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Near-Earth objects

Near-Earth objects

Interim report of the Action Team on Near-Earth Objects (2008-2009)

I. Introduction

1. The Action Team on Near-Earth Objects[1] was established in response to recommendation 14 of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) and was given the following terms of reference:

(a) Review the content, structure and organization of ongoing efforts in the field of near-Earth objects (NEOs);

(b) Identify any gaps in the ongoing work where additional coordination is required and/or where other countries or organizations could make contributions;

(c) Propose steps for the improvement of international coordination in collaboration with specialized bodies.

2. At its fifty-first session, in 2008, the Committee on the Peaceful Uses of Outer Space noted with satisfaction the work carried out by the Working Group on Near Earth Objects of its Scientific and Technical Subcommittee and by the Action Team

* A/AC.105/C.1/L.297.

[1] A near-Earth object (NEO) is an asteroid or comet whose orbit brings it close to the Earth, usually defined as within 45 million kilometres of the Earth's orbit. This includes an object that will come close to the Earth at some point in its future orbital evolution. NEOs generally result from objects that have experienced gravitational perturbations from nearby planets, moving them into orbits that allow them to come near to the Earth.

on Near-Earth Objects and endorsed the following amended multi-year workplan for 2009-2011:[2]

2009 Consider the reports submitted in response to the annual request for information on near-Earth object activities and continue intersessional work. Continue to review policies and procedures related to the handling of the NEO threat at the international level and consider drafting international procedures for handling the NEO threat. Work within the framework of the International Year of Astronomy, 2009 to raise awareness of the NEO threat. Review and prepare an updated interim report of the Action Team on Near-Earth Objects.

2010 Consider the reports submitted in response to the annual request for information on near-Earth object activities and continue intersessional work. Continue drafting, and seek agreement on, international procedures for handling the NEO threat. Review progress on international cooperation and collaboration on NEO observations. Facilitate, for the purpose of NEO threat detection, a more robust international capability for the exchange, processing, archiving and dissemination of data. Review and prepare an updated interim report of the Action Team on Near-Earth Objects.

2011 Consider the reports submitted in response to the annual request for information on near-Earth object activities and continue intersessional work. Finalize agreement on international procedures for handling the NEO threat and engage international stakeholders. Review progress on international cooperation and collaboration on NEO observations and on the international capability for the exchange, processing, archiving and dissemination of data for the purpose of NEO threat detection. Consider the final report of the Action Team on Near-Earth Objects.

3. The present interim report is a summary of the input received from members of the Action Team on Near-Earth Objects for 2008-2009 and serves as an update to its previous interim report, which covered the period 2007-2008 (A/AC.105/C.1/L.295). The present report presents activities and issues relating to the NEO hazard, the current understanding of the risk posed by NEOs and the measures required to mitigate that threat. In accordance with the terms of reference of the Action Team, it is expected that an updated interim report will be issued each year to reflect the existing state of knowledge, related activities and the consensus on prioritization of the issues to be addressed and their possible solutions. More detailed descriptions of activities are provided in the annual national reports provided to the Committee by Member States and in the presentations made by the Committee members and observers at the annual session of the Subcommittee.

[2] *Official Records of the General Assembly, Sixty-third Session, Supplement No. 20* (A/63/20), para. 153.

II. Interim report of the Action Team on Near-Earth Objects

A. Near-Earth object detection and remote characterization

4. The first step in addressing the risk posed by an NEO is to detect its presence and infer its size from its trajectory and observed brightness. The United States of America makes the most significant contribution to the field of NEO detection and remote characterization. The Near-Earth Object Program of the National Aeronautics and Space Administration (NASA) of the United States funds five NEO search teams to operate nine separate 1-metre class survey telescopes across the south-western United States and one in Australia, which can detect objects, on average, down to magnitude 20. The Near-Earth Object Program is supplemented by orbit follow-up observation activities carried out by a variety of professional and amateur astronomers around the world.

5. The Action Team recognized that significant efforts were being made internationally to detect and, to a lesser degree, follow up observations of potentially hazardous NEOs larger than 1 kilometre in diameter. As at 1 October 2008, 823 objects larger than 1 kilometre had been found, out of a population estimated to be fewer than 1,000 such objects. However, the Action Team noted that objects in the range of 100 metres to 1 kilometre, for which the current surveys were not optimized, still posed a significant impact threat.

6. The Action Team encouraged NASA, along with its international partners, to continue to seek ways in which the threshold for the detection of NEOs could be reduced to 140 metres, as the Action Team recognized that such objects were likely to pose a more immediate threat to the Earth than the smaller number of kilometre-sized objects. The Action Team noted that discovery and precision orbit determination were the critical first steps in characterizing an NEO threat and initiating a mitigation action, and that facilities and capabilities for collecting and rapidly processing the discovery data were essential. The Action Team also noted that some NEOs were binary in nature (that is, they had accompanying moons), which were themselves large enough to pose a hazard, and that those moons might complicate considerations for deflection plans. The Action Team therefore expressed concern that the planetary radar at Arecibo, operated by Cornell University for the United States National Science Foundation, which had the world's best capabilities for determining the orbit of NEOs such as Apophis, as well as estimating their size and spin state and detecting accompanying bodies, was scheduled to be shut down during the 2012-2013 apparition of Apophis. The Action Team recognized that the use of Arecibo during that period was important for determining whether Apophis posed a serious threat of impact with the Earth in 2036, and that it was likely to remain important as new objects were discovered.

7. The Action Team agreed that a coordinated observation campaign of Apophis should be implemented during the winter of 2012-2013, when Apophis would have an apparent magnitude of approximately 17 (m_V~17), in order to refine its ephemeris and in particular characterize the magnitude of the non-gravitational forces (Yarkovsky effect), which need to be known for orbit extrapolation. Given that Apophis will be in the southern hemisphere, it is expected that such a campaign would mainly involve observatories in Africa, Australia and South America.

8. The Action Team was encouraged to note that the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), funded by the United States Air Force, was expected to start operations on its first prototype instrument in the near future. The capability to detect moving objects in the collected image data and extract observations for newly discovered objects, as well as known objects, had been completed with NASA funding, and NASA would also fund a portion of the Pan-STARRS-1 operations for NEO search purposes, starting in 2009. The Planetary Science Division of NASA was also funding efforts to incorporate NEO detection capability within the data-processing segment on the Wide-field Infrared Survey Explorer (WISE) mission (also to be launched in the near future), sponsored by the Astrophysics Division of NASA. The primary mission of the spacecraft was to produce a detailed map of the extra-galactic sky in four infrared bands, but during the collection of those data over the planned six-month prime mission, the infrared signature of many NEOs and other asteroids and comets could be extracted and processed to produce observations to be sent to the Minor Planet Center. The transient image data would also be archived for use in making more accurate size estimates on known objects and to provide another resource for finding precovery observations (extraction of observation data from existing image archives once an object is discovered and previous positions can be calculated and correlated with the archived image sets). Since that enhancement to the mission only required additions in the ground processing of the WISE data, it could be incorporated even though the spacecraft was less than a year from planned launch. Approximately 200 new NEOs were expected to be detected during the six-month mission and the capability existed to extend the mission an additional six months if it performed well, doubling the amount of data that could be obtained. The Action Team encouraged agencies to consider other opportunities to address such complementary primary and secondary objectives for future prospective missions.

B. Orbit determination and cataloguing

9. The Action Team considered that it was important that objects detected from the ground were uniquely identified and that their orbits were refined to assess the impact threat to the Earth. The Minor Planet Center was fundamental to that process. The Center was operated by the Smithsonian Astrophysical Observatory, in coordination with the International Astronomical Union, based on a memorandum of agreement giving the Center an international charter. Pursuant to the memorandum of agreement, the Center had, since 1978, served as the international clearing house for all asteroid, comet and satellite astrometric (positional) measurements obtained worldwide. The Center processed and organized data, identified new objects, calculated orbits, assigned tentative designations and disseminated information on a daily basis. For objects of special interest, the Center solicited follow-up observations and requested archival data searches. The Center was responsible for the dissemination of astrometric observations and orbits via so-called Minor Planet Electronic Circulars (issued as necessary, generally at least once a day) and related catalogues. In addition to distributing complete orbit and astrometric catalogues for all small bodies in the solar system, the Center facilitated follow-up observations of new potential NEOs by placing candidate sky-plane ephemerides and uncertainty maps on the Internet via the NEO confirmation page. The Center focused specifically on identification, short-arc orbit determination and dissemination of

information pertaining to NEOs. In most cases, observations of NEOs were distributed to the public free of charge within 24 hours of receipt. The Center also provided a variety of tools to support the NEO initiative, including sky coverage maps, lists of known NEOs, lists of NEO discoverers and a page of known NEOs requiring astrometric follow-up. The Center also maintained a suite of computer programs to calculate the probability that an object was a new NEO, based on two sky-plane positions and magnitude. Links to those Internet resources can be found on the website of the Center (www.cfa.harvard.edu/iau/mpc.html).

10. The Action Team recognized that the role of the Minor Planet Center was critical to the dissemination and coordination of observations and welcomed the confirmation by NASA of its increased sponsorship of the Center to upgrade its capability to process all observations received from worldwide observatories and disseminate the resulting orbit information without charge via the Internet, and to allow the Center to accommodate the anticipated significant increase in NEO observation data with the "next generation" search efforts. The Action Team continues to recognize the benefit of establishing a "mirror" capability to the Center, possibly hosted in Europe or Asia. The two nodes could share analysis protocols and processes, and could have a common data management and access policy, but would perform a complementary operational role, perhaps performing the same operations on a different subset of the observation data, but independently maintaining a complete database. The two sites could also then act to validate and verify their more critical respective outputs.

11. On a daily basis, the Minor Planet Center made NEO astrometric data available to the Near-Earth Object Program and to a parallel, but independent, orbit computation centre in Pisa, Italy, with a mirror site in Valladolid, Spain. Through the Sentry system of the NASA Jet Propulsion Laboratory (http://neo.jpl.nasa.gov/risk), risk analyses were automatically performed on objects that had a potential for Earth impact, usually when the object had been recently discovered, and lacked the lengthy data interval that would make its orbit secure. Those objects were prioritized for the Sentry system according to their potential for close approaches to the Earth's orbit and according to the existing quality of their orbits. The Sentry system automatically updated the orbits of approximately 40 NEOs per day and close-approach tables were generated and posted on the Internet (http://neo.jpl.nasa.gov/cgi-bin/neo_ca). Approximately five risk analysis cases were performed each day, with each analysis providing 10,000 multiple solutions up to 2105. That process was also performed in parallel in Pisa, Italy, and significantly non zero Earth-impact cases were manually checked at the Laboratory and at the orbit computation centre in Pisa before the risk analysis data were posted on the Internet. For recently discovered objects of unusual interest, the Minor Planet Center, the Laboratory and the centre in Pisa would often alert observers that additional future or recovery observation data were needed.

12. The Action Team noted that the Sentry system and the Near-Earth Objects Dynamic Site system were completely independent systems that employed different theoretical approaches to providing impact risk assessments. Hence, if the long-term orbit propagations from each converged to a single solution, the wider community could have some confidence in the predicted outcome. Whereas the Sentry system was funded as part of the Near-Earth Object Program of NASA and thus its operational future could be considered relatively secure, the long-term funding for

the Dynamic Site system was not so clear. As with the operation of the Minor Planet Center, the Action Team considered that an independent but complementary capability to the Sentry system was critical for the purposes of independent verification and validation of predicted close approaches.

13. The Action Team was particularly encouraged to note how effectively the process outlined above had been implemented in the recent discovery and subsequent impact of NEO 2008 TC3. That very small (around 3 metres in diameter) object had been discovered by the United States Catalina Sky Survey team just 20 hours before it entered the Earth's atmosphere on 7 October 2008. Within eight hours of collection of the discovery observations, the Minor Planet Center had identified the object as a potential impactor and alerted both NASA and the Jet Propulsion Laboratory. While the Center requested follow-up from all available observers and the Jet Propulsion Laboratory produced more precise predictions and compared results with the Near-Earth Objects Dynamic Site system, NASA headquarters started the actions required to alert the global community of the impending impact. During the subsequent 12 hours, the worldwide NEO network had provided the Center with some 570 observations from 27 different observers. Based on the precise predictions provided by the Jet Propulsion Laboratory and the Near-Earth Objects Dynamic Site system, NASA had provided information for public release and dissemination via diplomatic channels to the effect that the entry would take place over northern Sudan at 0245 Coordinated Universal Time on 7 October 2008. Released six hours in advance, the information had been accurate to within seconds of the entry observed by meteorological satellites and detected by infrasound sensors.

14. Having recognized the critical role that the Center played, the Action Team was pleased to learn that the Planetary Science Division of NASA was continuing to fund the Center's operations and upgrades, and almost wholly supported the centre, providing over 90 per cent of its financing. Noting the importance of the Near-Earth Objects Dynamic Site system, the Action Team hoped that a similar firm funding basis might be found for the team at the University of Pisa, possibly through the envisaged Space Situational Awareness programme, which was being considered by the member States of the European Space Agency at its Ministerial Council in November 2008.

C. Consequence determination

15. The Action Team recognized that, in considering a science-based policy to address the risk posed by NEOs, it was important for Governments to evaluate the societal risk posed by such impacts and to compare that risk with the thresholds established for dealing with other natural hazards (for example, meteorological and geological hazards) so that a commensurate and consistent response could be developed. The Action Team felt that more work needed to be done in that area, especially on impactors of less than 1 kilometre in diameter. The issue was discussed in detail at the Tunguska Conference, held in Moscow in June 2008, hosted by the Russian Academy of Sciences and attended by a number of Action Team members. The 1908 Tunguska airburst from a small asteroid had generally been estimated to have had an energy of 10-15 megatons. The corresponding size for a rocky impactor was roughly 60 metres in diameter. The Action Team noted that

Mark Boslough of Sandia National Laboratories, United States, had generated new supercomputer simulations that had suggested a smaller Tunguska explosion. Boslough's models required less energy in the explosion because of the inclusion of a substantial downward momentum of the rocky impactor, rather than modelling it as a stationary explosion. If that revision (down to an estimated energy of 3-5 megatons and a corresponding diameter of perhaps as little as 40 metres) was correct, the expected frequency of such impacts would change from once in a couple of millenniums to once in a few hundred years, with consequent implications for hazardous impact event statistics.

D. In situ characterization

16. The Action Team noted the importance of the Hayabusa (MUSES-C) mission, which had rendezvoused with the near-Earth asteroid 25143 Itokawa in late 2005, not only because of the scientific knowledge that had been gained on the characteristics of the asteroid, such as topography and composition, but also because of the important operational lessons that had been learned from rendezvous and proximity operations in a very low gravity environment and because of the implications for future in situ investigations and possible mitigation activities. Hayabusa followed in a long line of successful missions such as Near Earth Asteroid Rendezvous, Deep Space 1, Stardust and Deep Impact, which had provided unique insights into the characteristics of the surprisingly diverse population of NEOs. Detailed NEO characterization could not be derived from remote observations and the Action Team looked ahead with anticipation to the upcoming missions to NEOs.

17. The Action Team was encouraged by the news that the Space Council of the Russian Academy of Sciences and the Russian Federal Space Agency had decided to fund a feasibility study for a low-cost space mission to Apophis in 2013. The major goal of the mission was to put a transponder in a circum-asteroid orbit, thereby improving the accuracy of the Apophis orbit determination. The Action Team welcomed the news that the Planetary Science Division of NASA had also funded a concept study for a low-cost, small-satellite, in situ characterization mission to Apophis during its next apparition, which was expected to occur between 2012 and 2013. In that concept, the spacecraft would be launched as a secondary payload from a geosynchronous primary mission and rendezvous with Apophis about one year later, during the next close approach to the Earth of the asteroid. A suite of miniaturized cameras and other instruments would fully characterize the potentially hazardous asteroid and provide sufficient high-precision ranging data to fully determine the orbit of the asteroid on subsequent close approaches over the following century. NASA had also funded a United States science team to participate in the study and development of the proposed Marco Polo mission of the European Space Agency, a planned sample return mission from an NEO, which was being considered under the Cosmic Vision programme of the European Space Agency.

E. Mitigation

18. Mitigation in this context is the process of either negating or minimizing the impact hazard posed to Earth by the sub-class of NEOs called "potentially

hazardous objects", through some form of intervention or interaction with the risk body, or by minimizing its impact on the population through evacuation or a similar response.

19. The Action Team noted that, in addition to the probability of impact and the time to impact, other parameters that would influence the response strategy would be the anticipated locus of intersection on the surface of the Earth and the vulnerability of that area to the impact. The various options for deflection and the implications (technical readiness, political acceptability, cost of development and operation, and translation of locus of intersection) of a particular deflection strategy would also have to be weighed against the alternatives. The Action Team acknowledged that it was possible that a specific impact might threaten only non-spacefaring nations. It might be considered more attractive for one capable actor to take the lead in mounting a particular deflection mission, rather than a group of agencies with different roles, owing to the complexity of the mission and the political expediency of protecting sensitive technical information. The Action Team therefore envisaged a range of options, with agreed responses to a range of impact scenarios and with identified players performing specific roles. The Action Team identified the need for an international technical forum, at which a range of probable impactor scenarios could be determined and a corresponding range of mitigation options for responses to a specific threat developed to a degree permitting reliable mission timelines to be established and inserted on a timeline for decision-making by the international community.

20. The Committee on Near-Earth Objects of the Association of Space Explorers notified the Action Team on Near-Earth Objects that the B612 Foundation had informed it that the results of its contract with the Jet Propulsion Laboratory for a detailed performance analysis to be carried out on the capability of a mitigation concept known as the "gravity tractor" had been completed and made available.[3] Recognizing that a successful NEO deflection campaign would involve several key functional elements, including the ability to precisely determine, in situ, the orbit of a threatening NEO prior to and post-deflection, and to precisely adjust the orbit of the NEO to ensure its successful passage between return keyholes at the time of its closest approach to Earth, the B612 Foundation requested the Jet Propulsion Laboratory to quantify those two critical capabilities. The analysis verified the ability of the gravity tractor to perform those critical deflection functions. The Action Team welcomed the new insight into potential mitigation options for addressing potentially hazardous NEOs.

F. Policy

21. The Action Team recognized that the threat of impact posed by NEOs was real and that any such impact, although its probability was low, was potentially catastrophic. It was also recognized that the effects of such an impact would be indiscriminate (that is, it was unlikely that they would be confined to the country of impact) and that the scale of those effects was potentially so great that the NEO hazard should be recognized as a global issue that could be addressed effectively

[3] The report on the performance of the gravity tractor is available from the website of the B612 Foundation, at www.b612foundation.org/press/press.html.

only through international cooperation and coordination. No country was known to have a national NEO strategy. Thus, the United Nations had an important role to play in informing the process of developing the required policy.

22. It was probable that within the next 15 years the global community would be confronted with a perceived impact threat (although the reality was more likely to be a near miss), which would make necessary, prior to the availability of certain knowledge that an impact would occur, the taking of critical decisions on whether action should be taken, and, if so, on the nature of that action, to protect life on Earth from a potential NEO impact. The dilemma would arise from the accelerating rate of discovery of the population of NEOs and the development of human capability to prevent an anticipated impact by pre-emptive action to deflect the NEO. The need for decision-making might therefore be significantly more frequent than the statistical incidence of impacts. It was recognized that, if humankind were given early warning that an impact was expected and knew that a deflection capability existed to prevent that impact from occurring, responsibility for the consequences of action or inaction was unavoidable. Given that the entire planet was subject to the threat of NEO impact and since the process of eliminating the risk to all by opting for deflection would inevitably result in a temporary increase in risk to populations not otherwise at risk, the United Nations would inevitably be called upon to facilitate the global effort to evaluate trade-offs and arrive at decisions on what actions should be implemented collectively.

23. Having recognized the need to advance the NEO decision-making process, the Committee on Near-Earth Objects of the Association of Space Explorers concluded, in September 2008, a series of international workshops held to examine the matter. To assist it in addressing the multitude of geopolitical issues involved, the Committee established an International Panel on Asteroid Threat Mitigation, made up of experts in diplomacy, law, technology and disaster management. The report of the Panel was transmitted to the Action Team on Near-Earth Objects, for its consideration.[4] The primary findings and recommendations of the report addressed three critical functional requirements for responding to the threat of asteroid impacts: (a) the need for an agreed source of information on and analysis and warning of NEO threats; (b) the need for coordinated space mission planning and operations carried out by the capable space agencies of the world, including in cooperation, and (c) the need for an NEO threat oversight group representing the international community and charged with the development of criteria and policies to ensure a coordinated international response. The Action Team welcomed the report as representing an important contribution to a possible NEO policy framework and recognized its value in informing the workplan of the Working Group on NEOs and in terms of its review of potential policies related to the handling of the NEO hazard and of its proposals on the drafting of international procedures for handling that threat.

[4] A summary of the report of the International Panel on Asteroid Threat Mitigation is contained in the annex to the present report, for consideration by the Working Group on Near-Earth Objects of the Scientific and Technical Subcommittee.

Annex

Summary of the report of the Association of Space Explorers International Panel on Asteroid Threat Mitigation entitled "Asteroid threats: a call for a global response"*

1. The following individuals are members of the International Panel on Asteroid Threat Mitigation: Russell Schweickart** (Chair), Adigun Ade Abiodun, Vallampadugai Arunachalam, Sergei Avdeev,** Roger-Maurice Bonnet, Sergio Camacho-Lara, Franklin Chang-Diaz,** James George, Tomifumi Godai, Chris Hadfield,** Peter Jankowitsch, Thomas Jones,** Sergey Kapitza, Paul Kovacs, Walther Lichem, Edward Lu,** Gordon McBean, Dorin Prunariu,** Martin Rees, Karlene Roberts, Viktor Savinykh,** Michael Simpson, Crispin Tickell, Frans von der Dunk, Richard Tremayne-Smith, James Zimmerman.

A. Introduction

2. In 2005, the Association of Space Explorers (ASE) recognized the global nature of the asteroid impact hazard. It noted that future impacts from near-Earth objects (NEOs) can occur anywhere on Earth and that the response required political will and technical capabilities to deflect a hazardous asteroid using the contributed expertise of all interested nations. Subsequently, ASE formed an NEO committee to consider the challenge of future asteroid impacts. Through its observer status on the Committee on the Peaceful Uses of Outer Space, ASE developed a plan to draft a document on an NEO decision-making process. It was agreed that the document be submitted for consideration and subsequent action through the relevant organizations of the United Nations.

3. ASE assembled its International Panel on Asteroid Threat Mitigation, enlisting volunteer experts in science, diplomacy, law and disaster management from around the world. That Panel, through ASE, has, over the past three years, continually advised the Committee's Action Team on Near-Earth Objects about its work. The Action Team, aware of that progress in the drafting of decision-making procedures to respond to asteroid threats, accepted the report of the ASE International Panel for further consideration and action.

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* The summary of the report of the Association of Space Explorers International Panel on Asteroid Threat Mitigation entitled "Asteroid threats: a call for a global response" was transmitted to the Action Team on Near-Earth Objects on 25 September 2008. The summary is reproduced in the present annex in the form in which it was received for consideration by the Working Group on Near-Earth Objects of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space at the forty-sixth session of the Subcommittee. The full text of the report is available on the website of the Association of Space Explorers (http://www.space-explorers.org/committees/NEO/docs/ATACGR.pdf). The definition of terms and concepts used in the summary of the report are contained in the full report.

** Member of the Committee on Near-Earth Objects of the Association of Space Explorers.

4. The report conveys the findings of the International Panel on Asteroid Threat Mitigation to the appropriate United Nations organs and programmes. The submission of the report begins the process of developing a global response to existing and future asteroid threats.

B. Background

5. The Earth's geological and biological history is punctuated by evidence of repeated and devastating impacts from space. Sixty-five million years ago, an asteroid impact caused the extinction of the dinosaurs, along with some 70 per cent of the Earth's living species. A more typical recent impact was the 1908 Tunguska Event, a 3-5 megaton explosion that destroyed 2,000 square kilometres of Siberian forest.

6. A future asteroid collision could have disastrous effects on our interconnected human society. The blast, fires and atmospheric dust produced could cause the collapse of regional agriculture, leading to widespread famine. Ocean impacts such as the Eltanin event (2.5 million years ago) produce tsunamis which devastate continental coastlines. The impact of asteroid 99942 Apophis, which has a 1-in-45,000 chance of striking the Earth in 2036, would generate a 500-megaton blast and inflict enormous damage.

7. Devastating impacts are clearly infrequent events compared with a human lifetime: events of the scale of the Tunguska event, thought to be caused by the impact of a 45-meter-wide asteroid, occur, on average, two or three times every thousand years. However, when NEO impacts occur, they can cause terrible destruction, dwarfing that caused by more familiar natural disasters.

8. Advances in observing technology will lead to the detection of over 500,000 NEOs over the next 15 years. Of those, several dozen will pose an uncomfortably high risk of striking the Earth and inflicting local or regional devastation.

C. The need for a global response

9. Faced with such a threat, we are far from helpless. Astronomers today can detect a high proportion of NEOs and predict potential collisions with the Earth. Evacuation and mitigation plans can be prepared to cope with an unavoidable impact. For the first time in our planet's 4.5-billion-year history, the technical capacities exist to prevent such cosmic collisions with the Earth. The keys to a successful outcome in all cases are preparation, planning and timely decision-making.

10. Efforts to deflect an NEO will temporarily put different populations and regions at risk in the process of eliminating the risk to all. Questions arise regarding the authorization and responsibility to act, liability and financial implications. These considerations make it inevitable that the international community, through the United Nations and its appropriate organs, will be called upon to make decisions on whether or not to deflect an NEO, and how to direct a proposed deflection campaign. Because of the substantial lead time required for a deflection, decisions will have to be taken before it is certain that an impact will occur. Such decisions

may have to be made as much as ten times as often as the occurrence of actual impacts.

11. Existing space technology makes possible the successful deflection of the vast majority of hazardous NEOs. However, once a threatening object is discovered, maximizing the time to make use of that technology will be equally important. Failure to put in place an adequate and effective decision-making mechanism increases the risk that the international community will delay in the face of such a threat. Such a delay will reduce the time available for mounting a deflection campaign. Therefore, timely adoption of a decision-making programme is essential to enabling effective action.

12. Within 10-15 years, the United Nations, through its appropriate organs, will face decisions about whether and how to act to prevent a threatening impact. To counter a threat of global dimensions, information-sharing and communication capabilities must be harnessed to identify and warn society of hazardous NEOs. To prevent an actual impact, an international decision-making programme, including necessary institutional requirements, must be agreed upon and implemented within the framework of the United Nations.

13. ASE and its International Panel on Asteroid Threat Mitigation propose the following programme.

D. Proposed Programme for Action

14. Because NEO impacts represent a global, long-term threat to the collective welfare of humanity, an international programme and set of preparatory measures for action should be established. Once in place, those measures should enable the global community to identify a specific impact threat and decide on effective prevention or disaster responses.

15. A global, coordinated response by the United Nations to the NEO impact hazard should ensure that three logical, necessary functions are performed, as described in the following three recommendations.

1. Information-gathering, analysis and warning

Recommendation 1

16. An Information, Analysis and Warning Network (IAWN) should be established. This network would operate a global system of ground- and/or space-based telescopes to detect and track potentially hazardous NEOs. The network, using existing or new research institutions, should analyse NEO orbits to identify potential impacts. The network should also establish criteria for issuing NEO impact warnings.

2. Mission planning and operations

Recommendation 2

17. A Mission Planning and Operations "Group", drawing on the expertise of the space-faring nations, should be established and mandated to outline the most likely options for NEO deflection missions. This group should assess the current global

capacity to deflect a hazardous NEO by gathering necessary NEO information, identifying required technologies and surveying the NEO-related capabilities of interested space agencies. In response to a specific warning, the group should use these mission plans to prepare for a deflection campaign to prevent the threatened impact.

3. Near-Earth object threat oversight and recommendation for action

Recommendation 3

18. The United Nations should exercise oversight of the above functions through an intergovernmental Mission Authorization and Oversight "Group". This group would develop the policies and guidelines that represent the international will to respond to the global impact hazard. The Mission Authorization and Oversight Group should establish impact risk thresholds and criteria to determine when to execute an NEO deflection campaign. The Mission Authorization and Oversight Group would submit recommendations to the United Nations Security Council for appropriate action.

19. These three functions are further elaborated in the appendix to this summary report.

E. Conclusion and way forward

20. The Association of Space Explorers and its International Panel on Asteroid Threat Mitigation are confident that with a programme for concerted action in place, the international community can prevent most future impacts. The Association of Space Explorers and its International Panel are firmly convinced that if the international community fails to adopt an effective, internationally mandated programme, society will likely suffer the effects of some future planetary disaster—intensified by the knowledge that loss of life, economic devastation and long-lasting societal disruption could have been prevented. Scientific knowledge and existing international institutions, if harnessed today, offer society the means to avoid such a catastrophe. We cannot afford to shirk that responsibility.

21. Humankind now possesses the technology to provide the first two essential elements necessary to protect the planet from asteroid impacts. Early impact warning is already under way for the largest objects of concern, and new telescopes will soon increase the capability to provide impact warning for more numerous smaller objects of concern. Asteroid deflection capability, while not yet proven, is possible with current spaceflight technology and is being actively investigated by several of the world's space agencies. The missing third element is the readiness and determination of the international community to take concerted action in response to a perceived threat to the planet.

22. An adequate global action programme must include deflection criteria and campaign plans that can be implemented rapidly and with little debate by the international community. In the absence of an agreed-upon decision-making process, we may lose the opportunity to act against an NEO in time, leaving evacuation and disaster management as our only response to an impending impact. The international community should begin work now on forging its warning,

technology, and decision-making capacities into an effective shield against a future collision.

Appendix

Implementation of the recommendations

A. Information, Analysis and Warning Network

1. Recommendation 1 calls for establishment of an Information, Analysis and Warning Network (IAWN). At the highest level, the responsibilities of such a network would include the following:

(a) To serve as the official source of information on the NEO environment;

(b) To designate and maintain the official clearing house for all NEO observations and impact analysis results;

(c) To review the existing NEO information set provided by the Jet Propulsion Laboratory Sentry System and the Near Earth Objects Dynamic Site (NEODyS) and possibly recommend modifications to them;

(d) To recommend policies to the NEO Threat Oversight Group (NTOG) regarding criteria for warning and, with the backing of the policy group issue "all-clears" and warnings;

(e) To consider and recommend to NTOG a public information policy on emerging NEO impact threats and to explore threshold levels at which such information as the risk corridor, potential tsunami simulations and other potential impact information should be released to the public;

(f) To identify, in cooperation with Member States of the United Nations, methods to engage designated national/international disaster response entities;

(g) To assist in mitigation response planning;

(h) To recommend, in cooperation with the Mission Planning and Operations Group, to the Mission Authorization and Oversight Group the criteria for initiating the planning of a deflection campaign;

(i) To develop and recommend to NTOG minimum NEO threshold characteristics warranting international community attention;

(j) To develop and recommend to NTOG a public information plan to include parameters, update criteria, dissemination means and an enquiry handling policy.

B. Mission Planning and Operations Group

2. Recommendation 2 calls for the establishment of a Mission Planning and Operations Group (MPOG). At the highest level, the responsibilities of such a Group would be the following:

(a) To determine specific decision and event timelines for all NEOs identified for preliminary deflection campaign analysis;

(b) To develop and recommend to NTOG a process for operational responsibility of deflection campaigns;

(c) To evaluate and recommend to NTOG alternative deflection concepts proposed by space-faring nations;

(d) To develop specific information required to support mission planning efforts and transmit them to IAWN;

(e) To develop costing models for each approved deflection campaign concept and for each planning and mission operations event.

C. Near-Earth Object Threat Oversight Group

Recommendation 3 calls for the establishment and tasking of an NEO Threat Oversight Group. At the highest level, the responsibilities of such a group would be the following:

(a) To develop a policy to fund Member States that conduct authorized NEO activities on behalf of the international community and to submit final recommendations to the United Nations Security Council for adoption and implementation;

(b) To consider and propose for adoption, by the appropriate United Nations organs, threshold criteria for various alert, warning and action decisions submitted by IAWN;

(c) To consider and decide upon general policy issues presented and/or recommended by MPOG;

(d) To sit ex officio in all IAWN and MPOG sessions.