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BepiColombo

Outlook

- With BepiColombo mission launched in October 2018, this report will be archived
- BepiColombo orbiters completed testing in launch configuration in July 2017
- MPO thermal vacuum tests and MMO environmental tests completed in late 2014
- Vibration testing conducted in August 2012; heat testing conducted in March 2013

Orientation

Description. The BepiColombo is a mission consisting of two spacecraft and propulsion modules that will explore Mercury.

Sponsor. The European Space Agency (ESA) and Japan Aerospace Exploration Agency (JAXA) cosponsor the program.

Status. The BepiColombo mission lifted off aboard an Ariane 5 on October 20, 2018, and is now traveling to Mercury.

Total Produced. Two.

Application. The BepiColombo will study the magnetosphere of Mercury and take images of the planet's surface.

Price Range. The total cost of the BepiColombo mission is estimated to be about $2 billion. That includes the spacecraft, launch, and operations during the seven years it takes to travel to Mercury and for two years on station.

Contractors

Prime

Airbus Defence and Space	http://www.airbus.com, PO Box 801109, Munich, Germany, Tel: + 49 89 607 0, Fax: + 49 89 607 264 81, Prime
European Space Agency, ESA	http://www.esa.int/esaCP/index.html, 8-10 Rue Mario Nikis, Paris Cedex 15, France, Tel: + 33 1 53 69 7654, Fax: + 33 1 53 69 7560, Prime
Japan Aerospace Exploration Agency, JAXA	http://www.jaxa.jp/index_e.html, Marunouchi Kitaguchi Bldg, 1-6-5 Marunouchi, Chiyoda-ku, Tokyo, Japan, Tel: + 81 3 6266 6000, Lead Contractor
Thales Alenia Space Italia	http://www.thalesgroup.com/en/global/activities/space, Via Saccomuro, 24, Rome, Italy, Tel: + 39 06 41511, Fax: + 39 06 4190675, Co-producer

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Subcontractor

Hensoldt Sensors GmbH	http://www.hensoldt.net, Willy-Messerschmitt-Strasse 1, Taufkirchen, Germany, Tel: + 49 89 3179 0 (Thermal Control)
Leonardo Land & Naval Defence Electronics	http://www.leonardocompany.com, Via Albert Einstein, 35, Campi Bisenzio, Italy, Tel: + 39 055 89501, Fax: + 39 055 8950600 (Solar Cells; Star Tracker)
QinetiQ Ltd	http://www.qinetiq.com, Cody Technology Park, Ively Rd, Farnborough, Hampshire, United Kingdom, Tel: + 44 0 8700 100 942 (T6 Ion Engine)
SEA Group Ltd	http://www.sea.co.uk, Beckington Castle, 17 Castle Corner, Beckington, Somerset, United Kingdom, Email: info@sea.co.uk (Remote Interface Units)
Saab Surveillance	http://www.saabgroup.com, Nettovägen 6, Järfälla, Sweden, Tel: + 46 8 580 840 00, Fax: + 46 8 580 322 44, Email: info@saabtech.se (Command & Control System)

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

Design Features. The BepiColombo mission consists of two spacecraft that will orbit and study Mercury. The European Space Agency is building the Mercury Planetary Orbiter (MPO), and the Japanese space agency will supply the Mercury Magnetospheric Orbiter (MMO). Propulsion will be provided by two modules: the Solar Electric Propulsion Module (SEPM) and the Chemical Propulsion Module (CPM).

Mercury Planetary Orbiter. The orbiter is a three-axis-stabilized, remote sensing spacecraft that will take images of Mercury's surface. Instruments will include a visible/near-infrared camera, four photon spectrometers, a neuron spectrometer, an accelerometer, and a Ka-band transponder.

The MPO is being designed to withstand radiation from Mercury. The thermal design includes a deployable shield that will protect the orbiter. Three sides of the spacecraft will carry solar panels. There will be two Zenith and two Nadir antennas on the orbiter that will allow it to communicate with the MMO.

Mercury Magnetospheric Orbiter. Also known as MeMs, this spacecraft will study the magnetosphere of Mercury. It carries a magnetometer, ion spectrometer, ion/electron analyzer, wave analyzer, cold plasma detector, and energetic particle detector.

The MMO will spin at 15 rotations per minute. The magnetometer and search coils will be mounted on a deployable rigid boom. An electric antenna, consisting of two 30-meter-long wires, will be deployed by centrifugal force. The two solar arrays will be attached to the sides of the satellite, each comprising 24 flat solar panels.

Mercury Surface Element (canceled 2003). The small MSE probe would have studied the physical properties of the planet's surface.

Solar Electric Propulsion Module. This unit is a thruster module designed to act independently from the rest of the spacecraft. The module has two large deployable solar arrays and four thrusters. A cold redundant unit will be included for use in case one of the thrusters fails.

Chemical Propulsion Module. This cylindrical module contains the main engine for capture and insertion maneuvers, as well as four redundant thrusters for attitude control.

The following table lists the currently approved MPO payload and the responsible institution.

Name	Payload	Institution
BELA	Laser Altimeter	University of Bern (Switzerland)
ISA	Radio Science Accelerometer	CNR-IFSI (Italy)
MERMAG	Magnetometer	Blackett Laboratory, Imperial College London (U.K.)
MERTISTIS	IR Spectrometer	University of Munster (Germany)
MGNS or **MANGA** (TBD)	Gamma Ray & Neutron Spectrometer	Institute for Space Research (Russia) or CESR (France)
MIXS	X-Ray Spectrometer	CCLRC RAL (U.K.)
MORE	Radio Science Ka-band Transponder	University of Rome (Italy)
PHEBUS	UV Spectrometer	University P&M Curie (France)
SERENA	Neutral & Ionized Particle Analyzer	CNR-IFSI (Italy)
SIMBIOSYS	HR & Stereo Cameras, Visual & NIR Spectrometer	Italian Space Agency
SIXS	Solar Monitor	University of Helsinki (Finland)

The following table lists the currently approved MMO payload and the responsible institution.

Name	Target	Institution
MGF	Magnetic Field	Space Research Institute (Austria)
MPPE	Low- & High-Energy Electrons/Ions, Energetic Neutrals	Institute of Space and Astronautical Science (Japan)
PWI	Electric Field, Plasma Wave, Radio Wave	Tohoku University (Japan)
MSASI	Spectroscopic Image (Na Line)	University of Tokyo (Japan)
MDM	Dust Count/Moment	Kyoto University (Japan)

	Metric	U.S.
Dimensions		
Diameter (launch configuration)	4.6 m	15 ft
Height (launch configuration)	7 m	23 ft
Weight		
Total mass at launch	2,272 kg	5,009 lb
Planetary orbiter	1,300 kg	2,866 lb
Magnetospheric orbiter	250 kg	551 lb
Performance		
Design life	7 yr	

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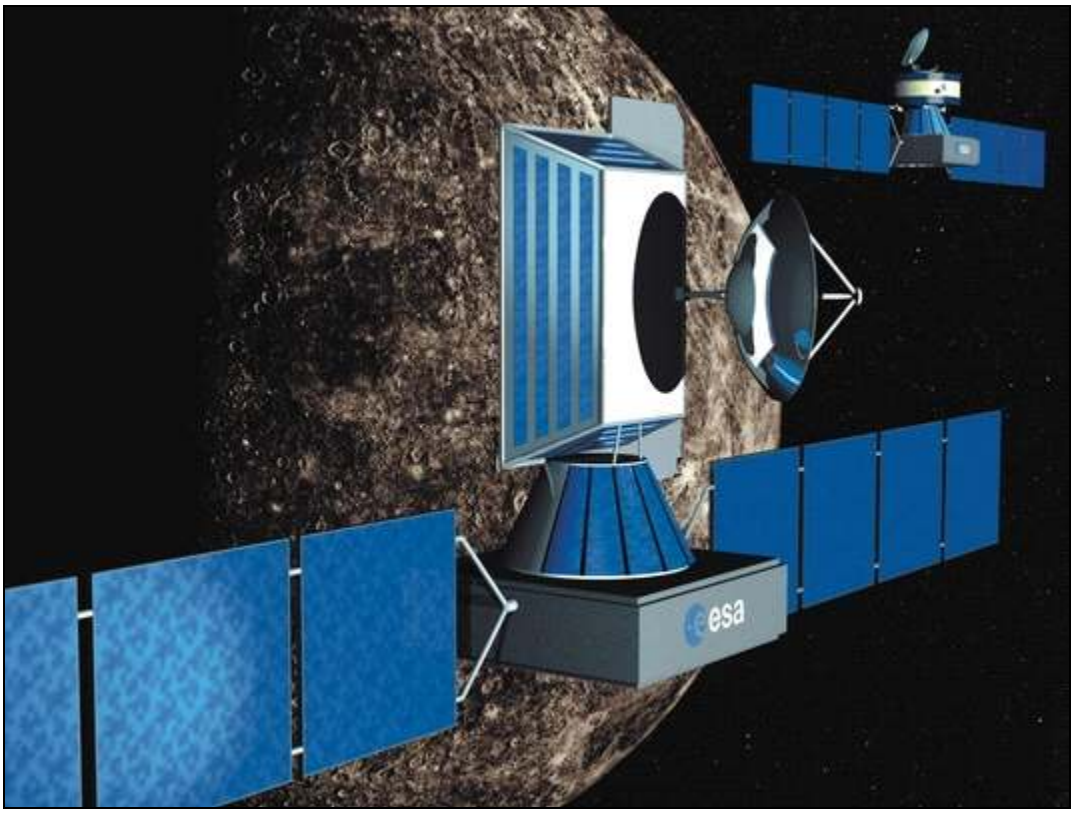

Artist's Depiction of BepiColombo in Mercurial Orbit

Source: European Space Agency

Program Review

Background. In 1994, ESA received proposals for Horizon 2000 Plus, a follow-on program to Horizon 2000. European scientists overwhelmingly suggested further examination of Mercury. As a result, ESA added the BepiColombo to its list of cornerstone missions. Shortly after the mission was approved, ESA cut the Space Science budget, and funding was frozen from 1996 to 2000. During that time, Space Science saw a 4 percent yearly budget decline due to inflation.

In September 2000, ESA's Space Science Advisory Committee (SSAC) selected four additional programs to join the BepiColombo in the Horizon 2000 Plus program. One month later, ESA's Science Program Committee (SPC) approved the SSAC's recommendations. The proposed package was planned for implementation between 2008 and 2013. However, in 2003, the SSAC's recommendations proved too costly an endeavor for ESA, as several unforeseen financial demands surfaced. The most publicly observable event was the grounding of the Ariane 5 fleet following the December 2002 failure, which forced a reallocation of funds to the tune of EUR100 million. Considered a temporary loan, the funds were reportedly paid back from ESA resources in 2006. This scenario, more than anything else, changed the opinions of SSAC members, resulting in a scaled-back – and therefore more affordable – approach to the BepiColombo.

The DevILS Advocate

In October 2002, the European Space Agency started a EUR50 million initiative called DevILS to develop plug-and-play, intelligent, lightweight spacecraft for use on future missions. Anton Linssen, head of ESA's Science Management Support Office, believes that the BepiColombo will be the first ESA mission to benefit from this program.

The traditional way to build a spacecraft is to make each one according to exact specifications – an expensive undertaking. For DevILS, Europe's major aerospace companies are developing a more commercial, off-the-shelf method of building a spacecraft in order to limit costs by maximizing the reuse of various systems. Furthermore, "intelligent" systems used on board DevILS spacecraft will accomplish the same tasks that

once required a number of units, thus reducing both size and mass and, consequently, launch costs. ESA is confident that the initiative will also stimulate the European aerospace industry to make satellites cheaper and lighter.

Japan Invests in BepiColombo. In July 2003, Japan agreed to contribute $114 million toward the development and launch of the Mercury mission.

Committee Scrubs Lander

During its 105th meeting in November 2003, ESA announced that the Cosmic Vision program would need to be retooled due to funding discrepancies. The BepiColombo mission would no longer include the MSE lander. The technological difficulties of landing on the planet closest to the sun were also cited. The ESA/JAXA mission will now consist of the two orbital observation spacecraft.

Nevertheless, with two spacecraft, the BepiColombo is still a large and costly mission, and is ESA's first effort to send spacecraft to "hot" regions of the solar system. The journey from Earth to Mercury will also be a first, involving a series of difficult maneuvers to break away from the sun's gravity. The spacecraft will have to rely on their own solar electric propulsion in addition to the gravity of the moon, Venus, and Mercury to accomplish this task. ESA's technology mission, the SMART-1, first demonstrated the technique.

Gravity-Assist Maneuver Planned

When approaching Mercury, each spacecraft will use the planet's gravity and a conventional rocket engine to insert itself into polar orbit. Observations from orbit will continue for one Earth year.

The precise details of the BepiColombo mission are still being defined. Key technologies for solar electric propulsion and coping with high temperatures and intense sunlight are under development at ESTEC, ESA's technical facility in the Netherlands.

BepiColombo Orbiter's Payload Selected

In February 2004, the European Space Agency issued a Request for Proposals for the Mercury Planetary Orbiter payload. In May 2004, the proposals were received and evaluated by the relevant committees. These committees then issued final recommendations that were approved by ESA's Science Program Committee in November 2004. The approved MPO payload package is detailed in the **Technical Data** section of this report.

The body that oversees ESA's finances approved the BepiColombo in 2007. ESA's Industrial Policy Committee approved contracts totaling $445 million for the two-spacecraft mission. At the time of the approval, ESA's total costs for the BepiColombo – including launch, six years of transit time, and a year of operations in Mercury's orbit – were estimated to be as high as $860 million.

In January 2008, ESA signed a contract with Astrium for EUR350.9 million ($519 million) to build the MPO.

Shortly after the contract was signed, reports began to surface that the program would cost significantly more than initial cost estimates. One factor inflating estimates is the weight of the system, which will be much higher than initially anticipated. The weight increase has forced ESA to use a larger launch vehicle than the originally planned Soyuz 2-1B. The Ariane 5 will now be needed to launch the craft, raising costs by as much as EUR120 million ($189 million).

In June 2008, ESA's Science Program Committee voted to decide whether to cancel the BepiColombo program. Opponents of the mission, however, could not garner the two-thirds majority needed to cancel the program.

In October 2009, the sixth BepiColombo Science Working Team meeting took place in Blois, France.

Beginning in January 2011, components of the BepiColombo mission began heat testing. The spacecraft had to endure temperatures of over 450°C. The testing, conducted at ESA's ESTEC facilities in the Netherlands, ensured that the spacecraft could survive Mercury's harsh orbit.

Vibration testing began in August 2012. These tests ensured that the BepiColombo spacecraft would be able to handle intense vibrations during launch. In March 2013, an engineering model was subjected to intense heat, equivalent to what the spacecraft will face when studying Mercury.

The BepiColombo shares a component found to be faulty during ESA's GAIA mission in October 2013. This component, a transponder used to generate timing signals for downlinking science data, will need to be replaced. Engineers believe its replacement will not cause a major disruption to the launch schedule.

Nevertheless, the BepiColombo mission has still been delayed for a variety of reasons. For example, engineers have had to replace some equipment to allow better heat resistance. Those delays pushed launch back, with liftoff finally occurring on October 20, 2018, aboard an Ariane 5.

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Funding

ESA's Office of Space Science and the Japan Aerospace Exploration Agency provide funding for the BepiColombo.

Timetable

Month	Year	Major Development
Oct	2000	BepiColombo chosen as cornerstone mission for Horizon 2000
Jul	2003	Japan agrees to contribute $114 million toward BepiColombo mission
Nov	2003	BepiColombo mission scaled back due to funding issues
Jan	2008	Astrium chosen as prime contractor for MPO
Jun	2008	Vote by SPC to end BepiColombo program fails
Dec	2014	MPO thermal vacuum tests and MMO environmental tests completed
Jul	2017	BepiColombo orbiters completed testing in launch configuration
Oct	2018	BepiColombo mission lifted off aboard Ariane 5
	2025	Planned arrival at Mercury
	2026	Planned end of nominal mission (one-year extension possible)

Forecast Rationale

The BepiColombo has faced a number of challenges and delays preceding its 2018 launch. The European Space Agency's budget has declined since the program's inception, and costs for the program have increased. In addition, the spacecraft's launch mass has increased, meaning it needed to launch on a heavier, more expensive Ariane 5, rather than on the cheaper, less expensive Soyuz as originally planned. Finally, technical issues delayed the program.

In 2008, ESA even held a vote to terminate the program. However, the motion failed to garner enough support to pass. ESA and its partner, the Japan Aerospace Exploration Agency, have remained committed to the program since then, with testing on the BepiColombo continuing. Vibration testing began in August 2012, and heat testing was conducted in March 2013. In late 2014, the Mercury Planetary Orbiter completed thermal vacuum tests and the Mercury Magnetospheric Orbiter completed environmental tests. In July 2017, both satellites completed testing in launch configuration.

However, delays have continued to mount for the program. For example, engineers needed to change the materials of some equipment to so that they could better withstand high temperatures while orbiting Mercury.

Launch of the MPO and MMO has been delayed numerous times. Originally scheduled to launch in 2014, the launch did not occur until October 20, 2018.

With a successful launch completed, this report will be archived.

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