

## DIVISION F/ NEAR EARTH OBJECT WORKING GROUP

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### TRIENNIAL REPORT 2015-2018

#### 1. Introduction

The Near Earth Object (NEO) Working Group exists within the IAU since almost two decades and was essentially the only formalized international group devoted to NEOs. In recent years, activities related to NEOs have led to the creation of new international organizations and committees. Many members of the IAU NEO Working Group (NEO WG) are involved in these organizations and committees. The general role of the NEO WG proposed since 2015 is not to add another committee with its own actions, which may add unnecessary complexity, but rather: 1) to provide to the IAU reports summarizing the main highlights and advances regarding NEO risk, space activities and science, 2) to serve as intermediary between the IAU and other entities, 3) to provide important information on NEOs to the IAU and contact points in case of media requests.

#### 2. Developments within the past triennium

##### 2.1. *NEO Working Group involvement in international actions dealing with NEO Risk*

The NEO WG works closely with three new entities dealing with NEO risk: the Planetary Defense Coordination office at NASA and two international endeavors recommended by the United Nations, in which some NEO WG members are involved.

##### 2.1.1. *Creation of the Planetary Defense Coordination Office (PDCO) at NASA*

In January 2016, the Planetary Defense Coordination Office (PDCO) has been officially established within NASA, and is responsible for:

- Ensuring the early detection of potentially hazardous objects (PHOs) greater than approximately 30 to 50 meters;
- tracking and characterizing PHOs and issuing warnings about potential impacts;
- providing timely and accurate communications about PHOs; and
- leading the coordination of U.S. Government planning for response to an actual impact threat.

In particular, if a PHO poses a significant chance of impacting Earth (that is, greater than 1 percent over the next 100 years), the PDCO prepares notification messages for the NASA Administrator to send to the Executive Office of the President, the U.S. Congress, and other Government organizations.

##### 2.1.2. *Actions at the United Nations Office of Outer Space Affairs*

The Committee on the Peaceful Uses of Outer Space (COPUOS) and its Action Team on Near Earth Objects (also known as Action Team 14), in which the NEO WG is represented, have recommended the establishment of two entities: the International Asteroid

Warning Network (IAWN) and the Space Missions Planning Advisory Group (SMPAG), i.e. two international endeavors for an international response to the NEO impact hazard, in which the NEO WG is also represented. These two entities now exist and are active.

IAWN (pronounced eyewahn) is an organization of asteroid observers, orbit computers, physical property specialists, radar astronomers, and other scientists and communication experts that study asteroids, specifically NEOs. It is open to any group petitioning to join IAWN, provided that it currently makes significant contributions to the study of NEOs, or makes precise and careful communication on NEOs and impact risks.

IAWN's functions are:

- To discover, monitor, and physically characterize the potentially hazardous NEO population using optical and radar facilities and other assets based in both the northern and southern hemispheres and in space;
- To provide and maintain an internationally recognized clearing house function for the receipt, acknowledgement and processing of all NEO observations;
- To act as a global portal, serving as the international focal point for accurate and validated information on the NEO population;
- To coordinate campaigns for the observation of potentially hazardous objects;
- To recommend policies regarding criteria and thresholds for notification of an emerging impact threat;
- To develop a database of potential impact consequences, depending on geography, geology, population distribution and other related factors;
- To assess hazard analysis results and communicate them to entities that should be identified by Member States as being responsible for the receipt of notification of an impact threat in accordance with established policies
- To assist Governments in the analysis of impact consequences and in the planning of mitigation responses.

The primary purpose of the SMPAG is to prepare for an international response to a NEO threat through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities (from the Terms of Reference). It is composed of official representatives of space agencies. ESA is chairing SMPAG until 2020.

Five IAWN meetings have taken place since the creation of IAWN, while nine meetings of SMPAG have taken place. Their activities already led to major decisions:

- 1) IAWN shall warn of **predicted impacts exceeding a probability of 1%** for all objects characterized to be **greater than 10 meters in size**, or roughly equivalent to **absolute magnitude of 28** if only brightness data can be collected.
- 2) Terrestrial preparedness planning should begin when warned of a possible impact:
  - a. Predicted to be **within 20 years**,
  - b. Probability of impact is assessed to be **greater than 10%**, and
  - c. Object is characterized to be **greater than 20 meters in size**, or roughly equivalent to **absolute magnitude of 27** if only brightness data can be collected.
- 3) SMPAG should start mission option(s) planning when warned of a possible impact:
  - a. Predicted to be **within 50 years**,
  - b. Probability is assessed to be **greater than 1%**, and
  - c. Object is characterized to be **greater than 50 meters in size**, or roughly equivalent to **absolute magnitude of 26** if only brightness data can be collected.

Regarding, SMPAG, an ad hoc Working Group in legal issues has been established in

order to study the SMPAG Work plan and address the possible legal questions stemming from it. Furthermore, in its statement to the 55th session of the Scientific and Technical SubCommittee of COPUOS in February 2018, SMPAG chair emphasized *the importance of the statement on deflection missions, which SMPAG had prepared in one of its previous meetings. Here is quoted from the statement: Given the degree of international interest in asteroid research and awareness of the impact hazard, advantage should be taken of opportunities to investigate asteroid deflection physics, techniques and effects as a part of science and technology demonstration missions. The SMPAG has identified the need to gain sufficient confidence in the viability of any proposed technique to deflect an asteroid from an impact trajectory. Therefore, the performance of the deflection technique to be utilized must have been actively demonstrated in a realistic planetary defence scenario to increase the current level of confidence. The SMPAG encourages actual demonstration of the kinetic impactor technique with a space mission, as it appears now to be the most technologically mature method of asteroid deflection.*

This statement supports the AIDA deflection test under study at ESA and NASA (see Sec. 2.2.3).

### 2.1.3. *Activities at the European commission: NEOShield-2*

NEOShield-2 is a European consortium that was funded from 2015 to 2017 by the European Commission (program Horizon 2020) and coordinated by the industry Airbus Defense and Space, regrouping several research labs and industries in Europe. The NEO WG was represented in this consortium. The task of NEOShield-2 was to study various concepts and technologies for asteroid deflection, and contribute to the physical characterization of NEOs. The final presentation of NEOShield-2 took place at the European Commission in Bruxelles in October 2017. Currently, there is thus no NEO activities within the European Commission until a next possible call.

## 2.2. *Space mission activities*

The year 2018 could be considered the year of NEOs. In effect, two sample return space missions are on their way to a NEO, namely Hayabusa2 (JAXA) and OSIRIS-REx (NASA). They will both reach their asteroid target in 2018. They will send the first detailed images of two primitive dark NEOs. Since those two NEOs have different sizes, ranging from 850 meters for Ryugu (target of Hayabusa2) to 450 meters for Bennu (target of OSIRIS-REx), we will also be determine the influence of the gravitational conditions on the surface properties of the asteroids by comparing the two surfaces in their different low-g environment. There is a great coordination and transparency between the teams of the two missions (some individuals and NEO WG members are members of both), which is a great demonstration to the world that science has no frontier.

Another mission, called AIDA, in the framework of an international cooperation is under study at ESA and NASA, which aim is to perform the first asteroid deflection test.

Finally, the Asteroid Retrieval Mission, which was studied at NASA, was eventually canceled.

### 2.2.1. *Hayabusa2 (JAXA)*

The Japanese sample return mission Hayabusa2 to the C-type NEO Ryugu has been launched on Dec. 3rd, 2014, and is now on its way to its target with no identified issue. Watanabe et al. (2017) give an overview of the mission. The arrival at Ryugu is expected to occur at the end of June. We will then have the first detailed image of a C-type NEO. Three samplings are planed, as well as the deployment of two mini-rovers (Minervas) and

a European lander (MASCOT) for in-situ measurements, as described by Tra-Mi et al. (2017), and finally an impactor (Small Carry-on Impactor, or SCI) that will perform an impact experiment, as described by Arakawa et al. (2017). The NEO WG is represented in the science and payload teams of this mission.

The current plan is to deploy the two minervas in September. The landing on MASCOT is then expected to occur on October 1st, and a first sampling should occur in mid-October of 2018. Other samplings and deployment of the SCI will occur in 2019.

Thus, a series of events with high potential media and public interest will happen in 2018 (first images of a C-type NEO, first landing on a small NEO etc ...), and communication plans are defined to ensure the visibility of this fascinating adventure and international cooperation.

### 2.2.2. *OSIRIS-REx (NASA)*

OSIRIS-REx was successfully launched on Sept. 8th, 2016 from Cap Canaveral. A search for Earth Trojan took place along the way to its target: the B-type NEO Bennu, whose known properties are presented by Lauretta et al. (2014). No Earth Trojan was then found. The approach will take place in August 2018. The NEO WG is represented in the science team of this mission.

OSIRIS-REx will perform a detailed characterisation of Bennu during 2 years before sampling it and return to Earth in 2023. There will also be great discoveries about a primitive NEO thanks to OSIRIS-REx and a great amount of samples for analysis in terrestrial laboratories.

### 2.2.3. *The Asteroid Impact & Deflection Assessment (AIDA) mission*

The Asteroid Impact & Deflection Assessment (AIDA) mission under study at ESA and NASA is composed of two components: an orbiter designed by ESA and an artificial projectile equipped with an imaging system and assisted by ground based observations designed by NASA.

The ESA component was originally called AIM (Asteroid Impact Mission) and has been recently redesigned and called Hera as described by Michel et al. (2018), while the NASA component studied at the Applied Physics Lab of the John Hopkins University was called DART (Double Asteroid Redirection Test) and is described by Cheng et al. (2016). The objective is to perform the first real asteroid deflection test using the artificial projectile DART on the small moon of the binary NEO Didymos, and to characterize the moon as well as to measure the impact outcome with Hera. The science PI of Hera is the President of the NEO WG.

DART has performed a Phase A and is now in Phase B. The Preliminary Design Review (PDR) will take place in April 2018. The launch remains planned in 2020 in order to perform the impact on Didymos' moon in October 2022, when the asteroid and the deflection can be measured from the ground with radar observations.

The original AIM study has been presented at ESA Council at Ministerial Level on December 1-2, 2016, but its full funding could not be obtained from ESA Member States, despite a high interest raised by some of them. The optimized version, called Hera, is under study and discussions are taking place with ESA Member States to start its Phase B1 in March 2018 until March 2019, so that the concept can be proposed for funding at the next ESA Council at Ministerial Level in 2019. The launch would take place in 2023 and the spacecraft will arrive a few years after DART's impact at the asteroid. Despite the fact that Hera won't observe directly the impact, it will still be able to measure its outcome, in particular, the mass of Didymos' moon and the crater's properties, which remain unchanged after a few years. These data are the most important information

allowing the validation of the numerical predictions and will offer a great improvement of our understanding of the impact process at asteroid scale.

Several presentations of the advances of both DART and Hera have been submitted or are planned in international congresses (9th Catastrophic Disruption Workshop in Kobe in May, COSPAR General Assembly in Pasadena in July, IAU General Assembly in Vienna in August).

Since AIDA is the only deflection test under study in space agencies and with a possible launch in a close future, a letter of support by the IAU sent to NASA and ESA may be considered to demonstrate the interest of the community.

#### 2.2.4. Asteroid Redirect Mission (NASA)

The Asteroid Redirect Mission (ARM) was under study at NASA until 2017. Its aim was to retrieve a boulder from a NEO (possibly 2008 EV5) to perform a gravity tractor test and to return the boulder to cis-lunar orbit, so that a human mission can be sent in the mid-2020s to investigate it and get a sample. It was part of NASA's plan to advance the new technologies and spaceflight experience needed for a human mission to the Martian system in the 2030s. However, after the presidential elections of 2017, the new administration canceled the project.

### 2.3. Asteroid Day

In February 2014, Dr. Brian May, astrophysicist and famed guitarist for the rock band QUEEN, began working with Grigorij Richters, the director of a new film titled 51 Degrees North, a fictional story of an asteroid impact on London and the resulting human condition. May composed the music for the film and suggested that Richters preview it at Starmus, an event organized by Dr. Garik Israelian and attended by esteemed astrophysicists, scientists and artists, including Dr. Stephen Hawking, Richard Dawkins and Rick Wakeman. The result was the beginning of discussions that would lead to the launch of Asteroid Day in 2015.

Asteroid Day takes place annually on June 30. It is a global awareness campaign where people from around the world come together to learn about asteroids, the impact hazard they may pose, and what we can do to protect our planet, families, communities, and future generations from future asteroid impacts. Asteroid Day is held each year on the anniversary of the largest impact in recent history, the 1908 Tunguska event in Siberia. Regionally organised large and small events are held on Asteroid Day, and range from lectures and other educational programmes to live concerts and broader community events, to raise public awareness of the need for increased detection and tracking of asteroids.

This activity is supported by the United Nations. In effect, in December 2016, the United Nations General Assembly adopted resolution A/RES/71/90, declaring 30 June International Asteroid Day in order to *observe each year at the international level the anniversary of the Tunguska impact over Siberia, Russian Federation, on 30 June 1908, and to raise public awareness about the asteroid impact hazard.*

In 2017, on June 30, Asteroid Day LIVE was the first-ever 24-hour live broadcast about space, and specifically asteroids, airing on June 30, 2017 made possible by support from OHB, SES, BCE and the Luxembourg Government. Asteroid Day LIVE included six hours from Luxembourg in addition to live programming from ESA, JAXA and NASA. The six-hour broadcast from Luxembourg plus hours of other international programming created a global conversation about some of the most important asteroid missions and new discoveries, with scientists and experts around the world, including IAU NEO WG members.

The organisation of the next one in 2018 is under preparation.

#### 2.4. *NEO related workshops (2015-2018)*

- 4th IAA Planetary Defense Conference, Frascati, Italy, April 2017
- AIDA meeting at the European Planetary Science Conference (EPSC) in Nantes, France, September 2015
- Asteroid Impact Mission (AIM) Science Meeting in ESAC (Madrid, Spain), March 2016
- European Geoscience Union (EGU) General Assembly 2016: PS1.5 Science and Technology for the Asteroid Impact & Deflection Assessment (AIDA) mission, Vienna, Austria, April 2016
- 2nd AIDA International Workshop in Nice, France, June, 2016
- 5th IAA Planetary Defense Conference, Tokyo, May 2017
- 3rd AIDA International Workshop, Laurel, Maryland, USA, June 2017
- Special Session on AIDA and Planetary Defense at the European Planetary Science Conference (EPSC) in Riga, Latvia, September 2017
- Workshop: Near-Earth Objects: Properties, Detection, Resources, Impacts and Defending Earth, to be held 14 May - 8 June 2018, organized by the Munich Institute for Astro- and Particle Physics (MIAPP)
- Didymoon Observer Workshop, 19-21 June 2018, Prague, Czechia
- Special Session Small Body Hazard, COSPAR General Assembly, Pasadena, USA, July 2018
- A panel on NEO hazard has been submitted to the organization of the International Astronautical Congress (IAC) in Bremen, October 2018.

### 3. Closing remarks

Near-Earth Objects and related planetary defense activities are a permanent issue with many current and future science applications and developments. Thus, it is proposed that this Working Group keeps existing in the IAU in relevant Divisions on a continuous basis so that IAU directorate is kept informed about NEO related activities, and has a formal contact point for the medias and politicians.

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