

Portable Calibration Standard Capabilities

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The principal idea behind the Portable Calibration Standard (PCS) is the high degree of redundancy in a measuring hardware, data analysis software and operational procedures. Using an independent measuring instrument or procedure, the possible error source may be identified. Additional error sources may be identified with the help of PCS using additional procedures not used in a routine SLR operation. The survey accuracy may be verified by ranging to several ground targets and evaluating the corresponding system internal delay. The error induced by the correlated radio frequency noise may be estimated by ranging to ground targets at different distances. The PCS is capable to identify most of the systematic error sources introduced by the ranging machine

The first generation Portable Calibration Standard [1] has been based on the Stanford Research Time Interval counter SR620. Two PCS units have been operated in Japan and China as a part of the Western Pacific Laser Tracking Project. The second generation PCS is based on the Pico Event Timer (P-PET) device [2].

The PCS missions to totally 9 satellite laser ranging stations have been completed within the last five years. The problems in operation procedures, local time base, calibration targets configurations, ground survey, meteo sensors and data processing have been identified [3]. The calibration mission to the SLR Herstmonceux, UK provided a detailed analysis of the time interval counters used for ranging, namely the time interval linearity and its range dependence, the time and temperature stability.

The Portable Calibration Standard based on the Pico Event Timer is a powerful diagnostics tool capable to reveal most of the systematic errors of the satellite laser ranging machine. The excellent performance of the Pico Event Timer in terms of time resolution, linearity and stability permits to use it as a reliable calibrator of timing devices used on the satellite laser ranging sites. The compactness and operational simplicity of the entire Portable Calibration Standard enable its fast re-location and installation on various satellite laser ranging sites.

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References:

1. I.Prochazka, K.Hamal, H.Kunimori, B.Greene, "Portable SLR calibration standard", *Proceedings of the 10th International Workshop on Laser Ranging Instrumentation*, Shanghai, China, November 1996
2. K.Hamal, I.Prochazka, *Picosecond event timer for millimeter laser ranging*, *Annales Geophysicae Suppl.*, Vol.16, 1998
3. K.Hamal, I.Procházka, J.Blazej, *Contribution of the picosecond event timer to the satellite laser station performance improvement*, 1999, SPIE 3865-05, ISBN 0-8194- 3460-4

Goals

- Creating the tool for SLR systems inter-comparison and standardization
- Satellite Laser Ranging machine diagnostics, identification of error sources due to :
 - epoch and time interval timing
 - epoch and frequency reference
 - data acquisition, filtering and processing
 - calibration scheme and ground survey
 - operational procedures
 - radio frequency interference
 - other sources (?)

Philosophy

- high degree of **redundancy**
- based on top **quality and certified** hardware
- **independent** on SLR under test
 - signal processing and cabling
 - grounding, power line, RF shielding
 - timing (time interval, epoch)
 - calibration targets and ground survey
 - data acquisition and data processing
 - staff
- operated **in parallel to existing SLR**
- **easy to re-locate** (personal luggage)

Portable Calibration Standard for SLR Capabilities

Block Scheme

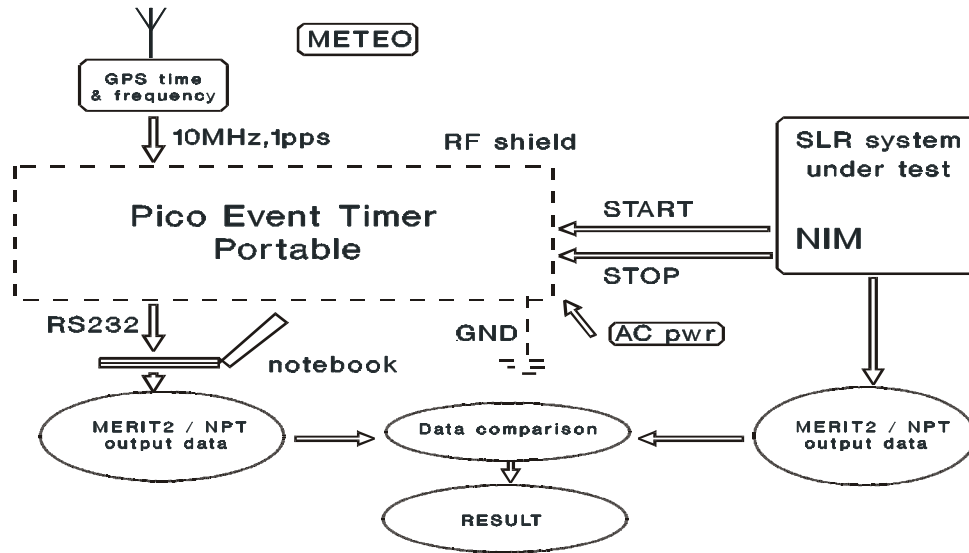


Figure 1: Portable Calibration Standard block scheme

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Portable Calibration Standard for SLR Capabilities

Pico Event Timer Portable Calibration Standard



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Portable Calibration Standard for SLR Capabilities

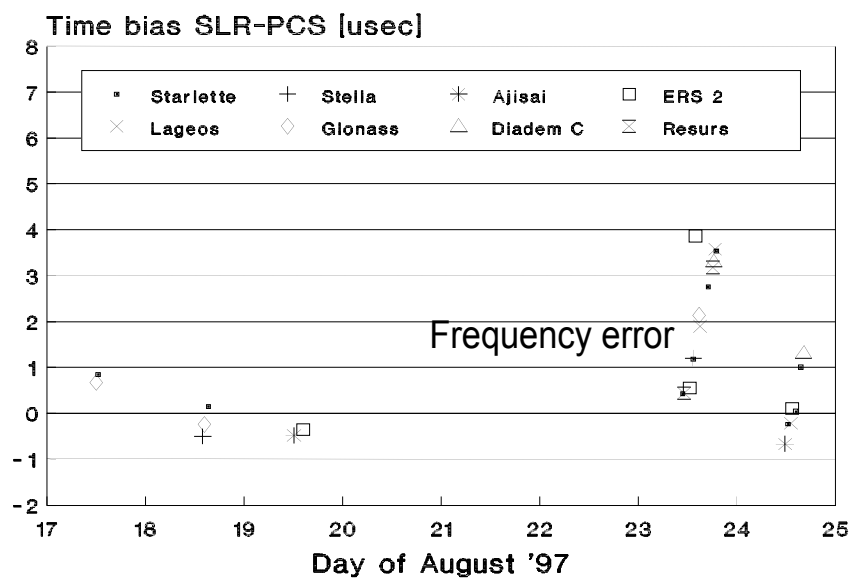
PCS Capabilities - Comparison

Systematic error source	collocation	Portable Calibration Standard
frequency and epoch	yes	yes
mount eccentricity	yes	partially
correlated RF noise	yes	partially
instrumental errors	yes	yes
stability	yes	yes
echo signal strength	yes	yes
data processing	yes	yes
operator errors	yes	yes
shot by shot comparison	no	yes
atmospheric data	yes	yes
experiment complexity and costs	> 10	1
time frame	> 10	1

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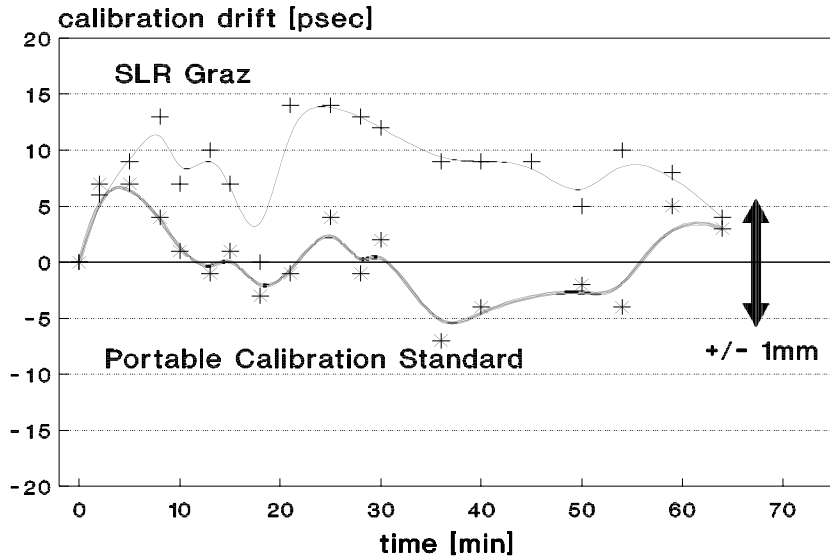
PCS (1G) in Changchun, Time Bias



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P-PET in Graz, Calibration Stability

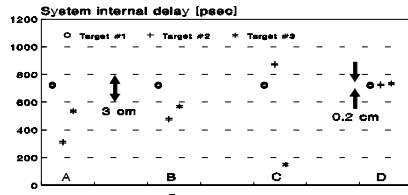


Kirchner,Koldl,Hamal,Prochazka,Graz 97

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Ground target calibration / survey P-PET at SLR Shanghai



Survey sequence

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Portable Calibration Standard for SLR Capabilities

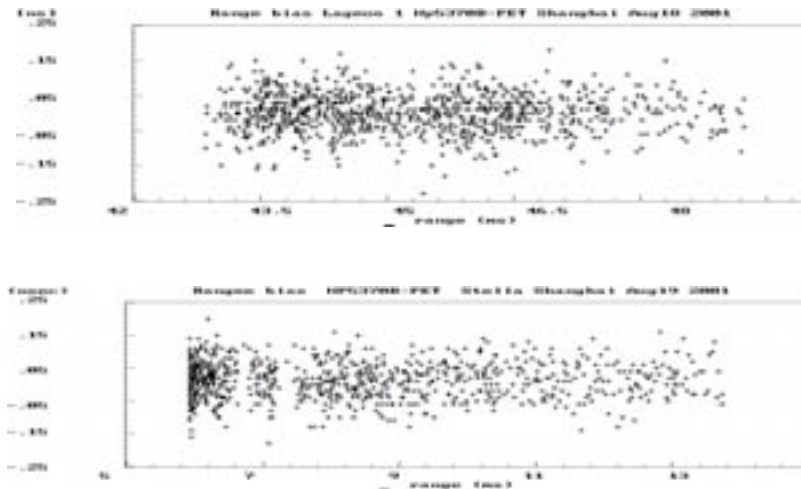
P-PET Results Summary, Shanghai 2001

Satellite	P-PET rms (mm)	SLR rms (mm)	Time bias (us)	Rng. bias (ns)
Starlette	7.5	12.7	0.1	0.02
Beacon-C	9.3	13.8	0.1	0.00
Ajisai	10.9	15.9	0.1	0.00
Lageos 2	10.5	17.3	0.1	-0.01
Starlette	9.0	15.1	0.1	0.03
Lageos 1	8.5	14.2	0.1	0.01
Beacon C	19.2	19.7	0.1	0.02
Topex	22.4	35	0.1	0.00
Topex	4.9	10.8	0.1	0.00
Lageos 1	7.0	13.5	0.1	0.00
Stella	6.1	12.4	0.1	0.00
Beacon C	10.0	16.1	0.1	0.00
Starlette	8.4	12.9	0.1	0.01
Westpac	--	16.6	0.1	0.03
Lageos 2	8.5	16.1	0.1	0.00
Stella	4.8	11.5	0.1	0.00
ERS-2	4.0	10.5	0.1	0.01
mean			0.1	0.01

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HP5370B / P-PET Counter Linearity Shanghai, 2001, Lageos (up), Starlette



No significant dependence identified

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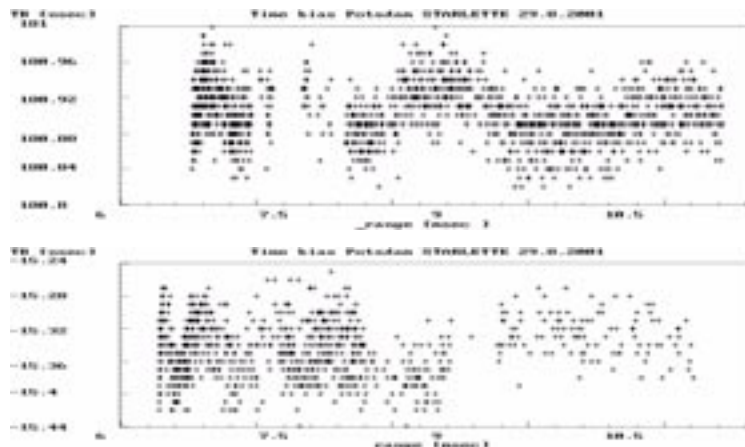
P-PET at Shanghai 2001, Conclusion

- SLR rms reduction down to 4.0 and 8 mm from original 10 and 14 mm for ERS-2 and Lageos, respectively, 2.5 sigma rejection
- time and range biases below the resolution limit 0.1 usec and 2 mm respectively
- three ground targets calibration consistency within +/- 2mm (final set-up)
- routine SLR calibration procedure problem identified and solved

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SR620 / P-PET Counter Linearity Potsdam, 29.8.2001, Starlette satellite passes



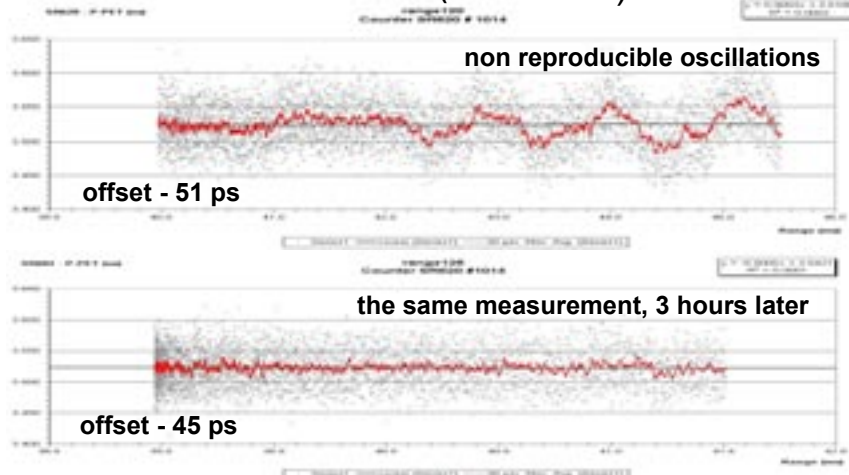
**Peak to peak 130 psec within 6-12 msec
not reproducible**

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Portable Calibration Standard for SLR Capabilities
SR620 / P-PET Counter Linearity
 Potsdam, 2001, LAGEOS pass

50 ps / div

Counter s/n 1014 (in routine use)



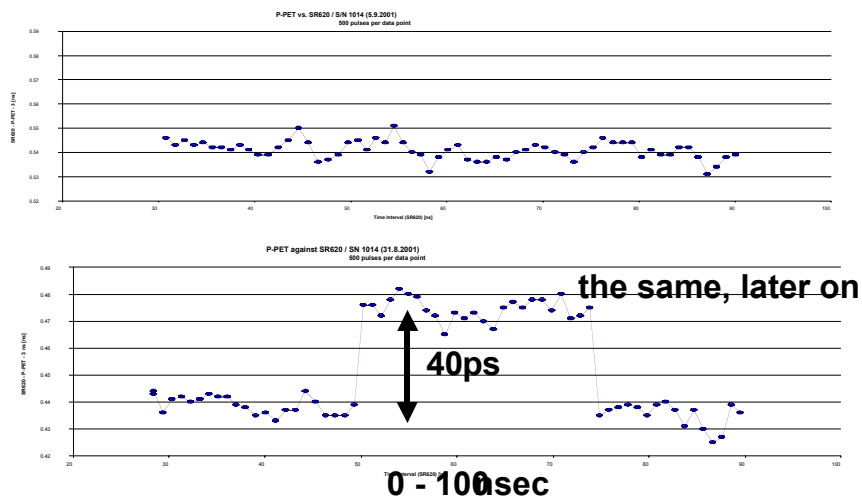
L. Grunwald, R. Neubert, H. Fischer, H. Pino, Potsdam, 2001

I. Prochazka, K. Hamal, Prague, September 2002

Portable Calibration Standard for SLR Capabilities
SR620 / P-PET Counter Linearity
 Potsdam, 2001, Short times

10 ps / div

Counter s/n 1014 (in routine use)



L. Grunwald, R. Neubert, H. Fischer, H. Pino, Potsdam, 2001

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P-PET at Potsdam SLR SR620 counters test - Summary

- counter reading jumps of 40 psec
random, not reproducible
- oscillations 50 psec amplitude, period ~ 60 sec
not correlated
- offset 20-50 psec between the nanoseconds
(calibration) and milliseconds (SLR) ranges

=> SYSTEMATIC ERRORS 45-80 psec

Conclusion

- Portable Calibration Standard based on a Pico Event Timer is a powerful tool to identify systematic error sources in the SLR “ranging machine”
- the entire system is compact, easy to transport fast to install and user friendly to operate, the calibration mission can be accomplished within one week time slot,
- P-PET mission to SLR sites did trigger several projects
 - WLRS (1998), TIGO(1999), Graz (2000)
timing systems upgrade
 - European millimeter SLR joint activity (2002),
 - Herstmonceux Workshop (2002)