

Mission to Mercury

One of the most exciting projects that spacecraft engineers in the UK are working on at the moment is BepiColombo. This international project, which plans to send a spacecraft to the planet Mercury, will combine revolutionary new rocket engine technology with exciting scientific goals - exploring the inner solar system in a way that has never been done before. Elaine Greaney describes how the spacecraft's ion propulsion motors will contribute to this mission.

Key words

spacecraft

Newton's laws
of motion

Mercury

propulsion

BepiColombo

BepiColombo is a joint mission to the planet Mercury (see Box) by the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). It is due to launch in 2014 on an Ariane 5 rocket from French Guiana, and it will then travel for six years until it reaches Mercury.

The European part of the spacecraft (the Mercury Planetary Orbiter) will be equipped with eleven scientific instruments to study the surface and internal composition of Mercury, whilst the Japanese part (the Mercury Magnetospheric Orbiter) will study Mercury's magnetic field.

The mission is named after Giuseppe ('Bepi') Colombo, an Italian scientist who was best known for studying the planet Mercury, and who worked out how to get a spacecraft into orbit around Mercury by first using a **slingshot manoeuvre** around Venus. The BepiColombo spacecraft will be propelled by an **ion propulsion** system and will use gravity assists from the Moon, Earth and Venus, before eventually being captured by the gravity of Mercury.

Mercury

Mercury is the planet in our solar system which is closest to the Sun. It is 1/19th of the volume of the Earth and is similar in appearance to our Moon. It is unusual because of its suspected iron core and magnetic field.

Mercury's closeness to the Sun makes it difficult for a spacecraft to travel there due to the extreme temperatures involved, but scientists are keen to send a probe there for the valuable clues that such a mission can provide in understanding both the planet itself and the formation of our solar system; clues which cannot be obtained with observations from Earth.



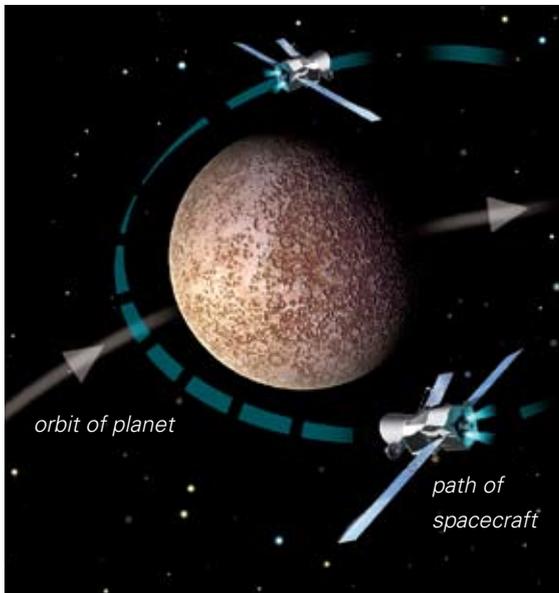
An artist's impression of BepiColombo as it approaches Mercury.



A photograph of Mercury's surface, taken by an earlier mission.

Slingshot manoeuvre

A 'gravitational slingshot' or 'gravity assist' manoeuvre is when the gravity of a nearby planet or other celestial body is used to alter the path and speed of a spacecraft, in order to save fuel and journey time. The Mariner 10 probe was the first spacecraft to use a gravitational slingshot manoeuvre. It visited Venus and Mercury in 1974.



The path of a spacecraft as it performs a slingshot manoeuvre around a planet.

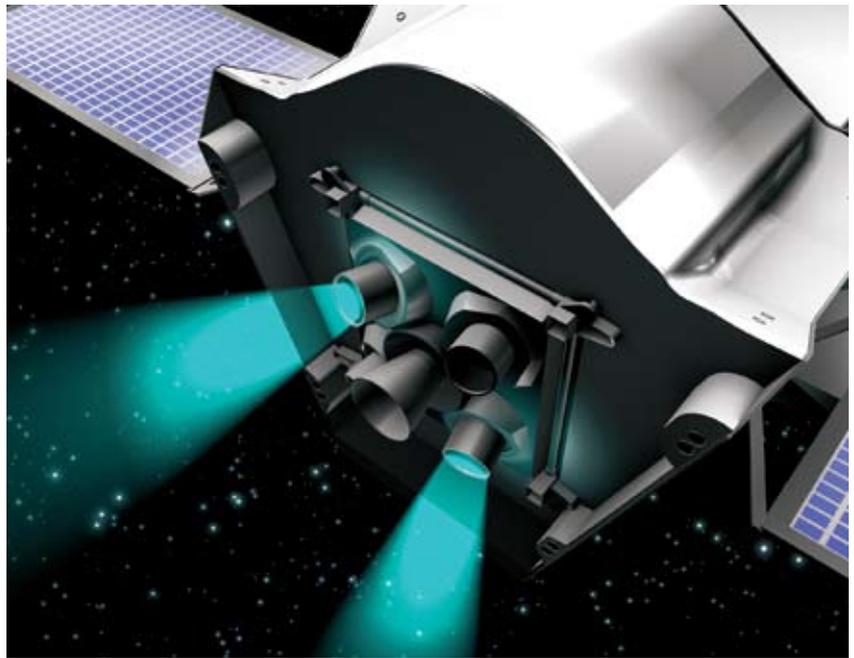
The main limit to using slingshot manoeuvres is that planets are not always in the right place at the right time in order to help a mission to a particular destination. This means that any missions planning to use this type of manoeuvre to speed up or slow down their spacecraft during its journey have to make sure that the manufacture and launch of the spacecraft is carefully timed to coincide with the planets being in the right place.

Note that, if a spacecraft is accelerated during a slingshot manoeuvre, the planet will be slightly slowed down – both energy and momentum must be conserved.

BepiColombo's engines

BepiColombo is a very high profile mission for the European Space Agency, and it is only possible because it will use ion propulsion technology. The ion engines which will carry the BepiColombo spacecraft to Mercury are being built at QinetiQ in Farnborough, Hampshire, where a group of scientists and engineers have been developing ion propulsion technology for decades.

The ion engines being built for BepiColombo work by creating a plasma made of ions from xenon gas, and then accelerating these ions out of the engine, generating thrust which pushes the spacecraft forwards. Xenon is used as a propellant because it is easy to ionise, and relatively safe to use. However, xenon is globally in short supply and very expensive.



BepiColombo's propulsion system – the solar panels use sunlight to generate the electricity required to power the ion propulsion engines.

Ion propulsion

Ion engines use beams of ions (charged atoms or molecules) to create thrust in accordance with Newton's 3rd Law. Unlike a chemical rocket which burns fuel very quickly, an ion engine produces much less thrust but can keep running for a long time. This allows a spacecraft to slowly build up speed and travel long distances. Ion propulsion is characterised by the high velocity with which the propellant is accelerated out of the engine – at about 50 km/s. This is 16 times faster than conventional chemical thrusters. This means that the amount of fuel that has to be used is much lower, so the spacecraft is much lighter and easier to launch away from the Earth's gravity.

Advantages of propulsion technology which uses less fuel than traditional chemical systems:

- Longer spacecraft lifetimes for the same amount of fuel
- Larger final spacecraft velocities
- More room on the spacecraft for scientific instruments
- Reduced cost of launching the spacecraft from Earth
- The amount of fuel which can be carried is enough to propel a spacecraft right across the solar system

Uses of ion propulsion:

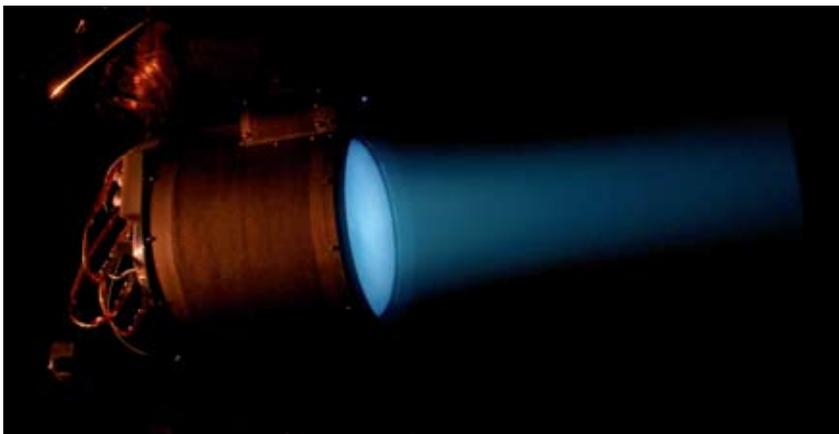
- Keeping communications satellites in geostationary orbits around the Earth
- Carrying probes large distances to other planets or asteroids
- Maintaining the orbits of scientific missions close to the Earth (e.g GOCE which is measuring the Earth's gravitational field)



One of QinetiQ's T6 ion propulsion engines ready for tests ...



the test chamber at Farnborough ...



a T6 engine generating 200 mN of thrust on a test balance.

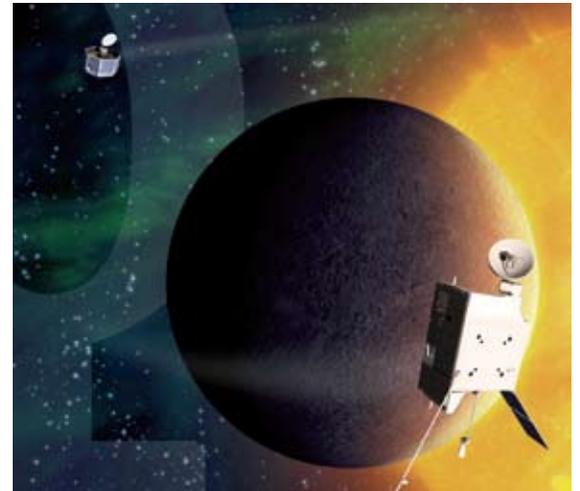
Build and test

The BepiColombo spacecraft will have a mass of 3000 kg and a solar panel wingspan of 26 m, but each of the 4 ion engines that will carry it to Mercury has a mass of just 8 kg and is only 30 cm wide. Each engine is assembled from over 1400 parts, by engineers in clean rooms wearing protective clothing to ensure that the engines are kept clean and don't cross-contaminate the sensitive spacecraft instruments.

Before launch, the engines will be tested in chambers that simulate the vacuum and temperatures of space. They will also be subjected to vibration testing to prove that they will be able to survive being launched on a rocket from Earth. After the spacecraft separates from the launch rocket, the engines will have to work non-stop for 26 000 hours to deliver the spacecraft to Mercury, so there is redundancy in the system in case a problem occurs.

To safely deliver the spacecraft to its destination, the engines will first be used to accelerate the spacecraft away from the Earth, then to position BepiColombo for its gravitational slingshot manoeuvres and then finally to brake and stop the spacecraft from crashing into Mercury. The spacecraft will be positioned safely in orbit around the planet, and then the job of the ion engines will be done; but the work of the scientific instruments and the scientists back on Earth will have only just begun!

Elaine Greaney is an ion propulsion engineer at QinetiQ.



An artist's impression of the two parts of BepiColombo after each has entered its own orbit around Mercury.

Look here!

The European Space Agency's page about BepiColombo:
http://www.esa.int/SPECIALS/Operations/SEMYRMQ/NVE_0.html

QinetiQ's page about rocket propulsion:
http://www.qinetiq.com/home/markets/related_markets/space/electric_propulsion.htm

More about how space rockets work:
http://www.sep.org.uk/catalyst/articles/catalyst_13_2_145.pdf