The Beagle 2 microscope

Conference or Workshop Item

THE BEAGLE 2 MICROSCOPE. B. S. Lüthi, N. Thomas, *Physikalisches Institut, University of Bern, Sidlerstr. 5, 3012 Bern, Switzerland, (luethi@phim.unibe.ch)*, S. F. Hviid, H. U. Keller, W. J. Markiewicz, T. Blümchen, *Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Germany*, P. H. Smith, R. Tanner, C. Oquest, R. Reynolds, *Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, U.S.A.*, J.-L. Josset, S. Beauvivre, *SPACE-X, Neuchâtel, Switzerland*, B. Hofmann, *Natural History Museum of Bern, Switzerland*, P. Rüffer, *Institut für Datentechnik und Kommunikationsnetze, TU Braunschweig, Braunschweig, Germany*, C. T. Pillinger, *Dept. of Earth and Planetary Sciences, Open University, Milton Keynes, U.K.*

Introduction: The microscope for the Beagle 2 lander, which was launched as part of the European Space Agency's Mars Express mission on 2 June 2003, is able to provide images of the Martian surface at around 6 microns resolution. It provides optical images of the surface of Mars at a resolution 5 times higher than any other experiment currently planned. The device has a working distance of 12 mm and uses a set of 12 light-emitting diodes which surround the optical aperture to illuminate the sample in 4 colors. The target is brought into focus using a translation stage.

We describe the scientific objectives and present measurements of terrestrial samples for illustration. We also give a brief summary of the design of the microscope. For a detailed description of the instrument and initial results from ground calibration exercises which were designed to validate the system see [1].

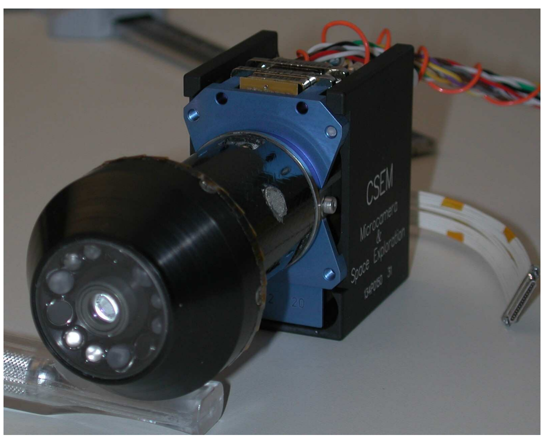

Figure 1: The Beagle 2 microscope with light-emitting diodes surrounding the optics aperture (in the front) and detector and read-out electronics (behind).

Scientific Objectives: A microscope has four distinctly different tasks in a lander package. It can be used to...

1. ...study the physical and structural properties of rock and soil surfaces and hence make a good geophysical analysis and contribute to the overall geological and mineralogical interpretation of the landing site.

   Figure 2 shows two images of samples of radically different origin. The left image is a layered limestone (cave sediment) from Piz Alv in Switzerland. The fine-grained crystalline appearance and the layering are both strongly evident at this resolution. On the other hand, the basaltic volcanic rock (from the Cady Mountains, Mojave, California) in the right image is not stratified and highly irregular. These examples show, that the microscope can provide a preliminary assessment of the origin of observed material.

Figure 2: Microscope images from a layered limestone (left) and a basaltic volcanic rock (right).

2. ...assist studies of the atmosphere of Mars. Specifically, dust particles are continuously precipitating out of the dusty atmosphere and hence a microscope can be used to constrain the sizes and shapes of particles for input into atmospheric scattering and radiative transfer models of Martian atmosphere.

   The microscope resolution is high enough to resolve individual dust particles from the higher end of the size distribution. In Figure 3 we show an image of the Martian regolith simulant JSC Mars-1 [2]. Information about the morphology of dust particles can be extracted, which in turn can give indications to the soil forming processes active on the surface of Mars.

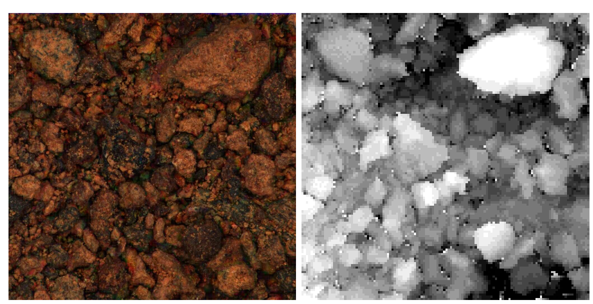

Figure 3: Microscope image of the Martian regolith simulant JSC Mars-1 (left) and its reconstructed elevation model (right).

3. ...investigate the morphology of a potentially biological sample and hence identify structures which may be characteristic of past or present biological activity.

   The UV illumination can be used to look for the presence of fluorescent rocks (Figure 4), which are indicative (but not proof) of rocks with a biological origin. To eliminate reflected UV from the incoming beam a filter has been introduced into the optics.

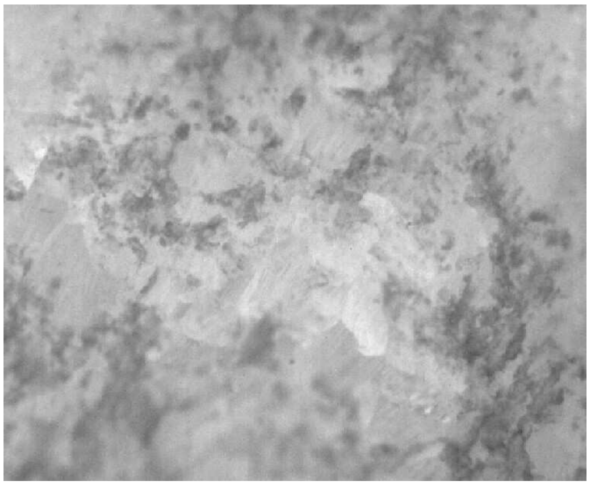

Figure 4: Image of a fluorescent rock illuminated with the UV LEDs of the microscope.

   On Earth living organisms create many characteristic shapes in the 10 - 1000 micron range. If such corresponding shapes exist at the landing site, they will be resolved by the microscope.

4. ...characterize and/ or select a sample before it is passed to another analytical instrument. It is used therefore to assist the chemical analysis.

Instrument Design: The microscope consists of several natural elements (see Figure 1): the optics with the surrounding illumination system, the micro-camera element and (to join the two elements) a light-tight tube providing a strong mechanical interface and baffling. The translation stage for microscope focussing forms a fourth work package. The properties of these elements are summarized in Table 1.

Table 1: Design properties of the Beagle 2 microscope.

Optics	magnification:	3.5:1
	lens design:	Cook triplet
	focal length:	15.75 mm
	depth of focus:	40 micron
	filter:	400 nm (rejects UV)
Illumination System	12 LEDs:	3 red, 3 green, 3 blue, 3 UV (fluorescence)
Micro-Camera	Detector:	1024×1024 frame transfer CCD
	pixel pitch:	14 micron
	typical QE:	15% at 640 nm
	ADC resolution:	10 bit
	provided by:	SPACE-X, Switzerland
Interface Tube	material:	carbon-fibre
	baffle:	reduces straylight
	2 microfilters:	for system-venting
Translation Stage	fine focus:	using a stepper motor
	step size:	0.1 micron
Complete System	pixel resolution:	4 micron
	dimensions:	$\sim 111 \times 52 \times 22$ mm^3
	mass:	$\sim$ 245 g
	power:	1.5 W (average)

Summary: The microscope for Beagle 2 provides optical images of the surface of Mars at a resolution 5 times higher than any other experiment currently planned. The device achieves this in three colors by using a novel illumination system. In addition, the system will be able to excite and detect fluorescent materials.

There are several distinctively different science objectives and the instrument can provide a wealth of interesting results.

In a forthcoming paper [3], images of rock and soil samples acquired with the microscope will be compared to images acquired with a standard laboratory microscope at similar spatial resolution.

References: [1] N. Thomas et al. (2003) Planet. Space Sci., submitted. [2] C. C. Allen et al. (1998) Lunar & Planet. Sci. Conf. XXIX. [3] A. T. Basilevsky et al. (2003) Planet. Space Sci., submitted.