HERA – THE EUROPEAN CONTRIBUTION TO THE FIRST ASTEROID DEFLECTION DEMONSTRATION. M. Küppers[1], P.Michel[2], I. Carnelli[3], S. Ulamec[4], P. A. Abell[5] and the Hera team, [1] European Space Astronomy Centre (ESA/ESAC), Operations Department, Camino bajo del Castillo S/N, 28692 Villanueva de la Cañada (Madrid), Spain (michael.kueppers@sciops.esa.int). [2] Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Lagrange Laboratory, CS 34229, 06304 Nice Cedex 4, France. [3]European Space Agency (ESA) Headquarters, Miollis, Bâtiment VI bis, 33 rue François Bonvin, 75015 Paris, France. [4]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Raumflugbetrieb und Astronautentraining, Köln-Porz, Germany. [5] Astromaterials Research and Exploration Science Division, NASA Johnson Space Center, Houston, TX 77058.

Introduction: Hera is a small mission of opportunity whose primary objective is to observe the outcome of a kinetic impactor test and thus, to provide extremely valuable information for possible future mitigation of the impact of a hazardous asteroid [1]. It is part of the Asteroid Impact & Deflection Assessment (AIDA) mission, in which the second component is the NASA Double Asteroid Redirection Test (DART) mission, which aims to send an artificial projectile to perform an asteroid deflection test [2]. The outcome will be observed by a cubesat provided by the Italian Space Agency (ASI) and carried to the target asteroid by DART, from ground-based observatories and from later observations by Hera during its rendezvous mission with the target asteroid. AIDA will thus be the first test ever to use a kinetic impactor to deflect an asteroid. The AIDA target is the binary Near-Earth Asteroid (NEA) (65803) Didymos (1996 GT), in particular the secondary component and target of the DART mission, called hereafter Didymoon. Here we discuss the Hera mission, an updated version of the Asteroid Impact Mission (AIM), originally proposed to be at Didymos during the DART impact. We show that most of the goals of AIM are still being fulfilled with the investigation of Didymos by the Hera mission.

Hera payload: The following instruments form the baseline payload of Hera:

- Asteroid Framing camera. This is a flight spare of the DAWN framing cameras [3] and will be used for science imaging and Guidance, Navigation, and Control. The image scale is ~1m/pixel from a distance of 10 km.
- Two 6 U cubesats will perform very close observations down to a resolution of a few cm/pixel, in particular of the the crater and its surroundings. The payload of the APEX cubesat includes a spectral imager from 0.5 µm to 1.6 µm and a point spectrometer from 1.6 µm to 2.5 µm, a secondary ion mass analyzer, and a magnetometer. The JUVENTAS cubesat carries a monostatic radar, a gravimeter and accelerometers. At the end of their mission, the cubesats will attempt to land on Didymoon
- Planetary Altimeter (PALT). This is a lidar that will perform accurate distance measurements. The operating wavelength is 1.5 µm and the beamwidth 0.5 mrad.
- A thermal infrared instrument. Different concepts for the instrument are currently being studied.
- Radio Science Experiment (RSE). Radio science makes use of existing hardware on the spacecraft to measure the gravity field of Didymos.

Additional resources may possibly become available onboard Hera. These will be allocated for additional payload should it be supported by ESA Member States.

Hera relevance for mitigation of an asteroid impact: Although the probability of an asteroid impact on Earth during the coming years is low, the potential consequences to our society could be very severe. Small bodies are continually colliding with Earth, however, the vast majority of these objects are very small (below 10 m in size) and pose no threat to human activity. Larger impacts (1 km or more) occur far less often but, when they do occur, they can lead to a major natural catastrophe. Fortunately more than 90% of the asteroid population with diameter of 1 km or larger is known and poses no risk. On the intermediate size (100-500 m range), damage can still be of regional scale (a country or a continent) and we only know a small fraction of these objects while their impact frequency becomes high enough (centuries to millenia, i.e., within the duration of a civilization) that we must study how to protect ourselves from the threat they pose. Indeed, the impact of an asteroid is the only natural disaster we may be able to accurately predict and prevent. For this we need to (1) improve our knowledge of the geophysical properties of bodies in this size range, (2) test our ability to deflect such a small asteroid, (3) complete the inventory of this population.

AIDA will allow us to address (1) and (2) for the first time. In terms of deflection techniques, we will never know whether we are ready if no test is performed. DART will hit the smallest component, whose size is the most relevant one for mitigation purposes. Groundbased observations will measure the change of the orbial period of Didymoon around Didymos imposed by the impact. However, only Hera can measure the mass of Didymoon, required to estimate the efficiency of the momentum transfer from DART to Didymoon. Furthermore, Hera will accurately measure the dynamical state of the Didymos system after the impact, directly measuring the excentricity imposed by the impact and any libration that may be have been introduced as a consequence of the impact. The investigation of the DART impact crater by Hera, together with the geophysical and surface properties of both asteroids, will allow us to validate/refine our numerical impact models that can then be used with higher confidence at such scales. All those measurements together will allow scaling of the results to other asteroids and therefore to predict the efficiency of the momentum transfer should the deflection of an asteroid be needed in the future.

Science Return: Although the requirements for Hera are entirely focused on planetary defense, the science return from this mission will be outstanding as it will include:

- First detailed images of a binary asteroid in orbit, offering informed constraints to models describing binary formation and dynamics, and verifying/constraining predictions from the radar shape model.
- First images and in-situ compositional analyses of the smallest asteroid ever visited, enabling the determination of the geophysical and compositional properties of such a small body compared to larger ones.
- Understanding of physical/compositional properties and geophysical processes in low gravity, with implications for our understanding of small-body surface properties and their evolution.
- First documentation of an asteroid-scale impact outcome (from DART), orders of magnitude beyond laboratory scales.

The last item will provide crucial data to validate numerical simulations of hyper-velocity impacts that are used in planetary science (planet and satellite formation, impact cratering and surface ages, asteroid belt evolution). It will offer new constraints for collisional evolution models of small-body populations and planetary formation.

About 15% of NEAs larger than 200 m in diameter are binaries, and many of these may be similar to Didymos. Therefore, some systematic process is expected to be at the origin of the creation of such systems. According to current knowledge, the YORP spin-up of a rubble pile is the most likely process. The characterization of Didymos by Hera will provide information not only about an individual asteroid but also about a sizable fraction of near-Earth and potentially hazardous asteroids.

Hera will perform the geophysical characterization of the target mostly based on images (and Doppler tracking for mass characterization). A big step will be achieved in our knowledge in such a low-gravity environment, in terms of shape, mass (and density), surface features, presence and kind of surface regolith, crater abundance and size distribution, boulder size distribution down to the resolution limit of the camera, as well as local slopes.

In addition to surface properties, information on the internal structure will be obtained from the radar on the Juventas cubesat. Surface images allow for the evaluation of surface structures, such as lineaments, crater shapes, crater ejecta, boulder existence/distribution, and mass wasting features. From these measurements, information on material strength, cohesion, porosity, etc., can be derived both for the asteroid regolith and interior. For instance, if the largest boulders found at the surface are comparable in size to the asteroid itself, this can indicate that they were produced during a catastrophic disruption or reaccumulation event (like in some binary formation scenarios), and the asteroid is more likely to have a rubble-pile structure. The Radio Science Experiment will also contribute to internal structure estimates.

.

References: [1] Michel P. et al. (2018), *Adv. Sp. Res.*, 62, 2261-2272. [2] Cheng A. F. et al. (2018), *Planet. Space Sci.*, 157, 104-115. [3] Sierks H. et al. (2011), *Space Sci. Rev.*, 163, 263-327.