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DIVISION F **NEAR EARTH OBJECT WORKING GROUP**

PRESIDENT **Patrick MICHEL**

TRIENNIAL REPORT 2018-2021

1. Background

In recent years, activities related to NEOs and planetary defense have benefited from dedicated international organizations and committees (e.g., the Un-endorsed International Asteroid Warning Network or IAWN and Space Mission Program Advisory Group or SMPAG, the IAF NEO Committee, etc), as well as from new results from sample return missions to NEOs (Hayabusa2 by JAXA and OSIRIS-REX by NASA) and the decision to fund planetary defense space missions by NASA (DART) and ESA (Hera). Many members of the IAU NEO Working Group (NEO WG) are involved in these organizations, committees and space missions. The role of the NEO Working Group 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.

NEO activities are regularly discussed and presented at the IAA Planetary Defense Conference, which takes place every two years and to which most actors in planetary defense participate. In 2018, it took place at College Park (USA) and in 2021 it takes place virtually on April 26-30, 2021, with the support of the UN COPUOS. Several IAU NEO WG members are part of the organizing committee. This conference covers all aspects related to planetary defense.

Since Near-Earth Objects and related planetary defense activities are a permanent issue with many science applications and developments, it is proposed that this Working Group keeps existing in the IAU in relevant Divisions on a continuous basis.

In the following, we present a brief and non-exhaustive summary of some of the NEO activities that occured during the past triennium.

2. Developments within the past triennium

2.1. *Planetary Defense Space missions*

The NASA DART mission, which will perform the first impact deflection test using the kinetic impactor techniques, will launch with a launch window ranging from the end of November 2021 to February 2022 to perform an impact on the small moon of the binary NEO 65803 Didymos, at $\approx$ 6 km/s in late September-early October 2022. The name of the small moon, Dimorphos, was given by the IAU WGSBN in a short time in May 2020. The ItalianCubesat LiciaCube (ASI) will be deployed by DART before the impact to observe the first instant after the impact and provide data on the first ejecta

produced by the impact. Ground-based observatories will perform a campaign to measure the resulting change in the orbital period of Dimorphos around the primary asteroid.

In November 2019, The ESA council at Ministerial Level confirmed the creation of the Space Safety Program that includes Planetary Defense. In this program, the Hera mission received the required funding to enter in development for launch in 2024 to Didymos. At the time of writing of this report, the mission is in Phase C. With its suits of onboard instruments (including a contribution by JAXA with a thermal infra-red imager) and its two cubesats, Juventas and Milani, Hera will fully characterize in 2027 the outcome of the NASA DART's impact and the binary asteroid, including for the first time, the sounding of an asteroid's internal structure using a low-frequency radar. The IAU NEO WG President also serves as mission PI of Hera.

DART and Hera will thus offer the first fully documented asteroid deflection test. The Asteroid Impact and Deflection Assessment (AIDA) collaboration, which includes scientists from around the world who are involved in those missions and some members of the IAU NEO WG, performs activities in support of the development of DART and Hera.

The UN-endorsed Space Mission Program Advisory Group continues its activities to prepare for an international response to a threat by a near-Earth object through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities. The last meeting took place virtually on March 24-25, 2021 (https://www.cosmos.esa.int/web/smpag/).

2.2. *NEO Sample return space missions*

In 2018, two sample return space missions, Hayabusa2 (JAXA) and OSIRIS-REx (NASA), arrived at their respective NEO target (Ryugu and Bennu). Both missions revolutionized our knowledge of these objects, showing very complex and active geological worlds and very dark surfaces that are globally covered with large boulders having different kinds of morphologies. Both also performed fully successfully their extremely complex operations, including the ultimate goal which was to retrieve samples from their surface. Hayabusa2 also performed an impact experiment with its Small Carry-on Impactor (SCI), which resulted in a crater whose unexpected large dimensions can only be explained if the surface has basically no cohesion. Moreover, despite the very low surface gravity, many ejecta from the crater returned to the surface, which was also not expected and demonstrates that impact physics in low-gravity remains a challenge for our understanding and proper numerical modeling. The data obtained by the two spacecrafts already allowed huge advances in our understanding of the formation, history and composition of these asteroids, with implications for planetary defense, and the analysis of the samples will allow making an enormous step in our understanding of these objects, in particular the possible role of carbonaceous asteroids in the emergence of life on Earth through the analysis of organics and hydrated minerals.

Hayabusa2 returned 5.4 grams of samples (goal= 0.1 gram) of the asteroid Ryugu to Earth on December 6th, 2020. ORISIS-REx performed its Touch and Go (TAG) on October 20, 2020 on the chosen site, called Nightingale, of Bennu's surface and it is expected that a few hundreds grams were collected (goal: 60 grams). A flyby on the sampling site is planed for April 7th, 2021, which will give us detailed information on the disturbance of the surface by the TAG and new knowledge on the surface mechanical response.

The extended Hayabusa2 mission was approved by JAXA, which will lead to the flyby

of a 800-meter-diameter L-type asteroid in 2026 and a rendezvous with a 30 meter-diameter NEO with a spin rate of about 10 minutes. This last target is specially relevant for planetary defense, as smaller objects are more numerous and they also tend to have high spin rates that tell us something about their structure, which we still need to understand, and pose a challenge for deflection techniques.

2.3. *NEO ground-based observations*

More than 25,000 NEOs have now been discovered, including almost all NEOs larger than 1 km in diameter. The goal is now to discover more than 90% of NEOs larger than 140 m, which are expected to be about 25,000.

On the ground, most discoveries are still performed by two telescopes: Pan-STARRS in Hawaii and the Catalina Sky Survey in Arizona. ESA is also building the fly-eye telescope that will be devoted to the discovery of small NEOs and shall be installed near the top of the 1865-meter Monte Mufara mountain in Sicily, Italy. This new European telescope splits each image into 16 smaller subimages, expanding its overall field of view similar to the technique exploited by a flys compound eye. It will offer performance equivalent to a 1 m-diameter telescope, and provide a very large field of view of $6.7^\circ \times 6.7^\circ$ or about 45 square degrees.

From space, the NEO Surveyor Mission (NEOSM) by NASA shall make the inventory of more than 90% of NEOs on a timescale of 10 years (including the computation of their impact probability over a century and the direct determination of their diameter thanks to its Infra-Red channel).

Other information can be found on the following websites:

- NASA Planetary Defense: https://www.nasa.gov/planetarydefense
- ESA NEO Coordination Center: https://neo.ssa.esa.int
- UN-endorsed International Asteroid Warning Network (IAWN): https://iawn.net

2.4. *Funded planetary defense projects by the European Commission*

In 2019, the European Commission selected two planetary defense projects for funding in its H2020 program under the main topic *SU-SPACE-23-SEC-2019: Advanced research in Near Earth Objects (NEOs) and new payload technologies for planetary defence.*

The Near-Earth Object Modelling And Payload for Protection (NEO-MAPP) project is coordinated by the IAU NEO WG President P. Michel (CNRS) and involves 15 European partners including industries. Its goals are to perform significant advances in both our understanding of the response of NEOs to external forces (in particular a kinetic impact or a close planetary approach), and the associated measurements by a spacecraft (including those necessary for the physical and dynamical characterization in general). The reference mission of the project is the ESA Hera mission, in which most of the NEO-MAPP members are involved (including the PI) and most activities will support the development of Hera while others will allow us to go beyond.

The NEO Rapid Observation, Characterization and Key Simulations (NEOROCKS) project is coordinated by E. Dotto (Istituto Nazionale di Astrofisica, Italy) and also involves 15 European partners, including industries. NEOROCKS is focused on the characterization of NEOs, through observations and modeling, as well as impact monitoring.

Both contain a significant amount of outreach activities and will perform their activities until 2023. More information can be found on the following website:

- NEO-MAPP: https://neomapp.eu
- NEOROCKS: https://www.neorocks.eu

3. Conclusion and future plans

The IAN NEO WG contributed to an important topic, which is to protect our planet from the impact of an asteroid. The risk is very low compared to other natural risks, but it is the only one that can be predicted and mitigated by means that are feasible and are now under implementation. As this report demonstrates, the prediction, which relies on the discovery of NEOs and impact monitoring, is on going, and the mitigation, which relies on the validation of at least one deflection techniques, is also ongoing. Moreover, an international response is also under study thanks to the two UN-endorsed groups, IAWN and SMPAG, which will allow an organized political to this issue at national and hopefully international level. A good example of this latter activity is the *Report on Near-Earth Object impact threat emergency protocols*released in January 2021 by the Executive Office of the President of the United States.

The current sanitary crisis shows us that a low probability risk with high consequences is extremely difficult to manage if a response is not organize in advance. The NEO risk is one of those low probability risks, for which there is no identified threat for the newt century and for which it is wise to be prepared before we need it.

The current efforts by the IAU NEO WG and the international activities (as reported here) are going into this direction in a very fruitful way. The next IAU NEO WG will keep playing its role and also promote NEO science among the IAU members and encourage inclusive participation in this important topic across all genders and backgrounds.