

Stuart Clark

Six ways to save the planet

It's a question of 'when' not 'if' – that's the expert opinion on the detection of an Earth-bound asteroid or comet. Somewhere, out in space, a kilometre-sized lump of rock could be inexorably edging closer to Earth. Or a similarly sized iceberg could be making its fateful plunge from the depths of space.

NASA is scheduled to launch a quick and dirty mission called Deep Impact on 6 January 2005. It will smash into a comet, revealing its interior, thereby providing clues about the structure of these deep space menaces.

In preparation for when the doomsday object is found, Stuart Clark looks at the options scientists are considering to save the planet.

Option 1: Nuke It

Despite being the early, obvious candidate, nuclear weapons are now seen as something of a last resort. Partly this is to do with safety – although it's difficult to see how an environmental campaigner could effectively lobby against a nuclear launch when, without it, the planet might be doomed. Mostly, it is to do with the wide variety of asteroid structures and the different responses that each might experience to a nuclear blast.

The perpetuated method for diverting an asteroid, enshrined by Hollywood, is to bury a nuke in the asteroid's heart (sacrificing a couple of crewmembers) and then just blow the mighty space rock to pieces. Unfortunately, it does not work that way. By shattering it, you turn a cannonball into buckshot without really altering its course. It's still going to hit Earth but now, over a much wider area than before.

Surface explosions could shatter the object as well, especially if it were fragile, like a comet. So, scientists have proposed the 'stand-off' explosion. Similar to an air-bursting nuclear weapon on Earth, the explosion takes place above the target, spreading the force of the impact over a much wider area. In the case of an asteroid, the explosion melts a large portion of its surface and the gas released from the molten rock (or ice in the case of a comet) pushes like a rocket motor to alter its course.

For fragile objects, smaller yield weapons could be used in sequence to provide the same explosive force but spread over a period of time to further reduce the risk of fragmentation.

One of the first studies of nuclear deflection was undertaken by students at the Massachusetts Institute of Technology (MIT) in Boston, America during the mid-late 1970s. Project Icarus, as it was called, asked for six Saturn V rockets (the kind used to transport astronauts to the Moon) to be stationed in permanent readiness at the Kennedy Space Center. Each rocket was to be equipped with a 100-megaton nuclear weapon and launched in sequence if an asteroid presented a threat to Earth. In the case of the study, they looked at deflecting near-Earth asteroid Icarus. The study was never implemented because of its horrendous cost but it did inspire the 1979 film *Meteor*, starring Sean Connery.

Although the nuclear option is now largely out of favour, it could still be a last resort option.

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| Time Needed: | Weeks or months so long as rockets were on permanent standby. |
| Pros: | Capable of delivering a massive force quickly. Most effective with solid asteroids. |
| Cons: | Could shatter object, creating greater problems. Not very controllable. |
| Chances of Success: | Moderate as technology largely exists but it could be like taking a sledgehammer to crack a nut. |

Option 2: Mine It

Mining an asteroid and chucking the debris off into space could provide all the force needed to gradually shift its orbit.

This method might be particularly applicable to so-called rubble-pile asteroids, which are assemblages of rock, rather than a single solid lump. When NASA's Deep Space 1 rounded asteroid Mathilde in 1997, the density it measured was too low for the asteroid to be solid, indicating a jumbled conglomeration of pieces. Rubble piles are held together by gravity and may be covered in a pebbly

layer known as the regolith. Some scientists believe they may even be the dominant type of asteroid.

A single, whacking great thump on a rubble pile, perhaps delivered by a nuclear weapon, would most likely just jostle the pieces around, rather than actually move the asteroid. This is because the pieces work like a car's crumple zones, absorbing the energy of impact. However, small pushes could gradually coax the asteroid away from its doomsday course and that's where the idea of mining it and ejecting the debris comes into play.

The device for chucking stuff into space is known as a mass driver and has been proposed by advocates of asteroid mining for decades. In 1953, Arthur C Clarke described in the Journal of the British Interplanetary Society, how to accelerate 'packets' of asteroidal matter into space using magnetic fields.

Scientists at the Space Studies Institute (SSI), Princeton, have constructed laboratory prototypes of mass drivers. Freeman Dyson, of SSI, recently analysed their efficacy as a planetary defence mechanism. Using a solar array the size of the International Space Station's to supply power to the magnets, Dyson proposed a two-pronged attack: one mass driver to 'de-spin' the asteroid and a second to do the job of diverting it. By curbing the asteroid's spin, the deflection mass driver can be used more effectively.

In this way, he estimated that a 1km asteroid (the smallest size capable of global consequence should it strike the Earth) could be re-routed in about ten years. Smaller ones could be moved even sooner.

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| Time Needed: | Years or decades |
| Pros: | Highly controllable – a mass driver can be turned on and off. Can deal with fragile objects. |
| Cons: | Requires a long lead-time. Requires construction of the mass driver on the object's surface. Litters space with debris. |
| Chances of Success: | Slim at the current technological level. |

Option 3: Paint It

Unlikely as it sounds, painting parts of an asteroid white (or covering it with white powder) may be enough to prevent global Armageddon. It's all to do with the way the asteroid absorbs sunlight during the day and re-emits that energy at night.

Because the 'evening side' of the asteroid is hot after the day, it emits more radiation than the 'morning side', which is cool after the night. This creates a lop-sided force on the asteroid that alters its orbit. The paint job would simply enhance this phenomenon.

It's called as the Yarkovsky effect after the Russian engineer who proposed the idea in around 1900 and has been detected on asteroid (6489) Golevka using radar measurements. In 12 years, this half-kilometre-wide rock has changed its orbit by just over a kilometre every year.

To deflect an asteroid from Earth, engineers reckon on having to shift it by a maximum of 6,000km, the Earth's radius. That's quite a difference. Nevertheless, Joseph Spitale, University of Arizona–Tucson, believes that the small natural drift could be enhanced by changing the way an asteroid's surface absorbs sunlight, for example by painting parts of it a reflective colour. Determining which areas to alter, would require knowledge of how the asteroid spins, its mass, its exact shape, and the naturally occurring pattern of dark and light on its surface.

A spacecraft with a sophisticated radar system and probably a hefty dose of artificial intelligence would be needed to apply the paint. And a subsequent, 'white-spirit' mission would have to return the asteroid to normal, in case its continued wandering caused more problems.

Perhaps the best scenario for this option would be to use it with centuries of warning, so that micrometeorite impacts on the surface of the asteroid will gradually erode the reflective surface, returning it to normal by the time the job is done.

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| Time Needed: | Decades or centuries. |
| Pros: | Fairly low tech solution. |
| Cons: | No way to stop the asteroid's orbit continuing to evolve. Impossible method if the asteroid is tumbling chaotically. |

Chances of Success: Moderate if there is plenty of warning time.

Option 4: Melt It

All that may be needed is a giant mirror in space, capable of reflecting sunlight onto the dangerous object. This could be similar to the *Paint It* option, in that heating one side of the asteroid means that the hemisphere turning away from the mirror will be hotter than the hemisphere turning into it and this will push it through space. Or it could be more extreme and actually focus sunlight so tightly that it melts the asteroid's surface, causing vaporized material to explode into space, pushing the asteroid in the opposite direction.

Jay Melosh, University of Arizona, believes that this may be the most effective of all the non-nuclear options. It would not require any deflection hardware to be taken to the asteroid itself. The mirror complex could be built in Earth orbit and operated by remote control. Large, reflective structures are currently being investigated by all space agencies in the guise of solar sails. These spacecraft use the energy of sunlight to push them through space but are similar in design to the mirror complexes that would be needed to focus sunlight towards a potentially hazardous object.

Nudging asteroids rather than nuking them has become favoured recently because experts are realising that potentially hazardous objects are most likely to make several close passes to Earth before settling on a collision course. With careful tracking, it is possible to calculate the critical points in space that each nearby asteroid would have to pass through, in order to be placed on a collision course with our planet. Such critical regions of space are called keyholes and may be very small, so tiny forces applied at just the right time can prevent asteroids from passing through these celestial danger zones.

A permanently readied mirror station in orbit and a comprehensive search and monitoring programme could be all that's needed to keep the Earth safe.

Time Needed: Years or decades

Pros: Highly controllable.

Very effective with fragile objects, such as comets.

Cons: Requires construction of the solar deflector in orbit.

Chances of Success: Good, providing solar sail research continues.

Option 5: Hammer It

A cosmic head-on collision may do the trick. Whilst the Deep Impact mission aims to prove that such a suicide run is possible, this probe will not attempt to move its cometary target. The naturally occurring jets on Comet Temple 1 will swamp any slight knock that Deep Impact will inflict.

ESA are studying a mission concept that will become the first to attempt to shove an asteroid by a measurable amount. Dubbed Don Quijote, it will do this by using two spacecraft: Sancho and Hidalgo. If fully funded, they will be launched together but Sancho will be placed on a faster route, arriving at the target asteroid to begin a seven-month campaign of observations and measurements. During this time it will land penetrators and seismometers on the asteroid to study its internal structure. Sancho will then watch as Hidalgo arrives and smashes into the asteroid at high speed. The impact will create seismic waves to probe the internal structure of the asteroid, as well as excavating some of the interior for Sancho to observe. After the collision, Sancho and telescopes from Earth will monitor the asteroid to see how its orbit and rotation have been affected.

Even if the experiment proves that impacting an asteroid is not the most efficient way of moving it out of harm's way, it is almost certain that a Don Quijote-like mission will be the first step in characterising a real threatening asteroid.

Another option is to pack the impacting spacecraft with explosives but this begins to tread the fine line leading back to the *Nuke It* option.

Time Needed: Years or decades

Pros: Achievable with current technology

Cons: Might need a large number of impacts or the use of explosives.

Chances of Success: Slim for large asteroids, good for small ones.

Option 6: Supercharge It

Perhaps it will be simplest to strap a rocket motor to the incoming object and blast it onto a benign orbit. Rather like the *Mine It* option, it would first be desirable to control the asteroid's spin so that the deflection rocket motor will always point in the right direction.

But what kind of rocket motor do you use? Chemical rockets, like those used in today's launch vehicles create an obvious problem: how do you carry the fuel necessary to make the engine work? On certain objects, generating the necessary fuel may be possible from the naturally available chemicals. A comet for example, would require a simple 'cracking station' to mine the ice and split it into hydrogen and oxygen. When mixed correctly, these two make a potent rocket fuel. On some asteroids, scientists may be able to adapt the In-Situ Resource Utilization (ISRU) technologies that are currently being developed to provide oxygen, drinking water and return rocket fuel for manned missions to Mars.

Many asteroids, however, are nothing more than the cosmic equivalent of furnace slag and contain nothing of much use to anyone. In these cases, mining the raw materials will be fruitless. Another option would be using an ion engine. Electric propulsion, as its pundits prefer to call it, requires little fuel but only provides a small thrust. Even so, ESA's SMART-1 mission has used nothing but the thrust equivalent to the weight of a sheet of paper to loft itself to the Moon. It has taken 13 months to cover the same distance that America's Saturn V's traversed in 3 days.

So, you'd need to tailor the engine to the incoming object and, if you use an ion engine, be prepared to wait a long time for results.

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| Time Needed: | Years or decades |
| Pros: | Highly controllable. Very effective with fragile objects, such as comets. |
| Cons: | Requires precise landing on the object. Could need sophisticated mining technology. |
| Chances of Success: | Moderate, providing ISRU and Ion engine research continues. |

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The Doomsday Scenario

In March 2880, there is a minuscule 0.33% chance that asteroid (29075) 1950DA will hit Earth. A lot can happen in eight centuries, as this asteroid is pushed and pulled by myriad delicate gravitational forces emanating from the planets and moons of our Solar System, even from the stars in the wider Universe. Astronomers will be able to bounce radar from 1950DA next in 2032, to see what orbital changes have occurred. It's most likely that the asteroid will have moved away from its close encounter with Earth, so there's no point in worrying about your great-great-great... grandchildren, just yet.