March, and there are three fantastic lunar eclipse trips in 2022.

DISCOVER THE HERITAGE OF ANCIENT EGYPTIAN ASTRONOMY DECEMBER 1-14, 2021

A tour of Egypt including a trip to the fabulous new Alexandria Library with outstanding scholar Dr. Bojana Mojsov.

ALASKA AURORA BOREALIS MARCH 10-16, 2022

Reserve your place now on this ever-popular winter-in-Alaska program, with dazzling evenings watching the aurora borealis.

GALAPAGOS ISLANDS TOTAL LUNAR ECLIPSE MAY 11-20, 2022

There is nothing like a lunar eclipse over the Galapagos Islands. The whole sky will sparkle with starlight in this super dark-sky location! Join this fascinating trip with Dr. Tyler Nordgren.



William Hartmann, *View of the 1908 Tunguska fireball from the town of Kirensk*

On the morning of June 30, 1908, an asteroid roughly 50 to 80 meters wide (160 to 260 feet wide) exploded above Tunguska, Siberia, leveling 2,000 square kilometers (770 square miles) of forest. No known pictures of the moment of impact exist, but Russian scientists collected eyewitness accounts from people up to hundreds of kilometers away.

William Hartmann, a planetary scientist and prolific space artist, used these reports to paint reenactments of the event from different distances and perspectives. Here, a schoolteacher in Kirensk, which is 400 kilometers (250 miles) southeast of ground zero, shields her eyes while watching the meteorite just seconds before it explodes.

Do you want to see your artwork here? We love to feature our members throughout this magazine. Send your original, space-related artwork to connect@planetary.org.