TERRAIN MAPPING COVERAGE AROUND A LANDER USING PASSIVE STRUCTURED LIGHT. A. C. Cook[1] and D. P. Barnes[2], [1] Institute of Mathematical and Physical Sciences, University of Aberystwyth, Penglais, Aberystwyth, Ceredigion. SY23 3DB. Wales. United Kingdom. Email: atc@aber.ac.uk , [2]Computer Science Department, Aberystwyth University, Penglais, Aberystwyth, Ceredigion. SY23 3DB. Wales. United Kingdom. Email: dpb@aber.ac.uk .

Introduction: We discuss the potential coverage of terrain around a planetary lander, using a low cost, light weight passive structured light (PSL) system [1]. This technique, would utilizes a single camera, in conjunction with tens to hundreds of < 1 cm diameter light weight, ultra thin mirrors placed around the lander arm, solar panels, deck etc. The mirrors, would project mirror shaped, or pin-hole camera-like, images of the Sun onto a planetary terrain. Over time, as the Sun moves across the sky in a precisely known way, the reflected light from the mirrors will trace out paths across the local terrain surface and be captured by an imaging camera. Providing that one knows the position and orientation of each mirror surface, which produced each sunspot of light, together with the position and orientation of the camera, then the positions of the sunspots in the camera image can yield their 3D locations. Hence by tracking these spots of light over time, a 3D terrain map may be derived. In this abstract we will illustrate some sunspot tracks for different orientations of mirrors using solar azimuth and altitude data generated using HORIZONS [2] for the MER Opportunity landing site [3].

A sunspot image: Sunlight reflected off of a flat mirror, and onto a very nearby planetary surface, forms initially a zone that approximates the size and shape of the mirror, though this will appear modified by surface slope, illumination and viewing angles. If the sunspot falls on a surface at a large distance, where the angular diameter of the mirror, as seen from the surface approaches the angular diameter of the sun, then the image of the sunspot will become circular with diffraction blurred edges. This distance, for a 1 cm diameter mirror here on Earth, is approximately 115 cm. The surface intensity of the sunspot up to this distance will be the approximately the same (albeit with some modification from the penumbral effect of the edges) per square cm of surface as direct sunlight, however after this the intensity per square cm will fall off as a ratio of the mirrors angular area to the angular area of the Sun. Practical experiments have shown that 1cm diameter mirrors can throw a spot of sunlight onto a surface up to distances of 20 m, and that this can remain discernable visibly, even with scattered light from the sky here on Earth. Figure 1 illustrates sunspots from a disco mirror ball. Note how the topography of the domes deflects the path of the sunspots as seen from the camera.

Illustrative Coverage: We consider arranging 100 mirrors at equal intervals around the lander and in this example chose a radial distance of 50 cm horizontally away from the camera. Obstruction by the camera or spacecraft will not be considered in this abstract, but will have some obscuring effects in practice. The mirrors are located at 90 cm above a modeled flat plane. The location of the MER Opportunity landing site is used at (354E, 2S) [3]. One Mars days worth of solar azimuth and elevation values were fed in for Jan 01 2008 [2].Three surface normal orientations are considered – all radially away from the camera: 30 deg tilt down from horizontal (Fig 2a), level (Fig 2b) and 30 deg tilt up from horizontal (Fig 2c).

Discussion: Fig 2 shows clearly that extensive azimuthal and altitude coverage can be obtained, even for just using a single days set of images. In practice less mirrors could be used and images taken over successive days, utilizing the ~0.5 deg motion of the Sun against the celestial sphere on Mars to help increase terrain point density. However there remain several problems to solve before the system can be deemed to be practical, namely how to determine "which mirror" produced "which sunspot"? Also, how to calibrate the position and orientations of mirrors if the initial landing distorts these from nominal. The former can be tackled with a number of approaches e.g. to permute / test sunspots : mirror locations until consistent terrain distances are produced, to utilize different sized, coloured, or shaped mirrors, to place clearly identifiable positional or orientation offsets in a sequence of mirrors, so that these show up in the image sequence of sunspots. The latter could perhaps be tackled by having some calibration targets on the spacecraft that sunspots will from time to time pass across, or to utilize crossovers between sunspot tracks in order to constrain relative orientations between mirrors.

If this PSL approach is proven to be practical, then it may help to reduce weight, power requirements and cost of some surface exploration landers by the replacement of a stereo camera with single cameras. Although one disadvantage is that hundreds of images may need to be captured each day –if adjacent images are stored as difference images and compressed heavily, then this should not impact much on a lander's memory storage. The technique may also prove useful on planetary rovers, for example with robot arms. If the mirrors are mounted on the arm surface, then the movement of the arm to known positions and orientations could significantly shorten the duration of the technique to map specific areas. A robot arm mirror technique, RIM, has been discussed by Barnes [4].

.

References: [1] Cook, A.C. (2007) ISPRS IV/7, Houston, Cook_ISPRS_2007.pdf. [2] HORIZONS (2008) http://ssd.jpl.nasa.gov/horizons.cgi. [3]. Maki et al. (2003) *JGR, 108(E12),* 8071.[4] Barnes, D.P. (2007) *Geo. Res. Abs* 9, 10815.

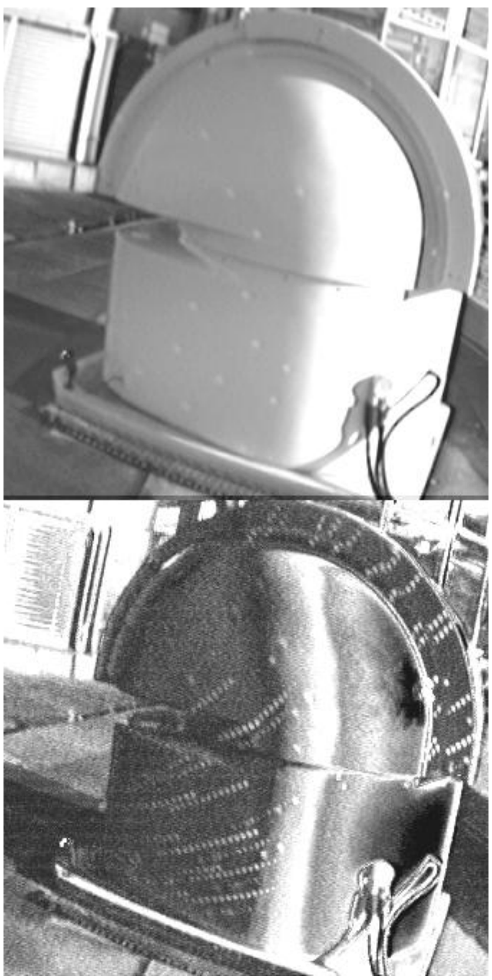

Figure 1 (top) Sunspots from approximately twenty 8x8 mm mirrors sited approximately 3 m away from the target. (bottom) images of sunspots at 2 minute intervals from an array of 8x8 mm mirrors on a "disco ball".

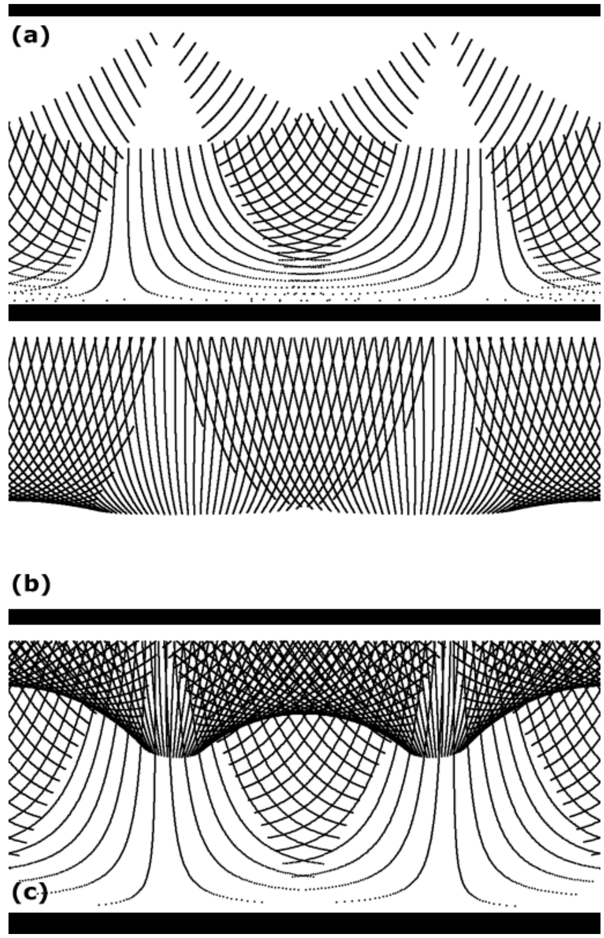

Figure 2 Sunspot tracks at the MER Opportunity landing site for Jan 01 2008 at 1 minute intervals over a complete day on Mars. 100 mirrors used. Azimuth runs from 0-360 deg left to right. Altitude angle ranges from 0 to -90 deg from top to bottom. (a) Is for mirrors tilted 30 deg downwards. (b) Is for mirrors that face horizontally outwards. (c) Is for mirrors that face 30 deg upwards