

Context & Objectives

The Time Transfer by Laser Link (T2L2) project is designed for the comparison of ground clocks utilizing a space instrument able to time tag laser pulses reaching the satellite and a SLR station network. Compared to the microwave techniques, such as the GPS-Common View, T2L2 should improve the time transfer uncertainty by at least one order of magnitude. The accuracy of this optical technique gives the opportunity to compare today's most accurate frequency standards. This poster presents the results of the direct comparison between T2L2 & GPS-CV, along with the independent link calibrations.

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Techniques of Time Transfer

Time Transfer by Laser Link

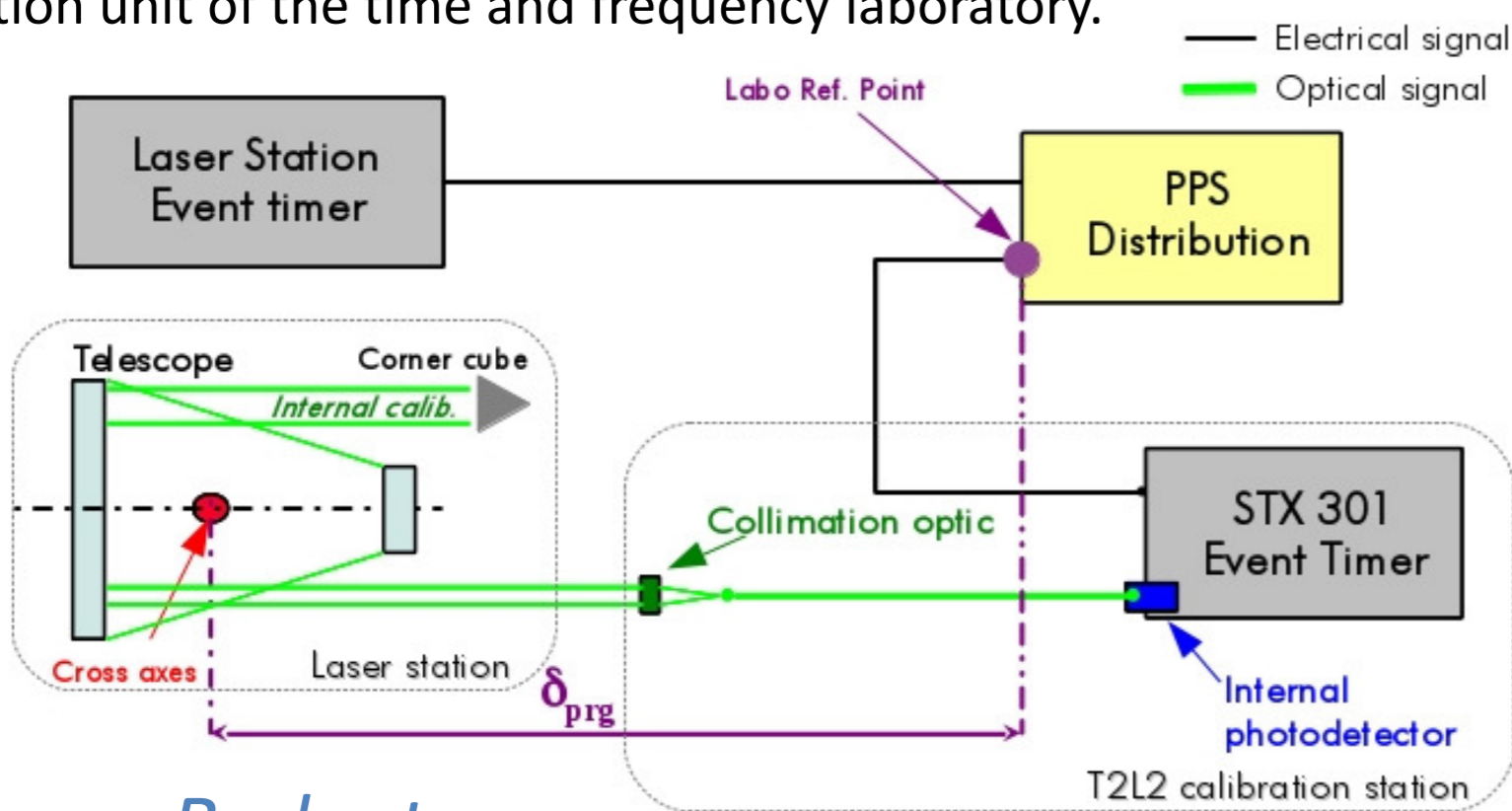
Description

- Based on a space instrument, launched in June 2008 on Jason2 (1330 km)
- 2 ways technique based on the timing of optical pulses emitted Tstart (and received Treturn) by a laser station and received by a space segment Tboard.

Link Calibration Process

[E. Samain et al., Time transfer by laser link (T2L2) error budget, Metrologia, 2014, submitted]

Based on a set of simultaneous measurements done between the usual chronometry of the laser station and the dedicated calibration station. It permits measurement of the delay between the optical pulse at the cross axis of the telescope and the electrical reference coming from a given output of the PPS distribution unit of the time and frequency laboratory.



Link error Budget

Issue from calculation in:
 [E. Samain et al., Time transfer by laser link (T2L2) error budget, Metrologia, 2014, submitted]

Time transfer	Type	u / ps
Ground to Space Expanded Uncertainty (k=2)	A & B	98
Ground to Ground Expanded Uncertainty (k=2)	A & B	138

GPS-Common View

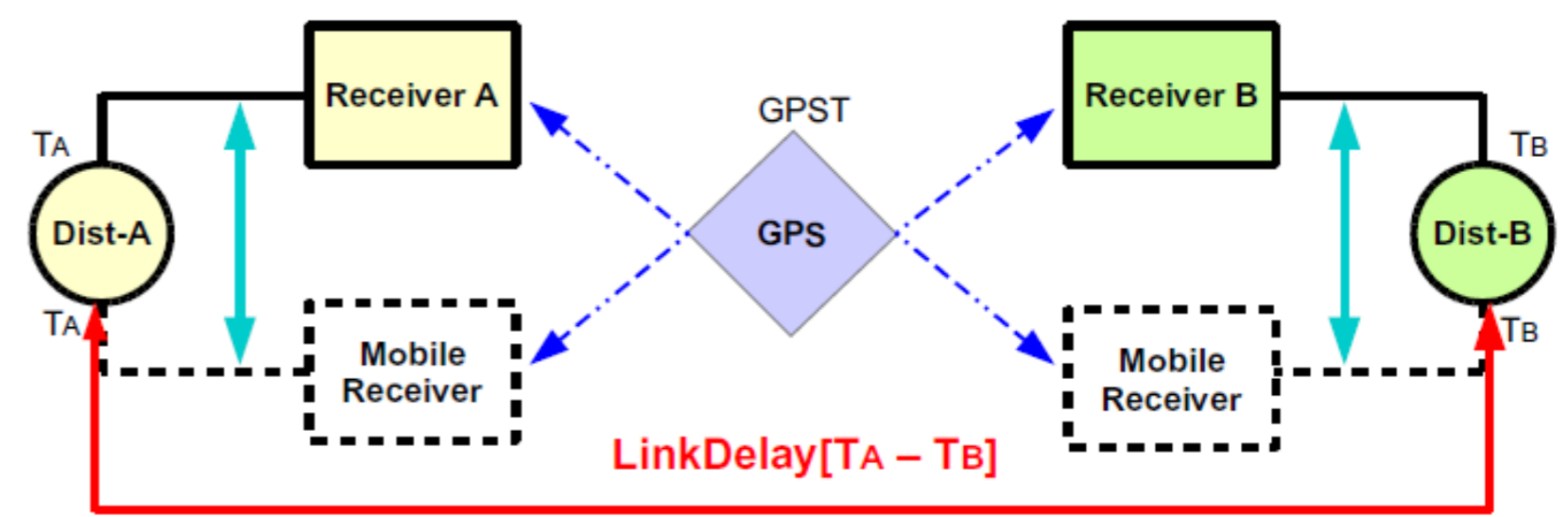
Description

- Based on the GPS satellite constellation
- In each station, a GPS receiver collects measurements of the differences between the local time scale and GPS Time, the common satellite system time scale

Link Calibration Process

[G. D. Rovera et al., Link calibration against receiver calibration: an assessment of GPS Time Transfer uncertainties, Metrologia, 51, 2014, 476-490]

Based on a relative calibration of receiver hardware by use of a traveling equipment moving around in a given network. We applied the link calibration technique instead of the receiver calibration one.



Link error budget

The uncertainty of the GPS-CV time transfer is between 2 ns and 3,2 ns (k=2). An improvement by at least a factor 1.2 is obtained with the link calibration technique

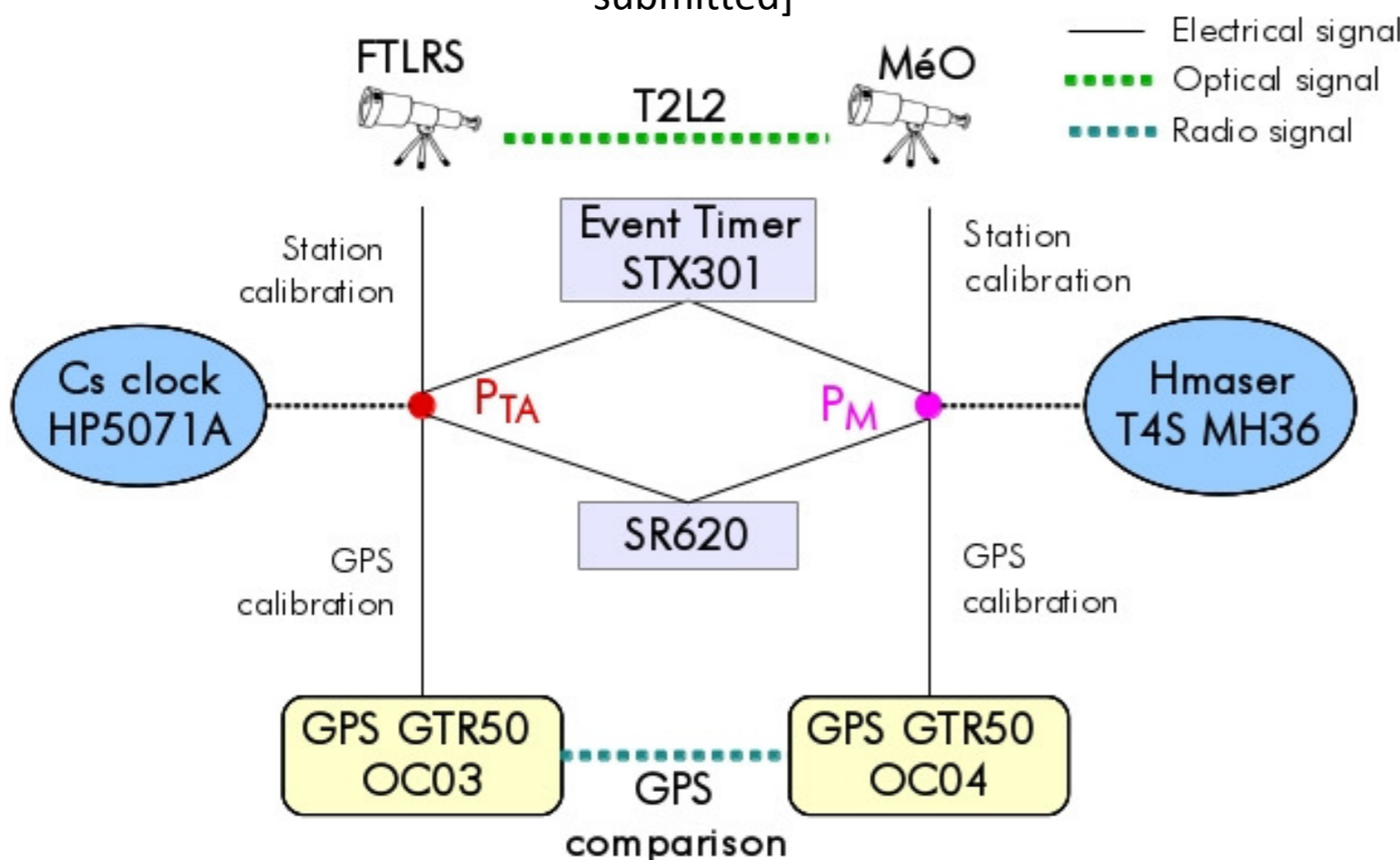
$u(\text{TAIP3 CV or PPP})$ k = 2	RecCal (ns)	LinkCal (ns)	Improvement Factor
OP-OCA	2.5	2.1	1.2
OP-SGF	2.0	1.5	1.3
OCA-SGF	3.2	2.1	1.5

Comparison campaigns

Campaign 2012

Comparison of 3 independent time transfer techniques calibrated : T2L2, GPS-CV, and direct comparison (event timer and counter)

[M. Laas-Bourez et al., Accuracy Validation of T2L2 time transfer in co-location, IEEE UFFC, 2014, submitted]



Main results:

The mean difference obtained between T2L2 and direct comparison, with the event timer, was around 188 ps with a standard deviation of 132 ps. The mean difference between T2L2 and the counter was about 150 ps with a standard deviation of 160 ps. This results is in agreement with the T2L2 ground to ground expanded uncertainty of 140 ps and the expanded uncertainty of the direct comparison.

However there are effects during a pass which are not well understood. We have also identified some improvements to make on the signal distribution and laser instrumentation.

Campaign 2013

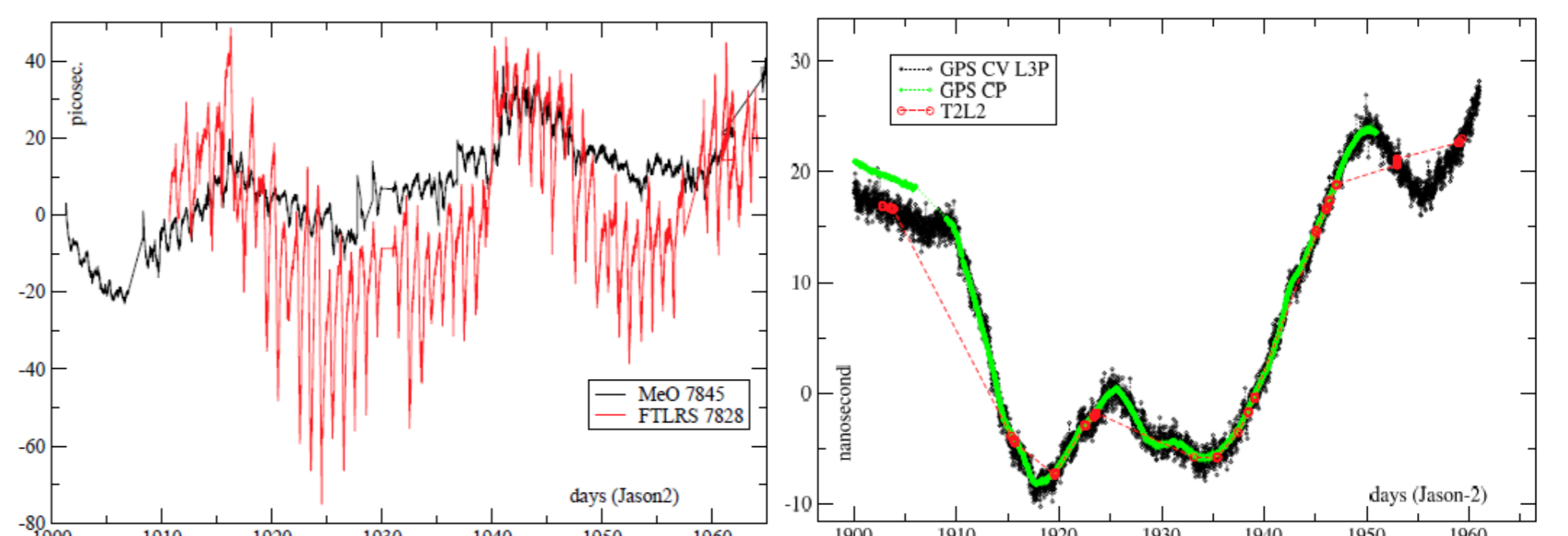
Comparison between independently calibrated techniques T2L2 & GPS-CV

[G. D. Rovera et al. A direct comparison between two independently calibrated time transfer techniques: T2L2 and GPS-CV Proceedings of CPDM, 2014]; [E. Samain et al., a sub-ns comparison between GPS-CV and T2L2, Proceedings EFTF 2014]; [P. Exertier et al., Time Transfer by laser link between calibrated geodetic observatories in Europe, in preparation]



TIME DIFFERENCES BETWEEN GPS CV AND T2L2

Link	Number of points	Average ns	Standard Deviation / ns	GPS CV	GPS filtered
SGF-OCA	42	0.09	0.49	0.37	
OP-OCA	12	0.24	0.48	0.25	
SGF-OP	5	0.10	0.32	0.32	



Monitoring of signal distribution (left) & Ground-ground time transfer between Herstmonceux & Grasse (right)

Main results:

The difference between T2L2 and GPS-CV remained in average below 300 ps, with a standard deviation below 500 ps mostly due to GPS-CV. The good agreement between the techniques confirms that the two independent calibration processes have been carried out in a rigorous way