Updated Centre of Mass corrections for LAGEOS and Etalon

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Abstract One of the enduring limiting factors in reaching the scientific goal of 1-mm accuracy satellite laser ranging to the geodetic satellites is the problem of referring the range observations to the centres of mass (CoM) of the spherical satellites. The cube-corner retroreflectors that are densely distributed over the surfaces of the primary geodetic satellites LAGEOS (diameter 0.60m) and Etalon (diameter 1.29m) give rise to broad, complex distributions in the returning laser pulses that are detected by the stations. Proper treatment of the resulting range measurements that take account of the various laser-station technologies is required in order to minimize potential systematic errors in the range that can reach more that 10 mm for the two LAGEOS and up to several cm for the two Etalon satellites. Earlier theoretical results have been used here to develop tables of CoM corrections and their uncertainties that are applicable in a simple way when analyzing range data from all the ILRS stations that have operated from 1980 onwards. We outline the results and discuss their impact upon weekly reference frame solutions contributed by the Herstmonceux AC to a pilot study organized by the ILRS Analysis Working Group.

Introduction It has been established for some years that in order to derive as accurate as possible laser-range CoM values for the geodetic satellites, a variety of factors have to be taken into account before choosing the appropriate value. The main conclusion of previous work in this area, most recently that of Otsubo and Appleby (2003), is that tracking station characteristics such as laser pulse-width, type of detector, return signal-strength and post-processing philosophy together lead to a range of possible CoM values that for LAGEOS span as much as 10mm. In this current work we took the theoretical values from the Otsubo and Appleby (2003) analysis, and associated time-dependent CoM values with each of the tracking stations that have contributed to the ILRS effort for the period 1980 to date. The vital resource to carry out this work is the individual site logs that are available through the ILRS website; for each station the site logs specify existing hardware, software and return-energy levels and, as importantly, track the changes in any of these components that often take place over the years, as improvements towards greater capability and higher precision are implemented. These changes, say an upgrade in detector from a multi-photon photomultiplier tube to a single-photon avalanche diode and perhaps a shorter laser pulse, can change the appropriate CoM value for LAGEOS by more than 5mm and considerably more for the Etalon satellites.

Implementation A limitation of the Otsubo and Appleby (2003) results was that it was left to the laser range analyst to identify each ILRS station with the broad hardware and software characteristics that were used in the paper to develop the various CoM values. For example, the paper gives a CoM value of 250mm to be used for LAGEOS observations made by stations with micro-channel-plate detectors, multi-photon operation and 200ps laser pulse width. In fact these are the characteristics of stations belonging to the NASA Network, and it is noteworthy that our derived CoM value of 250mm is very close to that (251mm) determined for those particular characteristics in the LAGEOS-2 pre-launch measurements (Minott *et al*, 1993). But clearly a time-dependent table directly linking individual site numbers to CoM corrections will be much more convenient to use and enable automatic processing. As far as practical, the current work reported here has taken all the stations that have or continue to operate during the period from 1980 to date and used the results in the paper to estimate an appropriate CoM value, and importantly, to associate with that value an estimate of its error, derived from the stated

operational practice. For instance, if a station states in its log file that it works strictly at single-photon levels of return, the results in the paper suggest that a small value, perhaps ±1mm, would

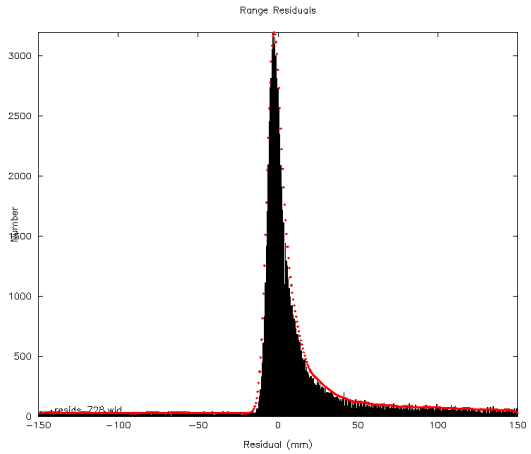

Figure 1 Distribution of Single-Photon Range Residuals from a LAGEOS Pass, with Modeled Distribution Curve from which a CoM Value of 245±1 mm is Derived

be an appropriate error estimate on the CoM value. An example of this high-precision situation is shown in Figure 1, where the modeled satellite signature curve (in red) is seen to fit the laser range residuals extremely well. A greater degree of variability in accepted return rate will, on the other hand, increase the uncertainty of the mean value of the CoM correction. Tables of values of CoM corrections for LAGEOS and Etalon, along with a simple Fortran interrogation code, have been released and evaluated during a short time-span pilot study conducted by the ILRS Analysis Centres (ACs) under the direction of the ILRS Analysis Working Group.

Evaluation and testing In common with the ILRS ACs, the UK SGF Herstmonceux AC carried out a six-month evaluation of the impact on the reference frame of using the LAGEOS and Etalon CoM values derived in this study. Weekly solutions from October 2011 to March 2012 for orbits, station coordinates and EOPs were carried out with and without the new CoM values for LAGEOS and Etalon, where 'without' means that the 'standard' CoM value for LAGEOS of 251mm was used for all stations except Herstmonceux, where the value (245mm) derived by Otsubo and Appleby (2003) was used. The results from the six-month evaluation showed only a minimal change in the mean scale of the reference frame of 0.03ppb. However, it is considered likely that a longer evaluation time-scale will reveal greater differences, since during the 1980s and 1990s extensive hardware changes were taking place at the stations, the effects of which on the appropriate CoM values as given in the new tables have not yet been evaluated in reference frame solutions.

References

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