MOON-NEXT: A PROPOSED ESA LUNAR LANDER MISSION SELECTED FOR PHASE-A STUDY.

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Introduction: The European Space Agency's Next Exploration Science and Technology Mission (NEXT) is intended to fill a gap in ESA's planetary exploration activities between ExoMars (due for launch in 2013) and Mars Sample Return (MSR; envisaged for the 2020 timeframe). NEXT must demonstrate key technologies for MSR and other future exploration missions, while also performing important scientific investigations. After an internal review process, ESA has now selected two proposed NEXT mission concepts for Phase A study – Mars-NEXT, which would perform activities at Mars, and Moon-NEXT, which would land a scientific payload near the South Pole of the Moon. Following the results of these studies, one concept will be selected for implementation. Here we report on the scientific, technological and exploration-related rationale for Moon-NEXT.

Mission objectives: The principal mission objectives of Moon-NEXT are as follows:

- Demonstrate precision soft-landing and hazard avoidance technologies required for MSR and future exploration missions;
- Prepare for future lunar exploration activities by characterizing the lunar surface environmemt and performing relevant life science investigations;
- Advance our understanding of the origin, structure and evolution of the Moon by performing a range of geophysical and geochemical investigations; and
- Assess the value of the lunar surface as a site for performing science from the Moon, using radio astronomy as an example.

Mission architecture: The Phase A mission definition document calls for both a lander capable of delivering a c.100 kg payload to a south polar location, which will include a rover with a c. 20 km range. A rover is essential for many of the scientific and exploratory objectives of the mission (see below), and will build on experience gained with the ExoMars rover. Demonstration of landing precision is a key technology objective of the lander, and the baseline 3-sigma semi-major axis of the landing ellipse is 500m. Nominal mission duration will be one year, with the spacecraft landing near the lunar south pole, taking advantage of >75% solar illumination during the southern summer. The nominal launch vehicle will be a Soyuz-SM, with a target launch date between 2015 and 2018. The precise scientific payload, and its distribution between lander and rover, is still to be decided. However, the science and exploration goals described below will necessitate at least the following core instruments:

- Multispectral imaging system
- Broadband and short-period seismometers
- Heatflow probe
- Alpha Particle X-Ray Spectrometer (APXS)
- Dust and micrometeorite detector/analyser
- Radiation detector
- Low frequency radio detectors (dipoles)
- Laser ranging retroreflector
- Life sciences experiment(s)

Scientific objectives: The principal scientific importance of the Moon is as a recorder of geological processes active in the early history of terrestrial planets (e.g. planetary differentiation, magma ocean formation and evolution, etc), and of the near-Earth cosmic environment throughout Solar System history [1,2]. Within this context, the principal scientific objectives of Moon-NEXT, building in part on those of the earlier 'MoonTwins' proposal [3], are as follows:

- To further our understanding of the origin, differentiation, internal structure and early geological evolution of the Moon. This will be achieved through the emplacement of geophysical instruments, principally seismometers and heatflow probes, and the polar siting of a laser reflector to better constrain the Moon's geodetic parameters. Owing to its large distance from the Apollo seismic network, a broadband seismometer at a polar location will significantly increase our knowledge of the structure of the lunar mantle and the size and physical state of the lunar core [4]. Similiarly, a measurement of the lunar heatflow in a location far from the Procellarum KREEP Terrain [5] will help constrain models of the thermal evolution of the lunar mantle [6]. The near surface crustal and regolith structure of the landing site will be probed by the short-period (SP) seismometer.

- To obtain *in situ* geochemical data from an area of the Moon not visited by previous missions. For a south polar locality this will include the first ever geochemical and mineralogical measurements from within the South Pole-Aitken Basin, which may have exposed lower crustal and/or upper mantle material [5]. These data will be obtained principally by the multispectral camera and rover-deployed APXS. By making measurements of rocks exposed in the blocky ejecta of small (c. 100m-sized) impact craters this will probe the composition below the surficial regolith and obtain some stratigraphical information (which may be compared with the results from the SP seismometer). For this purpose rover-facilitated mobility is essential, both to navigate between boulders within an ejecta blanket, and to visit several such craters with a range of sizes (which will have excavated material from different depths). These measurements will also provide 'ground truth' geochemical data to complement orbital remote-sensing observations.
- To measure the current impact flux on the Moon by detecting the seismic signals of impacts, possibly by a network of SP sensors, and by detecting impact-generated dust.
- To assess the value of the lunar surface as a future site for radio astronomy by performing low frequency radio observations with dipole antennas on the rover and the lander (thereby permitting a variable baseline).
- To assess the effect of the lunar environment (reduced gravity, radiation, etc) on biological systems, and to better understand the adaptation of life to lunar conditions. These experiments will be based on a closed micro-ecosystem similar to that envisaged for the First Extraterrestrial Man Made Ecosystem (FEMME, [7]), and will yield both fundamental biological knowledge (building on experiments to be performed on the ISS), and yield knowledge of direct relevance to the construction and operation of lunar life support systems for a human habitat. Assessing the consequences of the long-term exposure of terrestrial organisms (and their ametabolic resting stages) to the lunar environment will also be important for a range of astrobiology studies [8], including the co-evolution of life with its planetary environment, panspermia, and planetary contamination issues. We note that the scientific results will be enhanced if the life sciences experiment could be returned to Earth at a later date, which could be achieved by deploying it close to the future site of a human outpost (for which there are additional very strong arguments, see below).

Exploration objectives: In 2004 the US announced a new *Vision for Space Exploration*, which has refocused NASA's objectives towards human missions to the Moon and Mars, and the European Space Agency's *Aurora* Programme has established similar objectives for Europe. There is considerable potential for international cooperation in these activities, as formulated in the recently agreed Global Exploration Strategy [8], and Moon-NEXT could be a major European contribution. In particular, the NASA Lunar Architecture Team [9] has identified the rim of the 19 km Shackleton Crater (89.9°S) as an optimal location for a future human outpost. As this polar location would also satisfy all of the top-level science and technology requirements identified above for Moon-NEXT, we recommend that this mission also be sent to Shackleton. This would permit a characterisation of the local geology, seismic and micrometeorite hazards, radiation environment, and regolith properties of the proposed outpost site prior to the landing of human crews.

Conclusions: By deploying a range of geophysical and geochemical instruments (including seismometers, a heatflow probe, and a rover-deployed X-ray spectrometer) to the lunar South Pole, ESA's Moon-NEXT mission will greatly add to our knowledge of the internal structure and geological history of the Moon. In addition, the mission will test the precision landing and hazard avoidance technologies required for MSR and other future planetary exploration missions. Finally, by choosing a landing site on the rim of Shackleton crater that is envisaged as a site for a future human outpost Moon-NEXT will make a major contribution to the international exploration of the Moon by characterizing the local geological, seismic, and radiation environments, the micrometeorite hazard, and ISRU potential of the site prior to the arrival of human explorers. This would constitute a major European contribution to the Global Exploration Strategy [8] while at the same time yielding fundamental scientific knowledge of the Moon's structure, history and environment. As such, we believe it offers the best possible option for ESA's NEXT mission in the 2015-2020 timeframe.

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