



Galileo IOV Timing Results

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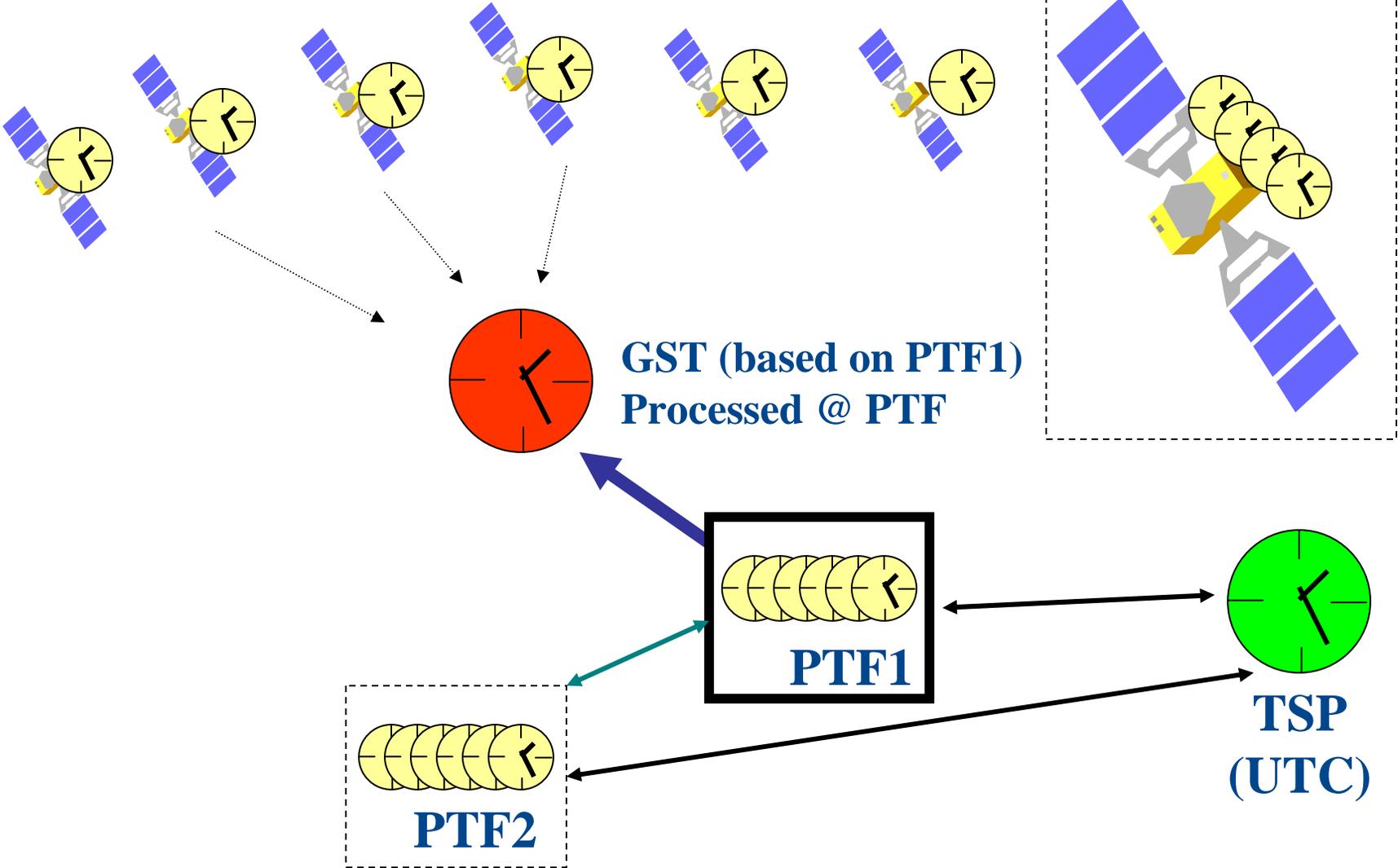
Galileo Timing User specs

User Performance	Specification
Frequency Accuracy (expressed as a normalised frequency offset relative to UTC, 2 sigma, over any 24 h interval)	$< 3 \times 10^{-13}$
User UTC determination uncertainty (2 sigma)	$< 30 \text{ ns}$

Setting-up Galileo System Time



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PTF-Precise Timing Facility TSP-Time Service Provider

Precise Timing Facility (PTF) **Core System**

- ★ **Navigation Timekeeping – critical for navigation**
 - ★ Stable and autonomous timescale
 - ★ Synchronisation of ground facilities
 - ★ Reference for satellite orbit and clock prediction
 - ★ Internal time tagging

- ★ **Metrological Timekeeping – necessary for Galileo Timing Service**
 - ★ Accurate timescale synchronised to UTC (modulo 1 second)
 - ★ Implementation of ITU recommendations
 - ★ (Legally) valid time-tagging of user position and time
 - ★ Timing service for specialised users

Time Service Provider

External

Definition of Galileo System Time (GST)

Galileo System Time (GST) shall be a continuous co-ordinate time scale in a geocentric reference frame, steered towards the UTC modulo 1 second.

GST start epoch: 00:00 on Sunday August 22nd 1999 (midnight between August 21st and 22nd). At the start epoch, GST shall be ahead of UTC by thirteen (13) leap seconds.

$GST-UTC = 16 \text{ s}$ (as of 01/07/2012)

GST format as broadcast in the satellite navigation message

- Week Number (WN)
- Seconds of Week

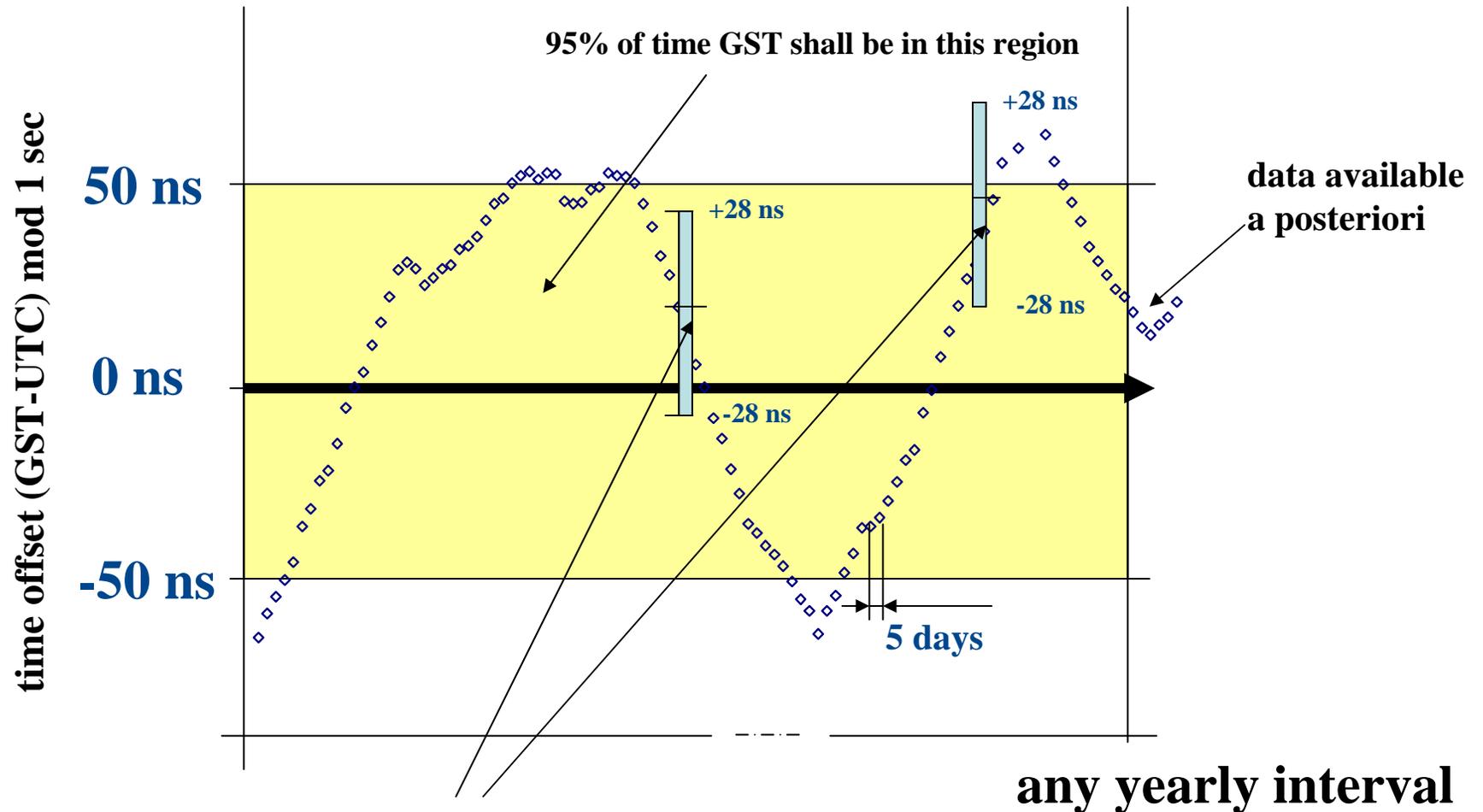
GST and GPSTime:

- $GST-UTC = GPST-UTC$
- $WN(GST) = WN(GPSTime(w. \text{ roll-over})) - 1024$
- Seconds of Week (GST) = Seconds of Week (GPSTime)

Galileo System Time vs. UTC mod 1 sec



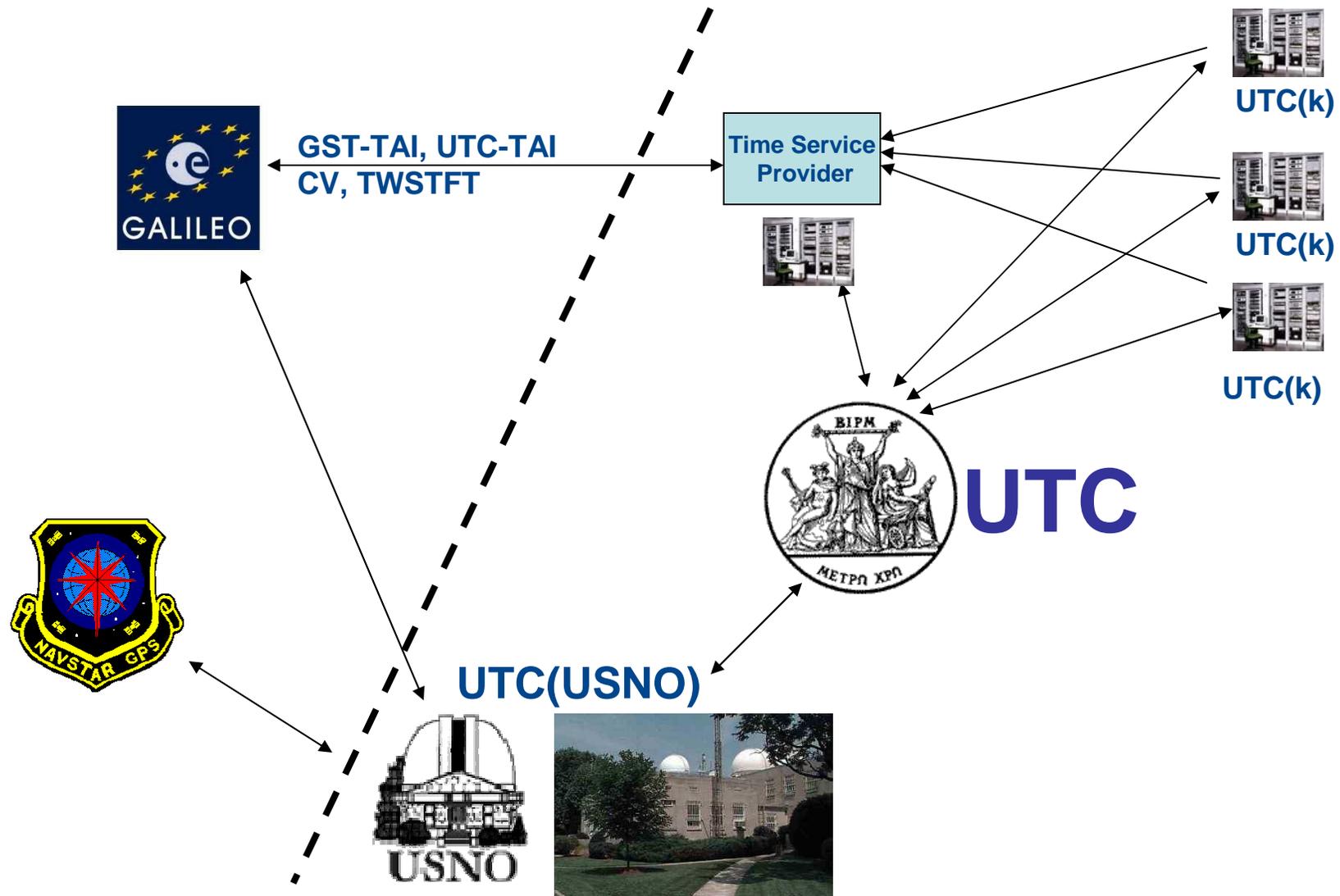
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predicted offset shall be in this region, 2sigma,
due to delay in UTC estimation (1.5 months)

not to scale

Galileo vs. BIPM, USNO, GPS



Time Service Provider

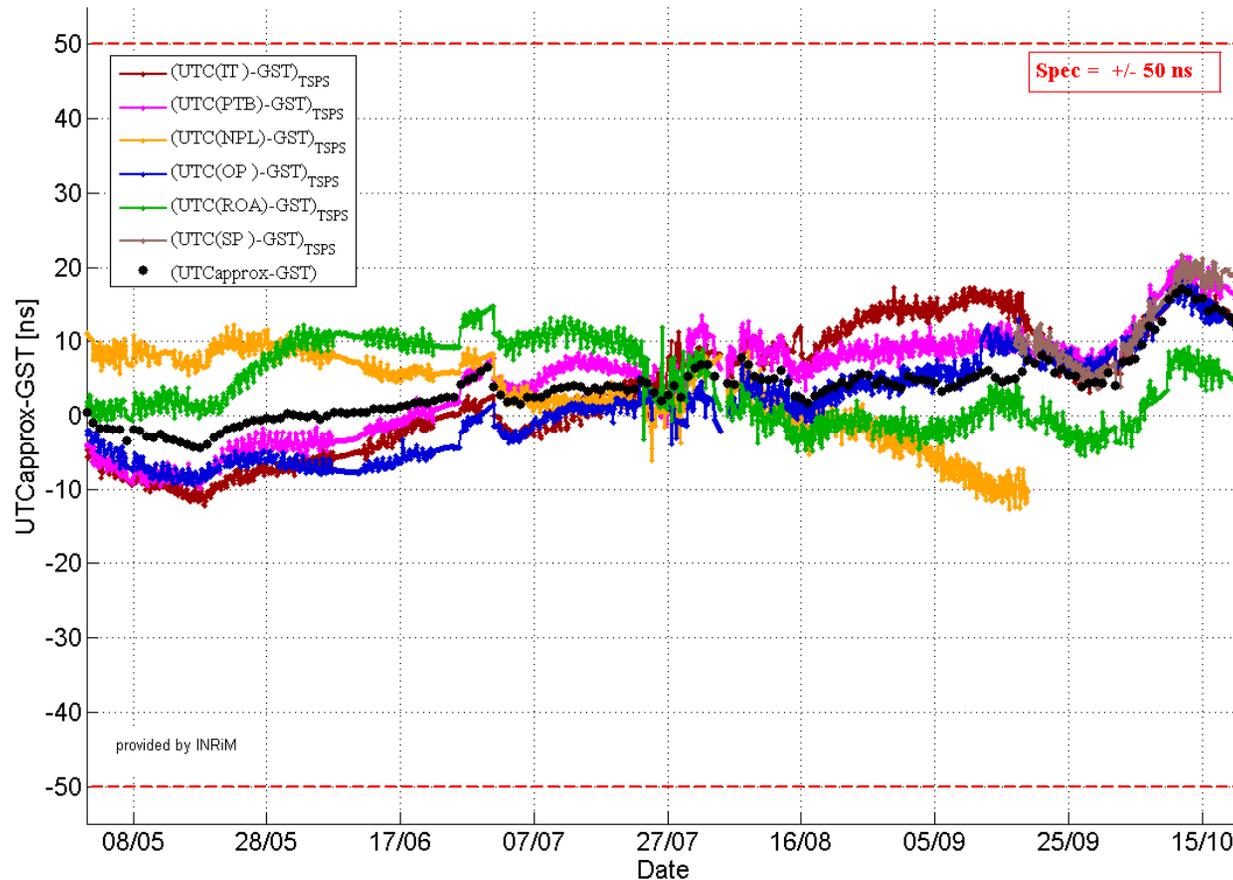
NOTE: Currently the TSP function is operationally fulfilled by the Time Validation Facility (TVF) until TSP is in place.

UTC(k) laboratories contributing to TVF IOV:



UTC(k) and UTCpredicted vs. GST (MC) Early Results

UTCapprox-GST (00 UTC) and TSPS baselines
from 01/05/13 to 20/10/13 (MJD 56413 - 56585)



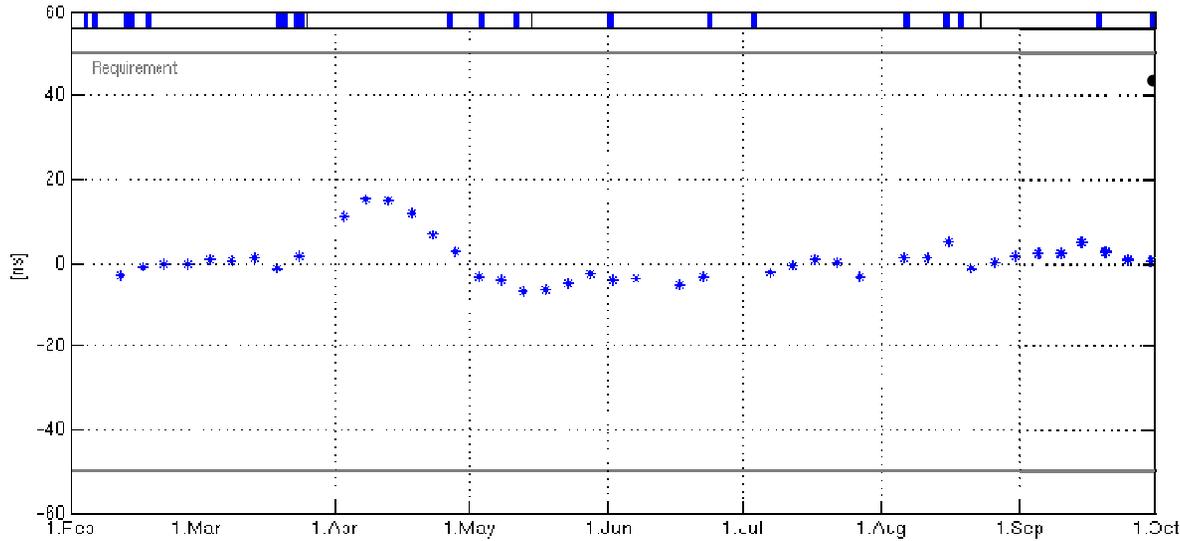
The plot shows daily average of GST(MC) offset to the national real-time realizations of UTC, named UTC(k). The offset UTC(k)-GST(MC) is measured using TWTFT and GPS CV techniques. The real time approximation of UTC named UTCapprox is the average of the five UTC(k)'s predicted vs UTC.

UTC-GST(MC) Time and Freq. Offset Early Results



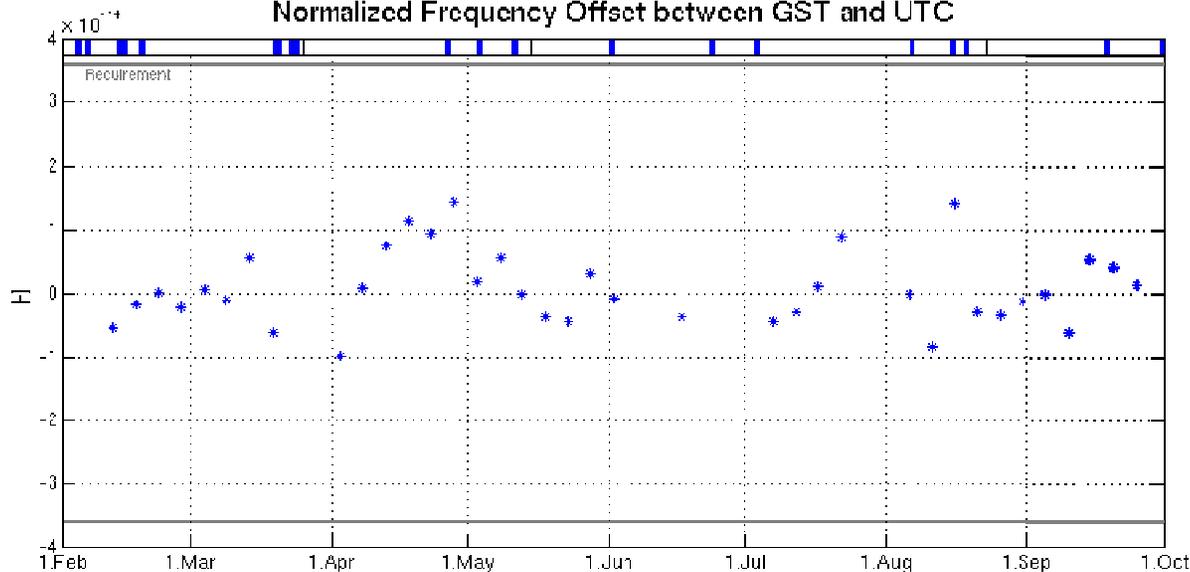
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GST vs. UTC Time Offset



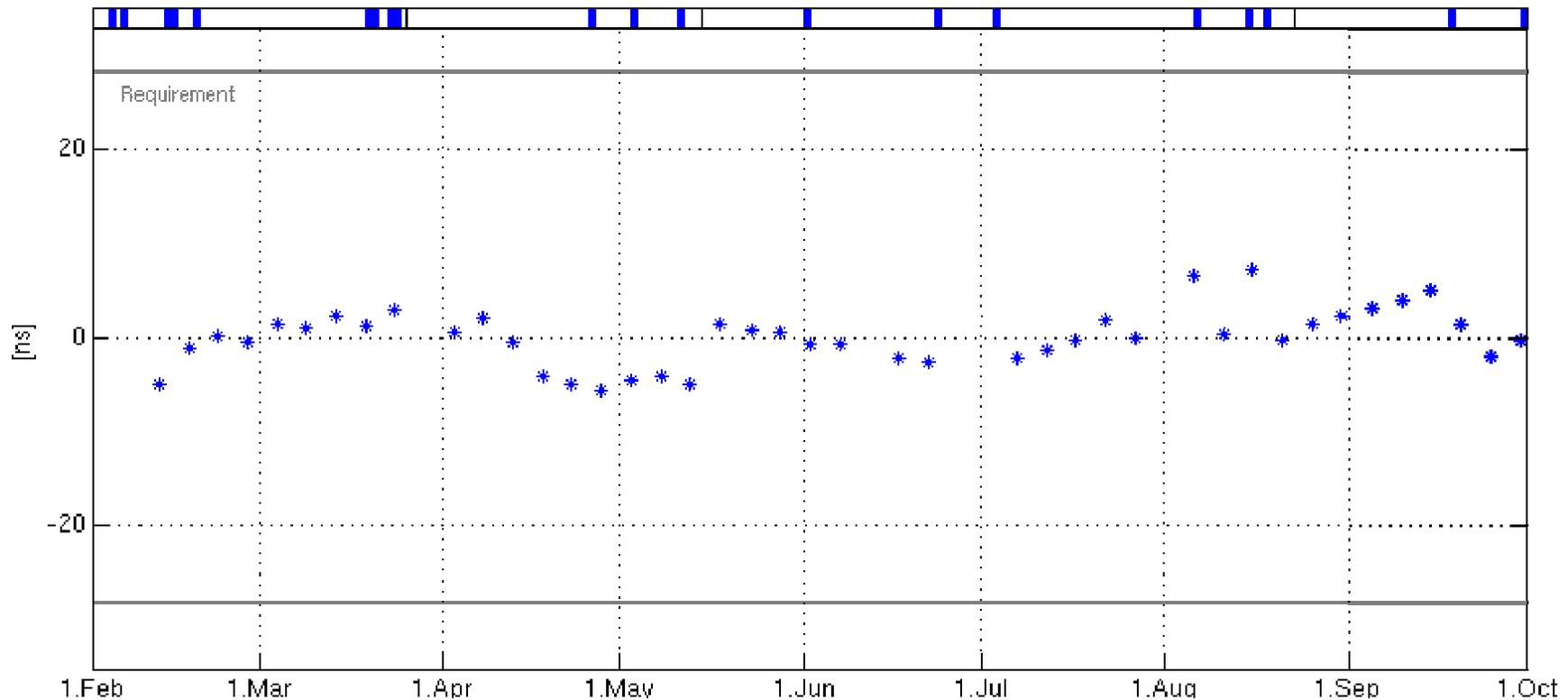
UTC-GST(MC) offset is evaluated monthly using BIPM Circular T

Normalized Frequency Offset between GST and UTC



UTC-GST(MC) Prediction Error Early Results

GST vs. UTC (modulo 1 second) prediction accuracy



- TVF daily evaluates a prediction value for UTC-GST(MC) time offset. The prediction is broadcast in the Galileo navigation message.
- The UTC-GST(MC) prediction error is evaluated by TVF monthly when CircularT is available.
- Through-out the IOV campaign, UTC-GST(MC) prediction error remains within +/- 5 ns

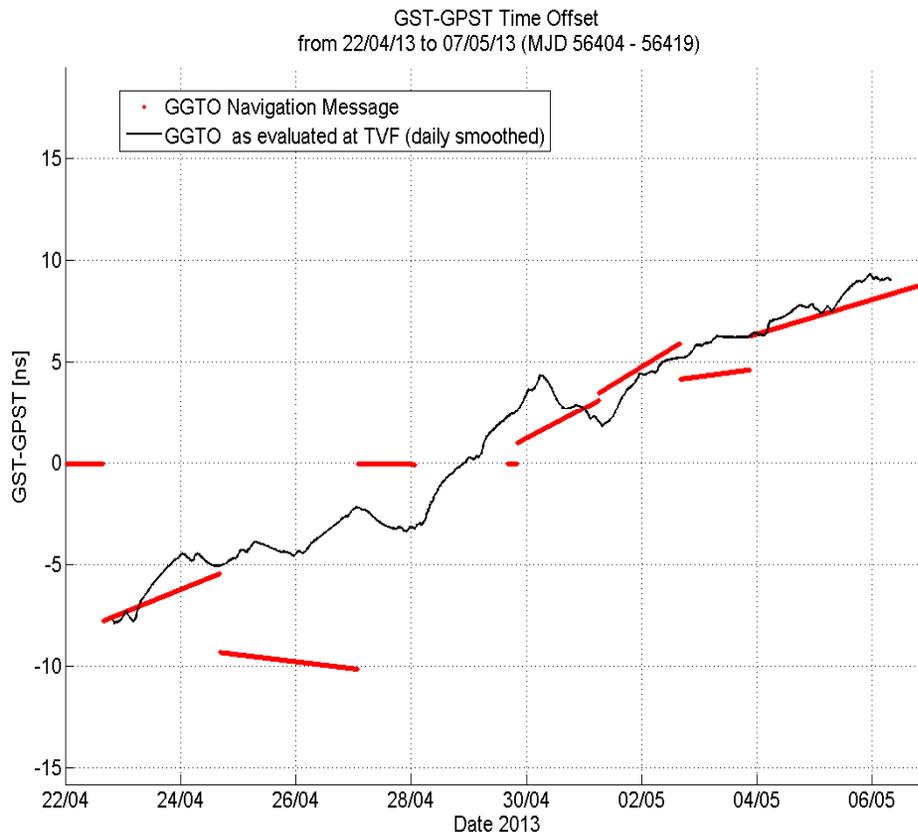
UTC Dissemination through Galileo

- ★ **ITU Recommendation 460-4, point 1:**
 - ★ all standard-frequency and time-signal emissions conform as closely as possible to Coordinated Universal Time (UTC)...
- ★ **Galileo provides both precise positioning and timing capabilities (UTC dissemination)**
- ★ **In all its services, Galileo broadcasts conversion parameters between its internal timescale GST and UTC (but not DUT1)**

Parameter	Definition	Bits	Scale factor	Unit
A_0	Constant term of polynomial	32*	2^{-30}	s
A_1	1 st order term of polynomial	24*	2^{-50}	s/s
Δt_{LS}	Leap Second count before leap second adjustment	8*	1	s
t_{0t}	UTC data reference Time of Week	8	3600	s
WN_{0t}	UTC data reference Week Number	8	1	week
WN_{LSF}	Week Number of leap second adjustment	8	1	week
DN	Day Number at the end of which a leap second adjustment becomes effective	3	1	day
Δt_{LSF}	Leap Second count after leap second adjustment	8*	1	s
GST-UTC Conversion Parameters		99		

Broadcast GPS-Galileo Time Offset (GGTO)

Early results



- The TVF estimates GGTO and compares its value with the GGTO transmitted in the navigation message (evaluated by PTF).
- The TVF's GST(MC)-GPSTime estimate is based on the PTF GPS receiver directly connected to GST(MC) and retrieving GPSTime from GPS Signal In Space.
- GGTO is not always updated daily.
- The broadcast value is mainly in good agreement with the TVF estimate



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http://www.esa.int/Our_Activities/Galileo

<http://ec.europa.eu/galileo>