Preparing for Astronomical Telescopes on the Moon

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The drivers for the next generation of telescopes are clear: more collecting area, broad spectral coverage, and higher angular resolution. The scientific goals are fundamental, but the technical demands are challenging. Large telescopes are absolutely necessary to gather the trickle of photons from the earliest condensations in the young universe after the CMB era. HST, Chandra and Spitzer have demonstrated the importance of angular resolution for a vast range of astronomical problems ranging from cosmology to the study of how planetary systems condense and evolve. Ultimately, large telescopes will have a major role in the study of earth-like exoplanets. The James Webb Space Telescope is now being prepared for launch only a few years from now, and it is already proving to be a challenge, since its design requires new technological solutions.

Astronomical telescopes have become more complex, and necessarily so, for the scientific drivers require larger structures in space, with more complex instrumentation. More complex telescopes increase the complexity of their design, and the desirability of astronaut repair and servicing has to be reviewed, and tradeoff studies should be carried out comparing a lunar location with free-flying missions of the future. The new thrust for a return to the Moon, with a base that can support scientific instruments on the lunar surface, makes it desirable to start such studies now. It is not at all clear that a large, complex instrument at L2 will be more reliable than an instrument on the lunar surface, nor is it clear how much a suite of robots, operating with a six-second time delay, will add to the cost, compared to the human interaction on the Moon.

After a review of the literature available so far, there seem to be no sound, unbiased, engineering studies that address lunar-based telescopes in a realistic, comparative way. ESA sponsored a comparative study of optical interferometers, but it addressed automated instruments only. The conclusion, that the Moon presented many uncertainties without offering significant advantages for an automated interferometer, needs updating in the light of the availability of human servicing. The study also needs generalization, since X-ray, gamma-ray, ultraviolet, optical, and infrared telescopes all have special needs. The American studies so far have mostly been PowerPoint projects, a start, perhaps, but too speculative to provide a firm foundation for ambitious telescope projects on the Moon.

Before any new site on the Earth is selected for a new observatory, it is standard procedure to conduct extensive site surveys, in order to gauge the appropriateness of the site for the planned observations. Site surveys are conducted with equipment far less complex and costly than the observatories themselves. We are currently in a situation where talk of lunar observatories will remain largely speculative until detailed site surveys can be conducted. In particular, surveys need to measure background radiation

across the electromagnetic spectrum. Lunar seismic activity should be understood, and we need a deeper understanding of the nature of lunar dust.

The special challenges of lunar telescopes have to be examined comprehensively. We already know a lot about lunar topography, the seismic environment, meteoritic bombardment, and the mechanical properties of the lunar regolith, but not enough to determine unequivocally their impact on lunar telescopes. Similarly, we know something about the surface conditions, including the existence of lunar dust, but there are few quantitative examinations of the special challenges that are presented, nor about the possibilities of mitigation. The background radiation at infrared and optical wavelengths is a non-negligible factor, as it is for free-flyers, and an examination of tradeoffs and mitigation measures should be undertaken. Radio emission from the Earth's magnetotail could affect low-frequency radio observations from the Moon. Again, this must be measured as part of a site survey.

For the next decade, no major telescope of any kind is likely to be placed on the Moon. Nevertheless, now is the time to examine what relevant studies can be made from lunar orbit, and what measurements might be made with relatively simple unmanned devices landed on the lunar surface. It is also reasonable to conceive of small site survey experiments that can be set up and conducted by astronauts, once a human return to the Moon has been accomplished.

The\ required measurements can be categorized as follows:

1. General physical properties of the surface, including its variability with location.
2. Physical properties of lunar dust and volatiles, particularly as it affects optical surfaces and mechanical systems.
3. Tradeoffs concerning possible telescope location; e. g. dark craters at the poles, equatorial locations at the limb, in craters, in maria, etc.
4. Measurement of background radiation at multiple wavelengths

In addition, there are technological considerations that must be examined in a sound engineering way:

1. Mitigation of sunlight, earth-shine, and thermal radiation.
2. Electrical power and power storage.
3. Telemetry
4. Astronaut interaction: assembly, adjustments, servicing, and the role of robots.
5. Lunar gravity as it affects telescope design.

The general thrust of these studies and measurements would be to establish the parameters for lunar-based telescopes in the new age of permanent human presence on the Moon. There are obvious international collaborations that should be both possible and desirable, in view of the many countries currently considering lunar exploration (ESA, Russia, Japan, China, and India).