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L. SYNERGISM OF SLR AND GPS

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The launch of GPS-35 (PRN 5) with a laser retroreflector has provided an opportunity to compare SLR-determined orbits of a GPS satellite with those determined by GPS receivers operated with the transmitted radio signals on the L_1 and L_2 frequencies. Operational considerations of the SLR and hardware design have influenced the amount and quality of SLR data collected on this satellite. As of February 1, 1994, all of the collected SLR data have been collected from northern hemisphere stations. Adequate southern hemisphere coverage is required to fully compare the results obtained from GPS L_1/L_2 and from SLR.

Preliminary comparisons have been made to provide an early assessment of the orbits determined by SLR and GPS L_1/L_2 . Using all available SLR data on GPS-35 covering 56-days after launch, the RMS of the SLR residuals was about 9 cm. Within this arc, day 322 of 1993 was one of the best tracked by SLR (except for the lack of southern hemisphere coverage). This day was extracted from the multiweek arc for comparisons with GPS L_1/L_2 . Several one day arcs were used for the comparison with the SLR-determined orbit. The orbit was determined by UT/CSR using 25 globally distributed Rogue-class receivers. The data from these receivers was used in a double difference mode. In addition, ephemerides were generated by the University of Berne, EMR of Canada, European Space Agency (Darmstadt), National Geodetic Survey, and University of California/Scripps. The comparison of each ephemeris with the SLR result for a one day arc is shown in Table 1.

Table 1. Comparison of GPS L_1/L_2 with SLR Ephemerides

| | L_1/L_2 minus SLR, RMS (m) | | |
|-----------|------------------------------|-------------|-------------|
| | Radial | Along-Track | Cross-Track |
| UT/CSR | 0.31 | 0.94 | 0.49 |
| Berne/COD | 0.25 | 0.99 | 0.55 |
| EMR | 0.24 | 1.05 | 0.50 |
| ESA | 0.25 | 1.07 | 0.51 |
| NGS | 0.26 | 1.15 | 0.71 |
| SIO | 0.26 | 1.25 | 0.67 |

Although each ephemeris has been corrected to the spacecraft center of mass for the comparison, the differences are meter-level, which warrant further study. The level of differences may be, in part, caused by lack of southern hemisphere data. A thorough comparison requires more complete coverage by the SLR network than the data available to date.

In addition to the use of SLR on GPS-35, the TOPEX/Poseidon (T/P) satellite carried instrumentation to support tracking by SLR, GPS and the French doppler tracking system, DORIS. Although the design of the GPS receiver limited use to periods when GPS Anti-Spoofing was deactivated, a significant amount of data was collected during the first 18 months since launch.

Direct comparisons of the T/P ephemerides determined by each of the three tracking systems has demonstrated for the first time in an on-orbit environment that GPS can produce precise ephemerides that agree with SLR/DORIS-determined ephemerides at the 2-3 cm level in the radial component and at the 10 cm level in the along-track and cross-track directions. The ephemerides used in the comparisons were obtained using similar orbit determination strategies and models, thereby demonstrating the compatibility between the somewhat different technical characteristics of each technique. As noted previously, the GPS receiver on T/P was a demonstration experiment which required agreements with the Department of Defense for operation of the GPS constellation without Anti-Spoofing for some period of time. Since February 1994, Anti-Spoofing has been activated and the ability of the GPS receiver to achieve comparable ephemeris accuracy with SLR has been adversely affected. Nevertheless, the operation of SLR, GPS, and DORIS on a single spacecraft enabled the calibration of the experimental GPS system. The GPS radial bias, attributed to the location of the GPS phase center on the T/P antenna, and apparent z-axis biases were identified. Even though the sources of these biases are not completely understood, the identification of their existence was hastened by the availability of independent tracking from SLR.

IV. THE SLR PROGRAM

