Mission to Mercury
BepiColombo

MIO -Mercury Magnetospheric Orbiter-

Humanity vs. Mercury

15-year development, 7-year cruise
A project transcending both generations
and borders in the challenge to explore Mercury

Institute of Space and Astronautical Science
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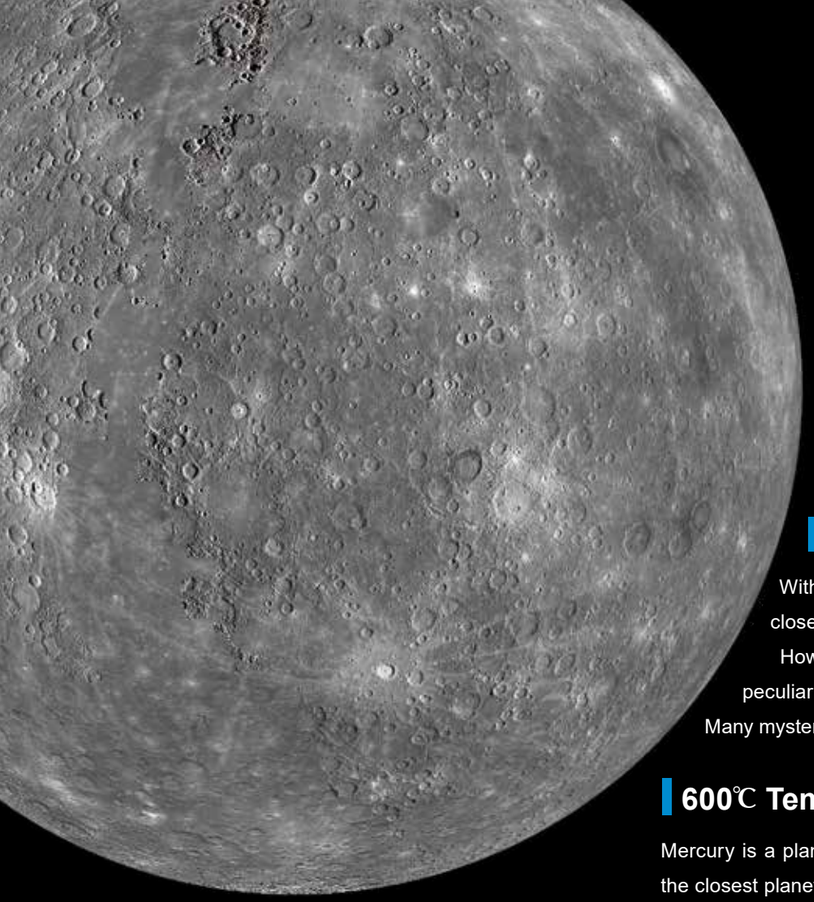

Mercury,

the nearest planet to the Sun in the Solar System

Aphelion	0.47 AU
Perihelion	0.31 AU
Diameter	4,880 km
Averaged Density	5.43 g/cm3
Orbital Period	88 days
Rotation Period	59 days
Length of Mercury Day	176 days

The Moon's Look-Alike

With a surface covered in craters, Mercury closely resembles the Moon in appearance. However, terrain has also been discovered peculiar to Mercury and not seen on the Moon. Many mysteries remain as to how this was created.

600℃ Temperature Difference

Mercury is a planet with a very harsh environment. As the closest planet to the Sun, Mercury receives sunlight ten times stronger than that on Earth. The surface temperature of Mercury reaches as much as 430℃ during the day. at night the temperature drops to about minus 170℃, because of heat escaping into space due to the lack of a thick atmosphere such as on Earth.

Rocky Planet Like Earth

Mercury is the smallest planet in the Solar System, with a size less than half that of the Earth. Despite its small size, the density of Mercury is roughly equal to that of the Earth and it is thought that the interior contains a huge iron core extending to three-quarters of the radius of the planet.

Magnetic Field Like Earth

Mercury also possesses a magnetic field with a strength of around 1/100th of that of the Earth's. A flowing liquid inner core is necessary for a planet to generate a magnetic field. Why Mercury, the smallest and easiest planet to cool and solidify, still has a magnetic field is a great mystery.

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やっとここまで来ました。マラソンでいったら
スタートラインに立ったところでミッションの完遂という
ゴールまでは まだまだ長い道のりがありますが、
謎の解明や新たな発見が数多くあるを期待しています。
早川 基

"Finally, here we are. If this were a marathon, we would be standing on the starting line. We still have a long way to go until we reach the goal of mission accomplished. However, I am looking forward to the many unlocked mysteries and discoveries we will make upon arrival. "

Hajime HAYAKAWA

BepiColombo Project: the First Large-Scale International Cooperative Mission

BepiColombo is an international plan to explore Mercury led by cooperation between the Japan Aerospace Exploration Agency (JAXA) and the European Space Agency (ESA). This challenge of this large-scale international cooperative mission is to simultaneously send two spacecraft to orbit Mercury —MPO (the Mercury Planetary Orbiter) led by ESA and MIO (previously called MMO, the Mercury Magnetospheric Orbiter) managed by JAXA— to conduct a comprehensive study of Mercury. The Ariane 5 rocket will launch BepiColombo from French Guiana in October 2018 and, following a total of nine planetary swing-by maneuvers, is scheduled to enter orbit around Mercury in December 2025.

Development Period :15 Years

In Japan, discussions regarding the exploration of Mercury began in 1997, with BepiColombo commencing as a project in 2003. Following a development period of 15 years, we are all now eagerly anticipating the moment of the BepiColombo lift-off! MIO's key observation technique has been enhanced through Japanese explorations for the Earth's magnetosphere. To demonstrate Japan's technical advantages, the researchers and engineers developed MIO with fervent enthusiasm.

The Origin of the Name BepiColombo

This project was named after the Italian astronomer Giuseppe Colombo, who proposed that Mercury's orbital and rotational periods were locked into a 3:2 resonance. He also pioneered using swing-by maneuvers in planetary probe navigation and designed the trajectory of the first probe to explore Mercury, Mariner 10. We can say that Colombo made the exploration of Mercury possible. Commemorating such achievements, we named our mission as 'BepiColombo,' adding his nickname, 'Bepi.'

MIO

Mercury Magnetospheric Orbiter

MIO's objective is to study Mercury's surrounding environment in detail, including its magnetic field, plasma, thin atmosphere, and dust. In addition to receiving sunlight around ten times as powerful as on Earth when in orbit around Mercury, MIO must also be able to withstand heat radiated from the surface, where the daily temperature reaches as much as 430℃.
Ingenuity was needed to enable observations in Mercury's severe thermal environment.

In addition to design choices to improve the efficiency of heat dissipation into space, MIO is covered with mirrors on the sides permanently exposed to sunlight. The reflection can reduce heat absorption as much as possible. Instruments have not been attached to the rear of the solar cells, as this surface is black and inevitably heats up.

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Scientific Instruments onboard MIO	Objectives
MPPE (Mercury Plasma Particle Experiment)	With seven sensors, MPPE measures electrons and ions at different energies and high-speed neutron particles.
MGF (Magnetic Field Investigation)	Measures the magnetic field of Mercury, its magnetosphere and the solar wind.
PWI (Plasma Wave Investigation)	Observes the electric field and electromagnetic waves in Mercury's magnetosphere and the solar wind.
MDM (Mercury Dust Monitor)	Detects interplanetary dust and that released from Mercury within the Mercurian orbit
MSASI (Mercury Sodium Atmosphere Spectral Imager)	Takes spectral images of the distribution and variation of Mercury's thin sodium atmosphere.

Attitude Control	Spin stabilized, with a rotation rate of 15 RPM
Shape and Size	Octagonal prism, measuring 1.8 meters between opposing faces and with an overall height of 2.4 meters including the antenna. Four 15 meter wire-antennas and two 5 meter masts are extended in orbit around Mercury.
Weight	255kg

MPO

Mercury Planetary Orbiter

The MPO's objective is to study Mercury's surface (terrain, minerals/chemical composition) and interior (gravity and magnetic fields) in detail. An attitude control system will ensure that the heat shield is always faced toward the strong sunlight. Thus, the orbiter is designed to maintain a low temperature for equipment that requires cooling.

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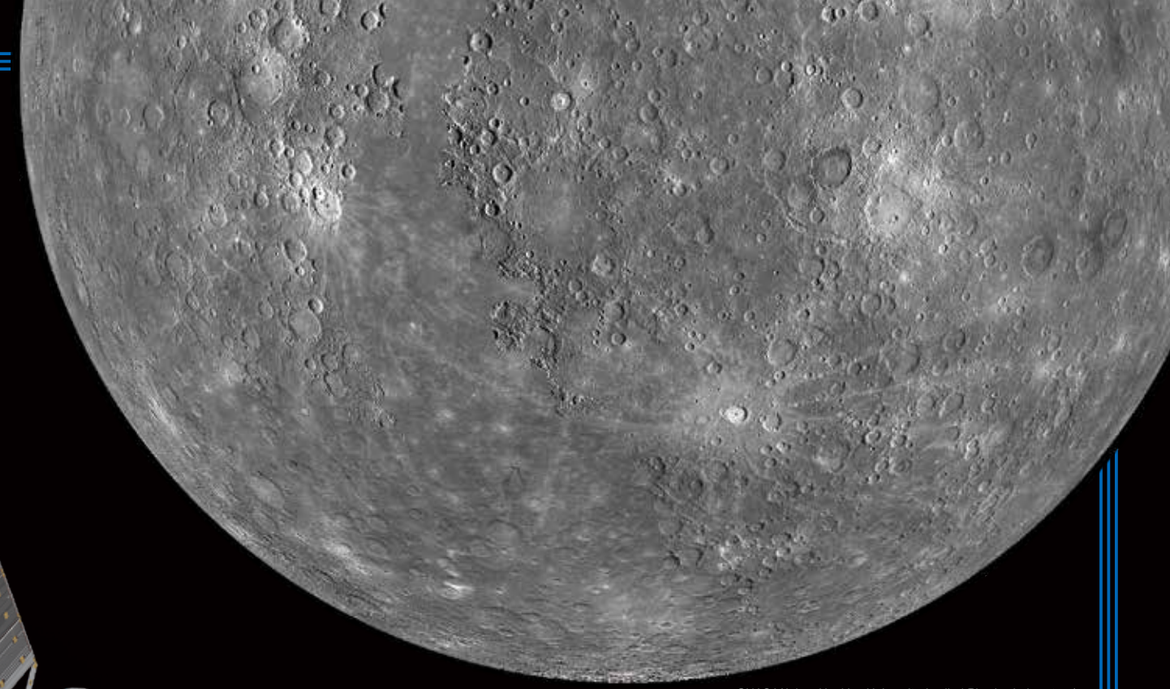
Scientific Instruments onboard MPO	
BELA (BepiColombo Laser Altimeter)	MORE (Mercury Orbiter Radio science Experiment)
ISA (Italian Spring Accelerometer)	PHEBUS (Probing of Hermean Exosphere by Ultraviolet Spectroscopy)
MPO-MAG (Magnetic Field Investigation)	SERENA (Search for Exosphere Refilling and Emitted Neutral Abundances)
MERTIS (Mercury Radiometer and Thermal Imaging Spectrometer)	SIMBIO-SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory)
MGNS (Mercury Gamma-Ray and Neutron Spectrometer)	SIXS (Solar Intensity X-ray and particle Spectrometer)
MIXS (Mercury Imaging X-ray Spectrometer)	

Attitude Control	Three-axis stabilization
Shape and Size	2.4 x 2.4 x. 1.7 meters. The solar array paddles (7.5 meters) are extended after the lift-off
Weight	1230kg

Voyage to Mercury

An Exploration Packed with Challenges

Mercury is tough planet to explore and requires an enormous amount of energy to visit. As a result, only two explorers, Mariner 10 and MESSENGER, have travelled to Mercury so far. In order to save propellant, BepiColombo faces a difficult journey to Mercury and will perform a total of nine planetary swing-by maneuvers.



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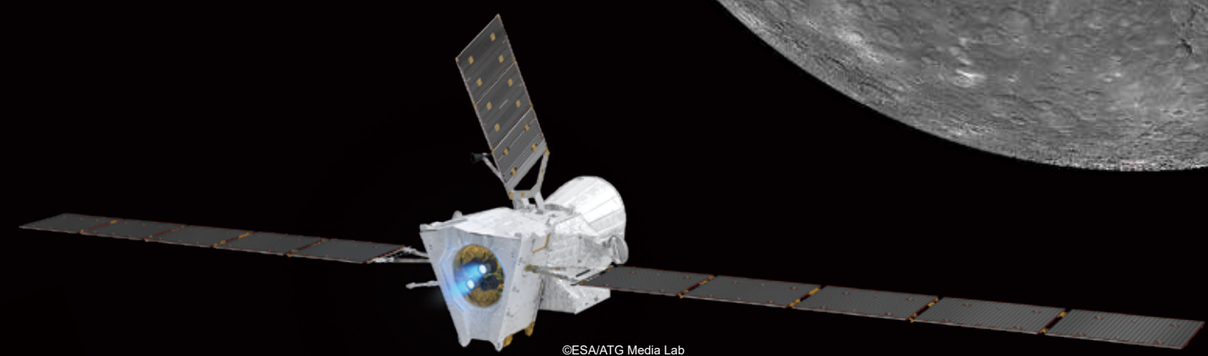

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Mercury swing-by
4. Oct. 2, 2021
5. Jun. 23, 2022
6. Jun. 20, 2023
7. Sept. 5, 2024
8. Dec. 2, 2024
9. Jan. 9, 2025
Nine planetary swing-by maneuvers in total

On December 5, 2025, the Orbital Insertion

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▲ Ariane 5
Oct. 2018 - launch

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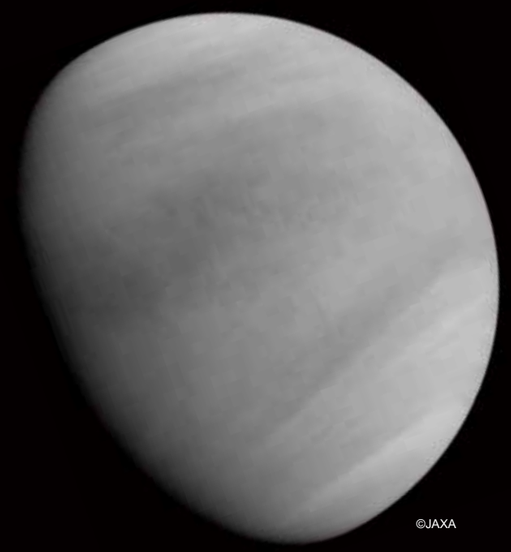
Earth swing-by
1. Apr. 13, 2020



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Venus swing-by
2. Oct. 16, 2020
3. Aug. 11, 2021

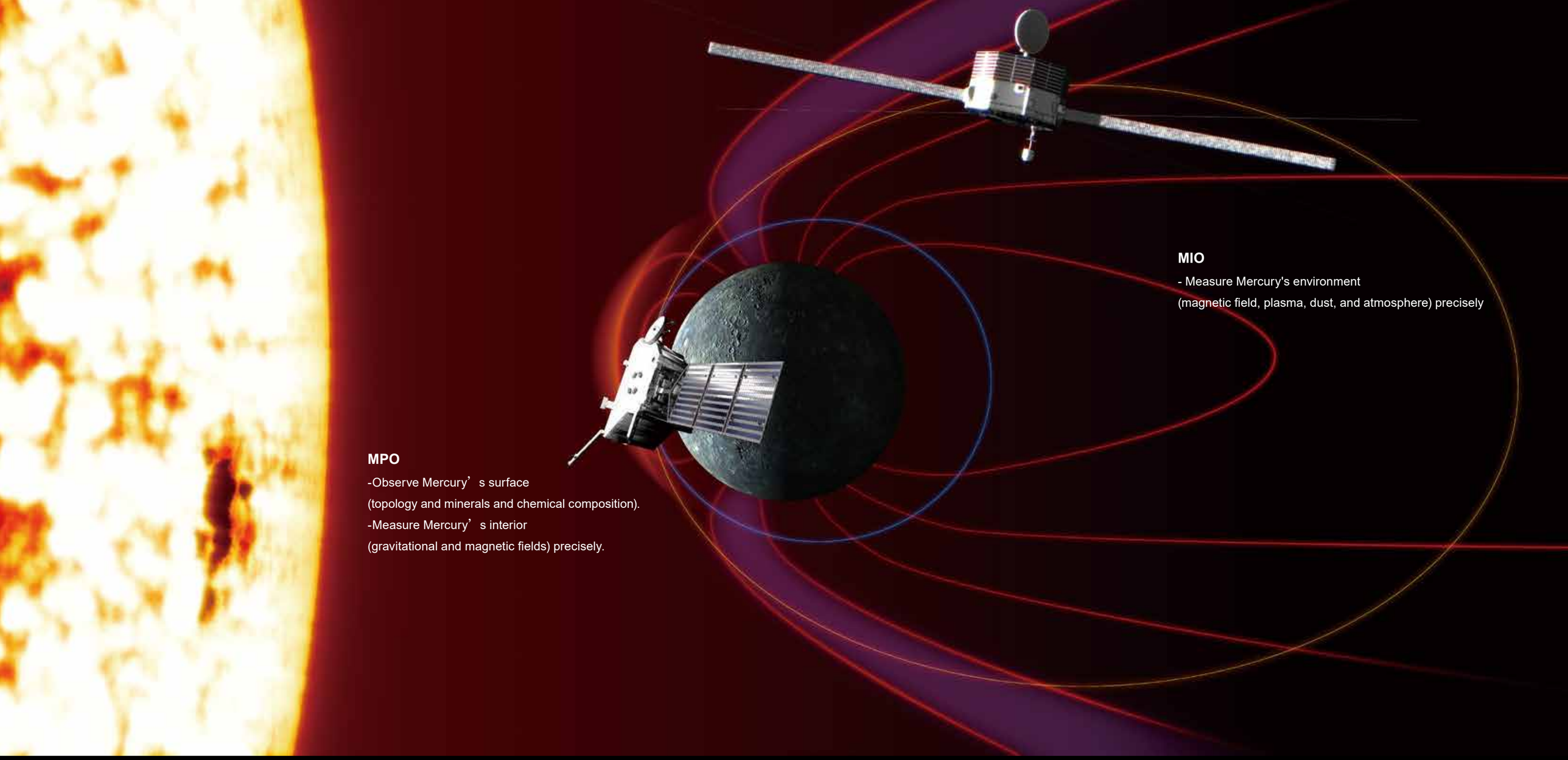
※ As of Aug. 2018

The Swing-By: the Key Technique for Arriving at Mercury

A spacecraft can change direction, accelerate or decelerate when passing close to a planetary body due to its gravitational field. The navigational maneuver for utilizing a planet's gravity to change a spacecraft's speed is called a swing-by. A spacecraft can adjust its course without propellants when using a swing-by. Nowadays, many planetary missions use swing-by maneuvers to reach their destinations.

Why Does it Take 7 years?

Why does it take as long as 7 years to arrive at Mercury? The reason lies in the number of swing-by maneuvers that must be performed. To ensure correct alignment with the planet, the spacecraft must sometimes orbit the Sun many times to wait for the correct timing for the swing-by. The 7 years is not due to Mercury being far from the Earth, it is down to the waiting times for the swing-bys.



Observations orbiting around Mercury

Placing the Two Satellites into Different Orbits

Upon BepiColombo's arrival at Mercury, in a world's first the two satellites will finally be inserted into orbit. The electric propulsion module, having completed its role, will be jettisoned and the spacecraft will enter into orbit around Mercury, with the MIO firstly coming into an extended elliptical orbit with a high apoapsis (the furthest point in orbit from Mercury). Next, the MPO, separating from MMO sun-shield, will gradually reduce its altitude and enter into a low-altitude orbit. From this point, the MIO and MPO will orbit the same orbital plane at different heights while performing their respective scientific observations.

The advantage of 2 Probes Observing Simultaneously

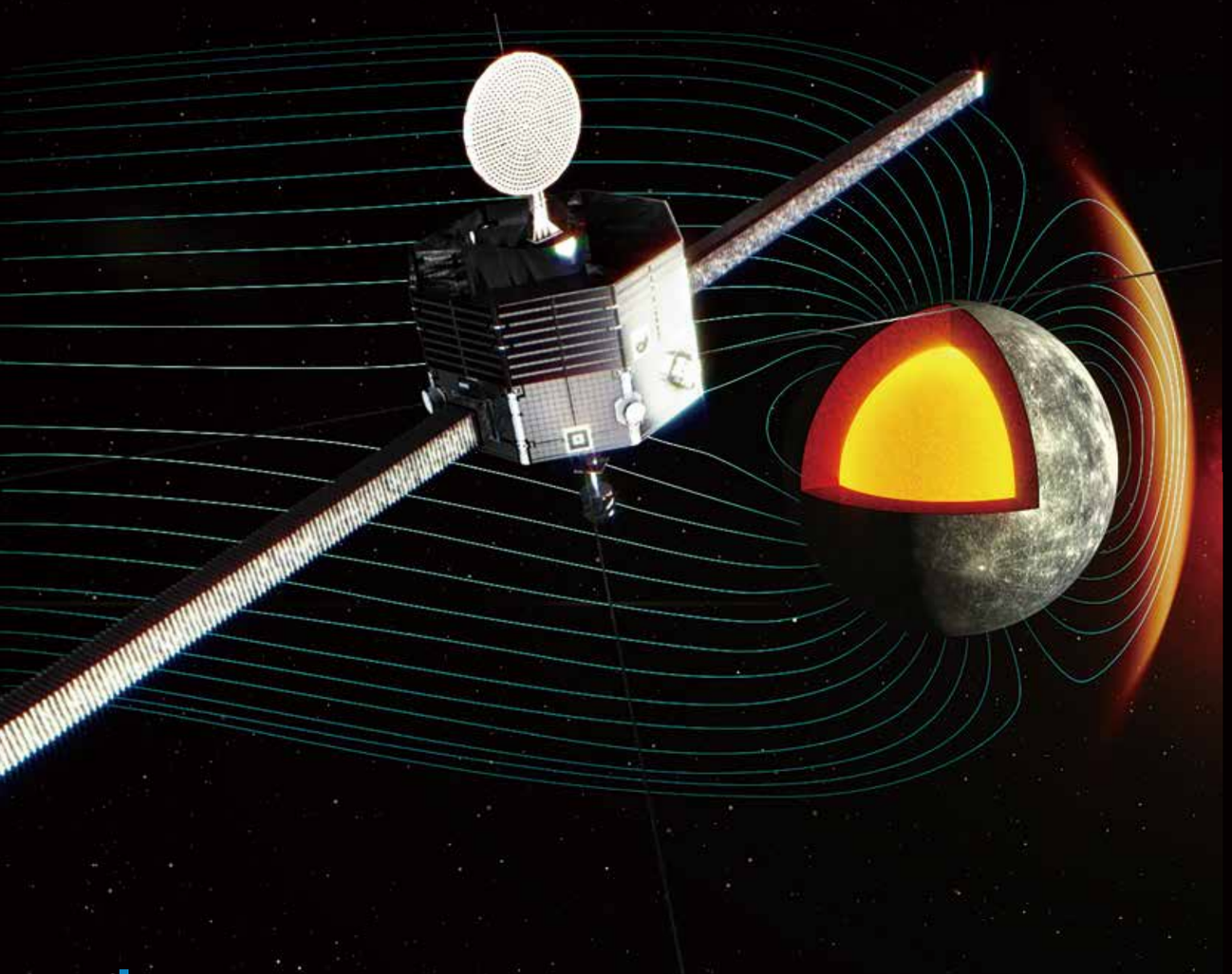
In order to know what is occurring in the interior of Mercury, it is important to precisely measure the planet's magnetic field. Meanwhile, the harsh solar winds around Mercury cause disturbances in the electromagnetic field and interfere in the measuring of the magnetic field. The combination of the MPO and MIO enables us to discriminate the Mercury's own magnetic field from that of the solar wind. Thus, we can obtain more precise information on the interior of Mercury.

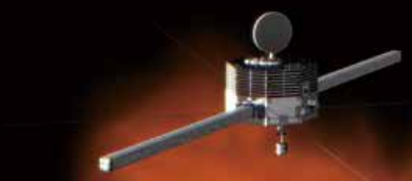
MIO's Observations

The plasma particle instruments, magnetometer, and plasma wave and electric field instruments, mounted on the MIO, will work together to understand the various physical phenomena occurring in the Mercury's magnetosphere.

A sodium atmosphere spectral imager will study Mercury's thin sodium atmosphere's luminescence to shed light on the mysteries of the atmosphere's production mechanisms. The Mercury dust monitor will observe the dust of the Solar System's innermost edge - of which about hardly anything is known.

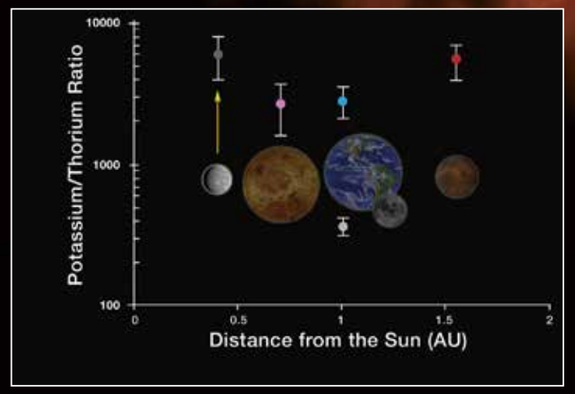
Science Objectives of BepiColombo





Understanding Geographical Features

Despite being the closest planet to the Sun, it was discovered that the mineral composition of Mercury's surface contains far more volatile elements than expected. Furthermore, the MESSENGER probe discovered strange depressions peculiar to Mercury. It is thought that maybe these depressions were formed when volatile elements escaped from the surface. These results may indicate that Mercury was once larger than it is now and could hold the key to a re-examination of the planet formation theory.



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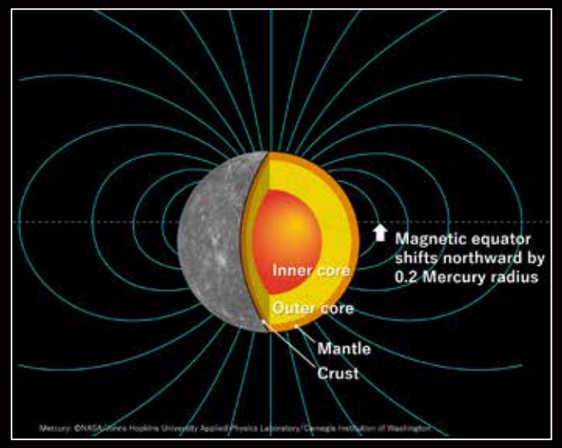
Understanding the Surrounding Environment

The planets in the Solar System are constantly bombarded by solar winds. While magnetic fields like Earth's are thought to perform the role of a barrier against solar winds, Mercury's magnetic field is about 100 times weaker than the Earth's as well as being subject to far stronger solar winds. Through understanding what kinds of phenomena occur in such an environment different to that of Earth's, we will clarify what role the planetary magnetic field plays in relation to the solar winds. And in the future, researchers believe that such an understanding will help in the search for the possibility of life on exoplanets.

Understanding the Magnetic Field



Based on research of the Earth, scientists believe that a planet with its own magnetic field must possess a liquid metal core which generates electric currents through circulating. Why Mercury, the smallest and which should be the easiest planet to cool and solidify in the Solar System, still has a liquid core remains a huge mystery. Moreover, observations of the MESSENGER probe revealed that the center of Mercury's magnetic field is actually north of its equator.

What kind of internal structure causes such an asymmetric magnetic field? BepiColombo will reveal the interior of Mercury through detailed magnetic field observations from the two satellites and decipher the information on planetary evolution.