DARK FATE

THE GOOD NEWS: It's highly unlikely that life on Earth will be wiped out by an asteroid such as the one that took out the dinosaurs. The vast majority of such planet killers are being monitored and appear to pose no threat. THE BAD NEWS: Tens of millions of smaller asteroids, many capable of taking out a major city, are swarming unseen around our planet all the time, despite our best efforts at detection. • "Space is big. It's dark. It's black," says Danica Remy, founder of Asteroid Day and the President of the B612 Foundation, a nonprofit with a mission to protect the Earth from asteroid impact. Asteroids are composites of a variety of rocks and metals, dominated by carbon, making them characteristically as dark as ash – perfect camouflage in the night sky. "If you don't know where an asteroid is or where it's going, you're not going to be able to find it in your telescope," Ms. Remy says. • And seeing it once would not be enough to understand the threat it may pose, says her colleague, Dr. Ed Lu, a former NASA astronaut who served on both Space Shuttle and the International Space Station missions. Along with fellow astronaut Rusty Schweickart, Dr. Lu in 2002 founded B612 (named after an asteroid in the children's novel, *The Little Prince)*. "You have to spot it multiple times," he says. "The probability of something hitting the Earth is a function of how well you know the orbit." MORE BAD NEWS: Even if we do spot an incoming disaster, we may have no way to stop it, depending on the amount of time before impact. • In 2013, an asteroid roughly 20 meters wide exploded without warning in the atmosphere above Chelyabinsk, Russia. Though relatively small, the meteor packed roughly 30 times the force of the first atomic bomb. Most of that energy was absorbed in the atmosphere, but enough of it reached the ground to shatter windows, damage thousands of buildings and traumatize the community. Over 1,500 injuries were reported. Damages were estimated at the time to be at least $33 million. • NASA's current detection efforts are ramping up significantly year by year, says Lindley Johnson, a former US Air Force officer and now NASA's first Planetary Defense Officer. Yet he isn't optimistic about our ability to prevent another Chelyabinsk. • "Our initial goal was to find the 1 kilometer and larger objects," says Mr. Johnson. An object that size could release 11,000 megatons of energy on impact, nearly 1 million times more powerful than the A-bomb – more than enough to wipe out an entire region of the planet and alter the climate. Having set the goal of finding such doomsday rocks 20 years ago, NASA believes it can now track "96 percent to 97 percent," and has begun searching for their smaller brethren. "We're working on this more challenging goal of 140 meters and larger. We believe the population of those is about 25,000, of which we have now found almost 8,400."

An even bigger crisis is headed our way. What's the plan? Brunswick's **CARLTON WILKINSON** reports.

THE SHADOW of the spacecraft Hayabusa2 creeps over the surface of Ryugu about 280 million kilometers from Earth. In addition to sending photos and data, the probe will return home in 2020 with samples of this potentially hazardous asteroid.

PHOTOGRAPH: JAXA

A rock 140 meters across could destroy a large city. Impacts of that size occur only once every 10,000 years, roughly, so the odds are good we'll find most of them before the next one strikes. "Time is on our side," Mr. Johnson says.

The Chelyabinsk meteor, on the other hand, was a fraction of that size and still caused damage and injury. That type impacts the planet on average once a century. Maybe more often. NASA estimates that about 1 million such objects could pose a threat.

"To be honest with you, we could get hit by an object that size without seeing it beforehand," Mr. Johnson says. "With our current dependence on ground-based telescopes, which see the night side, if it came at night I think we would definitely see it beforehand. But the 2013 event is an example of an object that came from the daytime skies, so we had no chance of detecting it."

DR. ED LU IS IN ORBIT in this photograph by cosmonaut Yuri I. Malenchenko, taken during a six-hour spacewalk outside the International Space Station in 2000. A former NASA astronaut and the current director of the B612 Asteroid Institute, Dr. Lu is now working on a dynamic map of the solar system that he foresees as a valuable tool for both asteroid detection and space exploration.

"It's important, not just for protecting the Earth, but also for the development of space," he told the Brunswick Review. "Take the big-picture view of where human beings are going over the next 50, 100, or even 200 or 300 years. This map and the tools that allow you to make use of it will be fundamentally important to the development of space, just as maps have been important to the development of any new frontier."

PHOTOGRAPH: COURTESY OF NASA.GOV

CRISIS PLAN

But what if we did have advance notice? What then? Inertia is a mighty enemy. In the void of space, those heavy rocks are moving very, very fast along the same gravitational grooves they've followed for billions of years. They're hard to stop. Plans for handling such an impending crisis have taken on an added urgency as our ability has increased to identify near-Earth objects, or NEOs.

Now in its 20th year, NASA's NEO Observations Program has gained support under both Obama and Trump (though it is not part of the proposed Space Force). Funding is expected to increase sharply to $150 million for 2019, up from $60 million.

An earlier NASA mission, NEOWISE, greatly expanded the current bank of knowledge about asteroids. Right now, NASA and the Japanese Space Agency JAXA have probes visiting asteroids, for the purpose of studying them, collecting samples and returning to Earth. NASA's OSIRIS-Rex mission arrived at asteroid Bennu in December. JAXA's Hayabusa2 landed French-German robots on the asteroid Ryugu in September.

This year, for the first time ever, the White House publicly unveiled a 23-page "Near-Earth Object Preparedness Strategy and Action Plan," which outlines steps NASA plans to take to increase advance detection and preparedness to deal with them. Of necessity, the plan is still heavy on preparedness, light on action to derail a danger once it's detected.

Data from NASA-funded telescopes, plus those of outside governments, science institutes and private citizens around the world, is continuously fed to the NASA-funded Minor Planet Center and the Planetary Defense Office at NASA headquarters. Sightings of near-Earth objects and impacts are compiled by the Minor Planet Center into reports that land on Mr. Johnson's desk.

"There is a protocol" in the event of an immediate threat, Mr. Johnson says. "We provide the information up through our management to the administrator and to the White House through the Office of Science and Technology Policy, alerting them of a potential impact – how big an object is and how near we are to impact – and our assessment of what the effect might be."

That message spreads not only through a network of US agencies, such as the Federal Emergency Management Agency, or FEMA, but also to any other nations that may be affected, via the State Department and the UN-sanctioned International Asteroid Warning Network, which informs the UN Office of Outer Space Affairs. If the impact were large and headed toward a densely populated area, a mass evacuation might be recommended, with the decision and handling left to that area's government.

Meteor strikes historically have not cooperated with this plan: They arrive unannounced. But on June 2, an astronomer working with the NASA-funded Catalina Sky Survey spotted a two-meter wide object headed for Earth, only the third such advance detection in history, a feat even more remarkable because of this asteroid's puniness. With that data, Jet Propulsion Laboratory scientists were able to predict where it would impact. Eight hours later, the spectacular fireball streaked across the night sky in Botswana, lighting up the rural landscape like a giant flash bulb. No one was hurt.

Eight hours would have been enough time to issue a warning that could have saved lives had the asteroid been larger and targeting a major city – but not long enough for a full evacuation.

Dr. Tim Spahr, the former Director of the Minor Planet Center and a founder of the Catalina Sky Survey, is now CEO of his own private consulting firm NEO Sciences. He says confidently that the bigger the threat, the greater the chance we might see it advance.

"Let's say instead of two meters, it was 40 meters," Dr. Spahr says. "We would have discovered it weeks ahead of time, not eight hours. And that's enough time to go, 'Hello! People in Botswana! You just need to get 30 kilometers away and you'll all be fine.'"

But even a few weeks is not nearly enough to mount any kind of deflection or intervention against the asteroid itself. Even if we had something to deflect it with. At the moment, an effective mission would require a warning of about 20 years. "They're trying to reduce that," Dr. Spahr adds. "The idea that you could do something on a decadal time scale [10 years instead of 20] is not out of the question."

In its five numbered goals, the NASA "Strategy and Action Plan" lists "Develop Technologies for NEO Deflection and Disruption Missions" as Goal No. 3. Another way of saying that: Those technologies, as a complete package, are not yet developed. We have the ability to launch missions to asteroids – but those take decades of work prior to launch. Existing machinery, in theory, could be adapted to thwart an impact once we get there – but we haven't tested it.

Still, sending a defense is feasible, building on technology developed on previous space missions. One idea would be to move the asteroid's orbit slightly so it doesn't hit Earth. Various theories for how to do that have been floated.

Among what NASA calls "the most mature in-space concepts": slamming a device into the asteroid's surface, known as a "kinetic impactor"; parking a man-made object nearby and letting its gravitational pull tug the asteroid off course, a so-called "gravity tractor" (an idea first proposed by a team that included B612's Dr. Lu); and last, exploding a hydrogen bomb near the surface, which should slow the asteroid's momentum, allowing it to miss Earth.

These remain untested. NASA has scheduled a kinetic impactor attempt in 2022, Mr. Johnson says, when a spacecraft will hit the smaller member of a twin asteroid system, Didymos, to slightly alter its path. For the immediate future though, safety plans in the face of threatening asteroids rest on early detection, warning protocols and public awareness.

ASTEROID DAY

The Botswana fireball flashed only briefly in headlines around the world, burning out within hours. Such is the standard trajectory for media reporting on meteors. Only a few years ago, however, coverage was scarcer. A few articles about asteroids appeared in major outlets, including Time Magazine, yet somehow public awareness remained low.

When Ms. Remy joined the B612 Foundation as Chief Operations Officer in 2012, "Nobody was talking about asteroids," she says. "We would go to donors and say, 'Would you give us a million dollars? Or $100,000?' They'd say, 'Well, I never hear about asteroids in the press.' Like, is it really a problem?"

When Chelyabinsk was hit in 2013, most of the injuries sustained were from flying glass. People saw the flash of the explosion but, not realizing what it was, they didn't know to take cover from the shock wave that would hit moments later. One substitute teacher told students to hide under their desks. She was treated as an international hero because the 44 fourth-graders in her charge were largely unharmed when the windows of her classroom blew out.

In 2014, Ms. Remy set out to create an annual day of awareness, urged on by B612 co-founder and NASA astronaut Rusty Schweickart and others, including astrophysicist and Queen guitarist Brian May, and director Grigorij Richters, whose film "51 Degrees North" imagined a meteor hitting London.

"The reason we started Asteroid Day – Brian, Grig, Rusty and myself – is that we needed a venue to get the public talking," she said. The idea was recognized by the UN, and the nation of Luxembourg signed on as a major sponsor. Launched on June 30, 2015 – the anniversary of a another famous asteroid impact in Russia, at Tunguska in 1908 – Asteroid Day has helped asteroid research gain considerable attention. In addition, it has become an international vehicle for educators to launch conversations with students and science organizations to generate public interest.

"Asteroid Day was intended to put a spotlight on anybody in the world who was having a conversation about asteroids, teaching or learning about asteroids," Ms. Remy says.

Building on interest in Chelyabinsk, the annual event has made a difference, she says, pointing to a 2018 report from Pew Charitable Trust that samples Americans' interest in aspects of space research. "This year, for the first time ever, at the top of the list second only to climate change is monitoring the Earth for asteroids," Ms. Remy says. "To me, that's a huge validation of the hard work that we've done."

Mr. Johnson agrees that asteroid awareness overall has increased and that Asteroid Day has played a part. But he adds that that success was aided by exciting results from ongoing scientific missions.

"We say, 'Every day is Asteroid Day at NASA,' because we find them every day," Mr. Johnson says. "The object is to find them before they find us." ◆

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The last time fatalities were recorded from an asteroid strike?

CHINA, 1490 A.D.

Reports say 10,000 people were killed. Because whole populations are at risk, the odds of dying from a meteor are greater than from a shark attack.

Expected **FATALITIES** averaged per year:

SHARK ATTACKS

3-7

ASTEROIDS

91

TOP 3 CAUSES OF FATAL INJURY RESULTING FROM METEORS:

1. Strong wind or shock wave
2. Intense heat
3. Tsunami

Stats from "Defending Planet Earth: Near-Earth Object Surveys and Mitigation Strategies," a consensus study report published in 2010 by the US National Academies of Sciences, Engineering and Medicine.