French LLR Station and New Project

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History
French LLR station

- Telescope diameter: 1.54 m
- Altitude: 1270 m
- Laser: Nd-YAG frequency-doubled 532nm, 70ps pulse width, 220mJ in green, 10Hz pulse rate
- Detection: APD in Single photon mode
History

– 2003:
  • Lunar Laser Ranging (LLR station)
  • Satellite Laser Ranging (SLR station)
  • French Transportable Laser Ranging System (FTLRS)

– 2008:
  • MéO station (Moon, satellites and other experiments)
  • French Transportable Laser Ranging System

– 2013:
  • MéO station
  • New station being studied
New considerations

• Tracking difficult for targets from LEO to the Moon
• Impossible to develop an automatic station
• Other projects:
  – Adaptive optic
  – Time transfer by laser link
  – Telecommunications by laser link
## SLR Global Performance Report Card

**July 1, 2013 through June 30, 2014**

<table>
<thead>
<tr>
<th>Location</th>
<th>LEO pass</th>
<th>LAGEOS pass</th>
<th>High pass</th>
<th>Total passes</th>
<th>LEO NP Total</th>
<th>LAGEOS NP Total</th>
<th>High NP Total</th>
<th>Total NP</th>
<th>Min. of Data</th>
<th>Cal RMS</th>
<th>LAG RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1000</td>
<td>400</td>
<td>100</td>
<td>1500</td>
<td></td>
<td></td>
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<tr>
<td>Zim</td>
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<td>19974</td>
<td>18612</td>
<td>150164</td>
<td>116511</td>
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<td>11.0</td>
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<td>4140</td>
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<td>6073</td>
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<td>50269</td>
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<td>3171</td>
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<td>5651</td>
<td>18606</td>
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<td>58017</td>
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<td>5.0</td>
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<td>Herst</td>
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<td>740</td>
<td>2189</td>
<td>6223</td>
<td>41520</td>
<td>7134</td>
<td>6647</td>
<td>55301</td>
<td>41768</td>
<td>7.2</td>
<td>15.3</td>
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<tr>
<td>Matera</td>
<td>2802</td>
<td>1080</td>
<td>1167</td>
<td>5049</td>
<td>33966</td>
<td>9379</td>
<td>5208</td>
<td>48553</td>
<td>48106</td>
<td>1.2</td>
<td>3.9</td>
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<tr>
<td>Potsdam</td>
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<td>269</td>
<td>3246</td>
<td>47611</td>
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<td>2102</td>
<td>52860</td>
<td>31236</td>
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<td>12.9</td>
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<tr>
<td>Grasse</td>
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<td>559</td>
<td>877</td>
<td>2331</td>
<td>34406</td>
<td>6624</td>
<td>3343</td>
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<td>16.2</td>
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## LLR Data Report Card

<table>
<thead>
<tr>
<th>Site Information</th>
<th>Data Information</th>
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<tbody>
<tr>
<td>Column L1</td>
<td>L2</td>
</tr>
<tr>
<td>Location</td>
<td>Station Number</td>
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<tr>
<td>Grasse_MEO</td>
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<td>McDonald</td>
<td>7080</td>
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<tr>
<td>Matera_MLRO</td>
<td>7941</td>
</tr>
</tbody>
</table>
New priorities

- First priority on the Moon tracking
- Geodetic satellites tracking (Lageos, Etalon)
- Time transfer on Jason 2 (T2L2)
- LRO tracking
- Short campaigns on HEO satellites
- Other experiments…
Infrared detection

- Tests of different APD
- Positive points:
  - More powerful laser
  - Better transparency of the sky
  - Less noise
- Negative points:
  - Lower accuracy
  - Dark noise more important
Infrared detection
Statistics: Number of echoes

The graph presents the number of echoes over the years 2009 to 2014, categorized by different codes:
- AXI
- AXIV
- AXV
- L1
- L2

The data points are as follows:
- 2009: AXI (51), AXIV (20), AXV (499), L1 (165), L2 (445)
- 2010: AXI (16), AXIV (165), AXV (499), L1 (99), L2 (20)
- 2011: AXI (2517), AXIV (2120), AXV (12406), L1 (997), L2 (112)
- 2012: AXI (1649), AXIV (1649), AXV (11311), L1 (353), L2 (112)
- 2013: AXI (538), AXIV (538), AXV (5760), L1 (961), L2 (28)

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Statistics: Number of normal points

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New Project

• S.HE.L.L.I.: 

  – Southern Hemisphere Lunar Laser Instrument 

  – NTT telescope, La Silla, Chile (ESO) 

  – Telescope diameter : 3.60 m 
  – Altitude : 2375 m
New Project, abstract

SHELLI is a Lunar Laser instrument to be installed at the Nasmith of NTT. With such instrumentation important, the scientific communities of fundamental physics and solar system formation will highly benefit of the only LLR station in the Southern Hemisphere. The quality of the NTT 3.6 meter telescope will also greatly complement the LLR 3.6 meter APOLLO instrument in the Northern Hemisphere (USA). Finally, about 50% of the observations will be operated during the day and during small sessions of about one or two hours.
Present and expected results of gravity tests realized in the solar system
Improvements in Moon dynamical and internal parameter estimations obtained by including simulated Southern Hemisphere observations (with a simulated accuracy of 2 cm) and 3.6m Southern Hemisphere observations (with a simulated accuracy of 0.5 cm)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Southern station</th>
<th>3.6 m Southern station</th>
<th>What for ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geocentric position and velocity of the Moon</td>
<td>10 to 30%</td>
<td>25 to 40%</td>
<td>Dynamics, Tests of GR</td>
</tr>
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<td>Gravity Field coefficients</td>
<td>2 to 30%</td>
<td>15 to 30%</td>
<td>Dynamics, Libration</td>
</tr>
<tr>
<td>C/MR² ratio</td>
<td>15%</td>
<td>25%</td>
<td>Inner core size and density</td>
</tr>
<tr>
<td>Love Numbers</td>
<td>10%</td>
<td>25%</td>
<td>Elastic properties of the Moon</td>
</tr>
<tr>
<td>T parameters</td>
<td>5%</td>
<td>25%</td>
<td>Q of dissipation</td>
</tr>
<tr>
<td>Mass of the Moon-Earth system</td>
<td>10%</td>
<td>30%</td>
<td>Dynamics, Tests of Gravity</td>
</tr>
<tr>
<td>Positions of the reflectors at the Moon surface</td>
<td>5%</td>
<td>20%</td>
<td>Dynamics, Libration, Tests of GR</td>
</tr>
</tbody>
</table>

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New Project, conclusion

“the science case of SHELLI is quite remote from that of the ESO community, and SHELLI requires using the telescope during day time, which may be problematic for subsequent night observing”

• Thanks for all the people of this community who help us for the proposal of this experiment
• In the future, if we want to succeed we need to find a new telescope in an new observatory!
• Fortunately Hartebeesthoek will provide LLR data from the Southern Hemisphere
Curiosity

EARLY APOLLO SCIENTIFIC
EXPERIMENT PACKAGE (EASEP)

The Apollo 11 EASEP consisted of two experiments: the Laser Ranging Retroreflector (LRRR) and a Passive Seismic Experiment (PSE).

The LRRR reflected laser beams back to Earth off an array of fused silica cubes. This permitted precise measurement of the distance between the Earth and Moon within 8 centimeters (3 inches). The LRRR was turned off finally in June 1981.

The PSE was a solar powered device with four seismometers. It measured lunar shock waves caused by moonquakes, impacts from meteors, or manmade objects. It ceased working in August 1969.
Thanks !!!