bepicolombo

→ INVESTIGATING MERCURY'S MYSTERIES

European Space Agency

ESA'S SPACE SCIENCE MISSIONS

solar system

bepicolombo
Europe's first mission to Mercury will study this mysterious planet's interior, surface, atmosphere and magnetosphere to understand its origins.

cassini-huygens
Studying the Saturn system from orbit, having sent ESA's Huygens probe to the planet's giant moon, Titan.

cluster
A four-satellite mission investigating in unparalleled detail the interaction between the Sun and Earth's magnetosphere.

juice
Jupiter icy moons explorer, performing detailed investigations of the gas giant and assessing the habitability potential of its large icy satellites.

mars express
Europe's first mission to Mars, providing a global picture of the Red Planet's atmosphere, surface and subsurface.

rosetta
The first mission to fly alongside and land a probe on a comet, investigating the building blocks of the Solar System.

soho
Providing new views of the Sun's atmosphere and interior, and investigating the cause of the solar wind.

solar orbiter
A mission to study the Sun up close, collecting high-resolution images and data from our star and its heliosphere.

venus express
The first spacecraft to perform a global investigation of Venus's dynamic atmosphere.

astronomy

cheops
Characterising exoplanets known to be orbiting around nearby bright stars.

euclid
Exploring the nature of dark energy and dark matter, revealing the history of the Universe's accelerated expansion and the growth of cosmic structure.

gaia
Cataloguing the night sky and finding clues to the origin, structure and evolution of the Milky Way.

herschel
Searching in infrared to unlock the secrets of starbirth and galaxy formation and evolution.

hubble space telescope
Expanding the frontiers of the visible Universe, looking deep into space with cameras that can see in infrared, optical and ultraviolet wavelengths.

integral
The first space observatory to observe celestial objects simultaneously in gamma rays, X-rays and visible light.

jwst
A space observatory to observe the first galaxies, revealing the birth of stars and planets, and to look for planets with the potential for life.

lisa pathfinder
Testing technologies needed to detect gravitational waves, in order to understand the fundamental physics behind the fabric of spacetime.

planck
Detecting the first light of the Universe and looking back to the dawn of time.

xmm-newton
Solving the mysteries of the violent X-ray Universe, from enigmatic black holes to the formation of galaxies.

exploration

exomars
Two missions comprising an orbiter to study the martian atmosphere, a landing demonstrator, a surface science platform and a rover to search for life below the surface.

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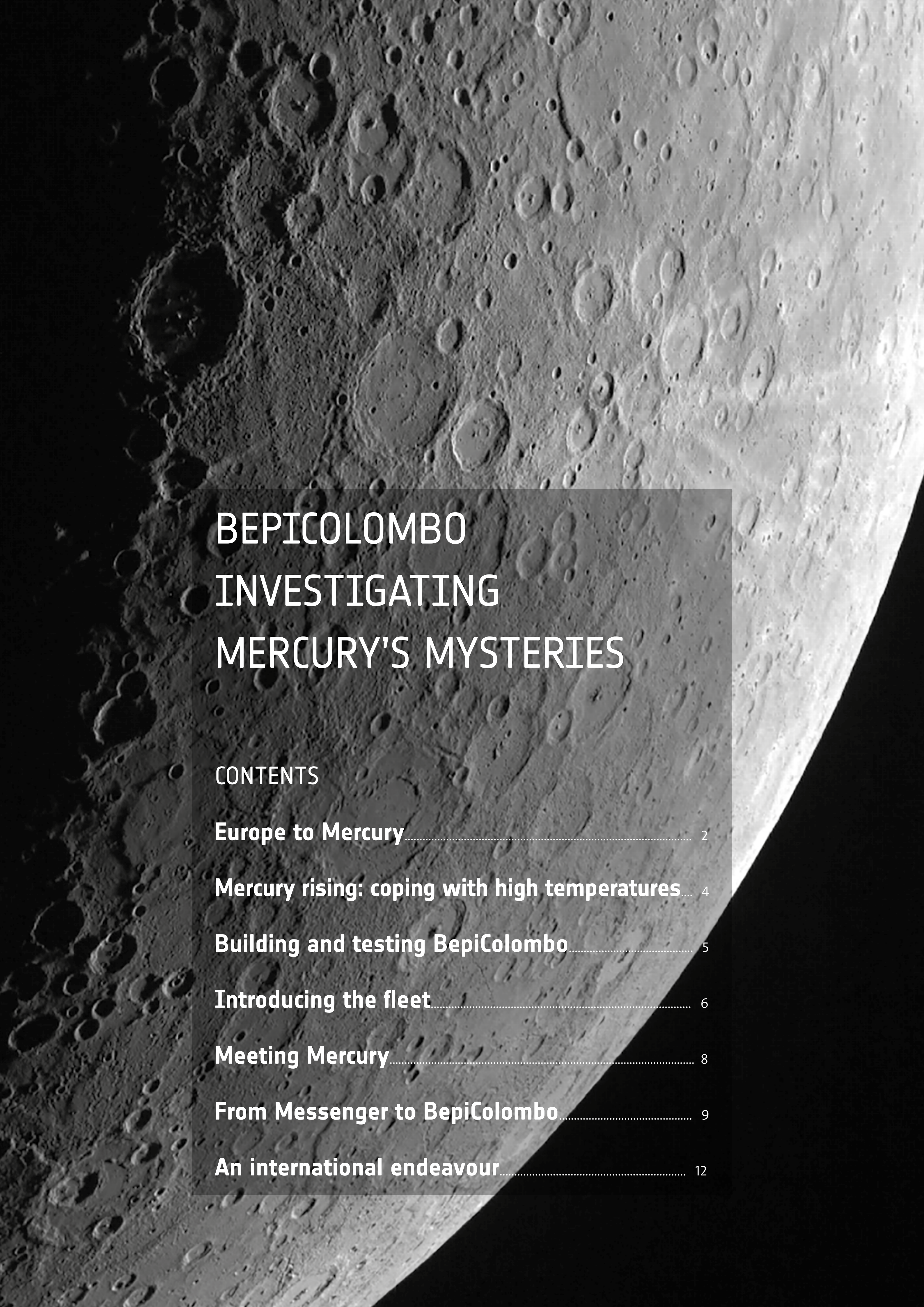

BEPICOLOMBO INVESTIGATING MERCURY'S MYSTERIES

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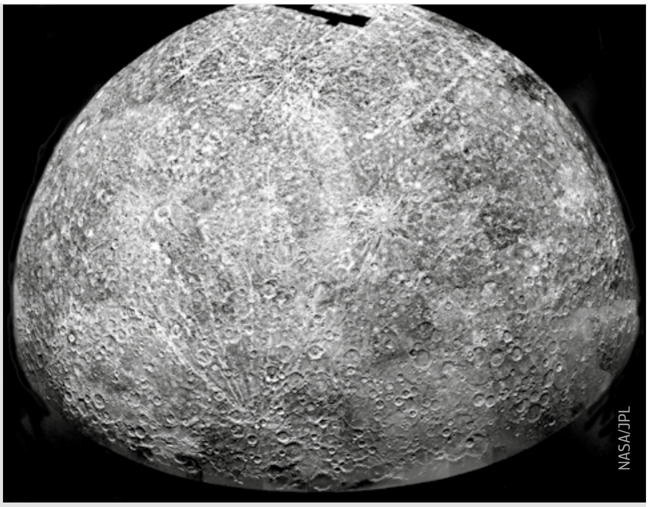
→ EUROPE TO MERCURY



Top: photomosaic of Mercury's southern hemisphere as seen by Mariner-10 in 1974. Bottom: Messenger's view of a part of Mercury not seen by Mariner-10, captured during its first flyby on 14 January 2008

BepiColombo is Europe's first mission to Mercury, the smallest and least explored terrestrial planet in our Solar System. Only two spacecraft have visited Mercury so far: NASA's Mariner-10 and Messenger (MErcury Surface, Space ENvironment, GEochemistry, and Ranging). Mariner-10 was a flyby mission and provided the first close-up images of the planet during three passes in 1974 and 1975. Messenger also conducted three flybys – in 2008 and 2009 – before studying the planet from orbit between March 2011 and April 2015.

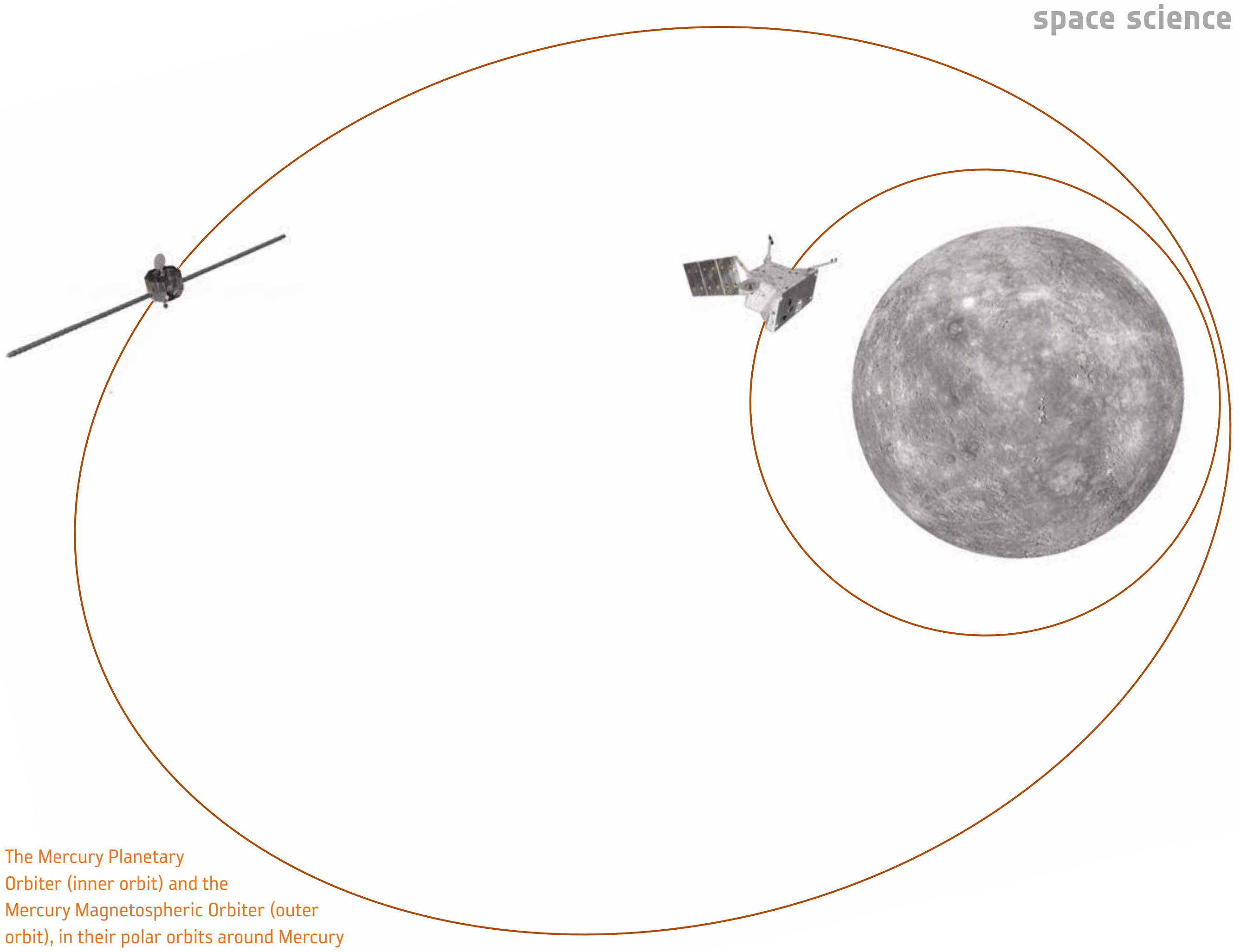
BepiColombo is a joint endeavour between ESA and the Japan Aerospace Exploration Agency, JAXA, and consists of two scientific orbiters: ESA's Mercury Planetary Orbiter (MPO) and JAXA's Mercury Magnetospheric Orbiter (MMO). It will build on the legacy of Messenger, providing complementary and new observations concerning the planet's interior, surface, exosphere and magnetosphere. The data will enable scientists to understand more about the origin and evolution of a planet located close to its parent star, and a better understanding of the overall evolution of our Solar System.

Inner Solar System tour

BepiColombo will be launched on an Ariane 5 from Europe's Spaceport in Kourou, French Guiana. It will use the gravity of Earth, Venus and Mercury, in combination with the thrust provided by electric propulsion, to reach Mercury. Based on an October 2018 launch date, the spacecraft will have a 7.2 year cruise, with one Earth flyby, two Venus flybys and six Mercury flybys before arriving in orbit at the end of 2025.

What's in a name?

The mission is named for the Italian mathematician and engineer Giuseppe (Bepi) Colombo (1920–84). He is known for explaining Mercury's peculiar characteristic of rotating about its own axis three times in every two orbits of the Sun. He also proposed to NASA the interplanetary trajectories that would allow Mariner-10 multiple Mercury flybys, by using gravity assists at Venus for the first time.



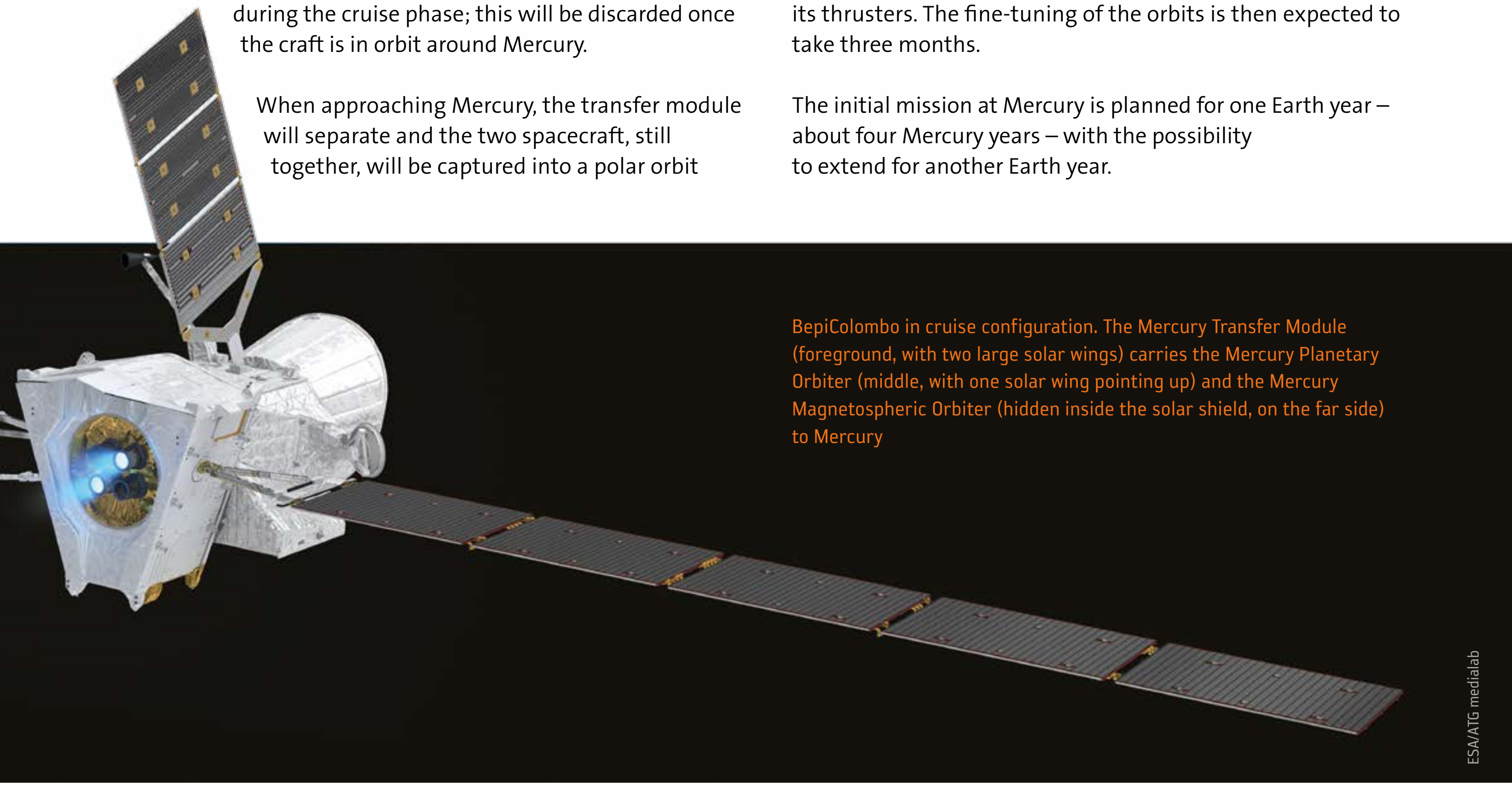
ESA/ATG medialab

The Mercury Planetary Orbiter (inner orbit) and the Mercury Magnetospheric Orbiter (outer orbit), in their polar orbits around Mercury

MPO and MMO will voyage to Mercury together as a single composite spacecraft, with a dedicated transfer module (MTM) providing power and propulsion. A sunshield will protect MMO from solar radiation and overheating during the cruise phase; this will be discarded once the craft is in orbit around Mercury.

When approaching Mercury, the transfer module will separate and the two spacecraft, still together, will be captured into a polar orbit around the planet. Their altitude will be adjusted using MPO's thrusters until MMO's desired elliptical polar orbit of 590 x 11 640 km above the planet is reached. Then MPO will separate and descend to its own 480 x 1500 km orbit using its thrusters. The fine-tuning of the orbits is then expected to take three months.

The initial mission at Mercury is planned for one Earth year – about four Mercury years – with the possibility to extend for another Earth year.



BepiColombo in cruise configuration. The Mercury Transfer Module (foreground, with two large solar wings) carries the Mercury Planetary Orbiter (middle, with one solar wing pointing up) and the Mercury Magnetospheric Orbiter (hidden inside the solar shield, on the far side) to Mercury

ESA/ATG medialab

→ MERCURY RISING: COPING WITH HIGH TEMPERATURES

Most of ESA's previous interplanetary missions have been to relatively cold parts of the Solar System. BepiColombo will be the Agency's first experience of sending a planetary probe close to the Sun. At Mercury it will endure temperatures in excess of 350°C. To cope with this, the spacecraft's external items, such as the antennas, solar arrays, Sun sensors and multilayer insulation, have temperature-resistant outer layers and protective coatings, which were individually qualified to prove their capability.

Despite travelling towards the Sun, the transfer module requires a large solar array, its two wings together totalling 42 m². Because of the high solar intensity, they cannot directly face the Sun without reaching excessively high temperatures, so they instead have to be rotated away from the Sun and therefore still need a large area to meet the power requirements of the spacecraft.

MPO is a three-axis-stabilised spacecraft with one side facing Mercury. It is equipped with a radiator of the largest size compatible with the Ariane 5 fairing diameter. This is specially designed to reflect heat directionally, thus allowing the spacecraft to fly at low altitude over the hot surface of the planet. Heat generated by spacecraft subsystems and payload components, as well as heat coming from the Sun and Mercury and 'leaking' through the blankets into the spacecraft, is carried away to the radiator by heat pipes. Most science instruments are mounted on the side of the spacecraft pointing at Mercury, with certain instruments or sensors located directly at the main radiator, to achieve the low detector temperatures needed for sensitive observations.

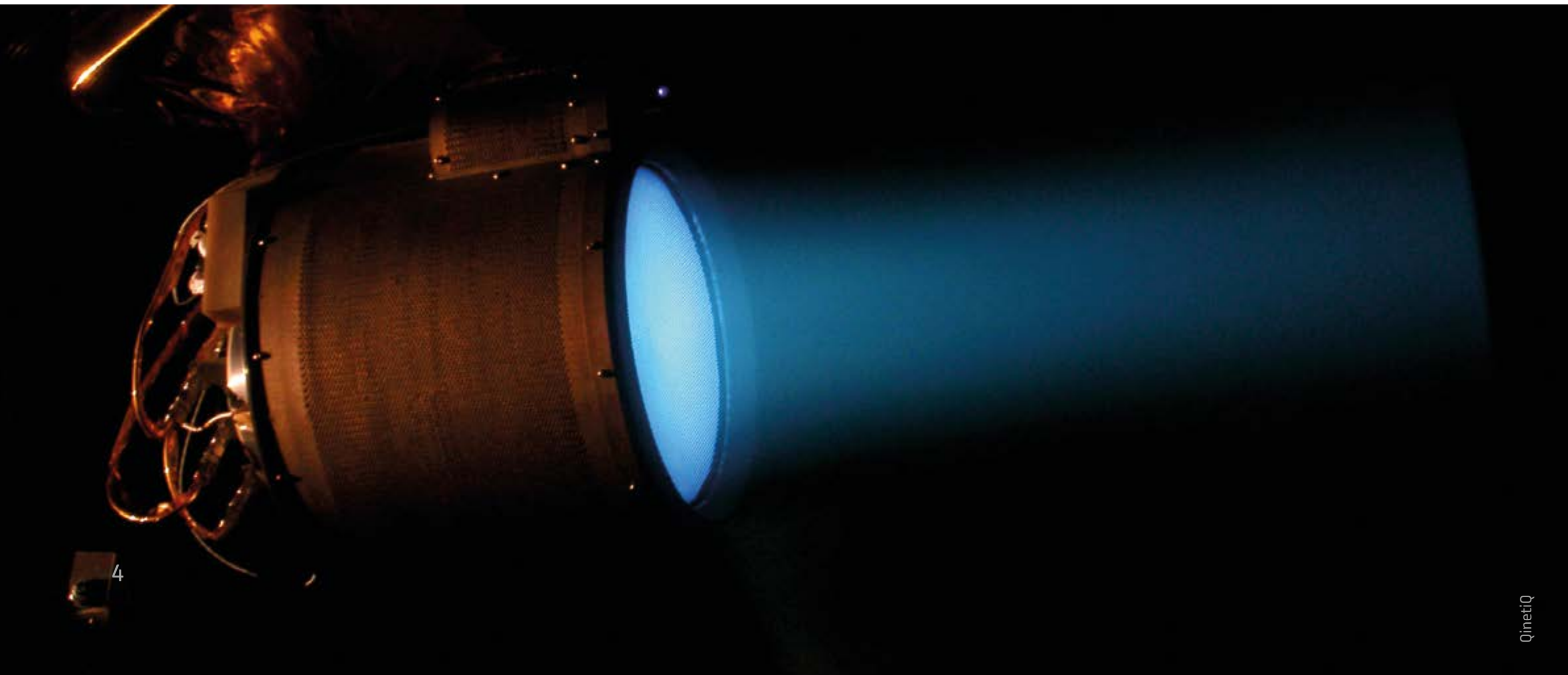
MMO is an octagonal spin-stabilised spacecraft; its spin axis will be nearly perpendicular to Mercury's orbital plane around the Sun, ensuring that the 'top' and 'bottom' of the spacecraft are never Sun-pointed. Each of the eight side panels is fitted with solar cells, with the areas not covered equipped instead with a mirror finish to reflect solar radiation. The spinning nature of the craft also helps to evenly distribute the heat, like roasting a pig on a spit. Because it will not be spinning during the cruise phase, it is thermally protected by the sunshield for the journey.

Electric propulsion to Mercury

The Sun's enormous gravity presents a challenge in placing a spacecraft into a stable orbit around Mercury: even more energy is needed than for sending a mission to Pluto. The spacecraft will leave Earth's gravity on an Ariane 5, and will use gravity assists at Earth, Venus and Mercury.

MTM's ion thrusters are used during the cruise phase and for delivering the two spacecraft to Mercury. Ion propulsion was first demonstrated by ESA's SMART-1 mission to the Moon. The low-thrust nature of the ion propulsion means that it will take a long time to reduce the velocity of BepiColombo as it approaches the Sun.

An ion thruster during a test firing. Four thrusters are installed on the Mercury Transfer Module



QinetiQ

→ BUILDING AND TESTING BEPICOLOMBO

The various components of BepiColombo have undergone significant testing at ESA's test centre in the Netherlands to prove they can withstand the violent shaking occurring during launch, the harsh radiation environment of space, and the high temperatures that will be encountered close to the Sun once orbiting Mercury.

MPO undergoing electromagnetic compatibility, radiated emission and susceptibility testing

The MTM Structural and Thermal Model in the Large Space Simulator, ahead of a 12-day Sun-simulation test

The Structural and Thermal Model of the composite spacecraft fully integrated into the configuration in which BepiColombo will be launched. From top to bottom: MMO inside the solar shield, MPO and MTM, mounted on a test system (bottom) to determine the position of the spacecraft's centre of gravity

MMO

Spacecraft vital statistics

	Composite spacecraft (at launch)	ESA's MPO (in Mercury orbit)	JAXA's MMO (in Mercury Orbit)
Dimensions	3.9 x 3.6 x 6.3 m; solar wings (deployed): 30.4 m	Main body: 2.4 x 2.2 x 1.7 m; radiator width: 3.7 m, solar wing (deployed): 7.5 m	1.8 m diameter, 1.1 m high, length of masts: 5 m each, length of antennas: 15 m each
Mass	4100 kg, including 1400 kg of propellant	1230 kg, including 85 kg science payload	255 kg, including 45 kg science payload
Science instruments		11	5
Payload power		100–180 W	90 W
Stabilisation	3-axis stabilised	3-axis stabilised	15 rpm spin-stabilised
Orientation	Sun-pointing	Nadir-pointing	Spin axis 90° to Sun
Orbit	Heliocentric	Polar, 2.3 h period; 480 x 1500 km	Polar, 9.3 h period; 590 x 11 640 km
Communication	Via MPO	1.0 m X-/Ka-band high-gain steerable antenna	0.8 m X-band phased array high-gain antenna

→ INTRODUCING THE FLEET

Mercury Planetary Orbiter

BELA: BepiColombo Laser Altimeter
Characterising and measuring the topography and surface morphology of Mercury to create digital terrain models (PI[1]: Nicolas Thomas, University of Bern, Switzerland, & Hauke Hussmann, DLR Institut für Planetenforschung, Berlin, Germany)

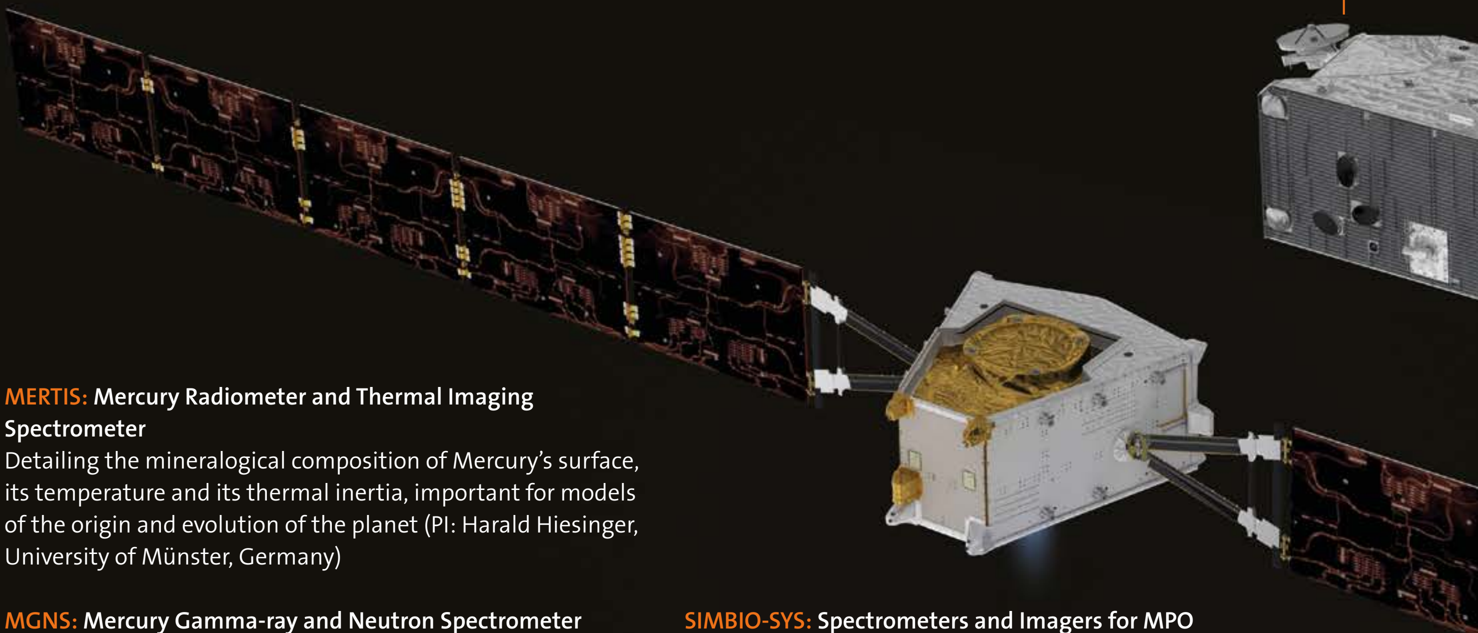
ISA: Italian Spring Accelerometer
Providing information on Mercury's interior structure and testing Einstein's theory of General Relativity to an unprecedented level of accuracy (PI: Valerio Iafolla, INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy)

MPO-MAG: Magnetic Field Investigation
Measuring Mercury's magnetic field, the interaction of the solar wind, and the formation and dynamics of the magnetosphere, and understanding the origin, evolution and current state of the planet's interior (PI: Karl-Heinz Glassmeier, Technische Universität Braunschweig, Germany)

MORE: Mercury Orbiter Radio science Experiment
Determining the gravity field of Mercury, and the size and physical state of its core; measuring the gravitational oblateness of the Sun and testing the most advanced interplanetary tracking system ever built (PI: Luciano Iess, University of Rome 'La Sapienza', Italy)

PHEBUS: Probing of Hermean Exosphere by Ultraviolet Spectroscopy
Characterising Mercury's exosphere composition and dynamics and searching for surface ice layers in permanently shadowed regions of high-latitude craters (PI: Eric Quémerais, LATMOS-IPSL, Guyancourt, France)

SERENA: Search for Exosphere Refilling and Emitted Neutral Abundances (neutral and ionised particle analyser)
Studying the gaseous interaction between Mercury's surface, exosphere, magnetosphere and the solar wind and interplanetary medium (PI: Stefano Orsini, INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy)



MERTIS: Mercury Radiometer and Thermal Imaging Spectrometer
Detailing the mineralogical composition of Mercury's surface, its temperature and its thermal inertia, important for models of the origin and evolution of the planet (PI: Harald Hiesinger, University of Münster, Germany)

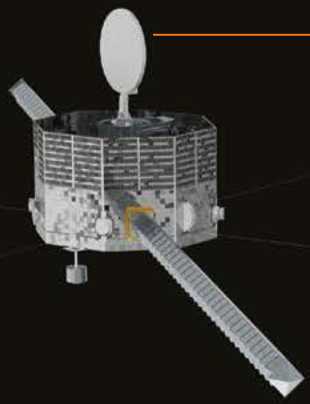
MGNS: Mercury Gamma-ray and Neutron Spectrometer
Determining the elemental compositions of the surface and subsurface of Mercury, and identifying the regional distribution of volatiles in permanently shadowed polar regions (PI: Igor Mitrofanov, Russian Academy of Sciences, Space Research Institute, IKI, Moscow, Russian Federation)

MIXS: Mercury Imaging X-ray Spectrometer
Producing a global map of Mercury's surface atomic composition at high spatial resolution (PI: Emma Bunce, Space Research Centre, University of Leicester, UK)

SIMBIO-SYS: Spectrometers and Imagers for MPO BepiColombo Integrated Observatory
Examining with stereo and colour imaging, and spectroscopic analysis, Mercury's surface geology, volcanism, global tectonics, surface age and composition (PI: Gabriele Cremonese, INAF-Osservatorio Astronomico di Padova, Italy)

SIXS: Solar Intensity X-ray and particle Spectrometer
Monitoring the flux of X-rays and particles of solar origin (PI: Juhani Huovelin, University of Helsinki, Department of Physics, Finland)

[1] PI = Principal Investigator



Mercury Magnetospheric Orbiter

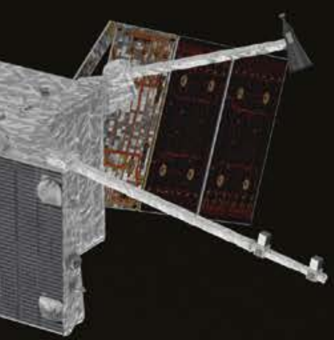
MMO-MAG: Mercury Magnetometer
Providing a detailed description of Mercury's magnetosphere and of its interaction with the planetary magnetic field and the solar wind (PI: Wolfgang Baumjohann, Austrian Space Science, Graz, Austria)

MPPE: Mercury Plasma Particle Experiment
Seven sensors studying plasma and energetic particles in the magnetosphere and the interaction between the solar wind and Mercury's magnetosphere (PI: Yoshifumi Saito, Institute of Space and Astronautical Science, Kanagawa, Japan)

PWI: Mercury Plasma Wave Instrument
In situ and remote-sensing analysis of electric fields, plasma waves and radio waves in Mercury's plasma environment (PI: Yasumasa Kasaba, Tohoku University, Sendai, Japan)

MSASI: Mercury Sodium Atmosphere Spectral Imager
Measuring the abundance, distribution and dynamics of sodium in Mercury's exosphere to investigate its sources and related processes (PI: Ichiro Yoshikawa, University of Tokyo, Japan)

MDM: Mercury Dust Monitor
Studying the distribution of interplanetary dust in the orbit of Mercury (PI: Masanori Kobayashi, Chiba Institute of Technology, Japan)



MMO Sunshield and Interface Structure (MOSIF)

This ESA component will provide thermal protection and mechanical and electrical interfaces for the MMO during the journey to Mercury orbit

Mercury Transfer Module

This ESA module will carry the two orbiters to Mercury using solar-electric propulsion (ion thrusters)

ESA/ATG medialab

→ MEETING MERCURY

NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Global colour mosaic of Mercury

Of the four inner Solar System planets, Mercury is the smallest and most dense, its vast iron core dominating its internal structure. As the closest planet to the Sun it experiences extreme temperature variations at its surface, from about +430°C on the day side to –180°C on the night side, and even lower in permanently shadowed icy craters. Its ancient, cratered surface shows signs of past volcanic and tectonic activity, and is heavily weathered by the harsh space environment.

Understanding Mercury is crucial to developing a better understanding of the early processes in the inner Solar System, including how our own planet Earth formed and evolved. BepiColombo will reveal information on the origin and evolution of a planet orbiting close to its parent star, which also has a direct relevance to planets in other star systems.

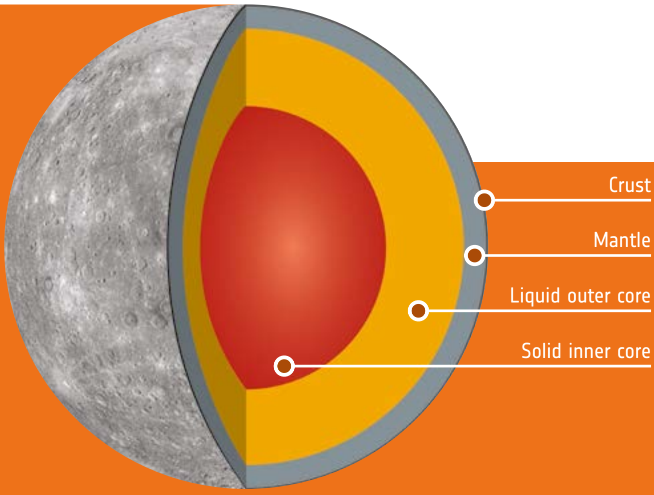
The mission will study all aspects of Mercury, from the structure and dynamics of its magnetosphere and how it interacts with the solar wind, to the properties of the planet's large iron core and the origin of the planet's magnetic field. It will make global maps of the surface chemistry, and image features in order to better understand geological processes and how the surface has been modified over time by impact craters, tectonic activity, volcanism and polar ice deposits.

It will also be able to test Einstein's theory of General Relativity to an unprecedented level of accuracy. Massive objects such as the Sun cause a distortion in spacetime, which may be recorded in the frequency shift of radio signals travelling through space. Microwave radio links to and from the spacecraft will be able to determine BepiColombo's position to an accuracy of 15 cm, making it one of the most advanced interplanetary tracking systems ever built. Furthermore, the spacecraft's accelerometer will measure all inertial accelerations caused by the incoming visible solar radiation and by the planet's albedo acting on the orbiter, such that any relativistic forces can be determined very precisely. This is essential for accurate determination not only of the spacecraft's orbit, but as a consequence, also of the position of the planet as it moves around the Sun.

The spacecraft will also determine the gravity field of Mercury and its time variations from solar 'tides', along with local gravity anomalies, which will provide crucial constraints to models of the planet's internal structure.

Mercury vital statistics

Diameter: 4879 km (0.38 Earths)
Surface area: 74.8 million square km (0.147 Earths)
Gravity: 3.7 m/s^2 (38% of Earth's gravity)
Mass: 3.3 x 10^{23} kg (0.055 Earths)
Density: 5430 kg/m^3 (Earth: 5515 kg/m^3)
Distance from Sun: 46 001 200 – 69 816 900 km (Earth: 149 597 900 km)
Solar irradiance: 6272 – 14 448 W/m^2 (Earth: 1366 W/m^2)
Day: 58 Earth days to turn once on its axis (Mercury rotation period); 176 days for the Sun to return to the same spot in the sky, as seen from a fixed point on the surface (Mercury solar day)
Year: 88 Earth days to orbit the Sun (Mercury orbital period)
Obliquity to orbit (axial tilt): 0.01° (i.e. the equator of Mercury nearly coincides with the orbital plane of the planet)
Surface temperature: –180°C to 430°C
Atmosphere: Very thin ($<10^{-14}$ bar), including oxygen (42%), sodium (29%), hydrogen (22%), helium (6%) and trace gases
Moons: None



The internal structure of Mercury is dominated by a large solid iron core, and a liquid outer core of iron, sulphur and silicates. An iron-poor silicate mantle lies below a 10 km-thick silicate crust

Mercury surface: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

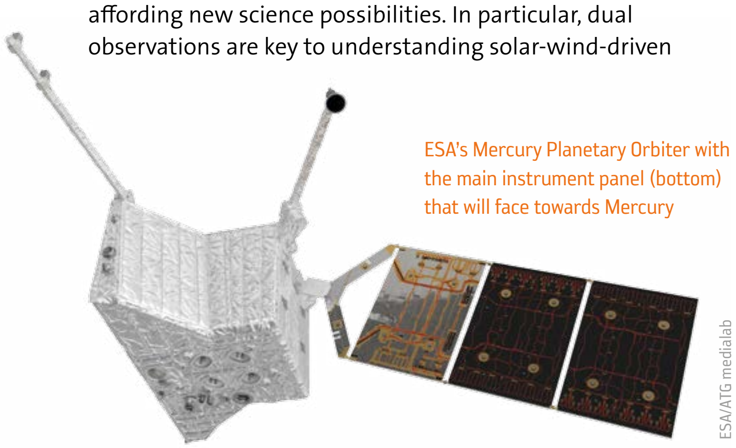
→ FROM MESSENGER TO BEPICOLOMBO

JAXA's Mercury Magnetospheric Orbiter, with magnetometer mast and antennas

BepiColombo is set to build on the achievements of NASA's Messenger mission, to provide the best understanding of the Solar System's innermost planet to date.

Messenger raised many questions that scientists did not even consider before the mission, which are now left open for BepiColombo to answer. Not only will the new mission provide complementary observations (separated by more than a decade) that will allow any changes to be compared and constrained, but it will also make many new observations.

One obvious difference between the two missions is that BepiColombo comprises two spacecraft in different orbits, affording new science possibilities. In particular, dual observations are key to understanding solar-wind-driven magnetospheric processes, and this will allow unparalleled observations of the planet's magnetic field and the interaction of the solar wind with the planet at two different locations at the same time.



ESA's Mercury Planetary Orbiter with the main instrument panel (bottom) that will face towards Mercury

Mercury is the only rocky planet in our Solar System other than Earth that has a magnetic field today, albeit 100 times weaker than Earth's. Messenger's observations showed that its centre of origin is offset from the centre of the planet by about 20% of its radius. Because ESA's MPO will orbit over the southern hemisphere of Mercury at a significantly lower altitude than achieved by Messenger, which reached its lowest altitude over the northern hemisphere, much more detailed observations of the magnetic field in this hemisphere will be obtained.

The lower southern altitudes will also be important for observations of the surface, in particular of the south polar deposits. BepiColombo will determine the chemistry of the contrasting bright and dark deposits discovered by Messenger in the north polar regions, which are thought to be water-ice.

Because MPO's orbit is not highly elliptical, and the instruments will be mainly pointing directly towards Mercury, errors in height measurements of the surface topography will be reduced. This will allow, for example, improvement of gravity and topography models, as well as give a higher-resolution coverage of surface features.

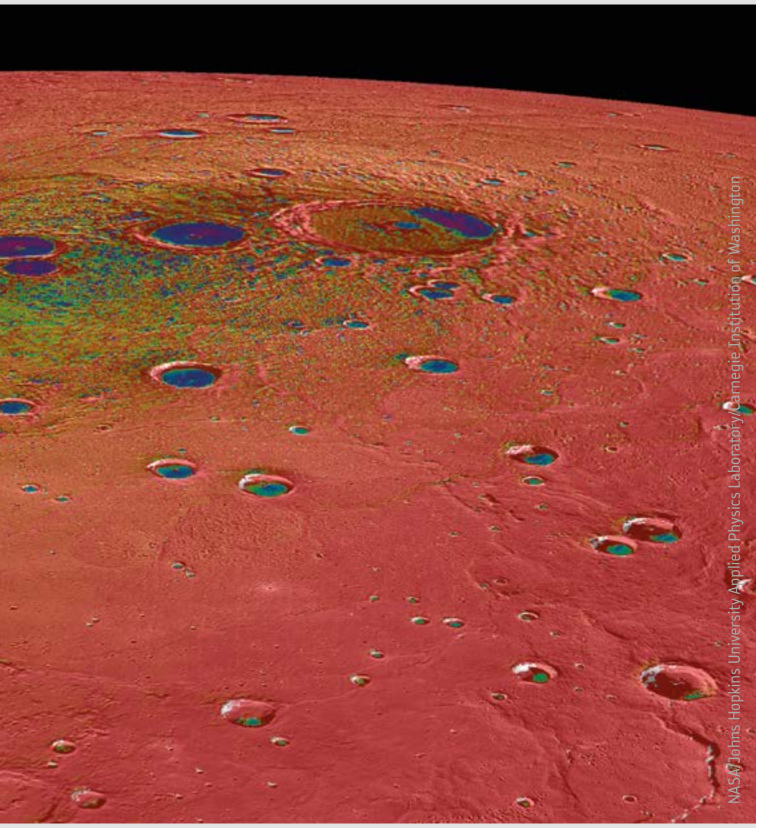
All in a spin

Mercury is unique in the Solar System for many reasons, but one is the fact that it rotates three times about its spin axis for every two orbits around the Sun. This means that any given point on Mercury experiences one day every two years. In addition, the planet's axis has the smallest tilt of any in the Solar System at just 0.01°, but the largest eccentricity: at its furthest point from the Sun it is 1.5 times further away than when it is at its nearest. These characteristics combined give rise to some curious effects.

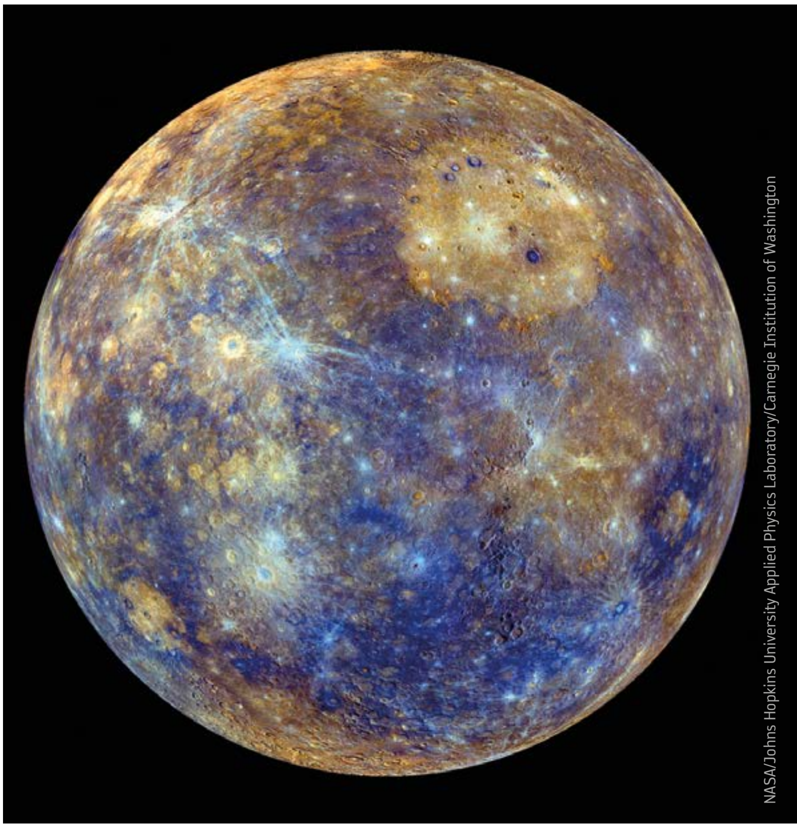
The small obliquity means there are no Earth-like 'seasons'; rather, there are thermal seasons dictated by the distance of the planet from the Sun.

In the polar regions the Sun never rises above some crater bottoms, meaning they are in permanent darkness. At the other end of the scale there are two regions on Mercury's equator, 180° apart, which always have the Sun directly overhead when the planet is closest to the Sun. For an observer located at these points the Sun would appear to be almost stationary overhead for two to three weeks, because the planet's orbital velocity equals that of its rotational velocity for that period.

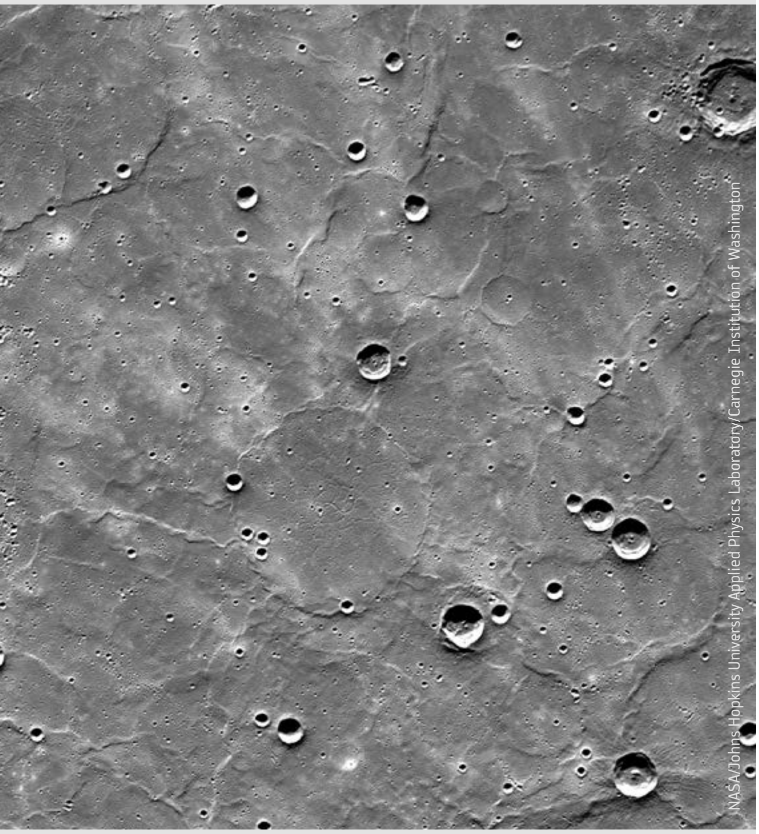
At certain points on Mercury's surface an observer would be able to see the Sun rise about halfway, then set slightly, and then rise again before setting again, all in one day.



Temperature map of Mercury's north polar region, showing the extreme contrast between scorching temperatures of over 127°C on the surface (red) and a frigid –223°C (purple) in permanently shadowed craters. The largest crater in the image, near top centre and named Prokofiev, has a diameter of 112 km



Enhanced colour image of Mercury, emphasising differences in surface composition. Dark blues = dark terrain (see: What makes Mercury dark? on page 11); light blue/grey/white = younger, fresher material; yellow = 'intermediate' terrain, typically lavas



Volcanic plains, with wrinkled ridges: sinuous features that form when lavas cool and subside, causing the crust to contract horizontally

New surface features

One open question from Messenger is the origin of recently identified features termed 'hollows' – shallow, irregular depressions that appear to be unique to Mercury. They appear bright and young, but the exact process of their formation is an active area of research: their appearance suggests that material is somehow being lost from the surface. BepiColombo's high-resolution imaging, and analysis of the chemistry of the materials associated with hollows (see the image on page 11), may help us to home in on how they form. Detailed imaging will also be important for better understanding of the 'pitted terrain' associated with past volcanic activity, with BepiColombo capable of improving the understanding of the variations in volcanic eruptive style over time.

A shrinking planet

There is plenty of evidence that Mercury has been shrinking – its wrinkly surface features pointing to a contraction of the surface as the planet's interior has cooled. Messenger found that Mercury has contracted by as much as 7 km in radius since its crust formed, much more than previously believed. But how was this contraction distributed over time? Documentation of features of different ages is needed, and in that regard BepiColombo's high-resolution imaging and topographic analysis will be particularly useful for identifying clues in the southern hemisphere, to add to the data acquired by Messenger. The results will help to improve knowledge of the cooling and tectonic history of a 'one-plate planet' – one that, unlike Earth, does not have plate tectonics.

What makes Mercury dark?

Understanding the chemistry of the surface is vital for understanding how the planet formed. Mercury's global surface is much darker than would be predicted from its measured elemental composition, and several competing theories have been proposed to explain this. One early idea attributed it to carbon enrichment from comets; another to the bombardment of micrometeoroids over time.

Messenger's measurements implied that the darkening agent could be graphitic carbon. When Mercury was very young, much of the planet was so hot that there was likely a global 'ocean' of molten magma. As the ocean cooled, most minerals solidified and sank towards the core, but graphite would have floated to form a crust. Abundant carbon on the surface suggests that remnants of Mercury's original ancient crust could be revealed in the volcanic rocks and impact ejecta observed on the surface today. BepiColombo is expected to follow up on these interesting observations, providing missing information regarding the nature and abundance of the carbon.

A tenuous atmosphere

Messenger made the first observations from orbit of Mercury's exosphere – an extremely thin 'atmosphere' that blends with the vacuum of space. As such, it is constantly changing, influenced by the Sun and solar wind, as well as the bombardment of micrometeoroids that feed the exosphere with species such as sodium, potassium, calcium and magnesium. Messenger found that these species all exhibit different spatial distributions that do not fit with standard models.

BepiColombo will provide additional insight into the temporal evolution of the structure and composition of the exosphere over the course of a year at the planet, analysing the *in situ* density along the spacecraft trajectory. It is also expected to detect other species in the atmosphere as well. The spacecraft will study the interplay between surface processes and the variations in the exosphere, and provide missing observations of volatile species at high southern latitudes. It will tackle questions such as: what is the role of solar events on electron impact and surface sputtering, and can this activity be identified in the exosphere? Does the exosphere vary with the Sun's radiation, solar pressure or meteoroid bombardment? Can surface composition be recognised in exosphere signatures? How do changes relate to day and night?

Just as Messenger dramatically improved our knowledge of this fascinating world, no doubt BepiColombo in turn will find new surprises and make unexpected discoveries that will have important implications for our understanding of the planet's place in Solar System history.

NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Enhanced colour image of a section of the floor and mountains inside an impact basin called Raditladi. The irregular depressions, called 'hollows', may have been formed by sublimation of a component of the material when exposed by the Raditladi impact. The image is about 20 km wide

→ AN INTERNATIONAL ENDEAVOUR

BepiColombo is the result of major international cooperation, with ESA being responsible for the overall mission design.

Airbus Defence and Space in Germany is the prime contractor for the design and procurement of the ESA parts of the spacecraft, including MPO, MTM, MMO's sunshield, and the interface between MPO and MMO. Furthermore, it provided the design and development of the data management, attitude and orbit control subsystems and solar wings.

Thales Alenia Space Italy is the co-prime contractor for the development of the MPO's electrical power, thermal control and communications systems and for the integration and test activities.

In the UK, Airbus Defence and Space is co-prime contractor for the electrical and chemical propulsion systems, for the structure of all modules and for the thermal control of MTM. Airbus Defence and Space in France has developed the onboard software.

MMO was designed and developed by JAXA, who in turn was responsible for procuring the spacecraft from an industrial team led by NEC Corporation.

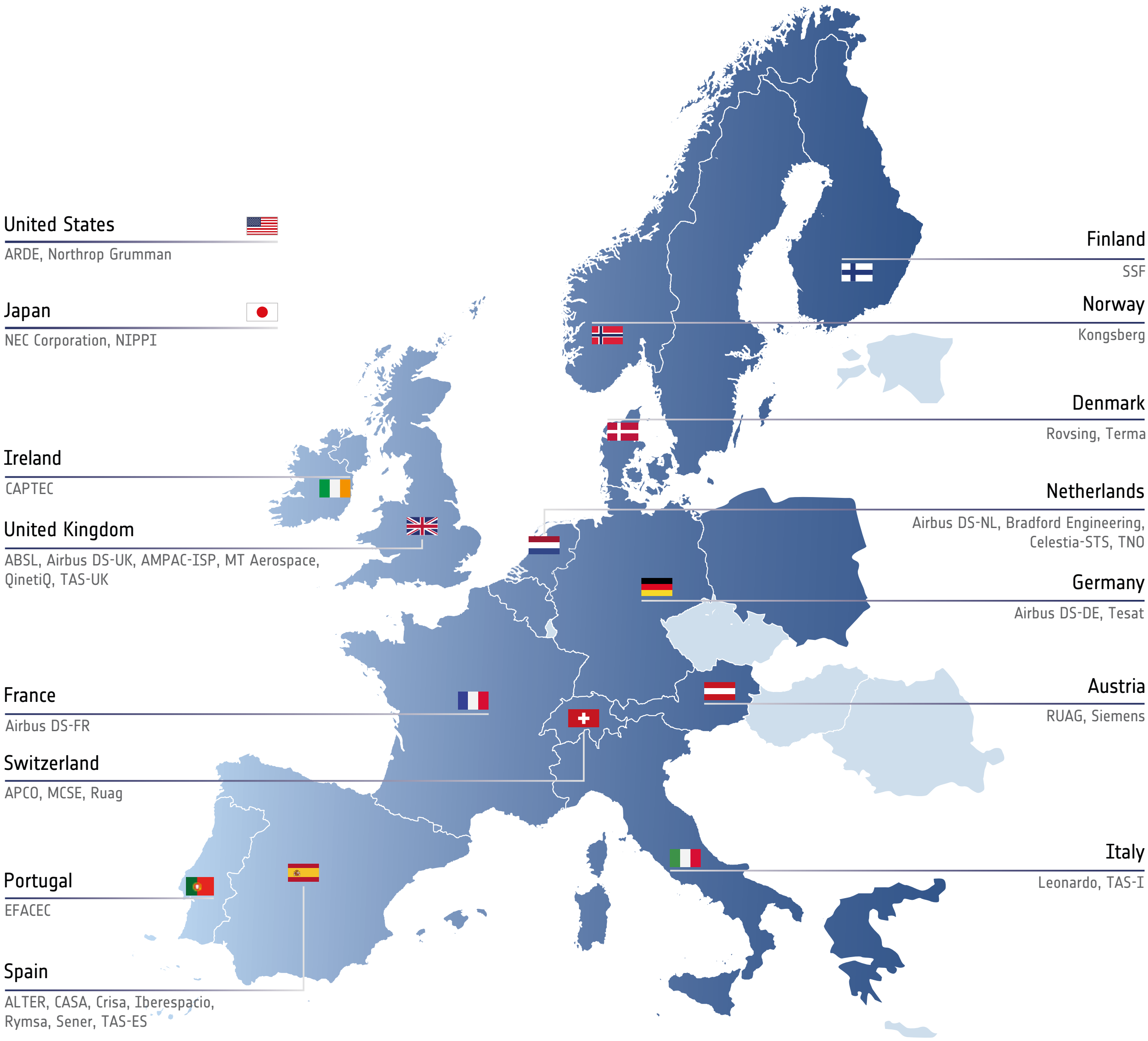
After launch, ESA is responsible for the operations of the spacecraft up until insertion of MPO and MMO into their orbits. During the cruise, the European Space Operations Centre (ESOC) in Darmstadt, Germany, will coordinate the operation of the composite spacecraft through communications links with ESA's network of ground stations with 35 m-diameter antennas. These include Cebreros in Spain – the primary ground station for BepiColombo – and Malargüe in Argentina. Malargüe will also be used to support radio science during the cruise. NASA's Deep Space Network station in Goldstone, California, US, will be used for radio science during the main mission.

The ISAS/JAXA Sagamihara Space Operation will take over the operation of MMO once it is in orbit around Mercury, using the Usada 64 m antenna in Japan, while ESOC will remain in charge of MPO mission operations.

ESA is also responsible for the scientific operations of MPO. The BepiColombo Science Operation Centre will be at the European Space Astronomy Centre (ESAC) in Villafranca, near Madrid, Spain. It will define and coordinate the scientific observations and assist the teams in operating their instruments, as well as manage the data archives.

Above: the Cebreros 35 m antenna in Spain. Below: the Usuda 64 m antenna in Japan

The European components of BepiColombo (i.e. excluding the MMO) have been developed and built with contributions from a large number of ESA Member States, as highlighted on the map below. Participating countries outside of Europe are indicated at the top left.



For more information, see:

esa.int/bepicolombo

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