ESA’s Hera Cubesats Missions to Asteroid Didymos

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Binary Asteroid System 65803 Didymos

→ Didymos type and size of secondary is representative of Potentially Hazardous Asteroids (PHA) capable of generating casualties independently from impact location on Earth

→ Heliocentric orbit well known

→ Asteroid system observed from ground with telescopes and radars through repeating encounters

→ Mass, size and shape of primary asteroid well known, secondary’s only indirectly based on certain assumptions
Hera Mission: Technology Innovation for Science

HERA mission statement

Interdisciplinary mission of opportunity to validate the planetary defence "kinetic impactor" technique in collaboration with NASA while testing Guidance, Navigation and Control (GNC) and deep-space cubesat technologies for future space missions.

HERA provides the optimal risk/innovation balance to test innovative technologies for future small planetary missions and space servicing vehicles, while delivering valuable asteroid science.
Asteroid Impact and Detection Assessment (AIDA)

International effort on collaboration programs to realize planetary defence goals

→ NASA’s Double Asteroid Redirection Test (DART) mission
  • Launch window begins in late July 2021
  • Impact on Didymoon at Didymos’s closest approach to Earth in 2022
  • Spacecraft relative speed of ~6 km/s at impact

→ ESA’s Hera mission
  • Further optimisation of ESA’s earlier Asteroid Impact Mission (AIM)
  • First launch opportunity in 2023 (with backup options in 2024 and 2025)
  • Arrival during Dydimos’s closest approach to Earth in 2026
  • Characterise the binary system and, in particular, changes in the geophysical and dynamical properties consequence of DART’s impact
  • Deployment of 2x 6U cubesats in the proximity of the Didymos system
Hera Mission Overview

→ First ever investigation of deflection test

→ First binary asteroid and smallest ever visited

→ First deep-space use of cubesats for very close asteroid inspection

→ First deep-space network with cubesats (providing relative navigation support and relayed communications via mothercraft)
The Challenges: Enabling Technologies and Operation Concepts

Critical commissioning from deployment in asteroid vicinity after long storage in Hera mothercraft during transfer

Relayed operations and communications with ground, as well as inter-satellite ranging to enhance navigation capabilities, using Inter-Satellite Link (ILS) communication system

→ Enhanced science research capabilities by means of complementary observations and risk leverage based on deep-space network of cubesats

→ Synergies with current cubesat and microsat miniaturization technologies under development for in-orbit inspection, distributed exploration and swarm constellations

Autonomous asteroid far- and close-range navigation and orbit control (incl. landing), and enhanced attitude pointing capabilities using asteroid centroid and potentially features tracking measurements

→ Synergies with technologies under development for in-orbit servicing, including novel Failure, Detection, Isolation and Recovery (FDIR) capabilities based on sensors data fusion
Orbit Stability in the Proximity of Binary Systems

Chaotic orbital dynamics consequence of coupling between Solar Radiation Pressure (SRP) and gravity effects around binary systems increases the probability of either escape or crash even within days.

→ Self-Stabilized Terminator Orbits (SSTO) are the most stable, up to 1-2 months [see top-right]

→ Co-planar orbits or slightly inclined could be stable up to ~2 weeks, e.g. retrograde orbits beyond the secondary’s orbit or in between primary and secondary’s orbit [see left]

→ Also trajectories around the Lagrange points of the system can be stable enough to be used [see bottom-right]
APEX: Asteroid Prospection EXplorer

IRF (SE), V-kvadrat AB (SE), KTH (SE), OHB Sweden (SE), DLR (DE), SSC (CZ), VTT (FI), Reaktor Space Lab (FI), Aalto Univ. (FI), Univ. Helsinki (FI)

→ Contribution to Hera’s asteroid science, resources utilisation and planetary defence objectives, as well as in-orbit technology demonstration objectives
→ Measurements complementary to those of Hera spacecraft will address the understanding of formation processes of binary asteroids, and characterisation of the interior structure, gravity field, composition, weathering, and thermal properties

Payloads:
→ Visible Camera, also for navigation
→ Magnetometer (MAG)
→ Asteroid Spectral Imager (ASPECT)
→ Asteroid Composition Analyser (ACA)
→ Inter-Satellite Link (ISL)
Juventas: 6U Cubesat in Support of the Hera Mission

GomSpace (DK,LU), GMV (RO), Astronika (PL), Brno Univ. (CZ), Emtronix (LU), ROB (BE), Tampere Univ. (FI)

→ Contribution to Hera’s asteroid science, resources utilisation and planetary defence objectives, as well as in-orbit technology demonstration objectives
→ Measurements complementary to those of Hera spacecraft will address the understanding of formation processes of binary asteroids, and characterisation of the interior structure, gravity field, surface properties, and dynamical properties

Payloads:
→ Visible Camera, also for navigation
→ Low Frequency Radar (LFR)
→ 3-axis Gravimeter
→ Accelerometers and Gyros
→ Inter-Satellite Link (ISL)
Thank you!

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Cubesat Studies from Hera’s Predecessor AIM Mission

**ASPECT**
- Vis-NIR spectral imagers and SWIR spectrometer
- Space weathering
- Shock effects
- Impact plume observation

VTT (FI), Univ. Helsinki (FI), Aalto Univ. (FI), CAS (CZ)

**AGEX**
- Mechanical properties of surface material
- Seismic properties of sub-surface
- Determine kinematics prior and after impact

ROB (BE), ISAE (FR), Antw. Space (BE), EMXYS (ES)

**PALS**
- High-resolution imaging
- Characterize surface structure and regolith
- Characterize magnetization
- Composition of volatiles
- Impact plume observation

IFR (SE), AAC (SE), DLR (DE), IEEC (ES), KTH (SE)

**CUBATA**
- Cubesat to Ground and ISL based radio science
- Gravity field
- Observe impact
- Perform seismology
- Velocity field of the ejecta

GMV (ES), Sapienza Univ. Roma (IT), INTA (ES)

**DUSTCUBE**
- Visual imager, Nephelometers and laser altimeter
- Dust environment
- Mineralogical composition
- Reflectance of the asteroid surface

Univ. Vigo (ES), UniBO (I), Micos (CH), Univ. Bern (CH)