

## A comparison of event timers HxET and A033-ET installed at the SGF, Herstmonceux

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### Herstmonceux Event Timer

In 2006, an epoch event timer (HxET), built in-house from two Thales Systems timing modules and a clock module, was installed at the Space Geodesy Facility (SGF) in Herstmonceux, UK. The new timer greatly improved both the accuracy and precision of the SGF satellite laser ranging normal points. It also enabled multiple laser shots to be in-flight, which was an essential prerequisite for the development of kHz laser ranging.



The inputs to the two HxET channels are from the laser fire, termed a 'start' pulse, and the SPAD detector, the 'stop' pulse. The start and stop epochs are read by the SLR control PC and matched and differenced in real-time to give time-of-flight measurements.

### Installing the A033-ET Riga Event Timer

In 2014, the SGF purchased a A033-ET timer manufactured by Eventech Ltd and the Institute of Electronics and Computer Science in Riga, Latvia.



The timer also has two input channels through which an input signal pulse is transformed to a 80-bit timing data block, comprised of the input channel identifier, 39 clock counter data bits and 40 interpolating data bits. These TD-blocks are accumulated in the on-board FIFO memory until they are read as a package of pre-determined size by the ET-server, which is hosted on a PC. The ET-server processes the TD-blocks to obtain the time-tags for the corresponding 'start' and 'stop' channels. The ET-server additionally provides a TCP/IP connection for a client obtain the event epochs.

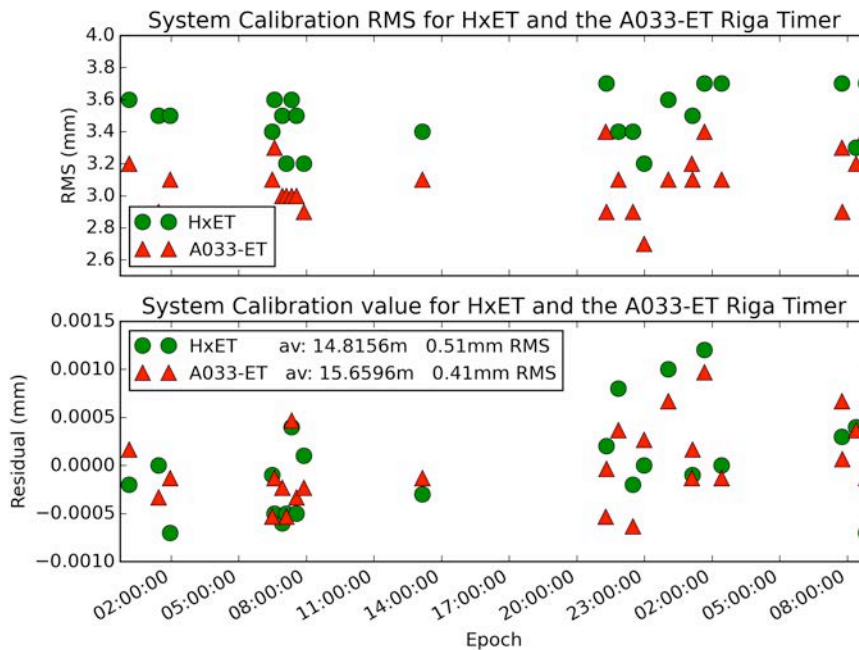
The A033-ET was integrated in to the Herstmonceux SLR system by providing a 1pps signal and a 10MHz signal from an active hydrogen maser (iMaser from [T4Science](http://www.t4science.com)) installed in the facility basement in January 2010. The 'start' and 'stop' signals were provided from same the discriminator board that provides the signals to the HxET timer. This enabled range measurements to be made simultaneously using both timers.

A TCP/IP client/server program was developed in-house to permanently connect to the A033-ET timer and to accept a connection from the SLR system to receive controlling messages at the beginning and end of satellite passes. During a pass, the program receives the TCP/IP data stream, forms the 1ps precision epochs, matches the laser fire 'starts' with the detector signal 'stops' using the predicted satellite range function and writes the epochs and ranges to a data file. This software is performing reliably and automatically records satellite and calibration range data as instructed by the SLR system.

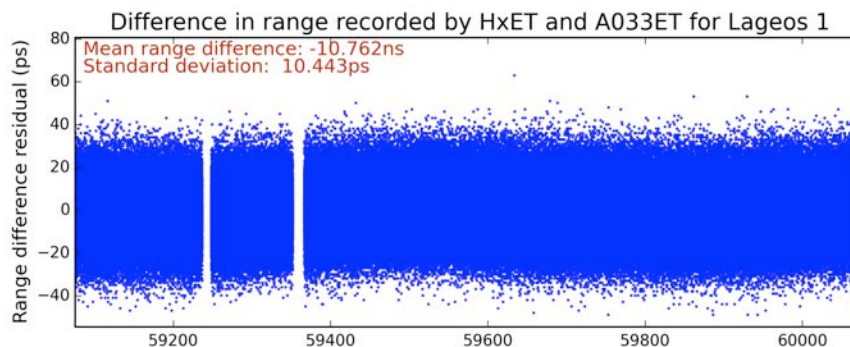
## Making Simultaneous Range Measurements

The SGF makes regular terrestrial range calibration measurements to a retro-reflecting flat panel target approximately 130 metres away. A typical calibration consists of about 1000 detected laser returns with a precision of less than 1mm. To make a comparison, calibration datasets were recorded from the same start and stop events by both the HxET and the A033-ET timers. These were then processed using a Gaussian fit to extract the measured range.

A mean measurement and a RMS value were recorded for each calibration and these are plotted below. The upper plot shows the calibration RMS recorded over a time period of about 35 hours for the HxET timer (green) and the A033-ET timer (red). The A033-ET repeatedly produces individual calibration data distributions with lower RMS, averaging at approximately 3.1mm compared to 3.5mm for HxET. The lower plot shows the corresponding calibration values, which are different due to the separate cables used for the timer inputs. The RMS of the measurements over time is less for the A033-ET at 0.41mm, compared to 0.51mm for HxET.



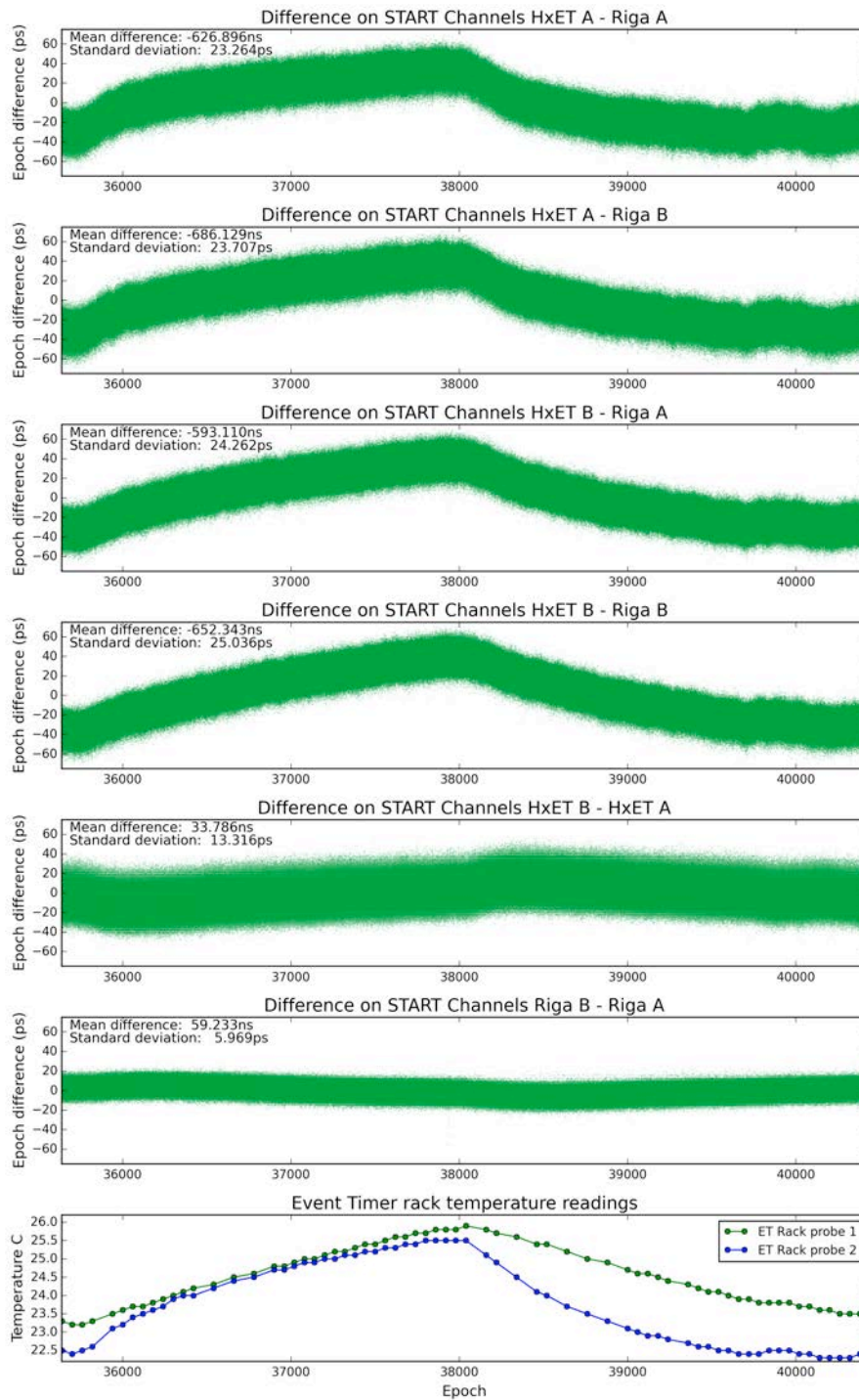
The epochs and ranges recorded by each timer in the separate data files were matched and compared for a number of calibrations and satellite passes. Below is typical plot of range difference recorded during a LAGEOS 1 observation. The plot shows an offset between the values but this is stable through the whole pass with an overall standard deviation calculated as 10.4ps. This shows good agreement between the timers, however the scatter is larger than would be expected from the timer specifications. Some long term drift was also apparent in these comparisons.



## 4-Channel Direct Comparison

To investigate this further, an experiment was setup to feed the laser 'start' pulse to the two channels of the HxET timer and to the two channels of the A033-ET timer. The differences between the channels are plotted below. Also in this experiment, the ambient temperature was increased by switching off the air conditioning,

which was later switched back on. The room temperature change was recorded by nearby temperature probes on the mounting rack.



The first 4 plots show the difference in the epochs recorded at a HxET channel and a A033-ET channel. All 4 show larger jitter and an increase and then decrease in the difference with the environmental temperature. The 5<sup>th</sup> plot show the difference between the two HxET channels and the 6<sup>th</sup> plot shows the difference between the A033-ET channels. The larger jitter is present only in the HxET plot, with the A033-ET performing to specification.

## Conclusion

The installation of the A033-ET timer has allowed, for the first time, the assessment of the performance of the operational HxET timer. It was shown to be performing well with a jitter of approximately 9ps. This is, however, greater than its specification. The temperature dependence of one of the timers is significant but

manageable in the temperature controlled environment in which both timers are kept. There may be an advantage if the Herstmonceux station were to switch to the A033-ET as its primary timing instrument for SLR.

## **References**

V. Bespal'ko, E. Boole, V. Vedin “*Event Timer A033-ET: Advancement and Performance Characteristics*”  
18<sup>th</sup> International Laser Ranging Workshop, Fujiyoshida, Japan 2013  
(<http://cdis.gsfc.nasa.gov/lw18/docs/papers/Session12/13-04-26-Boole.pdf>).