GNSS station absolute calibration for Galileo OS timing performances monitoring in the frame of GRC-MS

ICG-13 – 7th Nov 2018

Jérôme DELPORTE

David VALAT

Amale KANJ

OUTLINE

Context

Galileo System Time (GST) is

- the reference time for the Galileo system
- under responsibility of the Galileo Mission Segment (GMS)
- computed on the ground at the Galileo Control Centre in Fucino (Italy) using the atomic clocks located at the Precise Timing Facility
- steered to UTC
- fully described in the corresponding ICG timing template

Context

- In order to better support timing applications based on UTC, the Galileo OS nav msg includes additional parameters that enable users to obtain a UTC realization by applying a correction to GST → UTC_SiS

- In order to insure interoperability between GPS and Galileo, their time difference, known as GPGA (or GGTO), is broadcast in the Galileo nav msg allowing users to benefit from a combined GPS/Galileo positioning
- GPGA can also be estimated by receivers if enough satellites are in view

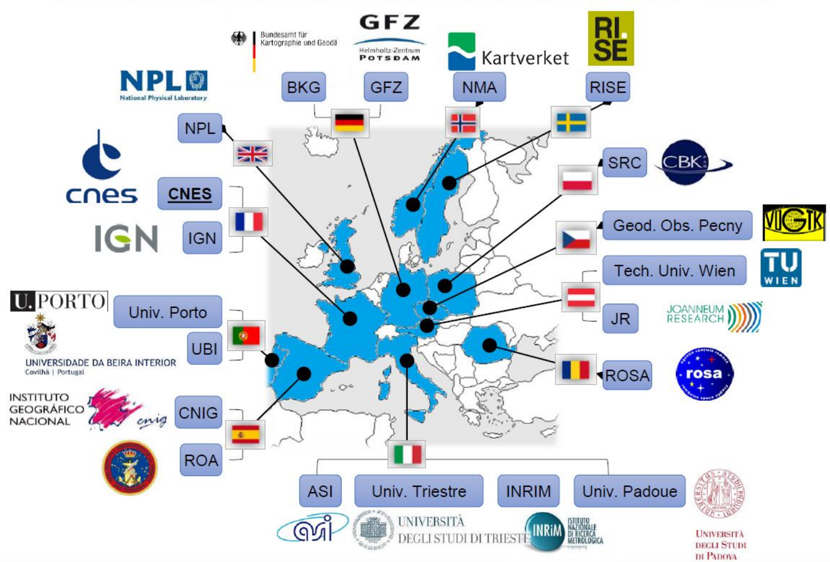
GRC and GRC-MS

Main task of GRC is to provide the GSA with a means for <u>independent</u> monitoring and assessment of the quality of Galileo Services

The GRC consists of a core facility operated by the GSA and EU member state contributions (GRC-MS)

GRC-MS is a contribution to the Galileo Reference Center by EU member states and associated states :

- **coordinator = CNES**
- **20 partners from 12 countries**
- **Specific Grant #1 KO = 11th Sept 2018**



GRC-MS and timing

Dedicated Work Package on timing with CNES as coordinator and 4 partners (INRiM, NPL, ROA and RISE)

First quarter analysed is Q4 2018 ► no consortium results to show yet

CNES already monitors (since the Initial Services declaration) three Key Performance Indicators (KPI) :

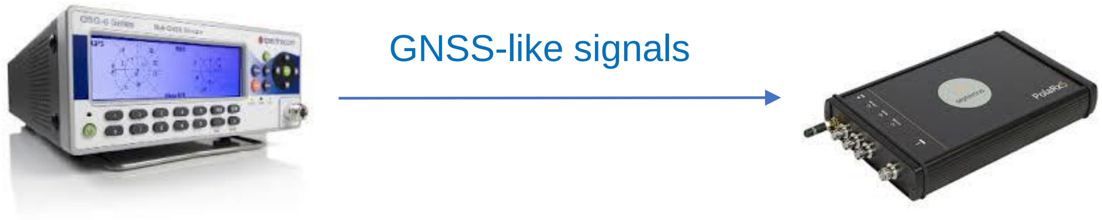
- ✓ The offset between UTC and Galileo System Time : UTC – GST
- ✓ the OS dual-frequency UTC dissemination accuracy : UTC – UTC_SiS
- ✓ the GGTO accuracy

METHODOLOGY

Positioning computation taking into account station delays provides GNSS_time – UTC(k) that can be compared to broadcast messages

>> this requires calibration of the station

Absolute calibration of the receiver



Delay of the receiver = PR of the receiver – PR of the simulator

Corrected by :

- the simulator delay
- the delay of the cables
- the delay between the internal reference of the receiver and the external 1 pps

Absolute calibration - results

Results for a Septentrio PolaRx4 TR PRO using 2 different simulators :

	Spirent 4760	Spectracom GSG-6
GPS P1	36.5 ns (σ = 0.5)	36.0 ns (σ = 0.5)
GPS P2	35.2 ns (σ = 0.5)	35.3 ns (σ = 0.9)
GPS C5	-	42.6 ns (σ = 0.4)
Galileo E1	-	36.1 ns (σ = 0.4)
Galileo E5a	-	43.0 ns (σ = 0.4)

Results agree within 0.5 ns for GPS P1 and P2

Absolute calibration of a GPS/BeiDou chain (NIM)

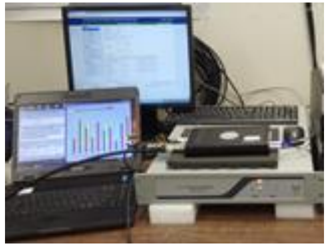
Delay of the receiver

(ns)	RxD	AD
C1	-45.5 (σ = 0.6)	20.0 (σ = 0.6)
P1	-44.9 (σ = 0.4)	20.7 (σ = 0.5)
P2	-49.6 (σ = 0.9)	14.8 (σ = 0.3)
B1	-45.8 (σ = 0.9)	22.4 (σ = 0.7)
B2	-40.4 (σ = 0.6)	14.6 (σ = 0.7)

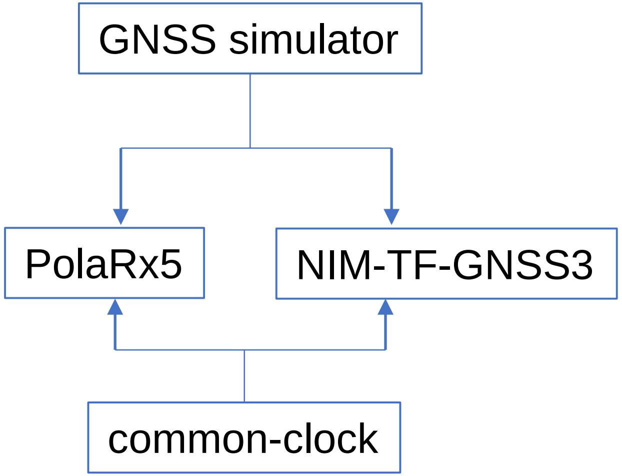
Delay of the antenna

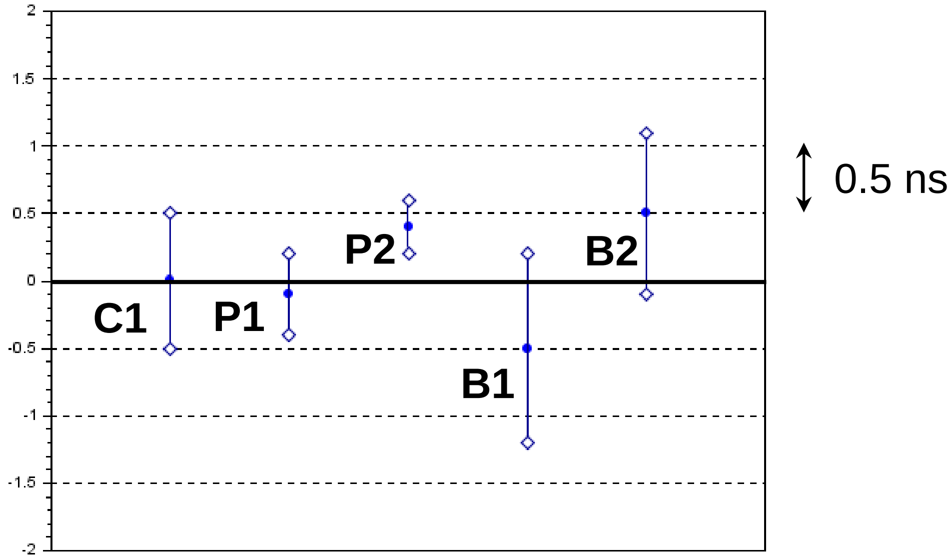
Receiver NIMTFGNSS-3
Antenna HARXON CSX 601A

Absolute calibration of a GPS/BeiDou chain (NIM)



Validation of the delay of the receivers in CV using a simulator





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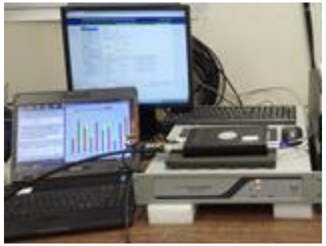

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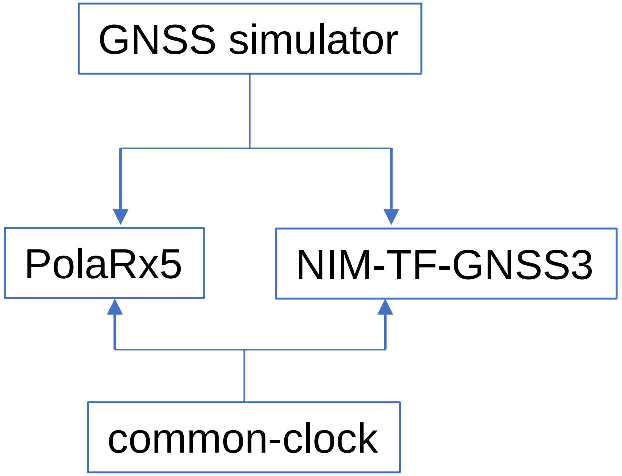
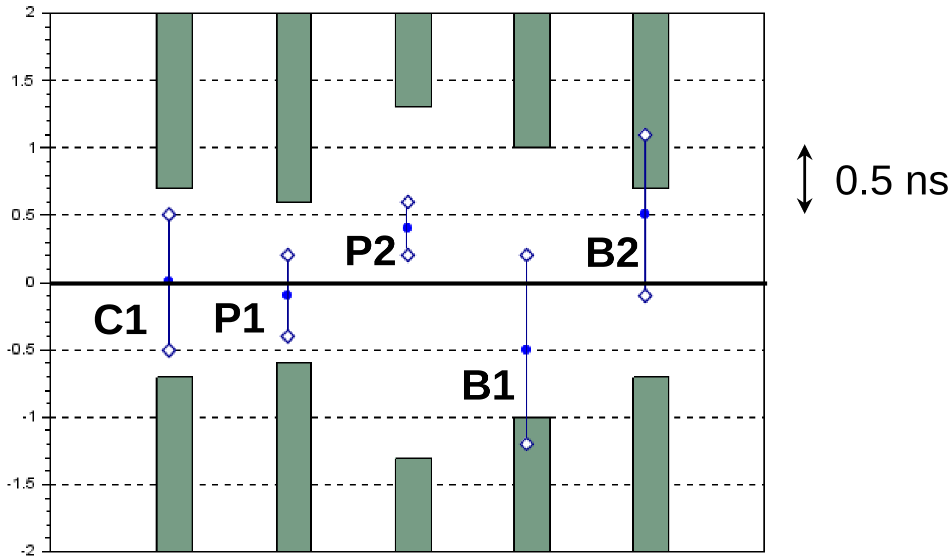
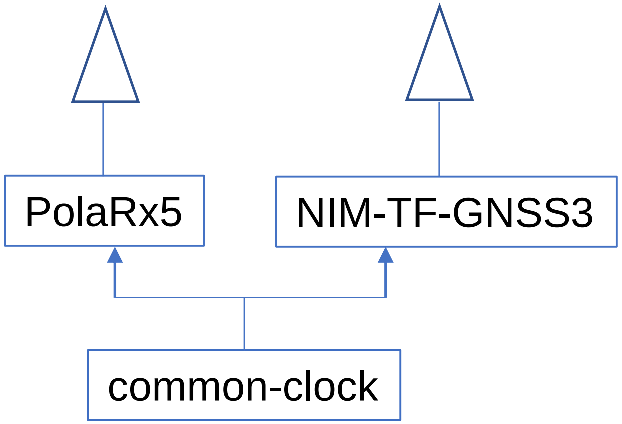
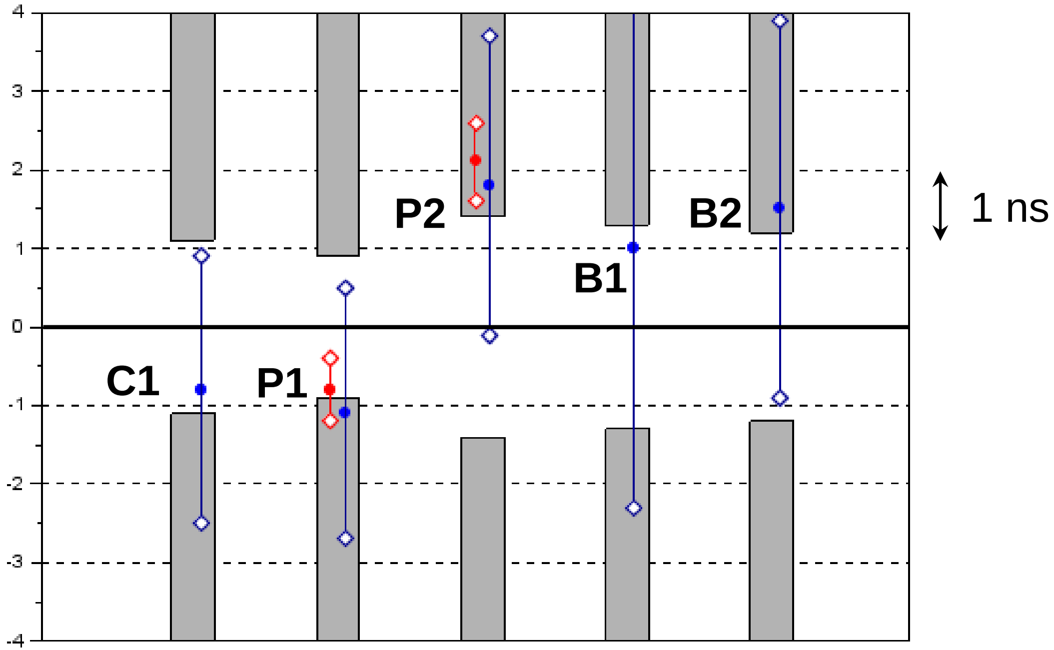




Absolute calibration of a GPS/BeiDou chain (NIM)

Overall validation in CV (CGGTTS and RINEX) using real signals





Means and tools

- **Software**
  - R2CGGTTS : ORB software that provides clock solutions for GNSS time transfer in the CGGTTS format
  - Alternative Software for RINEX to CGGTTS conversion will be used (SPRING, ROA, RISE-GNSS)

- **Stations**
  - CNES : absolute calibration for GPS P1, P2 and Galileo E1, E5a (since 7th June 2017) [1]
  - INRiM, NPL, ROA and RISE :
    - GPS P1, P2 : relative calibration vs. their reference station
    - Galileo E1 considered as equal to GPS P1 [1]
    - Galileo E5a : calibrated using the original technique developed by ORB [2]

[1] « Progress on absolute calibrations of GNSS reception chains at CNES », J. Delporte et al. , Proc. of IFCS 2016

[2] « Advances on the use of Galileo signals in time metrology: calibrated time transfer and estimation of UTC and GGTO using a combined commercial GPS-Galileo receiver », P. Defraigne et al., Proc. of PTTI 2013

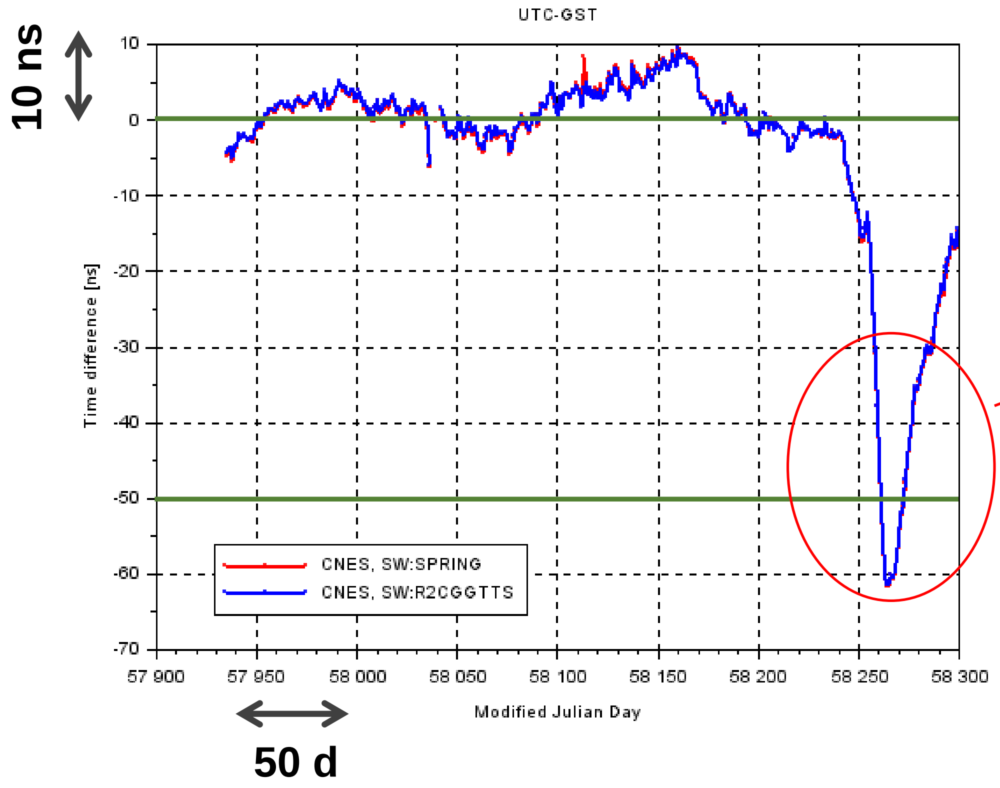
KPI#1 : UTC-GST offset

$$UTC - GST = (UTC - UTC(k)) + (UTC(k) - GST)$$

from BIPM circular T
(daily values obtained by interpolation)

computed at 00:00:00
(by linear regression)
using SPRING and R2CGGTTS software

KPI#1 : UTC-GST offset
CNES station (June 2017 to June 2018)



Mean : -3.8 ns
Std : 14.0 ns
95% : 37.5 ns

Behavior accurately reflected in the UTC-GST brdc info
► no impact to users
(see next slides)

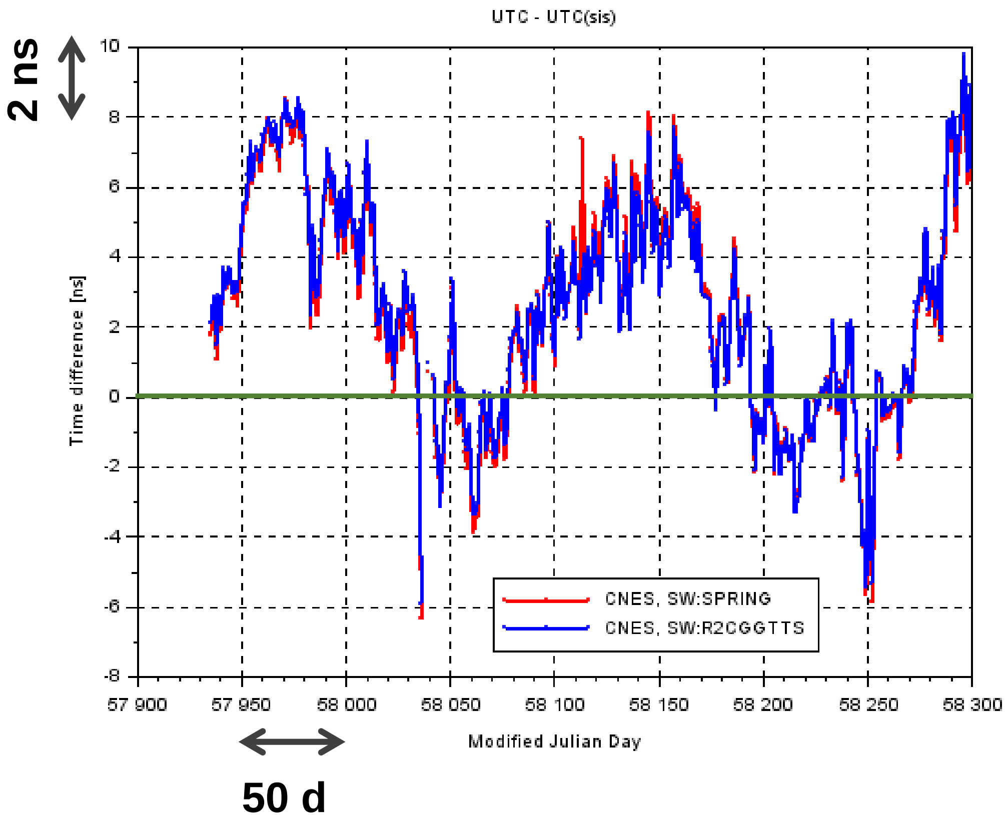
KPI#2 : UTC - UTC_SiS offset

$$UTC - UTC\_SiS = (UTC - GST) - (UTC\_SiS - GST)$$

computed as previously explained

from GAUT broadcast values in the Galileo RINEX nav file

KPI#2 : UTC - UTC_SiS offset
CNES station (June 2017 to June 2018)



Initial Services Requirement < 30 ns, 95 % over all age of data, normalised annually

Mean : 2.5 ns
Std : 3.1 ns
95% : 7.7 ns

OK ☑

KPI#3 : GGTO accuracy

GGTO accuracy = GGTO_computed – GGTO_SiS

computed as :
(GST – UTC(k)) – (GPST – UTC(k))

from GPGA broadcast values in the RINEX nav file

RINEX v3.04

Up to v3.03, the RINEX navigation file header showed :

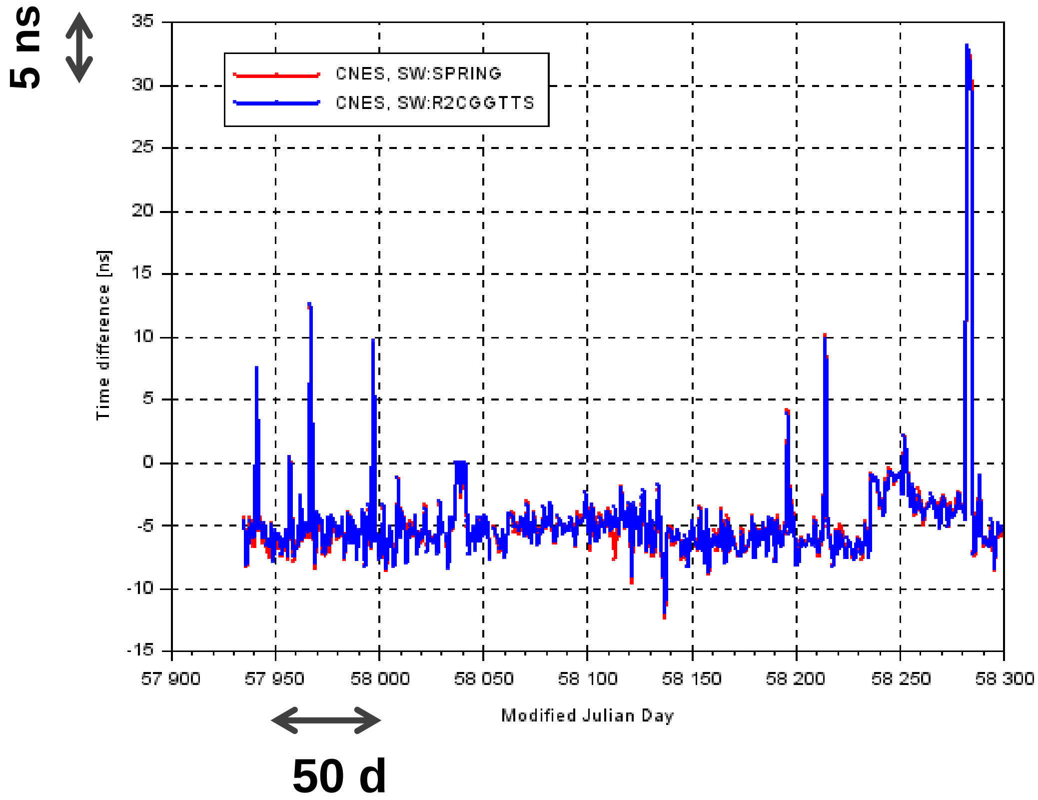
- GPUT = GPS to UTC
- GAUT = GAL to UTC
- GPGA = GPS to GAL … but was in fact GAL – GPS

New v3.04 will clarify :

- GPUT = GPS – UTC
- GAUT = GAL – UTC
- GAGP = GAL – GPS

New formulation in v3.04 is no more ambiguous

KPI#3 : GGTO accuracy
CNES station (June 2017 to June 2018)



Initial Services Requirement < 20 ns, 95% of average daily offset, normalised annually

Mean : -5.4 ns
Std : 1.8 ns
95% : 8.2 ns

OK ☑

SUMMARY

- The GRC-MS will monitor independently the performances of Galileo, and in particular of GST
- This monitoring requires absolute calibration of the station
- CNES has already started the monitoring of 3 timing KPIs, that are up to now compliant to the Galileo OS time requirements
- GST has underwent a drift in May-June 2018 but the broadcast information GST – UTC remained accurate, inducing no impact to users

Thank you for your attention

Questions ?

jerome.delporte@cnes.fr