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JUNE 2008 ATLANTIC MONTHLY

The odds that a potentially devastating space rock will hit Earth this century may be as high as one in 10. So why isn't NASA trying harder to prevent catastrophe?

BY GREGG EASTERBROOK

The Sky Is Falling


Image credit: Stéphane Guisard, www.astrosurf.com/sguisard

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Gregg Easterbrook leads an illustrated tour through the treacherous world of space rocks.

Breakthrough ideas have a way of seeming obvious in retrospect, and about a decade ago, a Columbia University geophysicist named Dallas Abbott had a breakthrough idea. She had been pondering the craters left by comets and asteroids that smashed into Earth. Geologists had counted them and concluded that space strikes are rare events and had occurred mainly during the era of primordial mists. But, Abbott realized, this deduction was based on the number of craters found on land—and because 70 percent of Earth's surface is water, wouldn't most space objects hit the sea? So she began searching for underwater craters caused by impacts rather than by other forces, such as volcanoes. What she has found is spine-chilling: evidence that several enormous asteroids or comets have slammed into our planet quite recently, in geologic terms. If Abbott is right, then you may be here today, reading this magazine, only because by sheer chance those objects struck the ocean rather than land.

Abbott believes that a space object about 300 meters in diameter hit the Gulf of Carpentaria, north of Australia, in 536 A.D. An object that size, striking at up to 50,000 miles per hour, could release as much energy as 1,000 nuclear bombs. Debris, dust, and gases thrown into the atmosphere by the impact would have blocked sunlight, temporarily cooling the planet—and indeed, contemporaneous accounts describe dim skies, cold summers, and poor harvests in 536 and 537. "A most dread portent took place," the Byzantine historian Procopius wrote of 536; the sun "gave forth its light without brightness." Frost reportedly covered China in the summertime. Still, the harm was mitigated by the ocean impact. When a space object strikes land, it kicks up more dust and debris, increasing the global-cooling effect; at the same time, the combination of shock waves and extreme heating at the point of impact generates nitric and nitrous acids, producing rain as corrosive as battery acid. If the Gulf of Carpentaria object were to strike Miami today, most of the city would be leveled, and the atmospheric effects could trigger crop failures around the world.

What's more, the Gulf of Carpentaria object was a skipping stone compared with an object that Abbott thinks whammed into the Indian Ocean near Madagascar some 4,800 years ago, or about 2,800 B.C. Researchers generally assume that a space object a kilometer or more across would cause significant global harm: widespread destruction, severe acid rain, and dust storms that would darken the world's skies for decades. The object that hit the Indian Ocean was three to five kilometers across, Abbott believes, and caused a tsunami in the Pacific 600 feet high—many times higher than the 2004 tsunami that struck Southeast Asia. Ancient texts such as Genesis and the Epic of Gilgamesh support her conjecture, describing an unspeakable planetary flood in roughly the same time period. If the Indian Ocean object were to hit the sea now, many of the world's coastal cities could be flattened. If it were to hit land, much of a continent would be leveled; years of winter and mass starvation would ensue.

At the start of her research, which has sparked much debate among specialists, Abbott reasoned that if colossal asteroids or comets strike the sea with about the same frequency as they strike land, then given the number of known land craters, perhaps 100 large impact craters might lie beneath the oceans. In less than a decade of searching, she and a few colleagues have already found what appear to be 14 large underwater impact sites. That they've found so many so rapidly is hardly reassuring.

Other scientists are making equally unsettling discoveries. Only in the past few decades have astronomers begun to search the nearby skies for objects such as asteroids and comets (for convenience, let's call them "space rocks"). What they are finding suggests that near-Earth space rocks are more numerous than was once thought, and that their orbits may not be as stable as has been assumed. There is also reason to think that space rocks may not even need to reach Earth's surface to cause cataclysmic damage. Our solar system appears to be a far more dangerous place than was previously believed.

The received wisdom about the origins of the solar system goes something like this: the sun and planets formed about 4.5 billion years ago from a swirling nebula containing huge amounts of gas and dust, as well as relatively small amounts of metals and other dense substances released by ancient supernova explosions. The sun is at the center; the denser planets, including Earth, formed in the middle region, along with many asteroids—the small rocky bodies made of material that failed to incorporate into a planet. Farther out are the gas-giant planets, such as Jupiter, plus vast amounts of light elements, which formed comets on the boundary of the solar system. Early on, asteroids existed by the millions; the planets and their satellites were bombarded by constant, furious strikes. The heat and shock waves generated by these impacts regularly sterilized the young Earth. Only after the rain of space objects ceased could life begin; by then, most asteroids had already either hit something or found stable orbits that do not lead toward planets or moons. Asteroids still exist, but most were assumed to be in the asteroid belt, which lies between Mars and Jupiter, far from our blue world.

As for comets, conventional wisdom held that they also bombarded the planets during the early eons. Comets are mostly frozen water mixed with dirt. An ancient deluge of comets may have helped create our oceans; lots of comets hit the moon, too, but there the light elements they were composed of evaporated. As with asteroids, most comets were thought to have smashed into something long ago; and, because the solar system is largely void, researchers deemed it statistically improbable that those remaining would cross the paths of planets.

These standard assumptions—that remaining space rocks are few, and that encounters with planets were mainly confined to the past—are being upended. On March 18, 2004, for instance, a 30-meter asteroid designated 2004 FH—a hunk potentially large enough to obliterate a city—shot past Earth, not far above the orbit occupied by telecommunications satellites. (Enter "2004 FH" in the search box at Wikipedia and you can watch film of that asteroid passing through the night sky.) Looking at the broader picture, in 1992 the astronomers David

Jewitt, of the University of Hawaii, and Jane Luu, of the Massachusetts Institute of Technology, discovered the Kuiper Belt, a region of asteroids and comets that starts near the orbit of Neptune and extends for immense distances outward. At least 1,000 objects big enough to be seen from Earth have already been located there. These objects are 100 kilometers across or larger, much bigger than whatever dispatched the dinosaurs; space rocks this size are referred to as “planet killers” because their impact would likely end life on Earth. Investigation of the Kuiper Belt has just begun, but there appear to be substantially more asteroids in this region than in the asteroid belt, which may need a new name.

Beyond the Kuiper Belt may lie the hypothesized Oort Cloud, thought to contain as many as trillions of comets. If the Oort Cloud does exist, the number of extant comets is far greater than was once believed. Some astronomers now think that short-period comets, which swing past the sun frequently, hail from the relatively nearby Kuiper Belt, whereas comets whose return periods are longer originate in the Oort Cloud.

But if large numbers of comets and asteroids are still around, several billion years after the formation of the solar system, wouldn’t they by now be in stable orbits—ones that rarely intersect those of the planets? Maybe not. During the past few decades, some astronomers have theorized that the movement of the solar system within the Milky Way varies the gravitational stresses to which the sun, and everything that revolves around it, is exposed. The solar system may periodically pass close to stars or groups of stars whose gravitational pull affects the Oort Cloud, shaking comets and asteroids loose from their orbital moorings and sending them downward, toward the inner planets.

Consider objects that are already near Earth, and the picture gets even bleaker. Astronomers traditionally spent little time looking for asteroids, regarding them as a lesser class of celestial bodies, lacking the beauty of comets or the significance of planets and stars. Plus, asteroids are hard to spot—they move rapidly, compared with the rest of the heavens, and even the nearby ones are fainter than other objects in space. Not until the 1980s did scientists begin systematically searching for asteroids near Earth. They have been finding them in disconcerting abundance.

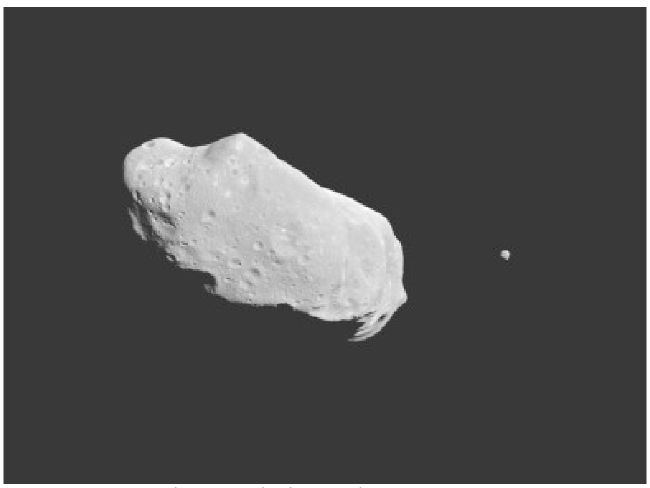
In 1980, only 86 near-Earth asteroids and comets were known to exist. By 1990, the figure had risen to 170; by 2000, it was 921; as of this writing, it is 5,388. The Jet Propulsion Laboratory, part of NASA, keeps a running tally at www.neo.jpl.nasa.gov/stats. Ten years ago, 244 near-Earth space rocks one kilometer across or more—the size that would cause global calamity—were known to exist; now 741 are. Of the recently discovered nearby space objects, NASA has classified 186 as “impact risks” (details about these rocks are at www.neo.jpl.nasa.gov/risk). And because most space-rock searches to date have been low-budget affairs, conducted with equipment designed to look deep into the heavens, not at nearby space, the actual number of impact risks is undoubtedly much higher. Extrapolating from recent discoveries, NASA estimates that there are perhaps 20,000 potentially hazardous asteroids and comets in the general vicinity of Earth.

There’s still more bad news. Earth has experienced several mass extinctions—the dinosaurs died about 65 million years ago, and something killed off some 96 percent of the world’s marine species about 250 million years ago. Scientists have generally assumed that whatever caused those long-ago mass extinctions—comet impacts, extreme volcanic activity—arose from conditions that have changed and no longer pose much threat. It’s a comforting notion—but what about the mass extinction that occurred close to our era?

About 12,000 years ago, many large animals of North America started disappearing—woolly mammoths, saber-toothed cats, mastodons, and others. Some scientists have speculated that Paleo-Indians may have hunted some of the creatures to extinction. A millennia-long mini–Ice Age also may have been a factor. But if that’s the case, what explains the disappearance of the Clovis People, the best-documented Paleo-Indian culture, at about the same time? Their population stretched as far south as Mexico, so the mini–Ice Age probably was not solely responsible for their extinction.

A team of researchers led by Richard Firestone, of the Lawrence Berkeley National Laboratory, in California, recently announced the discovery of evidence that one or two huge space rocks, each perhaps several kilometers across, exploded high above Canada 12,900 years ago. The detonation, they believe, caused widespread fires and dust clouds, and disrupted climate patterns so severely that it triggered a prolonged period of global cooling. Mammoths and other species might have been killed either by the impact itself or by starvation after their food supply was disrupted. These conclusions, though hotly disputed by other researchers, were based on extensive examinations of soil samples from across the continent; in strata from that era, scientists found widely distributed soot and also magnetic grains of iridium, an element that is rare on Earth but common in space. Iridium is the meteor-hunter's lodestar: the discovery of iridium dating back 65 million years is what started the geologist Walter Alvarez on his path-breaking theory about the dinosaurs' demise.

A more recent event gives further cause for concern. As buffs of the television show *The X Files* will recall, just a century ago, in 1908, a huge explosion occurred above Tunguska, Siberia. The cause was not a malfunctioning alien star-cruiser but a small asteroid or comet that detonated as it approached the ground. The blast had hundreds of times the force of the Hiroshima bomb and devastated an area of several hundred square miles. Had the explosion occurred above London or Paris, the city would no longer exist. Mark Boslough, a researcher at the Sandia National Laboratory, in New Mexico, recently concluded that the Tunguska object was surprisingly small, perhaps only 30 meters across. Right now, astronomers are nervously tracking 99942 Apophis, an asteroid with a slight chance of striking Earth in April 2036. Apophis is also small by asteroid standards, perhaps 300 meters across, but it could hit with about 60,000 times the force of the Hiroshima bomb—enough to destroy an area the size of France. In other words, small asteroids may be more dangerous than we used to think—and may do considerable damage even if they don't reach Earth's surface.



ASTEROID 243 IDA, about 35 miles long, and its moon
(Image courtesy of NASA/NSSDC)

Until recently, nearly all the thinking about the risks of space-rock strikes has focused on counting craters. But what if most impacts don't leave craters? This is the prospect that troubles Boslough. Exploding in the air, the Tunguska rock did plenty of damage, but if people had not seen the flashes, heard the detonation, and traveled to the remote area to photograph the scorched, flattened wasteland, we'd never know the Tunguska event had happened. Perhaps a comet or two exploding above Canada 12,900 years ago spelled the end for saber-toothed cats and Clovis society. But no obvious crater resulted; clues to the calamity were subtle and hard to come by.

Comets, asteroids, and the little meteors that form pleasant shooting stars approach Earth at great speeds—at least 25,000 miles per hour. As they enter the atmosphere they heat up, from friction, and compress, because they decelerate rapidly. Many space rocks explode under this stress, especially small ones; large objects are more likely to reach Earth's surface. The angle at which objects enter the atmosphere also matters: an asteroid or comet approaching straight down has a better chance of hitting the surface than one entering the atmosphere at a shallow angle, as the latter would have to plow through more air, heating up and compressing as it descended. The object or objects that may have detonated above Canada 12,900 years ago would probably have approached at a shallow angle.

If, as Boslough thinks, most asteroids and comets explode before reaching the ground, then this is another reason to fear that the conventional thinking seriously underestimates the frequency of space-rock strikes—the small number of craters may be lulling us into complacency. After all, if a space rock were hurtling toward a city, whether it would leave a crater would not be the issue—the explosion would be the issue.

A generation ago, the standard assumption was that a dangerous object would strike Earth perhaps once in a million years. By the mid-1990s, researchers began to say that the threat was greater: perhaps a strike every 300,000 years. This winter, I asked William Ailor, an asteroid specialist at The Aerospace Corporation, a think tank for the Air Force, what he thought the risk was. Ailor's answer: a one-in-10 chance per century of a dangerous space-object strike.

Regardless of which estimate is correct, the likelihood of an event is, of course, no predictor. Even if space strikes are *likely* only once every million years, that doesn't mean a million years will pass before the next impact—the sky could suddenly darken tomorrow. Equally important, improbable but cataclysmic dangers ought to command attention because of their scope. A tornado is far more likely than an asteroid strike, but humanity is sure to survive the former. The chances that any one person will die in an airline crash are minute, but this does not prevent us from caring about aviation safety. And as Nathan Myhrvold, the former chief technology officer of Microsoft, put it, "The odds of a space-object strike during your lifetime may be no more than the odds you will die in a plane crash—but with space rocks, it's like the entire human race is riding on the plane."

Given the scientific findings, shouldn't space rocks be one of NASA's priorities? You'd think so, but Dallas Abbott says NASA has shown no interest in her group's work: "The NASA people don't want to believe me. They won't even listen."

NASA supports some astronomy to search for near-Earth objects, but the agency's efforts have been piecemeal and underfunded, backed by less than a tenth of a percent of the NASA budget. And though altering the course of space objects approaching Earth appears technically feasible, NASA possesses no hardware specifically for this purpose, has nearly nothing in development, and has resisted calls to begin work on protection against space strikes. Instead, NASA is enthusiastically preparing to spend hundreds of billions of taxpayers' dollars on a manned moon base that has little apparent justification. "What is in the best interest of the country is never even mentioned in current NASA planning," says Russell Schweickart, one of the *Apollo* astronauts who went into space in 1969, who is leading a campaign to raise awareness of the threat posed by space rocks. "Are we going to let a space strike kill millions of people before we get serious about this?" he asks.

In January, I attended an internal NASA conference, held at agency headquarters, during which NASA's core goals were presented in a PowerPoint slideshow. Nothing was said about protecting Earth from space strikes—not even researching what sorts of spacecraft might be used in an approaching-rock emergency. Goals that *were* listed included "sustained human presence on the moon for national preeminence" and "extend the human presence across the solar system and beyond." Achieving national preeminence—isn't the United States pretty well-known already? As for extending our presence, a manned mission to Mars is at least decades away, and human travel to the outer planets is not seriously discussed by even the most zealous advocates of space exploration. Sending people "beyond" the solar system is inconceivable with any technology that can reasonably be foreseen; an interstellar spaceship traveling at the fastest speed ever achieved in space flight would take 60,000 years to reach the next-closest star system.

After the presentation, NASA's administrator, Michael Griffin, came into the room. I asked him why there had been no discussion of space rocks. He said, "We don't make up our goals. Congress has not instructed us to provide Earth defense. I administer the policy set by Congress and the White House, and that policy calls for a focus on return to the moon. Congress and the White House do not ask me what I think." I asked what NASA's priorities would be if he did set the goals. "The same. Our priorities are correct now," he answered. "We are on the right path. We need to go back to the moon. We don't need a near-Earth-objects program." In a public address about a month later, Griffin said that the moon-base plan was "the finest policy framework for United States civil space activities that I have seen in 40 years."

Actually, Congress *has* asked NASA to pay more attention to space rocks. In 2005, Congress instructed the agency to mount a sophisticated search of the proximate heavens for asteroids and comets, specifically requesting that NASA locate all near-Earth objects 140 meters or larger that are less than 1.3 astronomical units from the sun—roughly out to the orbit of Mars. Last year, NASA gave Congress its reply: an advanced search of the sort Congress was requesting would cost about $1 billion, and the agency had no intention of diverting funds from existing projects, especially the moon-base initiative.

How did the moon-base idea arise? In 2003, after the shuttle *Columbia* was lost, manned space operations were temporarily shut down, and the White House spent a year studying possible new missions for NASA. George W. Bush wanted to announce a voyage to Mars. Every Oval Office occupant since John F. Kennedy knows how warmly history has praised him for the success of his pledge to put men on the moon; it's only natural that subsequent presidents would dream about securing their own place in history by sending people to the Red Planet. But the technical barriers and even the most optimistic cost projections for a manned mission to Mars are prohibitive. So in 2004, Bush unveiled a compromise plan: a permanent moon base that would be promoted as a stepping-stone for a Mars mission at some unspecified future date. As anyone with an aerospace engineering background well knows, stopping at the moon, as Bush was suggesting, actually would be an impediment to Mars travel, because huge amounts of fuel would be wasted landing on the moon and then blasting off again. Perhaps something useful to a Mars expedition would be learned in the course of building a moon base; but if the goal is the Red Planet, then spending vast sums on lunar living would only divert that money from the research and development needed for Mars hardware. However, saying that a moon base would one day support a Mars mission allowed Bush to create the impression that his plan would not merely be restaging an effort that had already been completed more than 30 years before. For NASA, a decades-long project to build a moon base would ensure a continuing flow of money to its favorite contractors and to the congressional districts where manned-space-program centers are located. So NASA signed on to the proposal, which Congress approved the following year.

It is instructive, in this context, to consider the agency's rhetoric about China. The Chinese manned space program has been improving and is now about where the U.S. program was in the mid-1960s. Stung by criticism that the moon-base project has no real justification—37 years ago, President Richard Nixon cancelled the final planned *Apollo* moon missions because the program was accomplishing little at great expense; as early as 1964, the communitarian theorist Amitai Etzioni was calling lunar obsession a "moondoggle"—NASA is selling the new plan as a second moon race, this time against Beijing. "I'll be surprised if the Chinese don't reach the moon before we return," Griffin said. "China is now a strategic peer competitor to the United States in space. China is drawing national prestige from achievements in space, and there will be a tremendous shift in national prestige toward Beijing if the Chinese are operating on the moon and we are not. Great nations have always operated on the frontiers of their era. The moon is the frontier of our era, and we must outperform the Chinese there."

Wouldn't shifting NASA's focus away from wasting money on the moon and toward something of clear benefit for the entire world—identifying and deflecting dangerous space objects—be a surer route to enhancing national prestige? But NASA's institutional instinct is not to ask, "What can we do in space that makes sense?" Rather, it is to ask, "What can we do in space that requires lots of astronauts?" That finding and stopping space rocks would be an expensive mission with little role for the astronaut corps is, in all likelihood, the principal reason NASA doesn't want to talk about the asteroid threat.

NASA's lack of interest in defending against space objects leaves a void the Air Force seems eager to fill. The Air Force has the world's second-largest space program, with a budget of about $11 billion—$6 billion less than NASA's. The tension between the two entities is long-standing. Many in the Air Force believe the service could achieve U.S. space objectives faster and more effectively than NASA. And the Air Force simply wants flyboys in orbit: several times in the past, it has asked Congress to fund its own space station, its own space plane, and its own space-shuttle program. Now, with NASA all but ignoring the space-object threat, the Air Force appears to be seizing an opportunity.

All known space rocks have been discovered using telescopes designed for traditional "soda straw" astronomy—that is, focusing on a small patch of sky. Now the Air Force is funding the first research installation designed to conduct panoramic scans of the sky, a telescope complex called Pan-STARRS, being built by the University of Hawaii. By continuously panning the entire sky, Pan-STARRS should be able to spot many near-Earth objects that so far have gone undetected. The telescope also will have substantially better resolving power and sensitivity than existing survey instruments, enabling it to find small space rocks that have gone undetected because of their faintness.

The Pan-STARRS project has no military utility, so why is the Air Force the sponsor? One speculation is that Pan-STARRS is the Air Force's foot in the door for the Earth-defense mission. If the Air Force won funding to build high-tech devices to fire at asteroids, this would be a major milestone in its goal of an expanded space presence. But space rocks are a natural hazard, not a military threat, and an Air Force Earth-protection initiative, however gallant, would probably cause intense international opposition. Imagine how other governments would react if the Pentagon announced, "Don't worry about those explosions in space—we're protecting you."

Thus, the task of defending Earth from objects falling from the skies seems most fitting for NASA, or perhaps for a multinational civilian agency that might be created. Which raises the question: What could NASA, or anyone else, actually do to provide a defense?

Russell Schweickart, the former *Apollo* astronaut, runs the B612 Foundation (B612 is the asteroid home of Saint-Exupéry's Little Prince). The foundation's goal is to get NASA officials, Congress, and ultimately the international community to take the space-rock threat seriously; it advocates testing a means of precise asteroid tracking, then trying to change the course of a near-Earth object.

Current telescopes cannot track asteroids or comets accurately enough for researchers to be sure of their courses. When 99942 Apophis was spotted, for example, some calculations suggested it would strike Earth in April 2029, but further study indicates it won't—instead, Apophis should pass between Earth and the moon, during which time it may be visible to the naked eye. The Pan-STARRS telescope complex will greatly improve astronomers' ability to find and track space rocks, and it may be joined by the Large Synoptic Survey Telescope, which would similarly scan the entire sky. Earlier this year, the software billionaires Bill Gates and Charles Simonyi pledged $30 million for work on the LSST, which proponents hope to erect in the mountains of Chile. If it is built, it will be the first major telescope to broadcast its data live over the Web, allowing countless professional and amateur astronomers to look for undiscovered asteroids.

Schweickart thinks, however, that even these instruments will not be able to plot the courses of space rocks with absolute precision. NASA has said that an infrared telescope launched into an orbit near Venus could provide detailed information on the exact courses of space rocks. Such a telescope would look outward from the inner solar system toward Earth, detect the slight warmth of asteroids and comets against the cold background of the cosmos, and track their movements with precision. Congress would need to fund a near-Venus telescope, though, and NASA would need to build it—neither of which is happening.

Another means of gathering data about a potentially threatening near-Earth object would be to launch a space probe toward it and attach a transponder, similar to the transponders used by civilian airliners to report their exact locations and speed; this could give researchers extremely precise information on the object's course. There is no doubt that a probe can rendezvous with a space rock: in 2005, NASA smashed a probe called *Deep Impact* into the nucleus of comet 9P/Tempel in order to vaporize some of the material on the comet's surface and make a detailed analysis of it. Schweickart estimates that a mission to attach a transponder to an impact-risk asteroid could be staged for about $400 million—far less than the $11.7 billion cost to NASA of the 2003 *Columbia* disaster.

Then what? In the movies, nuclear bombs are used to destroy space rocks. In NASA's 2007 report to Congress, the agency suggested a similar approach. But nukes are a brute-force solution, and because an international treaty bans nuclear warheads in space, any proposal to use them against an asteroid would require complex diplomatic agreements. Fortunately, it's likely that just causing a slight change in course would avert a strike. The reason is the mechanics of orbits. Many people think of a planet as a vacuum cleaner whose gravity sucks in everything in its vicinity. It's true that a free-falling body will plummet toward the nearest source of gravity—but in space, free-falling bodies are rare. Earth does not plummet into the sun, because the angular momentum of Earth's orbit is in equilibrium with the sun's gravity. And asteroids and comets swirl around the sun with tremendous angular momentum, which prevents them from falling toward most of the bodies they pass, including Earth.

For any space object approaching a planet, there exists a “keyhole”—a patch in space where the planet’s gravity and the object’s momentum align, causing the asteroid or comet to hurtle toward the planet. Researchers have calculated the keyholes for a few space objects and found that they are tiny, only a few hundred meters across—pinpoints in the immensity of the solar system. You might think of a keyhole as the win-a-free-game opening on the 18th tee of a cheesy, incredibly elaborate miniature-golf course. All around the opening are rotating windmills, giants stomping their feet, dragons walking past, and other obstacles. If your golf ball hits the opening precisely, it will roll down a pipe for a hole in one. Miss by even a bit, and the ball caroms away.

Tiny alterations might be enough to deflect a space rock headed toward a keyhole. “The reason I am optimistic about stopping near-Earth-object impacts is that it looks like we won’t need to use fantastic levels of force,” Schweickart says. He envisions a “gravitational tractor,” a spacecraft weighing only a few tons—enough to have a slight gravitational field. If an asteroid’s movements were precisely understood, placing a gravitational tractor in exactly the right place should, ever so slowly, alter the rock’s course, because low levels of gravity from the tractor would tug at the asteroid. The rock’s course would change only by a minuscule amount, but it would miss the hole-in-one pipe to Earth.

Will the gravitational-tractor idea work? The B612 Foundation recommends testing the technology on an asteroid that has no chance of approaching Earth. If the gravitational tractor should prove impractical or ineffective, other solutions could be considered. Attaching a rocket motor to the side of an asteroid might change its course. So might firing a laser: as materials boiled off the asteroid, the expanding gases would serve as a natural jet engine, pushing it in the opposite direction.

But when it comes to killer comets, you’ll just have to lose sleep over the possibility of their approach; there are no proposals for what to do about them. Comets are easy to see when they are near the sun and glowing but are difficult to detect at other times. Many have “eccentric” orbits, spending centuries at tremendous distances from the sun, then falling toward the inner solar system, then slingshotting away again. If you were to add comets to one of those classroom models of the solar system, many would need to come from other floors of the building, or from another school district, in order to be to scale. Advanced telescopes will probably do a good job of detecting most asteroids that pass near Earth, but an unknown comet suddenly headed our way would be a nasty surprise. And because many comets change course when the sun heats their sides and causes their frozen gases to expand, deflecting or destroying them poses technical problems to which there are no ready solutions. The logical first step, then, seems to be to determine how to prevent an asteroid from striking Earth and hope that some future advance, perhaps one building on the asteroid work, proves useful against comets.

None of this will be easy, of course. Unlike in the movies, where impossibly good-looking, wisecracking men and women grab space suits and race to the launchpad immediately after receiving a warning that something is approaching from space, in real life preparations to defend against a space object would take many years. First the necessary hardware must be built—quite possibly a range of space probes and rockets. An asteroid that appeared to pose a serious risk would require extensive study, and a transponder mission could take years to reach it. International debate and consensus would be needed: the possibility of one nation acting alone against a space threat or of, say, competing U.S. and Chinese missions to the same object, is more than a little worrisome. And suppose Asteroid X appeared to threaten Earth. A mission by, say, the United States to deflect or destroy it might fail, or even backfire, by nudging the rock toward a gravitational keyhole rather than away from it. Asteroid X then hits Costa Rica; is the U.S. to blame? In all likelihood, researchers will be unable to estimate where on Earth a space rock will hit. Effectively, then, everyone would be threatened, another reason nations would need to act cooperatively—and achieving international cooperation could be a greater impediment than designing the technology.

We will soon have a new president, and thus an opportunity to reassess NASA’s priorities. Whoever takes office will decide whether the nation commits to spending hundreds of billions of dollars on a motel on the moon, or invests in space projects of tangible benefit—space science, environmental studies of Earth, and readying the world for protection against a space-object strike. Although the moon-base initiative has been NASA’s focus for four years, almost nothing has yet been built for the project, and comparatively little money has been spent; current plans don’t call for substantial funding until the space-shuttle program ends, in 2010. This suggests that NASA could back off from the moon base without having wasted many resources. Further, the new Ares rocket NASA is designing for moon missions might be just the ticket for an asteroid-deflection initiative.

Congress, too, ought to look more sensibly at space priorities. Because it controls federal funding, Congress holds the trump cards. In 2005, it passively approved the moon-base idea, seemingly just as budgetary log-rolling to maintain spending in the congressional districts favored under NASA's current budget hierarchy. The House and Senate ought to demand that the space program have as its first priority returning benefits to taxpayers. It's hard to imagine how taxpayers could benefit from a moon base. It's easy to imagine them benefiting from an effort to protect our world from the ultimate calamity.
