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How to Stop a Killer Asteroid

When a civilization-ending space rock bears down on us, this nuclear option might just save our species.

By Steve Nadis | Thursday, January 22, 2015

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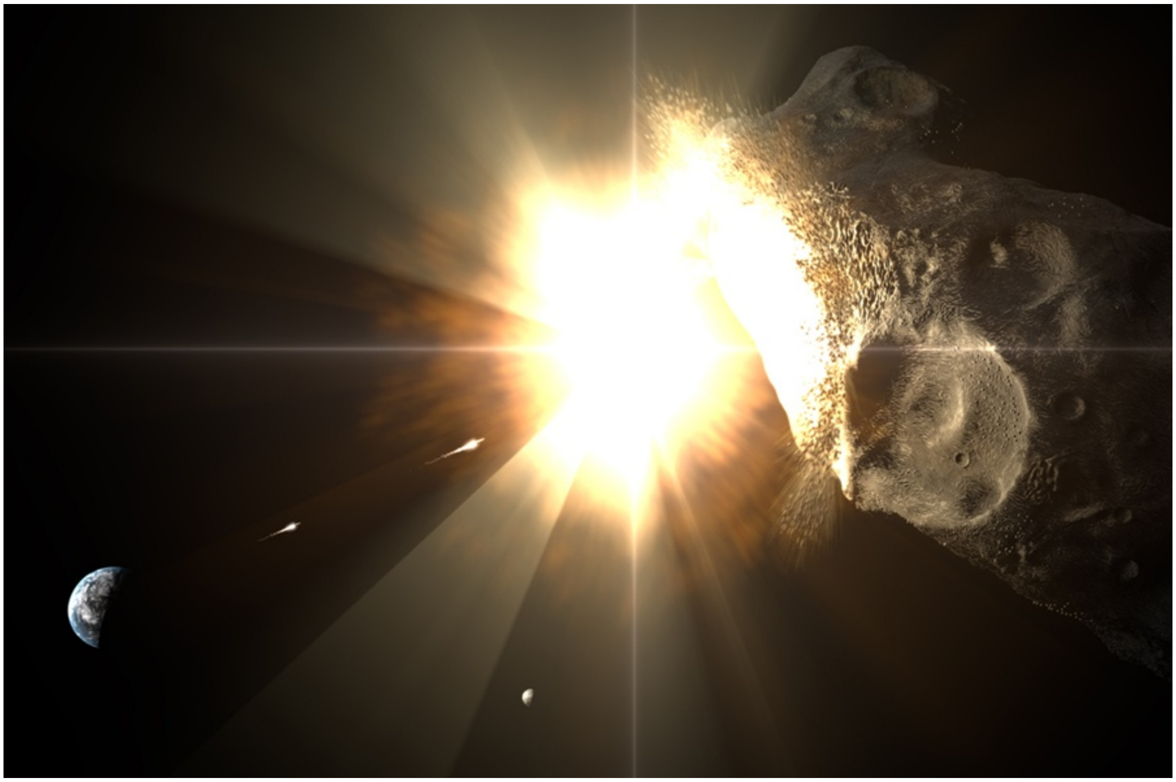


Detonating a nuclear device near an incoming asteroid's surface would vaporize just a portion of its top layer, providing a big enough push to knock it off course.

Rhys Taylor

Nothing fills movie theaters like the end of the world, which may be why Hollywood keeps turning out apocalypses. Yet most big-screen disaster scenarios pale in comparison to the genuine cataclysm that befell Earth some 66 million years ago, when a 6-mile-wide asteroid slammed into our planet. It left behind a roughly 120-mile-wide crater in the Yucatan and wreaked global environmental havoc. Many scientists believe this was the event that wiped out the dinosaurs and about 80 percent of all animal species. Events of this magnitude are rare, but astronomers assure us something similar will happen again.

Nature provided a little reminder on Feb. 15, 2013. First, a 56-foot-diameter rock exploded without notice above the Siberian city of Chelyabinsk, releasing the energy of more than 30 Hiroshima-size atomic bombs. Later that day, a totally unrelated 150-foot-wide asteroid named 2012 DA14 made a close approach, coming within about 17,000 miles of hitting us — some 5,000 miles closer than many TV and weather satellites.

Astronomers believe millions more large, undiscovered and potentially deadly asteroids lurk out there and could catch us unawares. Testifying before Congress a month after Chelyabinsk and 2012 DA14's flyby, NASA chief Charles Bolden said that if we had just a few weeks' notice before an impending asteroid impact, he could offer only one word of advice: “Pray.”

John Remo, a 73-year-old physicist living in New Mexico, finds that remark troubling. For Remo, a scientist at the Harvard-Smithsonian Center for Astrophysics, Bolden's statement serves as a painful reminder that we, as a country and a world community, have done little to prepare humankind to fend off asteroids bound for Earth, even though it's within our means to do so. We have the rockets and technical know-how, but have not yet put the pieces together — or mustered the will to do so.

For the past two decades, Remo has devoted himself to rectifying that oversight. In particular, he's focused on the option of “last resort,” which may, in extreme circumstances, be our first and only resort: using nuclear blasts in outer space to push a menacing asteroid out of harm's way and onto a benign trajectory. His most recent research has helped quantify the amount of push a nuclear device could deliver in a dire emergency, when no other technology could save us.

In other words, the same devices that laid waste to Hiroshima and Nagasaki and brought the world to the brink of destruction might offer our only means of salvation in the face of an asteroid-induced Armageddon. It comes down to a question of awareness and resolve, Remo says. “Can we humans do what the dinosaurs could not — amass our expertise and technological resources in the defense of our planet?”

Physicist John Remo holds a slice of the Leoville chondrite, a meteorite billions of years old. He has tested many varieties of space rocks in his research.

Mark Holm

Taking Aim at Errant Rocks

Remo got his Ph.D. in quantum optics in 1979 after developing the mathematics that would make lasers more powerful, stable and efficient. His journey through graduate school took longer than usual because he taught at several universities, traveled quite a bit and undertook extensive research in astrophysics, looking in particular at how the composition of asteroids and meteoritic fragments affects their size. He became absorbed in this line of study, even though it set him back on his dissertation. At the time, Remo wasn't thinking about near-Earth objects, bodies in the solar system whose orbits may one day intersect with Earth's. He was more interested in the solar system's origins, viewing each extraterrestrial rock he came across as "a poor man's space probe."

Upon graduating from the Polytechnic Institute of New York, he decided he could best maintain his independence, and carry out the most innovative work, by forming his own company. His firm, Quantametrics, developed technology for high-powered space lasers, working for clients like the "Star Wars" missile defense program and NASA, which relies on lasers for certain types of astronomical observations. The holder of about 20 patents, Remo continued his research on meteorites on the side, and both strands of work brought him into contact with scientists at various national labs.

Owing to his combined expertise, he spoke at a 1992 Los Alamos National Lab conference on asteroid defense. This was the first major meeting to explore options for intercepting near-Earth objects that threatened Earth, and it brought about a rare commingling of astronomers and weapons lab researchers.

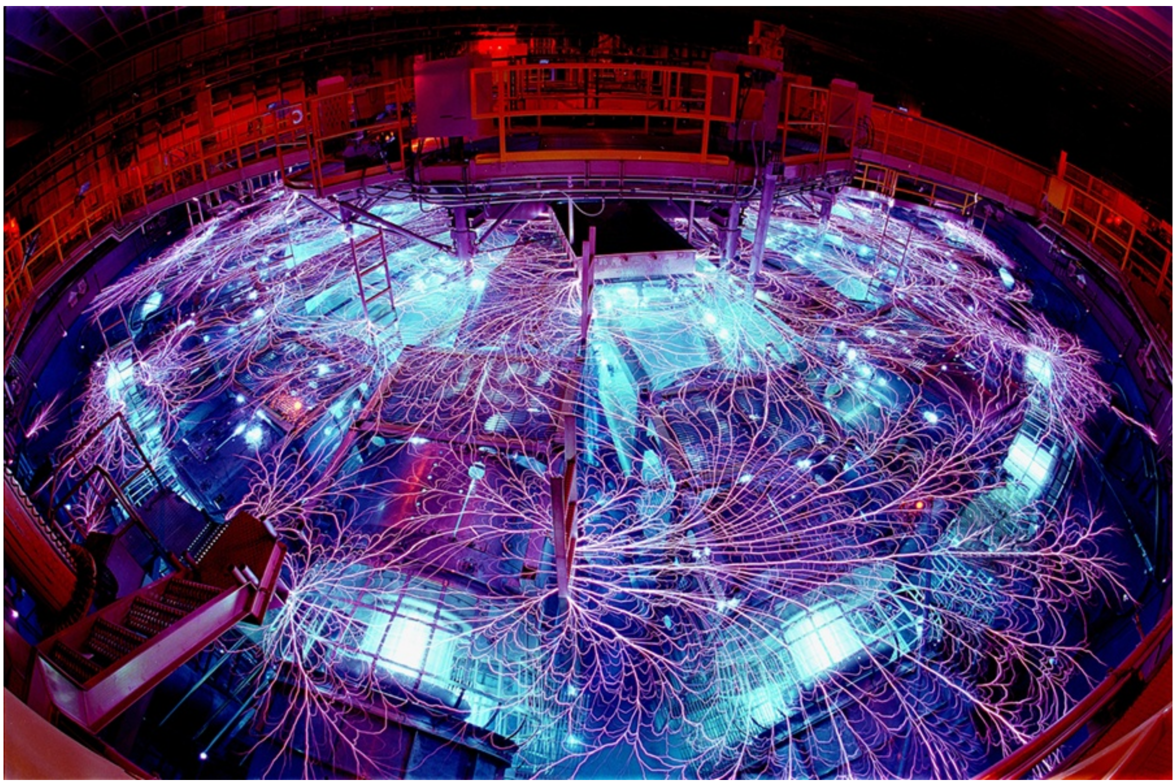
The civilian scientists who attended, notes astronomer Clark Chapman of the Southwest Research Institute, "went expecting it to be unusual, and we weren't disappointed." There was talk of "fringe stuff like antimatter weapons," he says, "and other outlandish proposals." Edward Teller, the father of the hydrogen bomb, spoke of developing a nuclear device 10,000 times more powerful than anything yet devised.

However, most of the ideas discussed at Los Alamos focused on deflection, giving an asteroid a push to dislodge it from a dangerous course. The most straightforward way to do this is the "kinetic energy" approach — simply ramming a spacecraft into an asteroid. But during the conference, Remo was struck by a realization already familiar to attendees more experienced in the subject: When you're talking about deflection, nothing can match the energy density of nuclear weapons.

Pound for pound, nuclear explosives — which derive their power from runaway chain reactions in their radioactive fuel — carry about a million times the energy density of chemical explosives. If you need to move a big rock (more than 3,300 feet), or if you're in a hurry to move a smaller rock (about 330 feet), nukes may be your best shot. The devices could be armed once they're out of Earth's atmosphere, and the intervention can occur far enough from our planet to keep any fallout or explosion risk well beyond the biosphere — the goal being to save the world without harming it.

Of course, the energy density of a nuclear device is not the whole story. Remo also realized during the conference that we can't predict how an asteroid will respond to a nuclear blast without a clear understanding of the object's material properties. Contrary to what intuition might suggest, a crumbly, carbonaceous asteroid can actually be nudged far more readily than a solid, iron-filled body. The biggest unknown at the time was how much momentum the nuclear radiation would impart to the asteroids — how big a push the blast would provide. "That question can only be addressed experimentally, not theoretically," Remo says.

He resolved to figure out just that, and for many years Remo used the proceeds from his laser work to privately support his asteroid studies. (He eventually received funding from the National Nuclear Security Administration and other federal agencies.) "John's experiments were the first to use real extraterrestrial objects — a collection of meteoritic material of various kinds," says Barry Shafer, a physicist formerly based at Los Alamos. And Remo was just getting started.



Sandia's Z machine uses magnetic fields and electrical currents to mimic the temperatures, pressures and radiation of a nuclear blast.

Sandia National Laboratories

Creating a Nuclear Kick

Here's the basic scenario that Remo had in mind for a hypothetical asteroid encounter: With a collision imminent, we'd launch a rocket into space. When close enough to its target, the rocket would set off a nuclear bomb (or possibly several) close to — though not in or on — the asteroid. The blast would vaporize a thin portion of the body's surface. The hot gases produced would immediately expand and rise from the surface, providing a concerted kick, or thrust, that would propel the asteroid away from Earth.

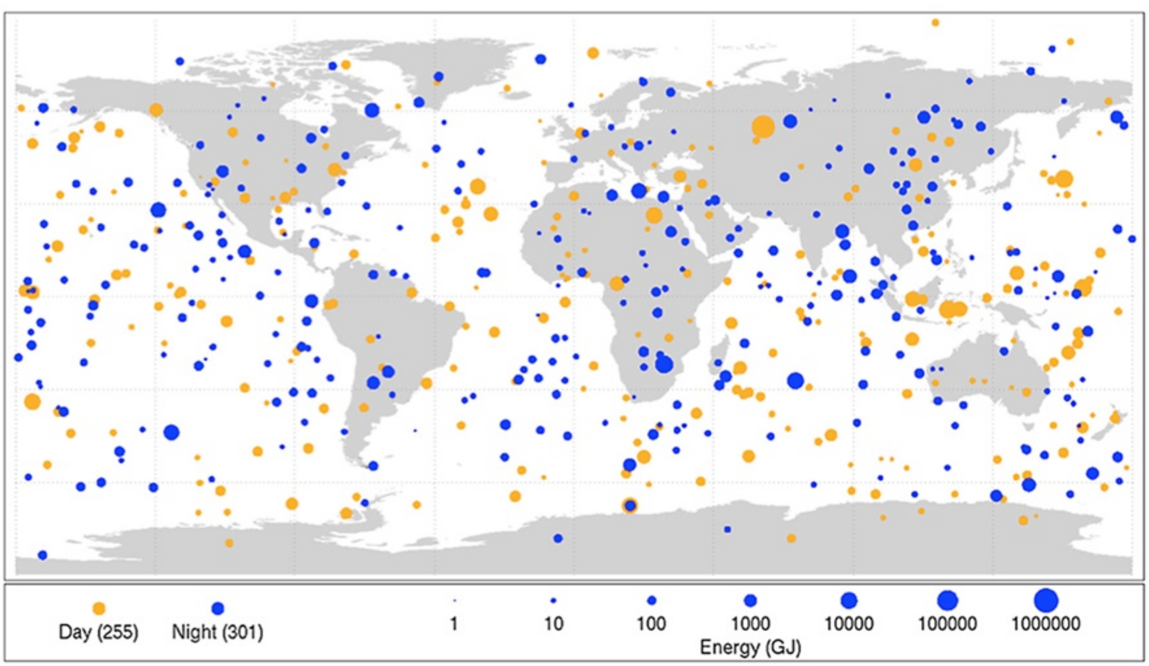
After spending about 10 years gathering meteorite samples, in 2000 Remo finally gained access to the perfect device for exploring the nuclear option: Sandia National Laboratories' Z machine, which happens to be the world's most powerful nuclear blast simulator, apart from nuclear weapons themselves.

A former particle accelerator reconfigured to its present guise in 1996, the Z machine is a platform for studying the physics and effects of nuclear explosions. It reproduces, for a fraction of a second, the high temperatures and intense radiation (predominantly in the form of X-rays) that accompany each detonation. The machine offered Remo his best hopes for figuring out how the X-rays from a nuclear blast would interact with, and possibly deter, incoming asteroids of varying compositions.

People have been investigating the effects of nuclear weapons for decades, but Remo offered a novel twist, says R. Jeffery Lawrence, a physicist who recently retired from Sandia: "He initiated studies of how X-rays interact with the stuff that asteroids are made of."

To simulate a nuclear "kick" in the lab, Remo and his longtime collaborator, Sandia physicist Michael Furnish, mounted small, disk-shaped samples of meteoritic material about 10 centimeters from the Z machine's X-ray source. When the X-rays briefly bombarded the disks, a little of their surfaces boiled off, providing an impulse that pushed the disks away. Remo and Furnish used a system invented at Sandia to calculate the velocity of each disk in the face of the X-ray barrage and became the first to effectively move asteroids (albeit minute ones) with radiation.

Remo and Furnish continued their tests, off and on, whenever the Z machine was available. In 2005, Remo, a lifelong New Yorker, moved from Long Island to the high desert of Placitas, N.M., so he could pursue this research more readily. "You can't do experiments by telephone," he says. All told, they tested about a dozen samples of different meteorite materials — some stony, some iron, some solid and some powdery — and studied the materials' response to varying levels of radiation by moving the targets closer to or farther from the X-ray source.



Small asteroids hit our planet's atmosphere with surprising frequency. Impact energy is measured in gigajoules; for reference, 1 gigajoule (1 billion joules) is about two-thirds the energy of a lightning bolt. Luckily these asteroids, which range from 3 feet to almost 60 feet, are small enough to disintegrate in our atmosphere in bright flashes known as bolides, or "fireballs." However, experts agree it's only a matter of time before something larger slips through and makes it to the ground.

NASA/Planetary Science

By 2010, Remo felt they had compiled "a complete body of work" on how radiation affects meteoritic substances. They enlisted Lawrence to help tally the results and do some computer modeling. Their joint findings were published in a 2013 paper in the *Journal of Plasma Physics*.

"The experiments show, first and foremost, that we can generate X-rays at a level sufficient to deliver the equivalent of a hammer blow to an object," says Lawrence. More specifically, they found that the motion induced by a blast was consistent for a given class of materials, such as stony versus metallic meteorites. "If we know from reconnaissance that it's a stony asteroid or a nickel-iron asteroid," explains Remo, "we can have a pretty good idea in advance how it will respond to an X-ray blast."

Prior to the Z machine studies, that response "had been a major uncertainty for a long while," says Harvard planetary scientist Stein Jacobsen. "John [Remo] deserves credit for coming up with a way to get a handle on this problem in the laboratory. He took the initiative and convinced Sandia to let him do these experiments."

Beyond the Lab

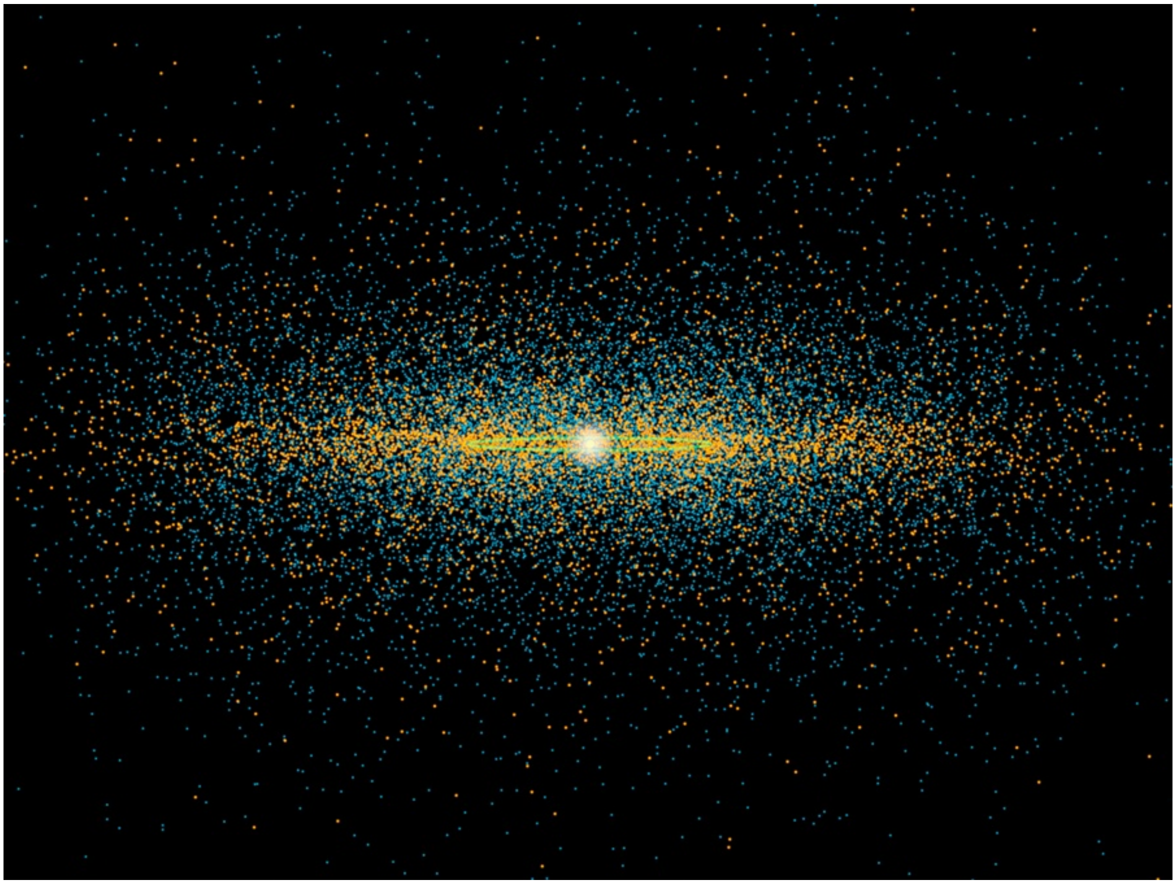
Going from a meteoritic sample less than a centimeter in diameter to an asteroid up to a kilometer or more in diameter involves a pretty big leap. Yet Remo feels scientifically justified in making that leap because the radiation interacts with a material's atomic properties, and those properties are the same for small and large bodies. Their minute experimental samples are still thick enough to absorb all the radiation.

"The X-rays won't penetrate any deeper into the asteroid than into the laboratory target" — just beneath the surface, he says.

Eventually Remo would like to see some of these ideas, and technologies, put to a test. But before trying it out in space, researchers first need to work everything out on paper in systematic fashion, like determining how far from a given asteroid the bomb should go off. His rough calculations indicate that, ideally, one would want to detonate the device from a distance of roughly two asteroid diameters away.

In addition, Remo would like to see a comprehensive review of all the components needed for this option: the launch vehicles, guidance systems, sensors and cradle holding the nuclear explosives. A 2007 paper he helped write recommended six nuclear missiles, released individually at intervals of about an hour. The bombs would go off in six separate blasts, each with a yield of up to 1.2 megatons (equivalent to about 100 Hiroshima-scale bombs).

With a series of separate pulses, Remo says, you could monitor the effects, making adjustments as you go along. Having several smaller explosions instead of one really big blast also reduces the chances of fragmenting the asteroid, which would make it more difficult to handle, Remo adds. “We want to give it just the right amount of energy — enough to give it a good kick but not so much that you break it into bits.”



This edge-on view of our solar system (with Earth’s orbit shown in green) includes a snapshot of the most potentially troublesome asteroids. Near-Earth asteroids are blue, and the subset of them known as potentially hazardous asteroids — those with orbits coming within 5 million miles and big enough to survive the descent through Earth’s atmosphere — are highlighted in bright orange.

NASA/JPL-Caltech

Can We Do It?

An operation of this sort might take months to pull off, from launch to interception, depending on the size and orbit of the object in question, and how prepared we are. With enough warning, it’s definitely possible.

Remo doesn’t even consider the technical challenges of conducting an actual space test all that daunting. Seventy-plus years into the era of nuclear energy, Remo says, “that technology is advanced and well-tested. We know how these devices work. And we don’t need any major advances in rocketry, either.” Ideally, he’d like to test this defensive capability in space, using unarmed warheads to demonstrate that, when the situation arrives, we really could set off the blasts as needed.

Tests involving actual nuclear warheads, however, would be problematic for political reasons, given that several international agreements prohibit bringing nuclear weapons into space, let alone firing them. But these statutes are not cast in stone, and they could be overridden in a life-or-death situation, with the fate of Earth hanging in the balance.

"If a near-Earth object is approaching Earth and we are in great peril, then the U.N. Security Council can make its own decisions about what to do," says Hans Haubold, a senior officer with the United Nations Office of Outer Space Affairs in Vienna, who has co-authored several papers with Remo. "The world powers could meet and determine what technology makes sense for dealing with a particular threat."

Remo fully believes that "when push comes to shove, and our survival is at stake, people will take advantage of any means available to protect the planet — if it comes to that. But they still have to go through the decision-making process, and I'm trying to help them make an informed decision."

If we ever face the prospect of an imminent assault on Earth from a large wayward rock, Remo hopes we can offer a bit more than divine intervention, which was all that Charles Bolden had for Congress in 2013. "I'm not anti-religious," Remo says. "I'm not against praying. But if you're going to pray, maybe you should pray that the rocket works."