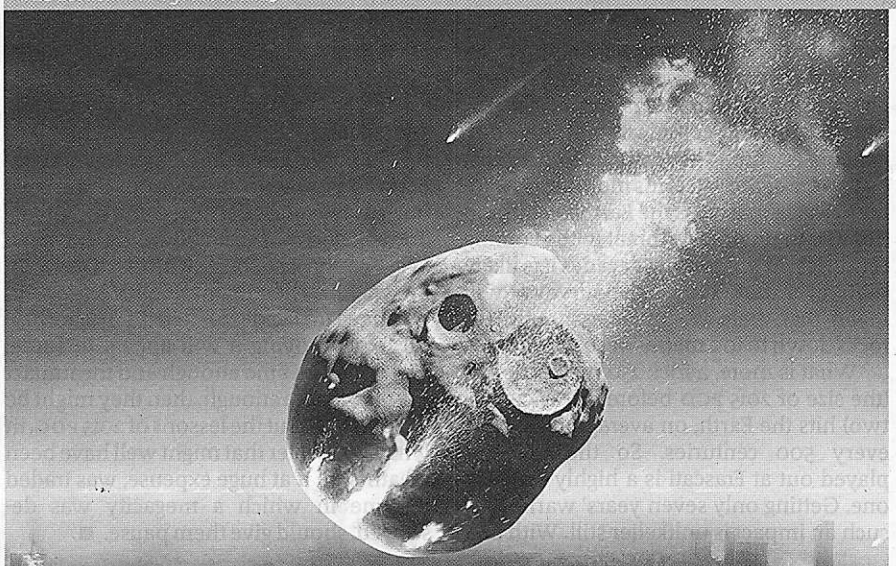


If an asteroid heads for Earth

Taking the hit

FRASCATI, ITALY

Just because you can move the stars in their courses, it doesn't mean you should

ON APRIL 13th 2015 the Minor Planet Centre (MPC), an office with a staff of six which looks after such matters for the International Astronomical Union, recorded hundreds of newly discovered asteroids—a typical daily haul. The one to which it assigned the name 2015 PDC, though, stood out.

When asteroids are discovered in orbits that come close to the Earth's, as this one did, the MPC makes various calculations to see if they pose a threat. Because observations of small, distant rocks cannot be made with perfect accuracy, those calculations define a "corridor" where the asteroid might be. The calculations for 2015 PDC showed that on September 3rd 2022 the Earth would cross the corridor where the asteroid might be. The two might collide.

That was not, in itself, too worrying. Newly discovered asteroids have had measurable possibilities of hitting the Earth before; further observations, and thus a more precise understanding of the rocks' orbits, have always ruled those impacts out. The one exception to that rule so far, 2008 TC3, was an asteroid only 4 metres (13 feet) across; when it exploded in the upper atmosphere in 2008, just days after its discovery, it mattered to no one except the meteorite hunters who rushed to Sudan to find the remains that fell to Earth.

As 2015 PDC's orbit became better known the corridor in which it might be on that fateful day in 2022 shortened. But it still contained the Earth. By June the probability of an impact had risen to 1%, making it the most threatening asteroid astronomers had ever seen. By September governments in America, Europe, Russia and China had started work on space missions aimed at changing the asteroid's orbit by ramming into it. Even at a speed of more than 10km (6 miles) a second, hitting a billion-tonne asteroid with a few tonnes of spacecraft will make only a minute difference to the asteroid's orbit.

But a minute difference, made early enough, can provide the margin between a near miss and a hit that is palpable on a planetary scale. And 2015 PDC looked like providing such a hit. Early estimates put its diameter between 140 and 400 metres. Even if it were at the small end of that range, though, when it hit the Earth at 11km a second it would release as much energy as hundreds of large nuclear warheads set off simultaneously. At the large end the hundreds would become thousands.

Towards the end of 2015 the sun came between the Earth and the rock, making further observations impossible for a while. After observations resumed the following year, though, an impact became certain. The remaining uncertainty was about where, exactly, it would hit. The risk corridor was wrapped around the Earth on a great-circle arc that began in the tropical Pacific and ran north-west over the Philippines and across the South China Sea before passing over a swathe of Asia beginning in Vietnam and ending in Iran. The track passed over a surprisingly large fraction of the world's population and three megacities—Dhaka, New Delhi and Tehran. You would have been hard put to have imagined a more threatening rock.

Designed to disturb

That was because Paul Chodas, an asteroid expert at JPL, the laboratory that manages most of NASA's planetary science, had put a lot of his own imagination into making 2015 PDC intriguingly disturbing. He and a few colleagues invented the asteroid, and its orbit, as a scenario to be discussed at the Planetary Defence Conference held in Frascati this April. The scenario unfolded over five days, in breaks between technical papers, with participants drafted in to imagine the reactions of world leaders, the media and the public. Their deliberations revealed a lot about the nature of the threat asteroids pose and the response that a real threat might provoke—a response which could make the danger greater than it would otherwise be.

As with all missions to other parts of the solar system, interceptors aimed at 2015 PDC could be launched only at a specific time defined by the asteroid's orbit. They would have to take off in late August 2019 in order to reach the rock in early March 2020, 900 days before the impact. The largest of the interceptors originally proposed fell by the wayside because the rocket could not be readied in time. Still, the six remaining spacecraft—three American attempts and one each from China, Russia and Europe—were to offer more than enough kinetic energy to change the asteroid's orbit by the two centimetres a second required to make it miss the Earth in 2022.

What was not much discussed—other than by Bhavya Lal of the Science and Technology Policy Institute in Washington, DC, who was representing India in the role-playing—was whether the deflection the spacefaring powers were undertaking was a good idea. By August 2019 the possible impact sites had been narrowed down to an arc stretching from the Philippines to Vietnam across the South China Sea. An impact in the middle of the sea would have threatened 80m people living on its coasts, almost half of them in China, with tsunami-like waves. The damage could be enormous—but unlike the hazards posed by most natural disasters its timing would be known, to within an hour, years in advance, and its effects could be modelled. Breakwaters could be built in front of the larger cities, evacuation plans perfected, ▸▸

nuclear plants at risk from the waves shut down, populations resettled either for a few crucial weeks or for good.

A fair bit of this work would be necessary to deal with the sea-level rises expected due to global warming anyway; the asteroid would just mean getting it done faster. The hundreds of billions of dollars invested would increase GDP, as spending after a disaster does. But this possibility—referred to at the meeting as "taking the hit"—got short shrift.

Oops

Which was a pity, because in Dr Chodas's scenario the deflection went wrong. Instead of being nudged safely onto a new trajectory, the asteroid was cleft in two. The larger part had been given a big enough impulse to no longer be an imminent threat, but the smaller part was still on a collision course. And now its orbit was newly uncertain. The corridor that had been shortening was lengthened, with the once-threatened, then-safe places between Vietnam and Tehran newly at risk again thanks to the actions of space programmes that were mostly based in places (Europe, America, Russia) that were at no direct risk at all. India began work on a mission that would use a nuclear warhead to try to blast the new fragment to smithereens on its final approach—but which might have simply changed its impact point again.

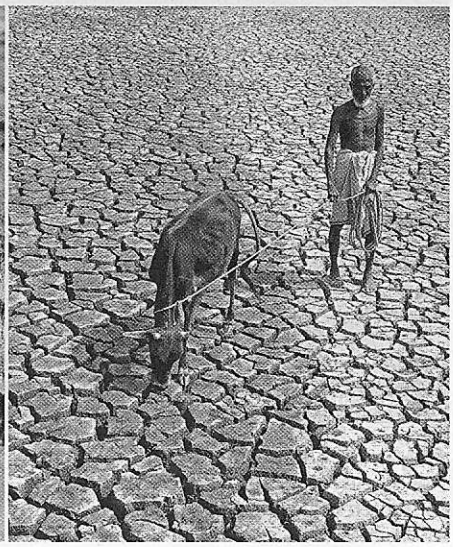
China warned that it wanted a veto over any such mission; if it did not approve of the way it was being done it would feel justified in using anti-satellite weapons to shoot down the Indian rocket pretty much as soon as it took off. Iran, previously safe, fulminated against the Great Satan, and it was hard not to think it had a point. Hannes Mayer, an Austrian lawyer who has given the application of space law to such situations a lot of thought, raised the possibility that by altering the asteroid's orbit the intercepting nations changed its legal status from that of a "celestial body" for which no one was responsible to that of a "space object"—and thus become liable for any damage that it did.

By the end of the scenario, when the asteroid was a few days from exploding in the sky over Dhaka with more power than 1,000 Hiroshima bombs and more than 20m people were being evacuated, that was looking like a great deal of liability. The question of India's last-ditch nuclear interception, and China's worries, were brushed aside as beyond the scenario's scope. In the real world, though, a botched interception which created a crisis for people who would otherwise have avoided one would be a grave issue—perhaps, in some circumstances, *casus belli*.

Bigger rocks have hit the Earth, doing great damage in the process. There is a 90km crater under Chesapeake Bay which bears witness to an impact 35m years ago, and a 180km crater on the Yucatan which marks the impact site of the rock that ended the age of the dinosaurs. But, in practice, astronomers are confident that their diligent observations have discovered almost every one of the asteroids more than a kilometre wide that cross the Earth's orbit, and none of them poses a threat in the coming centuries. In the coming decades it is likely that ever-more-thorough surveys will mean that there is similar assurance for rocks down to 100 metres or so.

What is more, a rock 250 metres across (the size of 2015 PCD before it was cleft in two) hits the Earth, on average, only once every 500 centuries. So the scenario played out at Frascati is a highly unlikely one. Getting only seven years' warning of such an impact is unlikelier still. With ample time it would be possible to use gentler methods to try to adjust the orbit.

At some point, though, a rock large enough to do real damage—something like the 50-metre beast that exploded over Siberia in 1908 with the force of the largest nuclear weapon ever tested, the sort of visitor statistics suggest should be expected every century or so—will be discovered on the way in. Then the nations of the world will have to decide what to do. The technical fix of moving it will appeal to some; and if there is time enough and the impact site is valuable enough, then they might be wise to try it. But the lessons of 2015 PDC, in which a disaster that might well have been weathered, if at huge expense, was traded for one in which a megacity was destroyed, should give them pause. ■



If India's monsoon fails

A billion-person question

DELHI

A more erratic rainy season in India could lead to mass famine. But there are ways to avoid such a disaster

NOTHING in India is as terrifying as the thought that the monsoon might not come. Robert Kaplan, in his book "Monsoon", claims global warming is causing a more erratic monsoon, which "could spell disaster". Around half of India's population, some 600m people, still depend on farming, and nearly two-thirds of fields have no irrigation, so must rely on rain. Without water at the right time, hundreds of millions of people would see their incomes crash. Food costs would rise. And as India is an emerging global giant in food production, exporting more rice than anyone, droughts could push up global prices.

Waiting for the monsoon is an annual ritual. In the early summer, weeks pass without rain. Temperatures and frustration rise. For villagers there is irritable inactivity, hours slumped on a charpoy under a tree, nights on a flat roof in hope of a breeze. Even birds and insects fall quiet, exhausted. Farmers yearn to start planting.

Cities are crowded and feel worse. The highest temperature ever measured in India, 50.6°C (123°F), was recorded in May 1956 in Alwar, Rajasthan. Delhi is delightfully leafy, but in these months a drab crust encases its trees, bushes and cars.

The rich retreat under air-conditioners ▸▸