

EUROPEAN SPACE AGENCY
SCIENCE PROGRAMME COMMITTEE
BepiColombo Mission Scenario

Summary :

This document summarises the results of the BepiColombo re-definition phase and presents the recommended mission scenario. Furthermore it provides the status of the Mercury Planetary Orbiter payload.

Decisions required :

At this point, the SPC should decide :

- (i) whether to replace the 2012 launch date with a nominal launch in 2013,
- (ii) the course of action to be taken to put in place a full nominal payload.

Otherwise, the SPC is asked to give general guidance on approaches to be followed.

Voting rights

Simple majority of all Member states

Legal basis

SPC terms of Reference
ESA Convention. Art. XI. 5.a.i.

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1. Introduction

The competitive definition studies with Alenia Spazio and EADS Astrium reached their final study review milestone in April 2004. At this time, the Executive received cost and schedule reports on the electric propulsion based mission from both Contractors, which led to the predicted CaC being significantly above the mission target CaC assigned by the SPC to the BepiColombo mission end 2003. Moreover, with the assumed Soyuz launcher, the mass margins had eroded such that the mission could not be recommended anymore for implementation within its current technical boundaries at an acceptable level of risk. As a consequence, it was decided not to proceed with the Invitation To Tender for the BepiColombo Implementation Phase.

The Executive therefore initiated a re-definition phase and completed a systematic review of the BepiColombo Programmatic assumptions, design drivers and mission scenarios with the objective to bring this project back to an affordable target and, if possible, to preserve the 2012 launch window. This activity was performed with the support of the definition study contractors in order to verify and confirm the technical validity of the new options, the corresponding risk reductions and associated cost savings.

These options are reviewed here in order that the SPC may offer the Executive guidance on the way ahead and set programmatic guidelines.

Launch windows for BepiColombo nominally repeat on a 19 month basis, however, the use of electrical propulsion gives more opportunities. The delay imposed in April 2004 immediately started eating into the schedule margin associated with a 2012 launch. At the present time, the six months delay that has already occurred renders any solution requiring critical technology very high risk for a 2012 launch. However, At present to ensure even a 2013 launch, with schedule margin comparable with that of the originally planned December 2005 kick-off for a 2012 launch, means issuance of an ITT at the end of 2005. In addition to these points related to the mission profile, the SPC at its November 2005 meeting will need to make a final decision on the acceptability of the payload procurement arrangements and the share of risk in payload development between national and SPC authorities as described in the formal agreement.

2. Summary of the Results of the Re-Definition Phase

The BepiColombo mission was conceived on the basis of compatibility with the Soyuz/Fregat launch vehicle, which requires implementation of electrical propulsion in order to provide the necessary delta-V within the launch capability and still allowing an acceptable cruise duration of approximately 5 years. Nonetheless, the use of electrical propulsion induces a high cost penalty, increasing at the same time the development risks. Furthermore the mass budgets evolved showing a launch mass margin of at best 10%, a value considered unacceptable at this stage of the programme. For these reasons, the re-definition phase was configured to re-examine alternative mission scenarios, based on chemical propulsion and gravity assists. In fact, in the final analysis, these lower risk mission scenarios were the only ones considered compatible with a launch in the 2012 window.

It must be stressed however that the switch to chemical propulsion introduces new disadvantages, namely the need for a more powerful launch vehicle and the longer cruise duration, both of which increase costs.

Mission Scenarios with Launch in 2012

The definition study contractors have studied the implementation of an all-chemical propulsion system to bring the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO) to Mercury. These studies have confirmed that this is a good technical option, which is considered to be of lower risk than an electrical propulsion mission. With respect to the industrial contract for the satellite development, the implementation cost will be significantly lower than of an electrical propulsion mission. On the other hand, a chemical mission requires a mass to escape orbit in excess of 3000 kg, which eliminates Soyuz as a candidate launch vehicle. Also a launch of BepiColombo on Ariane 5 to Geostationary Transfer Orbit with a co-passenger has had to be ruled out, because the mass available to the co-passenger was predicted to be below 1000 kg. The remaining chemical mission scenarios for launch in 2012 are summarised in the following table, together with some back-up opportunities in 2013:

Throughout the paper launchers considered in options shown are European launchers or launchers developed by our partners in Japan. The latter are shown for illustrative purposes.

It should be borne in mind that there is as yet no indication at all that any such foreign launcher provision could be considered.

Case	Launch Date	Cruise Duration	Arrival Date	Launcher	Launch Strategy	System Margin
Chem 1	March 2012	6.3 years	July 2018	Ariane 5 ECA	Direct Escape	Sufficient
Chem 2	March 2012	6.3 years	July 2018	Ariane 5 ECA	Highly Elliptic Orbit	More than sufficient
Chem 3	March 2012	6.3 years	July 2018	H-IIA304	Direct Escape	Sufficient
Chem 4	August 2012	8.5 years	February 2021	Ariane 5 ECA	Direct Escape	Sufficient
Chem 5	August 2013	8.5 years	February 2022	Ariane 5 ECA	Direct Escape	Insufficient
Chem 6	August 2013	8.5 years	February 2022	Ariane 5 ECA	Highly Elliptic Orbit	More than sufficient
Chem 7	October 2013	8.5 years	April 2022	Ariane 5 ECA	Direct Escape	Sufficient

Option Chem 1 is very sound from a technical point of view as it has sufficient system margin and still offers a reasonable cruise duration such as to allow the scientific phase to start in July 2018. However, considering the cost for the Ariane launch services, as offered by Arianespace, in the project's cost at completion, the cost savings expected by the chemical mission are completely neutralised, although naturally SEP development risk is mitigated.

The cost at completion for this mission is estimated at 650 M€(this is almost identical to the cost at completion projected for the original electrical propulsion, Soyuz based mission).

Option Chem 2 is the same mission as option 1 once cruise injection is achieved. However to go from the highly elliptic orbit to the escape trajectory, a larger and therefore more costly propulsion system would be required.

Option Chem 3 requires the heavy lift version of the Japanese H-IIA launch vehicle, which is still in development and it will not fly before 2007 for the first time. However the option seems to be purely illustrative as the required launch date violates seasonal launch constraints at Kagoshima that exist due to agreements between the Japanese authorities and local fishermen that preclude H-II launches in this period of the year.

Option Chem 4 seems unacceptable due to the long cruise duration for an overall CaC similar to option Chem 1.

The back-up options Chem 5 to Chem 7 seem unacceptable because, in addition to the above arguments, the start of the scientific phase is very late. Note that long cruise duration also introduces potential mission risk as well as potential increased operations costs.

Mission Scenarios with Launch in 2013

In parallel to the chemical mission scenarios identified above, the Executive continued to investigate electrical mission scenarios. However, because of the schedule and risk considerations, these inevitably were restricted to a 2013 launch.

The spacecraft design will essentially correspond to that of the definition study review. Therefore the definition study contractors were not requested to support these additional studies in order to allow them to focus on the chemical options.

In view of the results on the chemical back-up mission scenarios Chem 5 to Chem 7 with a launch in 2013, in particular the cost at completion and cruise duration, chemical missions cannot be considered as nominal options for the 2013 launch window.

The resulting options for launch in 2013 comprise only electrical mission scenarios, as summarised in the following table:

Case	Launch Date	Cruise Duration	Arrival Date	Launcher	Launch Strategy	System Margin
SEP 1	September 2013	9.3 years	December 2022	Soyuz/Fregat	Highly Elliptic Orbit + Lunar Fly By	Barely sufficient
SEP 2	February 2013	7 years	March 2020	Soyuz/Fregat	Highly Elliptic Orbit + Lunar Fly By	Barely sufficient
SEP 3	September 2013	5.8 years	June 2019	H-IIA202	Highly Elliptic Orbit + Lunar Fly By	More than sufficient
SEP 4	September 2013	4.9 years	August 2018	H-IIA2024	Direct Escape	More than sufficient

Option SEP 1 is still based on the Soyuz/Fregat as launcher, necessitating significant mass savings in order to restore the system margin to an acceptable level (~20%). This can be done by implementing lower thrust level, which limits the size of the solar array, with more than 9 years cruise duration to reduce the amount of fuel. The resulting arrival time at Mercury appears unacceptable and these measures still only appear marginally able to recover the system margin. Therefore, the mission using Soyuz/Fregat as launch vehicle is seen by the Executive as carrying too high a risk.

Option SEP 2, also based on Soyuz/Fregat as launcher, is similar as option 1 but with a shorter trajectory. This option has the same difficulties as option 1 with in addition a severe strain on the schedule margin.

The only option that would remain for use of Soyuz/Fregat would be to combine the scientific payload of the MPO and MMO into a single spacecraft, but this is a different mission, likely to lead to significantly reduced scientific capabilities at a total cost of the same order of magnitude as that of the baseline mission. The single spacecraft option has not yet been reviewed by the science advisory structure and in case of need for a new payload selection, further delay is inevitable. Nonetheless, the SPC may wish to recommend such a review combined with mission and cost analysis to determine if a reserve position exists.

Option SEP 3 considers the possibility to employ the basic flight validated version of the H-IIA to launch the cruise composite into a highly elliptic orbit. This mission option relies upon an optimisation of the thrust level and solar array power to reduce the costs and development risks of the electric propulsion subsystem, while offering a cruise duration remaining below 6 years, arriving at Mercury in June 2019 and providing the required system margin. The cost at completion is currently estimated at 620 M€ excluding the cost of the launcher.

Option SEP 4 proposes a fast direct escape trajectory to arrive at Mercury in August 2018, but it is more expensive than option 2 for two reasons. First, a more powerful version of the H-IIA rocket with 4 solid strap-on boosters is needed. Second, a higher thrust level of the electric propulsion engines will be required, needing larger solar arrays and increasing the overall development cost and risks. In view of the above, the Executive recommends discarding this option.

Back-up launch opportunities for electrical propulsion missions exist within approximately one year of the nominal launch date.

Programme level consideration

Finally, while an attractive low risk technical option is achievable with option Chem 1, its expenditure profile is incompatible with the financial capabilities offered by the Scientific Programme, unless other approved elements in the presently approved programme (worth a cumulated amount of 150 M€) are removed in favour of BepiColombo.

Option SEP 3 emerges clearly as the most promising nominal mission option that will deliver science by mid 2019 at an acceptable implementation risk. With the launch delayed to September 2013, its expenditure profile becomes compatible within the Science Programme envelope with the present mission portfolio.

3. Mercury Planetary Orbiter Payload Status

The payload instrument and definition work was continued and further detailed in close cooperation with the selected instrument teams. A first set of ESA controlled draft experiment interface documentation has been completed and is under review by the definition study contractors. The documentation will be iterated for the ITT release during the ongoing meetings with the Principal Investigator teams.

Considerable progress has been made on the internal instrument design, with their predicted scientific performance being compatible with the BepiColombo objectives. The requested mass, higher than the allocated mass for some instruments, could be reduced by local optimisation; however the overall resource situation remains tight and will need continuous attention by the payload design teams and monitoring by the ESA Project Office throughout the development phase.

The forthcoming payload activity requires consolidation of the accommodation and in particular of thermal interfaces. In order to avoid local over-design on both the instrument and spacecraft side it is essential that interface and accommodation iteration with Industry is started as soon as possible. The definition phase, with two different spacecraft designs from the competing study contractors, leaves a number of options open, until a firm spacecraft design is selected. Consequently, to ensure the timely and efficient procurement of the instruments, further progress on the payload work depends on the selection of one spacecraft design (the prerequisite being to select the prime contractor).

For three instruments (BELA, MGNS and MANGA) being subjected to a feasibility phase, their teams worked intensively to demonstrate that the agreed criteria are met. The results shall be provided in detailed reports to the Project Office by mid September and will be reviewed during individual meetings planned for end September such that the findings and recommendations can be presented for review by the SSWG and SSAC and to the November SPC for confirmation as planned.

The definition of ESA provided common items has progressed with the following steps:

- The advanced ITT for the Central Parts Procurement (CPPA) services available for MPO and European MMO hardware providing institutions has been issued and related information was given to the experiment teams;
- The trade-off for the provision of interface electronics is completed (FPGA, software libraries and development environment). The Project Office is currently progressing to release boards for evaluation by the instrument teams in the main contributing member states;
- The Spacecraft Interface Simulator specification has been released to experiment teams for review and comment.

The experiment teams reported that the delays in the funding for the definition phase are currently being alleviated, through bridging by their institutions.

The British Particle Physics and Astronomy Research Council finds itself in difficulty to fund the two proposed UK-led instruments. The MERMAG magnetic field instrument had been refused funding earlier in the year. However, in June, PPARC's Science Committee further rejected funding for the MIXS X-ray spectrometer on the basis of peer review. The PPARC is the only possible source of UK funding for planetary science instrumentation and its Executive has proposed a compromise of providing about 40% of the estimated funding:

- MERMAG is proposed to be recovered by a change of responsibilities with K.H. Glassmeier (Technical University of Braunschweig, D) as a new Principal Investigator. The recovery, capitalising on a similar instrument selected for MMO, involves Germany and Austria as major contributing funding agencies. The predicted scientific performance satisfies the requirements as before. Recommendations by SSWG and SSAC will be attached to this paper.
- For the MIXS X-ray instrument, ESA have continued up to now to cooperate with the MIXS/SIXS team and PPARC to identify precisely the elements not funded. The tasks and deliverables that cannot be covered through the presently offered UK funding are the design, development and procurement of the ASIC read out electronics for the focal plane detectors, the optics, the structure, the thermal control, the electronics units and the assembly, integration and testing of the instrument. The part not funded is estimated to be in the range 8 to 11 M€ the value depending on the procurement method to be adopted.

No viable back up has been identified to fulfil the MIXS science objectives. Cancellation of this instrument would result in severe loss of unique chemical composition information and significant degradation of the scientific return of the mission. As no other partner could be identified to make contributions to the MIXS experiment, PPARC has requested ESA (SPC) to provide the missing elements.

Managerially the PPARC request complicates matters and would lead to a diffusion of authority as was experienced with the implementation of the Beagle 2 Mars Lander. Mindful of the criticism from ESA and UK authorities of both the Executive and SPC for taking similar risks in the development of the Beagle2, the Executive feels unable to recommend such an approach to the SPC.

Two other options could be considered.

The first would be to follow the precedent taken after British (and American) withdrawal from support of instrumentation for Integral in the mid-90's. Member State institutions outside the UK took up the major roles originally identified for British and American institutions. Indeed there was a major reorganisation as British capabilities were transferred to Italian institutes and other Member States picked up work originally foreseen for Italy. However this approach, although successful for Integral does not seem viable for BepiColombo in present economic circumstances. The Executive does not propose to go further in this direction.

The criticality of the MIXS instrument to the mission will be discussed at the forthcoming SSWG and SSAC meetings and their resolutions will be attached hereto. If, in agreement with the information we are receiving from the BepiColombo scientific community, the MIXS instrument is deemed scientifically fundamental to the mission, the Executive propose that the SPC consider a second option. The SPC could declare that the MIXS instrument, critical as it is to the mission, is a European facility instrument with funds entirely provided by SPC ab initio. There would be no UK leadership acknowledged for the instrument. Scientific leadership and science team would be determined by an AO openly competed across ESA Member States. The Science Management Plan would need to be modified accordingly. The SPC is accordingly asked to decide on acceptance of such an approach, in order that the Executive can investigate the cost and feasibility and report at the November 2005 SPC.

Otherwise the final financial commitment from the Lead Funding agencies to support the BepiColombo payload complement is awaited and will need to be obtained in accordance with the Science Management Plan. These commitments are expected before the November SPC meeting.

4. Way Forward

The Executive cannot recommend a launch of BepiColombo in 2012 since:

- The nominal electric propulsion mission is too risky;
- The chemical propulsion appeared as a good, low risk technical alternative;
- Both the electrical and chemical propulsion options lead to approximately the same cost at completion, which makes the corresponding funding profile not affordable by the Science Programme.

In the view of the Executive, it appears that the electric propulsion mission with launch in September 2013 is the only realistic option since:

- The technical risk for the implementation is acceptable as adequate system margin is available;
- This mission, while far above the target cost assigned in 2003, still can be accommodated within the present financial envelope of the scientific programme;
- However, the most economical solution would require agreement with Japan for provision of the launcher and for any such arrangements to be seen to be consistent with European launcher policy.

The Executive proposes to initiate all steps for preparing the implementation of the BepiColombo mission, electric propulsion based, for launch in September 2013. In order to get proper momentum, in particular on the payload detailed definition and interfacing with the satellite, the Executive intends to issue the ITT for the implementation phase in December 2005. The mission definition work on the spacecraft and propulsion modules is sufficiently mature to permit release of an ITT and selection of a prime contractor on the basis of a committing proposal, even if the launcher provision is not completely settled by that time.

The Executive will come back to SPC for formal approval of the mission CaC prior to kick-off of this development contract. This procurement will be phased such that the contractual action could be stopped at PDR, end of phase B2, should the launcher provision not be solved by this time. Performing Phase B2 will allow the detailed definition of the payload and its interfaces to proceed without delay and the development and consolidation of the detailed system design and specification, enabling a realistic schedule for the issue of the subcontract ITTs.

Meanwhile, the Executive is proceeding to clarify how the launch might be procured. The status of this action will be reported by the November 2005 SPC meeting. At the same meeting, it is expected that the Executive, following guidance given by SPC at this meeting, will provide a consolidated description of the payload funding for confirmation by SPC.