Executive Summary

Workshop on the

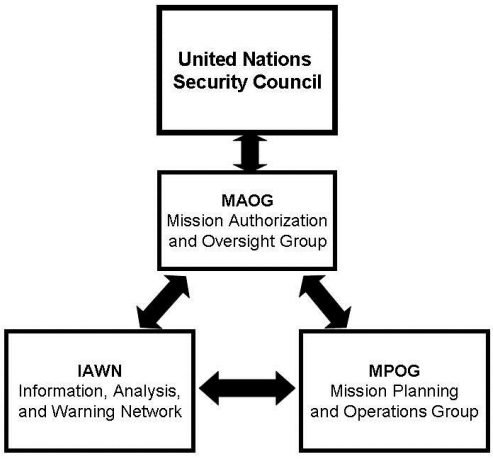
NEO Mission Planning and Operations Group

27-29 October 2010

I. Introduction

The Secure World Foundation, the Association of Space Explorers, and the European Space Agency sponsored a workshop exploring the formation of a Near-Earth Object (NEO) Mission Planning and Operations Group. The meeting was held in late October 2010 at the European Space Operations Control Center in Darmstadt, Germany. (See Appendix 1 for a list of attendees).

The Mission Planning and Operations Group (MPOG) is one of three functional groups proposed by the Association of Space Explorers as part of an international decision-making framework to deal with the global asteroid threat (ASE, 2008). These three functional groups are under consideration by the United Nations' Committee on the Peaceful Uses of Outer Space, as part of the work of the NEO Working Group of the Scientific and Technical Subcommittee.



The Darmstadt Workshop followed a similar meeting in January 2010 in Mexico City dealing with the Information, Analysis, and Warning network (SWF/ASE 2010). Future workshops discussing the role and responsibilities of the related Mission Authorization and Oversight Group (MAOG) are pending.

The MPOG would perform the function of planning for potential NEO *in situ* characterization and deflection campaigns, and lay out possible mission plans for the deflection of a threatening NEO. To consider how an MPOG might function, space agency representatives and NEO experts

examined two NEO fictional impact scenarios and derived a set of conclusions about possible responses designed to prevent an impact. See Appendix 2 for details of the two scenarios.

Scenario 1 posited an impact threat from asteroid Apophis, which will closely approach Earth in 2029 and has a remote possibility of returning on an impact trajectory in 2036. Scenario 1 projected that Apophis would in 2029 pass through a gravitational keyhole close to Earth and thus strike Earth seven years later. The participants discussed how the world's space agencies should respond to the need to plan and execute a deflection campaign, forcing Apophis to miss the 2029 keyhole passage.

Scenario 2 proposed the fictional discovery in 2016 of NEO 2016 U04, which has a high probability of impact in 2030. Unfortunately, ground-based telescopes will not be able to track the asteroid again until 2023, just seven years before impact. The MPOG Workshop was asked to discuss the planning necessary to prepare to divert 2016 U04 in the seven-year interval between rediscovery and potential impact.

II. Major Conclusions of the MPOG Workshop

After exploring both scenarios, the MPOG Workshop participants agreed on the following major conclusions:

1. **The Workshop participants concluded that space agencies should establish a forum similar to a Mission Planning and Operations Group (MPOG), comprised of representatives of those agencies.**

   Such a group would enable world space agencies to coordinate their NEO science and technology research programs, including exploration missions, to include and address planetary defense objectives. The group would also develop general timelines, mission plans, and cost estimates for representative asteroid deflection campaigns. When confronted with a threatening asteroid, the MPOG would recommend how, and by what entities, a deflection campaign should be executed.

   The process of instituting the MPOG will be aided by the activity of Action Team 14, established by the U.N. Committee on the Peaceful Uses of Outer Space (COPUOS) to deal with Near-Earth Object (NEO) issues.

2. **The MPOG should identify to space agencies the technical issues involved in planetary defense, in order to take advantage of synergies among human exploration, science, and NEO hazard research activities.**

   The MPOG can recommend key research required for planetary defense. Such investigations can be addressed through ground-based NEO observations, laboratory research, and deep space missions. These activities will yield results in three areas: the scientific understanding

of NEOs, their characterization as human exploration targets, and planetary defense planning. All will help the international community deal with the hazard posed by near-Earth asteroids.

3. **The MPOG should propose NEO research objectives to guide space agencies in addressing those areas most critical for effective deflection strategies.**

   The MPOG should identify research opportunities for international collaboration. Coordination of the NEO research programs across space agencies will be more efficient than independent pursuit of planetary defense knowledge. Joint pursuit of technologies and techniques for NEO deflection will help avoid costly duplication of effort, and speed the development of an effective diversion capability.

4. **The MPOG Workshop participants recognize the value of finding hazardous NEOs early in order to obtain precision tracking data, thus averting the considerable costs of future deflection missions. This strategy requires upgraded NEO search and tracking capabilities.**

   Rapid enhancements to current detection and tracking systems are a wise investment. Assessment of the impact hazard requires a thorough survey of the NEO population to detect the hundreds of thousands of small near-Earth asteroids (and comets) that can penetrate the atmosphere. Early execution of this survey, at relatively modest cost, will enable repeat observations and precise orbit determination. Accurate orbit knowledge will eliminate many spurious NEO impact scenarios and the associated deflection planning and operations costs.

   As an example of priority NEO research, Workshop participants recommended an analysis of the value of space-based detection and tracking to accelerate identification of potentially hazardous NEOs and enable precise orbit determination, thus reducing the need for future deflection campaigns.

III. Supplemental MPOG Conclusions

5. The MPOG should develop and adopt a set of reference missions, addressing a variety of potential NEO impact and deflection possibilities. These reference missions will enable accurate technical planning and provide a basis for deflection campaign cost estimates. Some of the technical issues addressed by these reference missions include:
   a. The technical maturity of deflection techniques and accurate cost estimates for deflection reference missions. The issue of how to share funding for deflection campaigns will be addressed at the policy level.
   b. The physical implications and consequences of NEO deflection techniques.
   c. Deflection targeting options (e.g. Earth miss distance). The group should reach a consensus on the minimum acceptable miss distance and provide this to the proposed Mission Authorization and Oversight Group (MAOG).

6. The MPOG should decide on its need for specific information from the Information, Analysis, and Warning network (IAWN) to enable NEO deflection mission planning and develop the set of reference missions.
    a. The MPOG Workshop recognized the value of a sanctioned, authoritative communications capability for dealing with NEO threat issues.
7. The MPOG should make technical recommendations to mission approval authorities, like the envisaged MAOG, to include:
    a. The MPOG could address the question of which entities are best capable of undertaking the different elements of deflection campaigns.
    b. The MPOG in its work should identify for detailed review any legal issues (e.g. liability) that may arise in undertaking such deflection actions.
8. Clear lines of responsibility and decision-making from policy makers to the MPOG would be necessary for a successful deflection campaign.
9. The MPOG Terms of Reference should be formulated via COPUOS Action Team 14.

Summary

As NEO search, tracking, and prediction capabilities improve in the next decade, astronomers will not only predict more impacts from small objects that do not penetrate the atmosphere to strike the surface, but also discover many larger near-Earth asteroids which pose a worrisome probability of impact. The key to finding these objects and taking action to prevent a possible damaging impact is to detect them early through a vigorous search and tracking program. Because NEO impacts are a global concern, this detection program is an activity which lends itself to international cooperation.

The Workshop participants agreed that the space-faring nations, through their national space agencies, should establish a forum similar to the Mission Planning and Operations Group to consider together the technical and scientific issues required to develop a near-Earth asteroid deflection capability. Such consultations of the MPOG should build on the cooperation and links already established by the Information Analysis and Warning network, whose major elements already exist.

The Workshop participants concluded that the MPOG should be established in the near term, because it is certain that Earth will be struck again by a near-Earth object. Participants agreed that world space agencies have in hand much of the technology needed to prevent a future impact; for a modest investment, they could assemble the shared capability to deflect a threatening asteroid.

Further, participants agreed that the MPOG should deal with threatening objects cataloged by the IAWN search program, and to develop, well in advance of necessary implementation, a jointly-agreed, affordable plan for an effective deflection campaign. Preventing a future damaging NEO impact requires advance planning and the demonstration of a variety of effective deflection techniques and technologies. The MPOG can help achieve these goals through coordination of space agencies' NEO research and exploration programs. The MPOG Workshop was an essential first step in a collaborative process that could eliminate future impact catastrophes for Earth and its peoples.

References

Association of Space Explorers. *Asteroid Threats: A Call for Global Response.* http://www.space-explorers.org/committees/NEO/docs/ATACGR.pdf (ASE: Houston, 2008).

Secure World Foundation, Association of Space Explorers. *Executive Summary: Workshop on a Near-Earth Object Information, Warning, and Analysis Network. Mexico City, 18-20 January 2010* http://space-explorers.org/committees/NEO/neo.html (ASE: Houston, 2010).

Appendix 1

List of Participants

Name	Affiliation
Robert Axmann	DLR
Nicolas Brobinksy	ESA
Sergio Camacho	Regional Centre for Space Science and Technology Education for Latin America and the Caribbean
Richard Crowther	United Kingdom Space Agency
Barbara David	Secure World Foundation
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Richard Tremayne-Smith	Secure World Foundation

Appendix 2

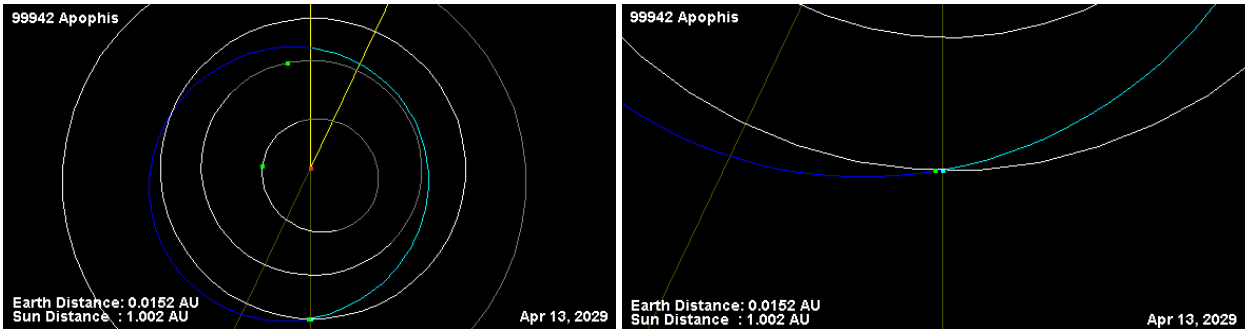
Impact Scenarios

MPOG Workshop, ESOC, Darmstadt, Germany; 27-29 October 2010

Scenario 1 – Keyhole Impact

A modified Apophis impact challenge highlighting the geopolitical issues relevant to this class of threat:

Vienna, Austria; 22 January 2013. The near-Earth asteroid Apophis, first discovered in 2004, was reacquired by telescopes around the world this month and found to be on a trajectory which still includes the possibility of an impact with Earth on 13 April 2036. While earlier tracking from 2004-2006 showed a low probability of impact with Earth (1 in 233,000 until recently) the new tracking data show that the impact probability in 2036 has now increased to 1 in 250 (0.4%). Astronomers report that this increase in the possibility of impact may be due to a slight shrinking of the asteroid's orbit due to the so-called Yarkovsky effect; the result of heating from the Sun, in combination with the asteroid's rotation, causing a slight slowing of its speed. The Information, Analysis, and Warning Network (IAWN) of the UN's Outer Space Committee states that this probability of impact will change very little during the next several years until Apophis is seen once again in 2021. Nevertheless, while the likelihood of an impact is improbable (249 chances for a miss out of 250) the IAWN has issued a formal advisory to the Mission Planning and Operations Group of UN/COPUOS recommending that they initiate preliminary mission planning should the probability of impact be found to increase further when Apophis again comes into view in 2021. Should a deflection mission be required it would be have to be completed by about 2027 in order to cause the asteroid to avoid passing through a narrow "keyhole" during its close pass by Earth on 13 April 2029.



[The orbital parameters of the NEO are, for scenario 1 purposes, those of 99942 Apophis in the JPL risk tables with the orientation of the Earth modified to shift the risk corridor to cross from the US on the west to Russia on the East.]

Based on current tracking Apophis is most likely to pass either in front of or behind the Earth as they pass through the potential intersection in space. Nevertheless the path across the face of the Earth where the asteroid may impact, referred to as the risk corridor, stretches across the United States to the west, across the northern Atlantic Ocean, and across Europe and Russia to the east.

If in 2021, after the next tracking update, Apophis remains a threat it is likely that a spacecraft would be launched to rendezvous with the asteroid and determine precisely, via an onboard radio transponder, whether in fact the asteroid were headed for an impact. If this were to be the case, the spacecraft would then be called on, using mutual gravitational attraction, or similar capability, to shift the impact point along the risk corridor to the east or west until it moves entirely off the Earth.

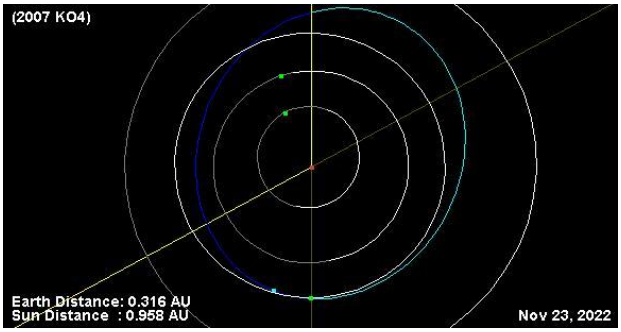
It is important to realize that the probability of this impact is low. Nevertheless the early planning and preparation for such a deflection campaign is prudent according to officials at the UN's Committee on the Peaceful Uses of Outer Space. For this reason early planning for such an eventuality is being initiated now.

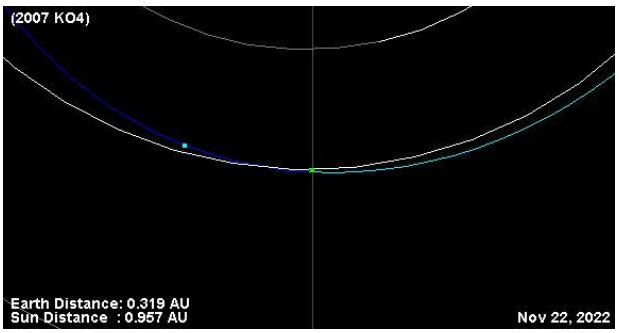
Scenario 2 – Direct Impact

A direct impact scenario designed to emphasize the time criticality and limited information quality which will be inherent in many relatively small object warnings:

Vienna, Austria; 24 December 2016. The near-Earth asteroid 2016 U04, estimated to have a diameter of 75 meters, has now disappeared from sight in the glare of the Sun after 2 months of tracking. The asteroid, discovered on 20 October 2016 has an unusually high probability of impact with the Earth, approximately 1 in 250, on 24 November 2030. Astronomers of the Information, Analysis and Warning Network (IAWN) of the UN Outer Space Committee estimate that if the asteroid impacts Earth it would explode with the equivalent force of approximately 1,400 Hiroshima atomic bombs (21 megatons of TNT equivalent).

Unfortunately the asteroid will not come into view of our telescopic tracking systems again until October 2023, only 7 years prior to the potential impact. Since a deflection campaign, if required, could not be initiated and executed successfully at that late date the IAWN has issued a preliminary warning to the Mission Planning and Operations Group of the UN COPUOS recommending that they initiate planning for a deflection campaign now.





[The orbital parameters of the NEO are, for scenario 2 purposes, those of 2007 KO4 in the JPL risk tables with the phasing of the asteroid adjusted to insure a direct impact on 24 Nov 2030. The time of day at impact is set to emphasize a population threatening risk corridor.]

While it is not yet possible to determine an impact point due to uncertainty in the orbit of the asteroid, the line of potential impacts across the Earth stretches from the Indian Ocean south of the tip of India, across the Indo-China Peninsula, the East China Sea and the Sea of Japan, passing just north of Sapporo, crossing the Kamchatka Peninsula and passing across Alaska north of Anchorage. The risk corridor for this potential impact has a strong southwest to northeast orientation due to the 25 degree inclination of the asteroid's orbit to the ecliptic plane. At the time of potential impact the asteroid would be passing up through the ecliptic plane from below.

The IAWN states that it issued its warning to the MPOG at this time since the next opportunity for additional tracking in 2022 will occur too late for a deflection campaign to be initiated should the asteroid indeed be on a collision course. It therefore appears prudent that a precursor mission to the asteroid be initiated now in order to determine precisely whether or not an impact will occur in 2030. The IAWN emphasizes that the likelihood of this impact is only 1 in 250 and that such a precursor mission will likely find no impact is imminent and the mission will revert to an asteroid scientific investigation. Nevertheless, in the unlikely event that the asteroid is on an impact trajectory, the precursor mission will make this determination and serve to observe and validate the primary deflection maneuver which would be mounted immediately.

[Note: For the purposes of Scenario 2 in our workshop, the assumption underlying the scenario is that the NEO is in fact on an impact trajectory. At the time of the IAWN warning, however, this cannot be known.]