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Committee on the Peaceful Uses of Outer Space

Information on research in the field of near-Earth objects carried out by Member States, international organizations and other entities

Note by the Secretariat

Contents

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I. Introduction

1. At its forty-fifth session, in 2008, the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space endorsed the amended multi-year workplan for the period 2009-2011 (A/AC.105/911, annex III, para. 11). In accordance with the workplan, the Subcommittee will, at its forty-sixth session, in 2009, consider reports submitted in response to the annual request for information from Member States, international organizations and other entities on their near-Earth object activities.

2. The present document has been prepared by the Secretariat on the basis of information received from the following Member States and international organizations: Germany, Japan, Committee on Space Research, International Astronautical Federation, International Astronomical Union and Space Generation Advisory Council. The present document contains reports received by 3 December 2008.

II. Replies received from Member States

Germany

[Original: English]

German Aerospace Center, Institute of Planetary Research, Berlin

Introduction

1. Scientists at the Institute of Planetary Research of the German Aerospace Center in Berlin-Adlershof have been engaged in international research on near-Earth objects (NEOs) for many years. The work includes the planning and development of space missions for NEO research; observation campaigns for the physical characterization of NEOs using major ground-based and space-borne astronomical telescopes (for which observation time is awarded on a competitive basis); theoretical two-dimensional impact simulations; data reduction and analysis and the publication of results in major peer-reviewed journals; and activities within the European Fireball Network.

Space missions relating to near-Earth objects

2. The Institute of Planetary Research has been selected to contribute the payload for the first "Kompaktsatellit" of the German Aerospace Center, which will consist of a series of small Earth-orbiting spacecraft. The winner of the German Aerospace Center internal competition was the AsteroidFinder project, the objective of which will be to search for Inner Earth objects using a 25-centimetre telescope with a 2 × 2 square-degree field of view and the novel Electron Multiplying Charge Coupled Device camera. The mission will be an ideal complement to ground-based NEO search programmes and should become operational in 2012, extending the search into regions of the sky that are difficult to observe or unobservable from the ground.

3. The Institute is taking a major role in the scientific definition of the Atlantic Stratocumulus Transition Experiment, which is a feasibility study funded by the German Aerospace Center for an in situ exploration mission to two NEOs. Current planning calls for the mission targets to have different mineralogical compositions: one asteroid should be of a “primitive” nature, while the other should be a fragment of a differentiated asteroid. The scientific goal is to explore the physical, geological and mineralogical nature of the asteroids and to provide information on the formation and evolution of the Earth’s planetary system. The mission scenario consists of an orbiting and landing phase at each target. The study is being carried out in collaboration with the Max Planck Institute for Solar System Research and a number of German industrial partners.

Observation of near-Earth objects

4. One of the major areas of activity of the Institute is observational work in the thermal infrared spectral region with telescopes such as those of the W. M. Keck Observatory and the Infrared Telescope Facility of the National Aeronautics and Space Administration (NASA) of the United States of America, both on Mauna Kea in Hawaii, and the NASA Spitzer Space Telescope. Data from those observations make it possible to determine crucial parameters such as the size and albedo of NEOs and provide information on surface characteristics via thermal inertia. The interpretation of those observations requires extensive theoretical work and computer modelling of the physical characteristics of NEOs. In certain cases, in which detailed information about an asteroid, such as spin vector and shape, are available from other sources, the thermal infrared data enable accurate information on size, surface roughness, thermal inertia and regolith properties to be derived.

5. The work is carried out in collaboration with groups in the United States (Massachusetts Institute of Technology and the universities of Arizona and Hawaii), and in Europe (Observatoire de la Côte d’Azur, France, and the universities of Belfast and Helsinki). Former research students of the Institute now hold positions at the Steward Observatory of the University of Arizona and at the Observatoire de la Côte d’Azur and continue to collaborate with staff of the Institute.

6. In cooperation with the Calar Alto Observatory (Spain), the Institute is preparing to sign a contract to operate the remotely controlled 1.2-metre telescope for optical photometric and astrometric observations of NEOs for about 100 nights per year, starting in 2009. Such observations can provide spin rates, rotation-axis orientations, shape information and other parameters that are particularly valuable in combination with thermal infrared and other types of observations.

7. In addition to the above-mentioned research activities, the Institute maintains an online database of the physical properties of all known NEOs, which is updated on a daily basis.[1]

Theoretical studies and simulations

8. A theoretical study, called “Planetary evolution and life”, involving advanced computer modelling and simulations based on a multimaterial hydrocode, analyses

[1] The online database of the Institute of Planetary Research, which records the physical properties of all known near-Earth objects, is available at http://earn.dlr.de.

the formation of craters and the associated effects of asteroid and comet impacts on the Earth, such as the distribution of ejecta, chemical processes in the impact vapour plume and evolution of the impact blast cloud. The project is part of a research alliance that started in 2007 and is scheduled to continue until 2012 and is funded by the Heimholtz Association of German Research Centres.

European Fireball Network

9. The Institute is involved in the operation of the European Fireball Network, a network of all-sky cameras that records the tracks of large meteoroids colliding with the Earth. The European Fireball Network provides fundamental data for the computation of the mass flux near Earth and of the probability of collisions with larger bodies.

10. Cameras of the European Fireball Network routinely monitor the night sky over Central Europe. The network comprises 10 camera stations in the Czech Republic, 2 in Slovakia and 13 in Austria, France and Germany, deployed approximately 100 kilometres apart to cover a total area of 10^6 square kilometres. In 2007, the Network detected 31 fireballs.

Publications

11. Publications relating to the above-mentioned research activities are available on request. The annual reports of the Institute of Planetary Research are available on the Internet.[2]

Japan

[Original: English]

1. Japanese NEO activities started with the establishment of the Japan Spaceguard Association in 1996. The Association constructed a 1-metre wide field telescope for NEO detection, which became operational in 2002 and which was mainly used for follow-up observations. The Association repaired the telescope in 2006 and it is now able to detect NEOs down to a magnitude of 20.5, which is comparable to detections by the Catalina Sky Survey and the Spacewatch programme in the United States. A list of NEO follow-up observations is shown in the table below.

2. The Association has carried out various educational activities over the last 10 years. For public outreach, it produced an educational package on NEO detection in English, Japanese and Spanish and published two books and a number of articles in journals and newspapers. In 2008, the Association held a “spaceguard symposium” and published the first issue of its research bulletin, entitled *Spaceguard Research*.

[2] The annual reports of the Institute of Planetary Research are available at http://solarsystem.dlr.de/KK/.

Near-Earth object observations by the Japan Spaceguard Association (as at September 2008)

	Near-Earth asteroids			*Comets*	
Year	*Number observed*	*Number of position measurements*	*Sum of position measurements*	*Number observed*	*Number of position measurements*
2000	23	205	4 240	20	113
2001	29	560	5 907	16	275
2002	24	243	2 018	13	339
2003	54	567	4 938	18	165
2004	23	233	2 908	4	20
2005	8	42	2 431	0	0
2006	25	297	3 224	5	66
2007	34	408	7 219	15	108
2008	23	129	1 387	11	95
Total	**243**	**2 684**	**34 272**	**102**	**1 181**

3. Another important NEO activity of the Association is the Hayabusa mission to the NEO called "Itokawa". The scientific purpose of the mission is to gain information on the mysteries behind the genesis of the solar system by analysing the composition of the asteroid; for this, technology to bring back samples of asteroids needs to be developed. In autumn 2005, when the Itokawa asteroid was nearer to the Earth, many enlarged images were obtained and a trial return sample of Itokawa surface materials was taken. The return of the Hayabusa mission, which is ongoing, is scheduled for June 2010. The Japanese Aerospace Exploration Agency is now considering the next sample return mission from another type of NEO and it is hoped that it will take place in the near future.

III. Replies received from international organizations and other entities

Committee on Space Research

[Original: English]

1. At the 37th Scientific Assembly of the Committee on Space Research, held in 2008, a special lecture entitled "The asteroid impact threat: decisions upcoming" was presented by Russell L. Schweickart, Chairperson of the Committee on Near-Earth Objects of the Association of Space Explorers.[3] The lecture was aimed at mobilizing the international scientific community to interact with political figures in the coming years as the NEO issue is debated and possible courses of action are considered. A related article is expected to appear in the forthcoming issue of the information bulletin of the Committee, entitled *Space Research Today*. Many members of the Committee believe that the topic of the NEO impact threat and the response of the international community should be considered by the Committee on the Peaceful Uses of Outer Space.

[3] A summary of the lecture is available at www.unoosa.org/oosa/en/natact/neo/2008.html.

2. In addition, as part of the core scientific programme of the 37th Scientific Assembly, the Committee on Space Research organized a meeting entitled “Small body exploration into the 2010s: materials, structures and temporal evolution”. One session of the meeting was devoted to the topic of “structural investigations of asteroids and impact hazards” and several papers were presented on the subject of NEOs. The Committee will continue to address the matter of NEOs in future scientific programmes.

International Astronautical Federation

[Original: English]

1. The International Astronautical Federation (IAF) has recently established a technical committee for near-Earth objects, with the following primary aims:

(a) To encourage, monitor and assess progress in understanding of the NEO population and the associated impact hazard and in the innovative application of space technology for purposes of NEO reconnaissance and mitigation;

(b) To exchange information on the current and prospective activities carried out with a view to improving understanding of the NEO environment and to applying space technology for monitoring and mitigation;

(c) To provide a point of contact, in particular for national and international bodies and the media, for authoritative information and advice on the NEO impact hazard and the possibilities for mitigation.

2. Through electronic media, meetings and workshops on topics related to the impact hazard and mitigation initiatives, the committee aims to provide a forum for the exchange, discussion and publication of ideas and results. As appropriate, the committee liaises and coordinates its activities with other relevant IAF technical and administrative committees, as well as with the Committee on Space Research, the International Academy of Astronautics, the International Institute of Space Law and other interested organizations.

3. Members of the technical committee of IAF will make themselves available to consult with or brief the Committee on the Peaceful Uses of Outer Space, should questions or the need for additional background information on near-Earth objects arise.

International Astronomical Union

[Original: English]

1. Minor Planet Center

1. The Minor Planet Center is operated at the Smithsonian Astrophysical Observatory in the United States and supported by the International Astronomical Union (IAU). The Center is responsible for the collection, validation and distribution of all positional measurements made worldwide of minor planets, comets and outer irregular natural satellites. While the Minor Planet Center handles

data on all classes of object, it focuses on the rapid collection and distribution of observations and information on the orbits of NEOs.

2. NEO data from observers worldwide is sent to the Center either via e-mail or file transfer protocol (FTP). Using a series of programmes and checking mechanisms, the Minor Planet Center automatically identifies each object as either known or unconfirmed and in need of further observations. One piece of software calculates the probability that each new object is a new undiscovered NEO; if this probability is greater than 50 per cent, the object is placed on a web page, called the "NEO confirmation page", which allows users worldwide to compute the predicted position of the object to allow for additional positional measures and further orbit refinement. As these measures are secured, further observations are e-mailed to the Center, allowing better orbital calculations to be made. At all times, these observations and orbits are publicly available, thus allowing anyone, worldwide, to determine the status of a potential new NEO.

3. Once the orbit for the new NEO is determined well enough for reasonable predictions, the Center issues an announcement in the form of a so-called Minor Planet Electronic Circular. The Circulars are posted on the Internet and e-mailed to subscribers several times a day and constitute formal announcements of NEOs to the public, including using the provisional designation of the object, such that it can be referred to appropriately.

4. As NEOs are posted on the NEO confirmation page, their orbits are checked for possible impacts with the Earth in the following 10 days. While these cases are extremely rare, a recent small object, 2008 TC3, was discovered that impacted the Earth the next day. The Center's software accepted the incoming e-mail, posted the object on the NEO confirmation page, secured additional follow-up observations, predicted the impact and alerted staff. In this case, the system worked nearly flawlessly and the object was announced to the public as an impactor several hours before it burned up harmlessly in the atmosphere.

5. Longer-term impact predictions are undertaken by the Jet Propulsion Laboratory of NASA or by a team at the University of Pisa. These calculations are started following the release of Minor Planet Electronic Circulars containing the discovery observations of NEOs.

6. The Center distributes all observations of NEOs collected in the previous day in a Circular released at around 2 a.m. Eastern Standard or Daylight Time. Thus, the NEO orbit and observing community is aware of all current information on all NEOs on a daily basis.

7. In addition to collecting and distributing observations and orbits, the Center staff facilitate cooperation among the world's cadre of follow-up observers by maintaining the NEO confirmation page and other follow-up pages, and exchanging frequent e-mails with observers. The Center staff serve on various IAU, NASA and United States Congress panels and committees, as necessary, to assist in advancing NEO science.

8. At 0639 hours Greenwich Mean Time on 6 October 2008, Richard Kowalski discovered an NEO using the Mount Lemmon 1.5-metre aperture telescope near Tucson, Arizona. When the initial discovery observations were reported to the Minor Planet Center, the preliminary orbit immediately suggested that the object

was headed for an Earth impact within 21 hours. The Center quickly made the discovery and subsequent follow-up observations available. The Center also notified NASA headquarters of the impending impact so that subsequent inter-agency alerts and intergovernmental notifications could be made by the Government of the United States. By the time the object entered the Earth's shadow 19 hours after discovery, some 570 astrometric (positional) observations of the object (which had been designated 2008 TC3) had been reported from 26 international observatories, both professional and amateur. The orbital computation centres at the Jet Propulsion Laboratory of NASA and at the University of Pisa continuously improved the orbit for 2008 TC3 as further data arrived from the Center and each centre verified the results of the other. Within an hour of receiving the initial data set, the Jet Propulsion Laboratory had predicted that the object would strike the Earth's atmosphere at an altitude of 50 kilometres above northern Sudan at 0246 Greenwich Mean Time on 7 October 2008. Impact prediction updates were forwarded to NASA headquarters. The final orbit, computed before impact, refined the impact time to 0245:44. The time and place of the predicted impact agreed very well with a number of atmospheric entry observations, including those from an unnamed United States satellite, infrasound signals from two ground stations, images from the Meteosat 8 weather satellite and a sighting by a KLM airline pilot flying over Chad. From the observed brightness of the object and an assumed typical reflectivity, the size of the NEO was estimated to be between 2 and 5 metres in diameter. The impact detections suggested an explosion at an altitude of 37 kilometres, which had an equivalent energy of about one kiloton of TNT.

9. That dramatic prediction of an actual impact underscored the success of the current NEO discovery and orbit prediction process. The discovery was made, observations were provided by 26 international observatories and the orbit and impact computations were determined, verified and announced well before the impact, which took place only 20.5 hours after the discovery itself. While improvements to the impact prediction process still need to be made, the system worked well for the first predicted impact by an NEO.

2. Near-Earth Object Observations Program of NASA

10. The vast majority of NEO discoveries have been made by wide field telescopic surveys funded by NASA. The selection of competitive peer-reviewed proposals forms the basis for funding by NASA of NEO search surveys, follow-up observation programmes and efforts to provide the physical characteristics of NEOs. The NEO survey teams currently supported by NASA include the Catalina Sky Survey, the Lincoln Near-Earth Asteroid Research (LINEAR) program of the Lincoln Laboratory at the Massachusetts Institute of Technology, the Spacewatch program of the Lunar and Planetary Laboratory of the University of Arizona and the Panoramic Survey Telescope and Rapid Reporting Response System (Pan-STARRS) program operated by the University of Hawaii.

11. Brief descriptions of the four programs are provided below:

(a) The Catalina Sky Survey program currently operates two telescopes near Tucson, Arizona: a 0.74-metre aperture telescope on Mount Bigelow and a 1.5-metre aperture telescope on nearby Mount Lemmon. The program also runs a 0.5-metre telescope at Siding Spring Observatory, Australia. The Catalina Sky Survey program is currently the most productive survey for discovering NEOs;[4]

(b) The Lincoln Near-Earth Asteroid Research program operates near Socorro, New Mexico. The LINEAR survey observes with two, co-located, 1-metre aperture telescopes using fast readout charge-coupled device imaging devices. The LINEAR program was, until a few years ago, responsible for the vast majority of NEO discoveries and is now second only to the Catalina Sky Survey;[5]

(c) The Spacewatch system operates a 0.9-metre aperture telescope for discovering NEOs and a second 1.8-metre aperture telescope that is primarily used to follow up discoveries made by their 0.9-metre telescope or by other observatories; both telescopes are located at the Steward Observatory near Tucson, Arizona, United States. Spacewatch has one of the most successful programmes for making such follow-up observations, a function that is critically important for securing the orbits of NEOs;[6]

(d) The Pan-STARRS system of the University of Hawaii is establishing a 1.8-metre aperture telescope on Mount Haleakala on the Hawaiian island of Maui. The very wide field telescope is the first of the search telescopes to be specifically designed to provide wide field coverage (7 square degrees) of the entire accessible night sky on a monthly basis and should, when operational in late 2008, become the premier instrument for NEO discoveries. There are further plans to build four co-located, 1.8-metre telescopes, to act in unison, on the large island of Hawaii at the top of Mount Mauna Kea.[7]

12. In addition to supporting the above-mentioned NEO search facilities, NASA also supports several observatories that provide follow-up observations for recent discoveries. Follow-up observations are required to ensure that the orbits of newly discovered objects become sufficiently accurate for the object not to be lost. These critical follow-up observatories, in addition to the work done by the Catalina Sky Survey and Spacewatch, include the Magdalena Ridge Observatory and the Astronomical Research Institute, both in the United States. A large number of these follow-up observations are provided by the international community of professional and amateur astronomers. These latter astronomers are amateurs in name only: many are technically sophisticated, have impressive equipment and are doing very professional work. Observational programmes to study the physical characteristics of NEOs are also funded by NASA.

3. Next-generation near-Earth object search programmes

13. All the current NASA-supported telescopic NEO search facilities use telescopes that were not originally designed for the purpose. The next generation of NEO search facilities will utilize very wide field survey telescopes that are capable of seeing significantly fainter objects for a given exposure. Examples of the next generation of search instruments are the previously noted Pan-STARRS and the Large Synoptic Survey Telescope.

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[4] The Catalina Sky Survey website is at www.lpl.arizona.edu/css/.
[5] Information on the LINEAR program is available at www.ll.mit.edu/mission/space/linear/.
[6] Information on the Spacewatch project is available at http://spacewatch.lpl.arizona.edu/.
[7] Information on the Pan-STARRS system is available at http://pan-starrs.ifa.hawaii.edu/public/.

14. With development funding from the United States Department of Defense, the current Pan-STARRS 1 telescope is a single 1.8-metre aperture telescope operating on Haleakala, Maui, Hawaii. The plan is to take charge-coupled device (CCD) images of patches of sky (7 degrees square) twice each evening and cover the entire accessible sky three times per lunar month (28 days) using the newly developed, very large format 1.4 giga-pixel CCD camera. Hence a moving NEO will receive two observations during the first discovery evening and a set of two additional observations for another two nights within each 28-day period. Once the Pan-STARRS 4 telescope comes on line with its four 1.8-metre aperture telescopes, the system will be able to image sky fields with twice the sensitivity (penetrate 0.75 magnitudes deeper into space) offered by the single-telescope Pan-STARRS 1 system, which will routinely survey to visual magnitude 23. The Pan-STARRS 1 system has been built and was expected to become fully operational in late 2008.

15. The Large Synoptic Survey Telescope is to be funded by the United States National Science Foundation, Department of Energy, private donors and a number of additional academic and institutional sponsors. The planned aperture of the telescope is 8.4 metres in diameter, with a field of view of 9.6 square degrees. It will be located at Cerro Pachón in northern Chile and, if the requisite additional funding can be secured, its launch will take place in 2016. The observing plans are to cover the entire accessible sky every three nights, down to fainter than apparent magnitude 24.[8]

16. While Pan-STARRS 1, Pan-STARRS 4 and the Large Synoptic Survey Telescope will not be devoted entirely to the study of NEOs, all three programs have included NEO discovery as a primary science goal. The product of a search telescope’s field of view multiplied by the aperture area of the telescope is often used as a metric for the efficiency with which a survey can discover NEOs. This product, referred to as the “system étendu”, is approximately 2 for the best-performing discovery system currently in operation (the Catalina Sky Survey). The étendus for Pan-STARRS 1, Pan-STARRS 4 and the Large Synoptic Survey Telescope will be approximately 12, 51 and 319 respectively.

4. Interactions of the Minor Planet Center with the trajectory computation centers at the Jet Propulsion Laboratory and Pisa

17. While the focus of the present report is the NEO Program Office at the Jet Propulsion Laboratory, the following is a brief outline of the activities of and interactions among the Minor Planet Center in the United States and the NEO trajectory computational centers located at the Jet Propulsion Laboratory and in Pisa, Italy. The Minor Planet Center is the international clearing house for astrometric data of NEOs and other solar system bodies. The Minor Planet Center, whose role is authorized by IAU, collects those data, designates and verifies them, provides object designations and discovery credits, and makes the data available to the public, including the trajectory computation centres at the Jet Propulsion Laboratory and Pisa. The Minor Planet Center has many additional responsibilities, including the generation of preliminary orbits for NEOs, Web-based notification of potential

[8] The website of the Large Synoptic Survey Telescope can be found at www.lsst.org/lsst_home.shtml.

new NEO discoveries to follow-up observers, and the generation of ephemeris information, which enables follow-up observations.

18. Particularly for NEOs, the Minor Planet Center quickly provides astrometric data and preliminary orbits to both the Jet Propulsion Laboratory and Pisa. At the Jet Propulsion Laboratory, once the data are received, an automatic orbit determination and future trajectory process is conducted with information on future close Earth approaches being made immediately available on the NEO website of the Jet Propulsion Laboratory. If a particularly close approach is noted as being possible by the automatic software system, the object enters the automatic Sentry system, which computes potential Earth impact probabilities and associated information such as impact time, relative velocity, impact energy, impact scale values, and so forth. Sentry alerts are automatically posted on the NEO Program Office website.[9] For objects with relatively high impact probabilities, high impact energies, and/or short intervals to the time of impact, the Sentry system will notify the NEO Program Office staff for manual verification before posting the results on the website. In such cases, the results are first checked for accuracy and then sent to Pisa for verification. At Pisa, a similar process will have been under way and if both the Sentry system and the Near-Earth Objects Dynamic Site system at Pisa yield equivalent results, the relevant information will be posted on both the Jet Propulsion Laboratory and Pisa websites almost simultaneously. Since the Sentry and Near-Earth Objects Dynamic Site systems are completely independent, this cross-checking provides a valuable verification process before the publication of information on high interest objects for which an Earth impact cannot yet be ruled out.

5. Near-Earth Object Program Office of NASA

19. In July 1998, NASA established a Near-Earth Object Program Office at the Jet Propulsion Laboratory to coordinate and monitor the discovery of NEOs and their future motions, to compute close Earth approaches and, if appropriate, their Earth impact probabilities. The NEO Program Office launched a website for information on NEOs in March 1999.[10]

20. The NEO Program Office receives astrometric data and preliminary orbits from the Minor Planet Center and then continuously improves those orbits and the resulting close Earth approach predictions as additional data are received. Once a new orbit has been successfully fitted to the available observational (astrometric) data, the trajectory of the object is numerically integrated forward in time to note any close Earth approaches in the following 100 years. The Jet Propulsion Laboratory orbital computations employ state-of-the-art numerical computer models that take into account the gravitational perturbations by the planets, the moon, large asteroids, as well as relativistic and thermal re-radiation and/or outgassing (non-gravitational) effects. These updated orbits and the close approach information are automatically computed and immediately posted to the NEO Program Office website. Those objects for which an Earth impact cannot yet be ruled out are automatically submitted to the Sentry system for further risk analysis.

[9] The Sentry alerts can be found on the NEO Program Office website, at http://neo.jpl.nasa.gov.

[10] The website on NEOs of the Near-Earth Object Program Office of the Jet Propulsion Laboratory can be found at http://neo.jpl.nasa.gov.

21. Within the Sentry system, the possible future orbits of an object are examined and Earth impact probabilities computed for specific future dates. The results are immediately posted to the Jet Propulsion Laboratory NEO website. The only exception to this chain of events occurs if relatively large objects that have relatively high impact probabilities and/or short time intervals to possible Earth impacts are discovered by the Sentry system. In those cases, an e-mail message is sent to the NEO Program Office personnel requesting verification of the events before the information is posted on the website. This manual verification process then includes electronic correspondence with colleagues at Pisa to compare results and, if they are verified, notification of those results to NASA headquarters. Additional verification at the Jet Propulsion Laboratory is also conducted by an independent "Monte Carlo" process that determines thousands of slightly different variant orbits that could be used to successfully fit the available observations and then numerically integrates each orbit forward to the time of the possible Earth impact. The spread of this family of trajectories at the time of the possible Earth impact gives a rigorous Earth impact probability. Because this Monte Carlo process requires substantial computer resources, it is used only to verify the results from the much faster Sentry system.

22. In addition to up-to-date information on the orbits, future close Earth approaches and Earth impact probabilities and circumstances (provided by the Sentry system), the Jet Propulsion Laboratory NEO website also provides the following information:

(a) Descriptions of NEO search programmes and links to their respective websites;

(b) Charts and statistics showing the history of NEO discoveries, which shows the dramatically increasing discovery rate since 1998;

(c) Descriptions of space missions to NEOs and links to each programme;

(d) Frequently asked questions on NEOs;

(e) Interactive orbital diagrams for all comets and asteroids;

(f) Orbital elements and absolute magnitudes (brightness estimates);

(g) Recent NASA reports relating to NEOs;[11]

(h) Reports on recent studies done by the NEO Program Office team, such as on the utility of gravity tractors for deflecting an Earth-threatening NEO;

(i) Recent news articles posted to the NEO website;[12]

(j) Time-ordered tables (ephemerides), which are used by astronomers to determine the celestial positions, velocities, solar and Earth distances, apparent brightness and more than 100 other categories of information for any particular object. The award-winning, online Horizons system of the Jet Propulsion Laboratory is also used by the international scientific community to generate accurate ephemeris information for the 450,000 currently known objects in the solar system. Those objects include the Sun, the planets, their moons, asteroids, comets

[11] Recent NASA reports relating to NEOs can be found at http://neo.jpl.nasa.gov/links/.

[12] Recent news articles posted to the NEO website can be found at http://neo.jpl.nasa.gov/news/.

and many spacecraft. The system is widely used by observers, researchers and mission planners to plan observations and track the targets of space- and ground-based telescopes, as well as spacecraft. Since its inception in October 1996, the Horizons system has responded to more than 10 million requests (more than 2,200 per day) received from 300,000 unique locations;

(k) A comprehensive report on the future motion of the NEO Apophis, which will pass within 5 Earth radii of the Earth's surface (below the distance of communications satellites) on 13 April 2029 and which currently has a 1 in 45,000 chance of impacting Earth seven years later, on 13 April 2036.[13]

23. Some of the most recent achievements of the NEO Program Office include:

(a) The rapid and successful prediction of the entry of the small (around 3 metres in diameter) Earth-impacting asteroid 2008 TC3 over northern Sudan at 0246 Greenwich Mean Time on 7 October 2008;

(b) The successful prediction of a close Earth approach by the NEO 2007 TU24, an object whose diameter is approximately 330 metres, to within 1.4 lunar distances (554,200 km) on 29 January 2008;

(c) The successful prediction of a close Mars approach by the near-Earth asteroid 2007 WD5, an object whose diameter is approximately 50 metres, to within 26,000 km on 30 January 2008;

(d) The establishment by NEO Program Office personnel of excellent interfaces with the next-generation NEO survey teams of Pan-STARRS and the Large Synoptic Survey Telescope.

24. The development of the automatic software system already in place at the NEO Program Office took into account the next generation of search, when the discovery rate is expected to increase by more than an order of magnitude. When this occurs, the additional load will be handled by additional computers running in parallel and no significant software changes should be required. The next generation of search will probably discover 40 times the current level of Earth impact warnings (mostly cases where an imprecise initial orbit does not yet rule out an Earth impact). While some processes and interfaces will need to be refined, the NEO Program Office at the Jet Propulsion Laboratory is well positioned to handle the increased activity.

Space Generation Advisory Council

[Original: English]

1. Introduction

1. NEOs have attracted much attention in recent years. Given the potential threat they pose to the Earth, the issue is clearly a global one and, with half the world population being under 25 years of age, one that also concerns youth. The Space Generation Advisory Council (SGAC) created an NEO project working group to address the issues. In collaboration with the Association of Space Explorers (ASE)

[13] The report on the Apophis asteroid is available at http://neo.jpl.nasa.gov/apophis/.

and other entities concentrating on NEOs, SGAC sought to design activities that would involve youth and enable them to contribute their ideas.

2. The project focuses on three main themes:

(a) *Legal framework*. ASE is working on a draft for a legal framework to be considered by the Committee on the Peaceful Uses of Outer Space. As a fellow observer in the Committee, SGAC supports the work of ASE with the Committee;

(b) *Asteroid deflection concepts*. After thorough research of existing NEO mitigation technology proposals, SGAC invited its members to propose novel ideas to support global mitigation efforts;

(c) *Outreach activities*. Several outreach methods were analysed to decide whether information regarding the threat of NEOs could and should be disseminated to the general public and groups thereof, such as youth, and, if it should, then what means of dissemination it would be advisable to adopt.

3. SGAC is a non-governmental organization that aims to represent the interests of students and young space professionals through dialogue with the United Nations, States and space agencies. SGAC has permanent observer status with the Committee on the Peaceful Uses of Outer Space.

4. A team of students and young professionals from SGAC have been discussing the real risks posed to humanity should a possible collision occur and looking at methods of prevention and deflection.

5. SGAC is involved in many aspects of NEOs, such as legal framework issues, technical deflection concepts and outreach activities, which are described in detail below.

2. Legal framework

6. The Committee on Near-Earth Objects of ASE was formed to observe the work on NEOs and convey information to important space organizations around the world. The Committee prepared a letter on potential impacts of NEOs and precautions to be taken. The letter stated that, while natural disasters could cause deaths and panic on a local or regional scale, an NEO impact could cause a global disaster, especially given the state of unpreparedness of the world. It emphasized that, although NEO impacts were not frequent, their consequences could range from global damage to total extinction. The advanced space technology now available could enable humankind to prepare, protect and survive. The letter suggested that laws and operational policies to permit decision-making during a crisis should be developed or deflection of an NEO by space power and propulsion procedures should be considered.

7. ASE has participated in conferences and workshops aimed at raising awareness of the importance of decision-making on NEO deflection. SGAC is supporting ASE in its efforts to create an international legal framework to respond to NEO threats.

8. As a member of the Action Team on Near-Earth Objects of the Committee on the Peaceful Uses of Outer Space, SGAC is involved in the ongoing discussions on the topic and offers support and cooperates with other members of the Action Team to identify solutions.

3. Asteroid deflection concepts

9. A great number of asteroid deflection concepts are currently being floated; they incorporate modern and future technological advances and are supported by firm scientific calculations and feasibility justifications. The concepts include laser and solar ablation, nuclear explosions and even the use of high-mass spacecraft acting as gravitational "tugboats", pulling the body off course to prevent it colliding with the Earth. The legal and political aspects of such strategies, such as funding, country involvement and the use of nuclear or military warheads, must be addressed.

10. Members of SGAC have discussed a number of concepts that could aid in asteroid mitigation, including high-powered magnets for metallic objects and the use of heat transfer to melt icy bodies, causing a change in momentum and thus a modified orbit.

4. Outreach activities

11. Outreach activities on the topic of NEOs need to be handled with care, for, although the public needs to be educated on the topic, given the tendency of the media to generalize, oversimplify and sensationalize, scare stories could cause public overreaction and have the opposite of the desired effect.

12. Being aware of the difficulties involved, SGAC decided to limit its outreach activities to students and young professionals already involved in the field of outer space. The NEO group of SGAC intends to use the experience gained through working with youth to fuel the generation of ideas for extending outreach activities to the broader public.

13. SGAC held a competition for students and young professionals, called "Move an asteroid 2008", the purpose of which was to encourage young people to develop unique and innovative concepts for deflecting an asteroid or comet that could impact the Earth. Two outstanding technical papers were selected by a jury and the winners won a trip to Glasgow to present their papers at the Space Generation Congress and at the 59th International Astronautical Congress. SGAC announced the competition results on the 100th anniversary of the last major impact of the Earth by an asteroid or comet, known as the "Tunguska explosion".[14]

14. Further interest was created by a survey of SGAC members, which was conducted to ascertain the opinion of the membership on the efforts of ASE to introduce a draft protocol to the Committee on the Peaceful Uses of Outer Space for a legal framework for NEO threat mitigation. SGAC presented the results of the survey to the Scientific and Technical Subcommittee of the Committee at its forty-fifth session, in 2008, and is currently preparing a follow-up member survey.[15]

15. As a direct result of that presentation, SGAC became involved with the organizing committee of the International Academy of Astronautics Planetary Defence Conference, to be held in Granada, Spain, in April 2009, with a view to supporting the participation of students in that conference.

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[14] Information on the "Move an asteroid 2008" competition is available at www.spacegeneration.org/asteroid.

[15] The results of the first survey, entitled "NEOs: a youth perspective", are available at www.unoosa.org/pdf/pres/stsc2008/tech-21.pdf.

16. The NEO group of SGAC is open to all interested students and young professionals. The enthusiasm and contributions of young people could be of significant help in protecting planet Earth from the threat of NEOs.[16]

[16] Information on the Space Generation Advisory Council can be found on the website of the Council, at www.spacegeneration.org/neo.