# Lunar Mission One: the first crowdfunded mission to the Moon presenting new opportunities for lunar science

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***LUNAR MISSION ONE*: THE FIRST CROWDFUNDED MISSION TO THE MOON PRESENTING NEW OPPORTUNITIES FOR LUNAR SCIENCE.** M. Anand[1] , I. A. Crawford[2], M. R. Sims[3], A. Smith[4], , R. Burgess[5], K. H. Joy[5], C. S. Cockell[6], M. A. Sephton[7], S. S. Russell[8], C. L. Smith[8], D. J. Smith[9], G. Woan[10], N. Bowles[11], M. M. Grady[1], J. C. Zarnecki[1], and D. Iron[12]. [1]The Open University, UK. [2]Birkbeck College University of London, UK, [3]University of Leicester, UK. [4]UCL Mullard Space Science Laboratory, UK. [5]University of Manchester, UK. [6]University of Edinburgh, UK. [7]Imperial College, London, UK. [8]The Natural History Museum, UK. [9]British Geological Survey, UK. [10]University of Glasgow, UK. [11]University of Oxford, UK. [12]Lunar Missions Trust. (Mahesh.Anand@open.ac.uk)

**Introduction:** *Lunar Mission One* (LM1) is an ambitious project that has recently secured funding from the members of the public (7297 backers pledging £672,447 (~1 million USD) as of Dec 2014) for the next phase of mission development via the crowdfunding platform, Kickstarter. Although unconventional in many respects, this mission concept presents tremendous opportunities for the global lunar science community to contribute towards the development of robust science goals that can be achieved through this mission, and, potentially with other follow on missions. In addition to the scientific goals, the project has a strong educational element with respect to motivating and inspiring the next generation of scientists and engineers by promoting STEM subjects through its global educational initiative. In this contribution, we mainly describe the primary science drivers that were perceived realistic and achievable at the time of initial LM1 project concept development. We will continue refining the science objectives and goals through input from the global lunar science community and through liason with the strawman payload definition.

**Mission concept:** *Lunar Mission One* is an exploratory robotic mission that aims to use pioneering drilling technology to drill a borehole > 20 m deep in the south polar region of the Moon. Bringing together schools, academics and the general public from across the world, LM1 will provide the funds to create a publically assembled, free to access digital archive of Life on Earth – of human history and civilisation, and a scientific description of the biosphere with a database of species. When the drilling experiments are complete, LM1 will bury the first edition of this public archive deep below the Moon's surface in the 21st Century equivalent of a time capsule. This unprecedented educational resource will also be available online, accessible to all, for ongoing contributions and development after the Mission. The public archive project will run alongside the LM1's education programme, ensuring that schools, colleges and universities can all contribute to decisions and discussions about the content.

**Scientific Drivers:** The remainder of this abstract summarizes the top-level science drivers for LM1 (as envisaged in Dec 2014). The original document which forms the basis of this abstract can be found at www.lunarmissionone.com. It is intended that the science goals will be prioritized, and instruments selected, as the mission becomes better defined.

*Landing site and science planning assumptions*: It is assumed that a south polar site will be selected in an area of long-duration sunlight - a few hundred days with eclipse durations of less than 50-70 hours. The specific landing locality will be defined after a full study of potential landing sites based on work already performed for previous mission studies (e.g. [1]). All the proposed landing sites (e.g. Shackleton crater and Mons Malapert) lie on, or just within, the rim of the giant South Pole-Aitken (SPA) impact basin [2]. Scientifically, these locations are of interest because the local regoliths may contain fragments of SPA impact melt (which could in principle be used to date the basin, a key event in lunar geological history), and fragments of lower crustal and/or mantle materials excavated by the basin. In addition, the detection and characterisation of volatiles that may be retained in these cold polar regoliths is of both scientific, and possibly (in the longer term) practical, interest.

To a first approximation, the near-surface environment of potential polar landing sites are likely to be similar, with several metres of unconsolidated regolith, probably containing blocks of more competent materials, overlying more compacted highland 'mega-regolith'. However, the detailed geological record preserved in the near sub-surface at various candidate landing sites may be different. As part of a detailed site selection process other potential landing sites will have different considerations and more work is required to define the geological contexts, and likely sub-surface environments for these sites.

The science case is largely predicated on studying samples retrieved from, and instruments placed within a borehole at the landing site. The drilling technology itself, likely either 'wire-line' or 'coiled tubing', will be subject to detailed study once funding is secured (see [3, 4] for some discussion of extraterrestrial drilling technologies). It is assumed that a sub-set of samples from the drilling will be cached for a potential sample return mission that may follow at a later date. If

there is sufficient mass budget available additional instruments may be deployed on the surface, for example to characterise the abundance and composition of volatiles in the local regolith and the surface environment.

*Top-level science drivers for Lunar Mission One***:** A thorough, top-level, prioritisation of lunar science objectives is provided in the US National Research Council (NRC) report [5] and this still represents a broad consensus in the science community on lunar science priorities. Based on this study, and on more recent reviews of the literature (e.g. [6,7] and refs cited therein) the following science goals for LM1 are suggested. These will be further refined as mission planning proceeds (no order of priority is implied):

*1. Understanding the geochemistry/mineralogy of the lunar crust*

a. Determine the physical properties, geochemical and mineralogical composition of the landing site versus depth beneath the surface and determine the extent and structure of the mega-regolith at the landing site.

b. Attempt to identify fragments of deep crustal and/or mantle materials excavated by the SPA impact within the local regolith, and characterise their chemical composition and mineralogy.

*2. Characterise the impact history of the landing site and constrain the age of the SPA Basin* - Attempt to identify impact melt fragments in the local regolith and attempt to date these (e.g. by using the *in situ* K-Ar method recently demonstrated by instruments on the Curiosity rover on Mars [8]). This may be able to constrain the impact history of the landing site, and possibly establish an approximate age for the South-Pole Aitken basin. It is recognized that accurate dating will require the return of samples to Earth. For this reason, LM1 will aim to characterise and cache appropriate samples for later collection and return to Earth to enable later accurate age dating and geochemical analyses.

*3. Understand the diversity and origin of lunar polar volatiles* - Determine the volatile content (including $OH/H_2O$) and associated isotopic composition of the local regolith, both at the surface and in drill samples.

*4. Constrain models of the lunar interior*

a. By placing thermal sensors in the borehole measure the lunar heat flow. This will help characterise the thermal state of the interior at a locality far from the Apollo heat-flow measurements and elucidate the workings of the planetary heat engine.

b. By placing a seismometer in the borehole use seismic signals generated by natural moonquakes and/or meteorite impacts to probe the structure of the lunar crust and mantle at a locality far from the Apollo seismic measurements. Such knowledge will shed light on the differentiation of the Moon and, when coupled

with geochemical studies, may further constrain the bulk composition of the Moon.

c. In addition, subject to available payload mass and the possible associated future missions, LM1 could also act as a node for a lunar geophysics network further informing our knowledge of the lunar interior.

*5. Characterise the lunar environment for future scientific exploitation and human exploration* - Measure the environment at the site and characterise its radiation, seismic, dust and charging environment as well as the local exosphere. This will identify possible hazards to future human exploration and habitation. It will also help characterise the lunar environment in preparation for future scientific activities (e.g. astronomical observations and fundamental physics experiments).

*6. Identify resources for future human space exploration* - Assess the potential for exploiting lunar resources for exploration and human habitation from the local mineralogy and volatiles (for context see reference [9] and references cited therein).

*7. Assess the potential of the lunar surface as a platform for astronomical observations* - Conduct initial proof-of-concept studies for future low-frequency radio astronomy from the Moon, including measurements of extra-galactic and galactic sources, terrestrial emission, the lunar exosphere, and the effects of the lunar surface on radio propagation and communication. Additionally, investigate the possibilities for studying the Earth and its magnetosphere from the Moon.

Within a notional 30 kg allocation, a model payload selection will be made following a detailed study of science return, technical maturity, accommodation (mass, power, telemetry, volume), operational needs, risk and cost, and international exploration priorities. Sample handling will be a key issue since this will impact the instrumentation that will study the recovered samples. A strawman payload will be developed that will form the basis of a preliminary design that will be periodically reviewed and refined on the basis of input from an international science advisory group.

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