DEPT. OF COSMIC DEBRIS

VERMIN OF THE SKY

Who will keep the planet safe from asteroids?

BY TAD FRIEND

"Armageddon" and "Deep Impact," the fireball-laden 1998 movies about, respectively, an incoming asteroid and an incoming comet, were seen by well over a hundred million filmgoers. So word got out that our sector of the solar system is a giant pachinko game, stuffed with asteroids and comets that whiz around looking for something to crash into. These near-Earth objects, or NEOs, as astronomers call them, have been implicated in three mass extinctions, most famously when a seven-mile-wide asteroid slammed into the sea off the Yucatán Peninsula, setting the planet afire and killing off the dinosaurs.

That was a long time ago, even before Ben Franklin or Copernicus. More recently, in 2002, an asteroid exploded over the Mediterranean, and later that year a fiery NEO crashed into a Siberian mountain. In 2008, S.U.V.-size asteroids plunged into the Sudanese desert and streaked over Saskatchewan, and, in 2009, one blew up high above Indonesia, with three times the power of the atom bomb that destroyed Hiroshima. Just last week, a several-ton rock blazed across the noonday sky above the Atlantic Ocean so brightly that it was visible from Massachusetts to Maryland. And still we earthlings haven't mustered a response.

The administrator of NASA, Charlie Bolden, recently declared that deflecting a NEO will be "what keeps the dinosaurs—we are the dinosaurs, by the way—from becoming extinct a second time." Then he admitted that the agency couldn't afford to do that. The annual federal allocation for "planetary defense" is $5.8 million—.03 per cent of NASA's budget—which supports a shoestring program to find NEOs and track their orbits. In truth, NASA doesn't really want the job of global savior, and no one else does, either. "With planetary defense, there's a complex interaction of science, psychology, politics, and money—and everything falls into a gap between disciplines," Robert Arentz, who heads the NEOs team at Ball Aerospace and Technologies Corp., said. "The science guys say, 'NEOs are not scientifically interesting, and saving the planet is not our job,' and the military guys say, 'We'll blow them up, but we don't have anything to do with telescopes or space missions.' The issue's an orphan."

Russell Schweickart has spent a decade trying to change all that. Schweickart, a rangy and congenial former astronaut known as Rusty, was the first man to fly a lunar module in space and the first to take an untethered space walk. He was also the Apollo program's resident hippie and gadfly, possessed of a New Age contrarianism which he maintains at the age of seventy-five. When he and other scientists launched a planetary-defense foundation, in 2001, they named it B612, after the home asteroid in Saint-Exupéry's "The Little Prince." In the belief that it won't be long before a big rock smashes into us at twenty-five thousand miles an hour, he has insistently prodded the government to find the undiscovered NEOs much faster, and to test a method of deflecting an asteroid in space by 2015.

This past June, Schweickart sat in his kitchen, in Sonoma, California, drawing complex orbital diagrams on a napkin to illustrate how a deflection could occur. He scoffed at such proposals as attaching a giant magnifying glass to a satellite to focus the sun's rays on an asteroid; wrapping a NEO in plastic, Christo style, to create a solar sail that would waft the danger aside; or placing a huge bazooka on the moon to pummel the intruder with boulders. Instead, he sketched out the three generally accepted options. Small asteroids discovered with plenty of warning could be nudged aside with a "gravity tractor"—

a plasma-powered craft that would hover near the NEO and use its own gravity to divert the target. (If you slow or accelerate an asteroid by just one centimetre per second, and you start ten years before the projected impact, the cumulative divergence will be sufficient.) For larger or closer NEOs, or those requiring a greater degree of deflection, you'd use "kinetic impactors," spacecraft loaded with lead or copper, to ram the target—speeding nails aimed at a speeding hammer. For NEOs larger than half a kilometre across, or those only a few years out, you'd need nuclear weapons. Such is the confused state of affairs that the Air Force would have to borrow a warhead from the Department of Energy—but couldn't, by law, let NASA stow it on a rocket.

Nonetheless, Schweickart said, "after years of drought, this is the opportunity." He was about to co-chair a task force that would advise NASA on the topic, and the White House—which has taken an interest in asteroids since President Obama declared last year that he wanted to send humans to an asteroid by 2025, as a precursor to an eventual voyage to Mars—had just proposed increasing the agency's planetary-defense budget to $20.3 million. That wouldn't get a deflection mission farther than Topeka, yet Schweickart believed that it indicated a growing awareness of our place in the cosmos. "If there is a cosmic community out there," he said, "they will already have passed this test, of protecting themselves from asteroid impacts that could have wiped them out. If we want to join them, we have to do it, too." He cheerfully acknowledged that such talk had left him vulnerable to the inference that, like David Bowie's Major Tom, he's floating in a most peculiar way. "When Rusty started getting cranked up about this, I can't tell you the slanderous things I heard—'He was up in space too long, and the radiation cooked his brain,' " Robert Arentz said. "For the longest time, studying NEOs was like wearing an aluminum hat."

Many scientists simply can't stomach the issue's chunky gumbo of astrophysics, nuclear buccaneering, and end-times entertainment. Dwayne Day, the study director of "Defending Planet Earth," a comprehensive report published last year by the National Research Council, said, "We're talking about very small risks—if a big asteroid was out there, we'd have seen it by now. And yet every time you turn on the sci-fi channel Earth is getting blasted by one of these things." The report noted with vexation that spending guidelines for appropriate defensive procedures can't readily be assayed, as "it is very challenging to measure . . . the value of entire social entities (such as ethnic groups, cities, and nations)." And it concluded, rather disapprovingly, that should a large NEO be observed heading our way a response would be difficult to coördinate, as "there would likely be a tendency for the entire social structure to collapse."

JAIME HERNANDEZ

If an asteroid threatened, a government report found, "there would likely be a tendency for the entire social structure to collapse."

Asteroids are would-be planets—rocky or metallic fragments left over from the beginning of the solar system, 4.6 billion years ago, that never amalgamated. There are several million in our general neighborhood, the bulk of them in the asteroid belt between Mars and Jupiter, all orbiting the sun up to ten times faster than a speeding bullet. They

were once known as "vermin of the sky," because they always seemed to obscure whatever astronomers actually wanted to see, but, paradoxically, when you *are* looking for asteroids, they're extremely elusive. Most absorb more than eighty per cent of the sunlight that strikes them, making them as visible as ashes at dusk, and those in Earth-like orbits can be hidden behind the sun for decades. Once discerned, however, they prove astonishingly diverse. Some are sturdy as anvils; some are cottony rubble piles; some spin wildly, surrounded by tiny moonlets; and some resemble dog bones. Mark Boslough, a physicist at Sandia National Laboratories, said, "They're like snowflakes, but even more variable."

Like snowflakes, they fall to Earth. About a hundred tons of dust- and sand-size space rock bombards our atmosphere daily, and bolides—NEOs that catch fire upon entering the atmosphere—have been implicated in everything from the Chicago Fire of 1871 to the wrathful "brimstone and fire" visited upon Sodom and Gomorrah. In 3123 B.C., a Sumerian astronomer reported seeing a bolide a kilometre wide streaking across the sky like a "white stone bowl approaching." Along its path over Sodom and Gomorrah, en route to crashing in the Austrian Alps, it would have broiled those below at temperatures reaching seven hundred and fifty degrees. A pair of British astronautical engineers, Mark Hempsell and Alan Bond, argue that the bolide inspired the Greek myth of Phaeton—who lost control of his father's sun chariot and plunged to Earth—and was also responsible for the demise of Ötzi, the mummified "ice man" found in the Alps, in 1991, with an arrowhead in his shoulder. One suggestion is that Ötzi was sacrificed afterward to placate the gods, but Hempsell believes that he died in the explosion, and points out that if you're about to be hit by a colossal shock wave, "having a quiver full of arrows on your back is not a good idea."

Earth itself was born of repeated impacts from primordial asteroids known as planetismals, which gradually swelled the size of the globe. (Along the way, a collision with a Mars-size planet broke loose the mass that became the moon.) Those impacts also brought us water, carbon, nitrogen, and amino acids, making life possible. Through the ages, then, asteroids have behaved like strung-out parents, screeching up to the house at random intervals to bestow lavish gifts or savage whippings.

In July, NASA's Ad Hoc Task Force on Planetary Defense gathered for two days in a shabby, fluorescent-lit conference room at the Millennium Harvest House hotel, in Boulder, Colorado. They were seven graying men with laptops and unstylish haircuts. Their mission—at least as far as Rusty Schweickart was concerned—was to take the uncertainties inherent in dealing with NEOs and make the problem seem manageable, fundable, and pressing.

Near the outset of their first session, Schweickart fired a warning shot at his colleagues, most of whom were planetary scientists who liked to look before they launched. "Some scientist will die to know that a body is eighteen per cent magnesium—I don't care," Schweickart said. "I care about finding as many of these things as quickly as possible and determining if they're coming at us."

Richard Binzel, an M.I.T. professor, replied, "If an object's a serious threat, we'd want to know its composition." Otherwise, he said, you'd have no idea whether the NEO would be jarred by a deflection impact or whether it would splinter into dangerous shards. Our understanding of what it's like to operate near an asteroid is almost nil. In 2003, the Japanese sent an unmanned probe to the asteroid Itokawa; once there, the probe lost power and its rover inexplicably angled off into space.

ON HARLECH BEACH

Sharpen your eyes looking back from the tide's headland,
and the Lowry figures on the beach could be movable type—
a "p," pink, "i," indigo, an "x" running yellow and tan
in pursuit of a flying stop. What an alphabet soup
the bay makes of them, these large fathered families
downloading their daughters and sons, sans serif and
sans grief on the centerfold page of the sand.

From which a Welsh double "l" is detaching itself—
lovers, hand-linked by a hyphen, weaving with ease
through the ins and outs of the waves' parentheses.
From a distance how simple they look, how picturesque.
Three dots (an ellipsis in action) rush back and forth—
terriers seeking, retrieving, time-free and carefree
as only dogs in illiterate joyousness can be.

It's a scene to write about. You could walk back
cheering—if not for the human story, for the display
it offers to the pattern-hungry eye—
the body sway of the lovers, a Frisbee caught
by a bronze torso, striped pigments of cloud and sky
brushed by an appearing, disappearing sun;
prone golden mums and their lucky cartwheeling young.

As if this were a playground raised from the dead for them,
the salvaged remains of old beachheads, suffered and won.
Unremarked by the holiday crowd, two faraway swarms—
I would paint them as shadows in khaki and bloodstained brown—
turn out to be birds: an invasion of scavenging "m"s
whose squabble of laughter is raucous enough to drown
those boys shouting "King of the castle" as they kick it down.

—*Anne Stevenson*

Schweickart threw his arms up and cried, "Please allow me to continue where I'm going, in trying to save the planet!"

"Who could stop you?" another committee member asked. Binzel's cell phone rang, broadcasting the "Star Trek" theme, and everyone smiled.

Schweickart noted that, as NASA finds more NEOs, "we're going to have to make more and more decisions about whether to try to deflect without knowing much about what we're deflecting—not only what a NEO is, exactly, but where." Observations of NEOs are often so brief, before they disappear below the horizon or behind the sun, that astronomers can be hours off in plotting their orbits—with each hour translating to some twenty-five thousand miles. Many NEOs' positions can be determined only to within a realm of possibility known as the "probability cloud" or, more frankly, as the "error cloud."

Testimony from Ed Lu, a former astronaut who helped dream up the gravity tractor, reinforced Schweickart's point. Lu explained that, because asteroids shift course after a "close approach" to a heavy object such as a planet, "you're not insuring that a point misses Earth but that a probability cloud misses Earth. As Apophis shows, when there are close approaches it can be difficult to eliminate the possibility of a later hit."

The asteroid Apophis, named after the Egyptian god Apep the Destroyer, was first observed in 2004. Astronomers calculated that it had a one-in-thirty-eight chance of hitting us in 2029—on Friday, April 13th, as it happens—and that the three-hundred-metre-wide rock would strike with the force of fifty-eight thousand Hiroshimas. Subsequent observations increased the probability of impact to one in twenty-seven. Then, after yet more observations, the odds fell to near zero; it now looked likely to miss—though by a mere eighteen thousand miles, putting it inside the orbits of our communications satellites. But there remains a very slim chance that on its close approach Apophis could slide through a so-called keyhole—a region near Earth in which our gravitational field would deflect the asteroid just enough that it would slam into us on a subsequent pass, in 2036.

"The decision-maker's dilemma," Lu said, "is either get more data or act now. Waiting makes deflection harder—it's much easier to deflect an asteroid from a keyhole twenty years in advance than to have to deflect it from the planet three years in advance."

Schweickart observed, "The real decision people are going to have to make is 'Do we spend a billion dollars for a mission that up to ninety per cent of the time will turn out to be unnecessary?' " The prevailing scientific view is that we should try to divert any large object that has at least a one-in-a-hundred chance of hitting us; however, most politicians would be loath to spend significant sums—and a 2004 study put the cost of a nuclear-defense campaign at about twelve billion dollars—unless it's absolutely clear that they must.

Richard Binzel said, "So maybe the thing to focus on is a super-precise way of determining orbits, by putting a dish on—oh, I'm being crazy—Mercury."

"Not Mercury!" Don Yeomans, the manager of NASA's NEO program at the Jet Propulsion Laboratory, called out. To have the best view of near-Earth objects, he argued, you'd want to be inside Earth's orbit, looking away from the sun—but you'd also want to be much closer than Mercury, so that objects appeared larger and brighter.

"O.K., Mars," Binzel said. Yeomans shook his head: then you'd be looking toward the sun. "I'm just trying to make them go away in the first place," Binzel continued, crossly. "Pretend that astronomers on *Venus* had helped us out for ten years—maybe Apophis is already gone as a threat." Yeomans nodded his approval.

Schweickart protested the conversation's drift away from deflection, saying that while the scientists were busy trying to pinpoint orbits an asteroid might heave up and strike us. Ed Lu added, "It'd be like putting smoke alarms in your house, but not having a fire department. All you can do is run out of the house." Unless you're stuck there.

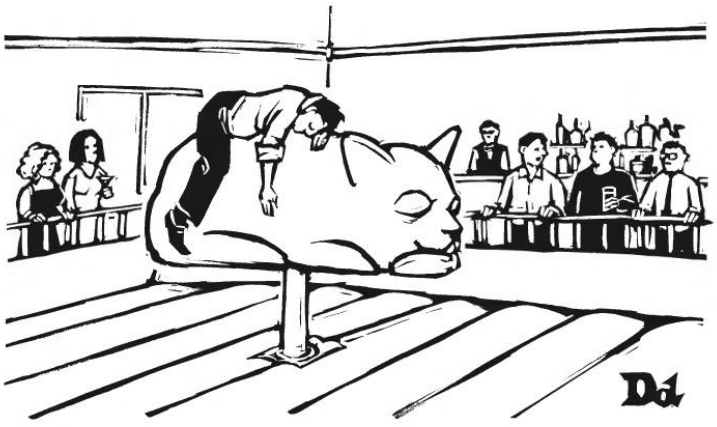
In 1980, only ninety-seven NEOs had been identified, and no one was really looking for more. We view the sky as fundamentally sheltering, and it's hard to conjure with events that occur on a timescale longer than our own; few people have firsthand recollections of the

last major impact, in 1908, when an asteroid flattened two thousand square kilometres of forest in the Tunguska region of Siberia. Ken Ford, the chair of the NASA Advisory Council, said, "The very short perspective we have as humans makes the threat of asteroids seem smaller than it is. People of all sorts find it easier to kick the can down the road and hope for a mystical solution later."

It's also hard to gauge, with low-probability, high-consequence events like a NEO strike, whether it's more appropriate to be paranoid or blasé. Statistics from the National Research Council suggest that future asteroid impacts could kill an average of ninety-one people a year; by way of comparison, five people die annually from shark attacks, and a million from malaria. But the impacts figure is nothing more than a guesstimate, as the number of people known for sure to have been killed by asteroids is, well, zero. (In 1954, a woman in Sylacauga, Alabama, was somewhat bruised by a brick-size meteorite that plunged through the roof and bounced off her radio.)

Global anxiety over the matter spiked in 1994, when the comet Shoemaker-Levy 9 hit Jupiter, leaving scars the size of Earth. The impressive photographs inspired screenwriters and bill writers alike. In 1998, Congress directed NASA to find and track ninety per cent of the NEOs greater than one kilometre in diameter, any one of which could obliterate France. In 2005, it amended the legislation to require the detection, by 2020, of NEOs larger than a hundred and forty metres in diameter: ones that could annihilate the Washington, D.C., region. By renting time on telescopes in the Western U.S., Puerto Rico, and Australia, NASA has met the earlier target; nine hundred and nine large NEOs have been identified, of the estimated thousand or so out there. But the agency lacks the resources to meet the deadline for smaller asteroids, having found only 6,903 of an estimated twenty-five thousand. "We need a leap, new tools," Jim Green, the director of NASA's Planetary Science Division, acknowledged.

The difficulty that planetary defense has always faced is that until an asteroid looms in its "death plunge" the topic seems remote from constituent concerns. No political glory or capital accrues from taking measures that might, decades later, prove to have been prudent. There's also the gravitas question, a.k.a. the "giggle factor." Representative Dana Rohrabacher, a conservative Republican from California's Orange County, who has been the leading (if not the only) voice in Congress for planetary defense, told me, "Anybody who talks about objects from space is ridiculed as the Chicken Little congressman." As a speechwriter for Ronald Reagan, he was an early proponent of the Star Wars initiative to blast incoming missiles, and he explains, "If you're going to protect yourself from some rogue missile out of Pakistan or Iran, yeah, that could cost hundreds of thousands of lives, but some NEO could land in the Pacific and cause a tsunami that would kill *millions* of people in California!"



"It's a lot easier than the mechanical bull."

When Rohrabacher was six, he remembers, he was overwhelmed on a family vacation by the sight of Arizona's Meteor Crater. In his congressional tenure, he's been disturbed by visions of similar impacts, so he's discouraged by the relative modesty of his legislative accomplishments: he sponsored the original bill that established the 1998 NASA survey, and at his instigation Congress recently gave the White House's Office of Science and Technology Policy the task of assigning a federal agency to oversee planetary defense. In his office, surrounded by model rockets, Rohrabacher gloomily observed, "I have no doubt that, if we saw one of these things, all of a sudden the members who now ridicule me would be saying, 'Oh, Dana, how visionary you were!' " In the meantime, he said, "the stampede of people trying to get the public to move on global warming versus the tiny number on an issue that really could destroy us—it gives me a further understanding of the flaws of humankind."

NASA, for its part, is stretched too thin to develop a muscular planetary-defense program, despite evidence that the public is devoted to the issue. (NASA's @AsteroidWatch Twitter feed has seven hundred and forty thousand followers, nearly as many as NASA's main feed.) The agency's budget, now nineteen billion dollars, has been cut severely since the Apollo program—to less than one-seventh its former share of federal spending. Not only does NASA lack the heavy-lift rockets necessary for an ambitious mission to intercept an asteroid; it won't even be able to get astronauts into near-Earth orbit once the Space Shuttle is mothballed, later this year. Elon Musk, the founder of the rocket-building company Space X, observed, "If something was on a track to hit us, one of the big rocks that leave only cockroaches and mushrooms, we'd be screwed. The state of rocketry sucks—we've regressed to being worse than the sixties."

Rusty Schweickart has always looked up for ideas about what to do next. As a boy, in rural New Jersey, he was transfixed by planes from a nearby naval air station that practiced dogfighting over his family's farm. After attending M.I.T., where he earned a B.S. in aero-

nautical engineering (and, later, an M.S. in aeronautics and astronautics), he became a fighter pilot. In 1963, he was chosen for NASA's third group of astronauts, along with Buzz Aldrin and Alan Bean. Bean recalls, "Rusty always had a broader, more humanitarian point of view. We had to take a nuclear device up to power experiments on the moon, and Rusty was unafraid to say, 'What happens if we have to abort? It could burn up and scatter nuclear waste all over'—where the rest of us were like, 'Shut the fuck up. Let's just hope that doesn't happen.'"

During his forty-seven-minute space walk, in 1969, Schweickart had a transforming experience. His epiphany, which he first discussed in 1974, at a New Age conference on Long Island, inspired a documentary film and a children's ballet and was later included in one of the "Chicken Soup for the Soul" books. Schweickart spoke of apprehending Earth's vulnerability as he gazed down on it: "It is so small and so fragile and such a precious little spot in that universe that you can block it out with your thumb. And you realize that on that small spot, that little blue-and-white thing, is everything that means anything to you—all of history and music and poetry and art and death and birth and love." By some chance, he felt, he'd been picked out to realize this, to be "the sensing element for man."

In the seventies, Schweickart was as likely to be found aboard Jacques Cousteau's bathysphere as checking a Skylab manifest. Stewart Brand, the futurist who created the "Whole Earth Catalog," introduced him to California's governor, Jerry Brown, who in 1977 made Schweickart his Assistant for Science and Technology. Schweickart fostered Brown's interest in space policy, which led to a statewide Space Day and plans for a state satellite—and ultimately boomeranged on the politician, when he was dubbed "Governor Moonbeam." But Brand notes that Schweickart's idealism is grounded in experience: "Going camping with Rusty was a memorable experience, because he watches the sky in a different way—he's looking for traffic, calling out satellites. And it makes you jump to realize he was out there, on the other side."

Recalling the effect of his space walk, Schweickart told me, "I came to call it cosmic birth—Earth is giving birth to consciousness into the cosmos. The fetus, near nine months, puts out a lot of waste, just as we're now putting out a lot of pollution, and begins to demand more resources than are available—and then the mother, naturally, but violently and traumatically, expels the child. The real relationship between mother and child starts after birth, when the child can look back at his mother. And that's what I was doing. My prior inclination toward environmentalism was dramatically amplified—my environment now became the planet."

After the Task Force concluded its first day's work, its members relaxed over dinner, at the Boulder Dushanbe Tea House, by pitying all those who get planetary defense wrong, which turned out to be pretty much everyone but the Task Force. "We were all snickering over 'Armageddon,' with oil drillers going into space on the Shuttle to bury nukes deep in the asteroid," Clark Chapman, an eminent planetary scientist, said. (The Shuttle can't go beyond a near-Earth orbit; nukes would be deployed in standoff explosions to nudge the asteroid, rather than in subsurface blasts that would send smithereens everywhere; and oil drillers wouldn't . . . well, it's pretty clear.)

"An asteroid as big as Texas!" Brian Wilcox, the lead engineer on several NASA projects involving robotic vehicles, marvelled. "There's only one asteroid that size in the solar system, and Ceres is not going to hit us."

Chapman recalled, "At the Los Alamos Conference on planetary defense"—in 1992—"Ed Teller actually said, 'I would love to blow up Ceres!'" Teller, the father of the hydrogen bomb, was also a zealous proponent of blasting rogue NEOs.

"What did Ceres ever do to us?" I asked.

Chapman squinted at me. "That wasn't really the point," he said. "The point was that it would be a really big bomb."

Deflection methods are freighted with symbolism: anything that smacks of nuclear vigilantism, or Bond-villain-style laser gizmology, could suggest that

we're militarizing space. Alarmists have even suggested that the U.S. might seek to divert an asteroid just enough that it lands on our enemies. However, a military figure familiar with the issue scoffs, "There are so many ways to kill people that precision-plowing an asteroid would be a preposterous way to spend money." Also, few generals would be willing to wait decades or even centuries for the necessary asteroid to come along.

The head of Russia's space agency declared not long ago that his country was planning a mission to deflect Apophis—which some Americans worry could misdirect the asteroid into a keyhole. The question of how the world should make such decisions has been sitting in the United Nations' relevant circle of hell, the Committee on the Peaceful Uses of Outer Space, for twelve years. Norm Augustine, who chaired two reviews of NASA's mission, says that international coöperation on the topic is such that, if we tried to deflect an incoming asteroid, "it would be just our luck that we decided to push it to the east, and the Russians decided to push it to the west, and we got there at the same time."

On the second day of the conference, as the Task Force began to discuss its recommendations, Schweickart addressed Richard Binzel: "So your question, which got me thinking half the night, was 'How do we get the most precise orbits?' Because getting precision on these things turns out to be more important than finding more of them." The group had heard two proposals for placing a satellite equipped with an infrared telescope—the ideal tool for picking up NEOs, which are dim in the visible spectrum—in a Venus-like orbit. Such a satellite would enable NASA to meet the congressional requirement for spotting smaller NEOs in seven and a half years—rather than the twenty to forty allowed by ground-based telescopes—and also to track NEOs for longer periods and pin down their orbits. Schweickart, with the enthusiasm of a new convert, now suggested that such a telescope would "dramatically pay for itself," as it would obviate expensive false-alarm deflection missions.

Surprised, Binzel said, "We're in violent agreement!"

But then Brian Wilcox, the robotics expert, posed another challenge to Schweickart's plans. He questioned the need to test a deflection mission, pointing out that, even though the NASA survey has been seriously underfunded, "we've gone in the last dozen years from an estimate of 1,166 fatalities per year to ninety-one. And pretty soon we're going to be down to twenty-five per year—a number that derives from a twenty-five-thousand-fatality event that happens every thousand years, probably somewhere outside the United States. Just to play devil's advocate, we kill forty thousand people a year in America on the freeways. An intelligent person from the outside world is going to say, 'Why do we need to do anything more than keep looking as we have been?' " NASA's position is that its survey has pretty much ruled out our being hit by any planet- or country-killing NEOs in the next century; the agency's Jim Green told me, "We now know, to a high degree of probability, that we're not under imminent threat in our lifetimes."

One well-placed government expert argues that NASA's confidence is unfounded: "We're not effectively safer; we're just better informed. If an asteroid heads for us, we still have no plan in place." Indeed, if an unknown comet or asteroid were to pop out from behind the sun, we'd have just three to six days' warning. And while long-period comets pose less than one per cent of the over-all threat, their sheer mass and force would make them almost invincible, even with years of warning. In 2005, Ball Aerospace banged a rocket into the comet Tempel-1 at twenty-three thousand miles per hour, basically to see what would happen. The comet was unfazed.

What's more, recent work by the physicist Mark Boslough has shown that even asteroids well under Congress's hundred-and-forty-metre limit can cause significant damage. Boslough persuasively argued, using computer simulations, that the asteroid that flattened the Tunguska forest in 1908 was only thirty to fifty metres wide—about one-third as massive as had been thought. Boslough determined that the bolide actually blew up in the air, creating a violent downward shock wave. All of which means, as there are many more small asteroids than large ones, that we've been hit with airbursting asteroids—and will continue to get hit—much more than we'd thought, as often as every two hundred years. And small ones are the hardest to detect.

"The actuarial argument is important," Chapman now told Wilcox. "But, unlike with Hurricane Katrina, we can do something about an asteroid. The question is whether we'd rather be wrong in overprotecting or underprotecting."

The scope of American power and accountability—the extent to which we are responsible for a Tunguska-like event abroad—lay uneasily beneath the Task Force's closing discussions. Robert Arentz, of Ball Aerospace, sitting in after making a presentation, wondered, "Is it ethical to play God with the lives of the rest of the planet?"

In early October, the NASA Advisory Council met in Palmdale, California, to hear the Task Force's report. Schweickart's bold vision had carried the day, and the recommendations included setting up a Planetary Defense Coördination Office within NASA, and spending as much as three billion dollars over ten years to, among other things, place an infrared telescope into a Venus-like orbit, and test both kinetic impactors and gravity tractors. Ken Ford, the Advisory Council's chairman, told me, "What I liked about the report was it wasn't 'The sky is falling,' and it wasn't 'We need an Apollo-level effort.' It was measured, incremental, and actionable."

Schweickart was listening in via Skype from his hotel in Kuala Lumpur, where he was attending a congress of the Association of Space Explorers, an international group that he founded in 1985. It was after midnight, local time. He said, "I was sitting in the hallway with the Romanian cosmonaut Dumitru Prunariu, using the Wi-Fi from locked conference rooms, on mute, with the hotel staff vacuuming up and down the hall." When the Advisory Council

unanimously approved the Task Force's findings, Schweickart and Prunariu jumped up and high-fived.

Nine days later, the White House's Office of Science and Technology Policy recommended that NASA be the agency that oversees all research into planetary defense. Significantly, the decision also yoked NEO detection and mitigation to President Obama's plan to send humans to an asteroid by 2025, envisaging deflection activities "as part of the overall mission planning and objectives."

At the moment, the number of asteroids judged suitable for a human visit is fewer than nine, and perhaps as few as zero. So there is an obvious need to find more asteroids—and to learn considerably more about what it's like to operate in their neighborhoods. Paul Abell, the lead NEO scientist at NASA's Johnson Space Flight Center, said that, to find the right asteroid for a human mission, "my personal opinion is we need a space-based survey telescope, which could give us up to forty times the number of targets." Within two and a half years, the Venus-orbit telescope touted by the Task Force could find several hundred promising asteroids closer to home, which could cut billions of dollars out of the price of a mission. Yet what would be a small step for a human mission turns out to be a giant leap for planetary defense: NASA has already indicated that it doesn't have the roughly six hundred and fifty million dollars needed to fund the telescope. And a practice grapple with an asteroid may occur, as vaguely promised by the White House, only when the human mission launches, in fourteen years. (If it does launch: in January, an internal NASA study suggested that a human mission to an asteroid would be "too costly.")

One senior planetary-defense advocate suggests that should the human mission take precedence the tail would truly be wagging the dog. "Saving millions to billions of people and civilization itself is a more important goal than displaying American plumage and vigor by visiting an asteroid," he said. "But, in order to support three to five guys going to an asteroid, I may finally be able to find money for planetary defense."

Still, Schweickart believes that his work as the Johnny Appleseed of NEO deflection has begun to bear fruit. "We're going to have the decision-making systems up and running soon," he insists. "And in my lifetime, if you give me twenty more years, which would be nice, the chance of our being hit by a twenty-five- to thirty-metre object is one in ten—yet there will be, conservatively, at least twenty other objects that will look like they *might* hit us. So we're going to have to make a tough decision at least twice while I'm around." Even if politicians temporize, Schweickart predicted, "before too long there will be a bolide in the sky over Washington, D.C., and that's going to *really* focus us." ♦

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Tad Friend talks about asteroids.