THE BEAGLE 2 ENVIRONMENTAL SENSORS: INTENDED MEASUREMENTS AND SCIENTIFIC GOALS.

M. C. Towner[1], T. J. Ringrose [1], M. R. Patel[1], D. Pullan[2], M. R. Sims[2], S. Haapanala[3], A.-M. Harri[3], J. Polkko[3], C. F. Wilson[3] J. C. Zarnecki[1], [1] PSSRI, Open University, Walton Hall, Milton Keynes, UK, m.c.towner@open.ac.uk, [2] Space Research Centre, Dept of Physics and Astronomy, University of Leicester, University Road, Leicester, UK, [3] Finnish Meteorological Institute, Geophysical Research Division, P.O. BOX 503, FIN-00101 Helsinki, Finland, [4] Atmospheric, Oceanic and Planetary Physics, Clarendon Laboratory, University of Oxford, Parks Road, Oxford, U.K.

Summary: Beagle 2 is a 30kg lander for Mars, optimized for exobiology, launching in June 2003 as part of the European Space Agency (ESA) Mars Express mission[1]. The expected lifetime on the surface is 180 sols, with a landing site in Isidis Planitia[2]. One of the instruments on board is a suite of sensors for monitoring the local environment, and hence helping to determine if life could, or still can, exist there. The suite consists seven sensor subsystems weighing 153 grams, and due to the tight constraints of the Beagle 2 lander, primarily of simple analogue sensors, distributed over the lander. The suite has 2 major themes:

A meteorological package will record wind speed and direction, atmospheric pressure and temperature at a variety of heights, and look for particle saltation.

A life environment subsystem will measure the local radiation environment, the surface UV flux, and attempt to verify the presence of oxidants such as hydrogen peroxide, (without identifying the particular species present). Additional sensors will record the upper atmosphere density profile (determined by the acceleration encountered during probe entry and descent).

Introduction: Measurements of the local environmental conditions on Mars are a valuable tool as part of a lander's repertoire - both as independent measurements in their own right (for example meteorology), or providing context information which adds to the value of data from specific instruments (for example local temperature). The Beagle 2 lander, part of the Mars Express mission to Mars includes an array of sensors, designated the Environmental Sensors Suite (ESS), designed to monitor various local conditions. The sensors are designed to answer specific science goals, as well as providing support for the other onboard instruments.

Instrument description: The ESA Mars Express mission is due for launch in late May or early June 2003, arriving at Mars on 26th December 2003, initially braking into an elliptical orbit, 250km by 11,580km [1]. If all goes well, it will be at Mars at the same time as the ISAS spacecraft Nozomi and the NASA Mars Exploration Rovers, Mars Odyssey (and possibly Mars Global Surveyor if still active). The Mars Express scientific payload is described by Schmidt *et al.* [1]. The Beagle 2 lander is due to land in the Isidis Basin, at 270°W and 10.5°N [2]. It has a landed mass of 30kg, and uses an airbag and parachute system for descent, with an intended primary mission lifetime of 180 sols on the surface.

Onboard Beagle 2, ESS will operate throughout the mission lifetime and is intended to study both short (seconds, minutes, days) and long term (seasonal) timescale variations in the local environment. It has 2 major themes:

1) Landing site meteorology, A major science goal of the meteorology program is to improve our understanding of the Martian dust cycle. High-frequency measurements will be used to characterize near-surface turbulence, and to make quantitative measurements of dust devils (convective vortices). These high-frequency measurements of potentially dust-raising winds are supplemented with a sensor which will estimate the momentum of saltated particles. Low-frequency meteorological measurements will provide a long-term meteorological record, enabling study of day-to-day and seasonal variation in weather patterns.

2) The astrobiological implications of the local radiation and oxidative environment. Since the major Beagle 2 payload instrument, GAP provides a comprehensive analysis of the chemical locale, it was decided to concentrate on the astrobiological factors that would not be seen by GAP - the oxidising properties of the near surface environment (such knowledge is also unlikely to be recovered easily by any future sample return mission). As such ESS attempts to quantify the existence of a local oxidising condition, oxidant production and transport. ESS investigates the local UV environment, to quantify a possible production mechanism [3], and measures the dust saltation rates (and the airborne dust loading via the camera) - a possible transport (storage) mechanism. Monitoring a simple *in situ* deposited silver film allows ESS to detect and quantify the oxidising capability of the air and regolith. One final astrobiological experiment, unrelated to oxidants, is the measurement of the total radiation dose over the mission lifetime. This characterization of the surface environment will also aid in the issue of the possibility of sub-surface life. Knowing the UV flux at the surface, it is possible to quantify UV penetration

into the regolith, especially when combined with surface analysis and imaging through the various instruments on Beagle 2.

Resources on the Beagle 2 lander are particularly scarce [6]. This has driven the overall mass budget for the seven chosen sensors of 153 grams. In some cases this has forced a move away from solutions based on designs with previous spaceflight heritage, in favour of commercial microtechnology-based solutions which are likely to have a higher associated risk of failure. However, this is compatible with the philosophy of the entire Beagle 2 design where cost and mass constraints have required an acceptance of risk throughout, including elimination of complete redundancy for mission critical systems.

Meteorology sub-system: *Wind sensor* This sensor is mounted on end of the robotic arm, such that it can be positioned at different heights and orientations. It is a hot film sensor, similar in concept to Viking and pathfinder instruments. It has been calibrated from 0-30m/s, although it will measure higher and further ground calibration remains to be done. Direction is measured to within to 10^o.

Temperature sensor Air temperature is measured at 2 heights. One sensor is incoporated intop the wind sensor, on the arm, , and the second is located on the edge of one of the solar panel sheets, to minimize interference from the probe body. Expected absolute accuracy is 0.1K, with a resolution of 0.05K. Simultaneous measurements of temperature at two different heights can be used to estimate a vertical thermal profile.

Pressure Sensor This sensor is profvided by the Finnish Meteorological Institute, based on a capacitive diaphragm design as flown on Mars-96. It has a range of 0-30mBar, with an absolute accuracy of 200μBar and a resolution of 2μBar.

Life environment sub-system: *Radiation sensor* This sensor is a RadFET, and provides a cumulative radiation dose information on the flux of high energy cosmic rays and solar protons at the Martian surface.

UV sensor Short wavelength UV, such as UVB and C are harmful to life, and can directly damage DNA. The UV environment on Mars is known to be harsh, and it is unlikely that life can survive on the surface, but subsurface life may still be possible. This sensor is a simple array of upward looking photodiodes with appropriate band-pass filters, giving a 5 point spectrum from 200-400nm. A 6th channel has no filter and provides aging information.

Wavelength (nm)	**Comment**
210	Main TiO2 dust absorption band
230	Biologically damaging and rapidly time varying regime
250	Secondary TiO2 band
300	Mid UVB
350	Mid UVA
Open channel	

Table 1, detailing the UV sensor channels

Oxide sensor One controversial issue arising from the results from the Viking landers is the postulated presence of hydrogen peroxide (H_2O_2) or other oxidizing compounds in the soil, used in several cases to explain the results of the experiments designed to detect Martian life. This sensor deploys a thin silver film in situ by pulsed evaporation of a silver bead, and monitors the resistance of the film with time as it oxidizes. By repeated evaporations at different times of day, in conjunction with input from the cameras, the UV sensor and the onboard microscope, useful information will be obtained about the 'life cycle' of any oxidants present.

Additional sensors: *Dust impact sensor* Impacts from dust in the atmosphere of Mars will help to indicate how material is moved over the planet's surface. The sensor is a simple 50x50mm Al sheet, 0.25mm thick, with a piezoelectric film on the rear face. Minimum sensitivity is around $1x10^{-6}$ $kgms^{-1}$

Accelerometer Measurements of deceleration of the probe during the atmospheric entry and landing sequence can be used (in combination with the drag coefficient for the heat shield) to derive the upper atmosphere density and pressure. See for example Withers et al [7].

Two single axis sensors are used, with ranges of±30g and ±10g on the probe axis. During the early entry phases pressure and density can be derived in upper atmosphere with an initial vertical resolution of 150m. Horizontal wind-speeds will be monitored during later descent after chute deployment, and the probe tilt once at rest will also be recorded.

Measurement Strategy: Throughout the surface-mission lifetime, each sensor will be sampled at a low rate, typically taking one reading from each sensor every 30 minutes. In addition to this, to study quickly changing conditions such as the dust devils seen by Viking[8] and Mars Pathfinder[9], the wind, temperature, pressure, and dust sensors will have ahigh sampling rate mode (1 per second), whereby data from the previous 5 minutes is buffered and onlyreturned to earth (along with a further 5 minutes of data) should any transient effects be detected. Of particular interest are dust devils, which may be the primary source of dust movement on Mars, and responsible for the homogeneity of the dust measured at the Viking and Pathfinder sites.

References: [1] R Schmidt et al, ESA Bulletin-European Space Agency, 1999, No.98, pp.56-66 [2] JC Bridges et al, JGR , 108 (E1): 5001, 2003 [3] AP Zent and C McKay, Icarus, 108, 146-157, 1994 [6] J Clemmet, ESA SP-468, 9-14, 2001 [7] P Withers et al, Planetary and Space Science, submitted. [8] For example, PP Thomas and P Gierasch, Science 230, 175-177, 1985. [9] JT Schofield, JR Barnes, D Crisp, RM Haberle, S Larsen, JA Magalhaes, JR Murphy, A Seiff, G Wilson, Science 278, 1752-1758, 1997