Transitioning the NASA SLR network from the Time Interval Mode to the Event Timing Mode

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Abstract:

The time interval counters used in the NASA SLR network have been obsolete since the early 2000. Maintaining this product for network operations has been extremely hard and in some cases has biased the SLR data. The Event timer is widely used and proven in the ILRS community and is the natural successor to time interval counters. For a SLR network with global data impact, transitioning to any replacement device requires significant scrutiny and long term validation. Any long term measurement, however, has the potential for interrupting the station's operational data flow to ILRS due to data quarantine. An operationally non-invasive concurrent data taking method was devised for the new and old hardware to perform simultaneous measurements in the stations without affecting the normal operational data flow, thus allowing intercomparison. This paper focuses on the measurement and analysis towards the transition.

Introduction

The stations in the NASA SLR network have been using the HP 5370 time interval counters/units (TIU) for the time of flight (TOF) measurements for the last 25+ years. For the time of flight (TOF) measurement, the TIU counting starts on the transmitted laser pulse and stops on the satellite return pulse. These devices have a time resolution of 20 picoseconds (ps), timing precision of ~20ps, and an instability anywhere up to ±50ps depending on the range, device settings, and device calibration. The obsoleteness of the product along with the occasional timing instability (causing range biases) has rendered the product difficult to sustain in the network. Furthermore, the GPIB digital interface of the TIU has significant overhead (~50 milliseconds (ms)). The NASA SLR data collection at the maximum rate of 10Hz occurs only for the LEO satellites, while Lageos ranging is at 5 Hz, HEO at 4 Hz, and GEO satellites at 2Hz. Since the satellite TOF may vary anywhere from 4-250ms, the GPIB overhead is restrictive for longer ranges at higher data rates. Using the TIUs,

Technical Approach

To manage the quality of the data as well as to maintain stable operations, the TIUs were replaced with Event Timer Modules (ETM). The ETM operates on independent channels for its start and stop for the time measurement, from which TOF is derived. It can measure long time duration (~1.5 hours) events at a high pulse repetition frequency (PRF). Many ILRS stations use Event Timers and this is especially true for all kilohertz (kHz) systems. The Cybioms' supplied ETM supports PRF as high as 10 kHz SLR and can be used with any of the current SLR systems.

Consistent with the ILRS practices, any data configuration change in an operational station must go through testing with the test data placed in quarantine followed by data scrutiny. The standard ILRS requirement is 20 Lageos 1, 2 passes for orbital analysis by the Analysis Standing Committee (ASC). The NASA SGP requirements are tighter than that of the ILRS and consequently a station can be in quarantine for a substantial period, thus affecting the needed data flow for data analysts. A concurrent scheme for data taking using the old and new was devised to support the test measurements without inhibiting the operational data flow. Figure 1 below illustrates this dual data configuration.

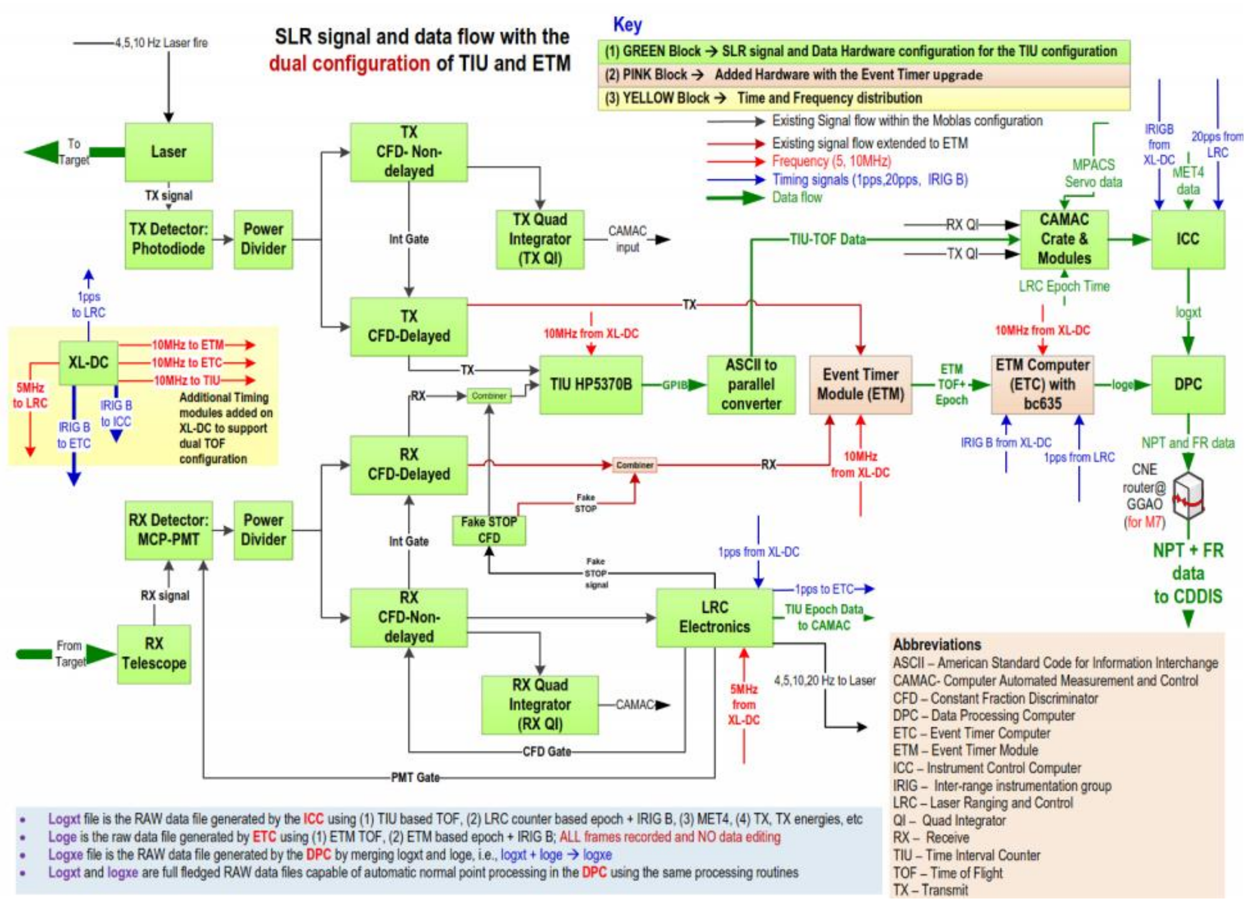

Figure 1: Data configuration of the NASA SLR system

In the above data configuration, the ETM device can be swapped to check multiple devices and to compare against the TIU. Figure 2 depicts this swap configuration used for intercomparison. This became necessary as we saw fairly large systematic range biases in the data and multiple devices were compared to a common TIU at M7. There were two swaps made in M7 (Greenbelt) and one in M5 (Yarragadee). One swapped device from M7 was then sent to M5 for a 2-way intercomparison. This two station intercompared device was designated for M8 (Tahiti) and the one station inter-compared device at M7 was sent to M4 (Monument Peak). Such inter-compared and validated ETM devices in one or more stations provide a common framework to compare the TIUs amongst the various stations as well. Furthermore, this pre-installation measurements allowed accelerated implementation of the ETMs into the network.

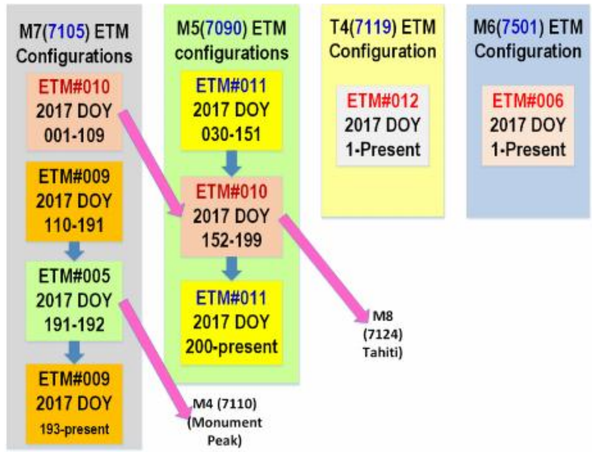

Figure 2: ETM swaps made in Moblas7 (M7, Greenbelt) and Moblas5 (M5, Yarragadee) stations

Results and Discussion

One of the important system performance measurement is the 1 hour system stability (Figure 3).

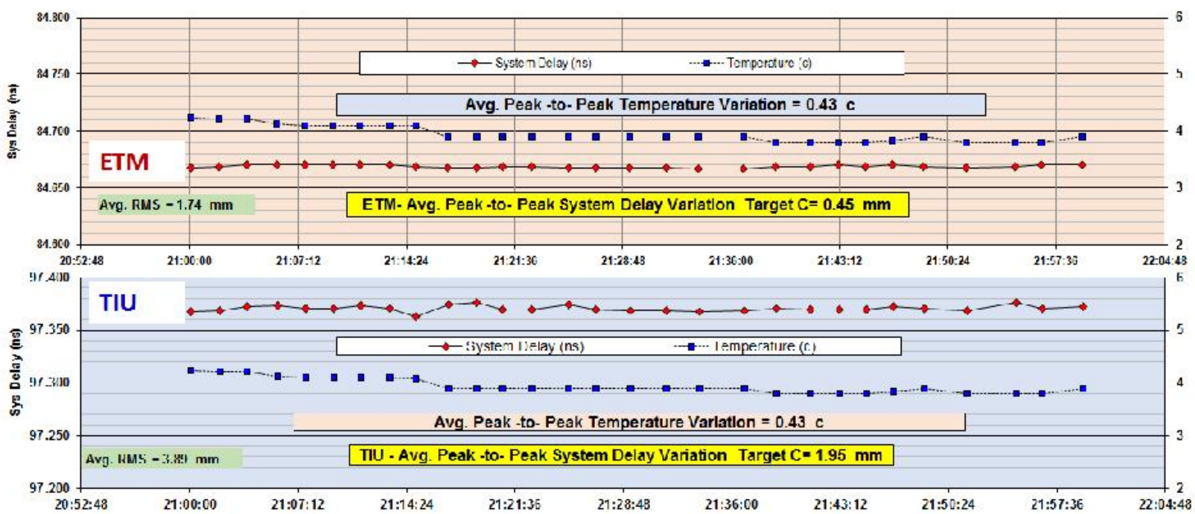

Figure 3: Stability intercomparison of the ETM and TIU

Thousand point data files were taken continuously on a ground target for a period of 1 hour and the statistics were computed. In the above plot, the mean value (in red diamonds) of the system delay is displayed using the primary Y-axis of the plot and the mean of the corresponding temperature data is displayed (in blue squares) using the secondary Y-axis of the plot. The primary Y-axis depicting the system delay is 10ps/divn, while each division of the secondary axis for the temperature is 0.2C. When the data is taken within the dynamic range (~8) of the discriminator's linear response, sub-millimeter stability was obtained. If the energy values from the ground target exceeded the discriminator dynamic range, then the variability observed will be higher. As part of the routine operations, care was taken to confine the data taking to the dynamic range of the discriminator.

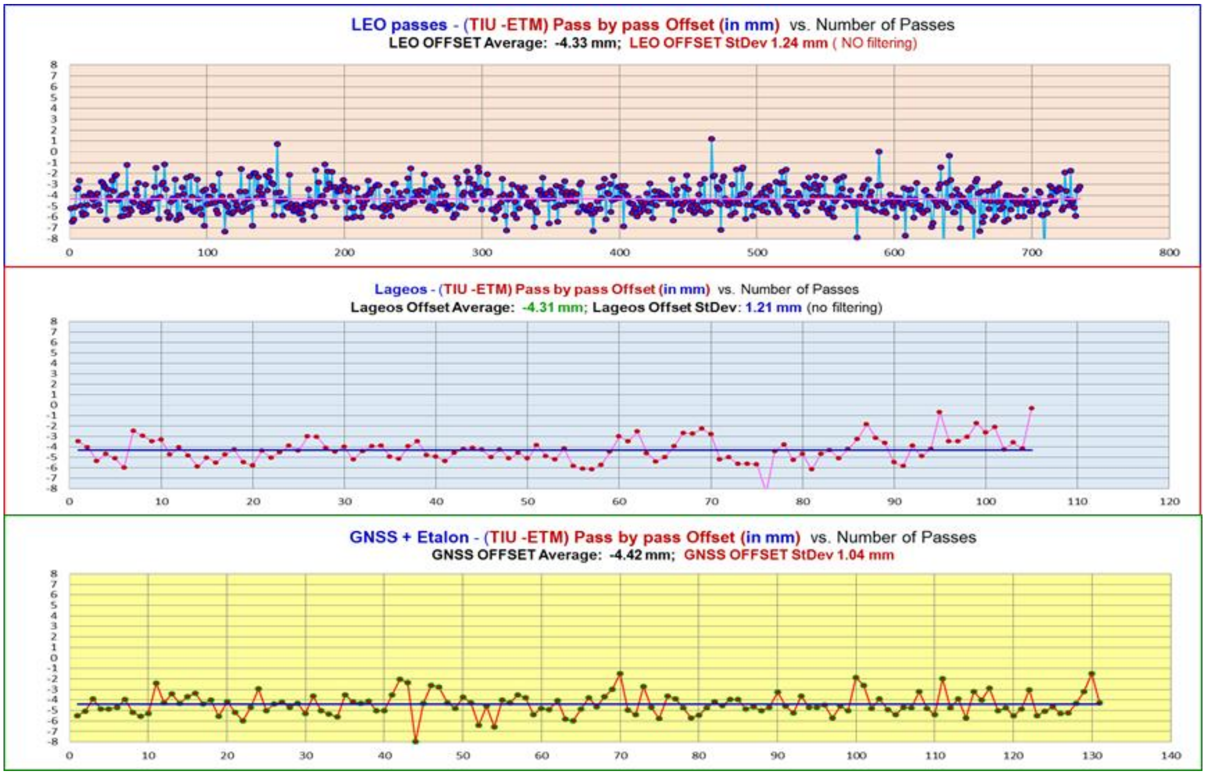

Figure 4: Intercomparison of ETM and TIU results on various satellites in M7.

For the above intercomparison of the M7 ETM and the TIU, the raw TOF data was used. The simultaneous point by point data from each group of these satellites were used for this direct intercomparison. The composite mean and RMS of each group of data was then computed. As can be seen, each of the above groups (LEO, Lageos, and HEO) of satellites exhibited range biases anywhere from -4.3 to -4.4 millimeters, which is a significantly large value. Interestingly, the SLR analysts [2] have seen similar data from the Lageos orbits during the last few years.

Conclusions

The introduction of the event timers in the NASA network has allowed the transition to a modern highly precise time measurement technique with picosecond stability and precision. The concurrent data taking approach did not perturb the operational configuration while allowing the comparison of the existing TIU performance at the submillimeter level. Multi-device comparison in a single station allowed the framework to place ETMs in other stations with higher level of confidence. Most importantly, the station specific and orbit dependent range biases due to the TOF measurement were uncovered by direct comparison at the sub-millimeter level.

References

1. Mike Selden, Thomas Varghese, Michael Heinick, and Thomas Oldham, Proceedings of the SLR workshop, ilrw8_section04, PP 4-1 through 4-8
2. Erricos Pavlis, Private communication

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