# NEW INTERNAL CALIBRATION TARGET AT SGF HERSTMONCEUX; DESIGN AND RESULTS

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Calibration is of course fundamental to realising the full potential accuracy of the satellite laser ranging technique. For several years, the SGF laser ranging system has used parallax-free targets at 100 and 400m distances for routine calibration and additionally for investigations into subtle distance-dependent effects in the Stanford counter cluster. However, the advantages of a close target include accurate environmental control, ease of access and, not least, availability during periods of poor weather. At SGF Herstmonceux we have designed and built a new calibration target fixed inside the laser telescope dome. This paper describes the mechanical features of the target, the difficulties encountered in arming the C-SPAD for such a close target and current investigations into observed small calibration differences between this new target and our existing long-range targets. We will attempt to show from experiments carried out on our additional moveable calibration target that this uncertainty in our measured calibration is caused by the behaviour at short range of the SR620 timers.

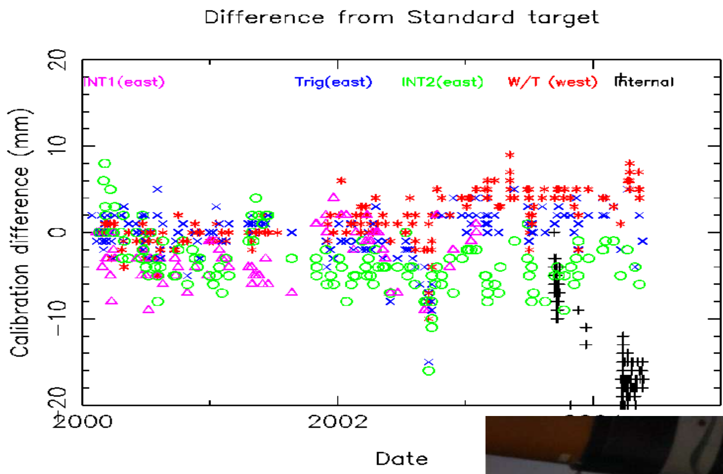
## Existing Targets

We have 5 targets at Herstmonceux. Two stainless steel retro reflectors to the west at a distance of ~120 metres, two stainless steel retro reflectors to the East at a distance of ~600 metres and one flat board target at ~600 metres – this was our original target. When we changed our detector from a PMT to SPAD system we had to change to one of our retro reflector targets, as we could not get enough data back through our telescope system onto the very small diode of the SPAD.

The flat board target, one of the east targets and our current calibration target in the west

were all included in the original site survey. A recent survey in 2003, which included all targets, gave agreement in the distances to the targets at the 3mm level.

We try to take calibration measurements to all our targets at least once a week and monitor the differences obtained when compared to our standard target. This is more to ensure that the targets/telescope are not drifting than to get a definitive value for calibration. We have been aware for some time that the SR620 can give us different results for these comparisons depending on what configurations we use.

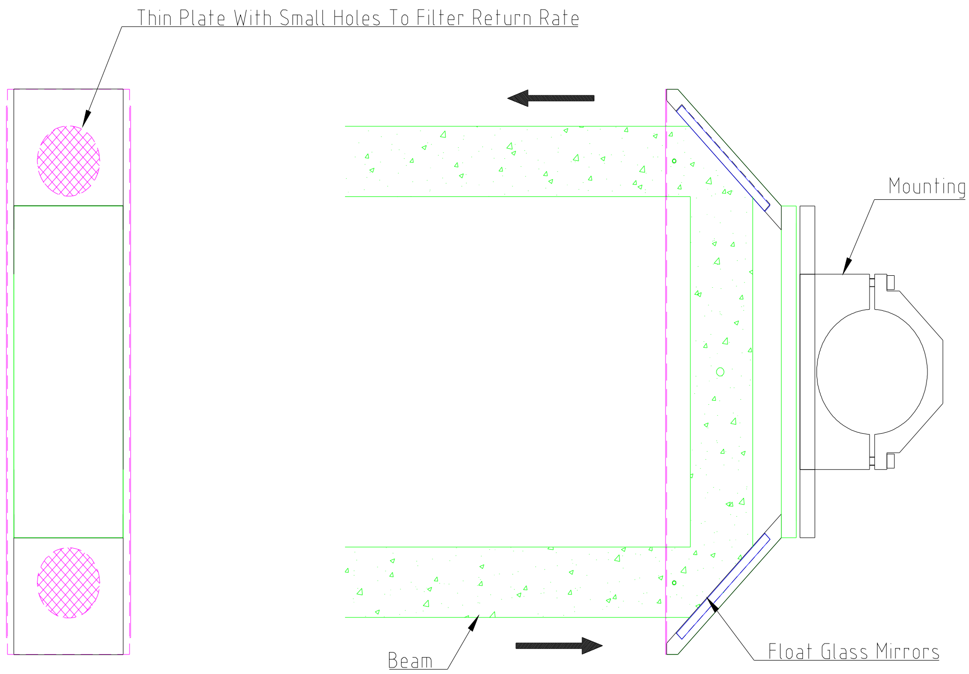



Shown here are the differences for all our targets compared with our current calibration target.
The difference for the internal target for 2004 clearly stands off. The pre-2004 internal target data used an unmeasured estimate of the distance from telescope to target.

## New Internal Target

Shown here is the new
Internal target. The “retros” are two mirrors with the reflective coating facing the telescope. A grating is situated in front of the mirrors to reduce the return rate.

Pictured below is the engineering diagram for the internal target.



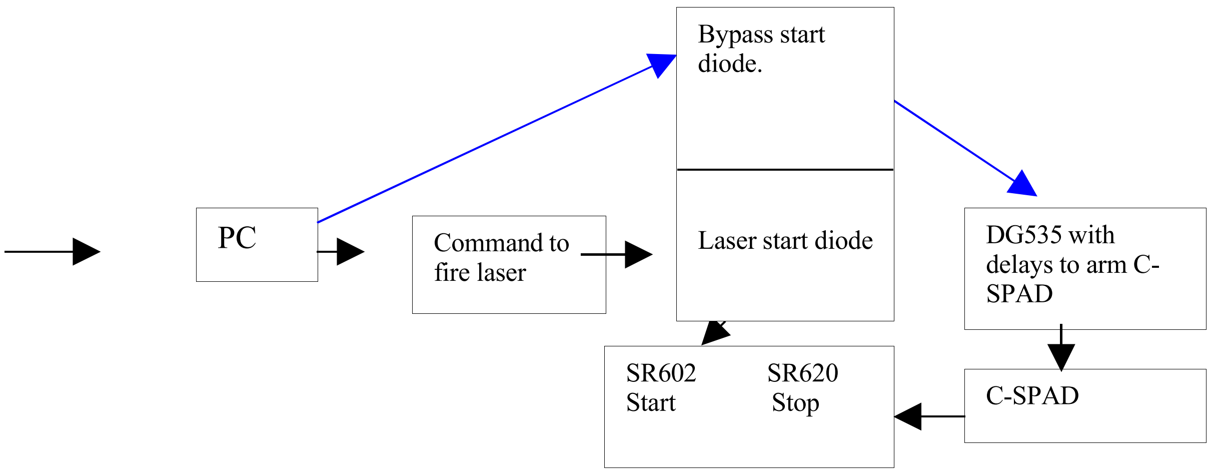

# Arming the C-SPAD

Because we have a C-SPAD detector we need to arm the device in time for the returning laser. The round trip time for the laser is ~110 ns. The minimum time for our arming route is ~400ns. This means we cannot arm the C-SPAD in the normal way. We measured the time taken from issuing a fire command and the actual time of firing and found an uncertainty of 10microseconds.
Therefore we tried to detect the build up of laser energy by placing a diode

i) behind the dye cell mirror
ii) near the wedge in laser cavity

The uncertainty in detection at both these points was large (>10microseconds).

Given that the uncertainty in detecting the laser early is as great as the variations in time delay when the request is sent from the PC we abandoned any attempt to detect the laser and just bypassed our normal arming system. This of course means the C-SPAD may be armed well before the true return from the target and the C-SPAD may easily be triggered by internal noise. This has to be taken into account when determining the return rate to keep the system at single photon.




## First Results

Now we can measure the distance from the target to the telescope axis, control C-SPAD arming and control return rate. We would therefore expect to get good agreement between our new target and existing targets at the few mm level. This turned out not to be the case.

Shown below are the results for our system, which has four SR620 timers, 2 connected to the uncompensated channel of the C-SPAD, 2 connected to the compensated channel. The results for the four timer/detector systems are made simultaneously and in theory should at least all agree.

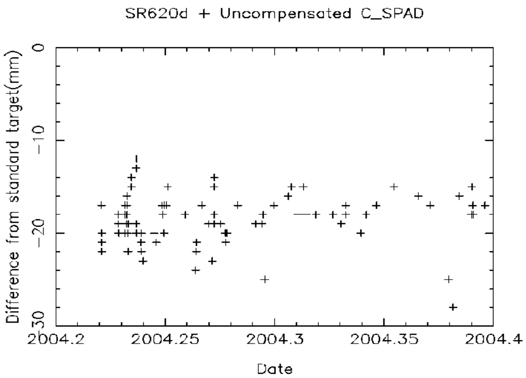
### Standard set-up
### Main Target – Internal Target

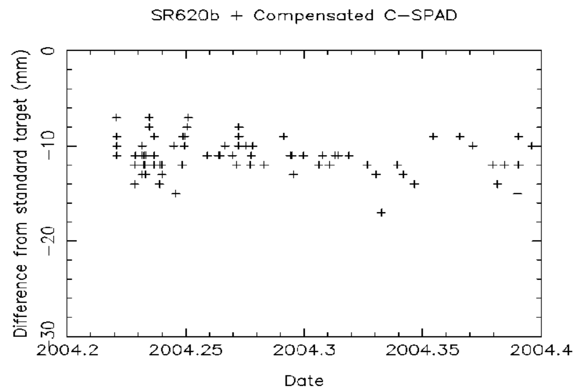
- Uncomp A 16mm D 17mm
- Comp B 9mm C 10mm

Given there seems to be a difference between the compensated and uncompensated systems we tried a couple of non-standard setups and connected all our SR620s firstly to the uncompensated channel of the C-SPAD and then to the compensated channel

### Non-standard setup

- Uncomp A 17mm B 15mm C 14mm D 18mm
- Comp A 16mm B 12mm C 12mm D 15mm




Shown above are the time series for both the SR620/Uncompensated and SR620/Compensated systems.

So whatever set-up we use we would appear to have a difference between our internal target and our standard target of 10-18mm.

## Possible sources of these differences

There are four possible sources of error that we can think of: - there may of course be others we haven't thought of

i) Survey measurements or measurement to Internal target wrong – this we do not believe is the case due to the site survey of 2003
ii) Uncontrolled single photon rate
iii) Decay in C-SPAD due to early arming
iv)Timer non-linearity

## i)Survey measurement

The survey of 2003 would seem to confirm to distances to the external targets and we are convinced we have measured the distance to the internal target correctly

## ii) Uncontrolled Single Photon Rate

The shown previously above were taken at very close to 0% return rate. If it was a return rate problem it should only show in the uncompensated channel. Even if there is a variable rate problem, the compensated data would indicate there is still a discrepancy of order 10-12mm

## iii) Decay in C-SPAD due to early arming

We know there are errors if you do not arm the C-SPAD adequately in advance. The requirements are

–Uncompensated 50ns - if not errors can be up to 15mm
– Compensated 100ns - if not errors can be up to 40mm.

For the internal target we arm the C-SPAD very early (up to 10microseconds).

–Can this cause a problem?

To check this we ranged to our 600 Metre target and armed C-SPAD between 100ns to 4000ns early.

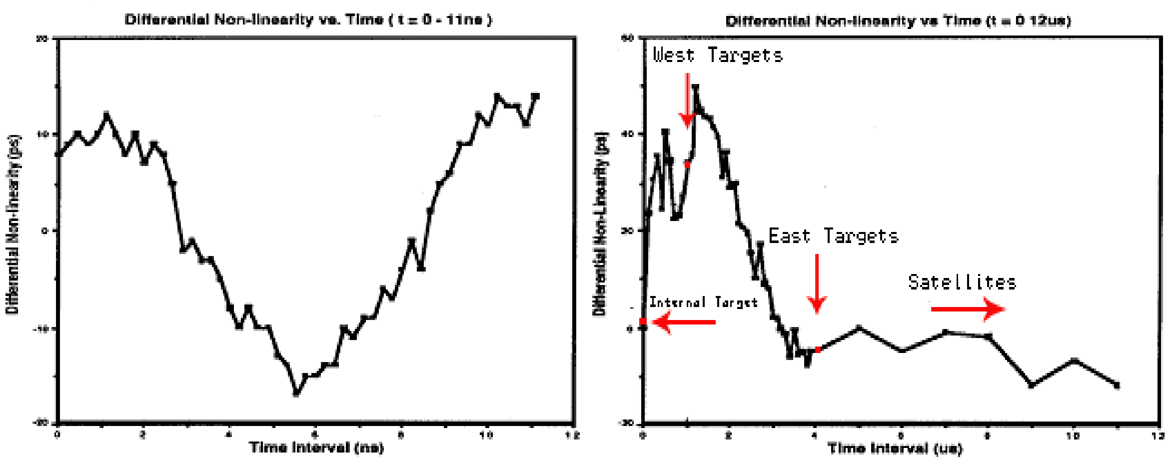
The calibration values varied only at the 1mm level.

We are therefore happy that it is not an arming problem with the C-SPAD.

## iv) SR620 timer non-linearity

The SR620 manual describes two differential non-linearities with plots shown below.

Specification Guide




Graph 1: Differential Non-linearity for time differences of 0 to 11 ns. This shows the residual non-linearity of the time-to-amplitude converters.

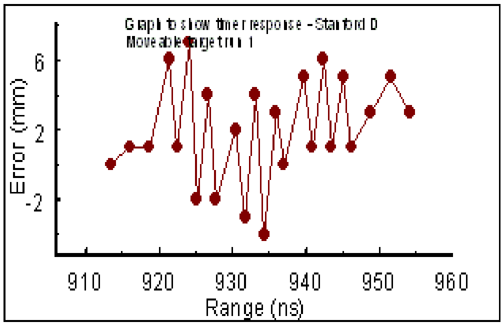
Graph 2: Differential Non-linearity for time differences of 0 to 11µs.

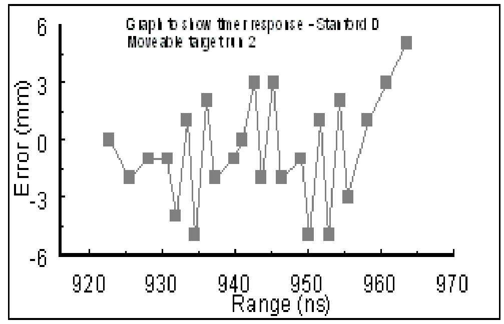
To try and investigate the first of these non-linearities over the 11ns (90KHz) range we constructed a moveable target. The target was mounted on a rail to be moved known distances. The rail allows movement of 2 metres (4 metres round trip, >11ns).

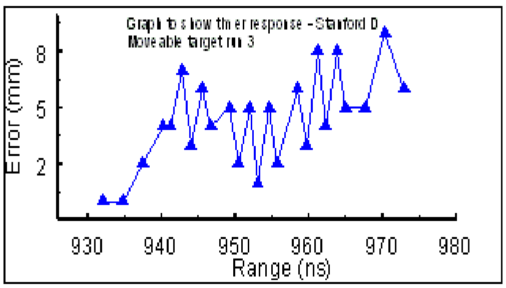
Calibration measurements were taken at given distances along the rail. Using the semi-train enables data sets of some 40ns for our tests. Adding cables to the start/stop train can also shorten or lengthen the measured range. For a truly linear system we would expect a change in calibration equivalent to the movement of the target.

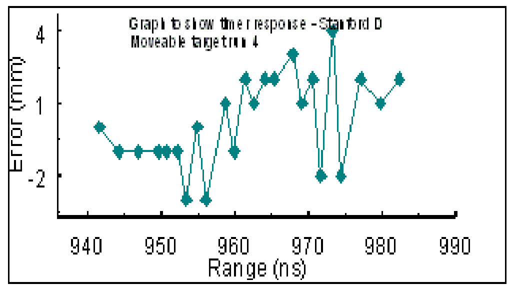
In the graphs shown below a ‘run’ is determined as one set of measurements across the 2m rail, successive runs indicate the addition of cable lengths. Due to these cable lengths the start point for each run can be said to be arbitrary.

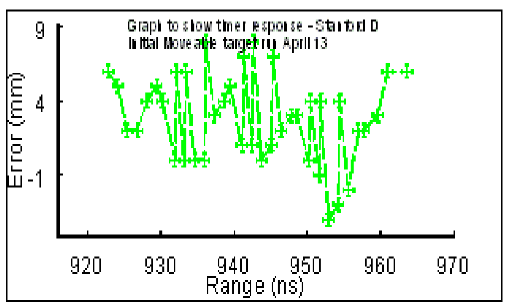
Shown below are the results for each of our Stanford Timers, labelled A-D, D is taken first as it is currently used for our ranging measurements.



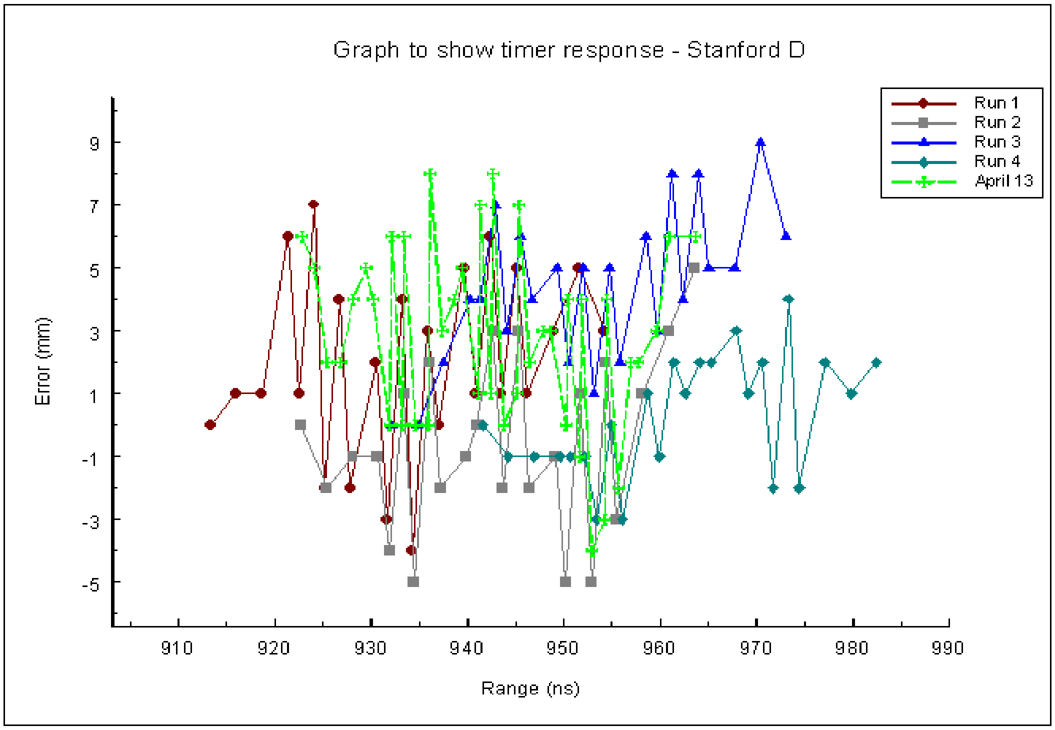



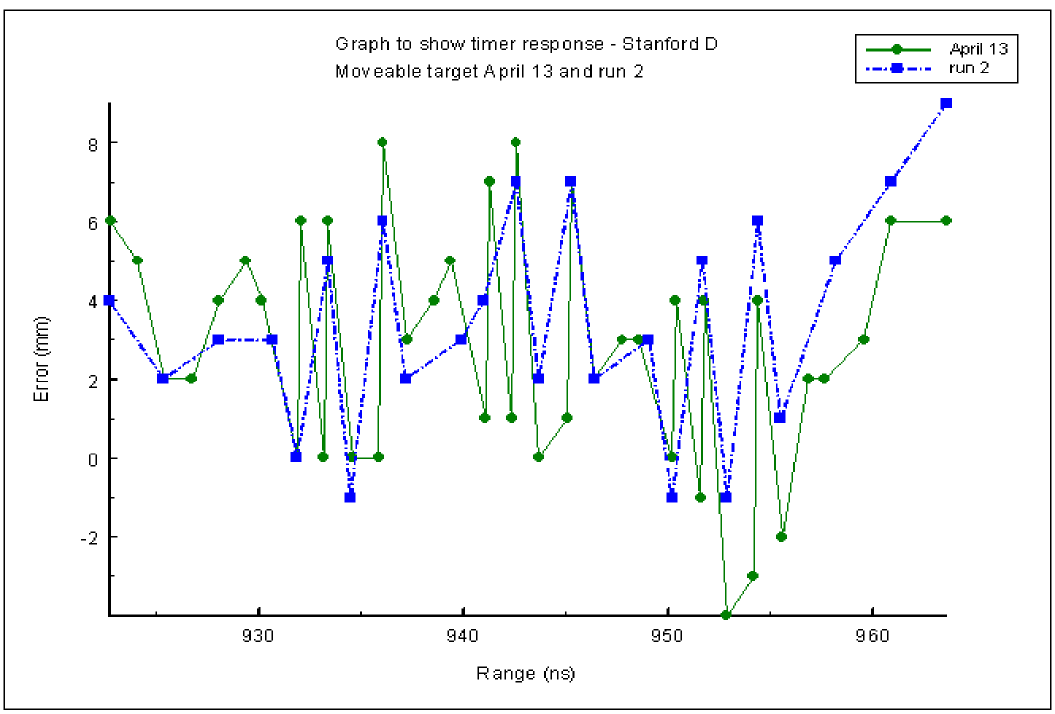




The above show a possible deviation of ± 6mm from the ideal of zero.

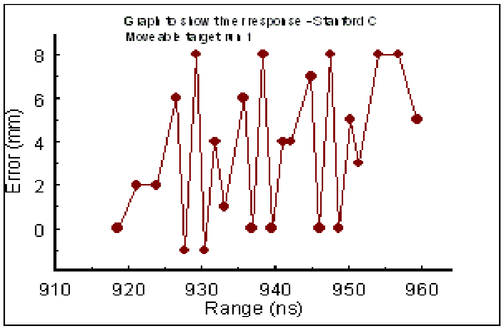
To better understand any trends which may appear on the above, the graph data was overlaid to produce one graph. This is somewhat messy however but we believe behaviour trends are shown. This can be more clearly seen by the second graph shown below.

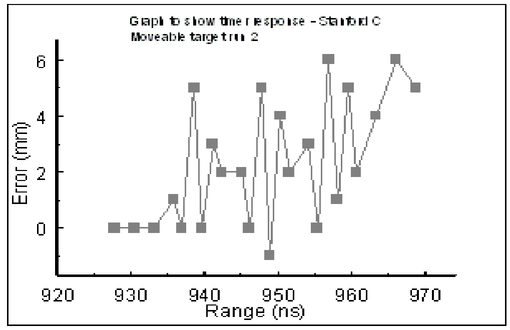


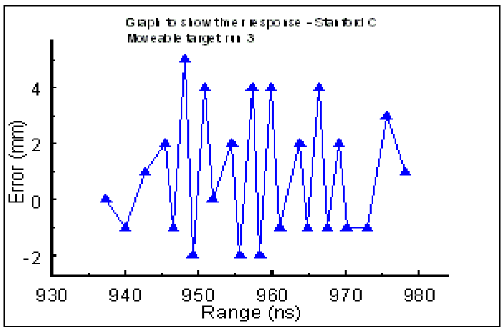

Throughout the distance range shown on the graph below behavioural trends can be seen. At nearly every point where data has been obtained for the same range, the behaviour of the two data sets agree.

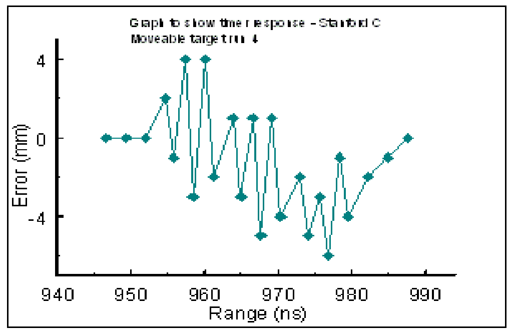



Timer C

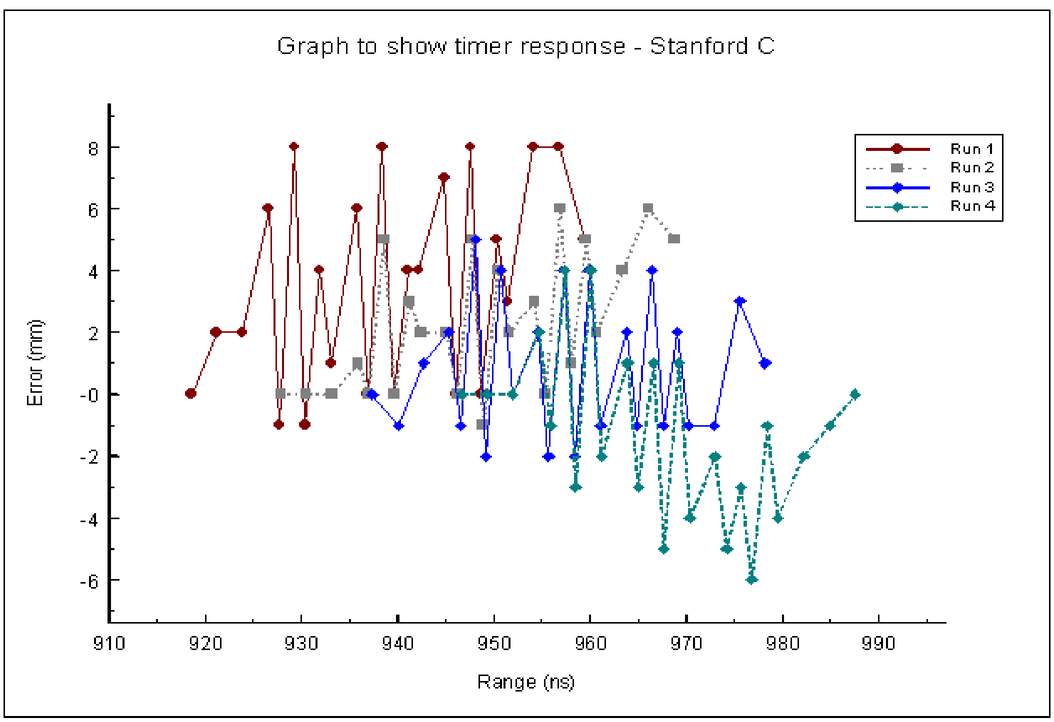


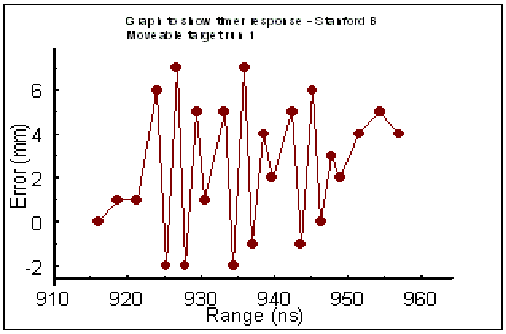



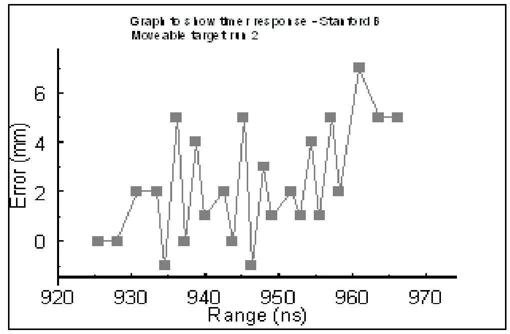



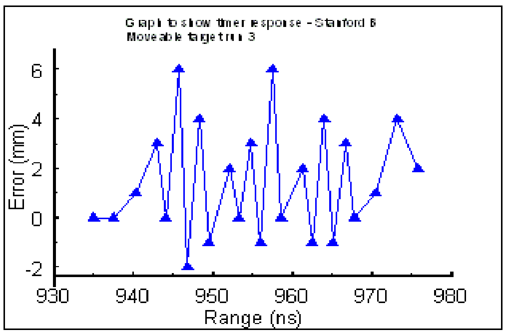

The behaviour for Timer C in the range 950ns – 970ns is clearly shown to exhibit similar characteristics for the different runs with runs 3 and 4 showing very similar response.

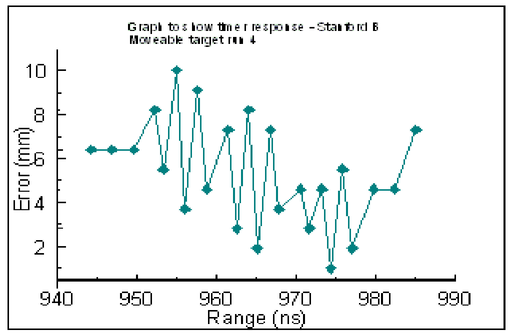


Timer B

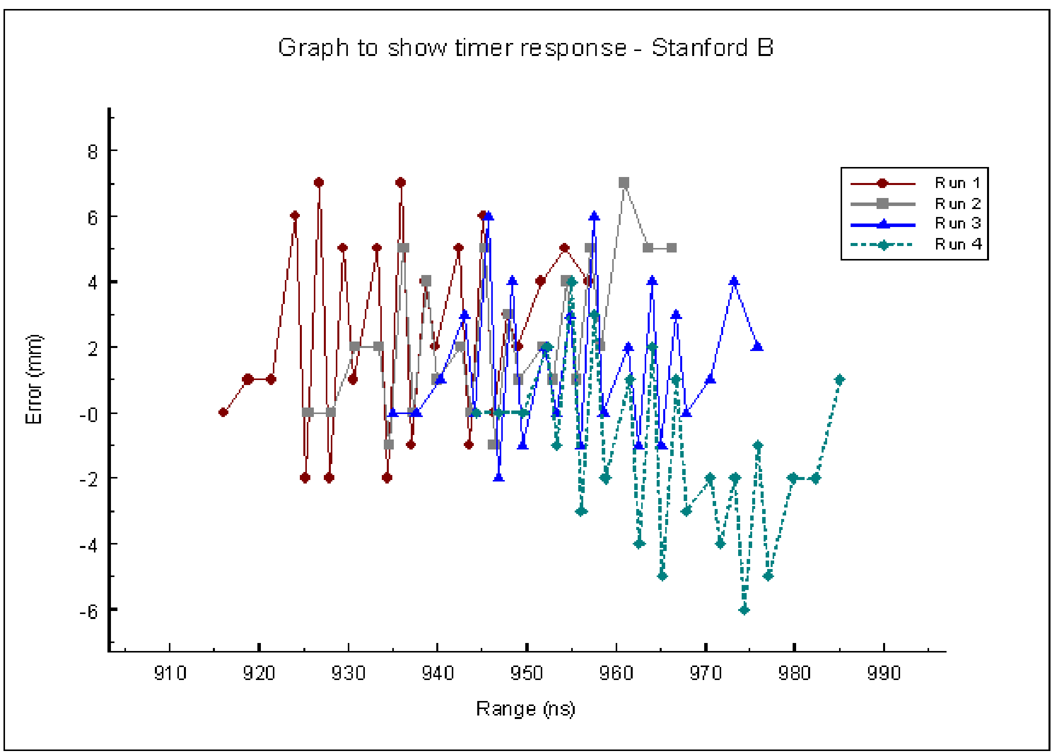


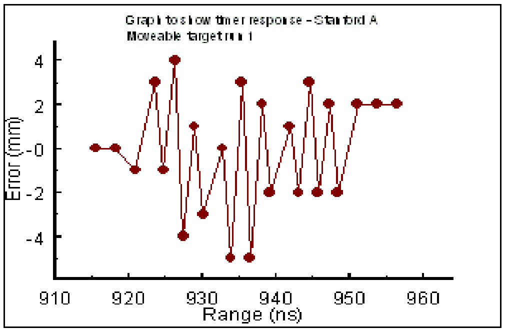



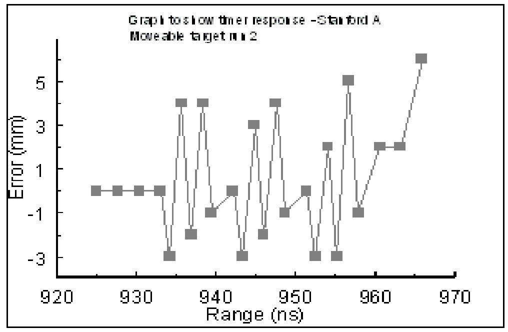



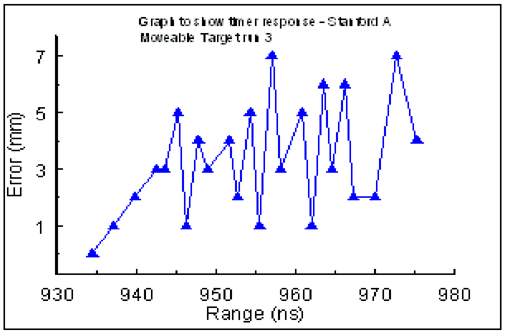

Again for the range from 950ns – 970ns the similarities in behaviour of the data is apparent.

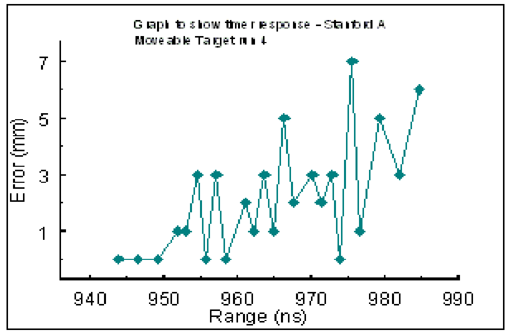



Timer A

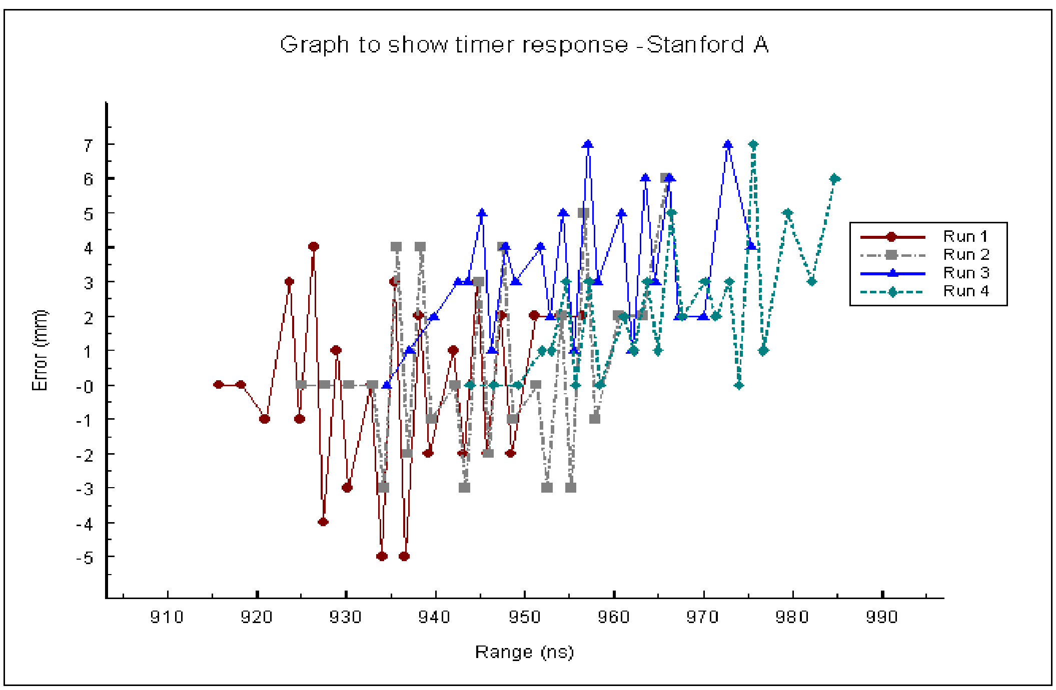


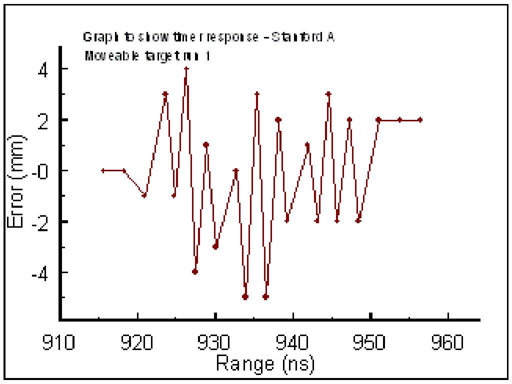



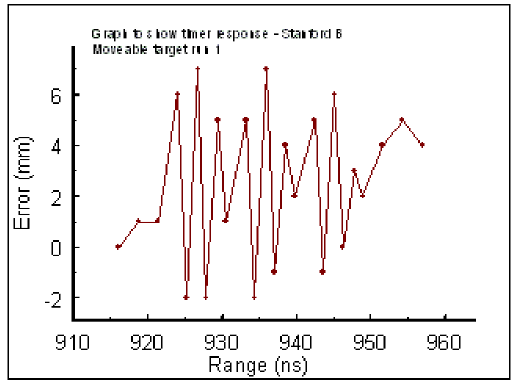

Timer A appears to exhibit slightly different characteristics than the other three timers, the trend in this case being an increasing bias to the positive as the range increases. However behaviour trends, whilst not as apparent as the other timers, are still seen.

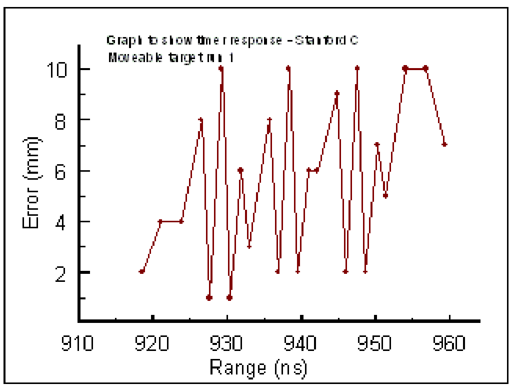


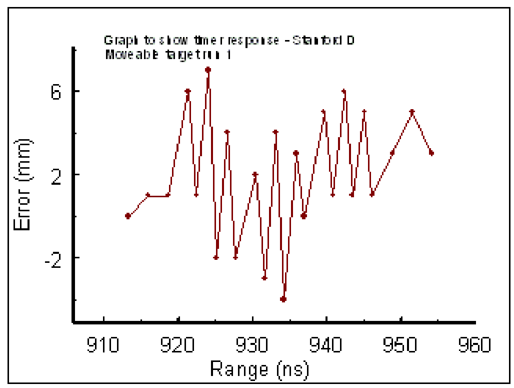

Timers A – D run 1

For the first run (from ~905ns - ~960ns) data from each timer is shown below to highlight the very different behaviour of each timer.




Conclusion

It has been seen that each timer displays a different characteristic response but this response is repeatable if the same ranges are used. It would appear each Stanford timer displays an inherent characteristic and surmised that due to the nature of the electronics the behaviour would not be identical for each device. However we do not believe the 11ns characteristic as given in the Stanford manual is apparent for any of the four Stanford Timers. In fact we see a much greater scatter on any 11ns period shown.

These tests are in an early stage and will probably only be concluded with the advent of future comparisons at Herstmonceux with an Event Timer.

The End....

Well nearly