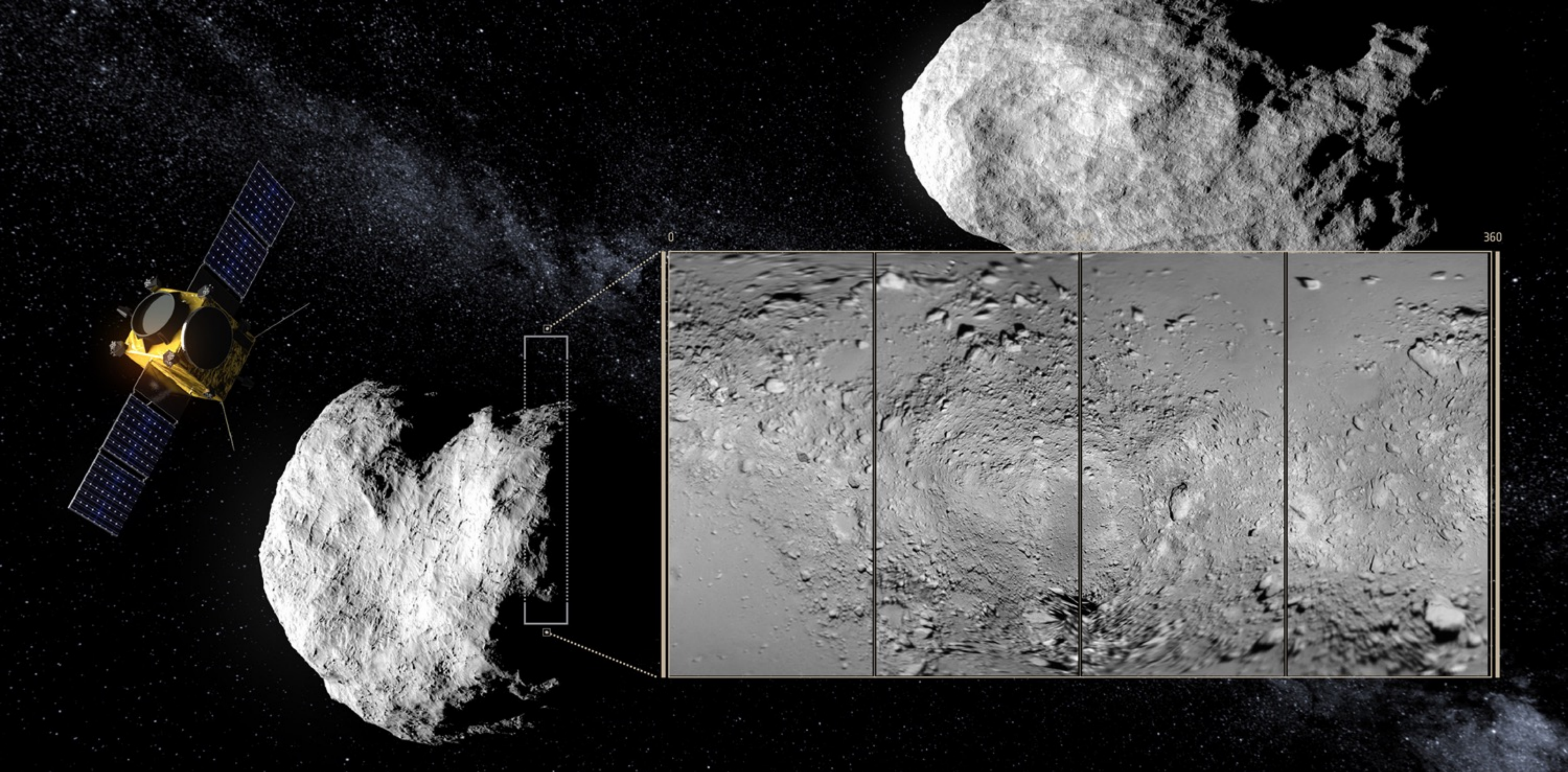



# → HERA MISSION

# HERA MISSION & CM16 lessons learned

- (CM16) Schedule criticality for 2020 launch

  → *Prepare Asteroid mission with **launch opportunities in 2023** (with **back-up in 2024 and 2025**)*

- (CM16) Payload selection unclear

  → ***Optimal payload** defined **+ JAXA impactor** (option), focus on planetary defense objectives (primary).*

- (CM16) DART status not sufficiently clear

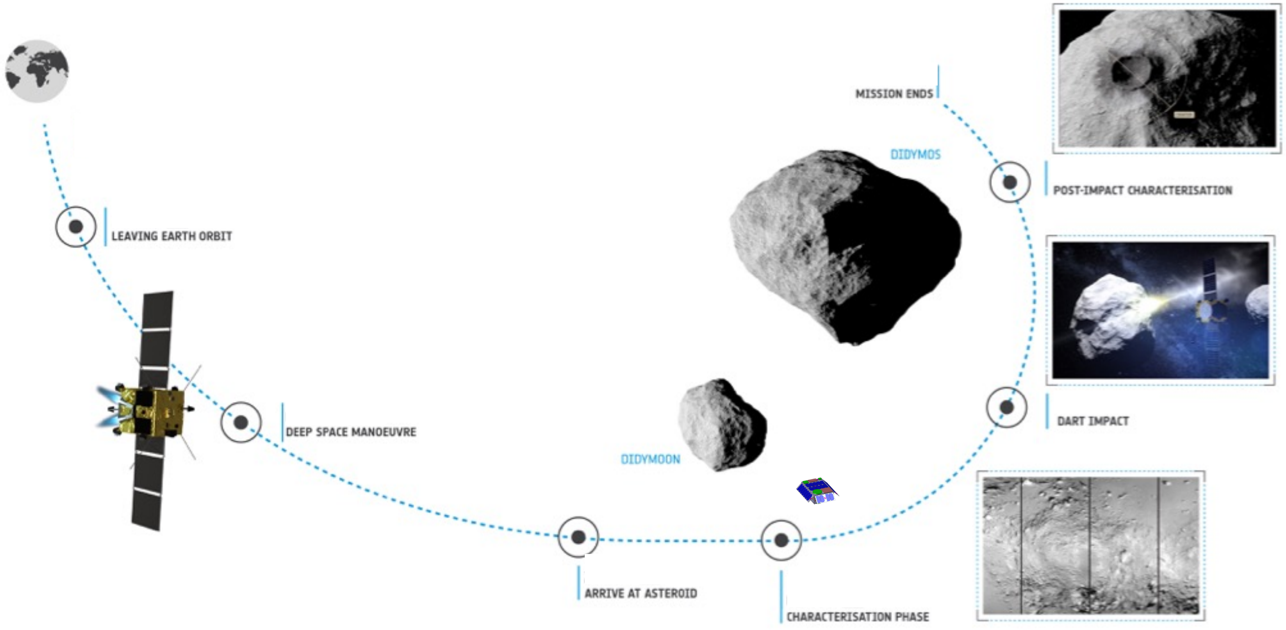
  → *Maintain cooperation with **NASA** now in **phase B** demonstrating kinetic impactor*

- (CM16) **Budget shortage** and **CaC consolidation**

  → *Perform **phase B1** in **SSA** + **GSTP** to prepare for CM19. Bilaterals with MS to consolidate interests before ITT in 1Q18. Establish a planetary defense initiative.*

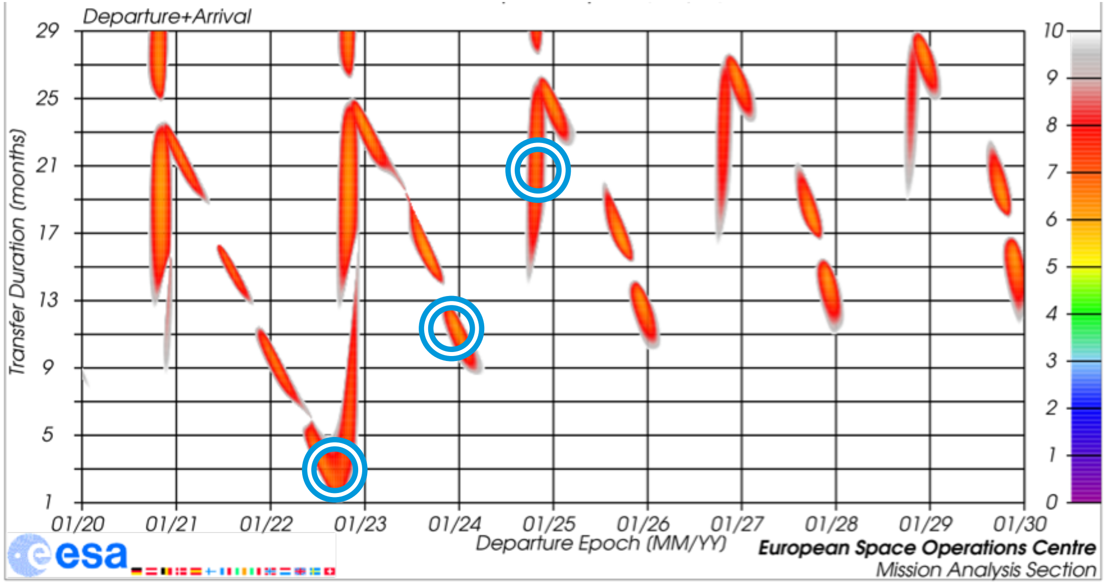
# HERA mission scenario

- First ever investigation of deflection test
- Detailed analysis of impact crater
- First deep-space CubeSat
- First binary asteroid and smallest ever asteroid visited



# Target asteroid

- Assess potential optimal binary asteroids among new discoveries
- Didymos still a good target as of 2Q 2017, later launch opportunities:

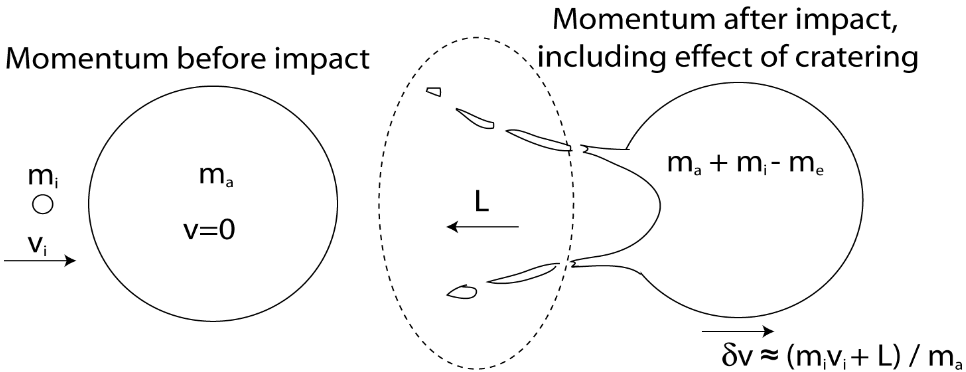


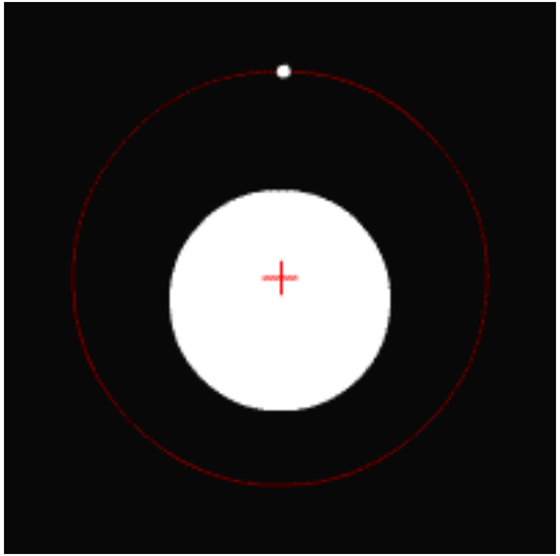

Departure date: **2023/10/22**
Earth swing-by: 2024/10/26
Arrival date: 2026/09/02
Delta-V: 1.405 km/s

Departure date: **2024/10/14**
Earth swing-by: N/A
Arrival date: 2026/7/13
Delta-V: 1.514 km/s

# HERA asteroid deflection objectives

1. **Measure the momentum transfer from a kinetic impactor on a binary asteroid**
   - Asteroid mass *(by wobble or radioscience)*
   - Asteroid dynamical properties

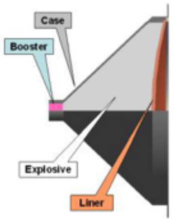


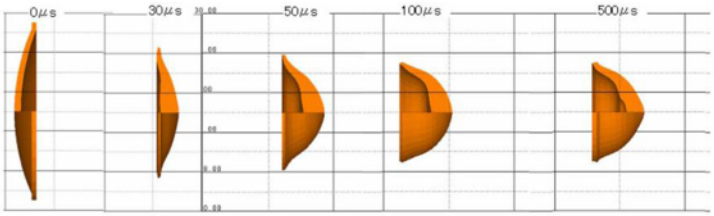



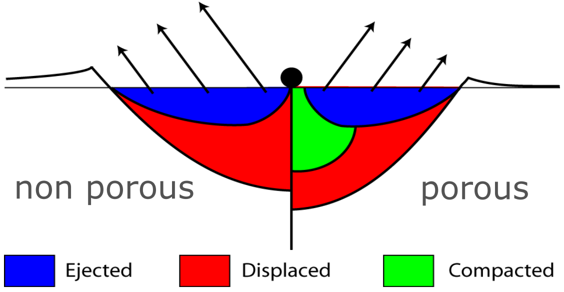
# HERA asteroid deflection objectives

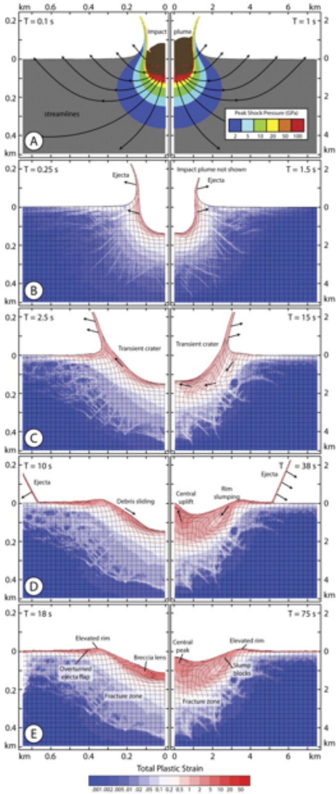
## 2. Impact models validation and extrapolation to other asteroids

- Density
- Crater size/morphology
- Validate *scaling laws* by performing second impact at different energy level with JAXA's S.C.I. payload (part of B1 study)
  - outside experimental range of experience
  - "Ground truth" for numerical models & scaling theory
- *Ejecta size distribution, ejection velocities (bonus)*
- *Change in the surface material (bonus)*



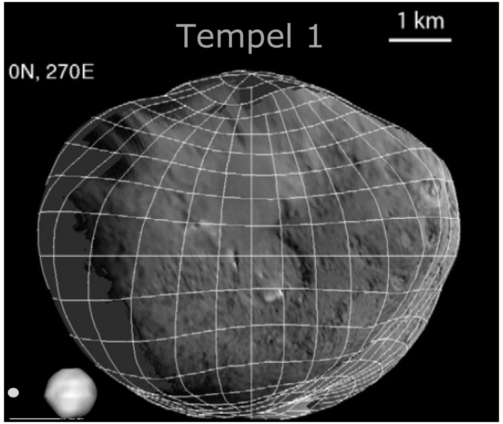



# Measuring crater properties

- Asteroid physical properties related to deflection test do not change over few years
- No erosion, no atmosphere (wind), no outside process (impact, dynamical) of magnitude allowing any change over few years



Didymos

Demonstration:

- **NASA Deep Impact** mission: impact cratering on the 6 km-size comet Tempel 1 on July 4th, 2005 (but no possibility to measure the crater's properties)
- **NASA Stardust NEXT**: returned to Tempel 1 in 2011 and could measure the crater's properties, although the comet passed its perihelion between the two moments!

Image taken by Deep Impact before its impact on comet Tempel 1 (2005)

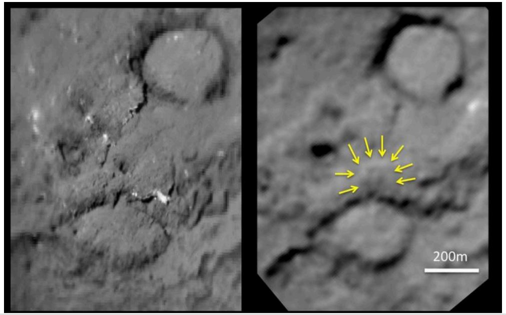
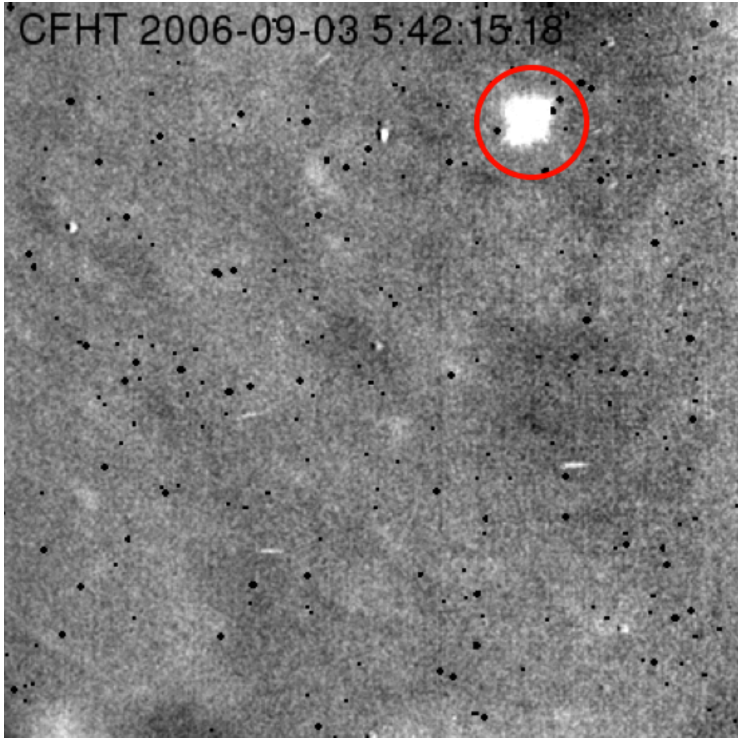



Image taken by Stardust NEXT (crater identification) after Tempel 1 perihelion passage in 2011 (5 years after the impact)

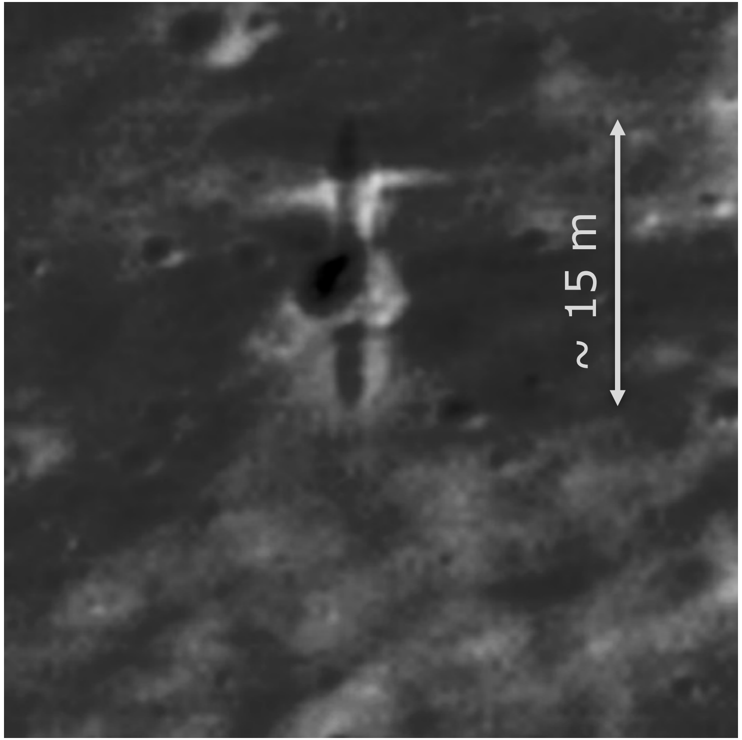
*Credit: NASA/JPL-Caltech/University of Maryland/Cornell*

# Measuring crater properties: SMART-1 impact

3 September 2006



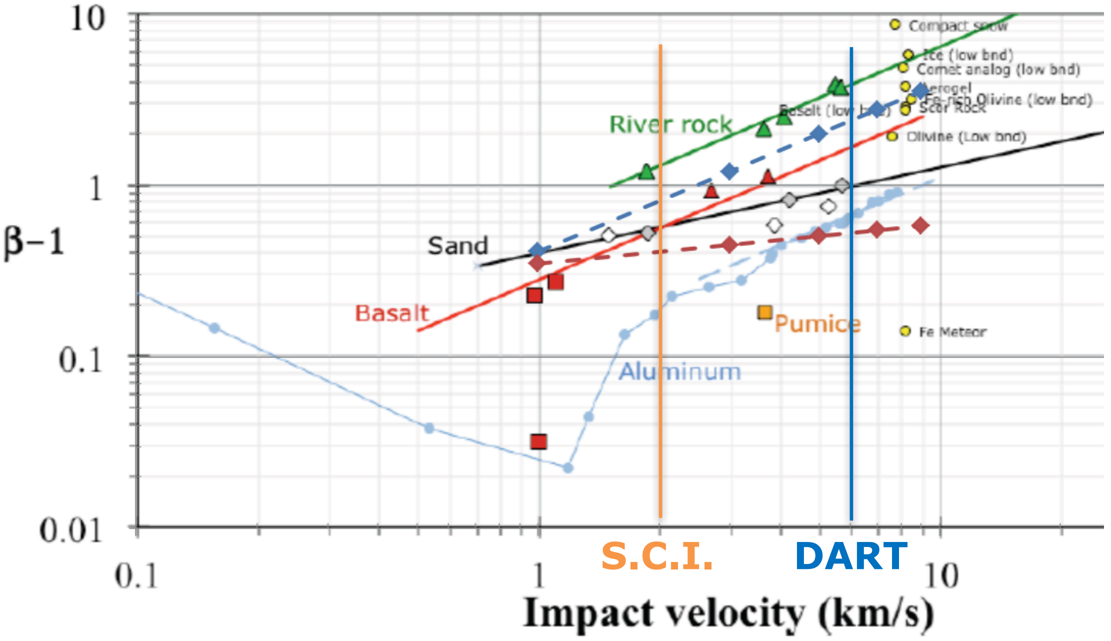

Press release 22 September 2017

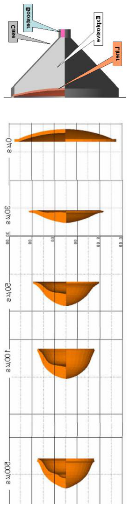


# Validation of scaling laws

Performing second impact at different energy level with JAXA's S.C.I. payload

- outside experimental range of ground laboratories
- "Ground truth" for numerical models & scaling theory



impactor kinetic energy

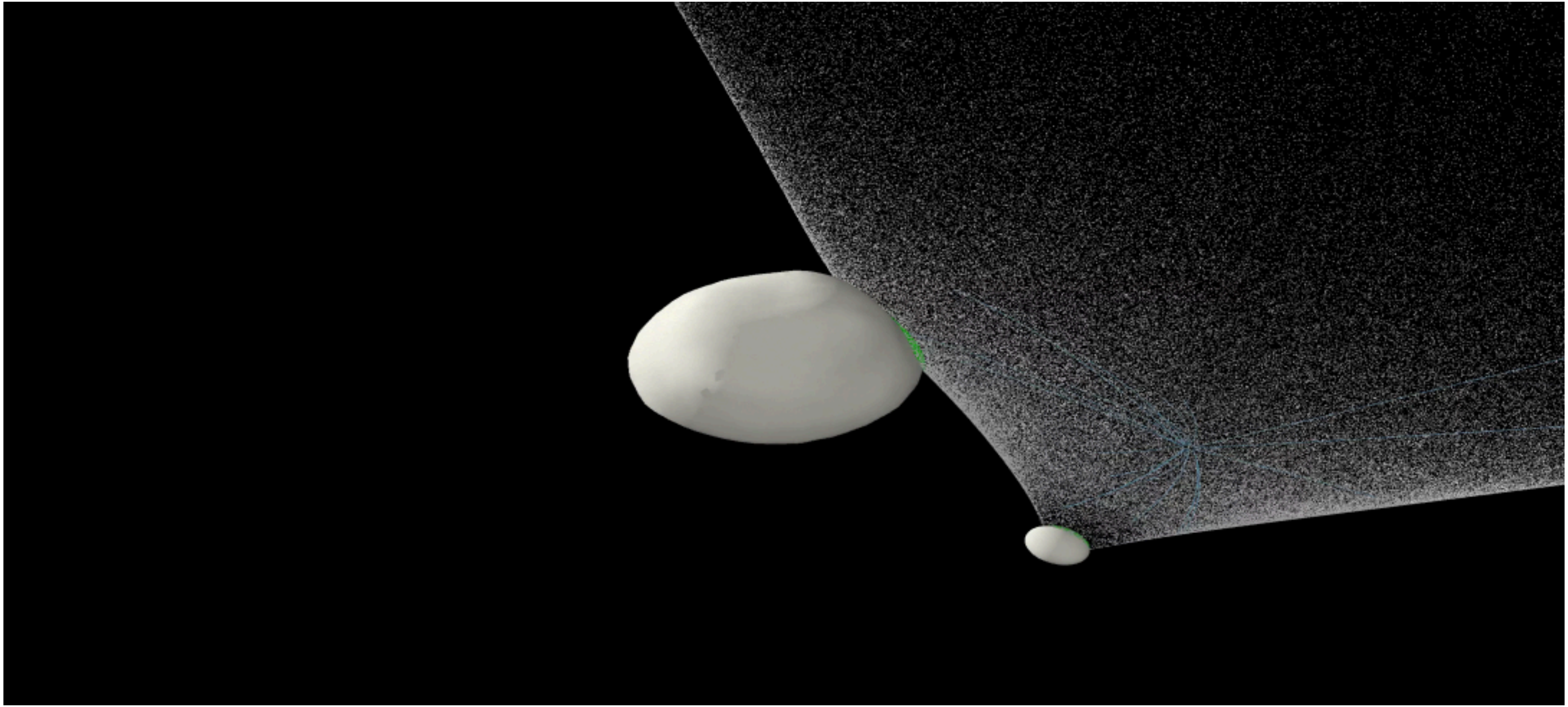
$$\beta \sim \left(\frac{\rho U^2}{Y}\right)^{(3\mu-1)/2}$$

slope of scaling law

*Y= f(**crater volume**, impactor velocity and density, surface gravity and surface density)*

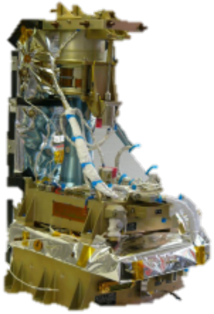
***asteroid strength***

# DART impact modelling and observation



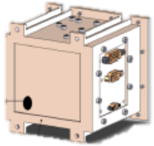
# PAYLOAD BASELINE

11.6 kg
17-34 W



**NAVCAM**
(In storage)

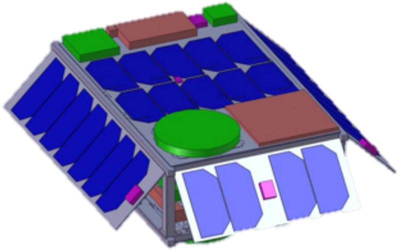
1.4 kg
9 W



**μLidar**

14.9 kg (6U)

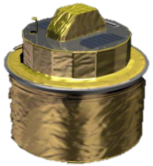
Interested MS



Two payload among:

- Hyperspectral imaging (ongoing)
- Volatiles
- Radioscience
- Seismometry
- Minearology
- Dust environment

**Option**: study accommodation and release of JAXA's Small Carry-on Impactor



# Mission measurements
(for background info)

| Parameter | Required accuracy | Associated payload |
|---|---|---|
| **Size, mass, shape, density** | ▪ Mass: 10%<br>▪ Density: 20%<br>▪ Shape accuracy of 6% or few meters | Mass from binary orbit, spacecraft tracking (camera, cubesat, radioscience)<br><br>Shape model (camera), Lidar |
| **Dynamical state**<br>(period, orbital pole, spin rate, spin axis) | ▪ Period already known to better than 0.1%<br>▪ Orbital pole: 5°<br>▪ Spin rate: 1%<br>▪ Spin axis: 1° | camera |
| **Geophysical surface properties, topology, DART crater's properties** | ▪ Global surface resolution: 1m<br>▪ Local surface resolution (10% of the surface): 10cm | Camera (surface features)<br>Cubesat (2 meter resolution) |
| **Chemical and mineral composition of Didymoon and Didymos** | Spectral resolution: 45nm or better | Camera, cubesat |
| ***Impact ejecta*** | No accuracy required | Camera, cubesat |

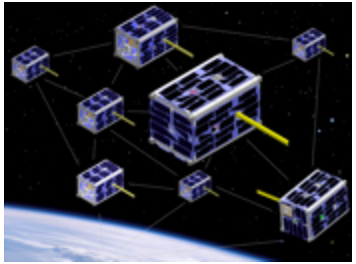
# HERA technology experiments

1. **demonstrate deep-space (6U) cubesat relayed via an inter-satellite link with ranging capability:**
   - Very high-resolution close up asteroid (hyperspectral) imaging
   - Provide complementary measurements to main spacecraft (e.g. spacecraft-CubeSat radioscience, seismology, end-of-life landing for surface properties characterization…)
   - Close-by imaging of DART impact (if delayed)

2. **Validate far-range navigation and close-range feature-tracking navigation increasing on-board autonomy**
   - *Synergies with technologies under development for in-orbit servicing, including novel FDIR based on sensor data fusion.*

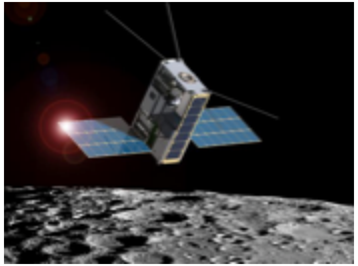
# CUBESAT and INTER-SATELLITE LINK

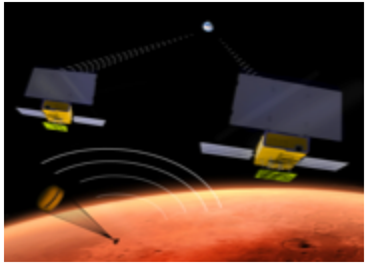
(for background info)



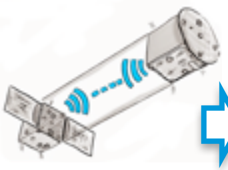
**6U CubeSat** allows for:

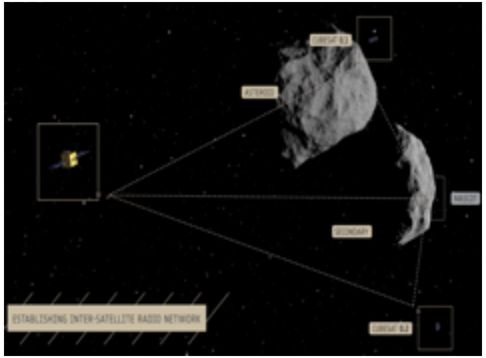
- higher resolution imagining
- Provide additional complementary information (e.g. mineralogy, volatiles, high-res information on porosity…)
- reducing risk to the main mission





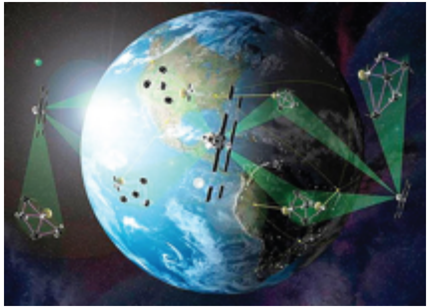
**Synergies with current CubeSat and microsat miniaturization technologies**





**Future applications**

- In-orbit inspection
- Distributed systems for exploration mission (in-situ characterization, remote sensing)
- Swarm architectures for future EOP missions



# Far range navigation
(for background info)

**Identify faint object and determine relative trajectory**

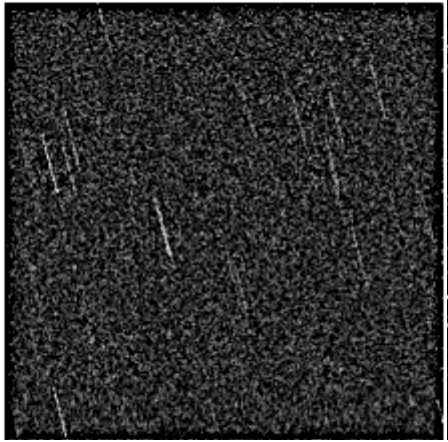
- Background: ROSETTA detection of asteroid Steins from 1AU
- HERA application: arrival to small asteroid

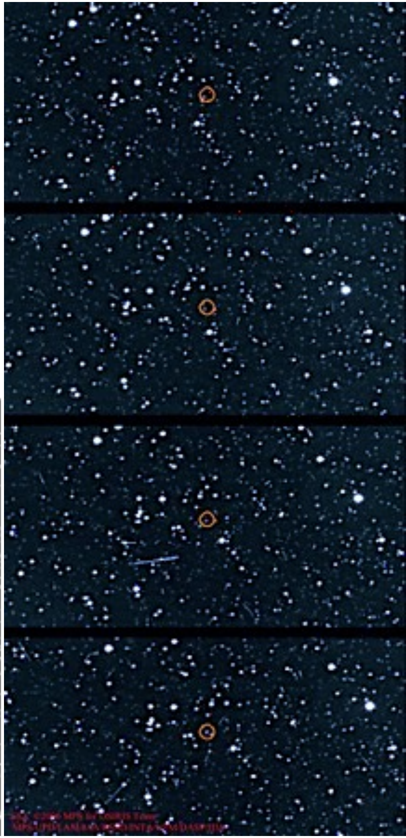
**Synergies with in-orbit servicing**: same HW and SW (detecting moving object against star background)

**Future applications**

- Active Debris Removal (localization of non-responding satellites/debris
- Mars Sample Return (precursor technology activity for GNC of the Orbiting Sample rendezvous)

EQUALIZED CALIBRATED (8-BIT LOG2)





# Close-range vision-based navigation
(for background info)

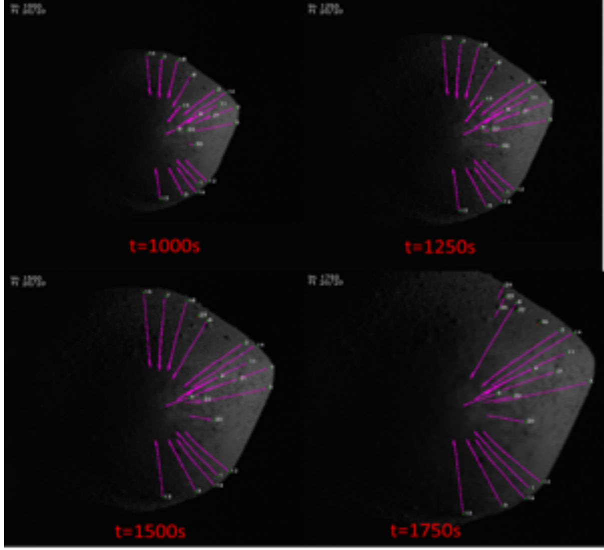
**Track unknown features on the surface to estimate relative trajectory**

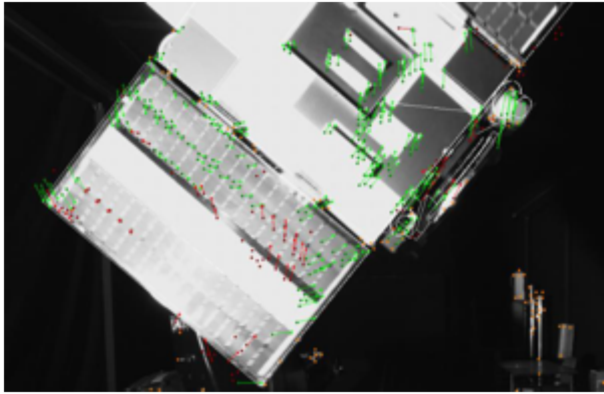
- Background: NASA Mars lander, ESA TRP & CTP activities
- HERA application: proximity operations around asteroid

**Synergies with in-orbit servicing**: same HW and part of SW (track features between frames)

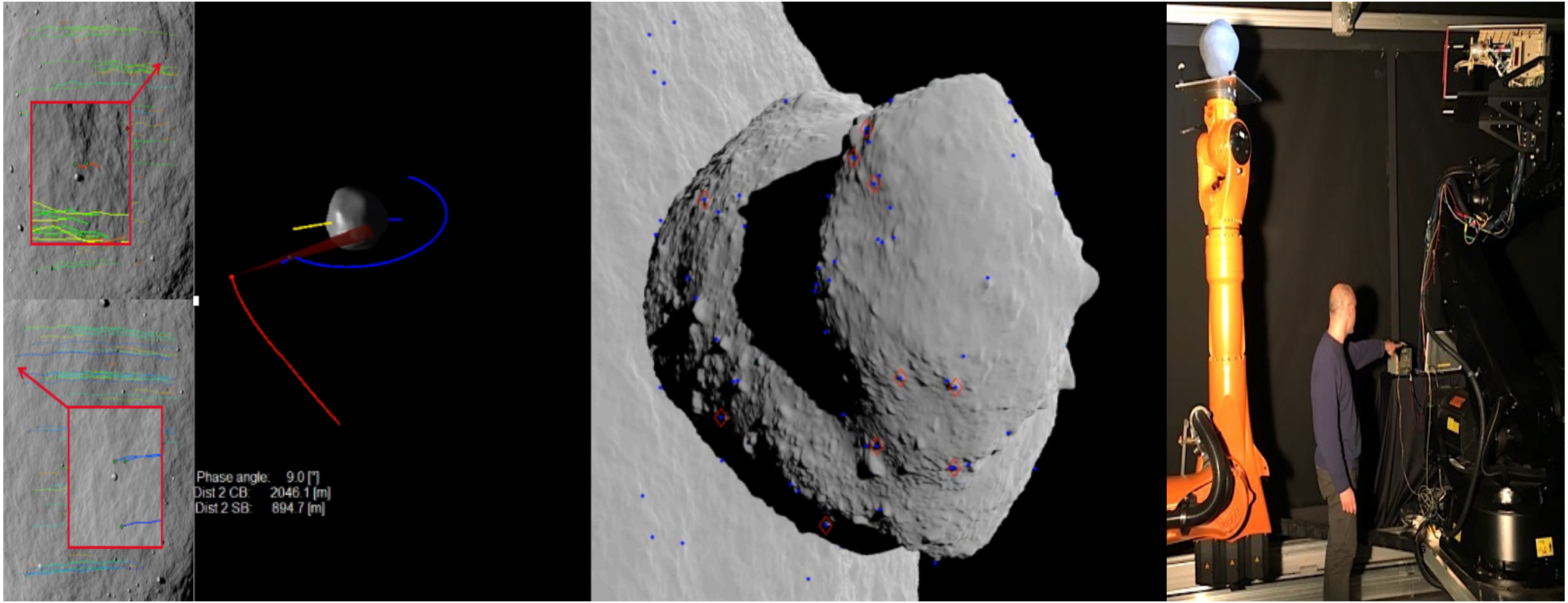
**Future applications**

- ADR, SpaceTug, In-Orbit Servicing, In-Orbit Assembly (pose estimation algorithms before capture)
- Earth Observation or telecomm satellites (autonomous tracking of targets on the surface)



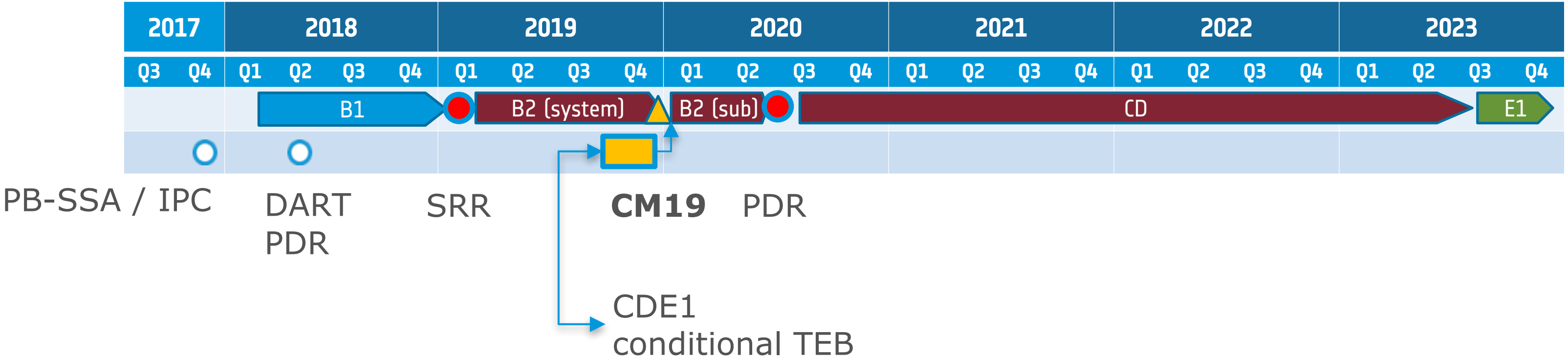



# Preliminary GNC tests results




Capable of performing autonomous close asteroid fly-by both with feature tracking and centroid measurements

# HERA schedule




| START | END | PHASE | |
|---|---|---|---|
| Mar-18 | Dec-18 | **Phase B1** | |
| Jan-19 | Feb-19 | **SRR** | |
| Feb-19 | Dec-19 | **Phase B2-A** | |
| Dec-19 | | **CM19** | *Sep-Nov 19: PhB2CD Conditional TEB |
| Jan-20 | May-20 | **Phase B2** | |
| May-20 | Jul-20 | **PDR** | |
| Aug-20 | Aug-23 | **Phase CD** | |
| Aug-23 | Oct-23 | **Margin/Launch Campaign** | |
| Oct-23 | | **Launch** | |