Organisation for Economic Co-operation and Development (OECD)

Global Science Forum

Workshop on Near Earth Objects: Risks, Policies and Actions

January 20-22, 2003 Frascati, Italy

Final Report

Background

The workshop was authorised in January 2002 by delegates to the Sixth Meeting of the Global Science Forum, based on a proposal submitted by the Delegation of the United Kingdom. The workshop was held on January 20-22, 2003, at the headquarters of the European Space Research Institute (ESRIN) in Frascati, Italy. It was attended by government-appointed delegates from fifteen Global Science Forum Member countries and Observers¹, representatives of three inter-governmental organisations², representatives of four non-governmental organisations³, invited speakers, and the OECD secretariat. The list of participants, and the agenda, are appended to this report.

The workshop was chaired by Dr. Richard Crowther of the United Kingdom. Preparations for the event had been supervised by an International Steering Committee that was appointed by OECD Members. The Committee had been chaired by Dr. Paul Murdin, who was obliged to step down in December 2002 for health reasons.

General Findings about Near Earth Objects

As part of the workshop preparations, a paper was commissioned from a leading expert, Dr. Clark Chapman of the Southwest Research Institute in the United States. The paper, entitled "How a Near-Earth Object Impact Might Affect Society"⁴ provides general information about the types of objects that can strike the Earth, and describes six specific scenarios for impactors of different kinds, using the following criteria: probability of occurrence; warning time; nature of the devastation; post-warning mitigation possibilities; after-event disaster management; advance preparation. The paper emphasises the importance of considering the threat from objects in the size range of 10 metres to 1 kilometre. The estimated probabilities of impact, and the estimated potential damage, are shown in the table that follows.

The table illustrates the fundamental characteristic of the NEO hazard⁵: the probability of a damaging event is low, but the potential consequences can be very severe. Another distinctive aspect of the issue is that scientists believe that, unlike more familiar natural hazards, some incoming asteroids and comets could potentially be deflected or destroyed before they reach the Earth.

¹ Australia, Belgium, Canada, the Czech Republic, Denmark, the European Commission, France, Germany, Italy, Japan, Korea, Norway, South Africa, the United Kingdom, the United States.

² The Council of Europe, the European Space Agency, the United Nations.

³ The European Science Foundation, the Spaceguard Foundation, the International Astronomical Union, the B612 Foundation.

⁴ The paper is available on the OECD Global Science Forum's Internet site, www.oecd.org/sti/gsf.

⁵ In this report "hazard" refers to the natural phenomenon (impact by various types of NEOs) and the associated probabilities. "Risk" is the combination of the hazard with the associated damage and consequences for society.

Asteroid or comet diameter [metres]	Chance of occurring during the 21 st century	Total energy, and where deposited	Estimated damage
10	6 per century	0.1 MT ⁶ upper atmosphere	Extraordinary explosion in sky; broken windows, but little major damage on ground.
30	1/2.5	2 MT stratosphere	Devastating stratospheric explosion; shock wave topples trees, wooden structures and ignites fires within 10 km; many deaths likely if in populated region.
100	1/100	80 MT lower atmosphere or Earth's surface	Low-altitude or ground burst larger than biggest- ever thermonuclear weapon, regionally devastating. Shallow crater approximately 1 km across.
300	1/500	2,000 MT local crater	Crater approx. 5 km across & devastation of area the size of a small nation, or ocean-wide tsunami.
1,000	1/5000	80,000 MT major regional destruction	Destruction of entire region (e.g., Europe) or ocean rim. Potential global climate disruption.
10,000	less than 1/1,000,000 ⁷	80,000,000 MT	Global catastrophe. Possible mass extinctions.

Findings and Conclusions for the Global Science Forum

While some of the presentations and discussions at the workshop were technical in nature, the goal was not to generate new scientific knowledge, but to promote information exchange and dialogue between researchers and government officials. Accordingly, the findings and conclusions enumerated below focus on <u>policies</u> related to Near Earth Objects, and actions that governments, inter-governmental organisations, and scientific organisations can undertake, separately and jointly, at national and international levels. There are findings and conclusions in five areas:

- 1. Acknowledging the problem
- 2. Enabling a policy-level response
- 3. Assessing risk at the national level
- 4. Strengthening risk assessment through research and development
- 5. Supporting exploratory R&D for mitigation

⁶ MT stands for "megaton", denoting an energy release equivalent to one million tons of TNT. For comparison, the most powerful thermonuclear weapon ever tested had a yield of 60 MT.

⁷ The probability of an impact by such a large object is particularly low since essentially all asteroids of this size are known and are not expected to hit the Earth. The residual hazard is due to long-period comets.

1. Acknowledging the problem

Finding 1

Over the past several years, astronomers have learned a great deal about asteroids and comets ("Near Earth Objects" or NEOs) that strike the Earth at random time intervals. Every day, thousands of small (centimetre-size) objects burn up harmlessly as meteors in the atmosphere. Impacts of very large (multi-kilometre) NEOs have in the past been overwhelmingly catastrophic but are, fortunately, extremely rare⁸. Objects of intermediate size can cause significant damage when they hit the Earth at random intervals of tens, hundreds, or thousands of years.

Many researchers believe that the threat to life and property from NEOs, when averaged over long time periods, is comparable to that from more familiar natural hazards such as earthquakes and extreme weather events. The consequences of NEO impacts can be very severe, but a great deal can be done to prevent some of the impacts entirely, and to reduce the damage of others significantly, provided timely actions are undertaken.

Conclusion 1

While there are still uncertainties regarding the frequency and consequences of NEO impacts, workshop participants agreed that enough is known at this time to conclude that OECD governments should assess the NEO hazard as it relates to public safety, determine the commensurate level of response, and undertake appropriate actions at national and international levels.

2. Enabling a policy-level response

Finding 2

The governments of a small number of OECD countries already support programmes to evaluate the risk from NEOs, and to detect one category of potential colliders: the large asteroids that, if they struck the Earth, could produce a global-scale catastrophe with billions of casualties⁹. Most OECD governments, however, have not considered this threat, and have not undertaken any actions related to NEOs. Although, in some of these latter countries, scientists do participate in NEO studies and observations, there are no administrators or offices whose responsibilities include dealing with NEO issues as they relate to public safety.

Conclusion 2

Workshop participants recommend that each government that has not already done so consider designating a responsible official (office, administration, etc.) within the government, tasked with following the ever-growing body of knowledge about NEO impacts, and, where appropriate, advising the government regarding the implications for public safety of the NEO risk.

⁸ The best-known event of this kind is believed to have extinguished the dinosaurs (and many other species) approximately 65 million years ago. Smaller collisions happen with greater frequency, but they can produce significant damage. For example, the impact that devastated the Tunguska region of Siberia in 1908 could have produced millions of casualties had it occurred over a large city. Participants of the OECD workshop visited a newly-identified impact crater situated some 100 kilometres from Frascati. According to preliminary analysis, it was produced about 1500 years ago by an iron asteroid that hit the ground with an explosive power several times greater than that of the first nuclear weapons.

⁹ These asteroids have diameters greater than 1 kilometre. Essentially all of them are being discovered by the four programmes currently funded by the United States government. Fortunately, none of the large asteroids detected to date will strike the Earth in the foreseeable future. The programs are not, however, designed to detect long-period comets.

3. Assessing risk at the national level

Finding 3

While the probability of an NEO impact is effectively the same for all points on the Earth's surface, the magnitude of the risk is not the same for all countries. It depends, amongst other factors, on the country's size, population distribution, topography, economic infrastructure, proximity to the ocean, and vulnerability to other natural hazards (e.g., earthquakes). The evaluation of the risk requires data and expertise from many scientific fields and other domains relevant to risk analysis.

Conclusion 3

Interested countries that designate officials/offices that are responsible for NEO issues could profitably consider working jointly to quantify and assess national exposure to the NEO hazard/risk. A co-operative international effort would allow the sharing of relevant resources (e.g., expertise, data, methodologies). The results of these analyses should indicate the extent of the national threat relative to more familiar natural and man-made hazards, and should accurately reflect the sources and magnitudes of the associated uncertainties. Such an assessment exercise should be compatible with methods and procedures that national and international bodies already use when evaluating risks to lives and property.

4. Strengthening risk assessment through research and development

Finding 4

The accurate assessment of NEO risks will benefit from the development of additional scientific knowledge, and the reduction of uncertainties about certain key scientific aspects of NEOs, their entry into the Earth's atmosphere, and the consequences of impacts on land and in the sea. Workshop participants identified a number of priority areas:

- a. Strengthening ongoing efforts to discover NEOs, and to follow up the discoveries by further observations that allow precise orbit determinations and accurate impact predictions. Observations carried out in the southern hemisphere are particularly desirable.
- b. Understanding the formation, propagation and effects of NEO-generated tidal waves (tsunamis) that, according to some researchers, may pose a greater overall threat than impacts on land.
- c. Determining the consequences of impacts by bodies smaller than those currently being systematically detected. These NEOs, 100 metres to 1 kilometre in size, could cause widespread regional destruction. This analysis is needed to determine whether they should be the subject of new observational programmes.
- d. Supporting the networks and projects through which NEO data are gathered, analysed and archived, and through which NEO observations are disseminated, especially if, in the future, observing programmes are to extend to smaller-sized NEOs.
- e. Studying the composition, surface and bulk properties, and other physical characteristics of NEOs, using both Earth- and space-based platforms.
- f. Understanding the threat posed by long-period comets relative to asteroids.
- g. Developing methodologies for, and performing, comprehensive, multi-disciplinary risk analysis of pre- and post-impact response that includes the economic, environmental (e.g., ecological consequences), legal, and sociological aspects of the NEO hazard. This work could be done in the context of an all-hazards approach to disaster risk management.

Conclusion 4

Interested OECD countries may wish to consider the provision of resources for ongoing and new research that is relevant to analysis and assessment of the NEO hazard and risk. The seven topics listed in the finding above deserve consideration by interested governments. While existing scientific agencies and programmes may continue to provide the appropriate frameworks, OECD governments may wish to consider whether funds that are designated for basic scientific research could in the future be augmented with those allocated to enhancing public safety.

The scientific community could provide the information and advice that government officials require to carry out the national risk assessments. This scientific work should extend beyond the traditional NEO community (principally astronomers) to include experts in areas related to the consequences of NEO impacts on the Earth, on society, and on the biosphere in general¹⁰. Consultation among experts could also focus on optimising internationally-agreed principles and procedures for communicating information about predicted potential impacts and near-misses.

5. Supporting exploratory R&D for NEO mitigation

Finding 5

To have any chance of success, mitigation¹¹ of large-object impacts must begin with detection. To prevent impact, large asteroids (one hundred metres and larger) have to be identified many years before the collision, allowing sufficient time for technology development and a possibly lengthy period of gradual deflection via a variety of proposed technical means¹². Smaller asteroids are more difficult to detect, because they are very faint at large distances from Earth. Thus, a small object might be detectable heading towards Earth with relatively little warning. Even with little or no advance detection, some mitigation of the effects of impacts of small and medium –sized objects (< 1 km diameter) is still possible via existing emergency response mechanisms such as tsunami warning systems and evacuation procedures. Should any impactor be detected only months ahead of impact, deflection might still be possible via a direct high-energy intercept (the technology would have to be developed, tested, and ready) or by evacuating the impact area.

Long-period comets are a special case. Most of their orbital period is spent in the outer reaches of the Solar System, where they are practically impossible to detect. They may remain unobservable until they are only months away from a collision with Earth. It is generally thought that comets strike the Earth much less frequently than asteroids do, but they have higher orbital velocities and can be significantly larger than the majority of asteroids¹³, leading to more damage in the event of a collision.

It is difficult currently to specify reliably the cost and timescales associated with detection and mitigation. The systematic cataloguing of most potentially hazardous asteroids would be a

¹⁰ An appropriate organising body for this work could be the International Council for Science (ICSU). ¹¹ "Mitigation" refers to the deflection or destruction of the incoming object, as well as to any efforts to reduce the consequences of an impact (e.g., warning, evacuation).

¹² A number of ingenious deflection mechanisms have been proposed, including use of focussed sunlight, a robotic device to eject portions of an asteroid into space, deployment of a tethered "solar sail", direct thrust using an attached propulsive unit, and judiciously planned nuclear detonations.

¹³ For example, comet Hale-Bopp, which was discovered in mid-1995 and crossed the terrestrial orbit two years later, had a solid nucleus about 40 km diameter. The short-period comet Shoemaker-Levy 9, which collided with Jupiter in 1994, had an estimated size of a few kilometres.

medium-scale scientific undertaking. The deflection or destruction of an identified collider would be a much bigger proposition, perhaps comparable in cost and complexity to the USA's Apollo project in the 1960s, although it is anticipated that any deflection mission would be a predominantly international effort.

Conclusion 5

Interested countries may wish to explore strategies for mitigating the impact of a range of characteristic NEOs, identifying the scientific, technical, legal and policy implications of mounting a NEO negation mission against a range of potential impactors and timescales. Countries at particular risk of certain impacts (e.g., coastal regions susceptible to ocean impact induced tsunamis) should consider enhancement and co-ordination of regional monitoring and response activities, and should consider assessing the adequacy of their emergency response procedures for dealing with hypothetical NEO-related scenarios.

OECD GLOBAL SCIENCE FORUM

WORKSHOP ON NEAR EARTH OBJECTS: RISKS, POLICIES AND ACTIONS

20-22 January 2003

Chairman Richard CROWTHER (United Kingdom)

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European Space Research Institute (ESRIN), Frascati, Italy January 20-22, 2003

Chairman: Richard Crowther (United Kingdom)

Programme

Monday, January 20

Session 1 The Threat from NEOs Relative to Other Hazards

- 1 Welcome and introductory remarks. Background and purpose of the workshop.
- 2 *Effects of Land Impacts from NEOs* Jan Smit (Vrije Universiteit, The Netherlands)
- 3 *Tsunamis from NEOs* Jack Gilbert Hills (Los Alamos National Laboratory, USA)
- 4 *How an NEO Impact Might Affect Society* Clark Chapman (Southwest Research Institute, USA) <u>Commissioned paper</u>

Session 2 Perceiving and Dealing with Hazards

- 5 Strategic Responses to the NEO Hazard: Lessons Learned from Crisis Management Patrick Lagadec (Ecole Polytechnique, France)
- 6 *The Threat of NEOs: Reactions from the Public and the Press* Oliver Morton (UK)
- 7 Why Should Governments be Interested? Lembit Öpik (House of Commons, UK)
- 8 *Video presentation: Asteroids in Space* Syuzo Isobe (National Astronomical Observatory of Japan)
- 9 General Discussion

Dinner

Speech by Sir Crispin Tickell (University of Kent, UK)

Tuesday, January 21

Session 3.A The Science of NEOs

10 *Facts and Uncertainties About NEOs* Donald Yeomans (Jet Propulsion Laboratory, USA)

Session 3.B Assessing and Managing the Risk

- 11 Asteroid Searches and Monitoring: Predicting Impacts Andrea Milani (University of Pisa, Italy)
- 12 What Might Be Done to Prevent an Impact? Ivan Bekey (USA)
- **13** *Technology Development for Diversion and Mitigation* Marcello Coradini (European Space Agency)
- 14 *Trustworthy Deflection of an NEO* Russell Schweickart (B612 Foundation)

Session 4 International Aspects

- 15 *Astronomers, Impacts and Society: the IAU Experience* Hans Rickman (International Astronomical Union)
- **16** *Coordination for Detection, Computation and Assessment* Andrea Carusi (Spaceguard Foundation, Italy)
- 17 *International Co-ordination at the Minor Planet Center* Brian Marsden (Smithsonian Astrophysical Observatory, USA)
- **18** *The Legal Basis for International Cooperation* Evan R. Seamone (University of Iowa, USA)
- **19** *National Programmes for Dealing with Natural Hazards (including NEOs)* Workshop participants

Wednesday, January 22

Session 5 General Discussion and Conclusions for the Global Science Forum