Hera is required to:

- fully validate the kinetic impactor technique
- enable its applicability to other targets
- provide unique science bonuses
- inspire the public, engagement in planetary defense
Hera: a mission of "firsts"

- **First** precise measurement of deflection efficiency and Planetary Defence capability
- **First** binary asteroid and smallest asteroid ever visited
- **First** detailed measurement of small body cratering physics
- **First** deep-space CubeSat for very close asteroid inspection
What will DART provide?
What will DART provide?

1. First **demonstration of KI technique** to deflect an asteroid

2. Test **autonomous GNC** for hypervelocity impact on 150m target (**good size / type**)

3. Measure deflection: Didymoon’s **orbital period change** (**ground observations**)
What will DART provide?

DART imaging (GNC plus science)

**Far range** → sizes, global shape, Didymoon volume (~30%)

- 30 min: ~11,000 km
  - A: 15 pix
  - B: 3 pix
  - A-B surfaces: 14 pix

- 4 min: ~1400 km
  - A: 112 pix
  - B: 21 pix
  - A-B surfaces: 102 pix

- ~7 m/pixel for final image that contains all of Didymos A

**Close range** → impact site location on Didymoon, local slope (+/-10deg) surface geomorphology (~50cm)

- 2 min: ~700 km
  - A: 225 pix
  - B: 42 pix
  - A-B surfaces: 204 pix

- ~3.5 m/pixel for final image that contains Didymos A

---

[Images of DART imaging results]
What will DART provide?

**SelfieSat** to perform ~5-6 min Didymoon fly-by

- confirm impact
- image ejecta plume
- assist shape determination

Phase-C kicked-off on 15 May 2018
What is missing (momentum transfer)

Momentum transfer factor, $\beta$:

- Need to know target’s mass (<10% accuracy)
- Need to disentangle orbit, rotation, shape effects

**Hera**

orbital parameters (→ total mass <10%), shape, volume (densities <20%), spin/orbit pole (1-5%), libration

**An anchor point of the impact deflection effect**
What is missing (libration)
What is missing

Hera is needed to transform a kinetic impactor experiment into a Planetary Defense mission

- Impact parameters
  - Impact velocity
  - Impactor density, mass

- Crater properties
  - Diameter, depth, volume
  - Shape

Target properties
- Porosity
- Strength

Critical parameter to
- evaluate outcome of DART
- validate models
- make accurate predictions

Understand how to do it if needed and...
- even for larger asteroids
Different types of porosity affect cratering

Pre-shattered

Micro-porous

Macro-porous

Validation possible only at lab scale

Macro and micro-porous
Effect of target properties on crater size $\rightarrow \beta$

Hera will provide unique data on crater size essential for reliable predictions from numerical modelling.

Poelchau et al. 2014
## AIM$_{D^2}$ spacecraft mass budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Nominal [kg]</th>
<th>Margin [%]</th>
<th>Total [kg]</th>
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<tbody>
<tr>
<td>EPS</td>
<td>34.9</td>
<td>10%</td>
<td>38.4</td>
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<tr>
<td>OBDH</td>
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<td>TT&amp;C</td>
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<td>8%</td>
<td>23.8</td>
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<td>AOCS/GNC</td>
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<td>CPS</td>
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<tr>
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<td>30%</td>
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<tr>
<td>Structure</td>
<td>84.8</td>
<td>20%</td>
<td>101.7</td>
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<td><strong>Platform total</strong></td>
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<td><strong>14%</strong></td>
<td><strong>305.5</strong></td>
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<tr>
<td>Payload</td>
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<td>0%</td>
<td>19.0</td>
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<tr>
<td><strong>Payload total</strong></td>
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<td><strong>0%</strong></td>
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<tr>
<td><strong>Spacecraft dry mass</strong></td>
<td><strong>286.4</strong></td>
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<td><strong>324.5</strong></td>
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<td>System margin</td>
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<tr>
<td><strong>Spacecraft dry mass + Margin</strong></td>
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<tr>
<td>Propellant mass</td>
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<td>Pressurant</td>
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<td><strong>Spacecraft launch mass</strong></td>
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<td>Launcher perf. (w/o adapter)</td>
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<tr>
<td>Launcher Margin</td>
<td></td>
<td></td>
<td><strong>130.6</strong></td>
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</tbody>
</table>
Hera baseline payload

11.6 kg
17-34 W

1.4 kg
9 W

475nm- 900nm

14.9 kg (6U)

Additional payload mass available, to be finalized during phase B1

Additional interests expressed to ESA (to be discussed bilaterally for consolidation, rejection or further assessment):

- Gravimetre
- µlander
- Cameras
- Monostatic radar
- Thermal imager
- Multispectral camera
- Bifocal metrology
- Hyperspectral imaging
- Volatiles
- Relative Radioscience
- Seismometry
- Minearology
- Dust environment
- Gravimetry

NAVCAM (In storage)

µLidar

CHIEM

RADIOSCIENCE

2 x 1U payloads among:

- CHIEM
- RADIOSCIENCE
Main Programmatic Categories for CM19

Applications

Science and Exploration

Enabling and Support (transp., tech, & ops)

Safety and Security
Safety and Security

in Space

Space Safety

from Space

Maritime

Food

Disaster Management

Safety and Security Applications
Space Weather
Cornerstones of Space Safety

Planetary Defence

Debris and Clean Space - Prevention
Space Weather (L5)

Asteroid deflection (Hera)

Cornerstone Missions

Debris removal

Spacecraft Collision Avoidance Sys.
Hera phase B1

- **ITT released** (DE, BE, RO, LU, SE, PT, ES, CZ, AU, FI, PL, CH) including breadboarding activities:
  - Onboard computer E(Q)M
  - GNC and FDIR software validation with hardware in the loop in robotic lab
  - Onboard Software prototype implementation and validation for autonomy

- 4 thematic **workshops** with industrial team + ESA teams:
  - $T_0+2$ “Cubesat”, $T_0+3$ “TEC”, $T_0+3.5$ “OPS”, $T_0+4$ “GNC”... $T_0+11.5$ “SRR”
Payload and technology activities

**AFC (Asteroid Framing Camera)** QM will be provided to contractor in phase B1 for GNC testing (2 flight models in storage)

**PALT (planetary altimeter)** RFQ in preparation (PT, RO), expected KO to be in parallel to spacecraft phase B1

**CHIEM (hyperspectral camera)** RFQ in preparation (BE), expected KO to be in parallel to spacecraft phase B1

**Cubesats** ITT for two parallel studies to be released mid-June, KO in September (DE, BE, RO, FI, SE, CZ, DK)

**Inter-Satellite Link (ISL)** RFQ to be issued mid-June (PT), expected KO to be in parallel to spacecraft phase B1
Hera community (working groups)

- Hera investigation workshop @ ESAC (payload) in November
- AIDA international workshop @ Europe in Q2 2019

**Impacts simulation**
Chairs: Kai Wunnemann, Martin Jutzi

**Dynamics**
Chairs: Menios Tsiganis, Adriano Campo Bagatin, Sébastien Charnoz

**Data Analysis Exploitation Interpretation**
Chairs: Alain Hérique, Jean-Baptiste Vincent, Paolo Tortora, Simon Green

**Ground-based observations**
Chairs: Petr Pravec, Julia de Leon, Benoît Carry, Alan Fitzsimmons

**ESA project scientist:**
Michael Küppers
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Required accuracy</th>
<th>Associated payload</th>
</tr>
</thead>
</table>
| **Size, mass, shape, density**                | ▪ Mass: 10%  
▪ Density: 20%  
▪ Shape accuracy of 6% or few meters | Mass from binary orbit, spacecraft tracking (camera, cubesat, radioscience)          |
| **Dynamical state**                           | ▪ Period already known to better than 0.1%  
▪ Orbital pole: 5°  
▪ Spin rate: 1%  
▪ Spin axis: 1°   | camera                                                                              |
| **Geophysical surface properties, topology, DART crater’s properties** | ▪ Global surface resolution: 1m  
▪ Local surface resolution (10% of the surface): 10cm | Camera (surface features) Cubesat (sub-meter resolution)                               |
| **Chemical and mineral composition of Didymoon and Didymos** | Spectral resolution: 45nm or better | Camera, cubesat                                                                     |
| **Impact ejecta**                             | No accuracy required                                                               | Camera, cubesat                                                                     |