MOONLITE: A COST EFFECTIVE PROPOSAL FOR ADVANCING MULTIPLE OBJECTIVES IN LUNAR SCIENCE AND EXPLORATION. I. A. Crawford[1], A. Smith[2], R. A. Gowen[2], and the MoonLITE Science Working Group[3] and UK Penetrator Consortium[4]. [1]School of Earth Sciences, Birkbeck College, London, WC1E 7HX, UK. [2]Mullard Space Science Laboratory, University College London, UK. [3]Members identified in the Acknowledgements. [4]http://www.mssl.ucl.ac.uk/general/news/UKLPC/UKLPC.pdf. (Email: i.crawford@ucl.ac.uk).

Introduction: MoonLITE is a proposal for a UK-led mission to the Moon that will place four instrumented scientific penetrators in the lunar surface for the purpose of making geochemical and geophysical measurements that cannot be made from orbit [1,2]. It has the potential to make major contributions to lunar science, while at the same time providing knowledge that will be of central importance in the planning of future human missions to the Moon.

Scientific objectives: The principal scientific objectives of the MoonLITE penetrator mission are:

- To further our understanding of the origin, differentiation, internal structure and early geological evolution of the Moon;
- To obtain a better understanding of the origin and flux of volatiles in the Earth-Moon system;
- To obtain 'ground truth' geochemical data to complement orbital remote-sensing observations;
- To collect *in situ* surface data that will help in the planning of future lunar exploration.

These top-level science objectives require that the penetrators emplace instruments capable of contributing to several different areas of scientific investigation, including seismology, heat-flow, geochemistry, volatile detection, radiation monitoring and magnetometry.

Seismology: The Apollo seismic network covered less than 2% of the lunar surface, and there is now a need for more widely spaced measurements [3,4]. The MoonLITE seismometers will have the following objectives: (a) determine the size and physical state of the lunar core; (b) explore the deep structure of the lunar mantle; (c) determine the thickness of the lunar crust outside the region covered by Apollo; (d) study the distribution and origin of natural moonquakes; and (e) Further constrain the current meteorite flux in the inner solar system via the seismic detection of lunar impacts.

Heat-flow: Measurements of surface heat-flow provide valuable constraints on the composition and thermal evolution of planetary interiors. An important measurement would be to determine the heat-flow as a function of distance from the anomalous Procellarum KREEP Terrain (PKT; [5,6]). Existing heat-flow data are only available from the Apollo 15 and 17 sites [7], and MoonLITE will extend these measurements to new localities (e.g. the polar regions and the farside).

Geochemistry: The only places on the Moon from which samples have been collected *in situ* are the geographically restricted Apollo and Luna sample return sites, limiting our knowledge of lunar geological processes. A precursor to additional sample-return missions would be to make *in situ* geochemical measurements, and MoonLITE would achieve this through penetrator-deployed X-ray fluorescence spectrometers. Such measurements would provide additional 'ground truth' for the calibration of remote-sensing instruments on forthcoming lunar orbital missions.

Polar volatiles: Confirmation of the tentative detection of water ice (and by implication other volatiles, [8]) at the lunar poles poles is important both for what it will reveal about the flux and composition of cometary volatiles into the inner Solar System, and because such volatiles could be a valuable resource in the context of future human exploration of the Moon. MoonLITE can address this question through the deployment of volatile detection instruments on penetrators targeted within permanently shadowed craters.

Magnetometry and radiation sensing: These are currently under consideration for penetrator deployment by MoonLITE. Surface magnetic field measurements would permit *in situ* studies of lunar remanent crustal magnetisation, and magnetic sounding of the deep lunar interior. Radiation monitoring at the 2-3m depth of the penetrators would be directly relevant to assessing the efficacy of lunar regolith as radiation shielding in the context of future human exploration.

Conclusions: By deploying a range of instruments to diverse locations on the Moon from which geochemical and geophysical measurements have not yet been obtained (including the poles and the farside), the MoonLITE penetrators have the potential to make major contributions to lunar science. At the same time, they will provide knowledge (e.g. of lunar seismicity, polar volatile concentrations, and the radiation environment) that will be of central importance in the planning of future human missions to the Moon.

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References: [1] Gao, Y., et al., *Planet. Space Sci.*,56, 368, (2008). [2] Crawford, I.A., Smith, A., *Astron. Geophys.*, 49, 3.11, (2008). [3] Lognonné, P., *Ann. Rev. Earth. Planet. Sci.*, 33, 571, (2005). [4] Neal, C.R., *Geotimes*, 51, 30, (2006). [5] Jolliff, B.L., et al., *J. Geophys. Res.* 105, 4197, (2000). [6] Hagermann, A. and Tanaka, S., *Geophys. Res. Lett*. 33, L19203, (2006). [7] Langseth, M.G. et al. *Lunar Planet. Sci. Conf.*, 7, 3143, (1976). [8] Feldman, W.C., et al.. *Science*, 281, 1496-1500, (1998).