Laser Ranging: Scientific Accomplishments of the Past and Requirements for the Future

Erricos Pavlis
GEST/UMBC, USA
epavlis@umbc.edu

Laser Ranging (LR) has a long and stellar contribution in Earth sciences for nearly half a century now, spanning most of the space age since the first satellite was launched. From tracking Beacon-B in 1964, ranging to the Moon since the Apollo program, measuring tectonic motions during the San Andreas Fault Experiment, providing valuable tracking data for the first detailed global gravity models (e.g. the GEM, GRIM and JGM series, EGM96, etc.) and even in recent years, during the Geopotential Mapping Missions' era, it is still considered as a valuable technique, especially for monitoring the long-wavelength static and temporal components of the field. Lunar LR has provided a trove of scientific data on the Moon's orbit, rotation and structure, paving the way for many of the recent lunar missions. LLR has been a unique tool for tests of fundamental physics theories on a cosmological scale.

All along these years of course, LR provided Precise Orbit Determination (POD) for numerous missions and it is still considered the best, low cost and fail-safe absolute POD approach. Deployments of transportable systems in the early years helped establish positions and monitor deformation in areas void of permanent systems prior to the development of GNSS systems (e.g. MEDLAS). LR supports numerous remote sensing missions such as those with oceanographic radar altimeters that require accurate calibration to maintain the continuity of the MSL change record. Mobile systems like FTLRS are crucial in this area, with multiple occupations of calibration sites usually far from permanent LR systems (e.g. Ajaccio, France, Gavdos, Greece, and Bass Strait, Tasmania). Laser altimeters have mapped the Moon, Mars and Mercury so far, in some cases providing us with topographic detail that we do not have even for Earth at present. On Earth on the other hand, laser altimetry has focused on icecap-volume monitoring over the two polar regions of the planet (ICESat), with incredible results and great synergy with those obtained from GRACE-based mass monitoring of these areas and the planet as a whole.

As we are about to enter the second half of the "LR century", the technique is facing a number of challenges stemming from burning scientific questions that by now have become social issues, including sea-level rise, climate change, ice-melting, earthquake and tsunami hazards, etc., since their effects will have significant repercussions on everyone's future including that of the planet itself. The ground-based global network is very slow in updating its hardware and adapting to automated operations that can significantly reduce the costs. Data accuracy has leveled off at millimeter-level normal points, however the sparseness of the network and available high-quality targets make it difficult to assess the absence of systematic errors at the 1-2 cm level soon after the data are collected, well prior to their use in the development of scientific products. With the stringent requirements imposed by GGOS on one of the primary geodetic products where LR plays a central role, the International Terrestrial Reference Frame (ITRF), delivering 1 mm accurate origin and 0.1 mm/y stability are still 10-20 times what we are achieving today. To reach this level on a routine basis we will require a much better ground segment (network), distributed in a more uniform way over the globe and co-located with all other geodetic space techniques, with automated 24/7 operations. Increasing the number and quality of the tracked targets from the two LAGEOS and ETALON at the moment, to perhaps another so many targets of higher quality will by and large result in achieving our goals. The recent launch of LARES has already elevated the space segment in the right direction in a modest but significant increment. Additional similar targets and improvements of our modeling for data analysis will still be required before we can be certain that our products meet the prescribed requirements.