MERCURY Surface and Sub-surface Measurements

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Abstract

BepiColombo, ESA's cornerstone mission to Mercury, will include a surface element, most likely a soft-lander, which will perform *in situ* measurements of the planetary surface, sub-surface and exosphere. Discussed here are possible instrumentation concepts to help answer some of the key scientific questions we have about Mercury.

Sensors are proposed for both the lander itself and a "mole" (sub-surface, self-penetrating) device. A mole can take advantage of its unique deployment method to study physical properties at varying depths, for example by observing regolith stratigraphy and measuring profiles of bulk density and thermal and electrical properties. Samples of the regolith can be ingested and analysed, e.g. heated so that any volatiles can be released and identified. Miniature, low-power devices mounted on the lander can be used to evaluate surface properties such as exospheric pressure, giving both ground truth for the orbiters and answering questions on, for example, the dynamics of surface-magnetosphere interactions.

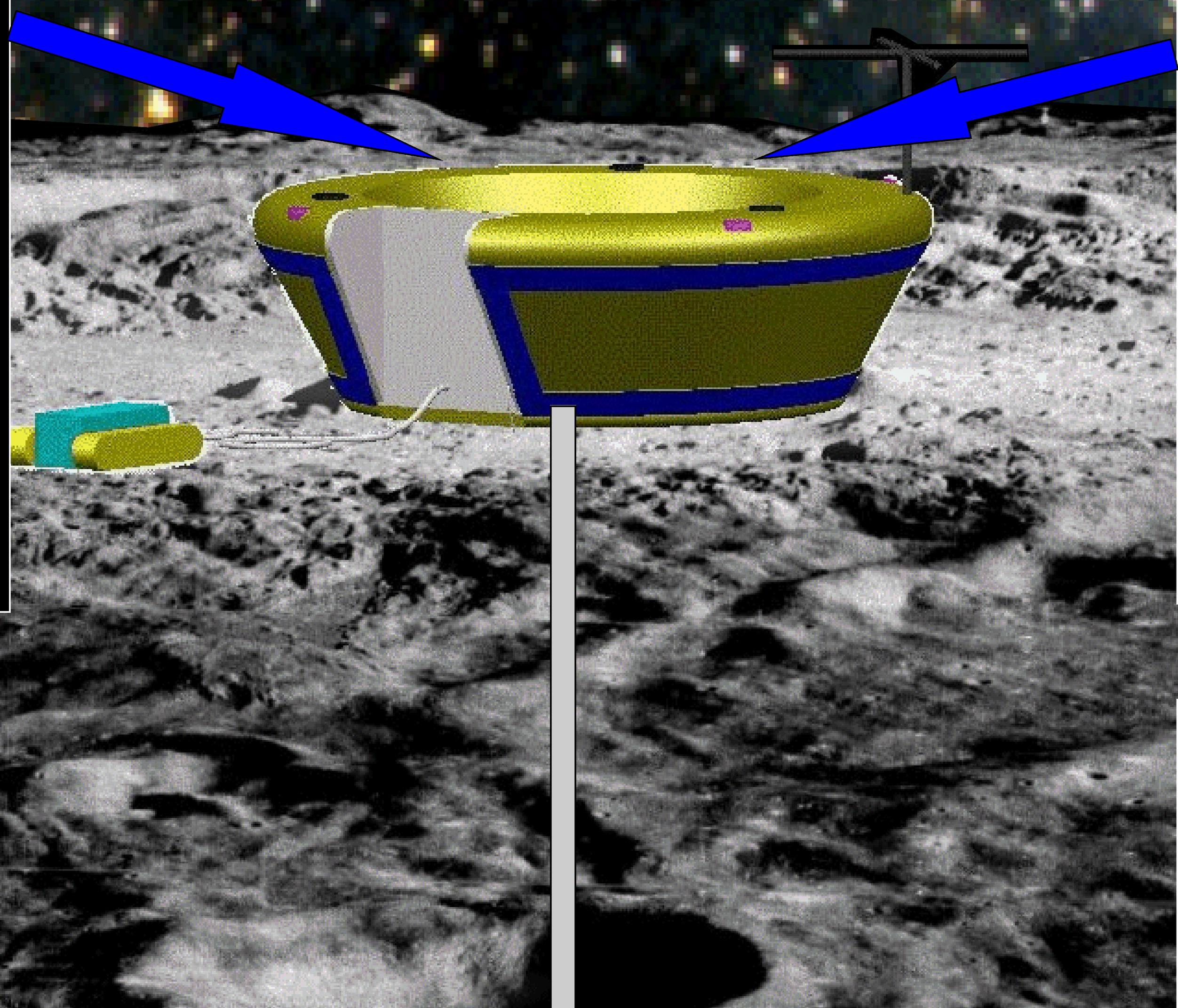
Possible instruments capable of recording these data are evaluated, as are the engineering challenges presented by both the extreme environment on Mercury and the harsh power and mass constraints placed on the lander.

Exospheric species analyser

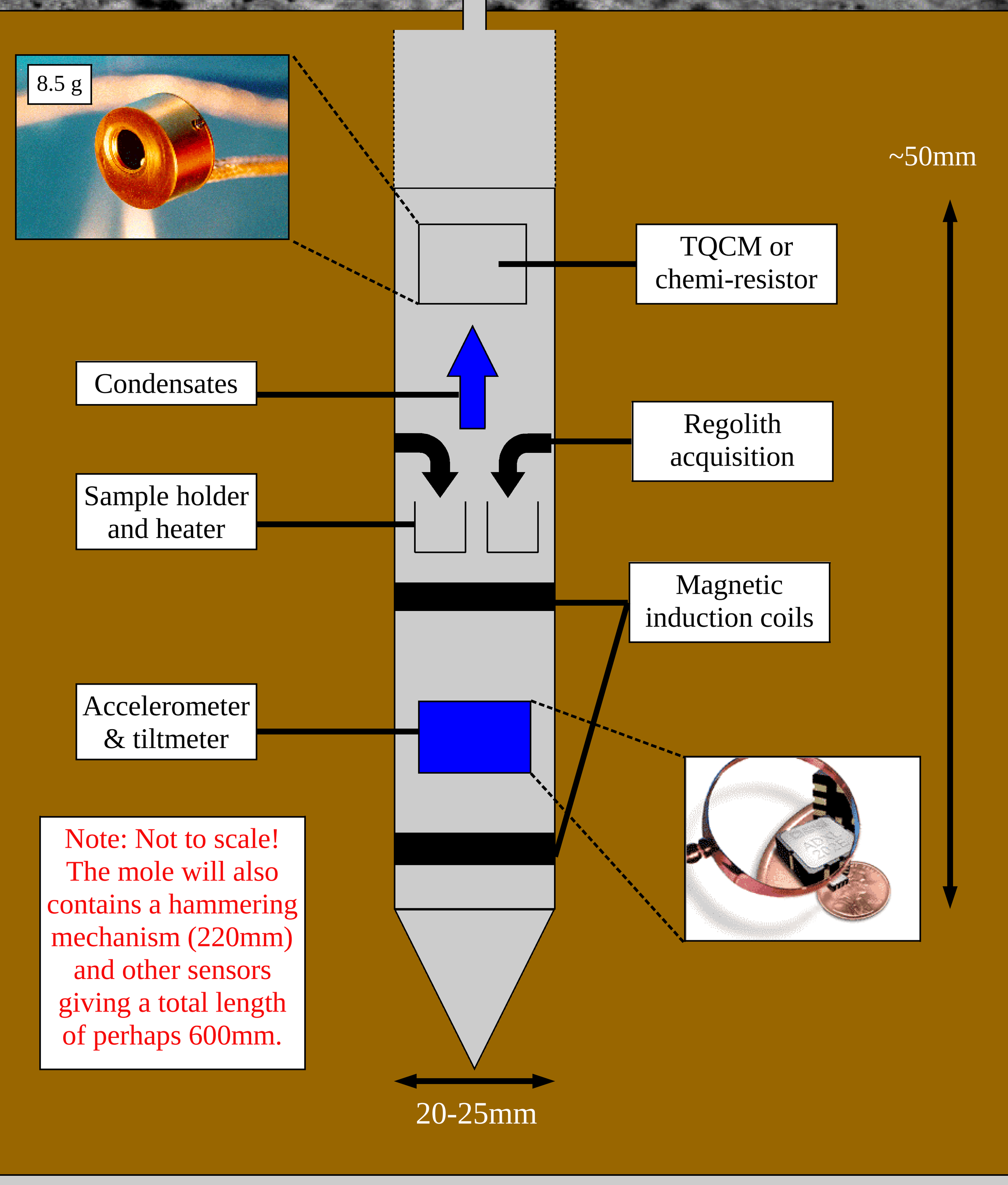
- Science Rationale: Remote sensing of the components of the Mercurian exosphere has so far been achieved by observing resonant scattering of sunlight and has been necessarily constrained to those species with probable transitions corresponding to bright portions of the solar spectrum. *In situ* identification of these species would greatly improve our understanding of source/sink mechanisms as well as providing confidence in measurements made from orbit.
- Solution: Chemi-resistor based on JPL's Mars Atmospheric Oxidant Sensor (MAOS)
- Technology: Chemical-specific sensors capable of almost molecular detection of specific chemical species. Absorption changes the resistivity of the film which can be measured. For our purposes detecting the presence and quantity of both species hard to observe remotely and those we can see (for comparison) would be useful.
- Pros: Unique identification of particular species. Low mass, low power.
- Cons: Can only detect specific species.

Exospheric pressure

- Science Rationale: Adding up the total mass of exospheric species observed to date there is a short-fall of approximately 2 orders of magnitude from the upper limit set by the Mariner 10 occultation experiment (10^{-13} Torr). *In situ* measurement of the surface gas density will help validate orbital measurements and quantify this "missing mass".
- Solution: Inverted magnetron cold cathode ionisation gauge
- Technology: Crossed *E* and *B* fields circulate electrons over long trajectories such that exospheric atoms will be ionised and the resultant current at the cathode measured.
- Pros: constrains other exospheric measurements, no hot filament to burn out
- Cons: affected by outgassing, airbag gases, pollution from CPM, measurements at the limit of expected pressure range, possible long integration time



An example of possible sensor accommodation in a segment of the mole. The mole is likely to carry other sensors in addition, for heat flow, thermal properties, bulk density and sub-surface multi-spectral microscopic imaging etc.
(see other posters / presentations in this session)



Sub-surface volatile composition

- Science Rationale: The recent resurgence of interest in Mercury was partly prompted by the speculative discovery of water-ice in permanently shadowed craters at moderately high latitude. An instrument capable of analysing sub-surface samples for the presence of water or other volatiles would not only help to answer this question, but would also be of interest for source and sink mechanisms of the exosphere.
- Solution: Sample acquisition mechanism, heater, TQCM-based evolved gas analyser
- Technology: A "passive" sample acquisition (e.g. a "cheese grater") system would be preferred. A temperature controlled quartz crystal microbalance could be used to identify condensates released during heating. See below for TQCMs.
- Pros: Integrated package that could perform differential scanning calorimetry on multiple samples and after calibration detect and identify volatiles and low-temperature decomposition products.
- Cons: High power requirements for heating / cooling possible heat-rejection problems, sample acquisition mechanism increases complexity.

Electrical conductivity

- Science Rationale: Electrical conductivity of the regolith is an interesting intrinsic parameter, but moreover has implications for possible closure paths of magnetospheric current systems. These systems would usually close through the ionosphere of a planet, but the exosphere is far too rarefied to allow current flow at Mercury.
- Solution: Magnetic induction measurements
- Technology: Based on a terrestrial well-logging technique, an alternating current is applied to a coil, inducing eddy currents in any conductive formations. A second coil picks up the voltage induced by these currents. Selecting only received voltage *in phase* with the transmitter gives a signal roughly proportional to the conductivity.
- Pros: Simple and easily accommodated into any mole design.
- Cons: Magnetic interference with other instruments e.g. magnetometer

Temperature-controlled Quartz Crystal Microbalances

Temperature Controlled Quartz Crystal Microbalances (TQCMs) measure mass deposition onto oscillating quartz crystals. This changes the resonance frequency in a detectable way. To avoid measuring thermal variations by mistake two crystals are used, one sealed and one open to the sample in question. The beat frequency between the two actually gives the mass flux.

TQCMs include a Peltier heater/cooler to aid condensation and then monitor the "boiling off" of adsorbed species, allowing identification of adsorbed species in a controlled manner.

For more information see: http://www.qcmresearch.com/

Physical properties

- Science Rationale: Very little information exists on the physical properties of the Mercurian surface. What little is known comes from indirect measurements such as data from the microwave radiometer on the Mariner 10 spacecraft and from analyses of returned images. The impulse from the mole hammer is well-characterised; integration of the acceleration signal should give incremental depth penetrated and thus a measure of the penetration resistance of the regolith. This is useful for comparison with lunar values. Accurate measurement of depth and deviation from vertical are important for heat flow measurement by other sensors proposed for the mole.
- Solution: Accelerometer and tilt-meter
- Technology: Solid-state capacitance-based accelerometers
- Pros: Very low power and mass constraints, commercial off-the-shelf (cheap!) products, very little external electronics (i.e. a capacitor and resistor), digital output.
- Cons: None apparent

Anyone requiring further details on these concepts or who is interested in collaborating should make contact using the details below.

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