Laboratory Update

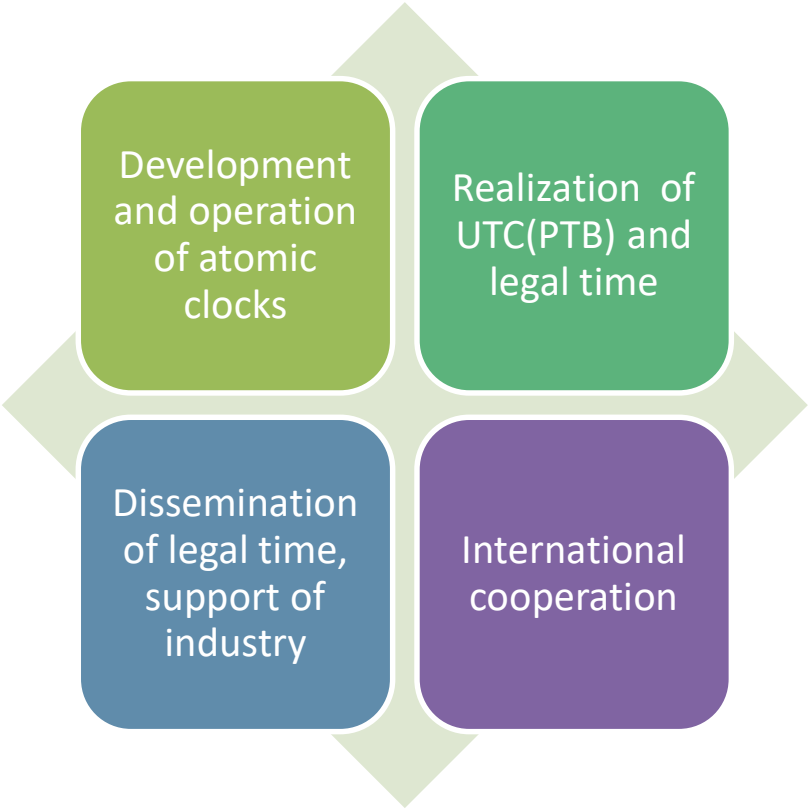
Andreas Bauch, PTB

CGSIC Timing Subcommittee
2021-09-20

Aerial view of Braunschweig campus

- National Metrology Institut of Germany since 1887,
- Governed by the Federal Ministry for Economy and Energy
- 2150 staff, 240 Mio. € budget

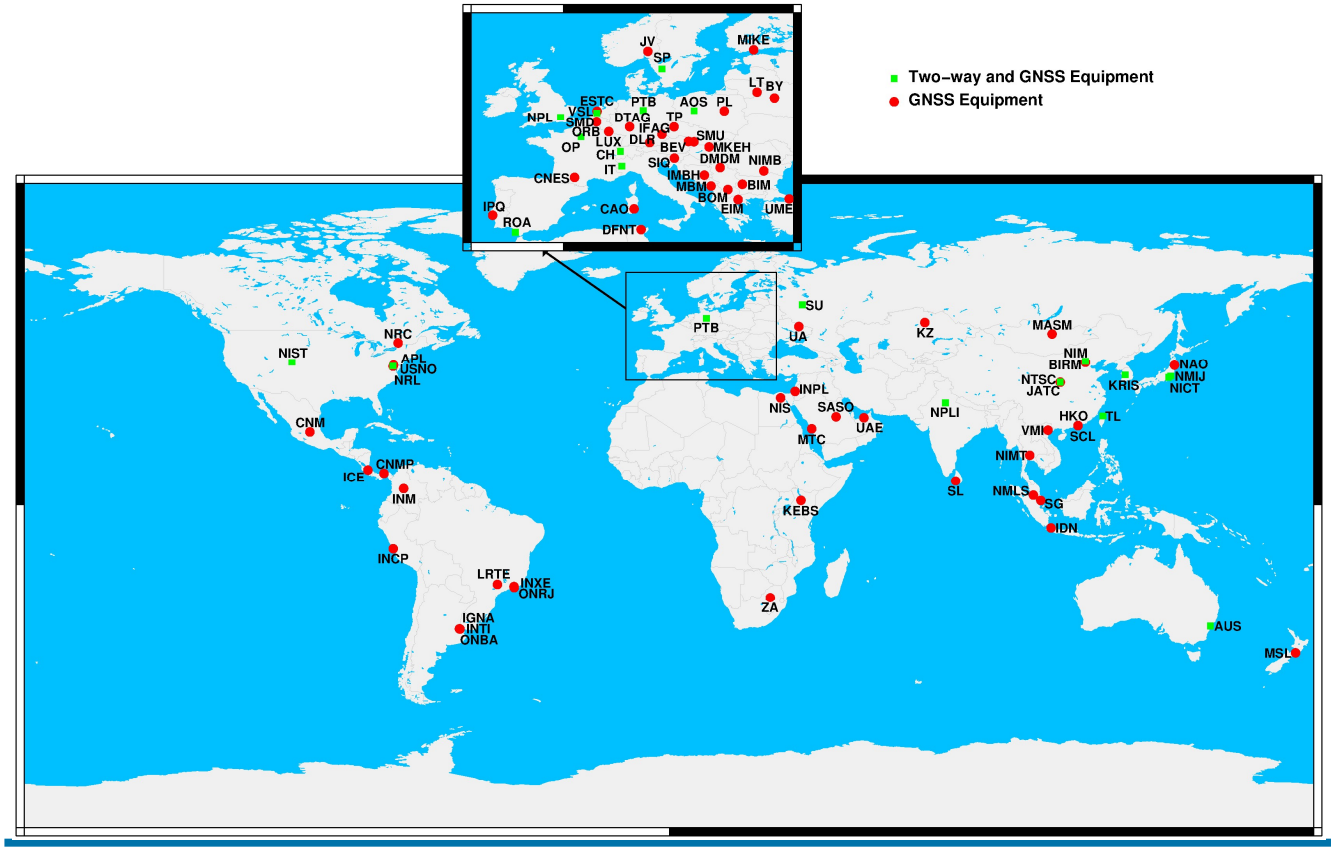
Activities in time and frequency



TC-TF
Time and Frequency
EURAMET Technical Committee

BIPM

Involvement in international metrology



UTC and TAI are realized by BIPM, based on inputs of some 80 timing institutes, operating some 400 atomic clocks

Circular T

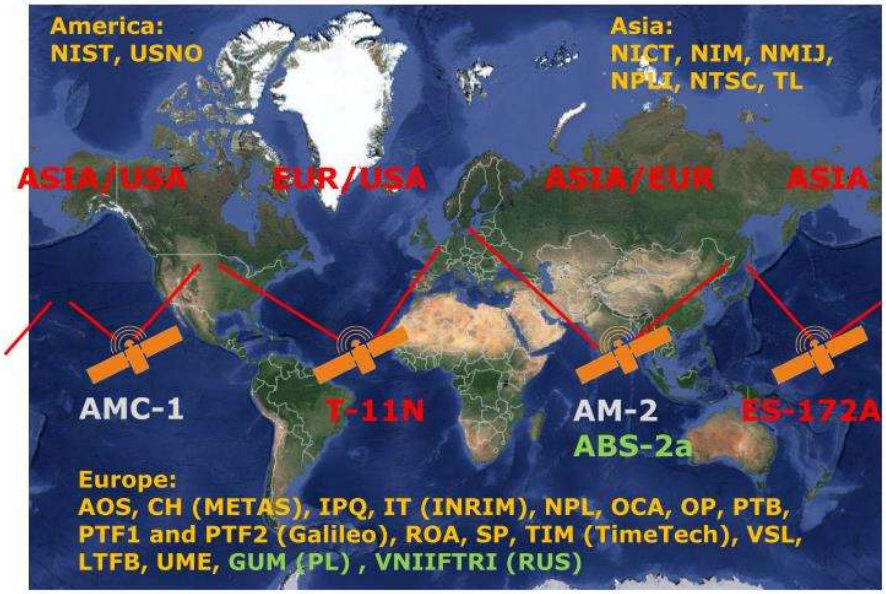
5 - Time links used for the computation of TAI, calibrations information and corresponding uncertainties.

Link	Type	Equipment	Cal_ID1/Cal_ID2	uStb/ns	uCal/ns	uAg/ns	Al/ns	YYMM
AGGO/PTB	GPS P3	TC_2 /PT13	NC /1001-2018	1.0	20.0			
AOS /PTB	GPSPPP	AO 4 /PT13	1014-2018/1001-2018	0.3	2.8	1.4		
SU /PTB	GPSPPP	SU31 /PT13	1001-2018/1001-2018	0.3	2.2	1.5		
TL /PTB	GPSPPP	TLT1 /PT13	1001-2020/1001-2018	0.3	2.0	1.1		
TP /PTB	GPSPPP	TP02 /PT13	1015-2019/1001-2018	0.3	2.7	1.1		
UA /PTB	GPS MC	UA05 /PT13	2003-2018/1001-2018	3.0	7.1	1.4		
UAE /PTB	NL							
UME /PTB	GPSPPP	UM01 /PT13	1011-2016/1001-2018	0.3	3.3	2.2		
VMI /PTB	GPSPPP	VM02 /PT13	2001-2019/1001-2018	0.5	7.1	1.1		
ZA /PTB	GPSPPP	ZA02 /PT13	1018-2018/1001-2018	0.3	2.8	1.3		

Link	Type	Equipment	Cal_ID	uStb/ns	uCal/ns	uAg/ns	Al/ns	YYMM
CH /PTB	TWGPPP	CH01 /PTB05	0523-2021	0.3	1.3	0.4		
IT /PTB	TWGPPP	IT02 /PTB05	0502-2019	0.3	1.5	0.6		
NIST/PTB	TWGPPP	NIST01/PTB05	0393-2015	0.3	2.1	1.6		
NPL /PTB	TWGPPP	NPL02 /PTB05	0525-2021	0.3	1.3	0.4		
OP /PTB	TWSDRR	OP51 /PTB55	0517-2020	0.3	1.2	0.5		
ROA /PTB	TWGPPP	ROA01 /PTB05	0504-2019	0.3	1.3	0.5		
SP /PTB	TWGPPP	SP01 /PTB05	0496-2019	0.3	1.6	0.6		
USNO/PTB	TWGPPP	USNO01/PTB05	0395-2016	0.3	1.8	1.3		
VSL /PTB	TWGPPP	VSL01 /PTB05	0527-2021	0.3	1.3	0.4		

PTB serves as the pivot for GPS time comparisons and TWSTFT, evaluated and used by the BIPM, because of

- Geographical position (TWSTFT to US and to Asia),
- Equiment in redundancy and reliably operated,
- Predictable, stable time scale UTC(PTB).



Involvement in international metrology

1st GPS receiver operated in PTB,

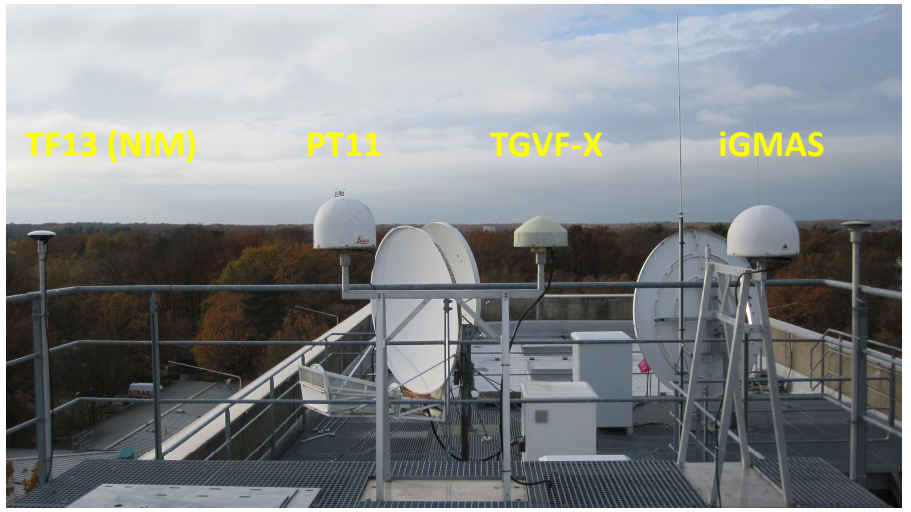
a gift from National Bureau of Standards 1982

Mission of the Time Dissemination Working Group in the GNSS context:

- Maintain a set of redundant receivers for all kinds of signals
- Operate IGS station PTBB (since year 2000)
- Monitor inter-receiver biases
- Support the use of GPS and Galileo signals for timing applications in different user communities
- Support the Galileo timing system through collaboration with the Galileo Time Service Provider and the Galileo Reference Centre
- Support BIPM calibration activities by determining GNSS signal delays in installations of G2 laboratories in Europe and elsewhere

GNSS installations at PTB

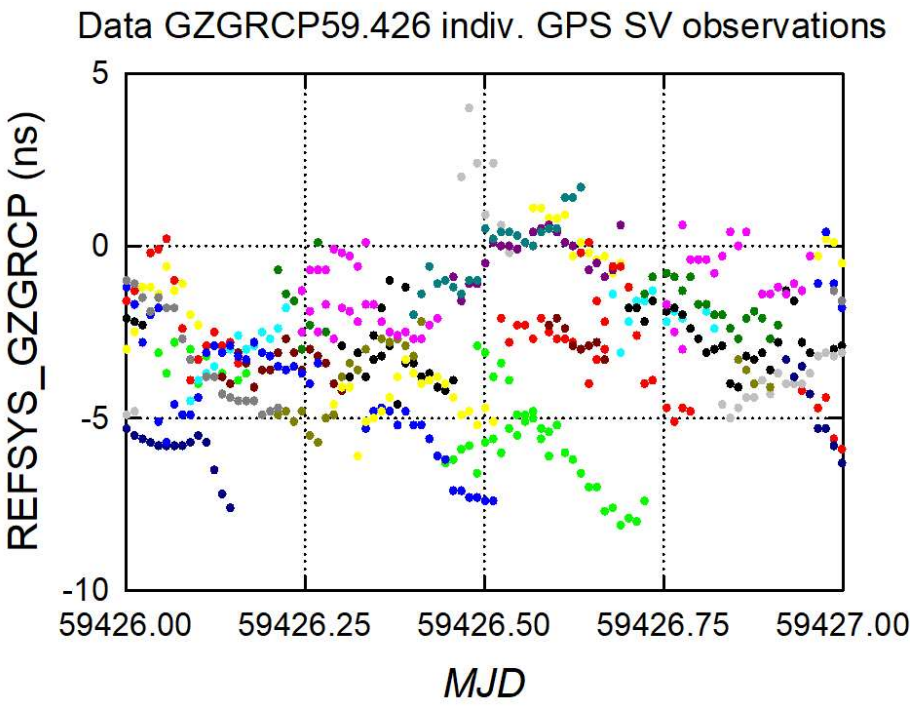
Two sites with GNSS-antenna installations
All receivers connected to signals representing UTC(PTB)

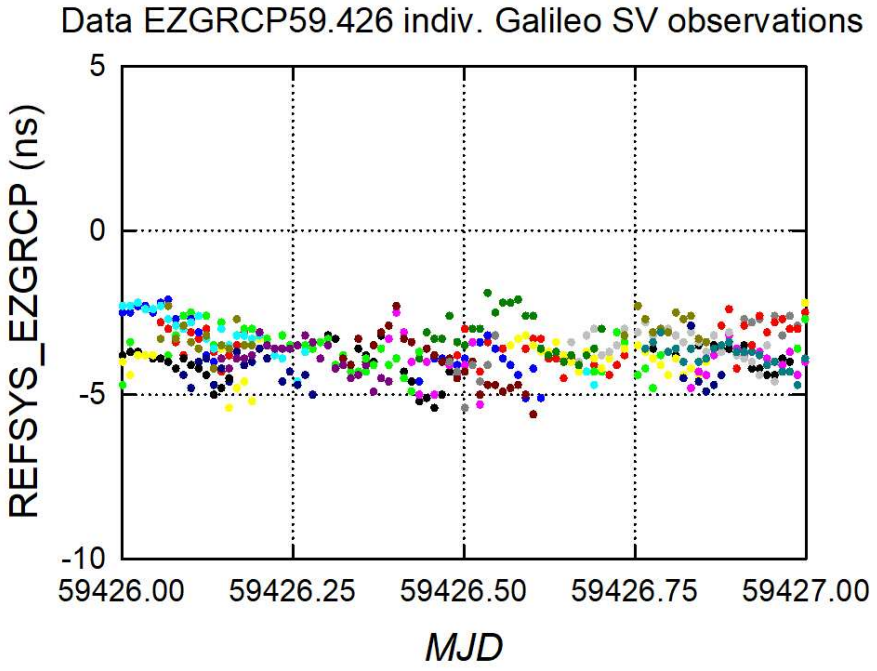


2 receivers GPS L1, L2 only: (PT07, PTBT)

6 Rec. multi-GNSS (PT09 – PT12, PTBB, PTBM)
4 Rec. multi-GNSS on loan / under contract

Observation of individual GNSS satellites





Observation of individual GNSS satellites

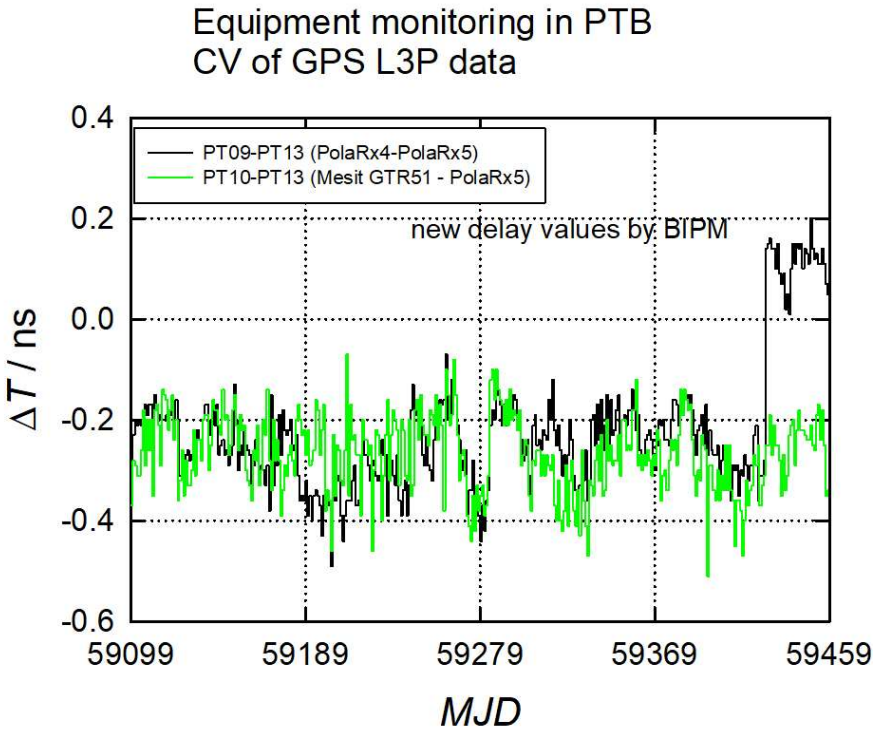
Apparently different quality of broadcast ephemerides and clocks

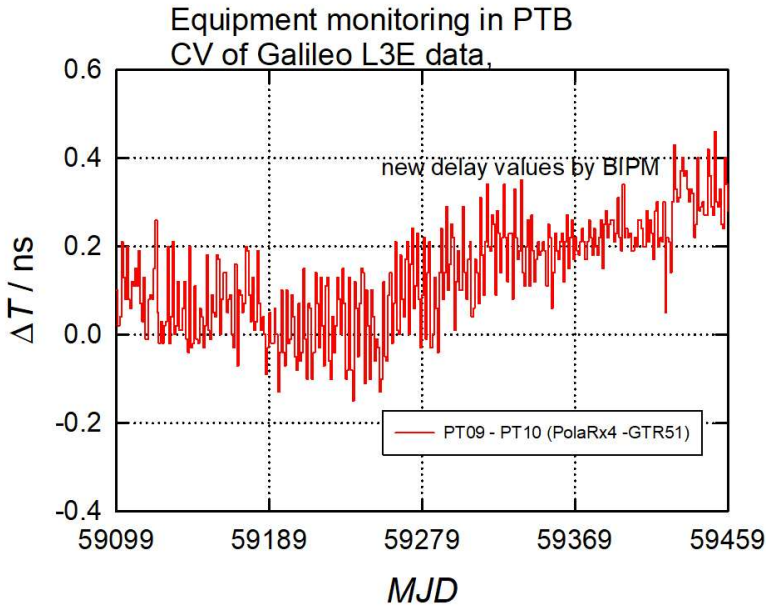
Way around:

evaluates all links in post-processing using precise orbit and clock products provided by IGS;

For local and continental comparisons, the legacy Common-View method is fully appropriate.

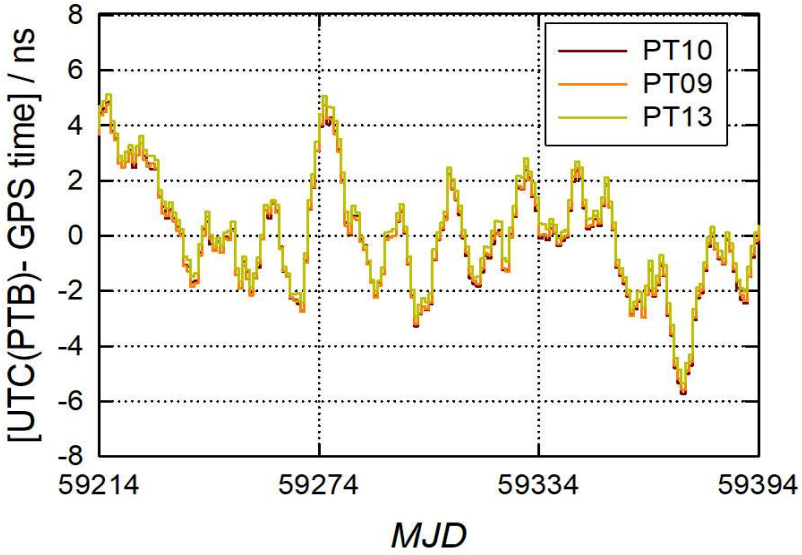
GNSS receiver bias monitoring at PTB



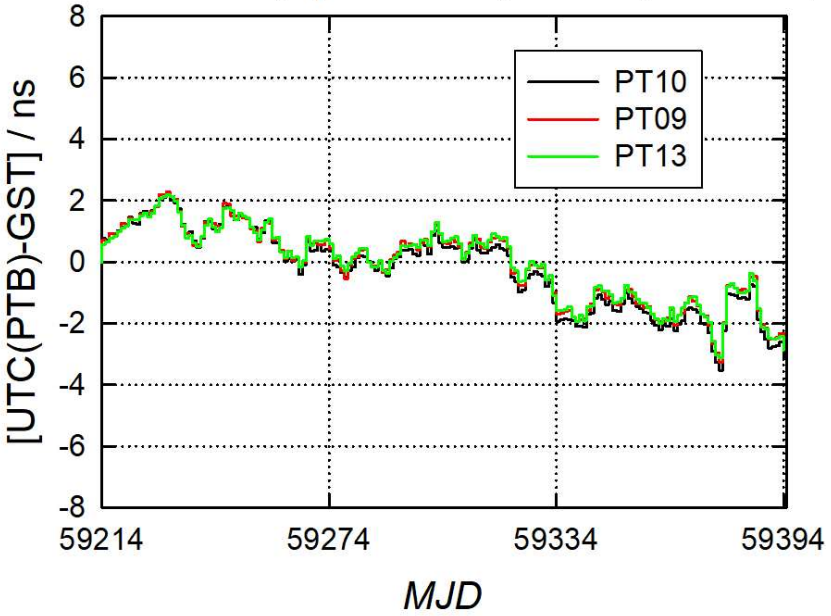


GNSS system time monitoring at PTB

GPS reception in PTB: Recording of REFSYS, with
PT09 and PT13 (Septentrio PolaRx) and PT10 (Mesit GTR51)

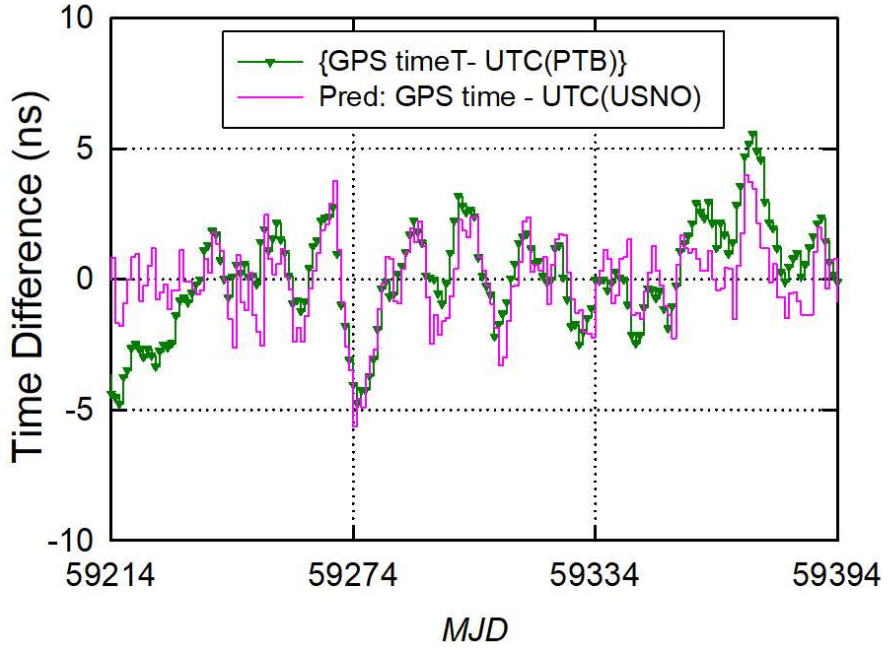


Galileo reception in PTB: Recording of REFSYS with
PT09 and PT13 (Septentrio PolaRx) and PT10 (mesit GTR51)

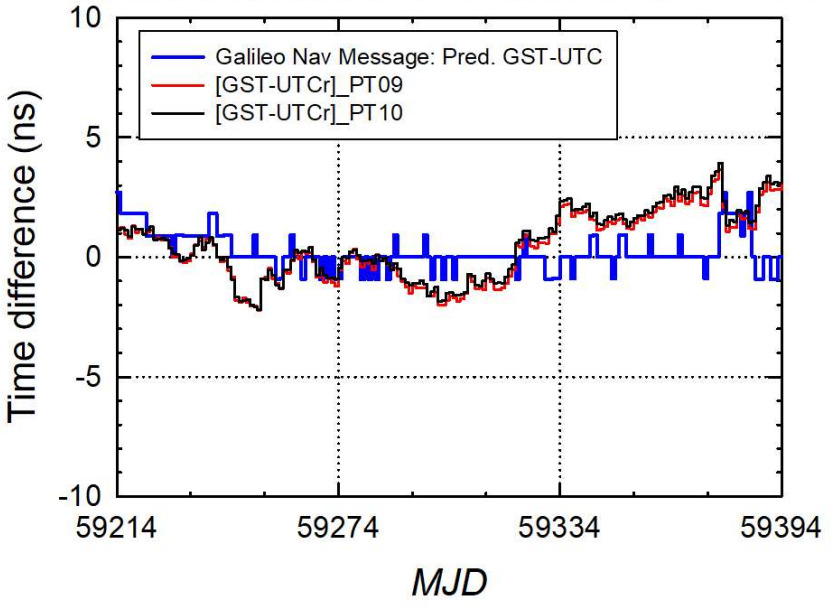


GNSS navigation message monitoring at PTB

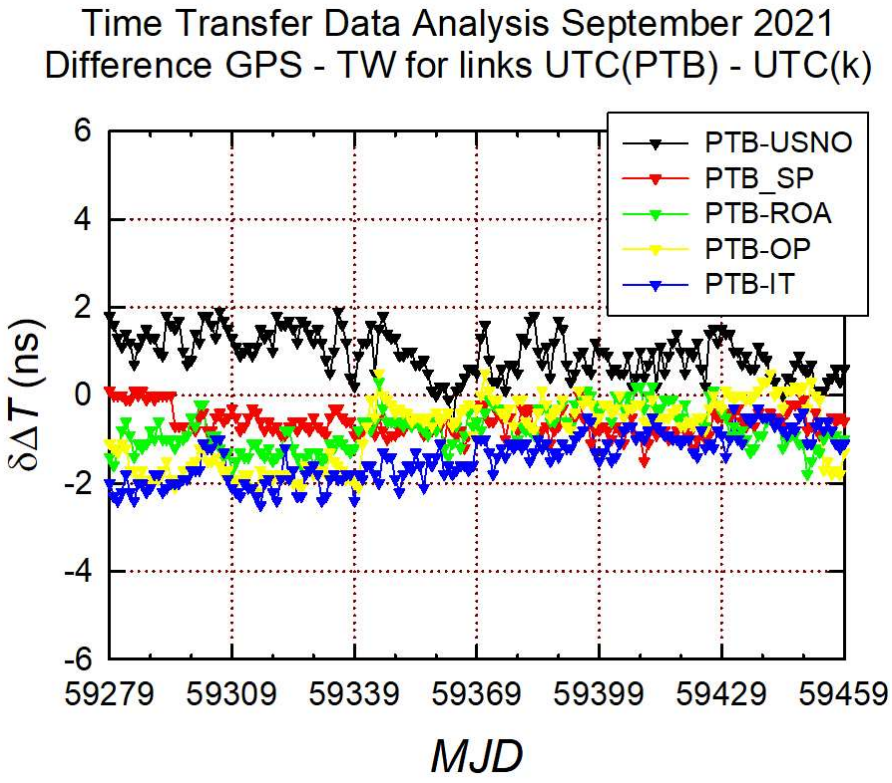
GPS time: Offset wrt to UTC(PTB) via PT09 and predicted offset "GPSTime minus UTC" in 2021, Q1+Q2



Galileo system time GST: Offset wrt to UTC(PTB) via two receivers and predicted offset "GST minus UTC" in 2021, Q1+Q2



Comparing GNSS with TWSTFT at PTB

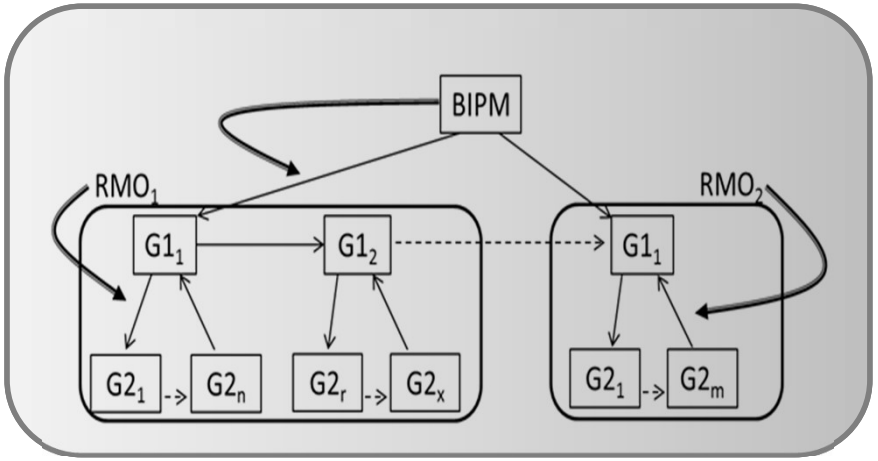


Major effort during 2021 as TWSTFT link configuration was changed twice

Thanks to
Frédéric MEYNADIER, BIPM

GNSS signal delay determination

PTB serves as one of the three European G1 labs, supporting BIPM for providing receiver delay determination,
including Galileo signal delay delays since 2020.



- 1011-2020 ORB (Bruxelles)
- 1013-2020 ESTEC (ESA)
- 1014-2020 BKG (Geodetic Observatory Wettzell, Germany)
- 1011-2021 INRIM (Italy)
- 1201-2021 JV (Norway)
- 1013-2021 UFE (Czech Republic) and VSL (the Netherlands)
- 1016-2021 DLR (Germany) – BEV (Austria) ongoing

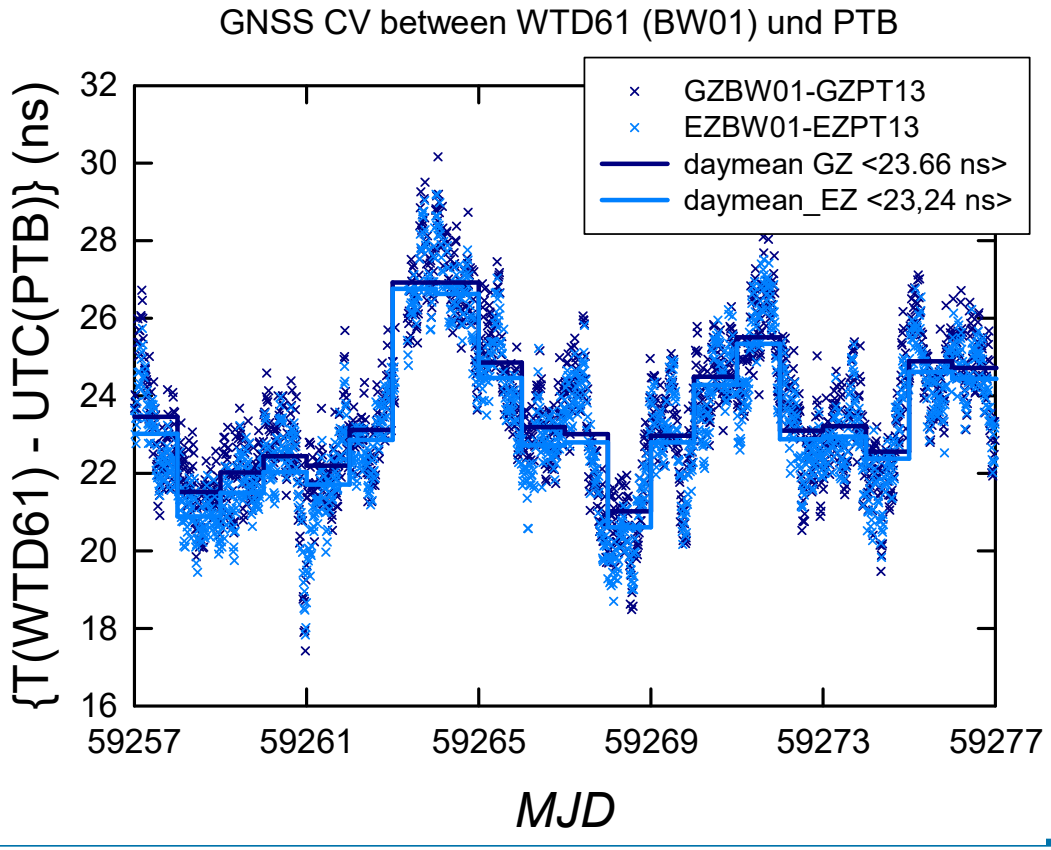
GNSS signal delay determination

Example from 2020:

Support of German Air Force, setting up a new time lab

GPS and Galileo CV between PTB after GPS and Galileo delays were applied.

WTD 61 operates a comm. Cs clock



Other time and frequency activities

In the department:

- Operation of the clock ensemble (5 active masers, 2 passive masers, 6 commercial Cs clocks, legacy primary clocks CS1 and CS2
- Operation and „perfection“ of Cs fountain clocks CSF1 and CSF2
- Development and operation of several optical frequency standards
- Integration of optical frequency standards into the time scale generation (WIP)

In the working group:

- Dissemination of legal time via long-wave DCF77 and telephone service
- Dissemination of 1 PPS and 10 MHz via optical fibers to Deutsche Telekom (and other user groups in the future)
- IT-based dissemination for the public and for restricted users, in cooperation with PTB IT-sector.

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Bundesallee 100
38116 Braunschweig

Andreas Bauch
Telefon:+49 531 592-4420
E-Mail: Andreas.Bauch@ptb.de
https://www.ptb.de/time