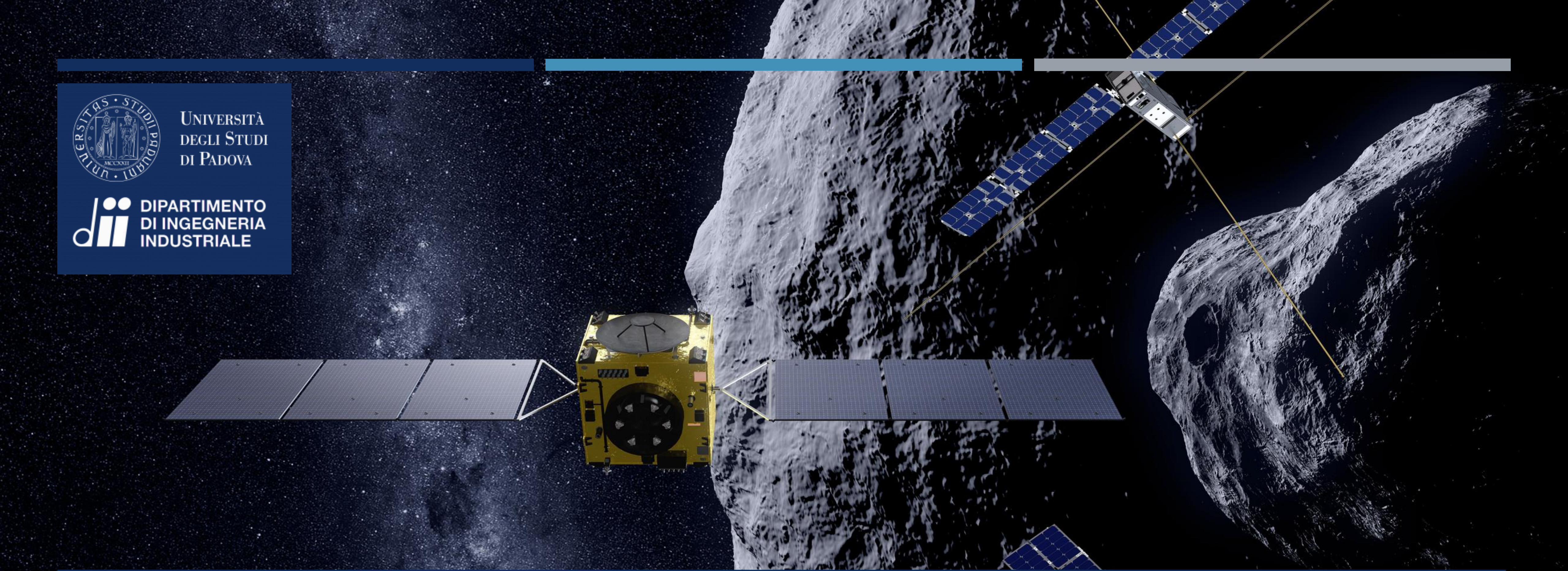

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Dipartimento di Ingegneria Industriale

HERA MISSION ANALYSIS: MILANI AND JUVENTAS CUBESATS

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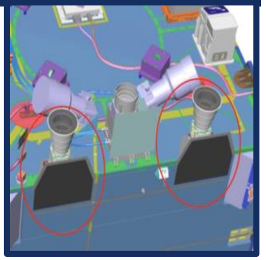
HERA SPACECRAFT



Main objectives

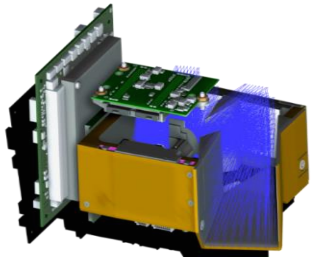
Hera is part of a double-spacecraft collaboration between ESA and NASA. Hera will arrive in late 2026 performing:

- Measurements on the crater left by DART mission.
- Mesuraments on Dimorphos orbit.
- Demonstration of autonomous and semi-autonomous navigation and deep space Inter Satellite Link (ISL).
- Characterization of the first binary asteroid system ever visited.

Payload

Hera will feature six main instruments to analyse the aftermath of DART impact.

- ***AFC***: Asteroid Framing Camera.
- **TIRI**: Thermal Infra-Red Imager.
- **PALT (Laser Range Finder)**:Planetary ALTimeter
- **Hyperscout 2:** near infra-red hyperspectral imager
- **ISL:** Inter Satellite Link
- **RSE:** Radio Science Experiment



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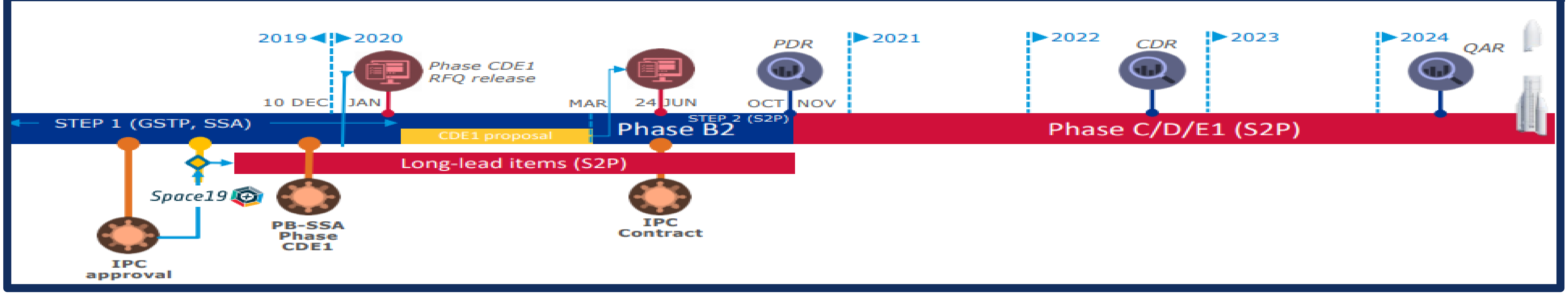
MISSION SCHEDULE



Phase 0 of Hera mission commenced back in 2019, currently Phase C has been almost accomplished and Phase D already started.

Phase E timeframe is as follows:

- Commissioning phase: 3 months;
- Transfer to Didymos: 2 years;
- Asteroid operations: 6 months.

Hera is scheduled to reach Didymos system on 28 August 2026. The two 6U Cubesats will be released after competition of the initial phase.

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HERA'S ORBIT SIMULATION

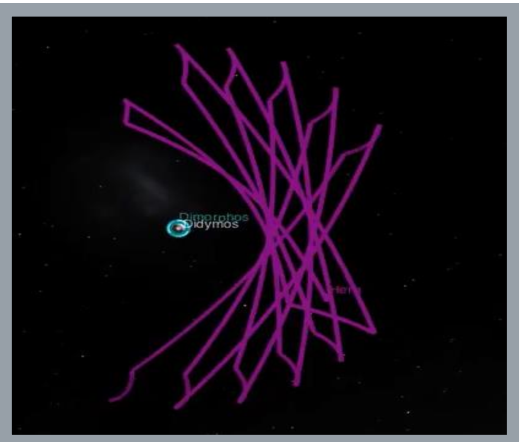
Hera's orbit around Didymos system is composed of intrinsically safe hyperbolic arcs, according to the system barycentre.

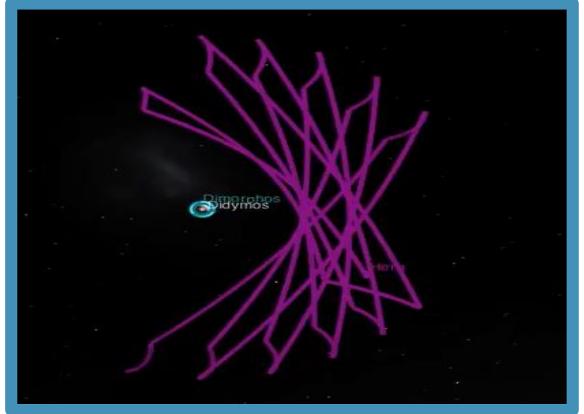
Simulations on the right are obtained by using the kernels provided by ESA, then plotted with Cosmographia 4.0 and Phyton.

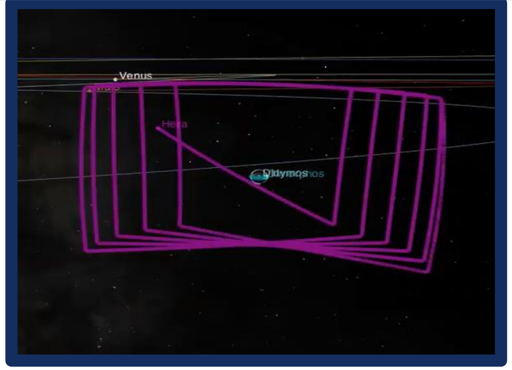
Kernels used for the simulations are:

- fk: kernels that define reference frames needed for the mission;
- mk: also called meta kernels which provide list of kernels suitable for the mission in appropriate order;
- pck: kernels that defines planetary constants;
- spk: orbit kernels for spacecraft and main solar system bodies;
- dsk: kernels for extended bodies such as the Didymos system.

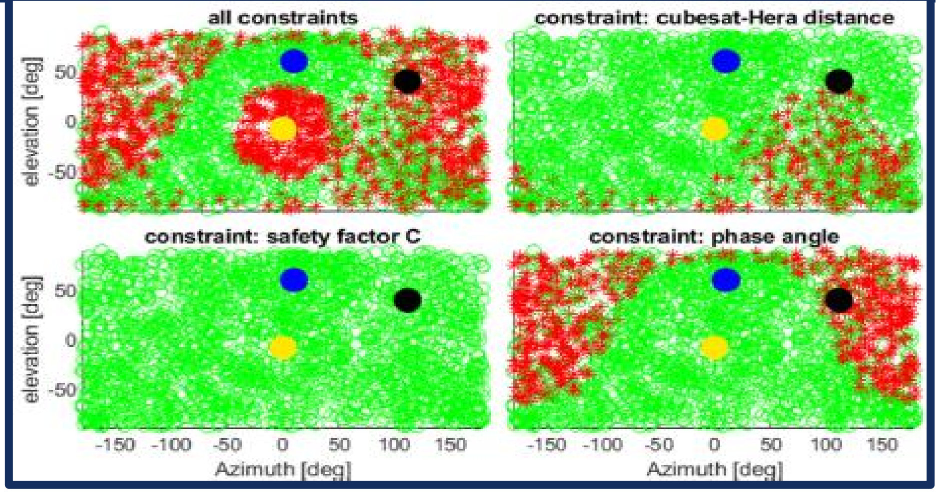
To allow Cosmographia to simulate the orbit, kernels have to be extracted in Phyton with the function "*spiceypy.furnsh()*" to load the file in the kernel pool. Afterwards the Phyton program containing now all the information of the trajectory, alongside with a simple cycle to repeat the orbit, can be injected in Cosmographia and the simulation can be plotted.







MILANI CUBESAT RELEASE STRATEGY



Milani is a 6U cubesat with manoeuvreing capabilities both of translational and attitude with full 6-DOF (Degrees Of Freedom). After the release, it will perform autonomous operations to reach its orbit. The main payload is the ASPECT hyperspectral camera.

Design constrains for release:

- Minimum angle between Milani release velocity direction and Milani-Sun direction of 45°;
- Minimum safety factor C=0.4.

The safety factor is defined as $v_{peri} = (1 + C)v_{parab}$;

C is the safety factor.

v_{peri} is the velocity at perihelion.

v_{parab} is the parabolic velocity.

Deploying mechanism and Hera's GNC accuracy required:

- Release velocity in range 0,5 ± 1cm/s;
- Release direction accuracy of the deploying mechanism within 5°;
- Release angle accuracy of Hera within 0.5°.

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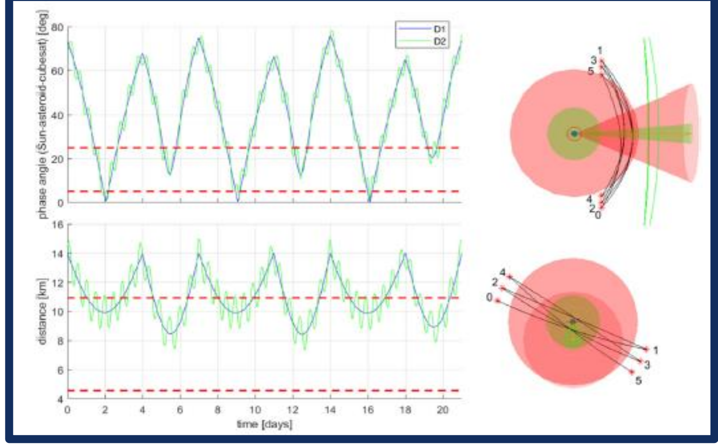
OPERATIONAL TRAJECTORY AND CONTROL



Scientific operations design constrains:

- Optimal range for both VIS and NIR cameras is between 4572m to 10940m from the system barycentre.
- 0° elevation above equatorial plain to ensure visibility of both poles.

Design drivers for the orbit are:

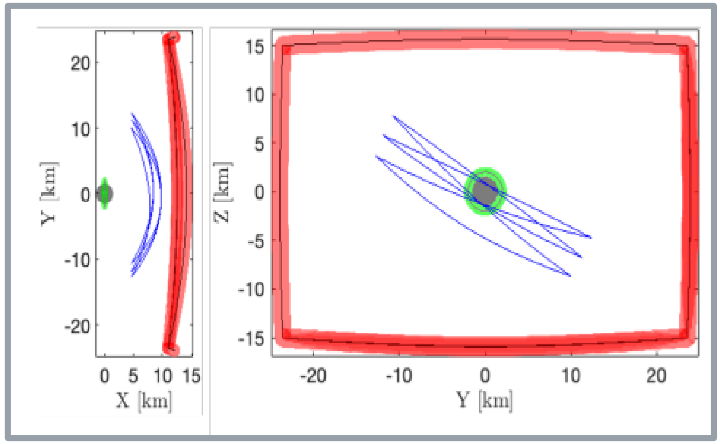
- Safety;
- Simplycity;
- Robustness;
- Cost.

Considering all of the constrains, an optimal pattern of 4-3-4-3 is chosen for Milani. Thus manoeuvers are performed every 4-days then every 3-days ballistic arcs are repeated.

Because of the unique operation scenario a Corrective Action Manoeuvre (CAM) has been prepared.

The CAM will be initiated in two particular occasions:

- Risk of collision with one of the other two spacecrafts or the asteroids;
- Risk of departure from nominal distance.



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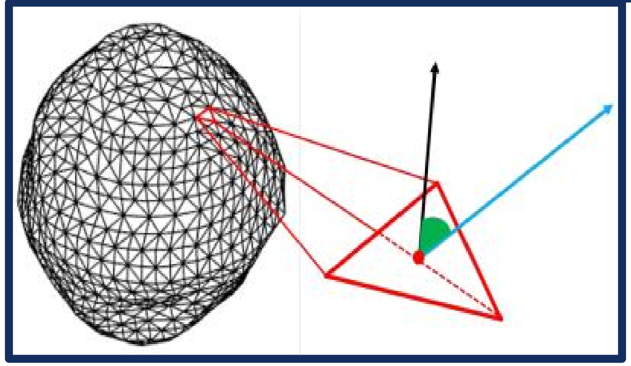
PAYLOAD OPERATIONS AND END OF LIFE

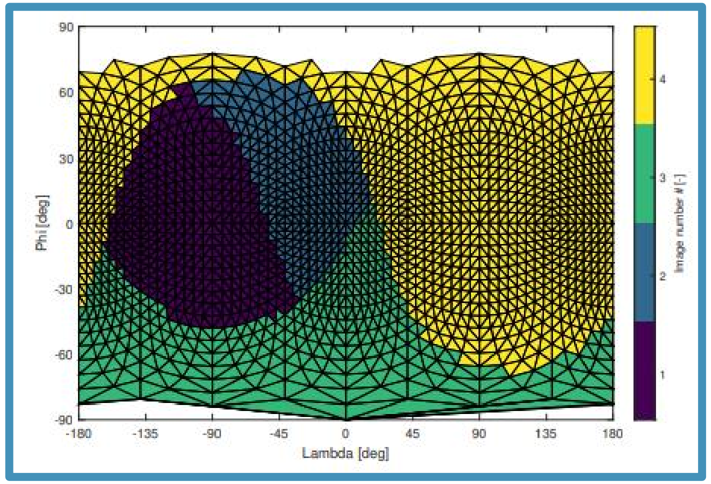


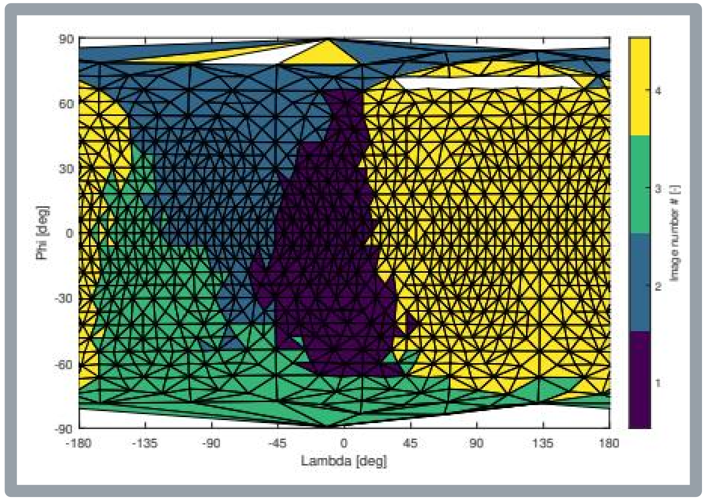
ASPECT operations:

ASPECT is Milani's main payload. The camera will perform a global map of both asteroids. To do so a cycle of 21 days of science observation is expected.

From 4.6 to 4.7 days of actual observation is expected for each orbit around the system.

ASPECT will map the asteroids by dividing the surface as a mosaic of pictures, then reassamble each image to create a global mapping. Bottleneck of this operations is the high data transfer required for the data, which is about a few Gbits.



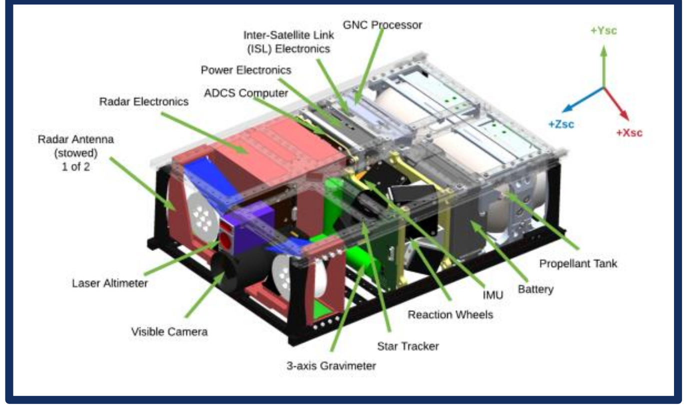


End of life:

Two options are available:

- Injection into a graveyard heliocentric orbit: cheap and safe option, do not require specific trajectory design;
- Landing attempt on Dimorphos:
  To provide additional data is possible to exploit Milani and try landing on Dimorphos.

JUVENTAS OBJECTIVES AND PAYLOAD

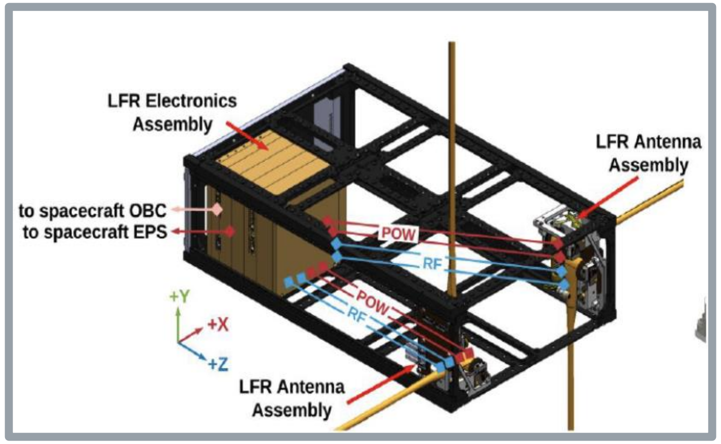


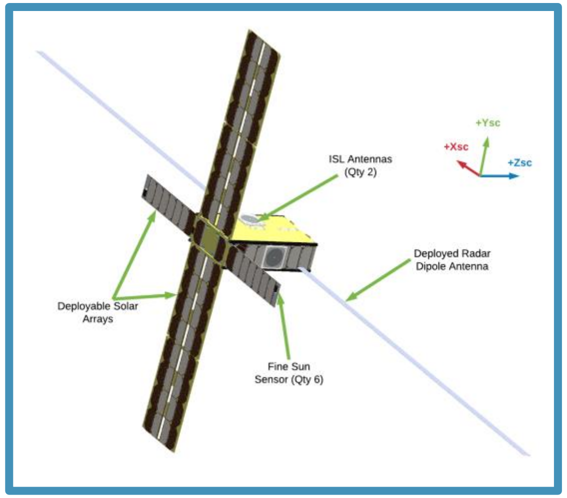
Just as Milani, Juventas was created to join in Hera's mission on asteroid research. Main objectives of Juventas are:

- Determinate the gravity field of Dimorphos and Didymos;
- Define internal structure of Didymoon and Didymos;
- Characterize the surface properties of Didymoon and Didymos;
- Secondary objective is also to delineate the dynamical properties of Dimorphos.

Juventas's payload is composed of:

- Main payload: the Low Frequency Radar (LFR);
- A 3-axis gravimeter;
- The ISL;
- IMU (gyros and accelerometer).



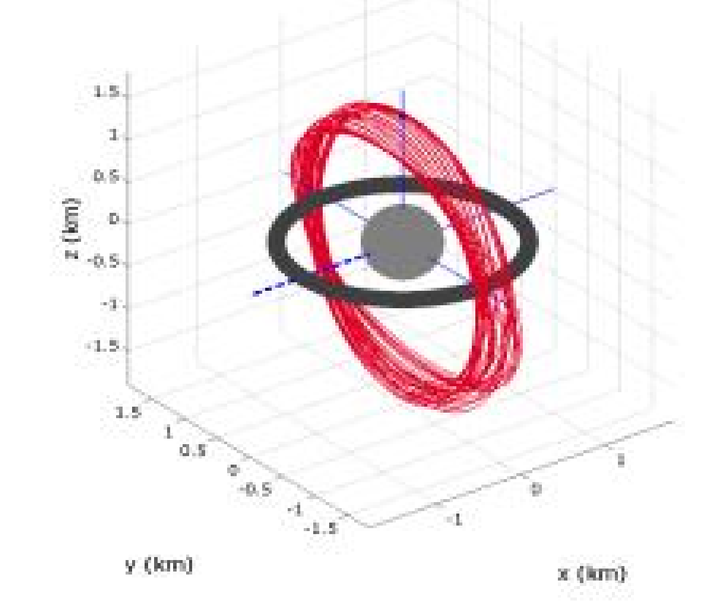


MISSION DESIGN AND SSTO

The operational period of Juventas is planned to be from 3 to 6 months.
The mission is divided in three phases:

- Commissioning: orbit definition and injection into the SSTO for the science phase;
- Observation: main science phase of Juventas where the main objective is to determinate Dimorphos internal structure;
- Landing: after the SSTO Juventas will attempt the landing on Dimorphos surface.

The release will initiate at a safe distance of 11 Km with a small release velocity from 1 to 5 cm/s.



The Self-Stabilized Termination Orbit:

The SSTO is a particular orbit chosen for the second phase, that coincides with the first science period of Juventas. The orbit is deemed to approach Dimorphos for landing. This tailored orbit is inherently stable and favourable for the payload operations. Although Δv required for station keeping is minimum, this causes complexity and long planning of the flight dynamics.

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APPROACH AND LANDING

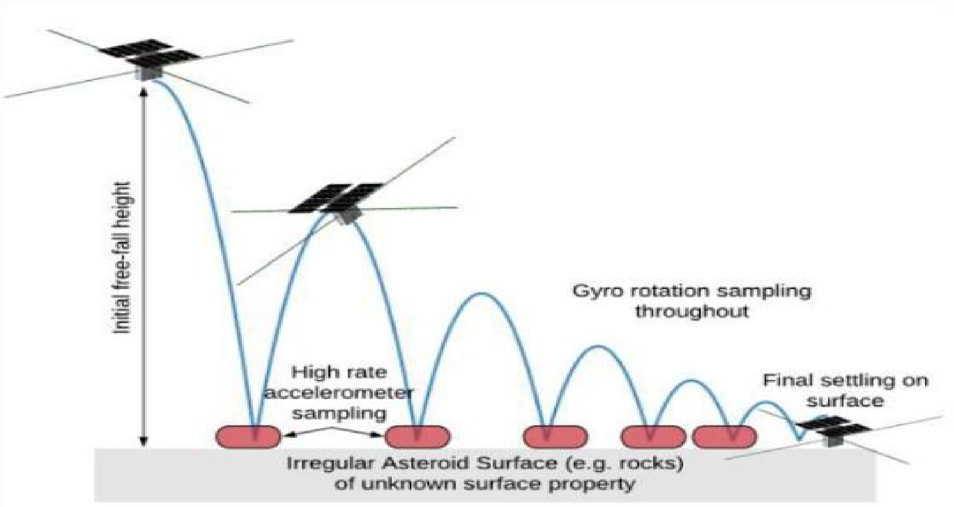
After finishing all assessments, the cubesat will initiate a series of manoeuvres and a transition from the SSTO to the landing trajectory. Juventas is not designed to be a lander and it will try to keep the impact speed below 10 cm/s.

Due to the low gravity of the asteroid surface the speed should be preferably a range between 1-5 cm/s in order to avoid bouncing.

The four 1.5 m antennas will be used as “landing gear” to try to stabilize Juventas on Didymoon surface.

During the final descent, Juventas will enable accelerometers and gyros to record the dynamics of the landing.

Despite the high risk of losing the cubesat, it is worth to attempt a landing on Didymoon considering the available amount of data to gather during the event.



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CONCLUSIONS

In 2024 Hera will launch for Didymos System carrying Milani and Juventas cubesats, it is scheduled to reach Didymos in 2026.

- Hera will study the system with a particular orbit (safe hyperbolic arcs) which allows high observation time and safety for the mothercraft;
- Hera will coordinate the constellation during the operational period of 6 months thanks to the Inter Satellite Link.

Milani is expected to be released alongside with Juventas once Hera is on a stable orbit around the system.

- Milani will map the system in hyperbolic arcs orbit with the ASPECT camera. Once the science operation phase is finished the cubesat EOL options will be evaluated;
- Juventas main payload, the Low Frequency Radar, will deterimante the internal structure of Dimorphos and Didymos. Thanks to the SSTO, the spacecraft is scheduled to complete this operation in 60 days. A landing on Dimorphos will be attempted afterwards.

The scale of Hera mission is monumental. Hera mission will not only prove our ability to deflect an asteroid but also our future prospect of deep space satellite constellations.