Joint Statement

European Lunar Observatories
Science Workshops, Bremen, March 2005 & Nov. 2006

Human and robotic missions to the Moon have become a serious possibility for the coming decade among space faring nations around the globe. This may open up the possibility for a range of scientific applications that might accompany or even drive lunar missions. An important scientific area where lunar missions could make a significant impact is astrophysics and space science. For that reason we invited the European astronomical community to two workshops over the last two years to address some of the following questions:

- Is there a need for lunar observatories and what could be reasonably proposed?
- What is the scientific justification and what are the specific benefits of a lunar platform, especially compared to free-flying spacecraft?
- What are the scientific demands on lunar exploration scenarios to accommodate scientific requirements?
- Which synergies can be found with other disciplines such as geology and geophysics?

These questions were addressed through presentations and discussions by experts from nine European nations (France, Germany, Greece, Italy, The Netherlands, Poland, Spain, Sweden, United Kingdom) spanning a wide range of scientific disciplines and wavelengths, including X-ray, UV, infrared, THz and radio bands. To investigate synergies with other sciences, and understand the feasibility of various concepts, input from geophysicists and geologists as well as industry was sought. The presentations will be available on the web (www.astron.nl/moon).

As a conclusion of the workshop we encourage the space agencies to investigate further the topic of lunar observatories, together with the growing scientific community interested in using the Moon as a potential experimental platform.

The following statements jointly signed by the participants have been formulated:

1. General Statements

- A large range of major space observatories – especially those discussed within ESA's Cosmic Vision programme – will continue to be well served by free-flying spacecraft that have achieved a high-level of sophistication over a few decades.

- The Moon, however, clearly has the potential for providing an outstanding, and in some cases unique, site for establishing astrophysical observatories.

- Upcoming missions and scenarios within Europe's exploration efforts should therefore take the requirements of lunar observatories into account to maximise impact of these missions. This will also further improve the

acceptance of exploration programmes by the general public which seems to react rather positively to space-based observatories.

- The final selection of science applications in upcoming lunar missions should be based on a fair and open-to-all peer-review process – as commonly established in astrophysics – taking into account the particular boundary conditions an exploration-driven programme naturally has.

- There is still significant scepticism in the scientific community towards exploration missions. This requires a continuous discussion process and outreach in the community. Funding of exploration-driven missions should not compete with the normal science funding and not endanger the further development of already planned large science infrastructures.

- Funding of preparatory studies and instrumentation development is needed to address some of the outstanding technical issues.

2. Statements on science goals and potential observatories

- Scientific topics that are being addressed by lunar observatories are extremely diverse and include: discovery-science in unchartered domains of the electromagnetic spectrum, cosmology and the early universe, star-formation and evolution, black holes, astroparticle physics, search for and studies of exoplanets, cosmic magnetic fields, interstellar and intergalactic medium, planetary science, solar-system science, space weather, and the origin and structure of the Moon.

- Some of the most outstanding scientific goals in astronomy that can be addressed by lunar telescopes is the study of the dark ages of the universe, i.e. the very early cosmos. Given that this goal eventually requires fairly large (e.g. radio and IR) telescopes in the time-frame >2020 significant prototyping on the Moon is required and possible already in the next decade.

- There are a number of high-level scientific applications where the Moon appears to be a unique site due to its lack of atmosphere, large-stable platform in free space, gravity, and shielding against terrestrial and solar radiation such that these applications can only be realised on the Moon and could provide breakthrough science. These applications are:
    - a large very low-frequency radio telescope for, e.g., the dark ages,
    - a very large liquid IR telescope for ultra-deep surveys of the first stars,
    - observations of the Moon itself, e.g.
        - with a seismic network to study core-mantle structure
        - with a seismic interferometry network to study the crust
        - by investigating the lunar surface with direct probes for e.g. geomorphology, mineralogy, geochemistry, regolith properties, and resources (cameras, spectrometers, Mößbauer, radar sounding, magnetometer, etc.)
        - or by studying the lunar evolution with probes below the surface for e.g. geothermal heat flux, regolith properties and structure.

- There are some high-level scientific applications where the feasibility and superiority of a lunar versus a free-flying installation has to be carefully evaluated. This concerns particularly multi-element interferometers or arrays where the Moon would offer a stable platform in space, e.g.:
    - Multi-element Far-infrared/THz interferometers
    - Multi-element optical interferometers (if problems raised in past studies, e.g. with dust and seismicity, can be clarified or resolved)
    - Array of (low-energy) cosmic ray detectors

- There is also a wide range of outstanding or very important scientific applications that could easily use and greatly benefit from a lunar infrastructure. This includes, but is not limited to the following:
    - UV telescope
    - Small X-ray telescope for very targeted scientific goals
    - Solar coronograph at a peak of eternal light

- Finally, there may be a number of spin-off or double-use applications utilising future communication infrastructure on or around the Moon, such as:
    - Radio and optical beacons for calibration of terrestrial telescopes and for geodetic applications
    - Radio-sounding of the lunar ionosphere

3. Statements on technical issues

- The Moon offers an experimental platform that can support a wide range of applications, serving a broad and diverse scientific community. This suggests that a significant level of synergies could be achieved by bundling various science packages in one mission. This might also enable a wealth of smaller science experiments which could perhaps not be realised as stand-alone missions. The fact that observatories can be placed on a surface utilising a multi-purpose infrastructure without the need to design a controlled spacecraft around it might turn out to be another practical advantage.

- Typical requirements that would enable a wide range of lunar observatories or prototypes:
    - Significant science payload mass (>0.5 ton)
    - Significant science payload volume (cubic metres)
    - Constant power supply (~kW) and data transmission (0.1-1Gbit/s and higher)
    - Rover capability
    - Multiple missions to different locations (polar, equatorial, far-side)

- Quite a fraction of projects could probably be realised robotically. Robotic precursors could be used as piggy-back mission for exploratory astronomy science missions.

- All the proposed projects enter unknown territory. Hence in the very near future a significant effort should be devoted to technical and scientific studies of the feasibility and demands of lunar observatories involving a wide range of scientific disciplines.

Undersigned by the participants and organizers of the workshop

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