CALL FOR SUBMISSION OF INTENTS TO PROPOSE EXPERIMENTS FOR THE BEPICOLOMBO MISSION TO MERCURY

BepiColombo is the fifth Cornerstone Mission of the Science Programme's long term plan, Horizons 2000. The mission is devoted to the thorough exploration of Mercury and its environment, with the aim to understand the processes of planetary formation and evolution in the hottest part of the protoplanetary nebula.

BepiColombo consists of three spacecraft science elements: the Mercury Planetary Orbiter (MPO), the Mercury Magnetospheric Orbiter (MMO) and the Mercury Surface Element (MSE). ESA is responsible for MPO and MSE, whereas MMO is expected to be contributed by the Institute of Space and Astronautical Science (ISAS) of Japan.

By means of this letter, we intend to probe the interest of the European and Japanese science communities in proposing and providing scientific instrumentation for any element of the mission. We are also interested in ascertaining the readiness level of the instruments and understanding the amount of technological development needed to transform a concept into an experiment. We earnestly ask for an honest assessment of your needs. It will underpin our assessment of the needs for advanced technical development in critical areas.

This exercise is preliminary to the payload instrument proposals and the competitive selection, which are scheduled to take place in Europe and in Japan, in the course of 2002 (MPO and MSE) and 2003 (MMO), respectively.

The deadline for the submission of Intents to Propose (ITP) experiments for the BepiColombo Cornerstone mission is: 23 July 2001

The European scientists should address their letters to:

Dr. Marcello Coradini, Solar System Missions Coordinator, ESA HQ

Marcello.Coradini@esa.int

With copy to:

Dr. Rejean Grard, BepiColombo Project Scientist, ESTEC

Rejean.Grard@esa.int

The Japanese scientists should address their letters to:

Prof. Hitoshi Mizutani, ISAS

mizutani@planeta.sci.isas.ac.jp

With copy to:

Prof. Toshifumi Mukai, ISAS

mukai@stp.isas.ac.jp

Letters should be sent electronically in a **Word, Wordperfect** or **RTF** format to the above e-mail addresses. ESA and ISAS will subsequently exchange copies of the received LoIs.

The ITP will not exceed 5 pages and be written in English, including possible annexes.

The ITP will contain:

1. the names and responsibilities of the institutes associated with the submission,
2. a brief description of the experiment and its science goals,
3. a clear indication of the BepiColombo element on which the instrument should be flown,
4. an assessment of the hardware maturity and heritage, with particular reference to the performance and survival of the detectors and front-end electronics in the thermal environment of Mercury,
5. an outline of the technological study programme that is required for demonstrating the validity of the proposed concept.

Preliminary information about mass, power, bit rate, electromagnetic cleanliness and viewing requirements, etc., is also welcome.

It is highly recommended to quantify the instrument maturity with one of the following statements:

1. Existing hardware (e.g. reflight);
2. Existing with minor modifications;
3. Existing with major modifications;
4. New, at detailed design level;
5. New, at preliminary design level;
6. Concept only.

The following text provides some basic information on the BepiColombo mission and its payload.

Further detailed information can be downloaded from:

http://solarsystem.estec.esa.nl/Mercury/MercuryAssess.htm

MISSION SUMMARY

Mercury is an extreme of our planetary system. Since its formation, it has been subjected to the highest temperature and has experienced the largest diurnal temperature variation of any object in the Solar System. It is the closest planet to the Sun and has the highest uncompressed density of all planets. Solar tides have influenced its rotational state. Its surface has been altered during the initial cooling phase and its chemical composition may have been modified by bombardment in its early history. Mercury therefore plays an important role in constraining and testing dynamical and compositional theories of planetary formation.

Only the American probe Mariner 10 has returned data from Mercury. The spacecraft made three flybys of Mercury in 1974-1975, and obtained images of somewhat less than half its surface and discovered its unexpected magnetic field that is small but strong enough to stand off the solar wind and form the magnetosphere. These data have been fully exploited but many gross features remain unexplained. Some conclusions are still speculative and have evoked many new questions.

- What will be found on the uninspected hemisphere of Mercury ?
- How did the planet evolve geologically ?
- Why is Mercury’s density so high ?
- What is its internal structure and is there a liquid outer core ?
- What is the origin of Mercury’s magnetic field ?
- What is the chemical composition of the surface ?
- Is there any water ice in the polar regions ?
- Which volatile materials compose the vestigial atmosphere (exosphere) ?
- How does the Mercury’s magnetic field interact with the solar wind ?
- What are the structures of the exosphere and magnetosphere ?
- How are particles energized in Mercury’s environment ?

BepiColombo’s other objectives go beyond the exploration of the planet and its environment, to take advantage of Mercury’s close proximity to the Sun:

- Fundamental science: is Einstein’s theory of gravity correct?
- Impact threat: what asteroids lurk on the sunward side of the Earth?

It appears that the best way to fulfil the scientific goals of the BepiColombo mission is to send two orbiters and one lander to Mercury.

(1) The Mercury Planetary Orbiter (MPO) is dedicated to planet-wide remote sensing, radio science and asteroid observations.

(2) The Mercury Magnetospheric Orbiter (MMO) accommodates mostly the field, wave and particle instruments.

(3) The Mercury Surface Element (MSE), a lander module, performs *in situ* physical, optical, chemical and mineralogical observations which serve as ground-truth references for the remote sensing measurements.

The method for transporting the spacecraft elements to their destinations emerges from a trade-off between mission cost and launch flexibility. It combines ion propulsion, chemical propulsion and gravity assists. The interplanetary transfer is performed by a Solar Electric Propulsion Module which is jettisoned upon arrival. The orbit injection manoeuvres are then realized with a Chemical Propulsion Module which is also jettisoned once the deployment of the spacecraft science elements is completed.

The spacecraft concept is modular and lends itself to a large variety of schemes. Two specific scenarios are being studied in detail:

(1) A single-launch scenario, where the three spacecraft science elements and the two propulsion modules are injected together into an interplanetary orbit with a large rocket, such as Ariane 5;

(2) A split-launch scenario, where the spacecraft is divided into two composites with nearly identical propulsion elements which are launched separately with smaller rockets, such as Soyuz-Fregat.

While the latter is presently considered to be the nominal one, the two approaches have been proven feasible and compatible with the given mission objectives and scientific instrumentation. They also provide for flexibility and offer alternative routes with different schedules and funding scenarios.

PAYLOAD SUMMARY

A number of possible instruments and their relevance to the scientific objectives are shown, as examples, in the following tables. This information is given for illustration purpose only and prejudge in no way the composition of the real payload. The list is not exhaustive and additional or alternative inputs are welcome. Conversely, the mention of a given instrument is not a guarantee of its inclusion in the final payload. The instrument selection process will take into account the potential science return and the scientific priority within the mission goals, the technical and financial feasibility and the availability of spacecraft resources.

Planetary Orbiter

The MPO spacecraft is three-axis stabilized. One axis points along the nadir direction for a continuous observation of the planet. The orbit is polar to facilitate global mapping and as low as possible to optimize spatial resolution. The minimum periapsis and apoapsis altitudes, at present 400 km and 1500 km, are imposed by the thermal environment.

Imaging and spectral analysis are performed in the IR, visible and UV ranges. These optical observations are complemented by those of the gamma-ray, X-ray and neutron spectrometers which yield additional data about the elemental composition of the surface. Information about regolith and exosphere compositions may also be provided by a dust mass spectrometer and a energetic neutral particle analyser. Imaging will be supported by topographic observations performed with an altimeter. Magnetic field measurements on the two orbiters would help discriminating the internal and induced fields.

The radio science experiments of BepiColombo aim at achieving four classes of measurements:

- the rotation state of Mercury,
- the gravity field,
- the local gravitational anomalies,
- the orbit of Mercury around the Sun and the propagation of electromagnetic waves between the Earth and Mercury, in order to test general relativity and to solve for other fundamental quantities.

A small telescope could detect Near Earth Objects whose orbits lie almost entirely inside that of the Earth and are hard to observe from the ground or from a space observatory near the Earth.

Magnetospheric Orbiter

The payload elements dedicated to the study of fields, waves and particles in the environment of the planet are accommodated on the Magnetospheric Orbiter. The MMO spacecraft is spin stabilised at 15 rpm, which facilitates the azimuthal scan of the particle detectors and the deployment of wire electric antennas. The orbit is polar and highly elliptic; its major axis lies in the equatorial plane to permit a global exploration of the magnetosphere from an altitude of 400 km up to a planetocentric distance of nearly 6 planetary radii. A camera could act as a back-up for the mapping system of MPO.

Surface Element

A lander system is the third scientific element of the BepiColombo mission. The Mercury Surface Element purpose is to explore a sample area of the planetary surface at a latitude of about 85° with the maximum possible resolution and to perform local measurements against which the data collected by the orbiters can be validated.

A mobile platform (Micro-rover) and a soil penetrating device (Mole) are considered as instruments delivered by Principal Investigators rather than MSE facilities.

Mercury Planetary Orbiter (MPO)	
Narrow Angle Camera (NAC)	0.35 – 1 µm
Wide Angle Camera (WAC)	0.35 – 1 µm
Infrared Mapping Spectrometer (IRS)	0.8 - 2.8 µm
Ultraviolet Spectrometer (UVS)	70 – 330 nm
X-ray spectrometer (MXS)	0.5 – 10 keV
Gamma-ray Spectrometer (MGS)	0.1 - 8 MeV
Neutron Spectrometer (MNS)	0.01 – 5 MeV
Radio Science Experiments (RSE)	32 – 34 GHz
Laser Altimeter (TOP)	1064 nm
Magnetometer (MAGP)	± 4000 nT
Neutral Particle Analyser (NPA)	0 – 100 keV
Dust Mass Spectrometer (DMS)	1 – 10 000 amu
Infrared Radiometer (IRR)	2 – 60 µm
Near-Earth Object Camera (NET)	18 mag
Mercury Magnetospheric Orbiter (MMO)	
Magnetometer (MAGM)	± 4000 nT
Ion spectrometer (IMS)	10 eV – 30 keV
Electron Analyser (EEA)	0 – 30 keV
Solar Wind Analyser (SWA)	10 - 15 keV
Cold Plasma Detector (CPA)	0 – 50 eV
Energetic Particle Detector (EPD)	30 - 700 keV
Energetic Neutral Atoms (ENA)	1 eV - 10 keV
Search Coil (RPW-H)	10 Hz - 1 MHz
Electric Antenna (RPW-E)	DC – 16 MHz
Positive Ion Emitter (PIE)	1 – 100 µA
Mercury Dust Counter (MDC)	$>10^{-11}$ kg ms^{-1}
Camera (SCAM)	0.5 – 0.8 µm + Na/K lines
Mercury Surface Element (MSE)	
Descent Camera (CLAM-D)	0.3 -1 µm
Surface Camera (CLAM-S)	0.3 - 1 µm
Magnetometer (MAGL)	± 4000 nT
Seismometer (SEIS)	0.05 – 50 Hz
Alpha X-ray Spectrometer (AXS)	0.9 – 10 keV
Close-up Camera (CUC)	0.3 - 1 µm
Mössbauer Spectrometer (MOS)	5 – 100 keV
Heat Flow and Physical Properties Package (HP^3)	
Micro-rover (MDD)	
Mole (MMR)	

Table 1: Possible instruments for the scientific payload of BepiColombo, with typical dynamic ranges and characteristic parameters.

S/C ELEMENT	INSTRUMENT	MORPHOLOGY	INTERIOR	COMPOSITION	MINERALOGY	EXOSPHERE	MAGNETOSPHERE	SOLAR WIND	FUNDAMENTAL SCIENCE	NEOs
MPO	NAC	X			X					
	WAC	X			X	X				
	IRS				X					
	UVS			X	X	X				
	MXS			X			X			
	MGS			X						
	MNS			X						
	RSE	X	X						X	
	TOP	X	X							
	MAGP		X				X	X		
	NPA			X		X	X			
	DMS			X		X				
	IRR		X	X						
	NET									X
MMO	MAGM		X				X	X		
	IMS			X		X	X	X		
	EEA					X	X	X		
	SWA					X	X	X		
	CPA					X	X	X		
	EPD					X	X	X		
	ENA					X	X	X		
	RPW-H						X	X		
	RPW-E						X	X		
	PIE						X	X		
	MDC					X				
	SCAM	X			X	X				
MSE	CLAM-D	X			X					
	CLAM-S	X			X					
	MAGL		X				X			
	SEIS		X							
	AXS			X						
	CUC	X			X					
	MOS				X					
	HP^3		X	X	X					

Table 2: Relevance of possible payload instruments to BepiColombo scientific objectives.