Highlights of Astronomy, Vol. 13
International Astronomical Union, 2003
O. Engvold, ed.

The BepiColombo Lander – MSE

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Abstract. The European Space Agency's BepiColombo mission to the planet, Mercury, is planned for launch in 2012. A lander called the MSE (Mercury Surface Element) has been proposed for the mission. To be compatible with all the constraints for a soft-landing on Mercury, the payload must be highly miniaturized. Although the requirements are challenging, significant study, design, and bread-board work has been performed which suggests that excellent science can be accomplished within a total payload mass of around 7 kg. The MSE would provide a substantial increase in our knowledge of the Hermean surface after that which can be obtained from orbital remote sensing.

1. Introduction

BepiColombo (BpC) is one of the main missions of the European Space Agency's Cosmic Vision programme. The mission is to provide a detailed investigation of the planet, Mercury (see Schulz et al., 2003). It was recognized early in the study phase that a complete investigation requires measurements which could only be acquired by landing on the surface. Hence, as a complement to the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO), a lander package known as the Mercury Surface Element (MSE) was studied. Two concepts were originally investigated (ESA, 2000). A hard landing system (penetrator) was one option. However, such systems have to be designed to withstand enormous shock levels. Perhaps more importantly, experiments can be compromised because the landing site is physically affected by the impact itself. In order to sample unaffected material, the experiments must somehow get to it. Hence, a soft landing was also studied. It was clear immediately that a soft landing would require a lot of fuel to decelerate the lander because of the absence of a Hermean atmosphere. The primary concern was mass. How massive would the lander have to be in order to provide a significant payload mass together with the accompanying infrastructure (landing system, communications sub-system, power supply and distribution unit, etc.) needed to conduct the experiments. Indications are that payload masses of the order of 5 to 7 kg could be available. Given the advantages of soft landing and the degree of payload miniaturization possible, it was decided, following mission selection in May 2000, to pursue this option exclusively. Here, we describe briefly the landing system, the scientific objectives, and the payload.

2. Scientific Objectives

The objectives of the MSE are
- to determine the elemental and mineralogical composition of the surface,
- to determine the mechanical and optical properties of the regolith,
- to search for small scale inhomogeneity,
- to determine the local magnetic field strength,
- to study the properties of the local exosphere,
- to determine the surface heat flow.
- to provide "ground-truth" for the measurements made from orbit.

3. The Landing System

The MSE will be launched separately from the MPO and MMO. It will enter orbit around Mercury and descent will begin by firing the main engine. A radar altimeter will be used to determine its altitude until it is approximately 2 km above the surface. The lander's horizontal velocity will then be reduced to allow direct descent to the surface. At 100 m above the surface thrusters will be fired again to slow the vertical descent. The main tanks will then be jettisoned to reduce impact mass. Airbags will then inflate and the lander will bounce onto the surface. Once the lander has stop rolling, the airbags will be released and the small lander will drop to the surface ready for deployment.

4. Landing Site Constraints

The solar flux at Mercury can be as high as 10 times that at Earth. With no atmosphere, any surface normal to the solar flux will heat to an equilibrium temperature determined by the surface albedo. Because of the proposed landing system and the large-scale surface roughness, it is hard to control the lander's orientation with respect to the Sun and thereby provide protection from the heat. Although not yet selected, it seems probable that the landing site should be on the night-side of the planet but close to the morning terminator. This would allow the lander to make an initial series of measurements and determine its own orientation before sunrise. Solar panels would then be oriented by the lander autonomously to provide both power and protection from the Sun.

5. The Strawman Payload

The payload has yet to be selected but, for engineering purposes, a payload which could fulfill the objectives within the available mass has been compiled.

5.1. Panoramic Camera

A stereo camera on a mast with an set of filters is, since the Imager for Mars Pathfinder (Smith et al., 1997), standard equipment on landers. Lighter versions are now possible through the development of integrated read-out electronics carried out by ESA within the technical research programme. The night-side landing makes provision of a "flash light" based on light-emitting diodes, an attractive addition.

5.2. Invasive Device

A lander allows penetration of the surface which gives access to material which has not been affected by recent space weathering. A penetration device (the "Mole") has been developed for the Beagle 2 lander and a modified version of this system is foreseen for the MSE. This version will incorporate temperature sensors and permittivity probes to make in situ measurements.

5.3. Mobility - Microrover

It has been recognized that mobility in a lander is a critical item. It can be used to limit bias because of local inhomogeneity. Mobility also allows experiments to get away from areas "damaged" by the landing itself. A 2.2 kg microrover (the "nanokhod") has been developed as part of an ESA study. The device runs on tracks and is powered by the lander itself through cables. This limits the total distance the rover can travel (up to 100 m traverses are nevertheless possible) but it greatly reduces the mass needed and is, for this reason, ideal for the MSE. The rover has a payload bay in which several experiments can be housed. The payload bay can be rotated and moved to bring the analytical experiment to the sample. Each experiment bay is small but 1.1 kg can be carried. Development of several experiments to fit in this mass and volume has been performed.

Micro-imager A proto-type stereo optical imaging system has been built to provide data on the regolith of the Hermean surface. Resolutions of about 100 microns are expected.

Mössbauer Spectrometer Mössbauer spectrometers are currently flying on Beagle 2 and the Mars Exploration Rovers in order to determine the iron mineralogy of the Martian surface. Similar goals could be envisaged for Mercury. The mass of the current devices are around 500 g but could be reduced for the MSE.

Alpha, X-ray Spectrometer The elemental composition of the surface can be addressed by alpha and X-ray spectroscopy. Similar systems have flown on, for example, Mars Pathfinder. Again, around 500 g would allow a fairly sophisticated instrument.

Laser Mass Spectrometer Laser-induced ablation followed by investigation of the mass spectrum via time of flight analysis is a relatively new technique in planetary exploration. However, new technological developments have been made which suggest that resolutions of 300 are achievable within a mass of roughly 250 g. This would allow isotopic composition analysis. A proto-type with a resolution of at least 60 has already been built.

5.4. Magnetometer

A magnetometer on the MSE would provide a lightweight estimate of the field strength at the surface. The MPO and the MMO both carry magnetometers but the influence of the solar wind on the magnetic field configuration of the planet is not likely to be simple. A magnetometer on the surface will constrain models by providing the largest "signal to noise" from the planet itself.

5.5. Other experiments

The payload is by no means fixed and other lightweight experiments might still be accommodated. There are several interesting possibilities. Seismometry would be desirable although with only one station on the surface, the interpretation of the data would not be straightforward. Investigation of the regolith structure might be achieved by an IR spectrometer and microscope combination. A corner reflector for a laser altimeter in orbit would be a further lightweight addition to the payload which could potentially enhance the science return.

The densities of the exosphere are highest at the surface, of course, and hence an investigation of the exospheric composition and its variation in composition and density with time is also an interesting experiment. One potential problem here is the influence of the landing system because the mass of propellant being used to slow the lander down before impact is a significant fraction of the local exosphere mass. This remains the subject of further research.

6. Concluding Remarks

The MSE is itself a challenging experiment. However, further progress in the field of planetology requires in situ investigation of planetary surfaces. The MSE is an example of how this might be achieved.

Further details on the MSE and the whole BepiColombo mission are given in ESA (2000). Updated reports on the mission will appear in due course.

7. References

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