Technological Challenges of SLR Tracking of GNSS Constellations

Summary of Session to Discuss Position Paper 7

Mike Pearlman summarised his Position Paper on Technological Challenges for SLR tracking of GNSS constellations. The main points raised are summarised below.

- The current diverse ILRS network technology was discussed and it was noted that the lack of an ideal geographic distribution is less of an issue for GNSS tracking

- Only a relatively few of the most capable stations currently make a significant contribution to GNSS tracking

- Several stations are being upgraded with event timers, high-rep lasers, photon-counting detectors, etc., that will significantly improve performance for the low-signal, high-altitude GNSS satellites

- The NASA Next Generation SLR is an example of this type of system

- Short-pulse, high-repetition systems probe the target arrays at high resolution, leading to clear single-cube signatures and the need for more complex data analyses

- Increased detector noise at high-repetition rates can be circumvented using very small range-gates, and work is being done to investigate potential small range bias effects in single-photon avalanche diodes (SPADs) when small (few ns) gates are used

- Array design issues were discussed; the efficiency of the retro-arrays is of paramount importance for high-orbiting satellites because poor return signals will rapidly dissuade stations from attempting tracking as well as providing too little data for serious analysis.

- Of particular interest is the material of the cubes, the size of the array and of the individual cubes, whether or not they are coated or uncoated, the 'spoiling' angle at the vertices and the likely thermal conditions once in orbit.

- The ILRS has developed standards for retro design that mission engineers should adhere to in order to provide sufficient return signal for day and night-time tracking, as well as to ensure the provision of very accurate metric data on the location both of the arrays and the satellites' centres of mass. The arrays are to provide a cross-section of at least 100 million square metres at GPS heights, suitably R^4 scaled for other heights.

Following the presentation of the Position Paper a number of related presentations were given, summaries of which follow here.

- David Arnold presented the theoretical basis for preferring uncoated, zero-dihedral-angle cubes for GNSS-height satellites. The diffraction pattern from a cluster of such cubes, properly oriented, is close to circular and thus ideal at all positions of a tracking station in the far-field. The lack of coatings is also likely to reduce thermal distortion effects.

- Reinhardt Neubert *et al* presented a design study for a proposal for a single, open, cube for the GALILEO satellites. The advantage of low-mass and small size did not appear to compromise their efficiency.

- A presentation of work by Toshi Otsubo looked at the potential for range bias from the extended, flat arrays on GNSS satellites. He compared a model of the expected signature effect from the arrays on the GIOVE satellites with that actually seen in residuals from kHz ranging at Herstmonceux, noting that careful treatment will be required to maintain mm-level range measurements to the satellites' centres of mass.

- A detailed study into the efficiency of the in-flight arrays on GPS, GLONASS, COMPASS-M1, GIOVE and ETALON was carried out and presented by Matt Wilkinson. His analysis used as a proxy for array efficiency the range-corrected return rates derived from archived full-rate data from a number of stations from 2007 to date. A further normalisation by number and geometric size of cubes in each array showed that per unit area the ETALON, GPS and GIOVE satellites give comparable responses. The COMPASS-M1 target is significantly better and the GLONASS targets are notably less responsive.

- Simone Dell'Agnello *et al* presented the latest status of the tests on existing arrays that are being carried out in the space-environment facility at INFN-LNF in Frascati, Italy. Such tests will be used on proposed designs, especially to test their thermal stability that is crucial for maintaining return signals at their theoretical levels.

- J-M Torre gave an update on the important upgrades to the MEO LLR/SLR system at OCA Grasse. The system is tracking the GNSS satellites to low elevations and hopes to begin operational LLR soon. The stumbling block here seems to be the performance of the telescope, which will require significant additional cost to improve, and additional down time.

- J-M Torre presented an update on T2L2 tracking and time-transfer results from colleagues at OCA. A good number of sites are now routinely tracking and delivering full-rate data in CRD format. More work will be done to monitor using the data from the maser-driven sites the stability of the on-board DORIS oscillator. The FTLRS system will shortly go to the Paris observatory to take part in a time-transfer experiment.

- Mikhail Sadovnikov finally presented some ambitious plans for new Russian laser systems that will attempt to reach sub-mm precision and accuracy. The plans include ranging at MHz rates with short-pulse lasers, and it is expected that preliminary results will be available in a year or so.

Overall, there are a number of technological studies, simulations and tests ongoing both at the station and LRA levels that will put the Network into a better position to contribute strongly to the increasing demand from the GNSS community.