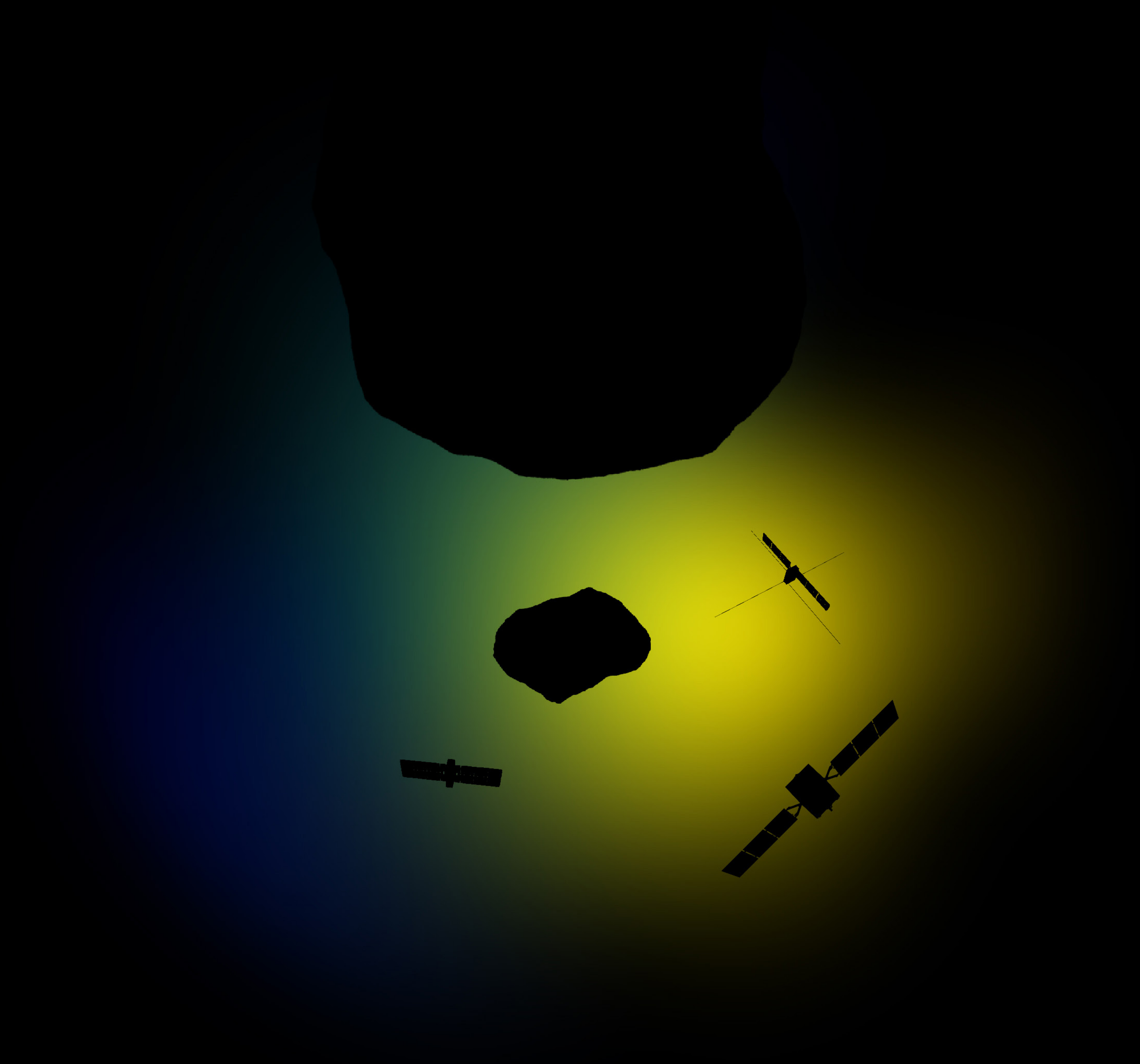


HERA: ESA'S PLANETARY DEFENCE MISSION - LAUNCH KIT

CONTENTS

HERA IN A NUTSHELL

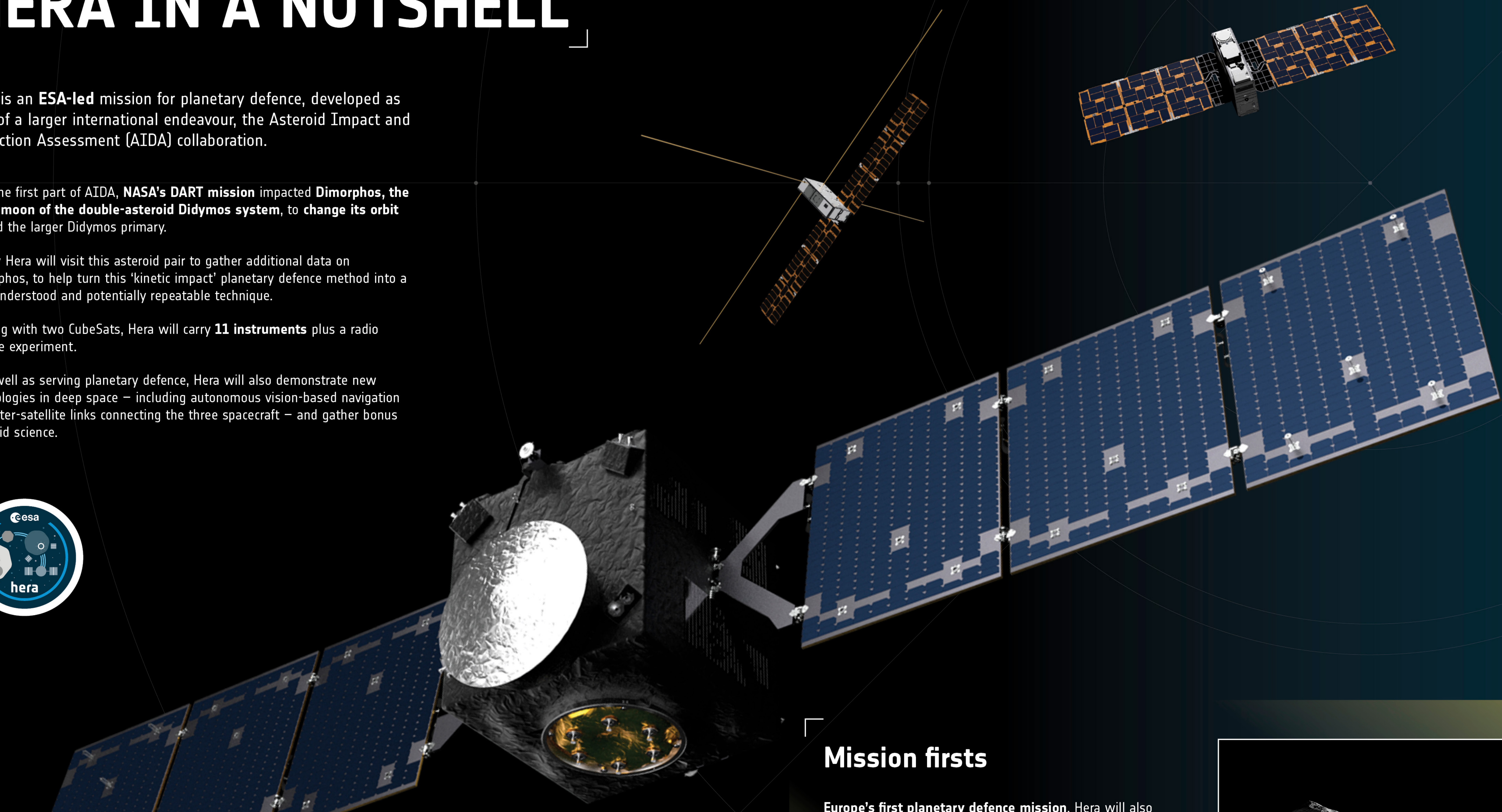
Hera is an **ESA-led** mission for planetary defence, developed as part of a larger international endeavour, the Asteroid Impact and Deflection Assessment (AIDA) collaboration.

→ In the first part of AIDA, **NASA's DART mission** impacted **Dimorphos, the small moon of the double-asteroid Didymos system**, to **change its orbit** around the larger Didymos primary.

→ Now Hera will visit this asteroid pair to gather additional data on Dimorphos, to help turn this 'kinetic impact' planetary defence method into a well-understood and potentially repeatable technique.

→ Along with two CubeSats, Hera will carry **11 instruments** plus a radio science experiment.

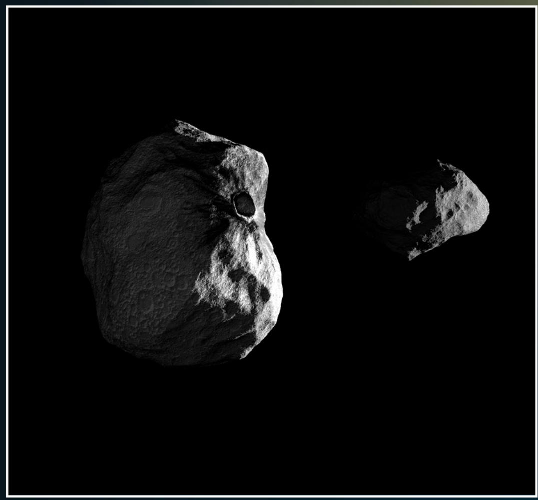
→ As well as serving planetary defence, Hera will also demonstrate new technologies in deep space – including autonomous vision-based navigation and inter-satellite links connecting the three spacecraft – and gather bonus asteroid science.



Mission firsts

Europe's first planetary defence mission, Hera will also be the first to:

- Rendezvous with a binary asteroid
- Deploy ESA deep-space CubeSats to orbit and land
- Visit (and land upon) the smallest asteroid yet explored
- Visit the fastest-spinning asteroid yet explored
- Perform a radar probe of an asteroid's interior



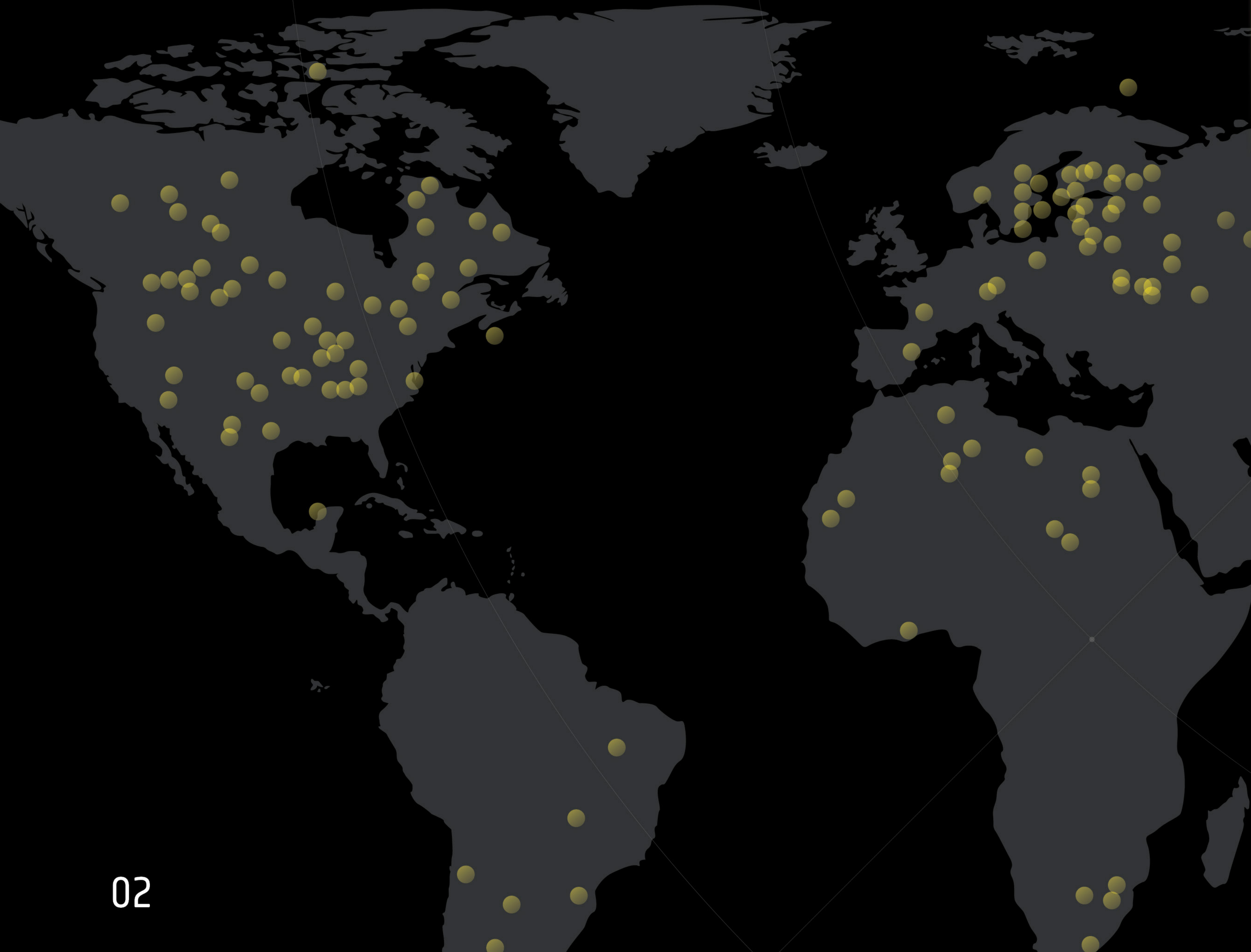
PLANETARY DEFENCE

Humans grew up in a **violent cosmic neighbourhood**; our homeworld has suffered **upwards of three million impacts** causing craters larger than 1 km in diameter – the largest stretching more than 300 km across.

→ Although the chance of a major asteroid impact is low, the potential consequences to our society could be very severe. The **1908 Tunguska event in Siberia, the largest impact event witnessed in human history**, was triggered by the explosion at about 8 km in the atmosphere of an incoming object of 30-40 m in diameter. The **2013 Chelyabinsk airburst**, whose shockwave struck six cities across Russia, was caused by an asteroid just 20 m across.

→ ESA's **NEO Coordination Centre** in Italy works along with NASA's Center for Near-Earth Object Studies to determine the orbits of potentially hazardous asteroids and assess the risk they pose.

→ **What if a dangerous object does get spotted by this system**? To respond to this question NASA's DART and ESA's Hera missions were put together to test the 'kinetic impactor' method of asteroid deflection.



Asteroid detected! Now what?

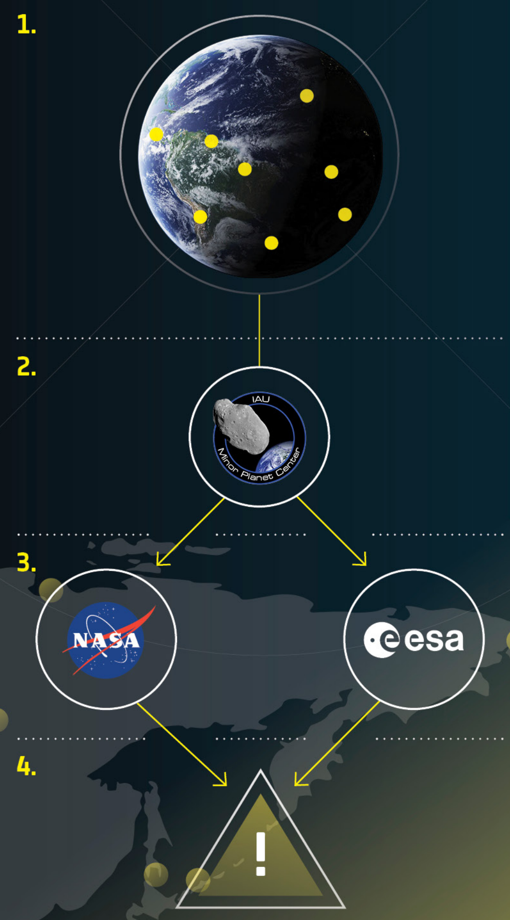
1. Detection - Space agencies, spacecraft, professional surveys and even individual amateur observers – these are the worldwide eyes on the sky watching for risky space rocks, or 'near-Earth objects'.

ESA's upcoming **'Flyeye'** will be Europe's first survey telescope, while the **Test-Bed telescopes** will soon join the Agency's **Optical Ground Station** in confirming the orbits of newly discovered NEOs.

2. The asteroid sorting hat - The International Astronomical Union (IAU)'s **Minor Planet Center (MPC)** collects observations from around the world, acting as a central clearing house for this crucial asteroid orbit data.

3. Risk analysis - Using these data, ESA's **Near-Earth Object Coordination Centre (NEOCC)** and NASA's Center for Near-Earth Object Studies (CNEOS) compute the orbits of hazardous asteroids, evaluate the degree of risk and estimate impact effects.

4. Warning - If an asteroid is determined to be potentially dangerous, **national civil authorities, the UN and other bodies** are alerted to the impact risk, with support and guidance from ESA, NASA and other national agencies.



DART'S IMPACT

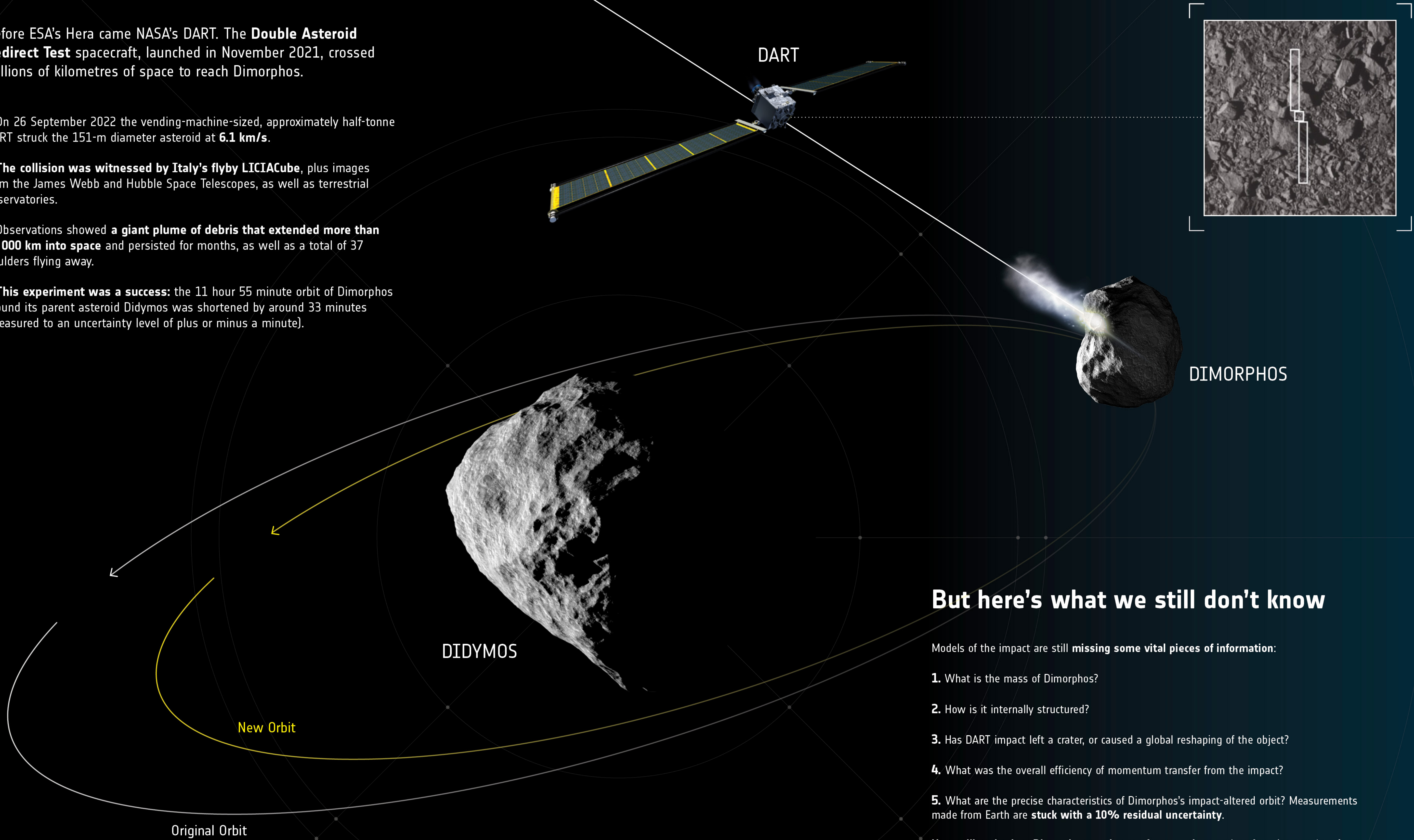
Before ESA's Hera came NASA's DART. The **Double Asteroid Redirect Test** spacecraft, launched in November 2021, crossed millions of kilometres of space to reach Dimorphos.

→ On 26 September 2022 the vending-machine-sized, approximately half-tonne DART struck the 151-m diameter asteroid at **6.1 km/s**.

→ **The collision was witnessed by Italy's flyby LICIACube**, plus images from the James Webb and Hubble Space Telescopes, as well as terrestrial observatories.

→ Observations showed **a giant plume of debris that extended more than 10 000 km into space** and persisted for months, as well as a total of 37 boulders flying away.

→ **This experiment was a success:** the 11 hour 55 minute orbit of Dimorphos around its parent asteroid Didymos was shortened by around 33 minutes (measured to an uncertainty level of plus or minus a minute).



But here's what we still don't know

Models of the impact are still **missing some vital pieces of information**:

1. What is the mass of Dimorphos?

2. How is it internally structured?

3. Has DART impact left a crater, or caused a global reshaping of the object?

4. What was the overall efficiency of momentum transfer from the impact?

5. What are the precise characteristics of Dimorphos's impact-altered orbit? Measurements made from Earth are **stuck with a 10% residual uncertainty**.

Hera will go back to Dimorphos to observe from up close and perform its own **'crash scene investigation'** of the asteroid moon's physical state following the DART impact. Hera's data will validate scientific models of DART's impact, rendering this deflection technique ready for application to other scenarios.

HERA SPACECRAFT

Powered by two 5-m long solar arrays with a hydrazine bipropellant propulsion system, **Hera is a relatively small-scale mission** in interplanetary terms.

→ The spacecraft has a box-shaped body built up of aluminium honeycomb panels with a central carbon-fibre reinforced polymer tube that also contains Hera's propellant tanks.

→ Hera measures approximately 1.6 m across per side, plus solar arrays that stretch 11.5 m across when fully deployed.

→ Hera is roughly the size of a small car and weighs in about 1081 kg fully fuelled.

(A) Asteroid Deck – Hosting all onboard instruments, see dedicated spread for details.

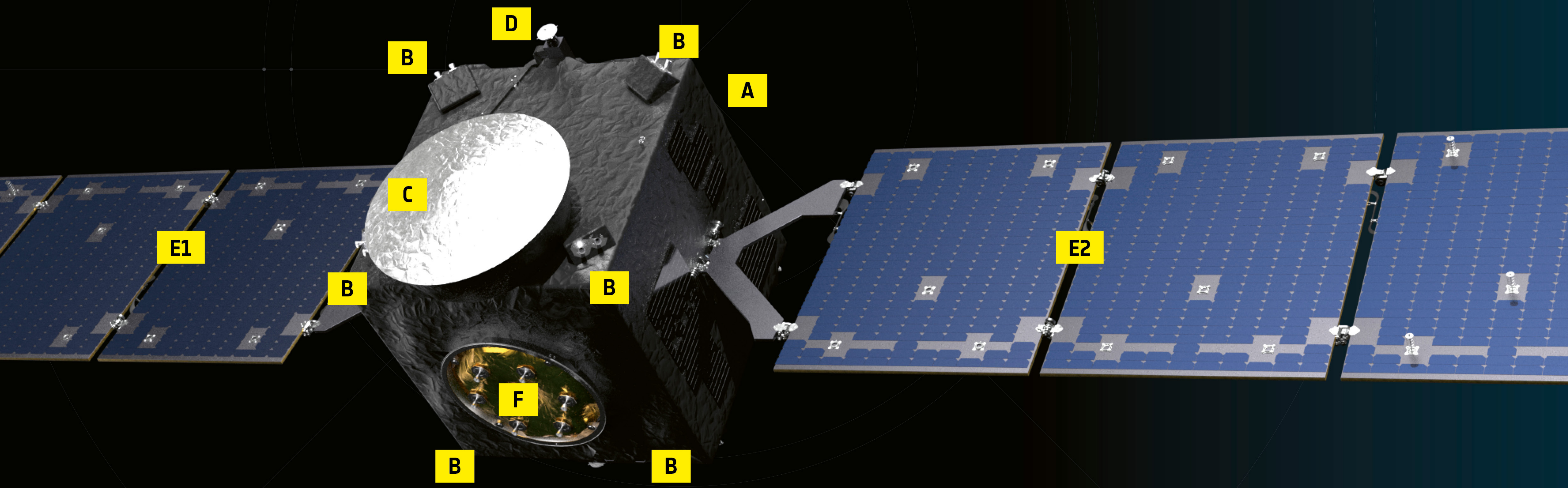
(B) Reaction Control Thrusters – Two placed on each corner of the Hera spacecraft, adding up to 16 10-Newton hydrazine bipropellant thrusters in all, firing individually as required to reorient the spacecraft, for instance to line up its High Gain Antenna with Earth.

(C) High Gain Antenna, HGA – This 1.13-m diameter X-band antenna is the Hera mission's main means of receiving commands and sending back data with the necessary volume. The antenna boosts Hera signals more than 4000-fold to reach Earth, focused down to only half a degree. Coupled with an innovative deep-space transponder, the HGA will also perform science in its own right. Doppler shifting in its signals due to gravity will be used to derive the mass and shape of the asteroid.

(D) Low Gain Antenna, LGA – Omnidirectional Low Gain Antenna for back-up, low data rate communications. A second LGA is positioned on the spacecraft's aft side

(E1 & E2) Solar Arrays – Two 5-m long wings, made up of three hinged panels each, adding up to 14 square metres, with more than 1600 solar cells.

(F) Orbit Control Thrusters – Oriented in a circle on Hera's underside, these six 10-Newton hydrazine bipropellant thrusters are fired three at a time for spacecraft manoeuvres and orbital changes.



HERA MISSION

Hera will be launched in October 2024 by SpaceX Falcon 9 launcher from Cape Canaveral Space Force Station in Florida, USA, with a launch window opening on 7 October and closing on 27 October.

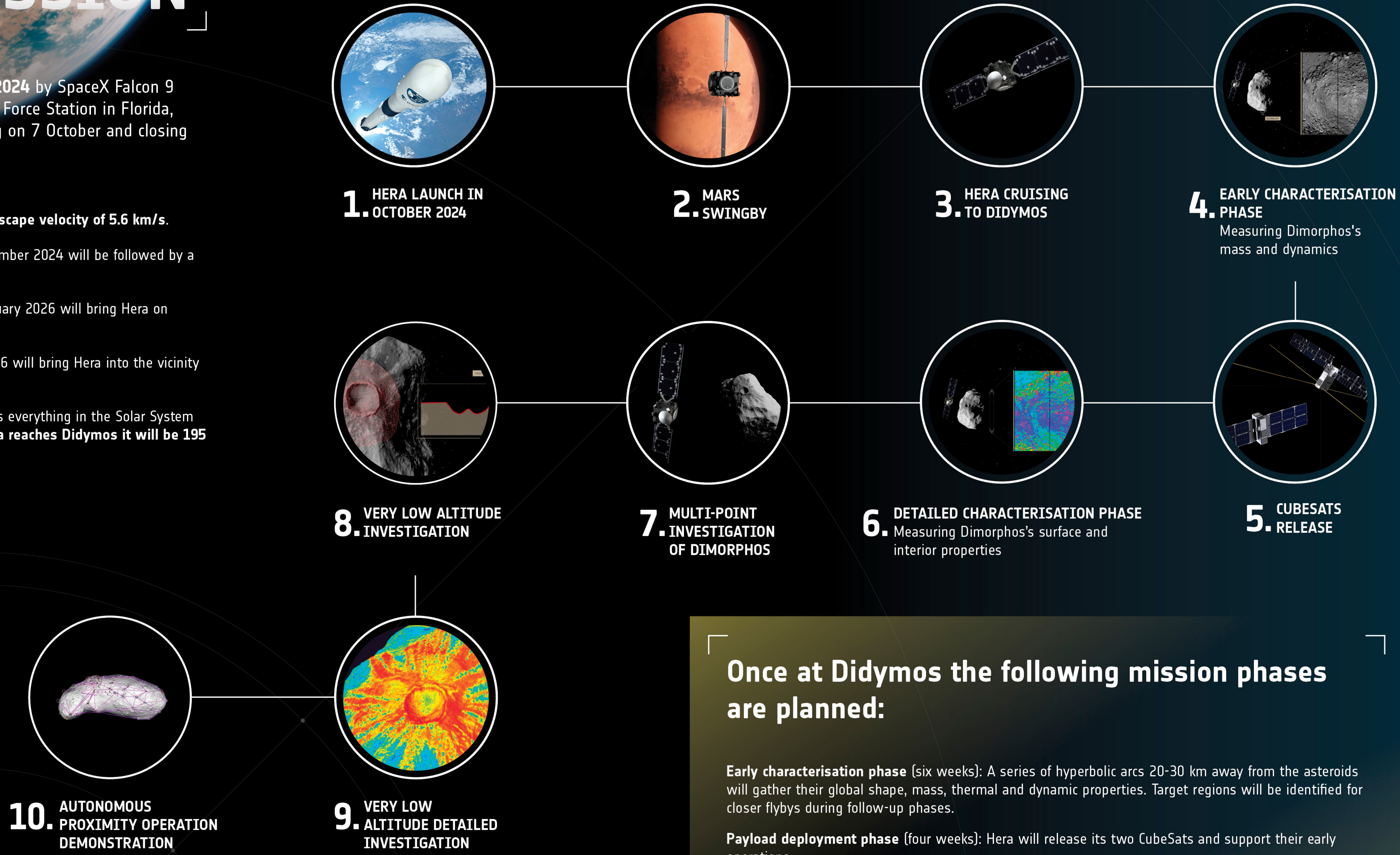
→ The spacecraft will leave Earth with an **escape velocity of 5.6 km/s**.

→ An initial deep-space manoeuvre in November 2024 will be followed by a Mars swingby in mid March 2025.

→ A second deep space manoeuvre in February 2026 will bring Hera on course to the Didymos system.

→ An 'impulsive rendezvous' in October 2026 will bring Hera into the vicinity of the asteroid system for orbit insertion.

→ Relative distances change continuously as everything in the Solar System orbits around the Sun, but **on the day Hera reaches Didymos it will be 195 million km away from Earth**.



Once at Didymos the following mission phases are planned:

Early characterisation phase (six weeks): A series of hyperbolic arcs 20-30 km away from the asteroids will gather their global shape, mass, thermal and dynamic properties. Target regions will be identified for closer flybys during follow-up phases.

Payload deployment phase (four weeks): Hera will release its two CubeSats and support their early operations.

Detailed characterisation phase (four weeks): Hera will reduce its distance from the asteroids to 8-10 km, performing metre-scale mapping of the asteroids. This phase will also include multipoint measurements between Hera and its CubeSats.

Close observation phase (six weeks): Continuing observations of previous phases while reducing the distance from the asteroids. This phase's 12 close flybys will be used for a large fraction of the surface area of Dimorphos, including the DART impact location.

Experimental phase (six weeks): Innovative navigation techniques will be used to achieve flybys down to lower altitudes of 1 km from Dimorphos, reaching decimetre-resolution, including the DART impact traces. This phase, and the mission itself, may end with the Hera spacecraft landing on Didymos.

TARGET ASTEROID

Didymos is a binary asteroid in solar orbit extending out beyond Mars.

→ The primary mountain-sized body has a **diameter of around 780 m** and a rotation period of 2.26 hours.

→ The **secondary body, Dimorphos, has a diameter of around 151 m, similar to the Great Pyramid of Giza**, and orbits the primary at a distance of around 1.1 km from the primary surface in around 11 hours and 22 minutes (reduced by 33 min after DART's impact).

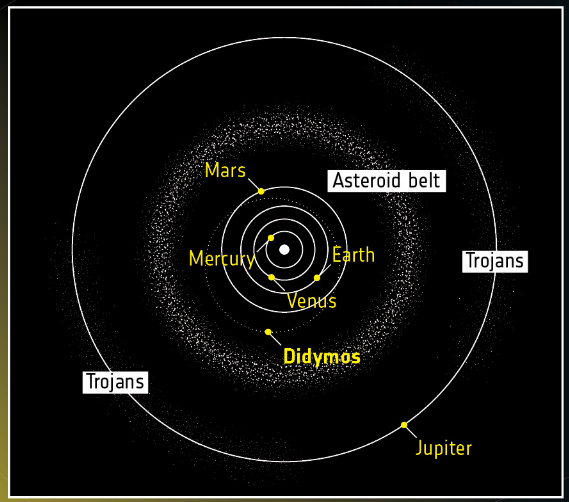
→ First dubbed 'Didymoon', the International Astronomical Union assigned Dimorphos its current name in 2020, **from the ancient Greek for 'having two forms'**. This reflects its status as **the first body in the Solar System to have had its orbit measurably changed through human action**, by the DART impact, expected to have reshaped much of the asteroid's surface.

→ Initially astronomers studied the Didymos system purely through radar techniques and the observation of 'lightcurves' – slight changes in the combined light of the two bodies over time.

→ DART's approach confirmed that Didymos has the 'spinning top' shape already measured by radar and observed in several asteroids, and revealed that the smaller Dimorphos has a much rockier surface. Its abundant boulders are surprisingly large, the size of cars to houses.

→ The majority of 1 km-class near-Earth asteroids in our Solar System have been detected and mapped, but **the majority of asteroids in the Dimorphos size class (and there are up to 30 000 of them in Earth's vicinity) are yet to be discovered**, despite their 'city-killing' potential.

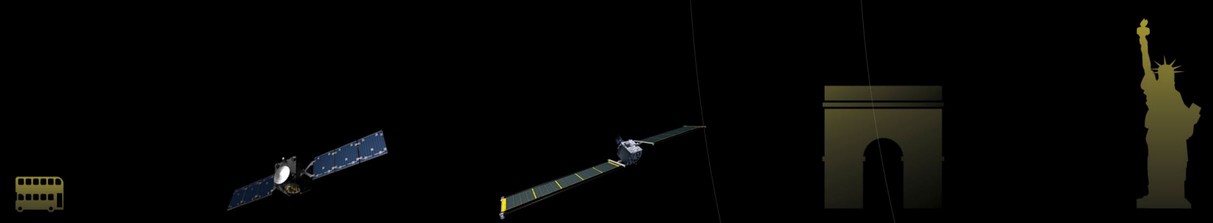
→ Finally it is important to note that **the Didymos asteroid pair poses no threat to Earth**. The system only came to within 11 million km of Earth during their 2022 close encounter. This makes the Didymos system an ideal candidate for such orbital deflection experiments and crucial science.

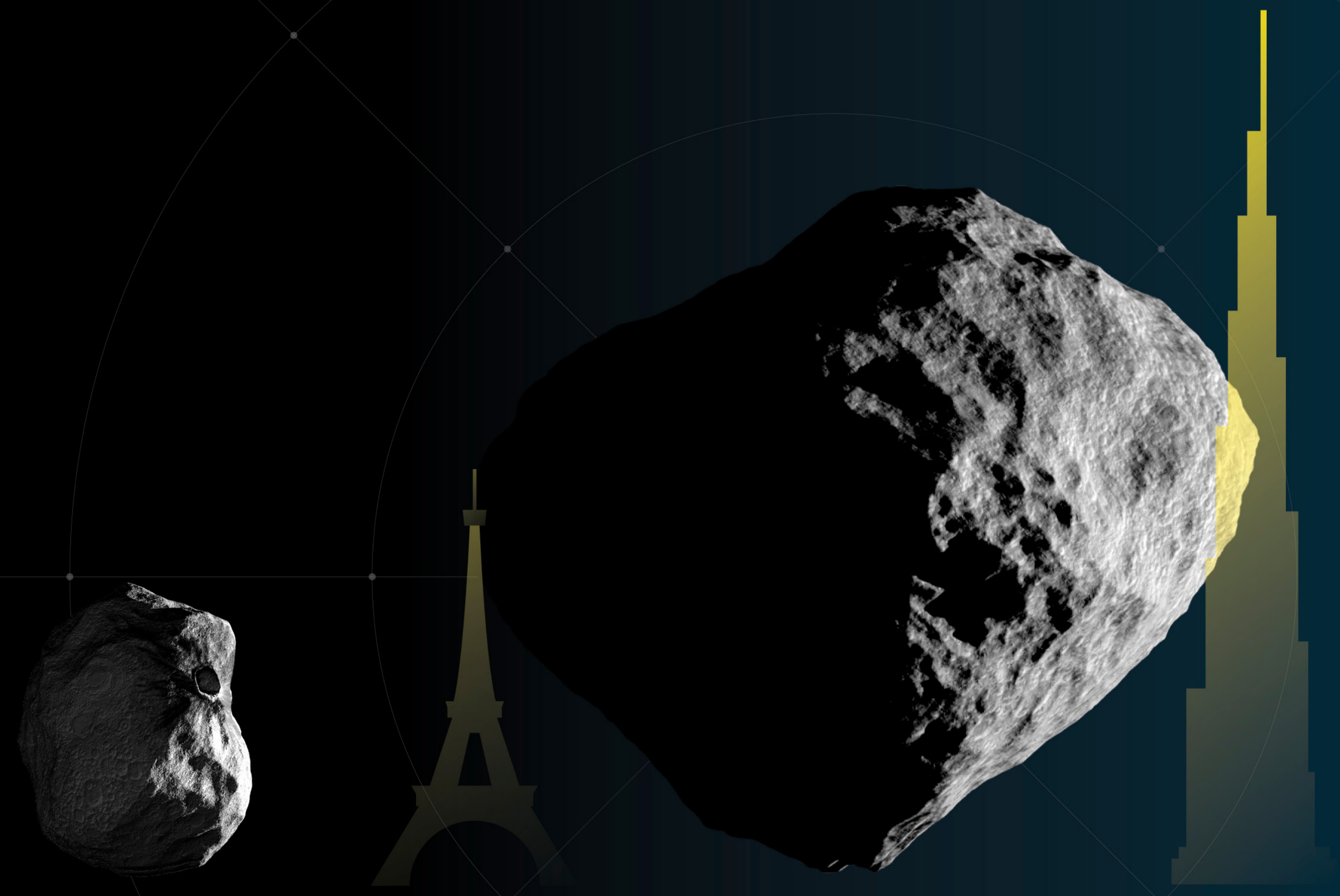


Know your asteroids

Asteroids are small, irregularly shaped bodies, left over from the formation of our Solar System 4.6 billion years ago. Today **more than 1.3 million asteroids have been charted**.

Asteroids can be classed by their brightness. **C-type asteroids** are rich in carbon compounds and extremely dark. **Shinier S-type asteroids** (like the Didymos system) are rocky, with some iron content, while **relatively bright M-type asteroids** appear to contain higher concentrations of metals.





ASTEROID MYSTERIES

Hera will **assess the efficiency of the kinetic impactor method of planetary defence** – while also delivering unique science.

→ **Hera will perform a close-up survey of all Dimorphos's properties.** Is it a rubble pile, held together mainly by gravity, encompassing large voids within it? Or a solid core surrounded by boulders and gravel? Hera's Juventas CubeSat radar will peer deep beneath its surface.

→ **The mass of Dimorphos will be measured** not just through radio science but also by observing the 'wobble' of its parent Didymos asteroid. Hera mission controllers will select key landmarks, such as boulders, on the larger asteroid surface then track their motion around the centre of mass of the overall asteroid system.

→ **The entire moon will be surveyed down to a resolution of a few metres**, with selected areas mapped down to 10 cm resolution.

→ **Dimorphos* is the smallest asteroid yet visited by humankind. Surveying it with its parent should reveal much about binary asteroid formation.** If the two turn out to be made of the same material, then it might be that Didymos spun faster than its structure could endure: debris thrown from its surface congealed into Dimorphos. Its internal structure can tell us how this happened.

→ **Didymos** itself is the fastest spinning Solar System object visited by humankind**, rotating once every 2.26 hours, close to the limits of cohesion depending on its actual density, so it may be regularly flinging dust and rocks into space. This spinning is believed to be due to the Yarkovsky–O'Keefe–Radzievskii–Paddack (YORP) effect. Named after four different asteroid researchers, this involves differential warming by sunlight across an asteroid surface, leading to heated materials leaving the surface, inducing thrust.

→ Down at smaller scales, **Hera's surface observations will reveal the range of physical phenomena other than gravity that govern asteroid surfaces.** Results would hold relevance for asteroid mining as well as planetary defence.

The scientific work of the Hera mission is being supported by researchers from all across Europe, the US and the wider world, see **https://www.heramission.space/**

Binary finds

Three decades ago the idea that asteroids might have their own moons remained in the realm of science fiction. Then on 28 August 1993, NASA's Galileo probe to Jupiter flew by the Ida asteroid to find it has a tiny egg-shaped moon which was named Dactyl.

Once the binary asteroid concept was proven, many more were found using lightcurves or radar surveys. Today **around 15% of asteroids are believed to be double (or triple) asteroid systems**. On the ground, 'doublet' impact craters caused by binary impacts have been spotted – such as the adjacent Lockne and Malingen craters in Sweden.

The **spinning top shape of many asteroids, in particular primaries of binary systems, could be due to the YORP effect**, as material shifts from their poles to its equator, and binaries might be formed by material being flung into space. Hera could observe such processes in action.

'Spinning top' asteroids

Ryugu - 1000 m across, visited by Japan's Hayabusa2 mission

Šteins - 5 km across, surveyed by ESA's Rosetta mission

Bennu - 0.5 km across, visited by NASA's OSIRIS-REx mission

Dinkinesh - Binary asteroid 790 m across, surveyed by NASA's Lucy mission

HERA'S ASTEROID DECK & INSTRUMENTS

The mission's instruments are hosted on the top panel of the cube-shaped spacecraft body, known as the 'Asteroid Deck'. Hera's two CubeSats – Milani and Juventas – will also be deployed from the Asteroid Deck (see pages 10 and 11). The spacecraft will tilt itself so that its Asteroid Deck faces forward while operating its instruments – employed both for navigation purposes and scientific study.

(A) Asteroid Framing Camera, AFC – Incorporating two baffle-protected cameras for redundancy, each Asteroid Framing Camera is a 1020x1020 monochrome visible-light sensor. Produced by **Jenoptik in Germany**, based on its ASTROhead design.

(B) Thermal Infrared Imager, TIRI – Imaging in the mid-infrared spectral region to chart the temperature on Dimorphos's surface. By charting the 'thermal inertia' of surface regions – or how rapidly their temperature changes – physical properties such as roughness, particle size distribution and porosity can be deduced. Supplied by the Japan Aerospace Exploration Agency **JAXA**, from a design deployed on Japan's Hayabusa2 asteroid mission.

(C) Startrackers – Twin startrackers for space navigation from **Sodern in France.**

(D) HyperScout H – Observing in a range of colours beyond the limits of the human eye, in 25 visible and near-infrared spectral bands to help prospect the asteroid's mineral makeup. The shoebox-sized imaging spectrometer comes from **cosine Remote Sensing in the Netherlands**.

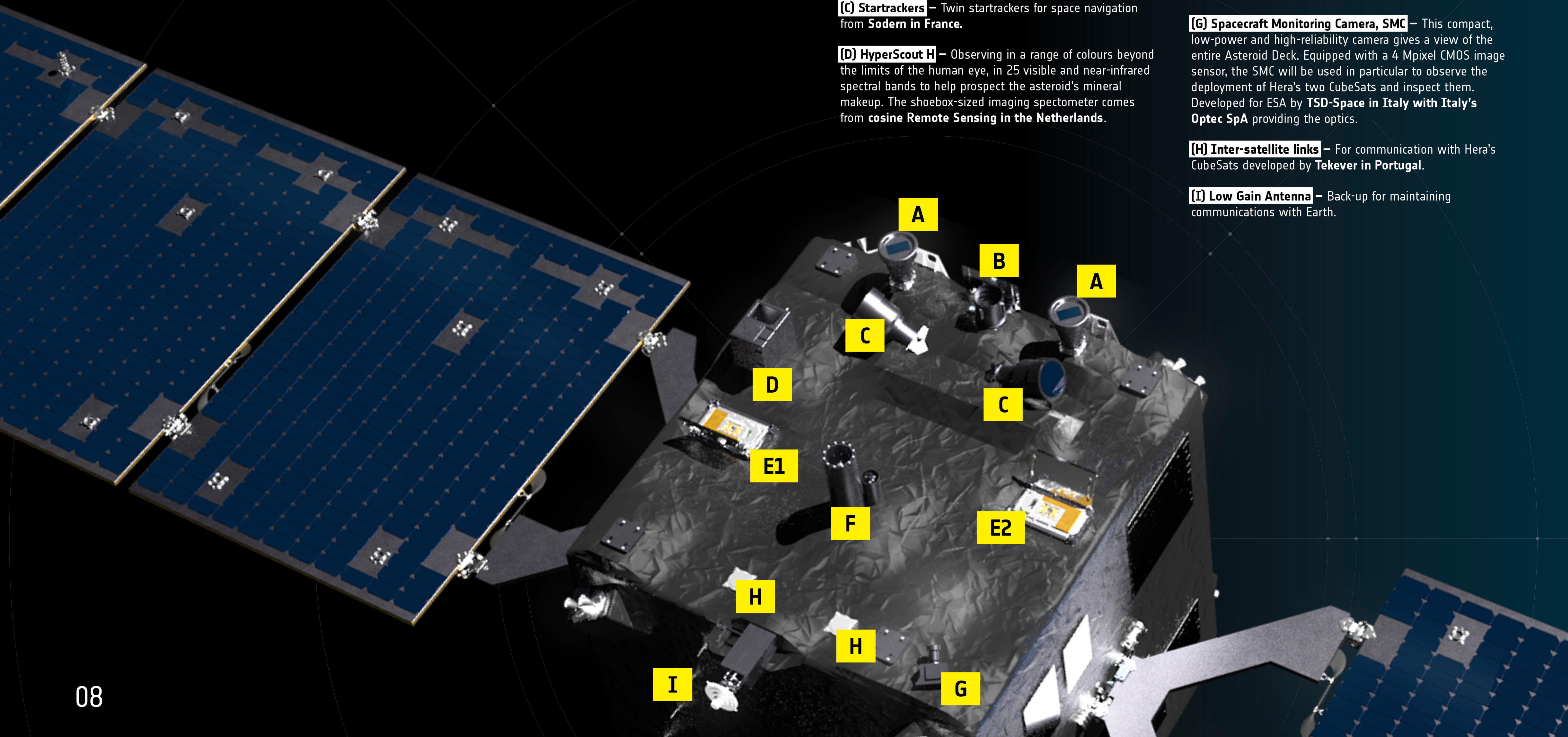
Deep Space Deployers, DSDs, for Milani (E1) and Juventas (E2) CubeSats – Keeping Hera's two CubeSats alive and healthy during their two-year cruise phase to the Didymos system then deploying them at Didymos. The DSDs come from **ISISpace in the Netherlands**, with **Finland's Kuva Space** supplying the Life Support Interface Boards linking the DSDs safely to the rest of Hera.

(F) Laser Rangefinder – Determining the distance to the asteroid surface by measuring the time of flight of 1550-nm wavelength laser beam pulses. These are bounced back to a receiver telescope with a distance accuracy of better than 1 m and a working distance of 10 m to 20 km. Supplied by **Jena-Optronik in Germany** (plus a parallel development is ongoing with Efacec in Portugal and Eventech in Latvia).

(G) Spacecraft Monitoring Camera, SMC – This compact, low-power and high-reliability camera gives a view of the entire Asteroid Deck. Equipped with a 4 Mpixel CMOS image sensor, the SMC will be used in particular to observe the deployment of Hera's two CubeSats and inspect them. Developed for ESA by **TSD-Space in Italy with Italy's Optec SpA** providing the optics.

(H) Inter-satellite links – For communication with Hera's CubeSats developed by **Tekever in Portugal**.

(I) Low Gain Antenna – Back-up for maintaining communications with Earth.

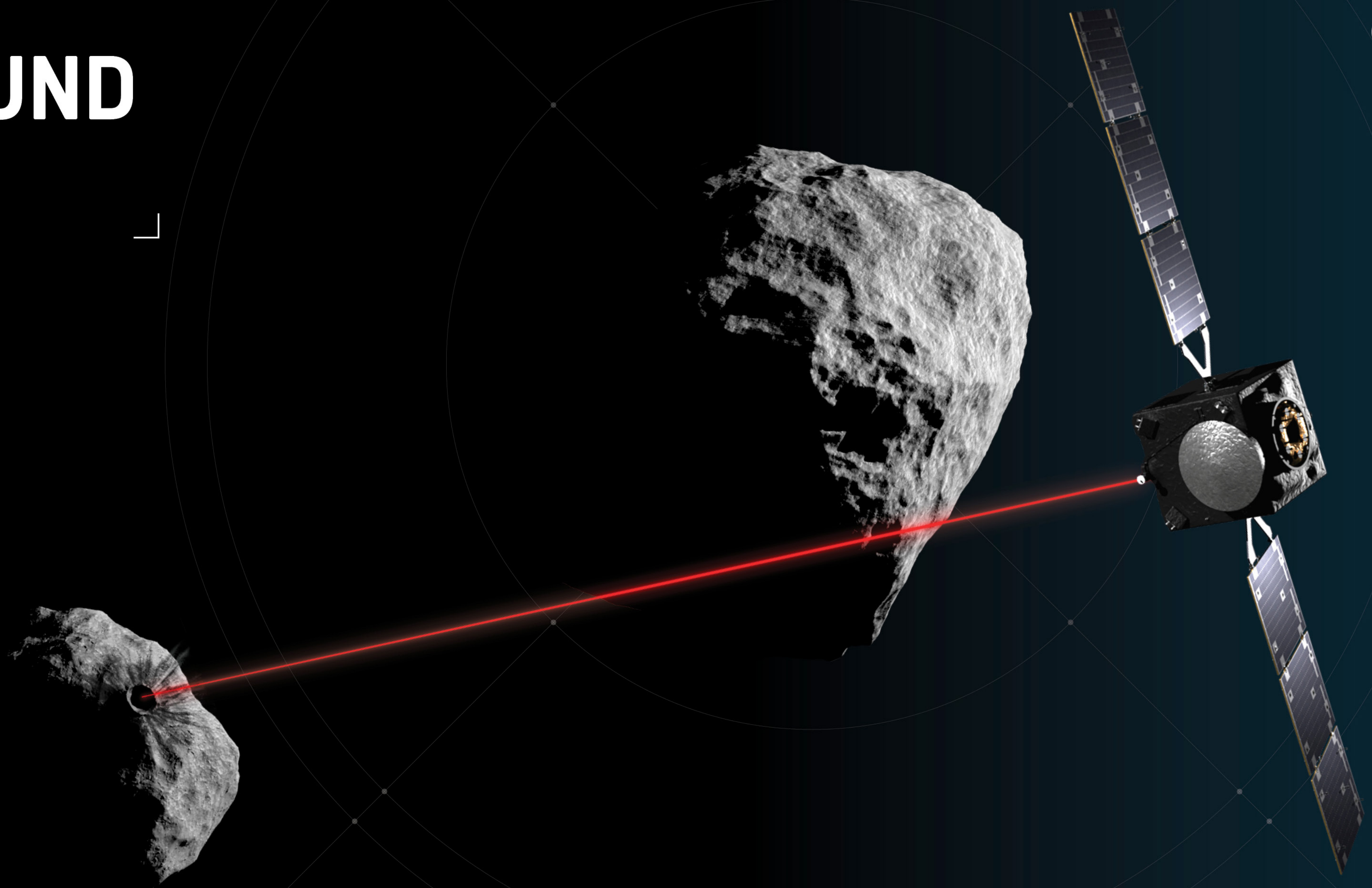


OPERATING AROUND AN ASTEROID

Hera has a **high degree of onboard autonomy**, fusing data from different inputs to build up a coherent picture of its surroundings, in a **similar approach to self-driving cars**. While designed to be fully operated manually from ground, once Hera's core mission tasks have been fulfilled, this novel autonomy will be tested out for real.

→ Hera's most crucial navigation data source will be its **Asteroid Framing Camera**, combined with inputs from its **startrackers** and laser **altimeter** to determine its distance from the asteroids.

→ In principle Hera should be able to **navigate safely as close at 200 m from the surface of Dimorphos**, delivering 2 cm imaging resolution.



Hera navigation modes

Hera will be navigated in three different modes:

→ On initial approach the main asteroid will appear as one more bright star among many. Multiple images will be acquired to **observe the asteroid's motion against the background starfield**.

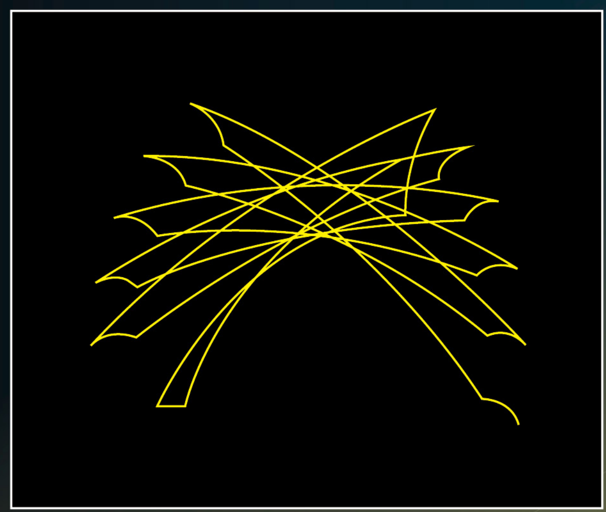
→ The next mode will be the dominant one for the bulk of Hera's mission between 30 km to 10 km distance, with **Didymos framed in its camera view as an overall reference point**. By keeping the big asteroid smaller than Hera's overall camera field of view the contrast of its edges with space can be detected. Later, when the spacecraft comes closer than about 10 km from Didymos and more than 2 km above Dimorphos, an image processing technique called 'centre of brightness' will be used, focused on the average position of Sun-illuminated pixels, due to the smaller asteroid's complex and uncertain shape.

→ Closer than 2 km, the asteroid fills the AFC field of view. Then comes **the most ambitious navigation mode of all, based on autonomous feature tracking** with no absolute reference. This will be a matter of imaging the same features – such as boulders and craters – in different pictures to gain a sense of Hera's altitude and trajectory with respect to the surface, combined in turn with other information including Hera's onboard gyro and TIRI while overflying the asteroid's night side.

Feature tracking will also be used to derive the mass of Dimorphos. Mission controllers will measure the 'wobble' it causes on its parent, relative to the common centre of gravity of the overall Didymos system. This will be achieved by identifying small metre-scale variations in the rotation of fixed landmarks around this centre of gravity over time.

Oddly shaped orbits

The gravities of Didymos and Dimorphos are so low that Hera will remain in orbit around their 'barycentre' (or common centre of gravity in the Didymos system) at a typical **relative velocity of around 12 cm per second**. Even so, this orbit will need ongoing corrections to be maintained at the desired distance, rather than gradually drifting away. The result resembles a set of flybys thrown regularly into reverse; **Hera borrows this 'hyperbolic arc' technique from ESA's Rosetta mission**. Short arcs of three days' duration are interleaved with long arcs taking four days, creating a weekly cycle, bringing the spacecraft within 20-30 km of the asteroid. Because Hera's overall velocity remains low, it takes little propellant to perform each individual manoeuvre. **The technique is inherently safe** because if any single manoeuvre fails then Hera will fly farther out into space, rather than risk an impact.



JUVENTAS CUBESAT

Named for the Roman name of the daughter of Hera, Juventas is **one of two miniature CubeSats** carried aboard. **This shoebox-sized '6-unitXL' CubeSat carries the smallest radar instrument ever flown in space**, which will perform the first radar sounding inside an asteroid.

→ The design of this JuRa 'Juventas Radar' instrument is **descended from the CONSERT radar which flew on ESA's Rosetta mission**, but using a single 'monostatic' antenna (Rosetta's bistatic radar sent waves between the Rosetta orbiter and Philar lander).

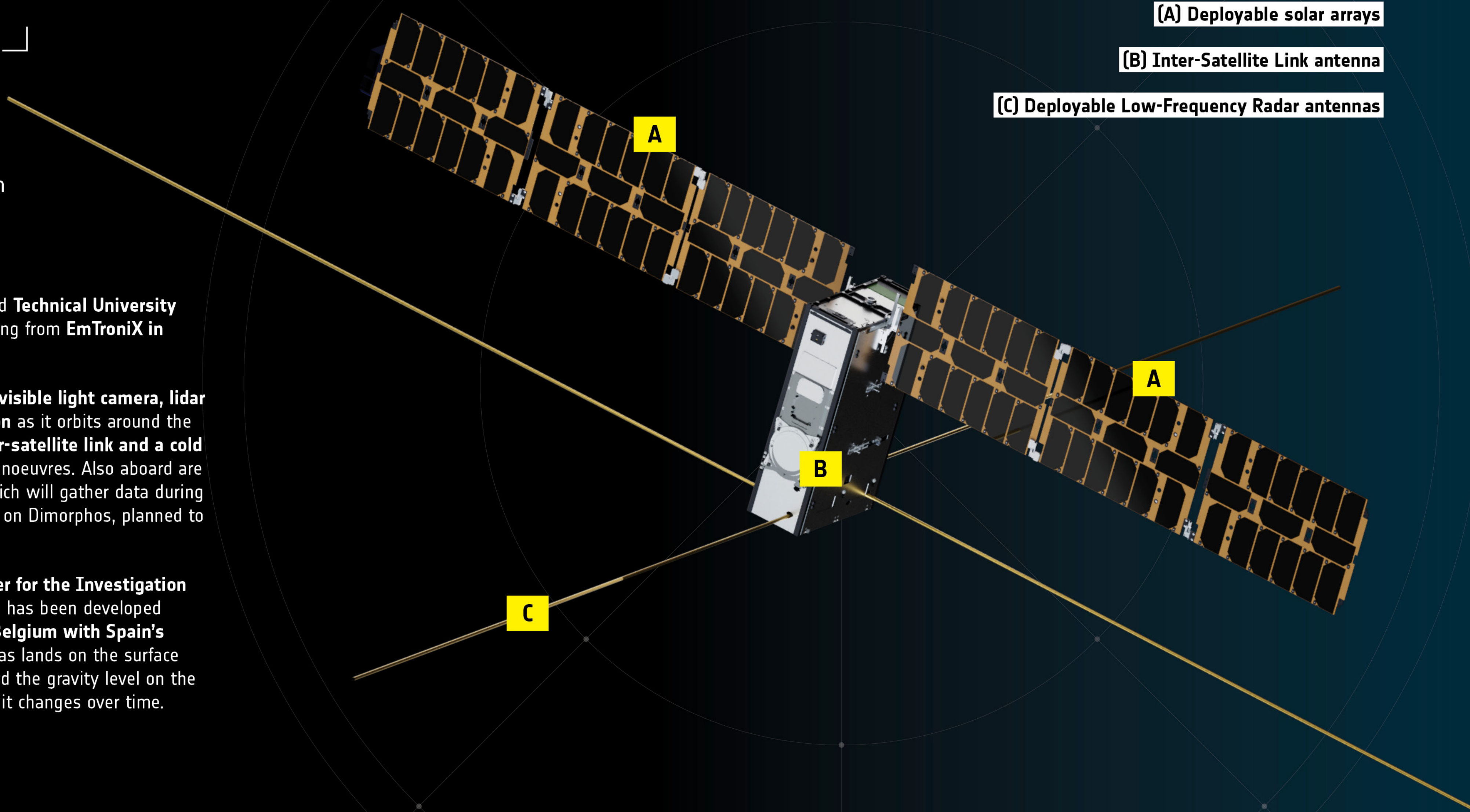
→ Juventas will unfurl a quartet of 1.5-m long antennas larger than the CubeSat itself.

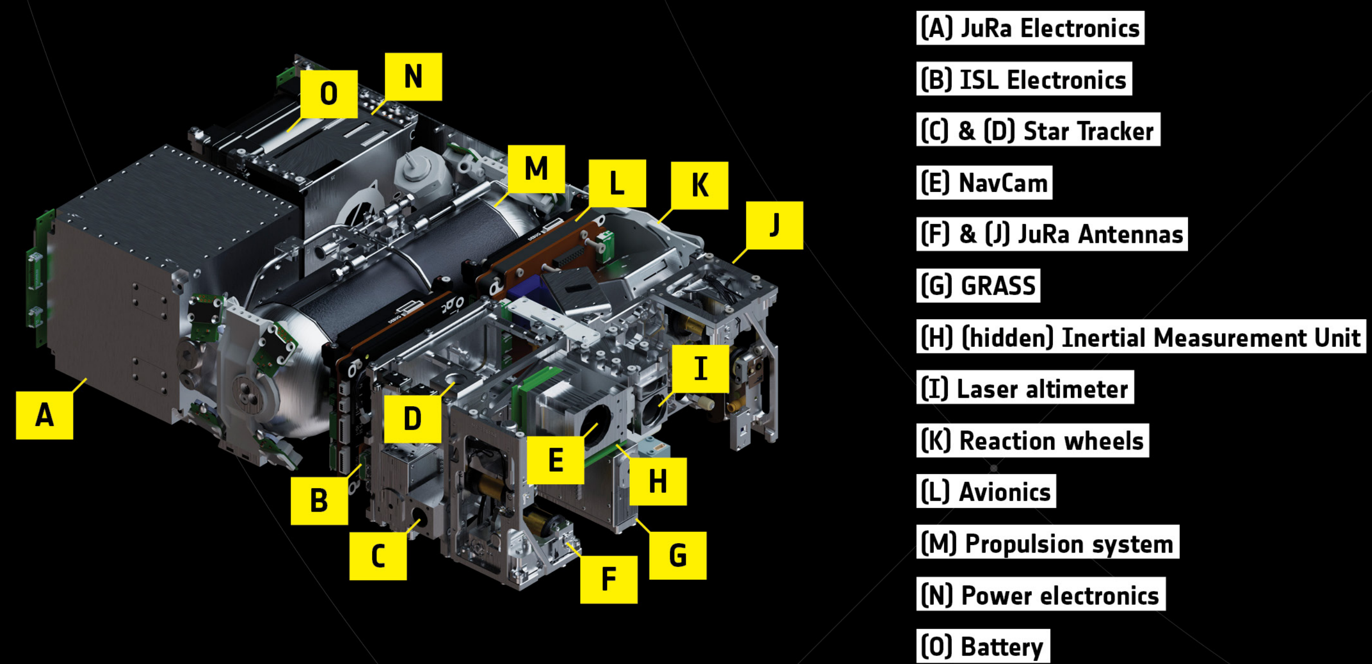
→ Its synthetic aperture radar design takes advantage of the low velocity and distance of Juventas to send the same signal multiple times to boost its signal to noise ratio, compensating for the CubeSat's lack of power. The signal is coded in such a way that the reflections can be disentangled back on Earth to compute a three-dimensional picture.

→ JuRa has been developed by **France's Institut de Planétologie et d'Astrophysique de Grenoble at the Université Grenoble Alpes** and **Technical University Dresden**, with electronics coming from **EmTroniX in Luxembourg**.

→ Juventas is equipped with a **visible light camera, lidar and startrackers for navigation** as it orbits around the Didymos asteroid, plus its **inter-satellite link and a cold gas propulsion system** for manoeuvres. Also aboard are **accelerometers and gyros** which will gather data during the CubeSat's eventual landing on Dimorphos, planned to conclude the mission.

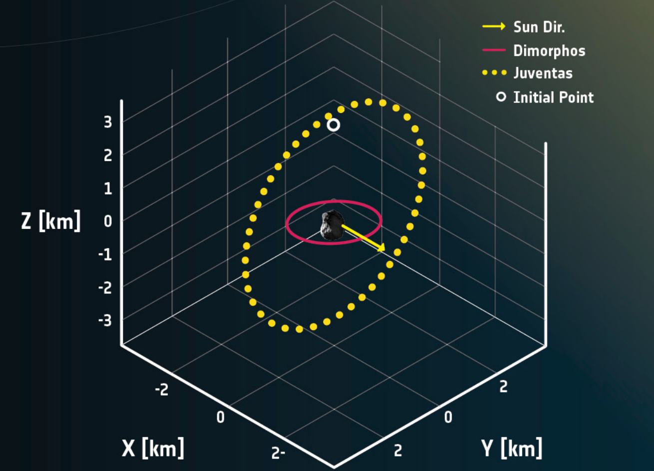
→ Juventas's **GRASS Gravimeter for the Investigation of Small Solar System Bodies** has been developed by the **Royal Observatory of Belgium with Spain's EMXYS company**. Once Juventas lands on the surface of Dimorphos, GRASS will record the gravity level on the surface of Dimorphos and how it changes over time.





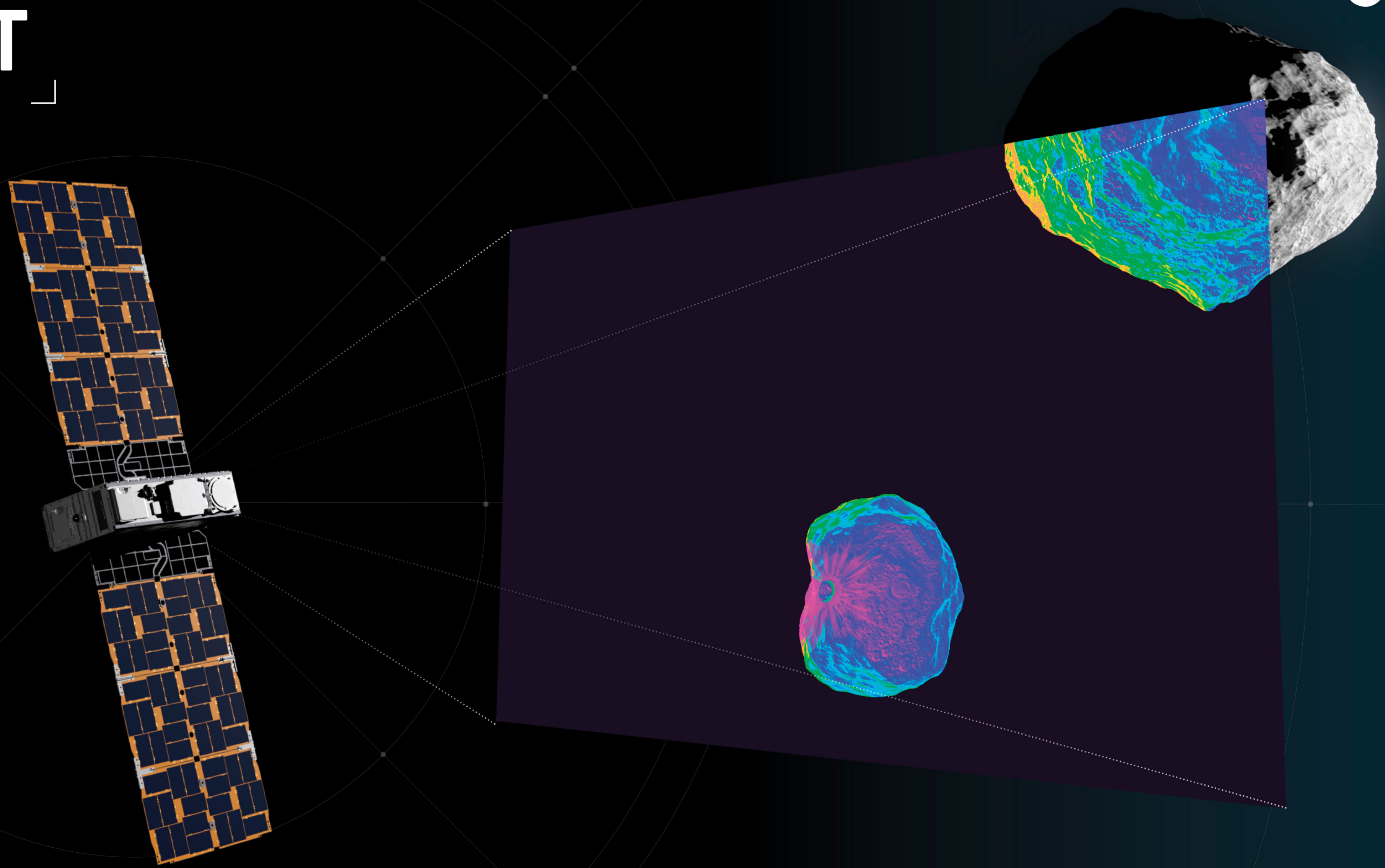
Self-stabilising Terminator Orbit

Juventas will enter a **unique orbit around Didymos**, perpendicular to the orbit of Dimorphos around Didymos, lined up with the Sun in parallel with the terminator line along Didymos. This '**Self-stabilising Terminator Orbit**' does not require propellant to maintain. Instead its position is maintained by balancing the faint gravitational pull of the Didymos system with the slight solar radiation pressure from sunlight.



MILANI CUBESAT

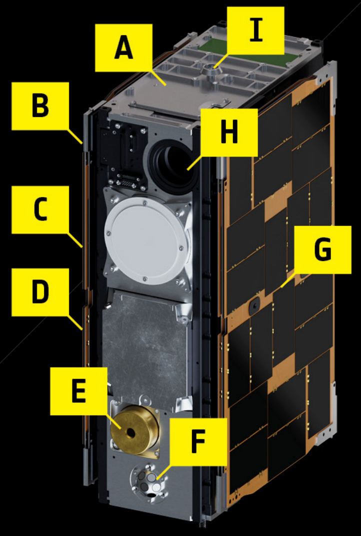
Milani will image the Didymos and Dimorphos asteroids in a wider range of colours than the human eye can see, prospecting the makeup of individual boulders. It will also **survey the dust environment surrounding these bodies.**



→ Its main instrument will be the **Asteroid Spectral Imager (ASPECT) hyperspectral imager**, which will combine visible and near infrared wavelengths to survey the surface down to a maximum spatial resolution of 1 m. ASPECT has been developed by **Finland's VTT Technical Research Centre**.

→ **VISTA, Volatile In-Situ Thermogravimetre Analyser**, is an Italian-built dust detector. Based on piezoelectric quartz microbalances, this 5-cubic-cm sized instrument **detects dust particles** smaller than 5-10 micrometres (thousandths of a millimetre). It can detect volatiles such as water in dust particles and identify their makeup. Developed by **Italy's National Research Council National Institute for Astrophysics and National Institute of Space Astrophysics and Planetology and Politecnico di Milano**.

→ In addition Milani carries a **visible camera, lidar and startrackers for navigation, an inter-satellite link, a cold gas propulsion system, plus accelerometers and gyros** employed when Milani performs its end-of-mission landing on Dimorphos. Milani is managed by **Tyvak International in Italy**.



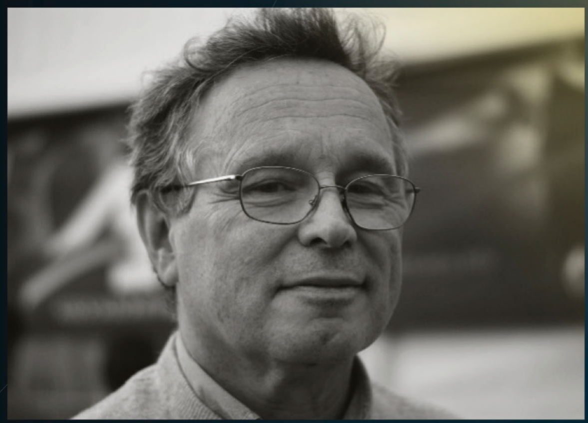
(A) Sensor module
(B) Vehicle umbilical
(C) ISL antenna
(D) Propulsion system
(E) VISTA payload
(F) Reflector
(G) Trifold solar array
(H) Star tracker
(I) Interface bracket

Milani's orbit

Milani will maintain its orbit around the Didymos system based on hyperbolic arcs similar to Hera's own orbit, but at lower altitudes. Flying in an inclined orbit, 20 degrees off the poles, its range to the asteroids will be reduced progressively from 10 down to 2 km. The CubeSat will perform 'corrective action manoeuvres' if it risks heading into 'risk tubes' surrounding either asteroid, Juventas or Hera itself.

What's in a name?

Milani was named for Andrea Milani, professor of mathematics at the University of Pisa until his untimely death in 2018. Andrea led the creation of the **first automated system to compute the probabilities that an asteroid could impact Earth in the future**, the NEODyS service, leading in turn to ESA's **NEO Coordination Centre** at ESRIN. Working with Deimos Space in Spain, Andrea devised the original version of the DART-Hera concept, the Don Quijote mission.



INTER-SATELLITE LINKS

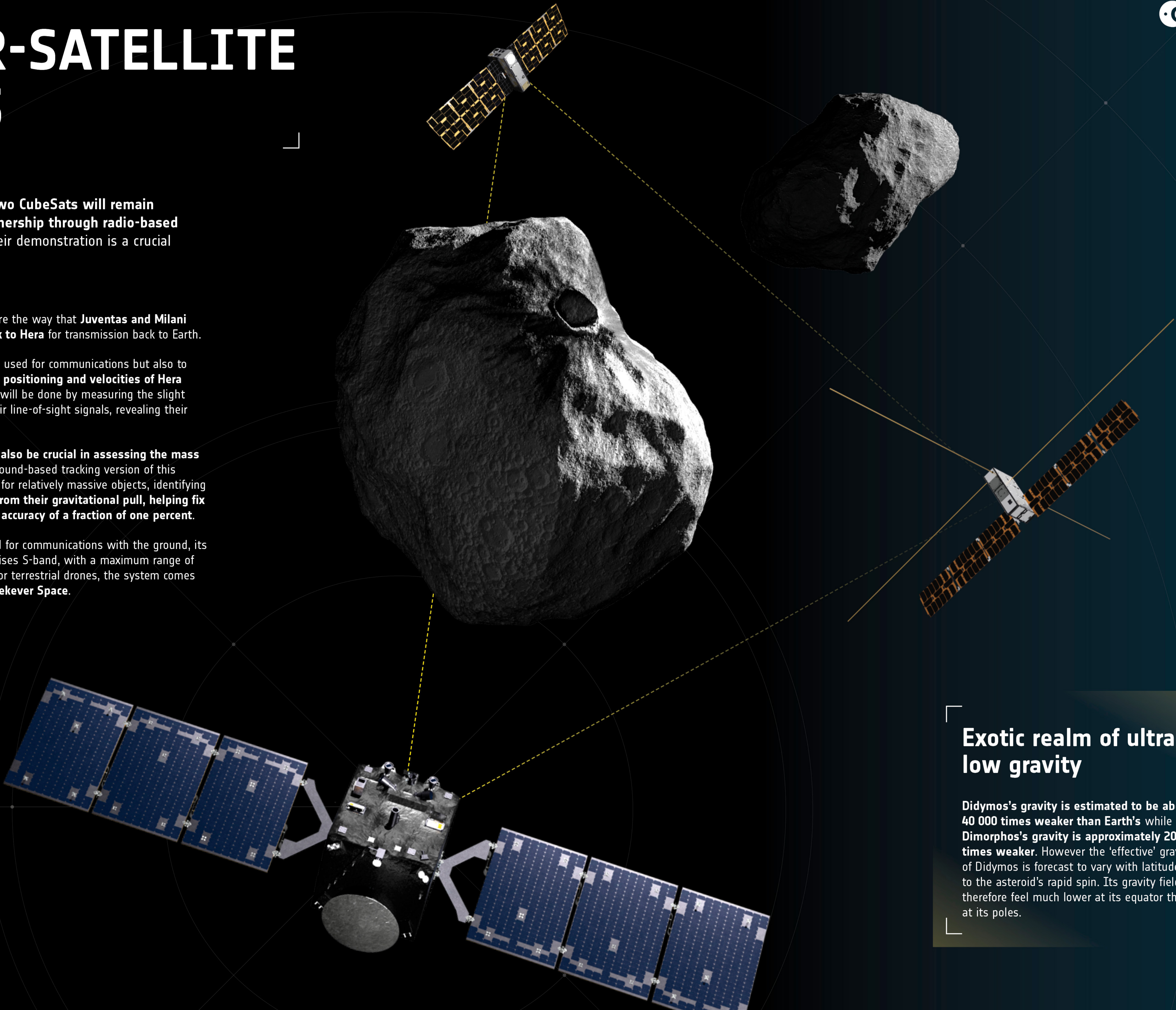
Once deployed, **Hera's two CubeSats will remain connected to their mothership through radio-based inter-satellite links**. Their demonstration is a crucial mission objective.

→ These inter-satellite links are the way that **Juventas and Milani will relay their findings back to Hera** for transmission back to Earth.

→ These links will not only be used for communications but also to precisely **assess the relative positioning and velocities of Hera and its two CubeSats.**. This will be done by measuring the slight degree of Doppler shift in their line-of-sight signals, revealing their corresponding rate of motion.

→ **This tracking method will also be crucial in assessing the mass of the two asteroids**. The ground-based tracking version of this technique is well established for relatively massive objects, identifying **slight tugs on a spacecraft from their gravitational pull, helping fix the gravitational field to an accuracy of a fraction of one percent**.

→ While Hera employs X-band for communications with the ground, its inter-satellite link system utilises S-band, with a maximum range of 60 km. Originally developed for terrestrial drones, the system comes from **Portuguese company Tekever Space**.



Exotic realm of ultra-low gravity

Didymos's gravity is estimated to be about 40 000 times weaker than Earth's while **Dimorphos's gravity is approximately 200 000 times weaker**. However the 'effective' gravity of Didymos is forecast to vary with latitude, due to the asteroid's rapid spin. Its gravity field will therefore feel much lower at its equator than at its poles.

COMING IN FOR LANDING

The CubeSats will **end their working lives by touching down on the asteroids they explore.** Juventas will land on Dimorphos to perform the measurements of the gravity field with its gravimeter and Milani will land once its scientific goals are achieved. Hera itself may land on Didymos at its end of life, depending on what kind of mission extension can be defined.

→ None are specifically engineered for landing, but will limit their velocities to **a few centimetres per second.** The hope is that they continue to operate after landing.

→ **Juventas will spend its working lifetime in orbit around Didymos to perform radar soundings of Dimorphos.** Once sufficient radar and radio science data has been gathered, the CubeSat will have its orbit shifted around Dimorphos to prepare for landing. No site selection or targeting is necessary. As it descends Juventas will use its cameras to image Dimorphos surface features – and hopefully the DART DART impact site – in the highest possible resolution. Before landing it will turn on its 3-axis GRASS gravimeter, accelerometers and gyros to record the dynamics of the impact or landing event.

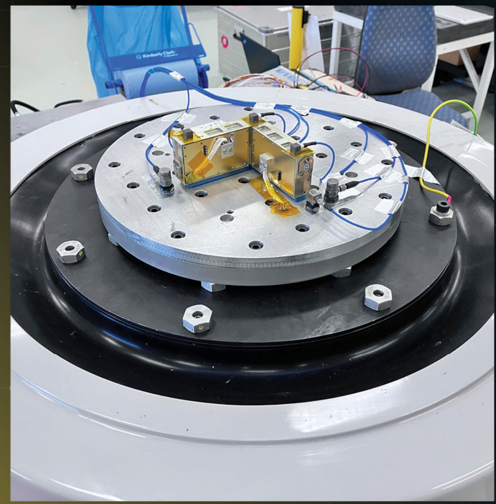
→ **Once Juventas comes to rest, it will use its gravimeter payload – the first to operate from the surface of an asteroid – to measure local gravity.** The goal would be to stay operational for one terrestrial day, equivalent to approximately two orbits of Dimorphos around Didymos. This should show how the local gravity field changes over time.

→ **Milani will already be in orbit around Dimorphos once its scientific mission is concluded.** It will similarly perform an uncontrolled ballistic soft landing on Dimorphos; the dynamics of its surface interaction will be captured through its accelerometers and gyros, capturing valuable details of the surface mechanical response of the asteroid in its extremely low gravity environment.

→ Assuming a stable landing, **Milani's VISTA instrument will be able to gather data on any surface dust that reaches it** (although ASPECT will be unable to focus on the ground before it).

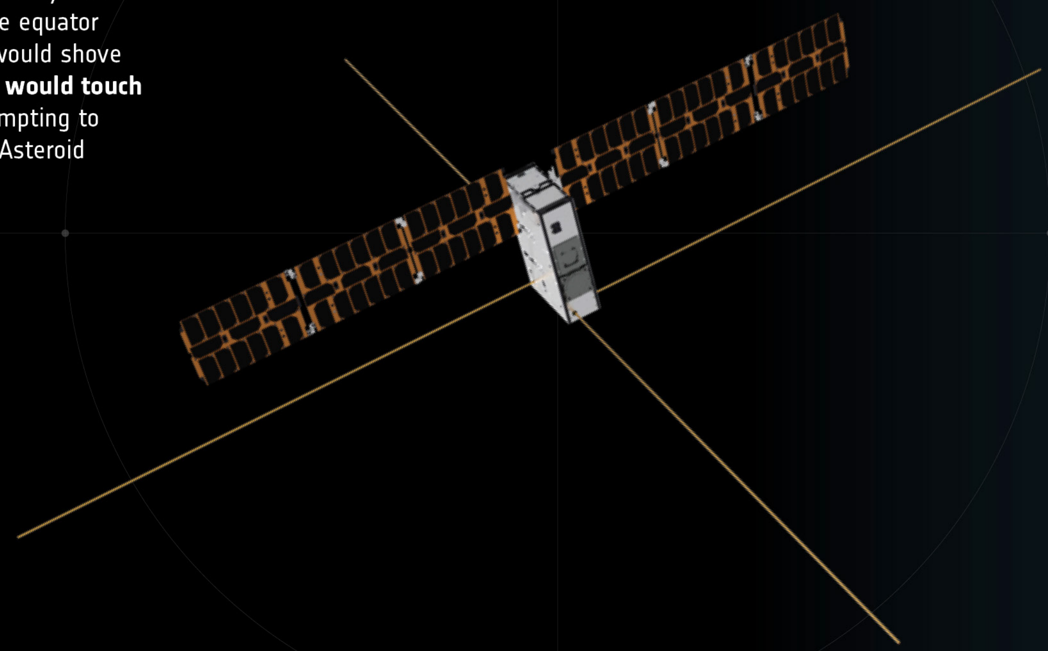
→ Results from both CubeSats will be gathered by Hera via its inter-satellite links.

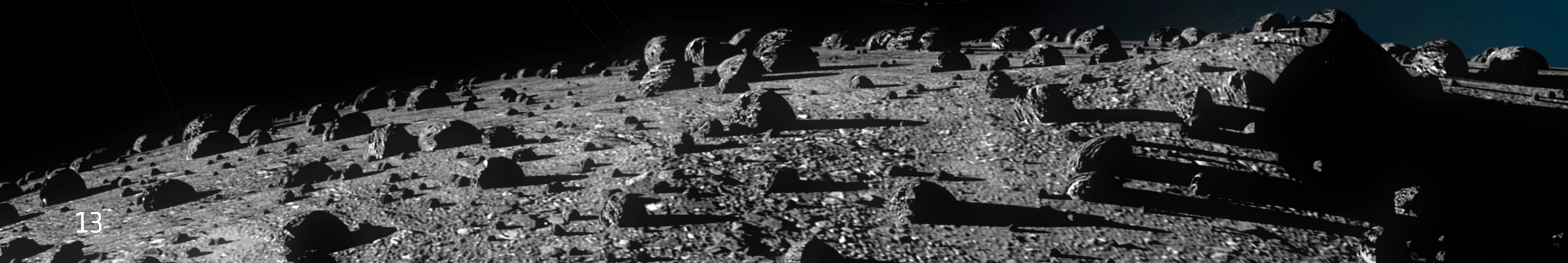
→ **Hera itself may end its own mission by attempting a landing on parent asteroid Didymos.** The body's rate of spin is so high that any landing around the equator would be impossible. This spinning motion would shove the spacecraft back into space. Instead **Hera would touch down at one of the poles of Didymos**, attempting to return very high-resolution imagery from its Asteroid Framing Camera.



Measuring gravity on an asteroid

The Gravimeter for Small Solar System Objects, GRASS, is an L-shaped instrument, the size of two smartphones stuck together, incorporating two sets of thin blades anchored within rotating cradles. Their slightest motion triggers voltage changes, producing sensitivity equivalent to a single micrometre – or thousandth of a millimetre. Once landed aboard Juventus, GRASS will run on battery power for around 20 hours, identifying gravity changes as Didymos moves overhead.





MARS SWINGBY

Hera's instruments will be put to use for the first time in March 2025, when the spacecraft performs a **swingby of Mars and a flyby of Deimos, one of the two martian moons**.

→ The spacecraft will come to within 6000 km of the martian surface, closer than both martian moons, Phobos and Deimos, and its trajectory will be tweaked to observe Deimos from within 1000 km.

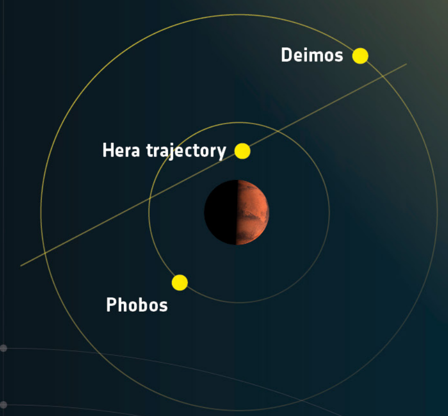
→ This swingby will lend Hera extra momentum to rendezvous with the Didymos system. It is not part of the mission's core objectives but offers an opportunity for science discoveries and for additional calibration of onboard instruments.

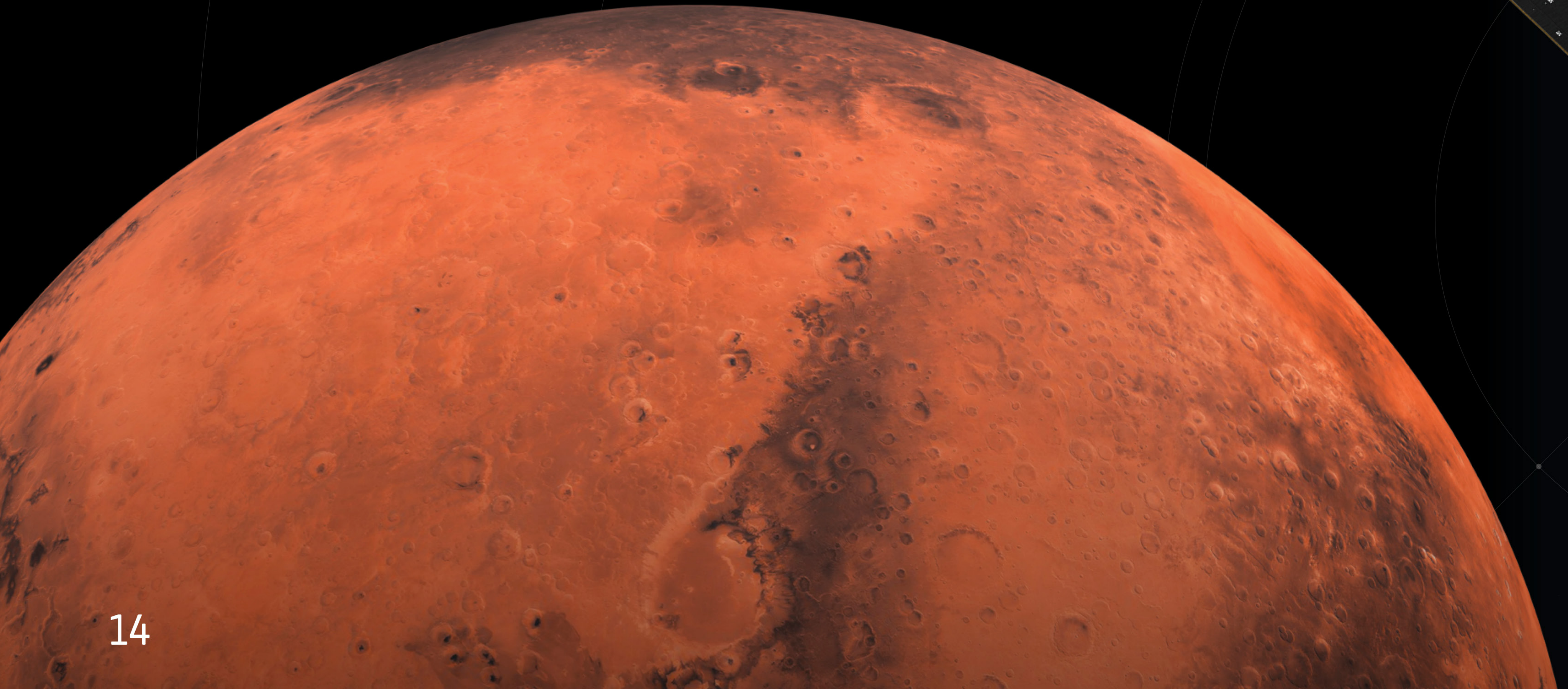
→ Hera will use its visual **Asteroid Framing Camera**, visual-near infrared **Hyperscout-H** imaging spectrometer and its **Thermal Infrared Imager** to observe Mars and Deimos during the swingby and flyby.

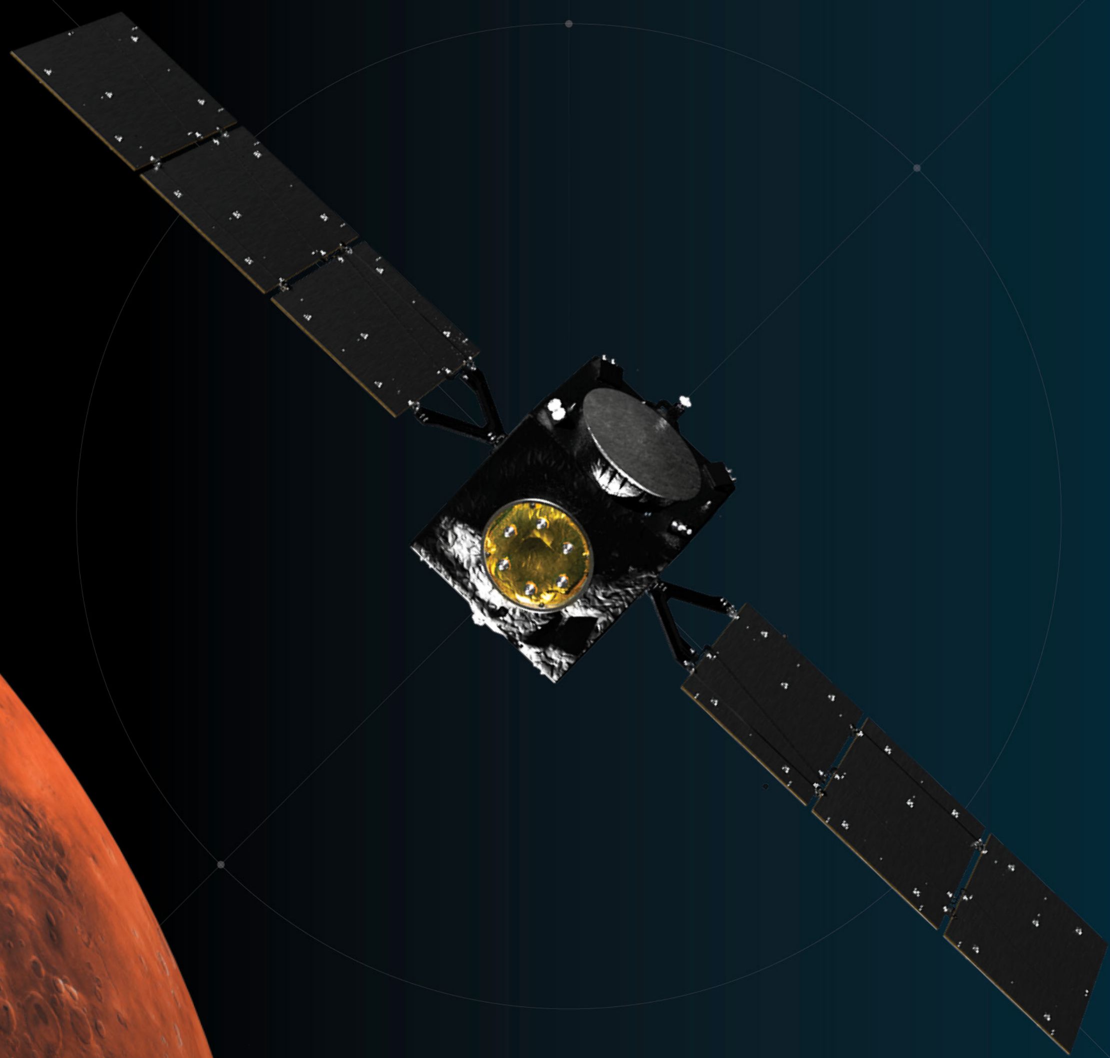
→ Hera will perform observations in synergy with the **Emirates Mars Mission 'Hope Probe'**, which launched in July 2020 and entered orbit around Mars in February 2021. Hope performs regular Deimos flybys, but **Hera's Hyperscout-H observes in a wavelength range not covered by Mars Hope**. Hera's flyby of Deimos will also gather data for planning the Japanese-led **Martian Moons eXploration mission MMX**, which is due to launch in 2026. MMX will survey both moons while also landing a small rover on Phobos and acquiring samples to return to Earth.

Moon of Fear

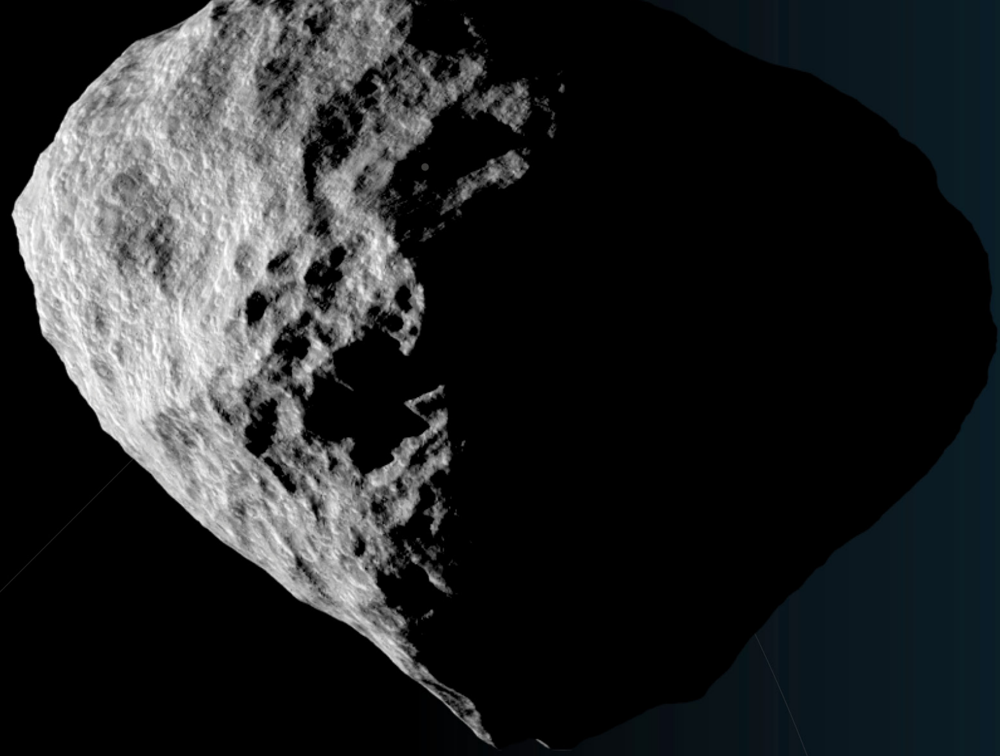
Orbiting 23 460 km from Mars, Deimos (its name coming from the Greek for 'Fear') is the farther and smaller of the two martian moons. The lumpy body has a diameter of 12.4 km across and has a dark surface reminiscent of C-type asteroids. One theory is that both Deimos and its fellow martian moon Phobos are in fact captured asteroids from the main Asteroid belt. Their surface characteristics have features in common with the planet below them however, conversely suggesting an impact-based origin.

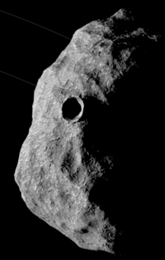






HERA GROUND SEGMENT



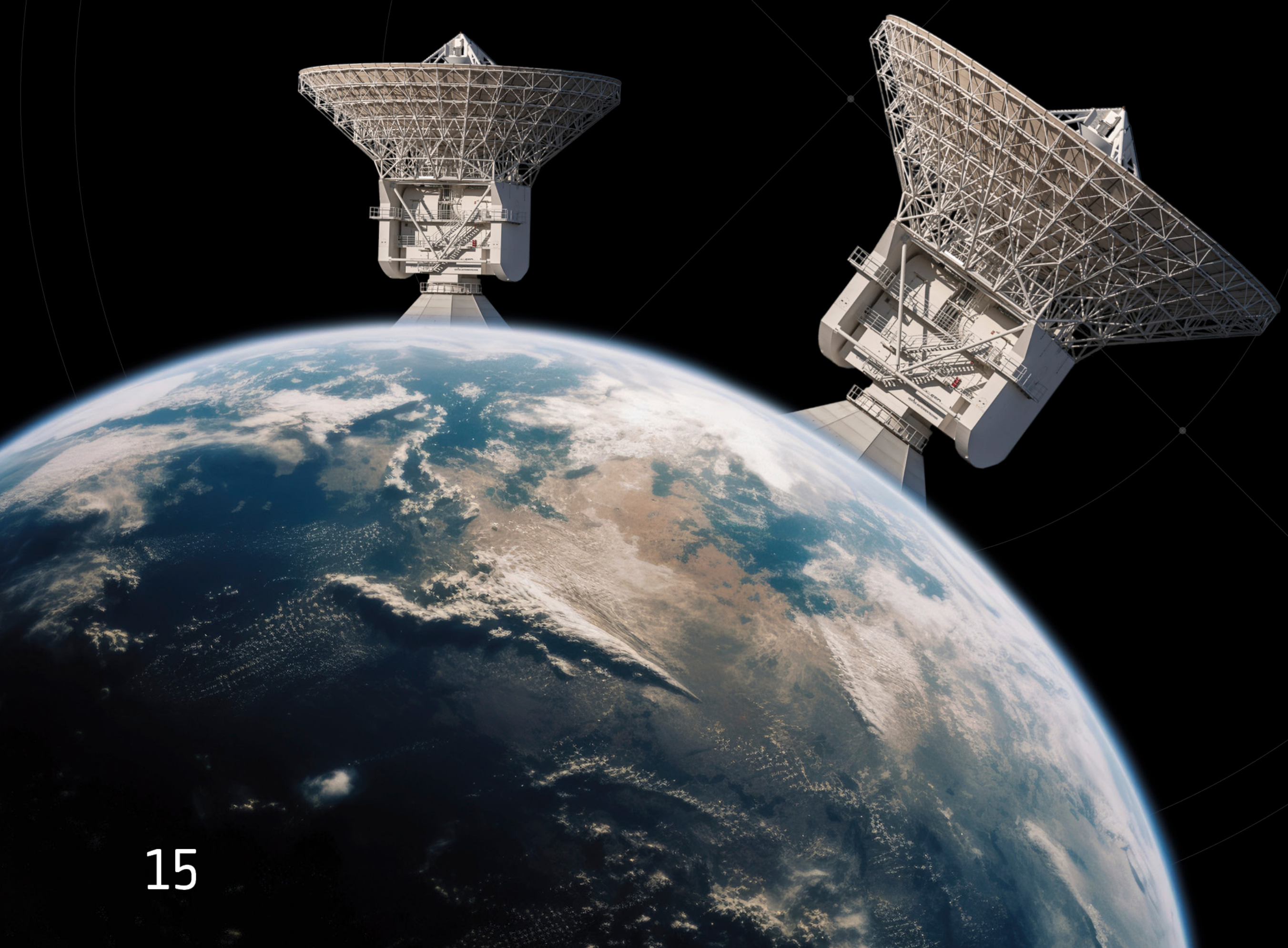


Hera will be controlled from the **European Space Operations Centre, ESA's mission control centre** in Darmstadt, Germany.

→ Contact will be maintained using ESA's trio of 35-m Deep Space Antennas, located in Cebreros (Spain), Malargüe (Argentina) and New Norcia (Australia).

→ During Hera's Launch and Early Orbit Phase additional coverage will be offered from NASA's Deep Space Network stations at Goldstone (US) and Canberra (Australia).

→ Once Hera deploys its Juventas and Milani CubeSats, these will be overseen from a purpose-built facility at ESA's European Space Security and Education Centre (ESEC), at Redu in Belgium, with Hera serving as a relay for signals to and from the CubeSat pair.



Commanding Hera's CubeSats

The focal point for oversight of Hera's CubeSats will be ESA's ESEC at Redu in Belgium. As well as serving as a ground station since 1968, the site specialises in control of small satellites, including ESA's Proba fleet, and CubeSat development and testing.

Juventas and Milani will be operated by their dedicated control teams from a purpose-built facility at the site.

Orbit determination for Hera and its CubeSats is carried out by ESOC's Flight Dynamics team in Germany. Mission planning for the CubeSats is carried out by the French space agency, CNES, using inputs from the teams at the CubeSat mission operations centre at Redu. The Hera spacecraft will serve as a relay for signals to and from the CubeSat pair via their inter-satellite links.

HERA: MADE IN EUROPE

Hera's overall mission cost is **€350 million** which includes spacecraft and payload development, launcher procurement and operations. Around **100 European companies and institutes across 18 ESA Member States** are involved in making Hera happen. Here are the leading contributors by country in the consortium, working with multiple subcontractors in turn:

→ **Germany - OHB** led Hera's industrial consortium for ESA, including responsibility for the overall spacecraft design, development, assembly and testing. **HPS** has produced Hera's High Gain Antenna, with **INVENT** making its main reflector dish and spacecraft composite panels. **DSi Aerospace** made Hera's Mass Memory Unit, storing instrument and computer data. **Jena-Optronik** produced Hera's Asteroid Framing Cameras while Azur Space supplied Hera's solar cells.

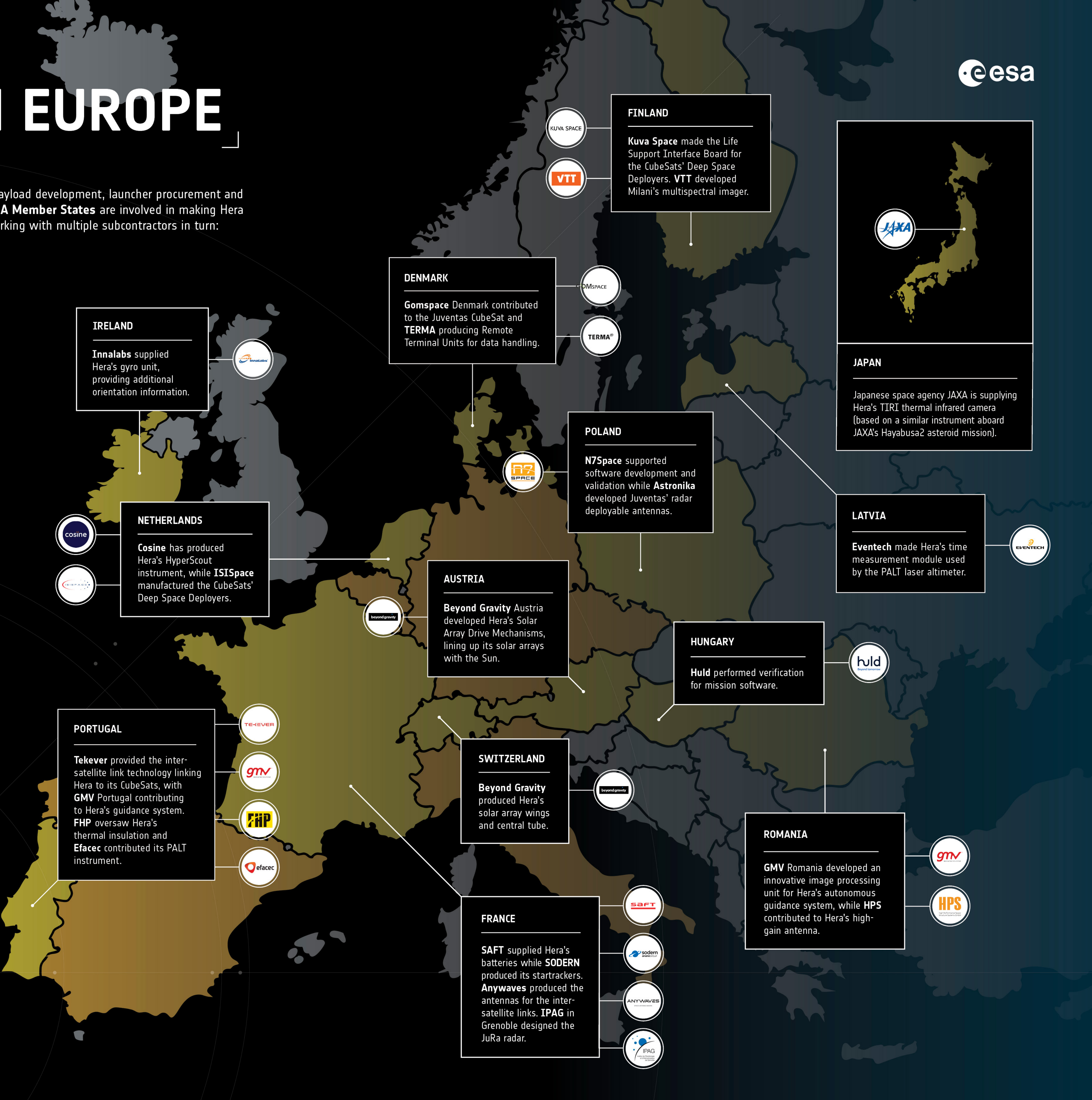
→ **Italy - OHB Italia** developed the electrical power subsystem and led the spacecraft harness design. **Avio** was responsible for integrating and testing Hera's propulsion subsystem while **Leonardo** integrated Hera's photovoltaic assembly. **Tyvak International** designed, developed, assembled and tested the Milani CubeSat, while INAF developed its dust detector. **TSD Space** developed Hera's Spacecraft Monitoring Camera.

→ **Belgium - Redwire Space** led the data handling subsystem including Hera's onboard computer while **SPACEBEL** developed the spacecraft central software, various simulation systems and the Cubesats' Mission Control Centre. **Thales Alenia Space** Belgium developed the power distribution and control unit as well as components for the communication subsystem. The **Royal Observatory of Belgium** developed Juventas CubeSat's GRASS gravimeter and, with **VITO**, contributed to the data processing and calibration of JAXA's Thermal Infrared Imager.

→ **Spain - GMV** led Hera's guidance, navigation and control system, with **EMXYS** developing Juventas's GRASS gravimeter electronics. **SENER** produced Hera's low-gain antennas while **Thales Alenia Space** Spain led the communications subsystem design.

→ **Czechia - OHB Czechspace** led the spacecraft structure subsystem design while **GLE** manufactured Hera's harness – its subsystem-and-component-connecting wiring.

→ **Luxembourg - Gomspace** had responsibility for the Juventas CubeSat design, integration and testing, with **Emtronix** developing the CubeSat's JuRa payload.



IRELAND

Innalabs supplied Hera's gyro unit, providing additional orientation information.

NETHERLANDS

Cosine has produced Hera's HyperScout instrument, while **ISISpace** manufactured the CubeSats' Deep Space Deployers.

PORTUGAL

Tekever provided the inter-satellite link technology linking Hera to its CubeSats, with **GMV** Portugal contributing to Hera's guidance system. **FHP** oversaw Hera's thermal insulation and **Efacec** contributed its PALT instrument.

DENMARK

Gomspace Denmark contributed to the Juventas CubeSat and **TERMA** producing Remote Terminal Units for data handling.

FINLAND

Kuva Space made the Life Support Interface Board for the CubeSats' Deep Space Deployers. **VTT** developed Milani's multispectral imager.

POLAND

N7Space supported software development and validation while **Astronika** developed Juventas' radar deployable antennas.

AUSTRIA

Beyond Gravity Austria developed Hera's Solar Array Drive Mechanisms, lining up its solar arrays with the Sun.

SWITZERLAND

Beyond Gravity produced Hera's solar array wings and central tube.

FRANCE

SAFT supplied Hera's batteries while **SODERN** produced its startrackers. **Anywaves** produced the antennas for the inter-satellite links. **IPAG** in Grenoble designed the JuRa radar.

HUNGARY

Huld performed verification for mission software.

ROMANIA

GMV Romania developed an innovative image processing unit for Hera's autonomous guidance system, while **HPS** contributed to Hera's high-gain antenna.

LATVIA

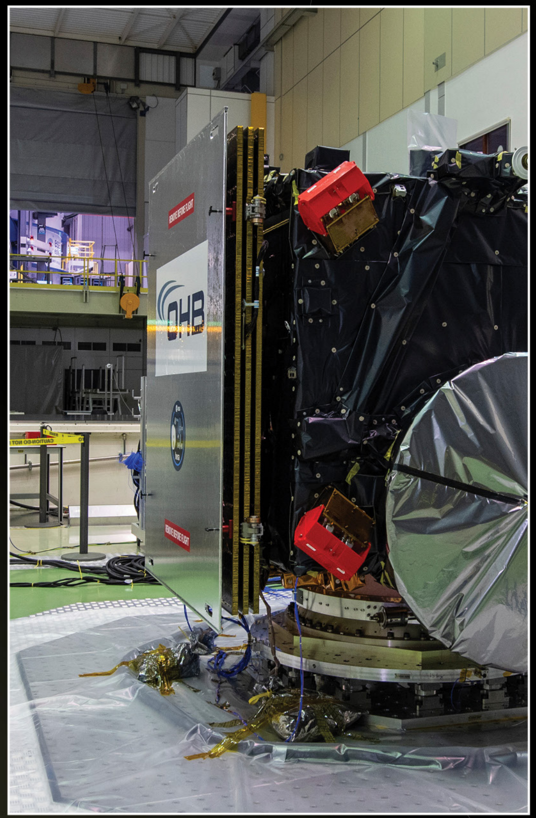
Eventech made Hera's time measurement module used by the PALT laser altimeter.

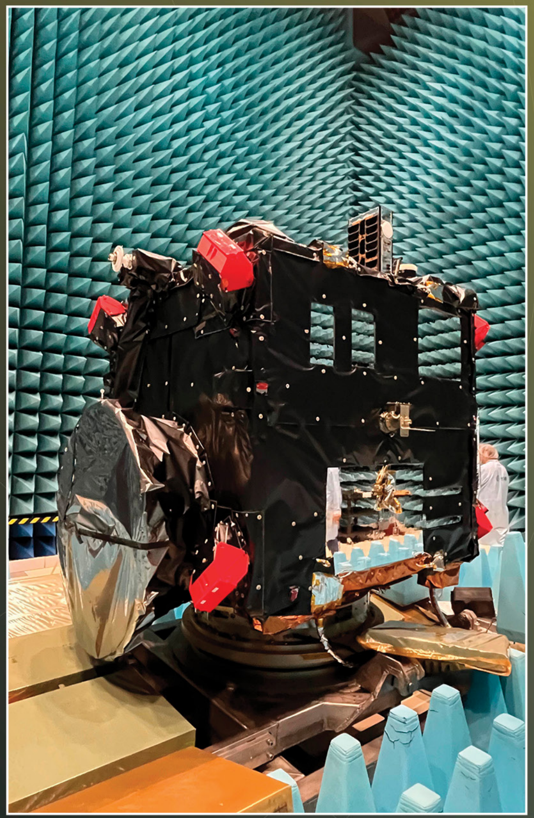
JAPAN

Japanese space agency JAXA is supplying Hera's TIRI thermal infrared camera (based on a similar instrument aboard JAXA's Hayabusa2 asteroid mission).

TESTING TIMES

Hera's readiness for space was put to the test in a 3000 sq. m cleanroom complex nestled in sandy dunes along the Dutch coast: the **ESA ESTEC Test Centre** in Noordwijk, Europe's largest satellite test site. Hera arrived here at the end of August 2023, just over a year before its planned launch. A rapid schedule of testing was to follow:





Solar array deployment – An initial 'cold deployment' saw the arrays unfolded by hand to confirm they fit correctly, followed by a 'hot deployment' where the arrays were deployed autonomously. The arrays were supported by a frame for testing because they are built for weightlessness.

Shaker testing – The spacecraft was put onto ESA's 640 kN QUAD shaker, whose metal plate is moved vertically by a quartet of water-cooled electrodynamic shakers, replicating launch vibrations. Potentially harmful internal resonances were also detected with a 'sine' sweep gradually building in frequency and amplitude.

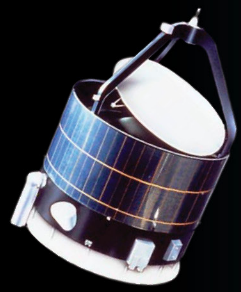
Acoustic testing – Hera was shut inside ESA's Large European Acoustic Facility, LEAF, to be blasted with noise. This is Europe's largest and most powerful sound system, fitted with a quartet of noise horns that can generate more than 154 decibels of extreme volume, to ensure Hera can survive the sound of its own launch.

Thermal vacuum testing – Hera was placed in the Phenix vacuum chamber for test operations in space-grade vacuum, just a billionth of the atmospheric pressure outside. The spacecraft sat within a thermal tent inside the chamber so its surrounding temperature could be brought up and down, checking that Hera can maintain an optimal operating temperature.

Electromagnetic compatibility testing – Hera and its CubeSats were closed inside the steel-walled Maxwell test chamber, lined with radio-absorbing pyramids to simulate the endless void of space. As well as checking if the three spacecraft can operate without internal radio interference, their inter-satellite link system was also put to the test.

ESA MISSIONS TO SMALL BODIES

Hera is only the latest in a **series of ESA spacecraft exploring small bodies in the Solar System**, with follow-on missions planned for the coming years.



Giotto
(launched 1985)

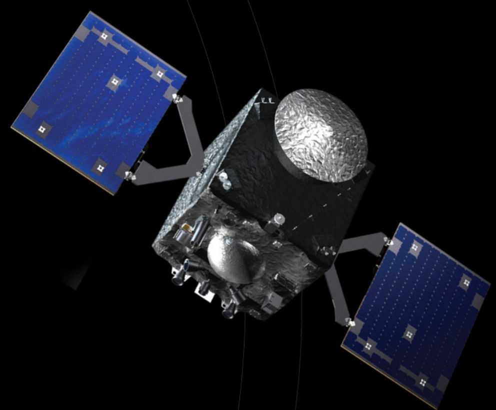
Launched as part of an international effort to investigate the return of **Comet Halley** on its 76-year orbit, the spin-stabilised Giotto probe ventured to within 596 km of the famous comet's nucleus. The spacecraft sustained hundreds of dust strikes, but revealed a **lumpy, unexpectedly dark, nucleus** 15 km long and 7-10 km wide. Giotto went on to explore a second, less active comet, Comet Grigg-Skjellerup.

Rosetta
(launched 2004)

Following a decade-long odyssey during which two asteroid flybys took place, Rosetta rendezvoused with **Comet 67P/Churyumov-Gerasimenko**. It studied the comet nucleus and its surrounding environment for nearly two years. Rosetta also set down its **Philae lander on the comet's surface** and performed the **first radar sounding of a cometary interior**.

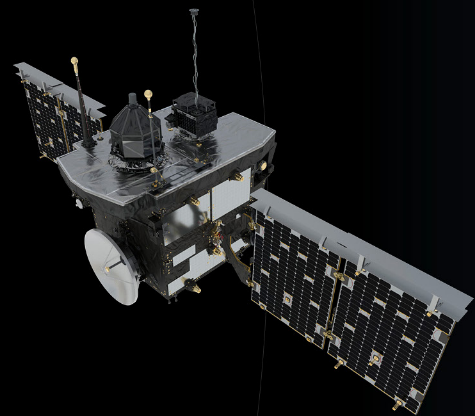
Hera
(to be launched 2024)

Hera is about two thirds Rosetta's size and a third of its mass. However Hera has various elements in common with its comet-chasing predecessor. The spacecraft will fly the same kind of hyperbolic arcs around its target asteroid and **Hera's Juventas CubeSat carries a descendant of Rosetta's radar instrument**.



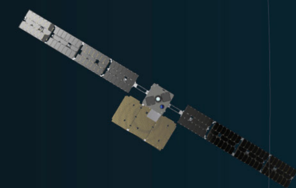
Ramses
(to be launched 2028)

Ramses – or **Rapid Apophis Mission for SEcurity and Safety** – is a candidate ESA Space Safety mission, prepared for consideration by ESA's Ministerial Council in 2025. Based on the Hera platform, Ramses is intended to **perform a rendezvous with 99942 Apophis, a potentially hazardous asteroid** with a diameter of about 340 m. On 13 April 2029 Apophis will approach Earth at a distance of less than 32 000 km. Ramses (carrying two CubeSats) would intercept the asteroid ahead of its flyby, allowing the observation of possible physical property changes as a result of Earth tidal forces.



Comet Interceptor
(to be launched 2029)

Comet Interceptor will be a **co-passenger with ESA's exoplanet-studying Ariel mission**, for delivery to the Sun-Earth Lagrange Point L2. Here the spacecraft will linger until its targets appears: **an as-yet undiscovered comet headed sunward for the first time, containing pristine matter from the early Solar System**. Built in OHB in Italy, the spacecraft derives its platform from the Hera mission, and **carries two smaller spacecraft** with it (one from JAXA).



M-Argo
(to be launched by decade's end)

ESA's **suitcase-sized** 'Miniaturised Asteroid Remote Geophysical Observer', or M-Argo, would be ESA's smallest scale asteroid explorer. A 12-unit CubeSat, M-Argo would **make its way autonomously to a chosen asteroid**, using a multispectral camera and a laser altimeter **to look for asteroid resources** such as hydrated minerals that could be extracted in future. M-Argo could use its flat reflectarray antenna to return science data to Earth from up to 150 million km away.

HERA ONLINE

ESA resources

ESA's Hera website
https://www.esa.int/hera

The Incredible Adventures of the Hera mission animated video series
https://www.esa.int/ESA_Multimedia/Sets/The_Incredible_Adventures_of_the_Hera_mission/(result_type)/videos

Hera photo gallery
https://www.esa.int/ESA_Multimedia/Missions/Hera/(result_type)/images

Hera video gallery
https://www.esa.int/ESA_Multimedia/Missions/Hera/(result_type)/videos

Hera videos for professionals
https://www.esa.int/esatv/content/search?SearchText=Hera&result_type=videos_broadcast&SearchButton=Go

ESA Photolibrary for professionals
https://photolibrary.esa.int/home-page/

Hera on ESA Flickr
https://www.flickr.com/photos/esa_events/albums/72177720319720340

ESA Web TV
https://www.esa.int/ESA_Multimedia/ESA_Web_TV

ESA's original Hera mission trailer with Sir Brian May
https://www.esa.int/ESA_Multimedia/Videos/2019/06/Hera_ESA_s_planetary_defence_mission

Instructions to make your own Hera LEGO model
https://esamultimedia.esa.int/docs/spacesafety/Hera_LEGO_instructions.pdf

Hera partners & institutes

Hera science community website
https://www.heramission.space/

Hera prime contractor OHB
https://www.ohb.de/

Japan Aerospace Exploration Agency JAXA's Hera website
https://hera.isas.jaxa.jp/wp-hera/en/

NASA's DART webpage
https://science.nasa.gov/mission/dart/

Johns Hopkins University Applied Physics Laboratory DART mission website
https://dart.jhuapl.edu/

ESA social media channels talking about Hera

ESA Twitter/X:

- ESA Hera
https://x.com/ESA_Hera

- ESA
https://x.com/ESA

- ESA Operations
https://x.com/esaoperations

- ESA Technology
https://x.com/esa_tech

ESA Facebook
https://www.facebook.com/EuropeanSpaceAgency/

ESA Instagram
https://www.instagram.com/europeanspaceagency/

ESA LinkedIn:

- ESA
https://www.linkedin.com/company/european-space-agency

- ESA Operations
https://www.linkedin.com/company/esa-operations

- ESA Space Safety
https://www.linkedin.com/showcase/esa-space-safety

- ESA Technology
https://www.linkedin.com/company/esatechnology

ESA Pinterest
https://nl.pinterest.com/EuropeanSpaceAgency/

ESA YouTube
https://www.youtube.com/europeanspaceagency

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