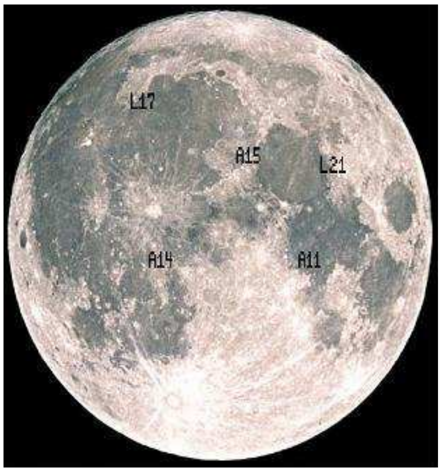
MEO IMPROVEMENTS FOR LUNOKHOD1 TRACKING.

J. M. Torre, M. Furia, J.F.Mangin, E. Samain.
Observatoire de la Côte d'Azur, avenue Copernic, F06130 Grasse.
jean-marie.torre@obs-azur.fr

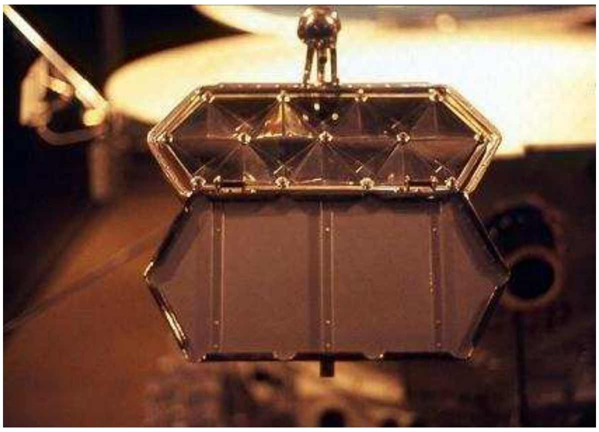
Introduction



The LLR experiment has started when Apollo XI disposed retro-reflectors in 1969[1]. Since this date, five targets have been set down on the Moon. Three by American missions (Apollo XI, XIV, XV) and two by Soviet missions (LUNA17, LUNA21). The targets of LUNA missions are installed on rovers (Lunokhod1 and 2). One of these targets, put down by LUNA17 mission, is not used at the present time.

The goal of the MeO improvements is to be in the best conditions to try to acquire data on Lunokhod1 retro-reflectors[2].

Lunokhod1 target constitution

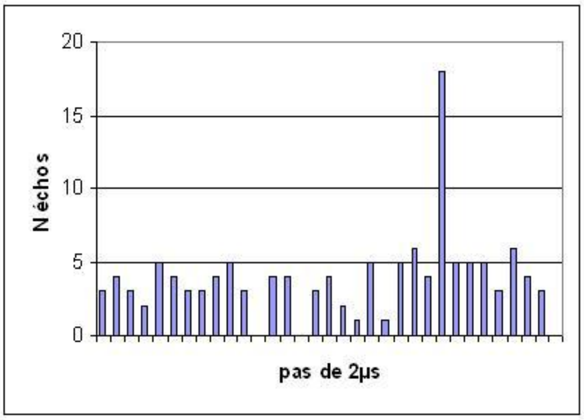


This target is made by fourteen triangular retro-reflectors (length side : 10.6 cm). Its size is 44 cm by 19 cm. These retro-reflectors have been optimised for 694.3 nm (ruby laser), nevertheless the efficiency increases by 8% at 532 nm. These retro-reflectors are efficient for 0 to 25 degrees beam incidence angle. The sides of the corner cube are covered by silver for best efficiency. The drawback of the silver coating is the deformation of the corner cube when the temperature increases. The following table gives the sensitivity to the sun light.

i sun	Night	90°	85°	71°	42°	23°
η	0.82	0.74	0.44	0.16	0.09	0.045

In conclusion, this target lost half of the efficiency twelve hours after the sunrise[3].

Previous campaigns



The first echoes have been obtained in December 1970 at the Pic du Midi Observatory (France)[4]. After this date, the Lunokhod1 vehicle moved to another place. Since this date, no return have been obtained. From Soviet Union, few returns have been obtained in 1974, but not enough to be used for research. In 1975 and 1998, some attempts have been done at Mac Donald observatory (Texas, USA) and Grasse LLR station (France) without any good result.

Tracking constraints

A. Reflector coordinates

The tracking difficulties are due to the bad knowledge of the reflector positioning. In 1998, Jim Williams provided a set of coordinates, probably with a large uncertainty. In the end of 2003, Jim Williams furnished a new coordinates set, based on a possible identification of the site of the Lunokhod1 rover by Prof. P.J. Stooke (University of Western Ontario in Canada). The uncertainty estimates are 1000 m for longitude and 600 m for latitude. The total range uncertainty is about 4 microseconds with 45 nanoseconds/hour range rate.

B. Good time ranging

The best ranging period is when the Moon is high in the sky (lowest crossing atmosphere thickness), and when the reflector is into the night (highest efficiency and low noise).

This favourable period begins in January and finish in June. The observations are done over six days, from four days after the new Moon to two days after the quarter.

MEO improvements

A. Detection improvements

The main difficulty is due to the bad knowledge of the distance. In fact, even if the position is not well known, the spot size of the laser beam on the Moon having six kilometres, the pointing is not too difficult. On the other hand, a kilometre uncertainty on the distance, make you activate during few microseconds the SPAD. To be in these conditions, we have had to remove the used SPAD (SSO AD230) and to adapt a new one (K14) less noisy.

B. Laser improvements

On the other Moon targets, we use a QUANTEL laser with 150mJ pulse in 300 picoseconds. Due to the lower range rate prediction, the echo detection is done by an histogram. As we have seen before, the range rate prediction of Lunokhod1 could reach 0.75 nanoseconds/minute. In ten minutes, if we want to detect echoes with an histogram like for the other targets, we need to have five nanosecond histogram step and height microseconds width. With such a large rate, the accuracy is not very good. Instead of using SLR software to increase the accuracy by time bias corrections, we choose to increase the efficiency by changing the laser.

Our BMI laser has been adjusted to emit 0.65 Joules in 7 nanoseconds pulse at 10 times per second rate. In this case the efficiency is four times higher than with the QUANTEL laser.

C. Conclusions

With the new SPAD, the station is slightly less efficient, but we are able to range with 8 µs gate. The new laser is four times more powerful.

Scientific interests

Like it has been written by Jim Williams, this reflector should be good for:

- Physical librations:
    - North-south spread increases of 36%
    - East-west spread increases of 20%
- Tides displacement
- New accurate location on the Moon

2004 Campaign

The attempts have been made during three Lunar days from March to the end of May. Only six nights by Lunar day are good for the observations.

The following table gives the results.

On the first line you have the quality of the sky and on the second line the number of echoes on Apollo XV corresponding to this quality.

On the three following lines you see the number of nights lost when the sky was cloudy, or the number of attempts when it was possible to range.

We have done an attempt on Lunokhod1 only if it was preceded by good results on Apollo XV. Each attempt is ten minutes ranging time.

<table>
<tr><td colspan="2">Sky quality</td><td>Very clear</td><td>Clear</td><td>Hazy</td><td>Cloudy</td></tr>
<tr><td colspan="2">AXV echoes</td><td>$N > 50$</td><td>$50 > N > 10$</td><td>$N < 10$</td><td>0</td></tr>
<tr><td rowspan="3">Nights or attempts</td><td>March</td><td>0</td><td>8 attempts</td><td>9 attempts</td><td>3 nights</td></tr>
<tr><td>April</td><td>0</td><td>0</td><td>5 attempts</td><td>3 nights</td></tr>
<tr><td>May</td><td>0</td><td>0</td><td>0</td><td>6 nights</td></tr>
</table>

Conclusions

We began the campaign too late, in March.

We have only installed the nanosecond laser in April.

We have not yet had good weather. It should be better to begin in December or in January, when the weather in the evening is often better than in spring.

We will try again next year with new improvements, except if there are results in the two new and performing Lunar Laser Ranging stations in Matera (Italy) or Apache Point Observatory (USA).

References

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[2] G. I. Petrov, "*Investigation of the Moon with the Lunokhod 1 space vehicle*", Space Research, XII, 1-12, (1972).

[3] M. Fournet "*Le réflecteur laser de Lunokhod*", Space Research, XII, 261-277, (1972).

[4] A. Orzag, J. Röch, O. Calame, "*La station de télémétrie de l'observatoire du Pic du Midi et l'acquisition des cataphotes français de Luna 17*", Space Research, XII, 205-210, (1972).