**UNITED NATIONS**
OFFICE FOR OUTER SPACE AFFAIRS

# NEAR-EARTH OBJECTS AND PLANETARY DEFENCE

UNITED NATIONS

ST/SPACE/73

Cover image: Meteor over the Dolomites. © Ollie Taylor. Used by permission.



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# Near-Earth Objects and Planetary Defence

## UNITED NATIONS AND INTERNATIONAL COOPERATION AGAINST AN ASTEROID IMPACT HAZARD

Forging global partnerships and building resilient societies through better coordination are among the key challenges of the twenty-first century. Given the global consequences of a near-Earth object (NEO) impact and the considerable resources required to prevent a collision, the United Nations, through its Office for Outer Space Affairs (UNOOSA), has been involved in the international discourse and dialogue on the topic of NEOs, raising awareness and promoting global cooperation.

Addressing such a hazard, including the identification of objects that pose a threat of impact to Earth, and planning a corresponding mitigation campaign, require cooperative action in the interest of public safety on the part of the global community.

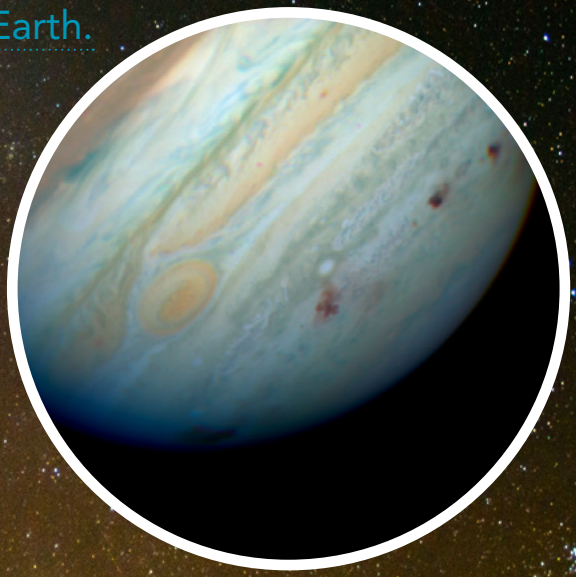
Acting as a gateway to space in the United Nations system, UNOOSA is uniquely positioned in intergovernmental cooperation and coordination on outer space activities, and in the broader perspective of space security, including the area of planetary defence. The Office supports and cooperates with two entities established in 2014: the International Asteroid

Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG). These two entities came into being through a series of recommendations for an international response to the threat of near-Earth object impact, endorsed by the United Nations Committee on the Peaceful Uses of Outer Space and ultimaly recommended by the General Assembly. The aim of these recommendations is to address the global challenge posed by NEOs, beginning with their detection and tracking and, subsequently, deflection and planetary defence.

The goal is to ensure that all countries, in particular developing nations with limited capacity for predicting and mitigating a NEO impact, are aware of potential threats as well as to guarantee an effective emergency response and disaster management in the event of a NEO impact. As this area is crucial to ensuring human security, the United Nations continues to facilitate the processes for developing an international response to a NEO-impact threat, with the Office for Outer Space Affairs playing an active role.

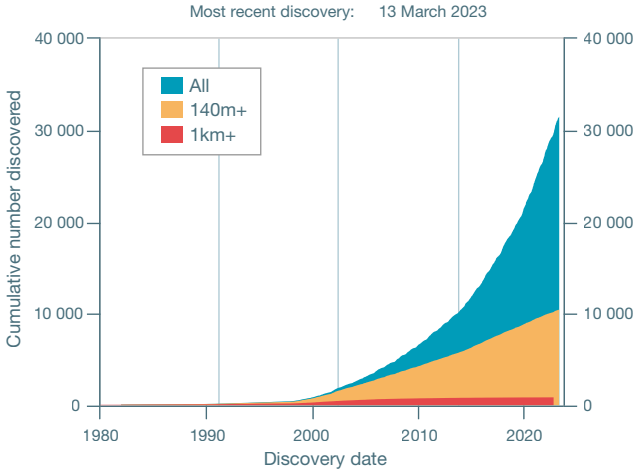
Impacts from asteroids and comets have contributed to mass extinctions and the evolution of life on Earth.

Impacts can potentially lead to significant damage to life and property on our planet. The impacts of Comet Shoemaker-Levy 9 on Jupiter in 1994 led to coordinated efforts to discover, track, characterize and catalogue NEOs, especially those that may pose a hazard to the Earth.



The Chelyabinsk super-bolide on 15 February 2013 serves as an explicit reminder that even relatively small asteroids (~20 metres across) can penetrate the atmosphere. In 2022, two previously unknown asteroids were observed only hours before they entered the Earth's atmosphere – one over the ocean near Iceland, the other over Canada. Both were small enough to disintegrate in the Earth's atmosphere and not result in any damage. While these asteroid impacts provided the unique and real-time opportunity to test the systems currently in place to track a celestial object's trajectory on a collision course with our planet, they also served as a further reminder that a NEO impact from an unknown asteroid could occur at any time.

## NEAR-EARTH ASTEROIDS DISCOVERED




**Near-Earth asteroids:**
31 414 all
10 401 >140m
853 >1km

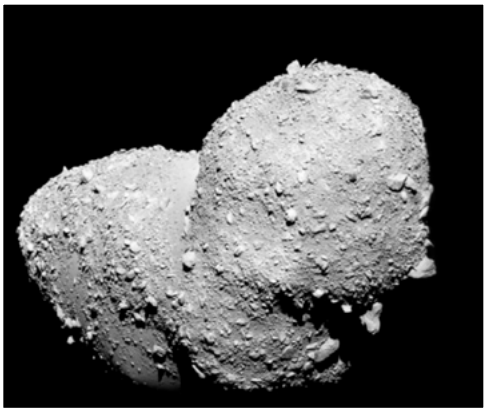
**Potentially hazardous asteroids:**
2 324 all
151 >1km

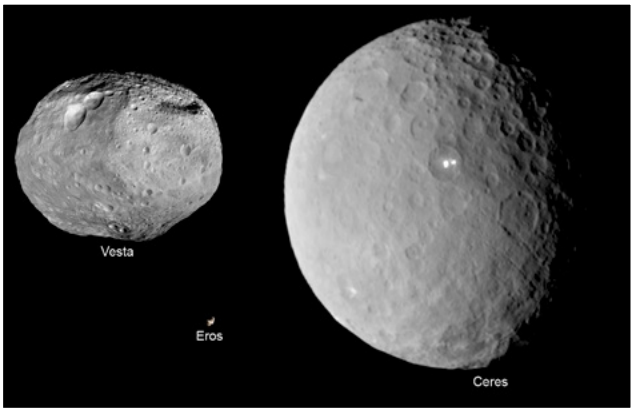
**Near-Earth comets:**
120

https://cneos.jpl.nasa.gov/stats/ Alan Chamberlin (JPL/Caltech)

To date, over 31,000 NEOs have been discovered. To increase our awareness of these potential hazards, it is essential to find them first, and then assess the risk they may pose to our planet.

Asteroids and comets are pieces of planetary debris that never formed into a planet, yet retain clues as to the early history of the solar system. While most asteroids are either rocky or metallic (or a mixture of the two) and maintain orbits in the main asteroid belt between Mars and Jupiter, comets are generally icy bodies that have very eccentric orbits and a wide range of orbital periods.





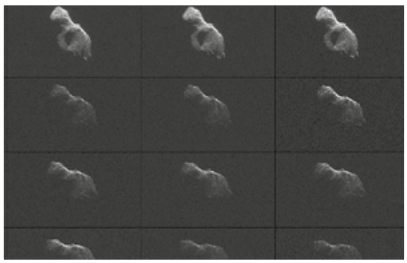

Itokawa (left) was the first asteroid to be the target of a sample return mission (the Japanese space probe *Hayabusa*) and the smallest asteroid photographed and visited by a spacecraft.

*Ceres* and *Vesta* (right) were among the first asteroids discovered over 200 years ago, orbiting the Sun between Mars and Jupiter. The image on the right shows a relative-size comparison between these large asteroids and *Eros*, the first ever near-Earth asteroid, discovered in 1898.

Credit: JAXA (left); NASA (right)

Another dynamic class of asteroids include those categorized as NEOs. In 1898, the discovery of the asteroid 433 Eros established the existence of a population of asteroid-like bodies on orbits that cross those of the inner planets. NEOs include both asteroids and comets whose orbits approach the Earth's orbit around the Sun. They range in size from a few metres to as much as 34 km across, with smaller objects being far more numerous than larger objects. Cometary bodies comprise less than one per cent of the NEO population.

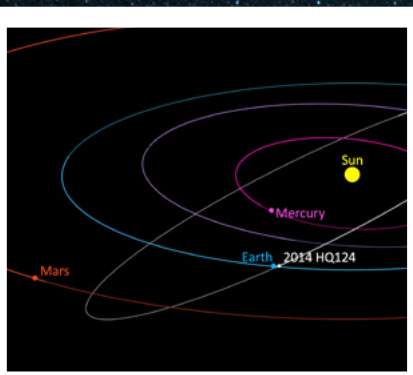
The bulk of the NEO population originates from the inner part of the Main Asteroid Belt. The gravitational influence of Saturn, Jupiter and Mars, coupled with some collisional activity within this source population, serves as the main reservoir for these primitive bodies that dynamically evolve into NEOs.

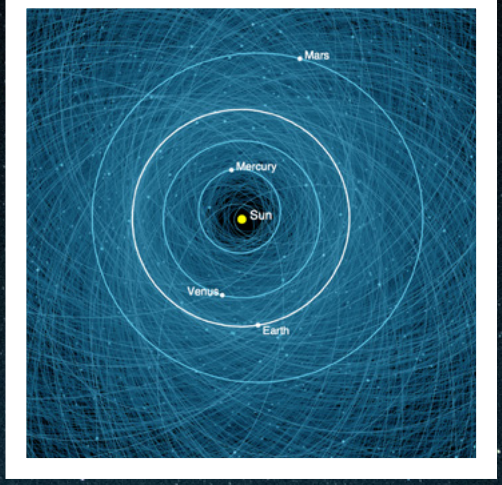


Working together, the Goldstone and Arecibo dishes obtained bistatic radar images of 2014 HQ124 on 8 June 2014 (day of closest approach) producing spectacular imagery of this potentially hazardous object (PHO).

Radar measurements indicate it is ~370 metres about its long axis and appears to be a contact binary. Large boulders appear to be embedded into the main body.

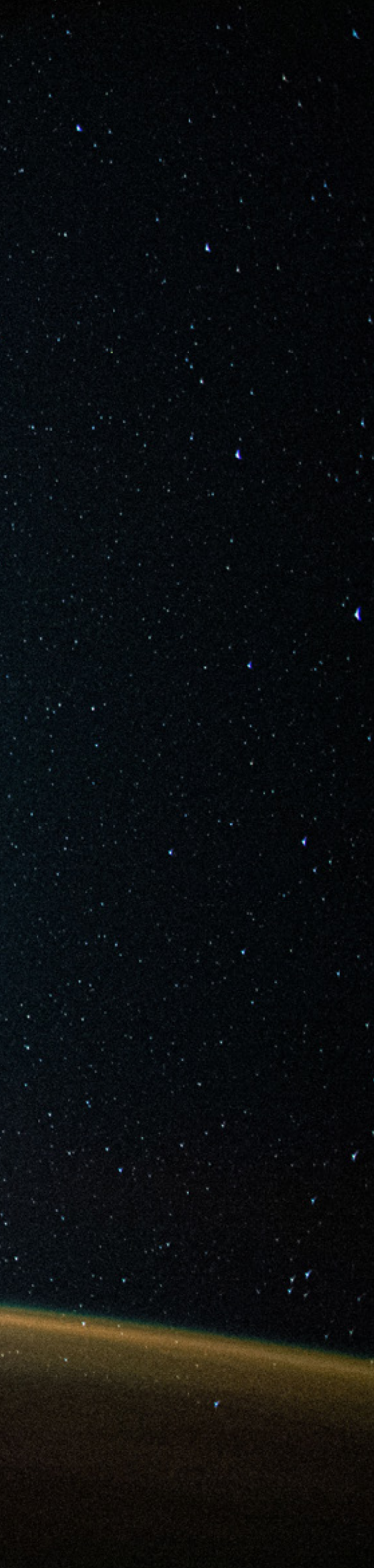
Characterizing such objects is key to mounting an effective defence against them.




Plot of orbits of all currently known PHOs that are 140 metres or larger and pass within 7.5 million kilometres of the Earth's orbit.

Future Flyeye telescope (ESA): "As part of the global effort to hunt out risky celestial objects such as asteroids and comets, ESA is developing an automated telescope for nightly sky surveys."





Of the over 31,000 NEOs known today (January 2023), there are nearly 2,000 objects classified as potentially hazardous objects (PHOs).

Around 1,500 objects are being tracked as having a computed impact probability larger than zero. Although none of the probabilities known today are significant, finding PHOs that have yet to be discovered is critical to understanding the true risk to Earth.

By definition, a NEO is an asteroid or comet that comes within 1.3 astronomical units (au) of the Sun. This implies that they can come at least within 0.3 au – about 50 million km – of the Earth's orbit. By contrast, PHOs come much closer and have a minimum orbital intersection distance of less than 0.05 au – about 7.5 million km – from the Earth's orbit, measuring more than ~140 metres across. An object of this size is large enough to cause devastation on a regional scale with possible global consequences.

However, objects much smaller than 140 metres can also cause considerable damage, although without producing global consequences. A NEO as small as 10 metres, under certain conditions, could be hazardous and its impact could lead to damage to buildings such as broken windows and result in some injuries to people.

## UNITED NATIONS AND NEAR-EARTH OBJECTS

The United Nations International Conference on Near-Earth Objects was held at United Nations Headquarters in New York in 1995. Organized by UNOOSA, the Conference raised the awareness of Member States to the potential threat from NEOs and proposed an expansion of existing observation campaigns to detect and track NEOs. It was one of the first gatherings of this magnitude to discuss the phenomenon on an international level. Policy perspectives emerged from the Conference to increase awareness of the threat from NEOs and to provide guidelines for cooperative observation, research and mitigation programmes. It was argued that there was a need to estimate probabilities of possible NEO impacts, due to the potentially severe consequences of medium- to large-sized asteroids or comets.

## NEAR-EARTH OBJECTS AT THE UNISPACE III CONFERENCE

In 1999, the issue received further attention at the third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), which resulted in the Vienna Declaration on Space and Human Development. The Vienna Declaration contained 33 specific recommendations, endorsed by the General Assembly, one of which was to address the need to improve international coordination of activities related to near-Earth objects.

In order to implement that recommendation, in 2001 the Committee on the Peaceful Uses of Outer Space established the Action Team on near-Earth Objects (Action Team 14). The work of this Action Team resulted in recommendations for an international response to the threat of a near-Earth object impact.

## UNITED NATIONS COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE-ENDORSED RECOMMENDATIONS FOR BUILDING AN INTERNATIONAL RESPONSE TO THE NEO-IMPACT THREAT

The recommendations (as contained in document A/AC.105/L.330) provide for an international response to the NEO-impact threat, agreed under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and welcomed by the General Assembly in its resolution 68/75 of 11 December 2013. They propose to ensure international information sharing in discovering, monitoring and physically characterizing potentially hazardous NEOs with a view to making all countries aware of potential impact threats, particularly developing countries with limited capacity in predicting and mitigating a NEO impact. They emphasize the need for effective emergency response and disaster management in the event of the discovery of a NEO impact threat.

## THE INTERNATIONAL ASTEROID WARNING NETWORK AND THE SPACE MISSION PLANNING ADVISORY GROUP: PLANETARY DEFENCE AT A GLOBAL LEVEL

The International Asteroid Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG) are two entities established in 2014 as a result of the United Nations-endorsed recommendations and represent important mechanisms at the global level for strengthening coordination in the area of planetary defence.

## UNITED NATIONS OFFICE FOR OUTER SPACE AFFAIRS, THE INTERNATIONAL ASTEROID WARNING NETWORK AND THE SPACE MISSION PLANNING ADVISORY GROUP

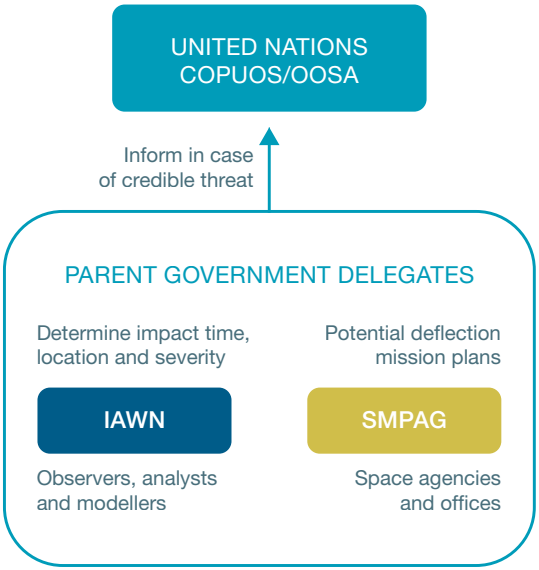
The United Nations Office for Outer Space Affairs (UNOOSA) works with IAWN, which maintains through its signatories an internationally recognized clearing house for the receipt, acknowledgment and processing of all NEO observations collected from observatories worldwide, by facilitating the dissemination of information related to near-Earth objects to Member States.

Pursuant to General Assembly resolution 71/90 of 6 December 2016, UNOOSA acts as secretariat to SMPAG, which works on laying out the framework, timeline and options for initiating and executing space mission response activities, as well as promoting opportunities for international collaboration on research on technology and techniques for NEO deflection.

Both IAWN and SMPAG submit a report annually to COPUOS through its Scientific and Technical Subcommittee under the agenda item on NEOs. In 2016, SMPAG also agreed to establish the SMPAG Ad Hoc Working Group on legal issues to address possible legal questions related to the workplan items of SMPAG.

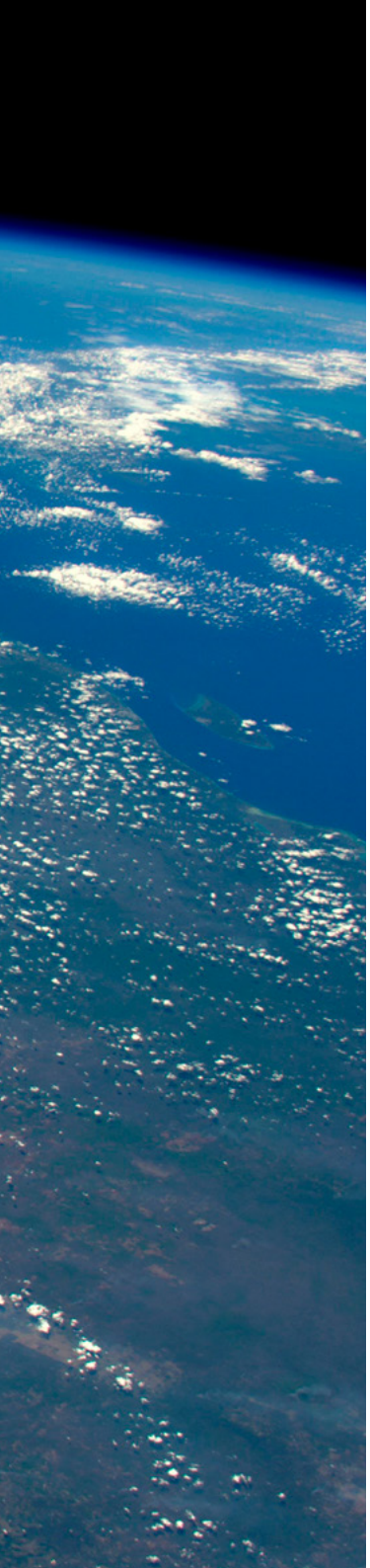
## IN THE EVENT OF A CREDIBLE IMPACT PREDICTION …

In the event of a credible impact threat prediction, warnings will be issued by IAWN. If the object is larger than about 50 metres and the impact probability is larger than one per cent within the next 50 years, SMPAG will start to assess mitigation options and implementation plans for consideration by the Member States. The goal is the global protection of the ecosystem, of human beings and their property on Earth, and of the civilization of humankind from the effects of a devastating asteroid impact.




This figure shows the relationship of IAWN and SMPAG to the United Nations. IAWN and SMPAG provide annual progress reports to the Scientific and Technical Subcommittee (STSC) of COPUOS on their work. They have non-permanent observer status at the meetings of the STSC. Information flow is facilitated via their parent government delegations.

Further information on IAWN can be found at
**www.iawn.net**





## INTERNATIONAL ASTEROID WARNING NETWORK

The International Asteroid Warning Network (IAWN) is a collaboration of space agencies, scientific institutions, observatories and other interested parties performing observations, orbit computation, modelling and other scientific research related to the impact potential and effects of asteroids on the Earth. It endeavours to foster a shared understanding of the NEO hazard and optimize the scientific return on these small celestial bodies. Members of the Network have signed a letter of intention to use their observation and analysis infrastructure and capabilities to detect, monitor and characterize NEOs, and to share their findings with the scientific, government and public communities.

IAWN signatories already include 50 members from over 20 countries worldwide. The primary functions of IAWN are to:

- Conduct and coordinate the search for NEOs that may pose a hazard to the Earth
- Make follow-up observations and characterization of NEOs
- Accurately calculate the orbits of NEOs and any impact probabilites
- Communicate the risks and benefits of NEOs to the public
- Maintain a clearing house for NEO data
- Maintain a database of impact consequences, and ultimately,
- Serve as the principal trusted source of information on NEOs

Since the discovery rate of NEOs is continually on the rise, it suggests that the need for the functions of IAWN will also increase substantially in the future.

## SPACE MISSION PLANNING ADVISORY GROUP

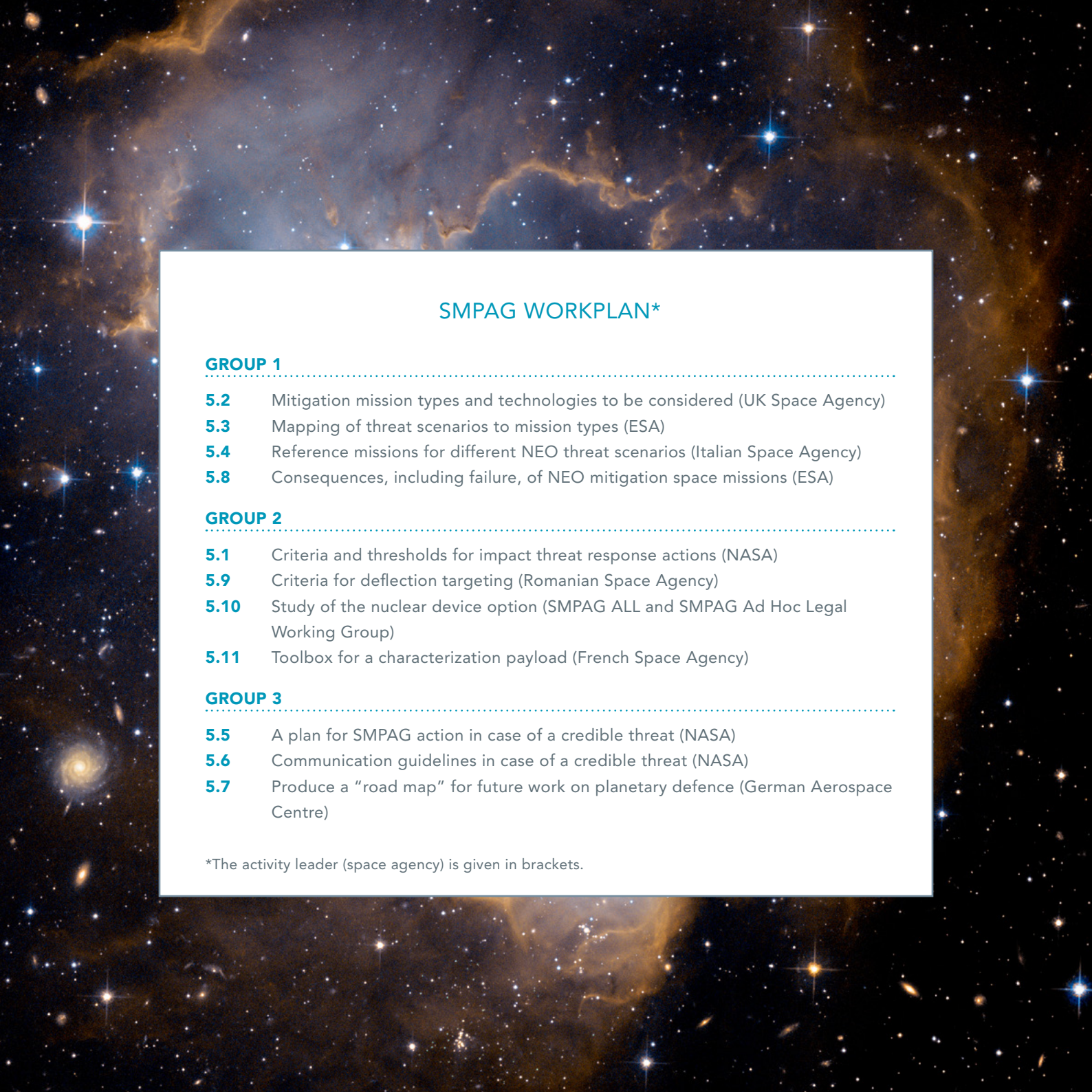
The Space Mission Planning Advisory Group (SMPAG) is a forum that links the space agencies of Member States with other relevant entities. Its responsibilities include proposing options and implementation plans for initiating and executing space mission response activities as well as promoting opportunities for international collaboration in research on technology and techniques for near-Earth object deflection.

SMPAG addresses the following main areas:

- Reference missions, technology road maps and collaborative research
- Communication and exchange of information
- International treaty and policy aspects – identifying issues for possible detailed reviews within appropriate forums
- Mitigation campaign planning activities

In 2015, SMPAG started developing its workplan. It initially listed 11 workplan items, each of which is the responsibility of one or more members of SMPAG. The workplan foresees a road map for planetary defence at the global level. It fosters agreements on initial criteria and thresholds for response actions to the threat of impacts, consideration of mitigation mission types and technologies, and the mapping of threat scenarios to mission types. It is also meant to trigger the development of a plan of action in the event of the discovery of a credible threat.

Activity reports and special presentations are available on its website at **www.smpag.net**



## SMPAG WORKPLAN*

### GROUP 1

**5.2** Mitigation mission types and technologies to be considered (UK Space Agency)

**5.3** Mapping of threat scenarios to mission types (ESA)

**5.4** Reference missions for different NEO threat scenarios (Italian Space Agency)

**5.8** Consequences, including failure, of NEO mitigation space missions (ESA)

### GROUP 2

**5.1** Criteria and thresholds for impact threat response actions (NASA)

**5.9** Criteria for deflection targeting (Romanian Space Agency)

**5.10** Study of the nuclear device option (SMPAG ALL and SMPAG Ad Hoc Legal Working Group)

**5.11** Toolbox for a characterization payload (French Space Agency)

### GROUP 3

**5.5** A plan for SMPAG action in case of a credible threat (NASA)

**5.6** Communication guidelines in case of a credible threat (NASA)

**5.7** Produce a "road map" for future work on planetary defence (German Aerospace Centre)

*The activity leader (space agency) is given in brackets.

## INTERNATIONAL ASTEROID DAY

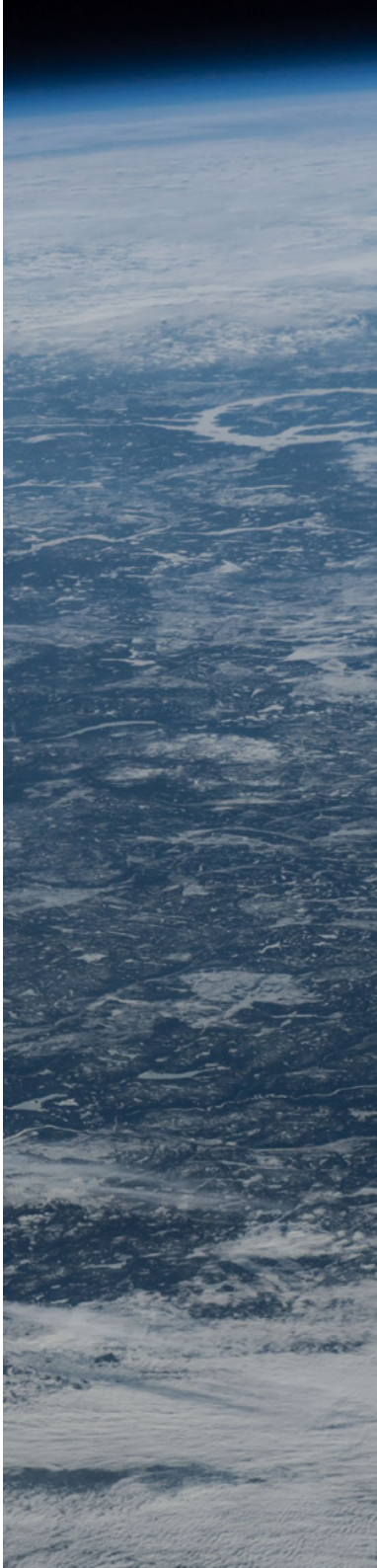
On 6 December 2016, the General Assembly proclaimed in resolution 71/90 that International Asteroid Day would be observed annually on 30 June to raise public awareness of the asteroid impact hazard.

30 June is the anniversary of the Tunguska impact over Siberia, now part of the Russian Federation, which occurred on 30 June 1908. The Tunguska asteroid impact devastated over 2,000 square kilometres of forest and is the Earth's largest confirmed asteroid impact in recent history.

International Asteroid Day encourages reflection on the impact hazard of asteroids and the global work undertaken in this area that UNOOSA facilitates, including work by COPUOS and its member States, IAWN and SMPAG.

All United Nations Member States, organizations of the United Nations system and other international and regional organizations, as well as civil society, including non-governmental organizations and individuals, are invited to observe International Asteroid Day.

The General Assembly's proclamation was based on a proposal by the Association of Space Explorers that was endorsed by COPUOS.





## PLANETARY DEFENSE CONFERENCES

As the key biennial global conference in this area since 2009, the international Planetary Defense Conferences (PDC) of the International Academy of Astronautics (IAA) bring together experts working to address the NEO hazard. Showcasing the broad range of issues related to a potential asteroid impact on our planet and its global significance, topics examined during the conference include but are not limited to: NEO discovery and characterization, planetary defence missions, asteroid deflection techniques, public communications and media relations, disaster preparedness, space policy implications, and legal implications, showcasing the broad range of issues related to a potential asteroid impact on our planet.

Each PDC also discusses a hypothetical asteroid impact scenario. This is meant to identify gaps that may exist and to make recommendations should such a high-impact low probability natural hazard ever occur. The exercises also contribute to the common goal of building more resilient societies, and to being better prepared for a potential asteroid impact hazard.

Information on the latest PDC is available at
**https://iaaspace.org/pdc**

## DOUBLE-ASTEROID REDIRECTION TEST WITH LICIACUBE, FOLLOWED BY HERA

On September 26, 2022, the NASA Double-Asteroid Redirection Test (DART) mission, the world's first-ever test for planetary defence, successfully impacted its target asteroid Dimorphos – which posed no threat to Earth – and marked humanity's first-ever purposeful movement of a celestial object's motion in space. DART's successful impact with Dimorphos demonstrated one method of asteroid deflection via a kinetic impactor spacecraft. The results from DART's roughly 22,530-kilometer per hour impact with Dimorphos analysed by planetary defence experts and observatories around the world help us to better understand how this technique of asteroid deflection could potentially be used to address a hazardous NEO in the future.

The last complete image of asteroid Dimorphos, taken by the DRACO imager on the NASA DART mission, 12 kilometers from the asteroid and 2 seconds before impact.

Credits: NASA/ Johns Hopkins APL

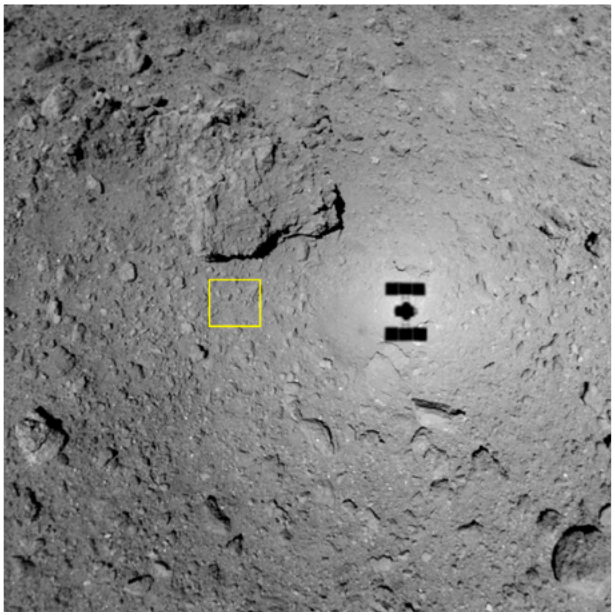
In the spirit of international collaboration, the Italian Space Agency provided the Light Italian CubeSat for Imaging of Asteroids (LICIACube), which rode along with DART and imaged the spacecraft's impact with its target asteroid to help experts visually characterize Dimorphos and the impact effects of DART. Additionally, the European Space Agency (ESA) Hera project is planned to launch later this decade and conduct detailed surveys of both Dimorphos and the parent asteroid it orbits around, Didymos, with a particular focus on the crater left by DART's collision and a precise measurement of the mass of Dimorphos.

The plume coming off of Dimorphos after DART impact, captured by the Italian Space Agency's LICIACube satellite.

Credits: ASI/NASA

## NEAR-EARTH OBJECT CHARACTERIZATION

Recent scientific missions involving asteroids in the near-Earth object population have advanced the understanding of asteroid physical properties. The JAXA Hayabusa2 spacecraft successfully acquired a sample from the asteroid Ryugu and delivered it to Earth for laboratory study in late 2020. The NASA OSIRIS-REx spacecraft acquired a sample from the asteroid Bennu for return to Earth in 2023. The Hayabusa2 extended mission is planning to acquire samples from 1998 Ky26 in July 2031.

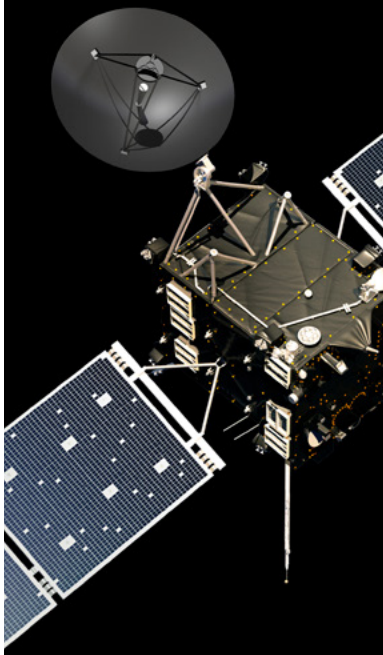


Surface of the asteroid Ryugu photographed by the Optical Navigation Camera-W1 on board Hayabusa2 at an altitude of about 49m.

Credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST.

## NEAR-EARTH OBJECT DISCOVERY

Signatories to IAWN have progressed in advancing technologies and techniques to accelerate the discovery of NEOs. Multiple IAWN signatories are developing and utilizing advanced image analysis techniques to maximize their observatory capabilities in detecting faint NEOs. ESA is completing its development of its Flyeye telescope in 2023 to add wide field survey capability with a unique multi-camera configuration. In 2022, NASA confirmed its plan for the NEO Surveyor space-based infrared telescope designed to meet the goal of discovering 90 per cent of asteroids 140 metres in size or larger within a decade of its launch, not later than 2028.



## YEAR 2029 – CLOSE APPROACH OF ASTEROID APOPHIS

On 13 April 2029, the asteroid 99942 Apophis will pass safely between the geostationary orbit and Earth. In astronomical terms, this is an extremely close approach. So close in fact that the asteroid will be visible to the naked eye to anyone under a dark sky. This is a once-in-a-lifetime event and is a unique occasion to dedicate the year 2029 to a worldwide campaign on raising awareness of asteroids, their scientific value as well as the potential hazard they present.

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