

A reassessment of laser ranging accuracy at SGF Herstmonceux, UK

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Outline of work

- A ps-level event timer (HET) has been built in-house from *Thales* clock units;
- A prerequisite for the upcoming kHz operations.

- Extensive use of HET to calibrate existing cluster of *Stanford* counters prior to routine use of HET;
- In particular back-calibrate Hx data 1994-present.
- Look at effect on range accuracy and station height in ITRF2000/05.

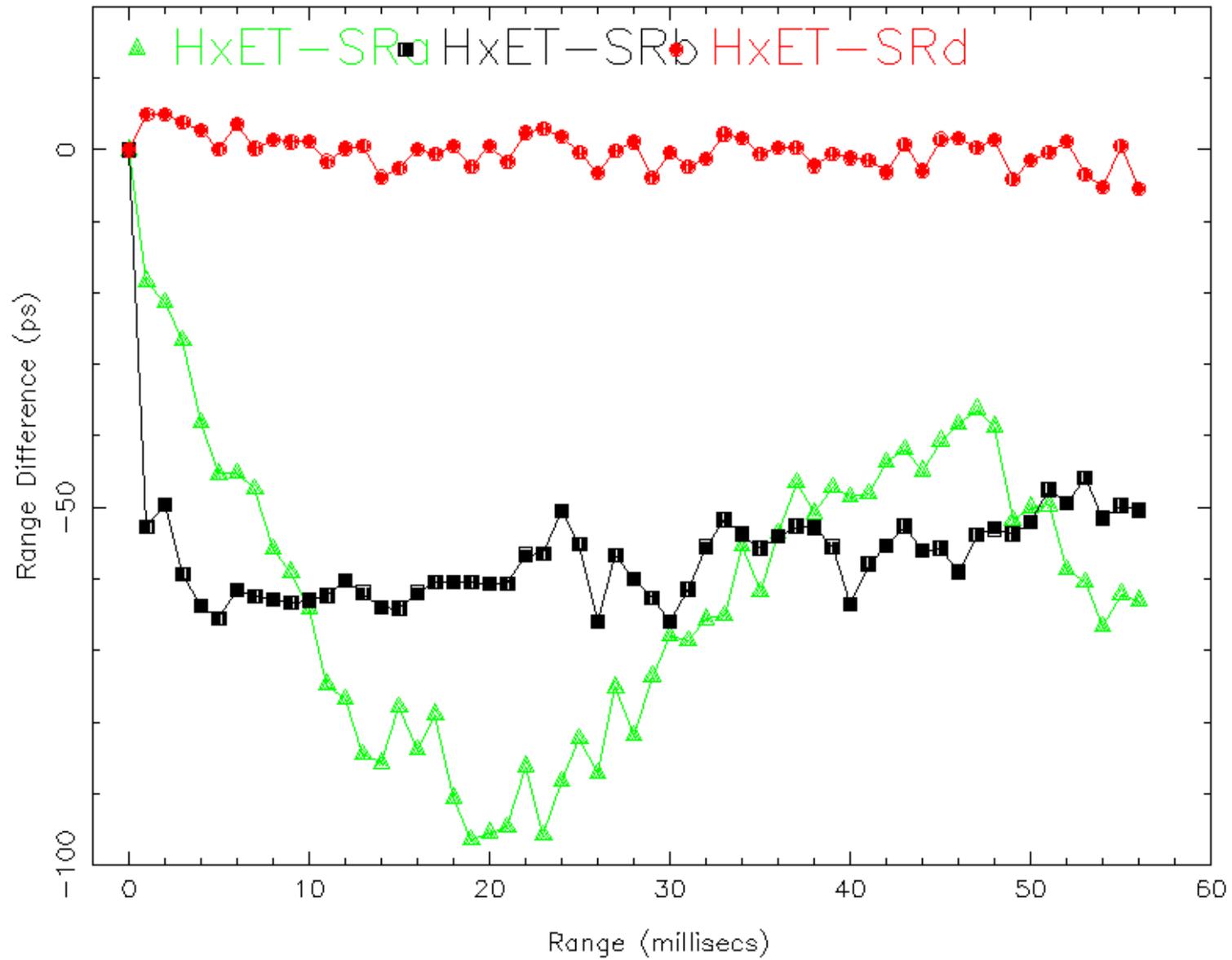
Previously

- Extensive tests on linearity of the Stanfords at satellite ranges (few to 150ms) were carried out by Gibbs (1999, 2001) using the PPET (Prochazka 1999, 2006).
- Correction table as function of range compiled and issued in SLRMail 0891 January 2002 – effective dates 1994 Oct – 2002 Jan.
- From 2002 February the corrections (~8mm) are applied at the station.

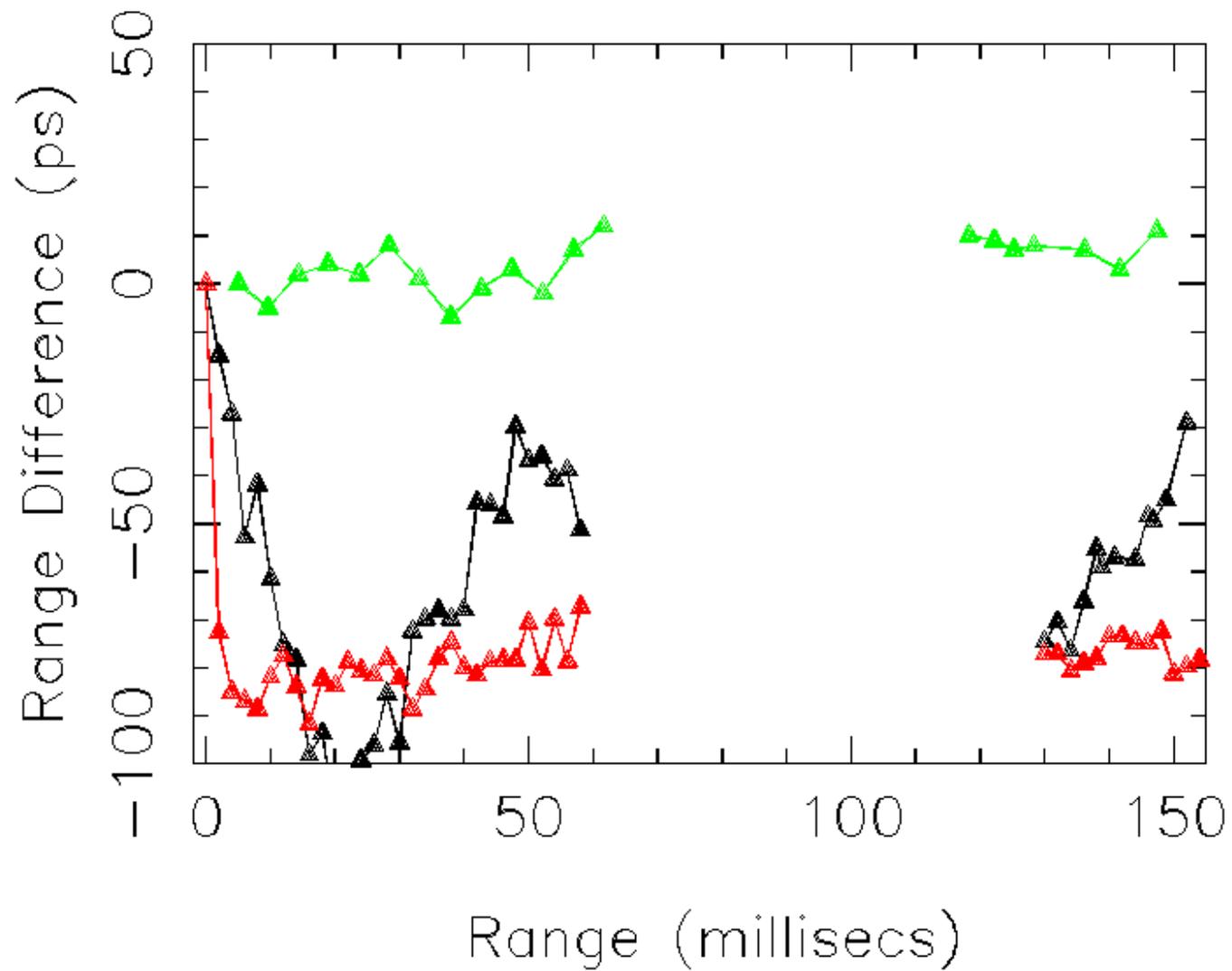
Confirmation of these corrections

- The original tests using PPET were repeated using HET during 2006 September.
- Stanfords seen to exhibit unchanged characteristics at few-150ms range.
- No need to revise correction table.

Comparison between Hx ET and SRa,SRb & SRd



Comparisons between SRd and SRa,SRb and PPET

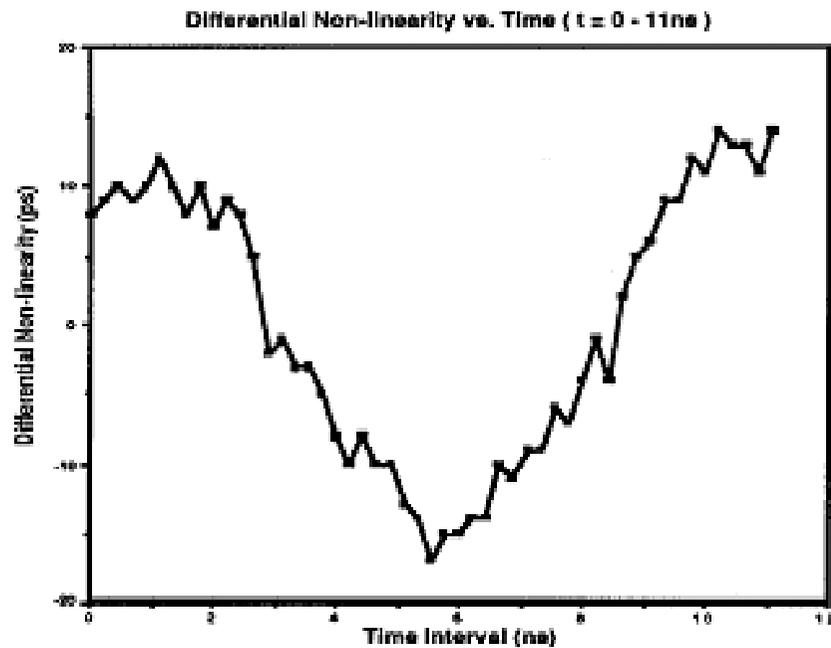


Further corrections, 2006 September

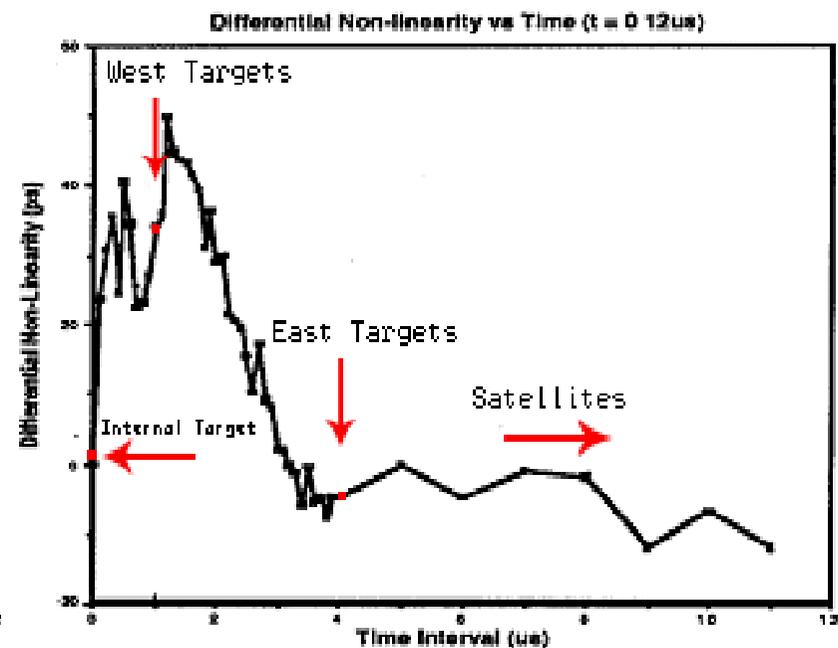
- Availability of HET cf borrowed PPET means more extensive tests could be attempted;
- In particular, interested in characteristics of Stanfords over short (few micro-sec) ranges;
- Effects here will corrupt calibration-board ranging and thus all satellite ranges equally.

From the Stanford manual

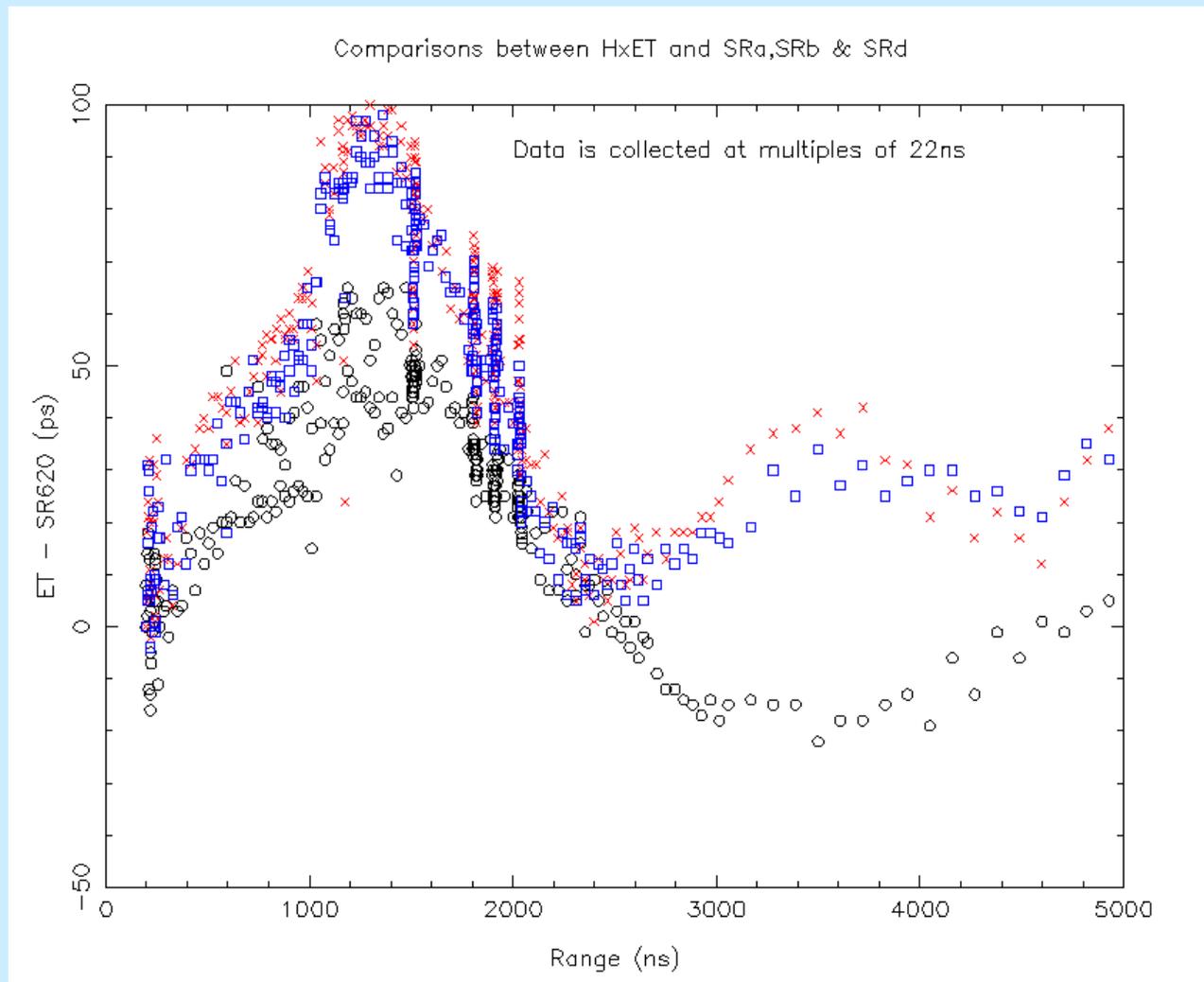
Specification Guide



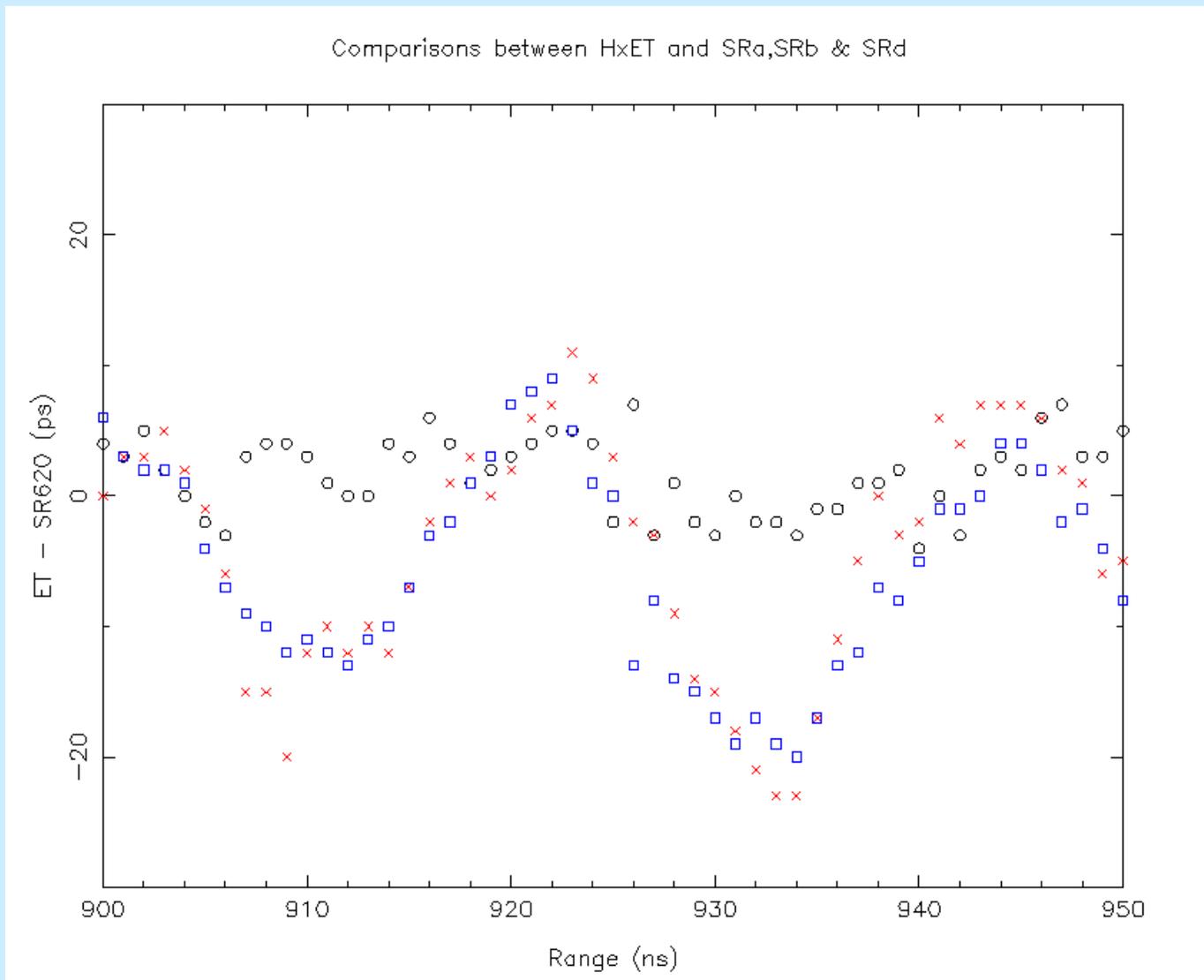
Graph 1: Differential Non-linearity for time differences of 0 to 11 ns. This shows the residual non-linearity of the time-to-amplitude converters.



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



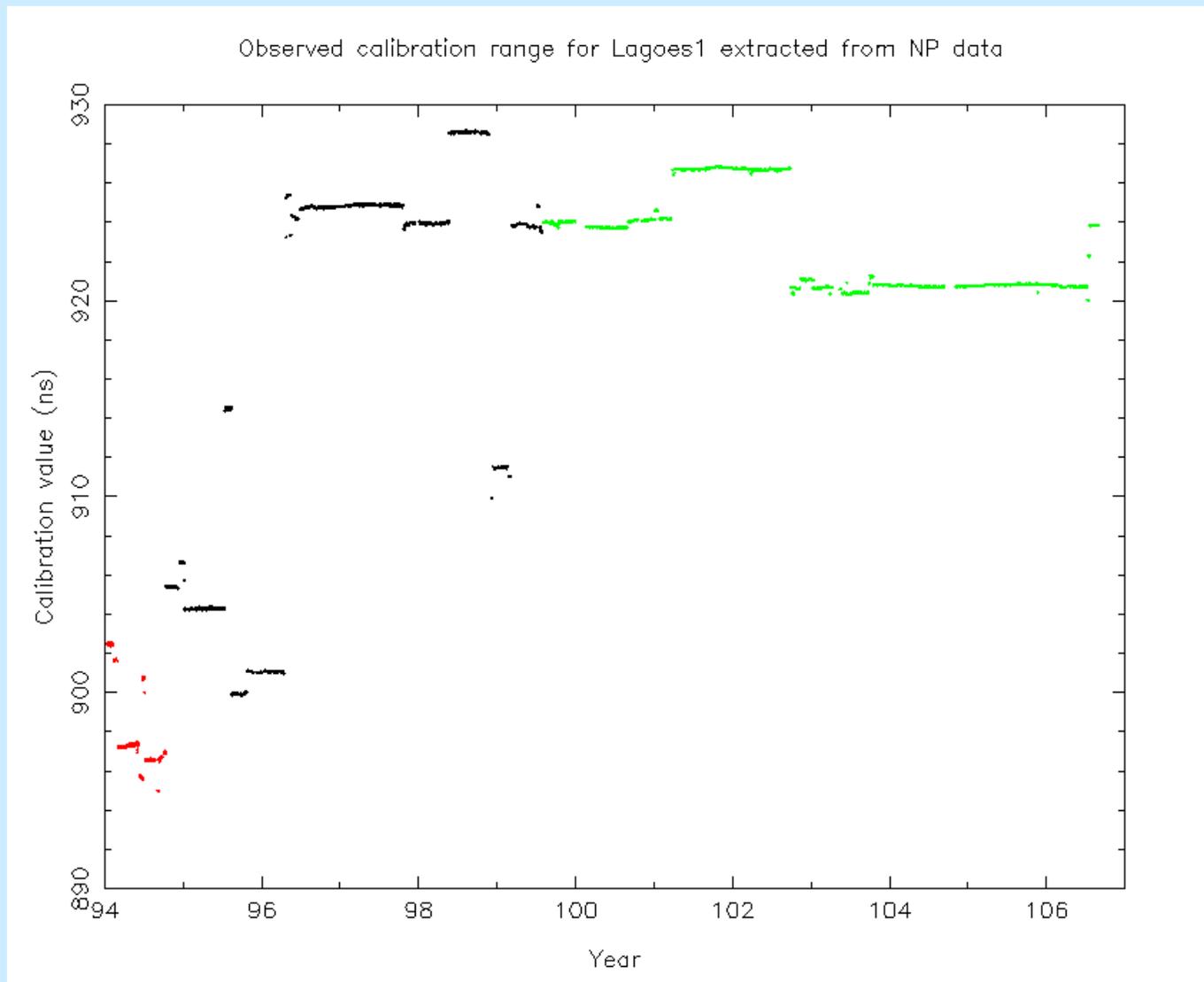
Tests run between HET and the Stanfords at 0-5000ns range
(calibration boards' distances);
Behaviour very similar to spec;
Errors up to 100ps, with some systematic detailed structure:



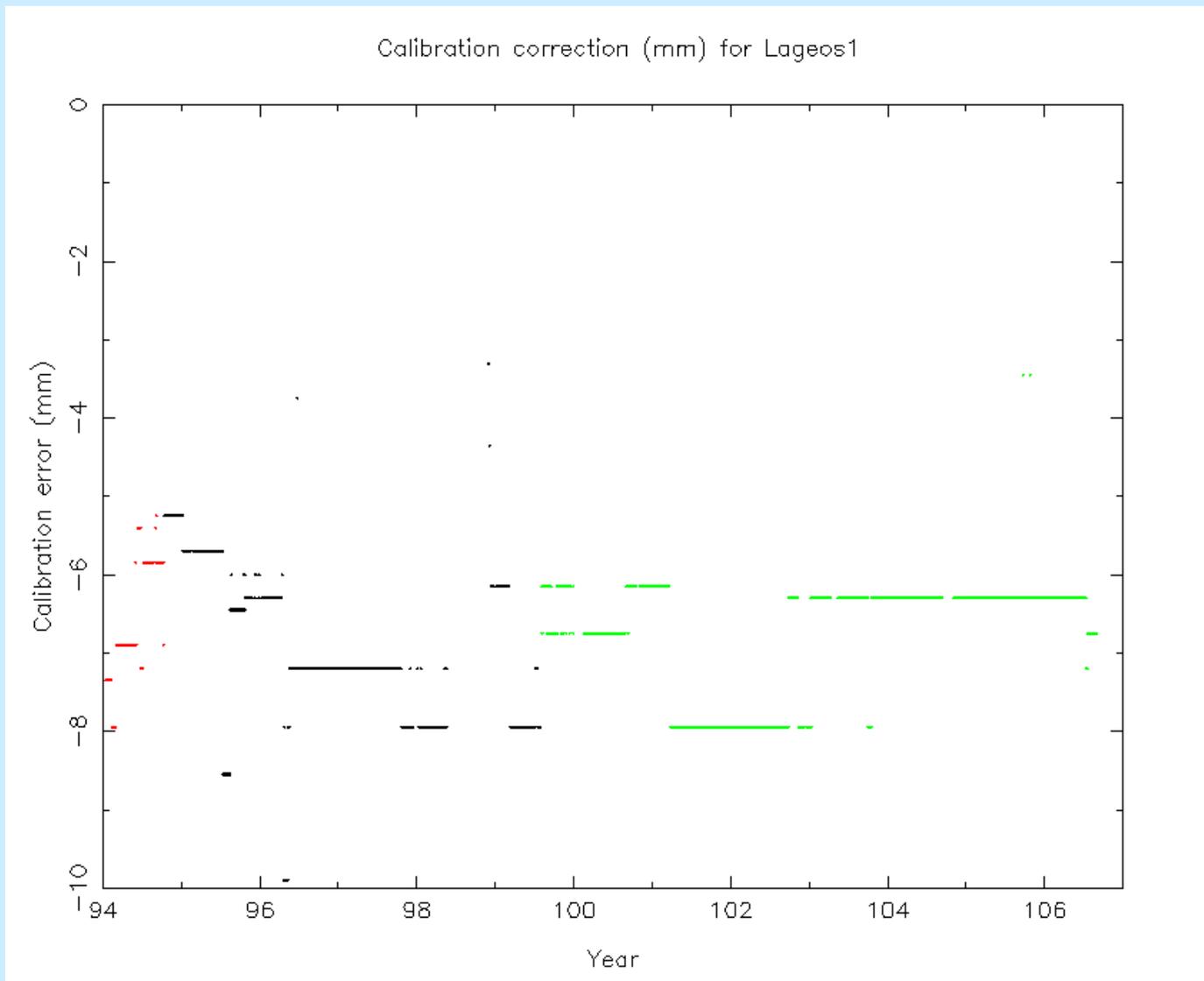
22ns periodic effects found (cf 11ns expected from spec)
Amplitudes up to 20ps (~3mm)

Summary of effect on calibrations

- At the effective range of the primary calibration target (890-930ps, dependent on electronic set-up), the non-linearity of the Stanfords:
 - imparts an average of ~ 50 ps error into the observed range;
 - Value is dependent on the range itself
 - Uncertainty in value is ~ 20 ps due to 22ns periodicity.



Actual calibration range (ns) used for 1994 – 2006.



Correction to calibration values (mm) 1994 - 2006

Effect on satellite ranges 1994 - 2006

From this work, the calibration values applied to all satellite ranges are

7 ± 2 mm too large on average over the period

We take the opportunity to correct for a filter inserted in the optical path during calibration but not during satellite ranging:-

- implies observed calibration ranges are 1.5 mm too large.

So calibrated satellite ranges are **8.5 ± 2 mm too short**

- **Would expect ~ 8mm negative range bias**

Detection of bias in LAGEOS' analyses?

The centre-of-mass correction for LAGEOS for 7840 Herstmonceux single-photon data is $245 \pm 1\text{mm}$ (Otsubo and Appleby, 2003);

In computing ITRF2000, the ACs used the 'standard' 251mm CoM for all stations, thus effectively increasing Herstmonceux ranges by 6mm and nearly cancelling the bias of -8.5mm present since 1994.

Thus coordinates (height) in ITRF2000 should have only a small bias:

The mean of 7840 LAGEOS 1/2 residuals in SGF daily QC using ITRF2000 is currently $-11 \pm 2\text{mm}$, so coordinates have not absorbed the range error and the full RB is apparent.

(see http://nercslr.nmt.ac.uk/slrweb/latest_longarc.html)

Detection of bias in LAGEOS' analyses?

- From an analysis of LAGEOS 1/2 data 1992-2006, J Ries (personal communication, April 2006) finds RB of minus 10-12mm and a height change of ~7mm
- From an analysis of LAGEOS 1/2 data 2001-2005, Otsubo, Appleby, Gotoh and Kubooka (EGU 2006) find 7840 RB of -9mm.
- For Etalon data, the above Otsubo *et al* authors find a similar RB.

Detection of bias in LAGEOS' analyses?

For the ILRS combined product included in ITRF2005, the individual ACs used the correct value of 245mm for 7840 LAGEOS CoM, and did not solve for a bias for this station (AWG resolution at ILRS Fall Meeting Eastbourne 2005).

Thus station (height) will be in error in ITRF2005 ?

We apply the +8.5 mm range correction to LAGEOS 1/2 data for 2004;

Our solution for station coordinates **and** RB gives an average:

- RB = $+1 \pm 2$ mm;
- $\Delta H = -5 \pm 1$ mm,

Implying that station height in ITRF2005 has absorbed half the RB and is in error by +5mm.

Conclusion

- All range data from 7840 Hx will soon be determined using HET;
- An SLRMail will announce the date and confirm that 8.5 mm should be added to all 7840 satellite ranges from 1994 – that date;
- The station height in ITRF2005 is 5mm too large;
- We regret this long-term error and encourage other users of Stanford counters to investigate possible similar effects in their data.