BepiColombo: ESA’s Interplanetary Electric Propulsion Mission to Mercury

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O. Sutherland¹, D. Stramaccioni², J. Benkhoff³, N. Wallace⁴, D. Feili⁵
European Space Technology Centre, European Space Agency, Noordwijk, 2200 AG, Netherlands

A. Rocchi⁶, R. Jehn⁷
European Space Operations Center, Darmstadt, 64293, Germany

Abstract: BepiColombo is an ESA Cornerstone mission to explore the mysteries of Mercury, together with its partner JAXA. It is named in honour of Professor Giuseppe (Bepi) Colombo, who first proposed the orbital dynamics of placing a spacecraft into a resonant orbit with Mercury allowing multiple fly-bys of the planet.

¹ Mercury Transfer Module Manager, Directorate of Science, orson.sutherland@esa.int
² Mercury Planetary Orbiter Manager, Directorate of Science, daniele.stramaccioni@esa.int
³ BepiColombo Scientist, Directorate of Science, johannes.benkhoff@esa.int
⁴ Electric Propulsion Engineer, Directorate of Technology, Engineering and Quality, neil.wallace@esa.int
⁵ Electric Propulsion Engineer, Directorate of Technology, Engineering and Quality, davar.feili@esa.int
⁶ Mission Analyst, Directorate of Operations, amadeo.rocchi@esa.int
⁷ Head of Planetary Defense Office, Directorate of Operations, ruediger.jehn@esa.int
The mission will place 2 independent spacecraft, each containing a suite of scientific instruments, in different orbits around Mercury to follow-up on the MESSENGER findings and investigate:

- the origin and evolution of a planet close to the parent star,
- the interior structure, geology, composition, surface composition and crater,
- the vestigial atmosphere (exosphere): composition and dynamics,
- the magnetized envelope (magnetosphere): structure and dynamics, dual spacecraft mission to separate inner and outer fields,
- and the origin of its magnetic field.

Transit to and operation in Mercury orbit at a third of Earth’s distance to the Sun imposes a unique set of requirements and technical challenges, principal among these being the extreme thermal environment and propulsion needed to achieve Mercury orbit with such a large payload.

Thermal constraints impose distinct spacecraft configurations, compatible with up to 10 times the Solar radiation power at 1AU and planetary surface temperatures up to 450°C. The Mio spacecraft, formerly the Mercury Magnetospheric Orbiter (MMO), developed by JAXA, will be placed in to a highly eccentric Mercury polar orbit of 11639 x 590 km, chosen for the magnetosphere coverage, with thermal and attitude control using a spin stabilised design. The Mercury Polar Orbiter (MPO) developed by Airbus Defence and Space, will be placed in a 1500 x 480 km orbit, also polar to maximise planetary coverage whilst minimising insertion delta-V. Unlike Mio, the MPO science payload forces the use of 3-axis stabilisation in combination with high temperature insulation and a large finned radiator designed to radiate to deep space whilst shielding from the planet. The orbiters are stacked on the 3-axis stabilised Mercury Transfer Module (MTM), with the MMO Sun-shield (MOSIF) protecting MIO from the sun, to form the Mercury Composite Spacecraft (MCS) with a total launch mass of 4.100 kg.
Extensive mission analyses performed in the early phases of the programme concluded that a high specific impulse Electric Propulsion system in conjunction with 9 planetary fly-bys, 1 at Earth, 2 at Venus and 6 at Mercury, was fundamental to the mission viability. The selected Electric Propulsion system, housed within the MTM and powered by 2 large deployable solar arrays, is based around a cluster of four 22cm diameter T6 gridded ion thrusters, each mounted on an independently controlled pointing mechanism. A mission total impulse requirement of 17.6 MNs is required from the EP system, at thrust ranges between 75mN -125mN using a single thruster and up to 250mN using simultaneous operation of two thrusters.

This paper presents an outline description of the mission and its scientific objectives, the main building blocks of the spacecraft, the critical role played by the electric propulsion system and serves as an introduction to the more detailed papers to follow in the session.

Nomenclature

AOCS  Attitude and Orbit Control System
CP    Chemical Propulsion
ERO   Earth Return Orbiter
GAM   Gravity Assist Manoeuver
Mio   Current name for the MMO
MMO   Mercury Magnetospheric Orbiter (JAXA)
MOI   Mercury Orbit Insertion
MOSIF MIO Sunshield and Interface Structure
mN    milli-Newton
MPO   Mercury Planetary Orbiter (ESA)
MTM   Mercury Transfer Module (ESA)
SEP   Solar Electric Propulsion
SEPS  Solar Electric Propulsion System

I. Introduction

EPICOLOMBO is ESA’s Cornerstone mission to Mercury together with its partner JAXA. It’s mission objective is to study the Solar System’s innermost planet in the greatest detail yet undertaken. Mercury is a key planet for understanding the evolutionary history of our Solar System and therefore also for the question of how the Earth and Life was formed. It is the planet closest to the Sun, the only planet besides Earth with a magnetic field and the smallest planet in our Solar System.

NASA’s earlier 2011 MESSENGER mission to Mercury made some new and in some cases unexpected observations, which require further follow-up investigation in order to piece together the evidence for the formation and evolution of the planet and our Solar System. BepiColombo has a comprehensive state of the art suite of payloads covering the entire electromagnetic spectrum plus mass spectrometry and plasma physics. The total number of payloads, the high spectral and spatial resolution, the presence of two dedicated spacecraft, the Mercury Planetary Orbiter (MPO) for the planet and the Mercury Magnetospheric Orbiter (MMO, dubbed Mio) for the environment, flying in dedicated and coordinated orbits will allow the Planetary Science community to follow-up the earlier findings
with higher granularity and breadth. The MPO will focus on a global characterization of Mercury through the investigation of its interior, surface, exosphere and magnetosphere. In addition, it will be testing Einstein’s theory of general relativity. The scientific payload onboard the MPO will provide the detailed information necessary to better understand the process of planetary formation and evolution in the hottest part of the proto-planetary nebula as well as the similarities and differences between the magnetospheres of Mercury and the Earth. The MMO spacecraft instruments are more focused on studying the plasma, particle and magnetic environment around the planet. BepiColombo will therefore also provide a rare opportunity to collect multi-point (on two spacecraft) measurements in a planetary environment. This will be particularly important at Mercury because of short temporal and spatial scales in Mercury’s environment. The foreseen orbits of the MPO and MMO will allow close encounters of the two spacecraft throughout the mission. Such intervals are very important for the inter-calibration of similar instruments on the two spacecraft.

Figure 1 shows an exploded view of the BepiColombo spacecraft stack, which consists of 4 separate elements (ordered here from launcher interface, left, to the “top” of stack, right):

**Mercury Transfer Module (MTM):** an EP space tug which flies the stack to Mercury and provides power and Attitude and Orbit Control for the Cruise phase;

**Mercury Planetary Orbiter (MPO):** ESA’s scientific contribution to the mission, which will operate in Mercury low orbit;

**Mercury Magnetospheric Orbiter (MMO):** dubbed “Mio”, JAXA’s scientific contribution to the mission, which will operate in a highly elliptical orbit around Mercury;

**MMO Sunshield and Interface Structure (MOSIF):** used to shield MMO during the cruise before being delivered to its operational orbit.

BepiColombo is unique in that it comprises 3 complete spacecraft flying together as a mechanically and electrically coupled stack, from launch up until the Mercury orbit insertions of its two orbiters. The scientific objectives of the mission require that two orbiters are brought to Mercury by the MTM, a large propulsion module and the primary source of electric power for the approximately 7 year cruise to Mercury. The high delta-V required to get into a Mercury orbit and the total mass to be carried pose challenging requirements to the mission analysis and to the propulsion systems. The selected strategy is to make use of multiple planet gravity assists to generate the bulk of the required delta-V together with high-power electric propulsion to generate the remaining velocity increment and to ensure the correct trajectory between fly-by’s. If required, small chemical bi-propellant burns are employed to perform Trajectory Correction Maneuvers (TCM’s) before and after the fly-by’s, based on tracking data from ground.

Following a direct launch into an escape trajectory, the MTM provides Solar Electric Propulsion (SEP) for the approximately 7 year cruise to Mercury, all of the electric power for the 3 modules and it must perform most of the attitude and orbit control for the stack. Finally, the MTM brings the two Mercury orbiting modules into a position from which they can reach their final Science orbits around Mercury. The thermal impact of flying three spacecraft...
together as one physical stack, considering a number of interactions and constraints, was accounted for in the design, and as far as possible, verified by test.

Figure 3 shows the BepiColombo spacecraft stack in Cruise configuration. In the top image the MTM can be identified at the base of the stack by the firing EP thrusters and the 2 large symmetric Solar Array wings. The central module is the ESA MPO identifiable by its single deployed Solar Array “fin” (this Solar Array is kept edge on to the sun during the Cruise to preserve its life time). At the top of the stack the MOSIF sunshield can be seen. In the bottom image the JAXA MMO can be identified inside the MOSIF sunshield stowed in cruise configuration.

The MTM functions bring a range of thermal control challenges, not least because the mission cannot simply be flown with the spacecraft stack in a single, sun-pointing orientation. For example, prior to each planetary fly-by, it is necessary to have a good degree of freedom in the range of sun angles permitted on the stack, in order that the Attitude and Orbit Control System (AOCS) can perform any fine trajectory correction maneuvers. In addition, at these critical times, an extra degree of flexibility in the spacecraft attitude is helpful for increasing the communication opportunities back to Earth. Smaller deviations to the purely sun oriented attitude originate from the need for wheel off-loading, which is performed using the MTM’s SEP thrusters. The MTM has to survive all conditions up to the Mercury orbit insertion point, at which time it is separated from the stack (see Figure 2).

To accomplish the mission described in the preceding section, the MTM thermal design incorporates a novel Sun shield using a special high temperature MLI and in excess of 9m² radiator area. When exposed to the 15.4kW/m² solar flux at 0.298AU, it must allow any two of its four ~5kW electric thrusters to run simultaneously, while maintaining internal temperatures suitable for the operation of 24 bi-propellant reaction control thrusters, internal electronic equipment with standard temperature ranges, thruster pointing mechanisms and a Xenon propulsion system, while still allowing significant flexibility in its orientation to the sun and the ability to survive short-term losses of attitude. The thermal design of the MTM is discussed in greater depth in Tuttle et al. The thermal design drivers for the MPO are to be found in connection with the Mercury approach phase and with the Mercury orbit phase where extremely high solar and planetary fluxes will occur. Given that the orbit of Mercury is quite elliptical, the solar irradiance is a function of the Mercury true anomaly varying from 6,290 W/m² at Mercury aphelion to 14,500 W/m² at Mercury perihelion. The thermal design of the MPO is a major design driver for the BepiColombo mission and mass and is discussed in greater depth in Ferrero et al.².

II. The BepiColombo Mission

A. Mission Concept

Bringing a payload to the innermost part of the Solar System is in general very demanding and different strategies can be adopted to achieve this objective. In the case of the BepiColombo mission the strategy selected was to use planetary Gravity Assists Manoeuvres (GAM) combined with Solar Electric Propulsion (SEP) to reach Mercury and Chemical Propulsion (CP) to perform the Mercury Orbit Insertion (MOI) and bring the payload to the selected operational orbit.

The mission can be divided into 4 high-level phases:
**Launch:** the BepiColombo spacecraft was launched on Vol Ariane 245 (Ariane 5) in the evening of the 19th of October 2018; the spacecraft assembly was injected into a direct escape trajectory toward interplanetary space by the launcher upper stage.

**Interplanetary Cruise:** during this phase SEP thrust arcs are alternated with coast arcs and GAMs. Before Mercury arrival, 7 years after launch, the MTM is separated from the spacecraft stack to lower the insertion mass and to achieve a safe orbit around Mercury with a view to Planetary Protection. The Interplanetary Cruise phase is described in detail later in this paper.

**Mercury Orbit Insertion:** the orbit insertion at Mercury (MOI) is achieved by means of a sequence of chemical burns, performed by the MPO CP system. Due to the arrival conditions targeted at the end of the Interplanetary Cruise phase, the spacecraft enters into Mercury’s sphere of influence in a so-called “weak” gravitation capture. As a result the spacecraft does not escape from Mercury even if the first burns are not successful. The baseline capture sequence lasts more than 3 months and consists of (see also **Figure 2**):

- 5 initial manoeuvres to reach MMO’s operational orbit
- Release of the MMO in its operational orbit
- Release of MOSIF (after performing a manoeuvre to separate its orbit from that of MMO)
- 9 final manoeuvres to reach MPO orbit.

This phase of the mission is rather delicate because several factors affect the whole sequence, including: eclipses, occultations, solar conjunctions, relative position of Mercury and the Sun, solar aspect angle during manoeuvres, gravity losses, time between manoeuvres/separation events as well as the specific constraints for the MMO separation (position in the orbit, visibility window from ground stations). The interaction of all these constraints, and especially the geometry of solar conjunctions, make it so that feasible MOI attempts cannot be executed at every orbit revolution of Mercury, but only in specific cases.

**Operation at Mercury:** nominally lasting 1 year, but with a possible extension of the same duration, this is the purely Scientific phase of the mission. In this period, MMO will study Mercury’s Magnetosphere from a highly elliptical polar orbit (pericenter altitude = 590 km, apocenter altitude = 11639 km), while the MPO will stay closer to the planet (pericenter altitude = 480 km, apocenter altitude = 1500 km), also in a polar orbit.

**B. Mission Analysis**

The transfer from Earth departure to Mercury arrival is achieved thanks to a hybrid approach in which GAMs are employed together with SEP. Planetary GAMs are very effective in changing the spacecraft velocity with respect to the Sun (with virtually no propulsive cost), but impose the interplanetary transfer duration once a sequence of swing-by’s is selected since phasing with the orbit of the planets constrains the duration of the arcs between the chain of encounters. A total of 9 GAMs will be performed by the BepiColombo spacecraft during the 7 year Interplanetary Cruise: the first will be at the Earth in April 2020, followed by two encounters at Venus and six at Mercury. In order to achieve this optimal sequence, the spacecraft is required to perform SEP thrust arcs between most planetary encounters.

Each of the MTM’s SEP branches is configured to provide between 75 mN and 125 mN per thruster, where any 2 branches can be fired simultaneously (provided enough energy is available); with an initial spacecraft mass of around 4 tons, the thrust-to-mass ratio at the beginning of Cruise is approximately $7 \times 10^{-5}$ N/kg, while the specific impulse is close to 4000 s.

GAM and SEP cannot overlap, since very precise navigation is necessary for fly-by’s, not only to avoid expensive corrections afterwards, but also to avoid accidentally passing too close to the target planet. For the BepiColombo mission a 30 day coast period is enforced before each encounter, as well as during the 7 days following the closest approach. The coast phase is used to perform precise orbit determination and if necessary trajectory correction manoeuvres (TCMs) are executed with the MTM chemical thrusters. Also immediately after launch and just before Mercury arrival thrust arcs are not allowed: after launch the spacecraft SEPS requires time to be commissioned before being fully exploited; before arrival, instead, time is required to separate MTM and accurately navigate the spacecraft to reach the targeted MOI conditions.

The arrival conditions at Mercury are selected so that a “weak” gravitational capture is possible: this technique takes advantage of the gravitation pull of both the Sun and Mercury to achieve a temporarily closed orbit around the latter (Ref. 6). The most demanding requirement needed to implement this technique is to have a sufficiently low
arrival velocity at Mercury. This is one of the primary objectives for implementing SEP on BepiColombo, since GAMs cannot be used for this purpose. Once the aphelion is smaller than the distance of Venus from the Sun, only Mercury is available for swing-by’s and the relative encounter velocity cannot be changed if no delta-V is applied to the spacecraft. The delta-V required to lower the approach velocity would have been possibly prohibitive if performed with conventional CP thrusters. The major advantage of adopting the “weak” gravitation capture technique is the added robustness of having multiple attempts available for the first crucial manoeuvre in the MOI sequence.

The baseline interplanetary transfer trajectory is reported in Figure 4. The whole transfer takes 7.2 years, with a total time with active SEP of around 650 days (25% of the total Cruise duration), resulting in almost 3 km/s delta-V imparted to the spacecraft; the total thrust time translates to around 10000 hrs per thruster, if 3 thrusters are assumed to be available from launch. In reality, the MTM is equipped with 4 fully cross-strapped SEP thruster chains, of which 1 is for redundancy. In practice, however, all 4 thrusters are cycled through 2 at a time to minimise wear on any given thruster (in some early phases only 1 thruster chain is used, but with the same principle of cycling applied). For the majority of their active life (primarily within the orbit of Venus), the thrusters will operate close to the maximum mission requirement of 125mN. Thrust arcs at lower levels (<120mN) are concentrated in the first interplanetary phase (from departure to Earth swing-by), where the distance from the Sun is greater and the limiting factor is the available power from the solar arrays. When the spacecraft reaches instead the inner part of the solar system, the solar flux is not the limiting factor and the solar arrays are tilted with respect to the Sun direction to avoid a higher rate of aging, while still providing all the necessary power required by the thrusters at maximum thrust level.

After the 2 month post-launch Near Earth Commissioning Phase (NECP), the BepiColombo SEPS successfully completed its first 2 month thrust arc. At the time of writing, and after a further 7 month coast phase, the SEPS has initiated a second 2 month thrust arc in preparation for the spacecraft’s first planetary encounter with the Earth in April 2020.

C. So Why Electric Propulsion?

Going to the inner Solar System automatically implies that there is plenty of solar energy available to run a SEP system. In the late 1990’s, early 2000’s, EP was also starting to make traction in the Telecommunications Satellite arena, with all-electric and electric/chemical hybrid options being developed on both sides of the Atlantic by the main Large Space Integrators. In 2001, the small North-South station-keeping (NSSK) EP system (comprised of 2 RIT10 and 2 UK10 thrusters) onboard ESA’s ARTEMIS satellite had saved the day by completing the orbit raising phase to
were based around existing technology and experience in Europe at the time, ultimately homing in on 5 kW class design - and in particular hardware and development risks -, the selected trajectory and ultimately the mission design, engines in general, is the thrust-to-mass ratio. Since its value is strongly related to and dependent on the spacecraft D.

accepting a delay on Science return.

Science objectives (to lighten the MPO), or a change of launcher (programmatically undesirable) in addition to would have been fatal for the mission that BepiColombo has become, no-doubt requiring major de-scoping of the EP and associated power subsystem were remarkably stable in mass over time. A decision to jump to CP in 2005 (resulting in an unvirtuous cycle of increasing volume and mass), the spacecraft wet mass had almost doubled over times of about 8 years and tight margins on system and launcher mass. EP, and in particular the BepiColombo mission duration would almost certainly have been the same due to other critical technologies (Solar Arrays, High Gain Antenna, Payloads). Moreover, the pre-PDR increase in launch mass was primarily driven by the MPO and its thermal and operational risk factors.

In any case, the conclusions of the 2008 analysis for a purely chemical mission design were much more negative and highlight the key weakness of CP spacecraft concepts: it is inflexible to mass increase (especially with the high gear-ratio of a stacked staged spacecraft)! With the true impacts of the spacecraft thermal design starting to crystalize (resulting in an unvirtuous cycle of increasing volume and mass), the spacecraft wet mass had almost doubled over the three years and had reached 4 tons. As a consequence a chemical mission design was much more negative (Ref. 4). When it became clear that these launch options had slipped (due to delays with payload and technology developments in Phase A/B1) a new mission analysis working paper was released in August 2008 presenting purely chemical launch options in 2014 and 2015 (Ref. 5). In 2005 a switch to a pure CP spacecraft concept seemed feasible. The transfer time for the 2012 launch option was only slightly more than 6 years. However, since the arrival velocity at Mercury for a CP mission is much larger than for a SEP option (1.5 km/s vs 0.3 km/s) a large orbit insertion motor (of no less than 400 N) would have had to have been implemented with all the associated issues of a “late” change (of course “late” is relative to active launch date). Moreover, the relatively high approach velocity makes a “weak” gravitation capture at Mercury impossible and therefore inherently less robust from an operations perspective. One counter argument to this, presented in Ref. 4, is that a failure of the 400 N engine at nominal orbit insertion can be recovered afterwards with a ΔV of less than 90 m/s. In addition, a 400 N engine can perform MOI in two or three burns rather than the 15 burns, which will be required using the four 20 N thrusters on-board BepiColombo. (Ref. 7), saving time and reducing operational burden. There are clearly arguments in both directions and the decision on hybrid-EP versus CP is not clear-cut. In the end it is a trade between several technology and operational risk factors.

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This position is only strengthened in hindsight when one considers that without SEPS, the spacecraft development duration would almost certainly have been the same due to other critical technologies (Solar Arrays, High Gain Antenna, Payloads). Moreover, the pre-PDR increase in launch mass was primarily driven by the MPO and its thermal requirements (independent of the cruise). Any increase in the MTM mass was driven by the MPO mass increase. The EP and associated power subsystem were remarkably stable in mass over time. A decision to jump to CP in 2005 would have been fatal for the mission that BepiColombo has become, no-doubt requiring major de-scoping of the Science objectives (to lighten the MPO), or a change of launcher (programmatically undesirable) in addition to accepting a delay on Science return.

D. What could we have done differently?

Probably the most important parameter driving the trajectory design of a mission employing SEP, and low-thrust engines in general, is the thrust-to-mass ratio. Since its value is strongly related to and dependent on the spacecraft design - and in particular hardware and development risks -, the selected trajectory and ultimately the mission design, selecting the best value is a multi-dimensional and multi-disciplinary task. Trade-offs for the BepiColombo mission were based around existing technology and experience in Europe at the time, ultimately homing in on 5 kW class...
gridded ion thruster systems, delivering between 75 mN - 150 mN with a specific impulse of around 4000s. Whilst in theory higher thrust levels could have been achieved, either at thruster level or by firing more thrusters in parallel, thermal, radiation and hence mass constraints limited the size of the power generation system to what it is today. Nonetheless in this last section we consider the implications of a different selection of EP operating points.

In the frame of risk minimization one relatively easy path for BepiColombo could have been to run the thrusters at lower thrust and therefore power. With even as much as a few tens of mN less, the same sequence of swing-by’s could be flown with negligible additional propellant required. However, since the amount of time required to perform any given delta-V change increases, the thrust-to-coast ratio between fly-by’s begins to saturate degrading trajectory robustness. For example, in case of a contingency and partial loss of a thrust arc, it would be more difficult to reach the next planetary encounters with the same geometry and timeline, especially if this contingency would have taken place during specific parts of the trajectory (e.g. during a thrust arc preceding a swing-by). Even in the rather extreme case where the maximum thrust level is halved compared to what is currently planned for flight, the GAM sequence can be maintained (with consequent impact on trajectory robustness) but significantly the arrival at Mercury would be delayed: the final revolutions after the last Mercury swing-by are in fact already occupied by long thrust arcs and there is no possibility to extend them significantly if not by delaying the arrival date by multiple orbital revolutions. There is of course a thrust level lower limit (not calculated) after which the baseline swing-by sequence becomes unfeasible and, if no other sequences are available leading to an admissible cruise time, arrival at Mercury falls out of reach.

At half the thrust and therefore roughly half the power, there would be a major impact on the entire power system from Solar Generators, through Power Distribution to thruster Power Processing as well as the Thermal Control System, with further positive knock-on impacts for the AOCS and CP wet mass, though a counter-balancing (through no doubt smaller relative) increase in Xenon wet mass due to lower specific impulse (for the T6). In short, it would clearly have led to a significant decrease in mass, complexity, verification and programmatic overhead. Moreover, thruster wear mechanisms are generally reduced extending life in terms of total hours, though not necessarily total throughput (the relationship between thruster wear and maximum thrust is not necessarily linear and it is not a given that halving thrust delivers significantly more total impulse). So why not do it? The answer lies in operational flexibility and robustness, not just in flight but also during the spacecraft development. Once the maximum thrust has been given up at Power/Thermal architectural level it cannot be regained (for example if a different launch slot was required). Looking to the future, when ESA’s experience in interplanetary EP further matures, especially in the operational domain, a finer line may be cut and more programmatic freedom could be given to the Project Office.

Similarly, at the opposite end of the scale, if the maximum available thrust level is increased the immediate consequence is increased trajectory robustness. A significantly higher thrust-to-mass ratio would clearly open up a range of new interplanetary transfers, unachievable with conventional chemical propulsion and a realistic propellant budget. These alternative transfers require more delta-V from the SEP (on the order of 10 km/s) but would also require fewer fly-by’s, thus reducing the transfer time significantly. Today, EP systems such as the QinetiQ T7 or the Ariane Group RIT-2X (or even more parallel firing T6 thrusters) could provide the required thrust and total impulse to achieve this required delta-V but the impact on the Power and Thermal Sub-Systems would be prohibitive (for a mission to Mercury) and a far bigger launch capability would be required (to accommodate the mass increase), both of which were not available to BepiColombo at the time. The simple conclusion is that the BepiColombo SEPS design sits right in the sweet spot of what was and is technologically available both at the time and today with-in Europe.

E. Next Generation: Earth Return Orbiter

Building on the experience garnered from the BepiColombo mission to date, ESA is studying together with NASA to fly to Mars and return surface samples back to Earth as part of a possible Mars Sample Return campaign. In addition to providing a rover and sample transfer arm, ESA’s major contribution to the Campaign is planned to be the Earth Return Orbiter (ERO), a spacecraft that will fly to Mars, rendezvous with an orbiting sample, fly back to Earth and return the samples back to the Earth’s Surface. The BepiColombo multi-module, high-power Electric Propulsion architecture is an excellent starting point for the ERO concept. As described in Sutherland et al.⁹, ERO represents a further step increase in high-power EP with up to 4 x 8.5 kW ion engines firing in parallel for the Cruise to and from Mars as well as the spiral down/up to/from Mars operational orbit. Like BepiColombo it will also jettison a module and several elements of the payload prior to its return to Earth.
Conclusion

BepiColombo is ESA’s Cornerstone mission to our Solar System’s innermost planet Mercury together with its partner JAXA. It will build on the early results of NASA’s MESSENGER mission from 2011 deploying a wide array of state of the art instruments across 2 synchronized orbiters. The mission concept for the 7.2 year cruise phase from Earth to Mercury relies on a combination of planetary Gravity Assist Maneuvers and Electric Propulsion. The thermal constraints on the spacecraft stack are considerable and have a major impact on the spacecraft and mission design. This is particularly the case in light of the high-power Solar Electric Propulsion System which employs 2 x 5 kW T6 gridded ion engines from QinetiQ Ltd. for most of the cruise phase. At the time of writing BepiColombo has successfully completed its first 2 month thrust arc and has just entered into its second after a coast period of about 7 months. Building on the experience from BepiColombo, ESA is planning to employ a similar spacecraft concept for the Earth Return Orbiter, one of 3 flight elements of the potential future NASA led Mars Sample Return campaign.

References