LLR Developments at Mount Stromlo

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1. Introduction

Lunar Laser Ranging is actually a growing technique, with many profound scientific questions for which it is well placed, even uniquely placed, to provide answers (Murphy et al, 2000). As well as the long-established LLR stations at McDonald and CERGA, several more stations are being developed for lunar capability either at existing SLR stations or at new facilities, as described elsewhere in these Proceedings.

The success of space debris laser tracking, using the Mount Stromlo SLR facility, upgraded by at least 6 orders of magnitude in link budget, is reported elsewhere in these Proceedings (Greene, 2002). The colocation of such a powerful debris tracking capability with an existing SLR facility presents an opportunity to investigate ranging to the moon for both scientific data and engineering research into tracking phenomenologies.

The geodetic precision, autonomous operation and calibration of the Stromlo SLR system, if combined appropriately with the link budget of the debris tracking system, could produce high quality lunar ranging data. Also, investigation of powerful, near-diffraction limited laser emissions from large (100 cm or greater) telescopes with sub-micro-radian tracking stability may benefit from a very far-field calibration target mounted on such a stable platform.

A further consideration at Mount Stromlo is the imminent availability of a second telescope of 1.8m aperture that will soon allow multi-aperture, multi-source, coherent and incoherent ranging to be effectively tested. The lunar reflectors present many of the ideal target features for characterisation of dual-aperture technology.

2. Technical Objectives

The LLR program at EOS has a range of objectives:

- Test the feasibility of LLR from Stromlo in order to support LLR science objectives.
- Acquisition of scientific data to support LLR objectives.
- Calibration of the link budget for debris tracking systems using lunar targets.
- Characterise the LLR link budget, for the first time, using the variable tracking link of the system over many orders of magnitude.
- Use the full link of the debris tracker to search for lunar targets not recently acquired.
- Test the feasibility of automated LLR operations.
- Explore dual aperture receiver geometry, using 100 cm and 180 cm receiving telescopes separated by about 20m.
- Test novel transmit and receive geometry on the ground.
- Test a dual-pulse, low cost LLR ranging configuration (below).

3. Mount Stromlo Facility Status

The Mount Stromlo SLR/LLR facility was totally destroyed by fires in January 2003. In its place, a SLR facility is now being developed as part of a new Space Research Centre.

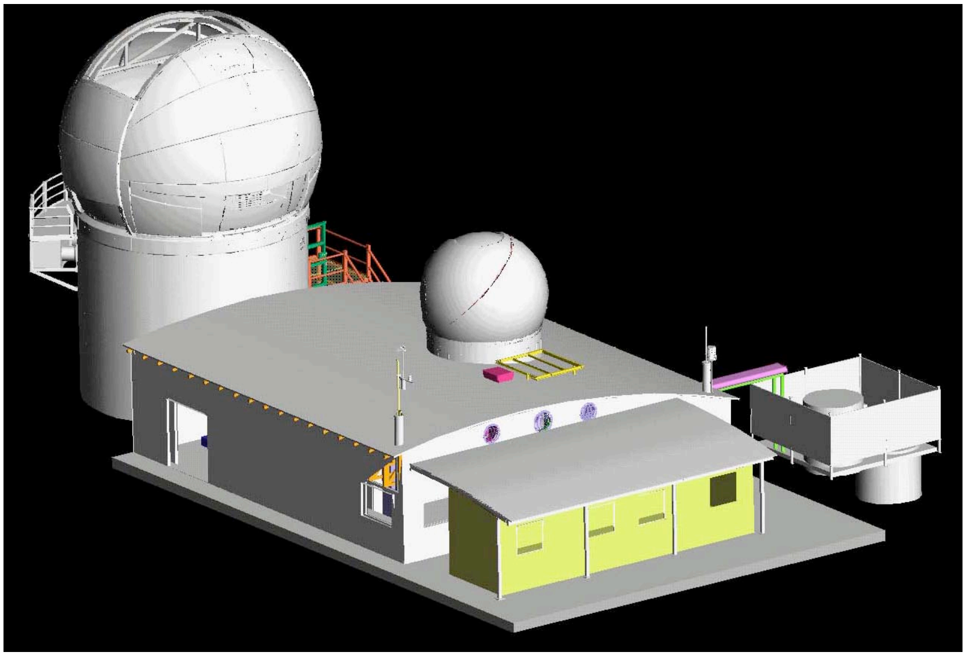

Figure 1a: Mount Stromlo Space Research Centre schematic. (Northeast view).

Figure 1b: The Stromlo site (July 2003) showing the SLR facility (prior to dome installation) and the 10m IceStorm dome housing the 180 cm telescope. Several telescopes are planned for the site.

The Space Research Centre occupies a site within the Mount Stromlo and Siding Spring Observatories campus at Mount Stromlo.

Figures 1a and 1b show the Space Research Centre with the following systems and capabilities:

a) SLR Facility.

The SLR is owned by Geoscience Australia (GA). This is the main building in the foreground of Figure 1a, and it occupies a central location in the SRC. Its prime function is SLR, but it has a significant role in EOS space research programs.

The sealed Typhoon dome is similar to that of the original Stromlo SLR system, and it sits above the main building. This dome encloses an EOS 100 cm laser tracking telescope.

Contracts between GA and EOS for the re-establishment of the SLR capability were executed on 4 July 2003, and the SLR facility will be completed by November 2003.

b) Telescope Test Facility.

The SRC includes a telescope test facility, to allow long-term operational testing for EOS telescopes up to 4m in aperture. At this time, an EOS 9m IceStorm enclosure and 180 cm astronomical telescope are undergoing long term testing for integrated operations. This facility, now completed, can accommodate telescopes up to 4m.

In Figure 1a the larger dome is an EOS IceStorm dome, within which is an EOS 180 cm astronomical telescope. This facility is

c) Optical Laboratories

The SRC has substantial laser and optical laboratories and support facilities.

Three of the former ground calibration targets are to be retained, but the fourth needs to be re-built. The antennae of new geodetic GPS and GLONASS receivers will be placed on their former marks, but the DORIS and GPS Timing antennae will be relocated on new piers.

Further expansion of the site is planned in 2004 for related purposes.

3. Initial System Hardware Configuration

For the LLR experiments, the system will be configured as follows:

Telescopes:	100 cm and 180 cm aperture
	Absolute pointing accuracy < 2”, stellar tracking < 0.3”
Lasers:	5 mJ, <20 ps, 50 Hz, @ 532nm and 1 J, 50Hz, @532 nm
Detectors:	CSPAD, 4 mm jitter, 1 mm bias for 532 nm
Boresight between Telescopes:	Better than 1 second of arc
Calibrations:	Four ground targets
	“spider retro” for real-time calibration on telescope
	“Minico” process using all ground targets.

4. Software Status

The prediction programs MITSHORT and EULER have been successfully transcribed and tested for the local ranging environment. The real-time ranging and tracking software has been configured to accept the ILRS Prediction Format Working Group's new LLR-compatible format and procedure for predictions.

Programs for crater tracking and terminator-crossing calculation are in an advanced stage of development, while the whole concept of mount modelling and star calibrations is being subjected to critical scrutiny with particular emphasis on pointing errors for lunar ranging. Post-processing software for filtering and Normal Point generation will be addressed in due course.

Lower-level software such as telescope and dome control, laser and T/R control, timing system control and data capture, scheduling and house-keeping tasks are likewise being actively reviewed, the aim being to ensure commonality and harmony between the ILRS and debris tracking functions.

5. Initial Experiments

Initial LLR experiments will commence in early 2004. Some early priorities will be;

a) Dual Pulse Ranging

The Stromlo team has pioneered the use of dual-pulse ranging, where a low power ranging system with marginal link budget is "guided" onto the target using a much higher power ranging system with surplus link, but (usually) poor ranging precision.

The pulses can be transmitted from the same aperture, and can be separated in time or wavelength, or both.

For example, a 20J laser [545 nm] transmitted at the same time and on exactly the same axis as a 100 mJ laser [532 nm] would quickly determine the correct pointing to the target, because of the srrong link available in the 545 nm channel. It is easy to separate 545 and 532 nm signal channels. The dispersion of these lasers in the atmosphere is similar.

Another approach is to transmit the more powerful laser on the same wavelength, but temporally shifted from the low power laser emission. In practice the beams must traverse the same atmosphere, so separations up to 1 ms are used. It is easy to separate returns from emissions 1 ms apart.

The Stromlo system can fire a picosecond and a nanosecond laser through the same telescope, and guide the low power system onto the target using the high power (ns laser) link.

It is also possible to fire each laser through a separate telescope, provided the telescopes are boresighted together to <<1 arcsecond. This is possible with the new generation of telescopes, as deployed at Stromlo.

b) Long Baseline Optical Ranging

The dual telescope geometry will be exploited for bi-static receiver (Schreiber, 2002) testing, where the incoming phase of the signal carries angular information.

The two Stromlo telescopes are interferometer-grade telescopes, with their optical centres mapped to 10 micron (RMS) for all sky-pointing angles. This will make them ideal for some aspects of this experiment, even though their physical separation is not large enough to provide the highest sensitivity for this test.

c) Search for Lunakhod-1

There is anecdotal evidence in the LLR community that the Lunokhod 1 rover from Luna 17 is active. However its location is not accurately documented. It is "just" south of Promontorium Heraclides, in an ancient subdued crater in Mare Imbrium (LePage, 1996).

An early mini-project will use the power of the space debris tracking system to scan this general area and establish the reflector location. The starting coordinates for the search will probably be those in the DE403 principal axis system estimated by J.G. Williams (Torre, 2002), namely:

radius	1735000 metres
longitude	-35.03394 degrees
latitude	+38.33479 degrees.

6. Acknowledgements

Thanks to Randy Ricklefs for providing test data for the prediction software, and Jean-Marie Torre for some software routines and for advice on the position of Lunokhod 1. Photos of all the target areas, with the positions of the various landings marked (except Luna 17/Lunokhod 1) have been obtained from the Digital Lunar Orbiter Photographic Atlas of the Moon, downloaded from http://cass.jsc.nasa.gov/research/lunar_orbiter/index.html .

7. References

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