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Near-Earth objects

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Interim report of the Action Team on Near-Earth Objects

I. Introduction

1. At its forty-ninth session, in 2006, the Committee on the Peaceful Uses of Outer Space noted with satisfaction that a working draft of a report summarizing the work carried out to date by the Action Team on Near-Earth Objects and indicating what further activity could help to complete the work of the Action Team would be presented to the Scientific and Technical Subcommittee at its forty-fourth session.[1]

2. The Action Team on Near-Earth objects 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.

* A/AC.105/C.1/L.287.

[1] *Official Records of the General Assembly, Sixty-first Session, Supplement No. 20* (A/61/20), para. 145.

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3. At its forty-third session, in 2006, the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space adopted the following workplan for 2006 and 2007:

(a) Member States and international organizations shall submit reports on their near-Earth object activities, including missions and search and follow-up, as well as plans for future activities;

(b) The Action Team will consider the way forward, including, specifically, the possible need for further activity to be carried out through national, regional or international cooperation. Such cooperation should be considered together with the prospects for harmonization and the avenues for broader collaboration;

(c) The Action Team will update the work programme for the third year as necessary and consider the need for intersessional work.

4. The present interim report is a summary based on input received from members of the Action Team on Near-Earth Objects. The report covers the activities and issues relating to the NEO hazard, the understanding of the risk posed by those objects 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 general consensus on the prioritization of the issues to be addressed and their possible solutions. More detailed descriptions of activities can be found in the annual national reports provided to the Committee by Member States and in the presentations by Committee members and observers at the annual session of the Subcommittee.

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

A. Near-Earth object detection and remote characterization

5. 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. Those five search teams are listed below, together with the related websites containing further information:

(a) The Spacewatch project of the Lunar and Planetary Laboratory of the University of Arizona operates two telescopes on Kitt Peak, Arizona (http://spacewatch.lpl.arizona.edu);

(b) The Near-Earth Asteroid Tracking programme of the Jet Propulsion Laboratory of NASA operates a detection camera on a telescope at Palomar Observatory, California (http://neat.jpl.nasa.gov);

(c) The Lincoln Near-Earth Asteroid Research project of the Lincoln Laboratory of the Massachusetts Institute of Technology under a United States Air

Force contract funded by NASA, operates two telescopes near Socorro, New Mexico (http://www.ll.mit.edu/LINEAR);

(d) The Lowell Observatory Near-Earth Object Search of the Lowell Observatory near Flagstaff, Arizona (http://asteroid.lowell.edu/asteroid/loneos/loneos.html);

(e) The Catalina Sky Survey, carried out by a separate team at the Lunar and Planetary Laboratory of the University of Arizona, operates two telescopes on Mount Lemmon, Arizona, and one at Siding Spring, Australia, the first southern hemisphere asset (http://www.lpl.arizona.edu/css).

6. The United States also operates two planetary radars capable of observing NEOs. For a short data arc, single apparition orbit solution, radar data are extremely powerful in reducing orbital uncertainties; radar observations can extend the orbital prediction capability to approximately 4.5 times longer than a comparable orbit solution using only optical observations. The Goldstone radar is located in southern California, in the Mojave Desert. It uses the 70-metre antenna of the NASA Deep Space Network, (DSN-14), which is currently equipped with a 450-kilowatt transmitter and can receive on that dish or other nearby antennas of the Deep Space Network. Because it is steerable, the antenna can reach much of the sky and can follow the often rapid apparent motions of NEOs. The second radar, located at Arecibo, Puerto Rico, is owned and managed by the National Science Foundation and operated by Cornell University under a cooperative agreement with the Foundation. The radar has an aperture of 305 metres and a transmitter power of 900 kilowatts. Its reach is further than that of Goldstone, but because it is a fixed antenna, it can look only about 20 degrees off its zenith position.

7. In Europe, scientists at the Institute of Planetary Research of the German Aerospace Center (DLR) have been involved in observation campaigns for the physical characterization of NEOs using ground-based and space-borne optical telescopes. Unlike the operational status of the United States detection systems, observing time on those telescopes is awarded on a competitive rather than dedicated basis. Observational work in the thermal infrared region is led by the United States and entities such as DLR of Germany, the Massachusetts Institute of Technology and the University of Hawaii of the United States, the Queen’s University Belfast of the United Kingdom of Great Britain and Northern Ireland, the University of Helsinki and the Turin Astronomical Observatory of Italy.

8. In addition, a partnership of astronomers in the United Kingdom, from Durham University, Queen’s University Belfast and the University of Edinburgh, has joined a group of German and United States institutions in using an advanced new telescope, the Panoramic Survey Telescope and Rapid Response System, which is equipped with the world’s largest digital camera and is located in Hawaii, on the island of Maui, to observe and determine the characteristics of NEOs.

9. Photometric light curve observations can be used to infer rotational properties and indicate the presence of binary objects. In 2006, the Calar Alto Observatory in Spain began operation of a 1.2-metre telescope for photometric and astrometric observation of NEOs. The Institute of Theoretical Astrophysics of the University of Oslo, together with researchers from Helsinki, Copenhagen, Uppsala and Oslo, uses the Nordic Optical Telescope at La Palma, Spain, to determine the physical and dynamic properties of asteroids crossing the Earth’s orbit.

10. Japan contributes to the field of remote observations through the Bisei Spaceguard Centre which has a 1-metre diameter optical telescope and a 50-centimetre diameter tracking telescope specifically designed for the observation of NEOs.

11. The joint NEO project team of the Korea Astronomy and Space Science Institute and Yonsei University Observatory has 50-centimetre robotic telescopes in South Africa and Australia. Operating in fully automated mode, they are used to discover and follow up fast-moving NEOs in parallel with other scientific programmes.

12. Along with the Ondrejov Observatory of the Czech Republic, DLR is a leader of the European Fireball Network, a network of all-sky cameras that record the tracks of large meteoroids colliding with the Earth.

13. The Action Team recognized that, overall, significant efforts were being made at the international level to detect and, to a lesser degree, make follow-up observations of potentially hazardous NEOs but noted that objects in the range of 100-1,000 metres, for which current surveys are not optimized, still posed a significant impact threat. Accordingly, it welcomed the anticipated response of NASA to the call by the United States Congress to plan, develop and implement an NEO survey programme to detect, track, catalogue and characterize the physical characteristics of NEOs equal to or greater than 140 metres in diameter in order to assess their threat to the Earth.

B. Orbit determination and cataloguing

14. It is important that objects detected from the ground are uniquely identified and that their orbits are refined in order to assess their impact threat to the Earth. The Minor Planet Center is fundamental to that process. It is 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 has, since 1978, served as the international clearing house for all asteroid, comet and satellite astrometric (positional) measurements obtained worldwide. The Center processes and organizes data, identifies objects, computes orbits, assigns tentative names and disseminates information on a daily basis. For objects of special interest, the Center solicits follow-up observations and requests archival data searches. The Center is responsible for the dissemination of astrometric observations and orbits via the 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 facilitates 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 Minor Planet Center focuses specifically on identification, short-arc orbit determination and dissemination of information pertaining to NEOs. In most cases, observations of NEOs are distributed to the public free of charge within 24 hours of receipt. The Center also provides 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 maintains a

suite of programs to calculate the probability that an object is a new NEO, based on two sky-plane positions and a magnitude. Links to those Internet resources can be found on the Center's website (http://cfa-www.harvard.edu/iau/mpc.html).

15. The Action Team recognized that the role of the Center is critical to the dissemination and coordination of observations. The current system is already working at capacity, and it is questionable whether it can cope with the significant increase in tasks associated with the anticipated goal of reducing the systematic detection threshold for NASA telescopes from 1 kilometre to 140 metres.

16. As part of its NEO observation programme, NASA has established the Near-Earth Object Program Office at its Jet Propulsion Laboratory (JPL). On a daily basis, the Minor Planet Center makes NEO astrometric data available to the NEO Program Office and to a parallel, but independent, orbit computation centre in Pisa, Italy, with a mirror site in Valladolid, Spain. Through the JPL Sentry System, risk analyses are automatically performed on objects that have a potential for Earth impact. Such an analysis usually occurs for an object that has recently been discovered and for which there is not yet a data interval sufficiently long to make its orbit secure. Those objects are 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 updates the orbits of approximately 40 NEOs per day, and close approach tables are generated and posted on the Internet (http://neo.jpl.nasa.gov/ca/). Approximately five risk analysis cases are performed each day, with each analysis providing 10,000 multiple solutions up to 2105. That process is also performed in parallel in Pisa, Italy, and significantly non-zero Earth-impact cases are manually checked by JPL and the centre at Pisa before the risk analysis data are posted on the Internet. Since the inception of the Sentry System in 2002, approximately 400 objects have appeared on the Sentry risk page (http://neo.jpl.nasa.gov/risk/). For recently discovered objects of unusual interest, the Minor Planet Center, JPL, and the centre at Pisa will often alert observers that additional future or precovery data are needed.

17. JPL maintains a searchable small bodies database containing data on 350,000 bodies for the international community. The Horizons on-line system of JPL is an interactive ephemeris-generation site that automatically generates some 3,000 ephemerides a day for the international science community (http://ssd.jpl.nasa.gov/?horizons).

C. Consequence determination

18. Significant work has been done in the United States to assess the impact hazard posed by NEOs. Much of that work is led by NASA with support from the University of California at Santa Cruz, with an emphasis on the threat posed by impact-induced tsunamis. The University of Arizona has created an easy-to-use, interactive website for estimating the environmental consequences of an impact on Earth. By providing inputs for the distance from ground zero and the projectile's diameter, density, velocity and impact angle, the program will estimate the ejecta distribution, ground shaking, atmospheric blast wave, the thermal effects of an impact and the size of the crater produced (http://www.lpl.arizona.edu/impacteffects/).

19. In the United Kingdom, the University of Southampton is conducting research into the effects of small NEO impacts. A tool has been created to tackle the hazard on both a local and a global scale, tracking the consequences of an impact on the human population. The overall hazard assessment of an NEO impact event is rated according to the potential number of casualties and the level of infrastructure damage.

20. The Action Team recognized that in considering a science-based policy to address the risk posed by NEOs, it is important for Governments to evaluate the societal risk posed by such impacts and compare that with the thresholds established for dealing with other natural hazards (for example, meteorological and geological hazards) so that a commensurate and consistent response can be developed. It was thus felt that more work needed to be done in that area, especially on impactors of less than 1 kilometre in diameter.

D. In situ characterization

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

22. Italy is providing a visible and infrared mapping spectrometer for the Dawn Discovery mission of NASA, which will visit Vesta in 2011 and Ceres in 2015. Visible/infrared mapping can provide data on the mineralogical composition and distribution of NEOs, which help to determine evolution processes and infer internal structure and bulk properties.

23. Italy has provided a number of payloads for the Rosetta orbiter and Philae lander, launched towards comet 67P/Churyumov-Gerasimenko for rendezvous in 2014. Among the suite of payloads is a visible and infrared mapping spectrometer to help study the coma of the comet, an important task for identifying landing sites, while a drill will provide samples for in situ investigation and characterization.

24. At the Open University of the United Kingdom, in addition to theoretical studies aimed at understanding the formation of smaller bodies in the solar system, a number of experimental programmes are also under way, among them the development of a penetrometry rig to simulate a high-mass, low-speed impact of a penetrometer fixed to a landing spacecraft. Penetrometers will be key to enabling in situ measurements on an NEO surface, which is likely to be delicate in nature, and they can yield structural and mechanical information on the body that is critical for its successful mitigation and negation.

25. The Action Team welcomed the news that NASA is evaluating the mission extension proposal put forward by scientists from the University of Maryland for the Deep Impact spacecraft to reach a new target, the comet Boethin, in December 2008. The new mission, called the Deep Impact Extended Investigation of Comets, will use the surviving spacecraft's three working instruments – two colour cameras and an infrared spectrometer – to study Boethin. Also under evaluation is a proposal, called "Stardust Next", to fly the Stardust spacecraft closely past comet Tempel 1 (the Deep Impact target body) in February 2011 and a proposal, called the "Origins Spectral Interpretation, Resource Identification and Security mission", to return a surface sample from primitive near-Earth asteroid 1999 RQ36.

E. Mitigation

26. Mitigation in this context is the process of either negating or minimizing the impact hazard posed by NEOs through some form of intervention/interaction with the risk body, or minimizing its impact on the population through evacuation or a similar response.

27. The European Space Agency (ESA) has, in the past, supported industrial and academic research studies on NEOs. Those activities have made it possible to identify an adequate project enabling Europe to make a significant, yet realistic contribution to international efforts to assess the NEO hazard. The result of that analysis was the Don Quijote NEO technology demonstration mission, currently being defined by European industrial teams. As a response to the call by the Council of Europe for ESA to take an active role in the assessment of the NEO impact hazard, several scientific and technical assessments were conducted. They were immediately followed by parallel mission feasibility studies, whose outcome was assessed by the Near-Earth Object Mission Advisory Panel of ESA, an independent panel of recognized experts on various aspects of the NEO problem. In accordance with the recommendations of the Panel presented in July 2004, work focused on the Don Quijote mission concept, which consists of two elements, a SMART-1-class, mini-satellite asteroid orbiter and a modified upper stage serving as an asteroid impactor. The orbiter, called "Sancho", would rendezvous with a small, 500-metre near-Earth asteroid and study it before the arrival of the impactor, called "Hidalgo", which would hit it at a very high relative speed. The Sancho orbiter would observe the impact and its results, especially the resulting deflection in the asteroid's trajectory. Suitable launch opportunities for the first element, the orbiter, begin in 2011. The impactor could be launched four or five years later, which would allow for an independent or staged development of the two mini-satellites. Choice of launch vehicle and the suitable launch windows largely depends on the selection of the target asteroid, which will be revisited by the Panel in the coming months. The mission has a modular architecture, two separate small spacecraft and the possibility of an independent asteroid "surface package", which would facilitate its implementation in the context of a cooperative project.

28. ESA recognizes that the efforts of major space agencies are now heading in similar directions and are reaching the critical mass needed to attain concrete developments with respect to space missions. Preparatory activities have enabled ESA to gain a good understanding of the key issues of a realistic NEO technology demonstration mission and have placed it in a good position to explore a way to

benefit from that convergence of interests or, at least, to establish an opportunity partnership with another agency with the aim of identifying cost-sharing and/or programmatic advantages.

29. In 2002, a number of Russian and Ukrainian organizations founded the Planetary Defence Centre with a view to combining the efforts of organizations and experts working in various fields towards the establishment of a planetary defence system. The main activities of the Planetary Defence Centre are the following:

(a) Design of a planetary defence system to address the threat posed to the Earth by asteroids and comets;

(b) Elaboration of possible space threat scenarios and methods and means of countering such threats;

(c) Participation in the preparation and conduct of simulation and demonstration experiments to test the components of the planetary defence system.

The activities of the Centre are based on the conceptual design for the Citadel system which consists of Earth-based and space-based elements.

30. The Institute of Planetary Research of DLR, in cooperation with the Dresden University of Technology, is investigating potential techniques for diverting asteroids and comets and is developing a tool that can determine the optimal deflection strategy for a given impactor.

31. The United Kingdom funds a number of activities related to the mitigation of the NEO hazard. The objective of the work conducted by the University of Glasgow is to develop fundamental optimal control theory and apply it to the interception of hazardous NEOs. The study has been moving along two parallel paths. The first is global optimization algorithms for an interplanetary trajectory. The tools developed are used to generate a number of possible trajectories to intercept NEOs. Future work will develop more accurate models of the static and dynamic properties of asteroids in order to study how those properties might influence or even invalidate certain deflection methods. Assessments of other deflection methods, such as the gravity tractor and use of the Yarkovski effect, will continue.

32. The Action Team noted with interest that the United States Congress, through the 2005 NASA Authorization Bill, requested an analysis of possible alternatives that NASA could employ to divert an object on a likely collision course with Earth.

F. Policy

33. The Action Team recognized that the impact threat posed by NEOs is real and that such an impact, although a low probability event, would be potentially catastrophic. It is also recognized that the effects of such an impact would be indiscriminate (that is, it is unlikely that they would be confined to the country of impact) and that the scale of an impact’s effects would be so great that the NEO hazard should be recognized as a global issue that can be effectively addressed only through international cooperation and coordination. No country is known to have a national NEO strategy. Thus, the United Nations has an important role to play in informing the process of developing the required policy.

34. A further challenge for the United Nations is that in the next 15 years, it will likely be confronted with making critical decisions about the actions to be taken to protect life on Earth from a potential NEO impact. That situation is due to the accelerating pace of the discovery of NEOs and humankind's increasing ability to prevent an anticipated impact by proactively deflecting the NEO. Given that early warning of an NEO impact and the capability to prevent such an impact are now both possible, humankind cannot avoid responsibility for the consequences of its action or inaction. Because the entire planet is subject to the threat of NEO impact and because the process of deflection intrinsically causes a temporary increase of the risk to populations not otherwise at risk, the United Nations will inevitably be called on to make decisions and evaluate trade-offs. Out of concern for that issue, the Association of Space Explorers established a committee on NEOs and has committed itself to bringing the issue to the attention of world leaders and institutions and to helping them respond to that challenge. At the forty-third session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, the Association of Space Explorers expressed its intention to facilitate that process by convening a series of workshops, calling on experts worldwide with relevant experience to address the challenge in detail and to prepare a draft NEO deflection protocol for consideration by the Committee. Those workshops will be conducted over the next two years to develop the draft protocol, which will be submitted by the Action Team to the Committee at its fifty-first session, in 2009.