System-dependent centre-of-mass correction of geodetic satellites

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The measurement precision of recent satellite laser ranging technology has reached 4-6 mm in a single-shot basis and 1-2 mm in a normal-point basis, mostly owing to the improvement of its optical and electronic components. We now encounter some error sources that were considered negligible. Spread of a retroreflected pulse, known as the satellite signature effect, is one of them. Given a widely spread pulse in time, the detection timing which should fall somewhere within the pulse can be significantly dependent on laser ranging systems. This effect degrades the determination of substantial geodetic parameters such as the gravitational scale of the Earth, the vertical position/velocity of a laser ranging station, the scale of the terrestrial reference frame, the satellite orbit and so on. We would like to discuss the optical response from spherical geodetic satellites and the centre-of-mass corrections of them.

We deal here with three satellites already in Earth orbit: LAGEOS, AJISAI and ETALON. They are all spherical, but their sizes and reflectors are quite different. We constructed the optical response model (function of two-dimensional angle of incidence) for each type of reflector. Then, for every angle of incidence toward the satellite, the response function, which is defined as the optical response to an incident laser pulse of zero width, can be calculated for the three types of the satellites.

It is recognised that the centre-of-mass correction of spherical satellite is dependent on the laser ranging system and the observation policy. Let us now consider the timing of detection for different systems; the single photon system, the C-SPAD system and the photomultiplier system.

The centre-of-mass correction for the single photon system is defined at the centroid of the response function which should agree with the mean of the full-rate residuals. That of the C-SPAD system can range from the single photon case right up to the start of the leading edge, depending upon the return signal intensity. That of the photomultiplier system is defined at some point in the leading edge of the return pulse and it is dependent of the response speed of the electronic devices.

We calculated the centre-of-mass corrections based on these assumptions. The following table shows the result in comparison with the standard values. Note that the response speed of 200 ps in the photomultiplier system is based just on the laser pulse width, ignoring the electronic response speed. The C-SPAD values vary much from the single photon case to the very strong return. The LAGEOS satellite shows less variation (less than 1cm) than the larger ETALON and AJISAI (more than 4 cm).

	Standard	Photomultiplier system(200 ps; half maximum)	Single photon(3-sigma clipping)	C-SPAD(very strong returns)
LAGEOS	251	250	245	257
ETALON	578	602	556	613
AJISAI	1010	1013	976	1023