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The ESA Hera Mission: Investigating binary asteroid (65803) Didymos and the DART crater

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1. Introduction

On 26 September 2022 NASA's Double Asteroid Redirection Test (DART) spacecraft will impact Dimorphos, the satellite of asteroid (65803) Didymos. The impact will change Dimorphos' orbital period around Didymos. As Didymos is an eclipsing binary, and on a close flyby of Earth on this date, the period change can be detected by Earth-based observers. Before impact, DART will deploy the Light Italian Cubesat for Imaging of Asteroid (LICIACube) that will provide images of the first instants after impact. ESA's Hera spacecraft will rendezvous with Didymos four years after the impact. It will perform the measurements necessary to fully understand the effect of the DART impact on Dimorphos, in particular by measuring its mass, and investigating its internal structure, and thus determining the momentum transfer and detailed characterization of the crater left by DART.

2. The Hera Mission

Hera launch is planned for October 2024 and arrival at the Didymos system in early 2027. After arrival, it will release two cubesats, Juventas and Milani, and the three spacecraft will investigate the asteroid system for 6 months (see Figure 1). The mission is divided into several phases:

- The Early Characterisation Phase (6 weeks): Hera will stay around Didymos on hyperbolic arcs at a distance of 20-30 km. The goal is the determination of the global system properties (global shape of asteroids, gravity, dynamic properties).
- Payload Deposition Phase (4 weeks): Release and commissioning of the cubesats. The trajectories will be of the same type as during Early Characterisation Phase
- Detailed Characterisation Phase (4 weeks): Hera will orbit Disymos on hyperbolic arcs at distances of 8-20 km. Detailed investigations (mass of Dimorphos, subsurface characterization

with radar).

- Close Observation Phase (6 weeks): Close flybys down to 4 km distance. Detailed characterization of surface properties and shape of DART impact crater.
- Experimental Phase (6 weeks): Close flybys down to 1 km distance from Dimorphos or less. High resolution observations of DART crater and other surface features. Landing of Cubesats on Dimorphos and of Hera on Didymos.

The following payload will study the surface, interior, and environment of the asteroid pair:

- Two Asteroid Framing Cameras (AFCs, visible imaging and navigation)
- The Hyperscout-H multispectral imager (spectral imaging 670 - 975 nm)
- The Thermal InfraRed Imager (TIRI, 8 - 14 μm), contributed by JAXA
- The Planetary Altimeter (PALT, Laser altimeter)
- The Radio Science Experiment (RSE)
- The JUventas RAdar (JURA), a monostatic radar operating at 50-70 MHz
- The Gravimeter GRASS on Juventas, to measure surface gravity after landing on Dimorphos
- The Asteroid SPECTrometer (ASPECT), a Fabry-Perot visible and near-IR imaging spectrometer on Milani
- The VISTA Thermogravimeter (Dust detection and Composition)

The Hera payload and cubesats have passed their Critical Design Reviews and are now being manufactured for delivery of the flight models in this year.

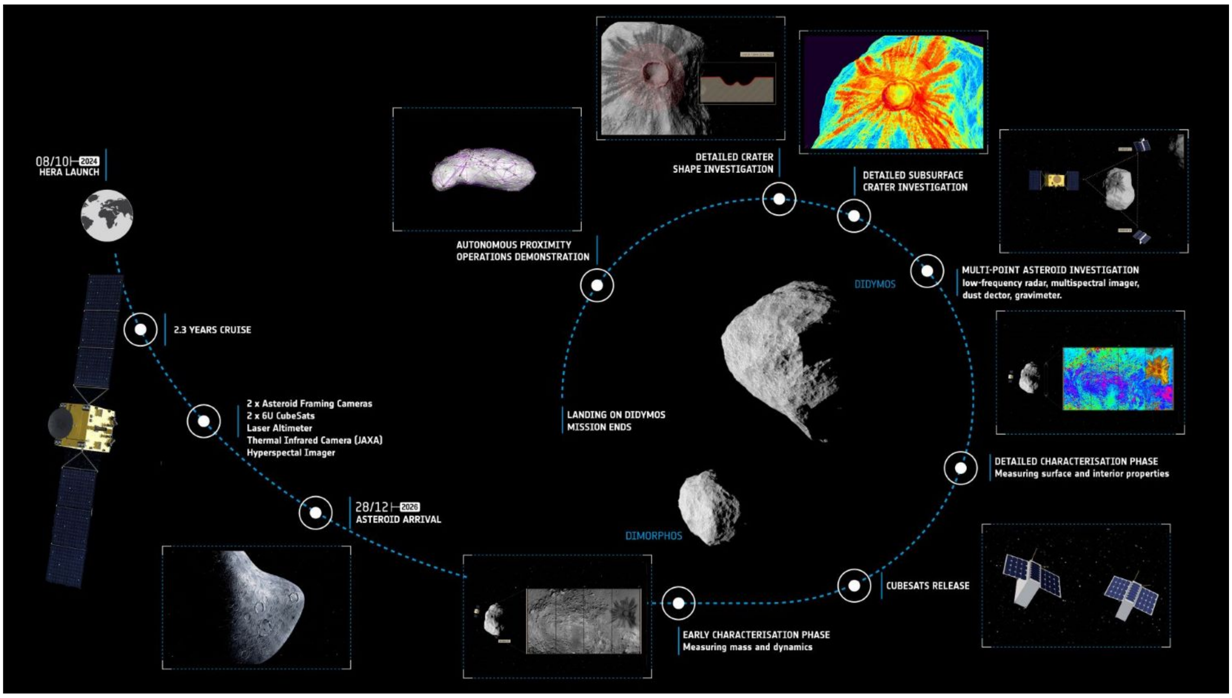

Figure 1: Overview of the Hera mission at (65803) Didymos.

3. Planetary Defence return

Hera will characterize in detail the properties of Dimorphos that are relevant for planetary defense. Its objectives related to the deflection demonstration are the following:

- Measuring the mass of Dimorphos to determine the momentum transfer efficiency from DART impact.
- Investigating in detail the crater produced by DART to improve our understanding of the cratering process and the mechanisms by which the crater formation drives the momentum

transfer efficiency.
- Observing subtle dynamical effects (e.g. libration imposed by the impact, orbital and spin excitation of Dimorphos) that are difficult to detect for remote observers.
- Characterising the surface and interior of Dimorphos to allow scaling of the momentum transfer efficiency to different asteroids.

4. Science return

Even though its requirements are driven by planetary defence, Hera will also provide unique information on many current issues in asteroid science. The reason is that our knowledge of these fascinating objects is still poor, especially for the smallest ones. The recent data obtained by the JAXA Hayabusa2 and NASA OSIRIS-REx missions have revolutionized our understanding of carbonaceous Near-Earth Objects. Hera has the potential to perform similar as it will rendezvous for the first time with a binary asteroid. Dimorphos has a diameter of only 160 m. So far, no mission has visited such a small asteroid. Moreover, for the first time, internal and subsurface properties will be directly measured. From small asteroid internal and surface structures, through rubble-pile evolution, impact cratering physics, to the long-term effects of space weathering in the inner Solar System, Hera will have a major impact on many fields, providing answers to questions such as: How do binaries form? What does a 160 m-size rock in space look like? What is the surface composition? What are its internal properties? What are the surface structure and regolith mobility on both Didymos and Dimorphos? And what will be the size and the morphology of the crater left by DART?

These questions will be addressed by Hera as a natural outcome of its planetary defence investigations

5. Conclusion

The DART impact on Dimorphos and the accompanying observations by LICIACube and Earth-based observers, together with the detailed investigation of the Didymos system by Hera will be the first full scale asteroid deflection test of mankind.

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