An asteroid approaches Earth. The NEOShield project is working towards preventing a potential asteroid impact.

Image components: NASA/JHUAPL und NASA

When things get too close for comfort

On 15 February 2013, an asteroid 17 metres in size and weighing some 10,000 tons entered Earth's atmosphere at around 64,000 kilometres per hour, exploding over Chelyabinsk in Russia. The energy released was equivalent to 500 kilotons of TNT, about 30 times that of the Hiroshima atomic bomb. The resulting blast wave damaged buildings and caused injuries to around 1200 people through flying debris and glass splinters. On the very same day, asteroid 2012 DA14, 45 metres in diameter, passed only 28,000 kilometres from Earth, beneath the orbits of TV and communications satellites. Despite the dramatic combination of the two unrelated events, the collision of a large asteroid or comet with Earth is actually a very rare event. But if such an impact were to occur it could trigger the worst natural catastrophe our civilisation has ever experienced. It is worth repeating to be absolutely clear: what we are talking about here is a minuscule risk, but one linked to potentially devastating consequences. Ignoring this risk is socially, politically and also economically very dangerous; it is a subject in which global thinking and acting is vital.

NEOShield – international defence against asteroids

By Alan Harris

Project NEOShield arose from these considerations. In 2011 the European Commission selected an international group of scientists and engineers under its Seventh Framework Programme for Research and Technological Development (2007-2013) to investigate methods of defence against asteroids. The primary goal of the resulting project, NEOShield, is to produce detailed designs of space missions to test the effectiveness of promising asteroid deflection techniques. A consortium of 13 partners, under the aegis of DLR, is being funded for a period of three-and-a-half-years from January 2012, supplementing the 4 million euros of European Commission support with 1.8 million euros of their own resources.

Alan Harris and Line Drube, a postdoctoral researcher at the DLR Institute of Planetary Research, discuss the physics of NEO defence methods.

A near-Earth object, or NEO, is an asteroid or comet with an elliptical orbit around the Sun that comes nearer than 50 million kilometres to Earth's orbit. By comparison, the Moon orbits Earth at a distance of around 400,000 kilometres, and at opposition, Mars is around 60 million kilometres from Earth. NEOs can endanger Earth. To date, there are nearly 10,000 known NEOs, ranging in size from a few metres up to 40 kilometres in diameter.

An impact of an object with a diameter of just one kilometre could have global effects; the reason is the enormously high speed – several tens of thousands of kilometres per hour – at which the object would enter Earth's atmosphere. Even so, it is somewhat reassuring that, thanks to a few, mainly US, observatories constantly scanning the night sky for NEOs, almost every object of more than one kilometre in diameter is known and is being tracked. DLR and the European Asteroid Research Node, EARN, are contributing to cataloguing the asteroid population in the Solar System. No large NEO that could threaten our civilisation in the next 100 years or so has been discovered to date.

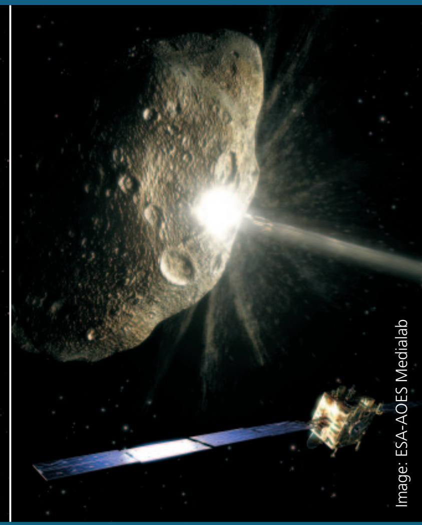
When Siberia shook 100 years ago…

But how dangerous could smaller NEOs be? There are an estimated one million objects with diameters between 30 and 50 metres, but only a fraction of these have been discovered to date. An object of this size is thought to be responsible for the Tunguska event in Siberia in 1908, when more than 80 million trees over an area of 2000 square kilometres – about twice the size of Berlin – were snapped and felled like matchsticks. The devastation was probably caused by an object that entered the atmosphere at 50,000 kilometres per hour and exploded at an altitude of five to 10 kilometres with a blast equivalent to 10 megatons of TNT. Another example of the devastating effects of a small NEO is Barringer Crater in Arizona, also known as Meteor Crater. The 50,000-year-old crater remains well

Artist's impression of an asteroid impact on Earth

A NEO with a diameter of just 30 to 50 metres created the Barringer Crater in Arizona 50,000 years ago

Artist's impression of a gravity tractor with an asteroid in tow



Artist's impression of a kinetic impactor mission. The impact is observed by a reconnaissance spacecraft

A nuclear explosion is considered to be a last option to prevent a collision, in the absence of feasible alternative methods.

preserved today as a result of its location in a dry desert. Depending on their geographic location, impact craters can be rendered unrecognisable reasonably quickly due to erosion, vegetation and geological activity. As metallic meteorite fragments have been found in the crater surroundings, we can assume that the 1200-metre-wide, 180-metre-deep crater is the result of the impact of a massive metallic object. The diameter of the impactor has been estimated at just 30 to 50 metres. It should also be remembered that, statistically speaking, two thirds of all impacts occur in the oceans, where they can trigger destructive tsunamis.

Potentially hazardous objects

What happened back then in Arizona is impressive enough. According to statistical estimates, an object with a diameter of 30 metres is expected to impact Earth every couple of centuries. As today's NEO search programmes are only finding a comparatively low number of these relatively small objects, a devastating impact could theoretically occur without warning. But there are currently several very sensitive NEO search programmes underway, so we can hope that more of these menacing small NEOs will be discovered years or even decades before a potential impact.

Two NEOs that will come dangerously close to Earth in the near future, relatively speaking, are Apophis and 2007 VK184. With a diameter of around 300 metres, Apophis will skim past Earth at a speed of 6 kilometres per second and at a distance of just 30,000 kilometres in April 2029. And that is not all: because its orbit is similar to Earth's, Apophis will remain an Earth-endangering object for the foreseeable future. There is a one in 2000 chance that 2007 VK184, which has a diameter of about 130 metres, might impact Earth at a relative speed of 68,000 kilometres per hour in 2048.

Warning time is crucial

Can we defend ourselves against an asteroid impact? Current space technology offers several promising methods – assuming that the search programmes guarantee a prediction time of 10 to 20 years, and that the threatening object's diameter is no larger than one kilometre. NEOShield partners are dealing with various aspects of the problem, from astronomical research into the physical properties of NEOs to the development of spaceflight technologies, such as guidance, navigation and control systems, needed for a deflection mission. But there is also on-going laboratory research into the material properties of the minerals that make up an asteroid, model calculations of the asteroids' interior structure, as well as identification of NEOs suitable as target objects for deflection test missions. The NEOShield partners are also researching a general strategy for asteroid defence – from identifying a threatening object and the sequence of decisions that must be made, through to determining the observations and missions required and deciding when and what kind of defence mission should be launched.

Three methods of asteroid deflection are being looked into at present. Firstly, the so-called kinetic impactor – a large space probe hits an asteroid at very high relative velocity creating an impact sufficient to change its orbit slightly. This method might be feasible using today's technology for objects with a diameter of up to one kilometre or so. But there are still many unanswered questions. What effects will the interior structure and porosity of the asteroid, its rotation and other physical factors have on the outcome of the mission? How must the impactor be steered to reach its target reliably and at the correct angle and speed? In this regard, consideration must also be given, for example, to the effect that movements of the fuel in the spacecraft have in the critical navigation phase just prior to impact.

A second method is to use a 'gravity tractor'. This method, which uses the weak attractive force between the asteroid and the spacecraft, may require years or decades to provide a sufficient change in the asteroid's orbit. So its usefulness would depend on having adequate warning time before a potential impact. If a spacecraft is steered into the direct proximity of a dangerous NEO, the small but significant attraction between the spacecraft and the asteroid could work like a tow rope. The probe might be able to use a solar electric propulsion system, for example, to accelerate itself and the asteroid until a sufficient change in the speed of the system, and the orbit of the asteroid, has been achieved. With adequate forewarning, changes of just a few centimetres per second or less might be enough to avoid a catastrophic impact on Earth.

Although this method is relatively slow in having the desired effect, it has one big advantage: the surface of the NEO remains undisturbed and no information of any kind about the interior structure and physical properties of the surface of the object is required. The best solution could be a combination of the two methods described, in which, for example, a gravity tractor is deployed after a kinetic impactor has struck, allowing small corrections to be made to the NEO's new orbit. In this way, it may also be possible to prevent future approaches of the NEO to Earth. NEOShield partners are investigating how realistic this idea is and under which circumstances a gravity tractor might be deployed.

The third option might be a nuclear explosion. In particular, if time is pressing or the object is unexpectedly large, the methods described above might not be sufficient. The largest force that could be deployed to deflect an asteroid would be one or more nuclear explosions. Although this option is regarded as highly controversial, a nuclear payload might be our last hope. But what effect would an explosion in the direct vicinity of an asteroid or on its surface have in the vacuum of space? In the NEOShield project this method is being studied in detail to provide information on its effectiveness and the circumstances that might make its deployment necessary. However, the investigations will be carried out using computer simulations; test missions with nuclear devices will not be proposed!

Asteroid defence is a global task

Because a NEO can impact anywhere in the world – there are no regions on Earth less likely to be hit than others – as many nations as possible should contribute to researching defence methods and strategies. Six countries are collaborating in the NEOShield Project: Germany, Great Britain, France, Spain, Russia and the United States. Besides the goals set out above, NEOShield is forging links to related international projects and initiatives to encourage international coordination in this field. In this regard, the NEOShield Project has already established close contacts with the Near-Earth Object section of ESA's Space Situational Awareness programme and the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) Action Team 14 on NEOs. There are also collaborations with national space organisations.

Although much greater investment and resources will be needed to launch missions to test NEO deflection techniques – not to mention an international agreement on carrying out defensive action – the EU-financed NEOShield project is an important step. It provides an excellent opportunity to investigate how asteroids can be successfully deflected in the future. As they used to say in the Asterix and Obelix comic strips: "May the sky not fall on our heads!" ●

More information:
www.DLR.de/PF/en
www.NEOShield.net

Partners in the NEOShield Consortium

- **German Aerospace Center (DLR)**
- **Observatoire de Paris, France**
- **Centre National de la Recherche Scientifique, France**
- **The Open University, United Kingdom**
- **Fraunhofer Institute for High-Speed Dynamics, Germany**
- **Queen's University Belfast, United Kingdom**
- **Astrium GmbH, Germany**
- **Astrium Limited, United Kingdom**
- **Astrium S.A.S., France**
- **Deimos Space, Spain**
- **SETI Institute Corporation Carl Sagan Center, United States**
- **TsNIIMash, Russia**
- **University of Surrey, United Kingdom**

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