ICG-14

Absolute calibration of GNSS receiver chains and cross-validation activities

ICG-14 – 10th Dec 2019

Jérôme DELPORTE - David VALAT - Amale KANJ (CNES)

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

OUTLINE

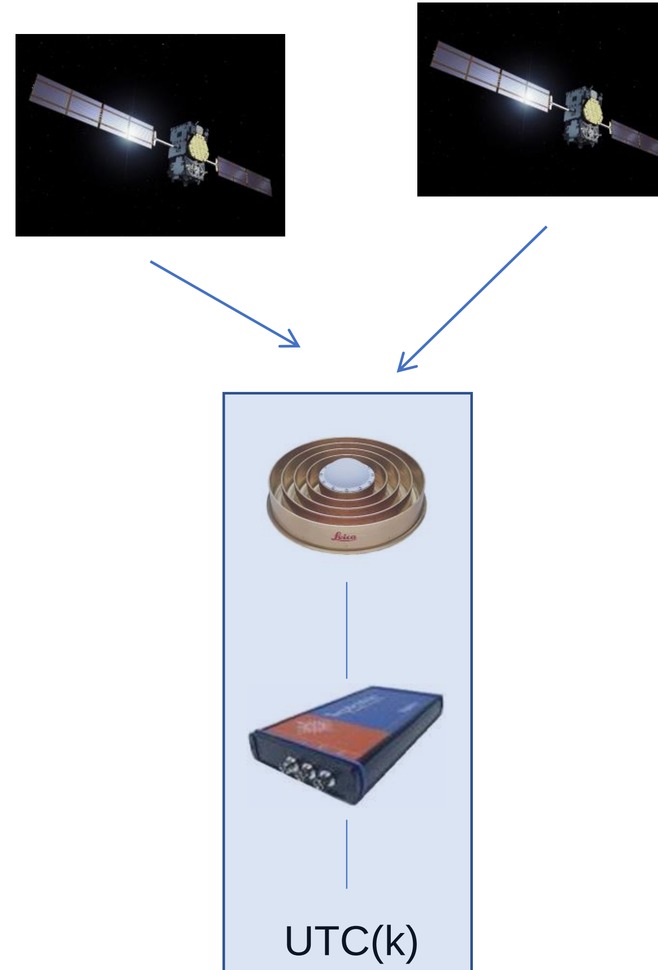
- RATIONALE
- ABSOLUTE CALIBRATION APPROACH
- RESULTS AT CNES
- CROSS-VALIDATION WITH ESTEC
- MONITORING OF GNSS TIMES

RATIONALE

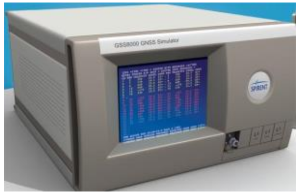
In order to determine GNSS_time – UTC, it is mandatory to use a GNSS receiver chain connected to a UTC(k) with correction of the station delays

This correction is the calibration of the station

This approach can also be used to determine the XYTO (GNSS to GNSS time offset)



Absolute calibration



A GNSS simulator can be used to calibrate each element of the GNSS receiver chain independently (with different setups)

GNSS-like signals

Absolute calibration of the receiver

GNSS-like signals

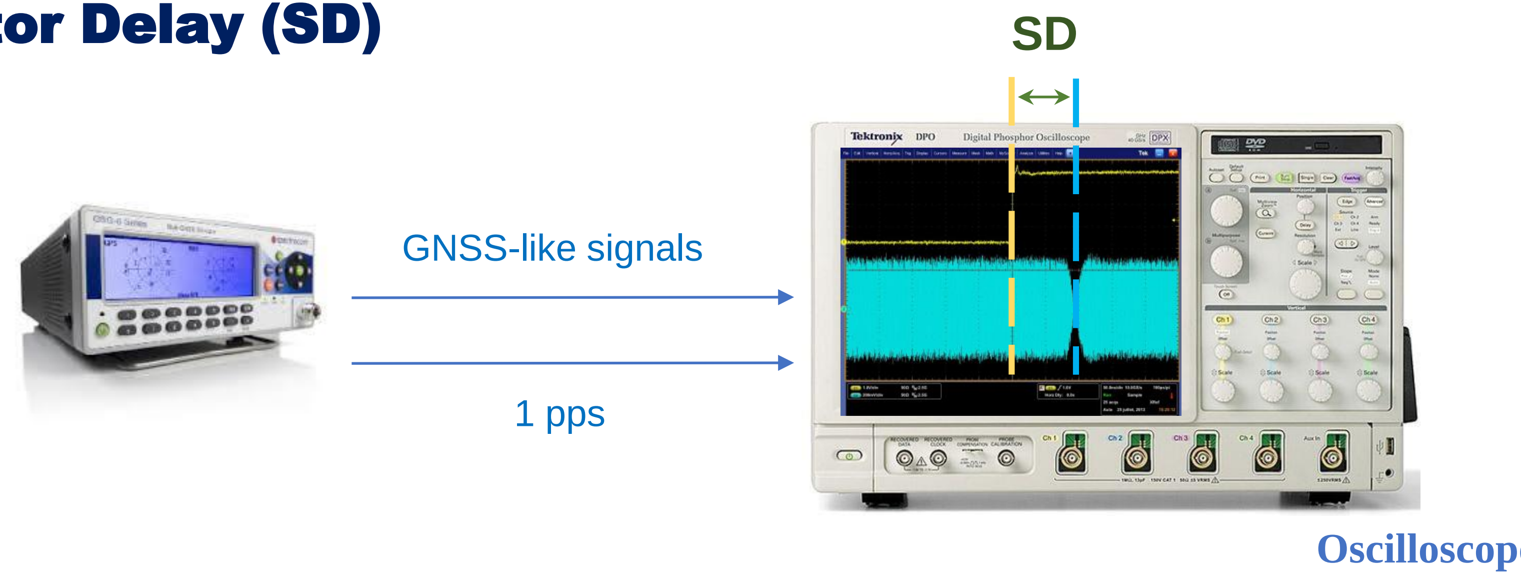
1 pps

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

Simulator Delay (SD)

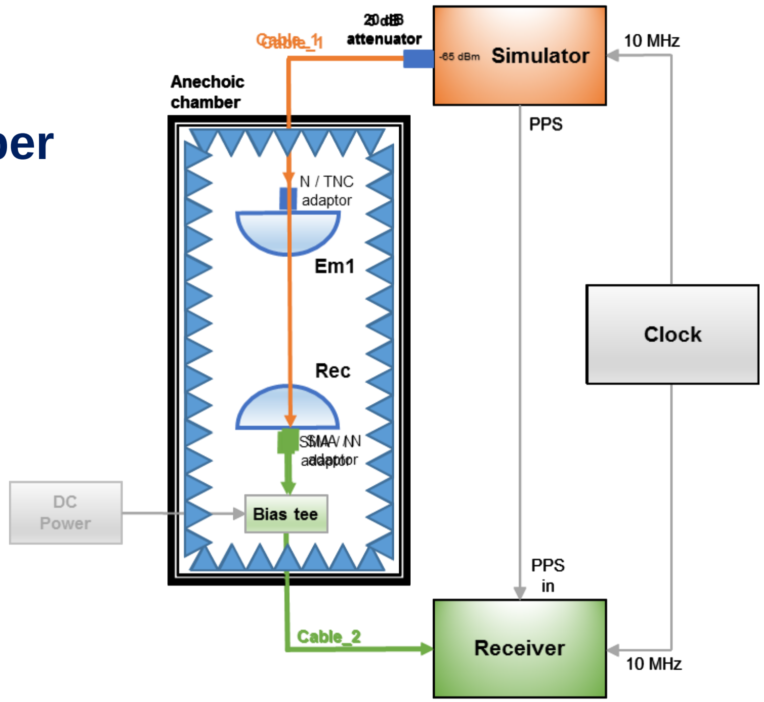


SD = time offset betwen the beginning of the GNSS code and the pps

Data analyzed by dedicated correlation software

Done for each GNSS signal successively

Absolute calibration of the antenna



Use of a small dedicated anechoic chamber

Zenith delay only

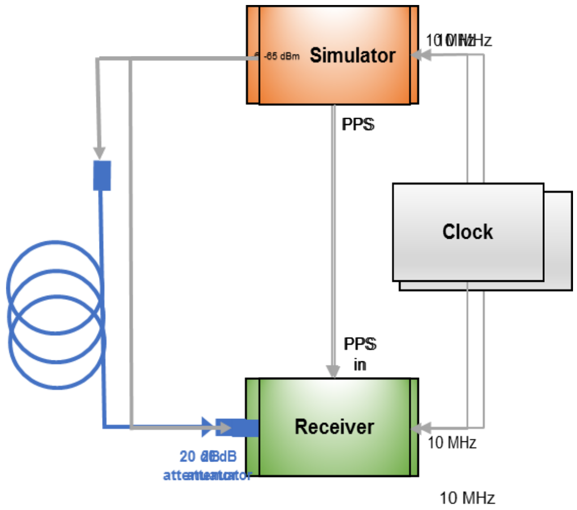
Differential measurement:

- ► no simulator or receiver calibration
- ► no cables measurement

Absolue calibration of the antenna cable

Differential measurement

Same approach as the antenna

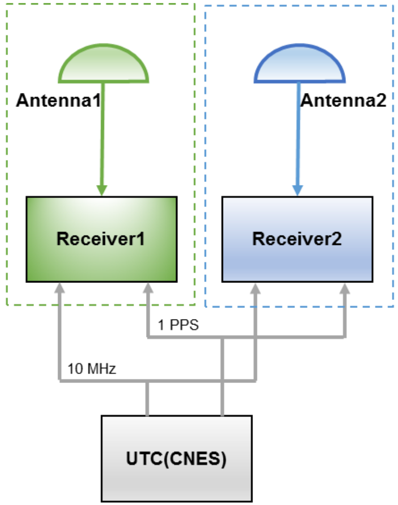


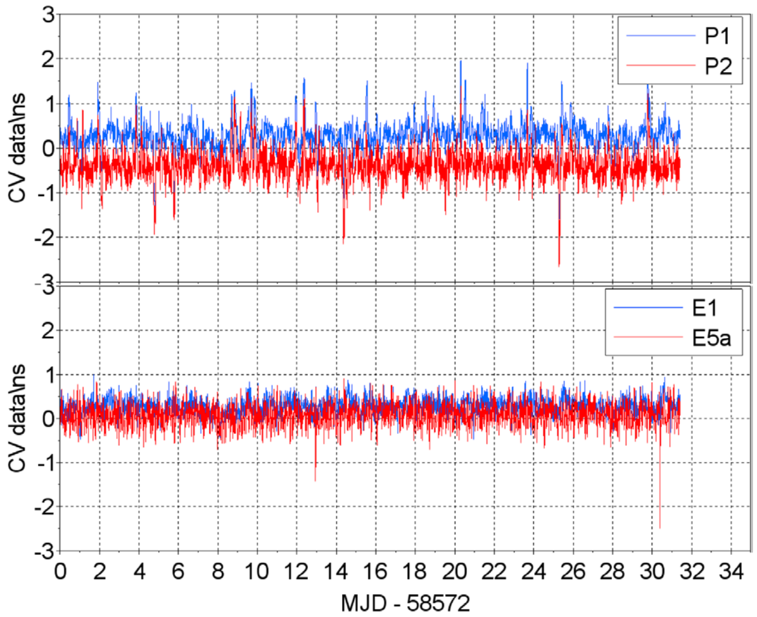
Uncertainties for a complete chain

	Typical uncertainty (ns)
Receiver	0.3 to 0.5
RF cable	0.2
Antenna	0.2 to 0.5
Rx1pps	0.1 to 0.2
Ref Delay	0.1
Position	0.1
Multipath	0.2
Total	**0.5 to 1.0 ns**

All details in
Valat D and Delporte J, “Absolute calibration of timing receiver chains at the nanosecond uncertainty level for GNSS time scales monitoring”, *Metrologia* (in press), https://doi.org/10.1088/1681-7575/ab57f5

Validation in common-clock





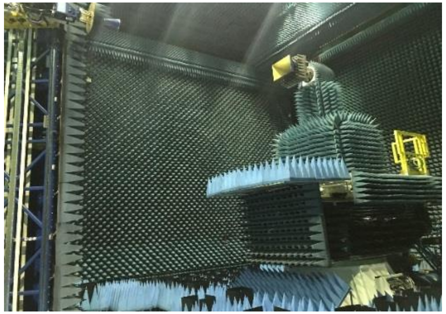
	GPS P1	GPS P2	GAL E1	GAL E5a
Mean difference	0.29	-0.39	0.28	0.08
Uncertainty	1.03	1.21	0.89	0.87

Validation with another absolute calibration [1/3]

Same antenna calibrated both by CNES and ESA

Significantly different setups

ESA	CNES
Large anechoic chamber	Small anechoic chamber
Azimuth/elevation delays	Zenith delay only
CW signals (VNA)	GNSS signals (simulator)



Results : consistency < 1 ns for GPS and Galileo codes

All details in
Waller P, Valceschini R, Delporte J, Valat D, “Cross-calibrations of multi-GNSS Receiver Chains”, *Proc. of IFCS-EFTF 2019*

Validation with another absolute calibration [2/3]

Same receivers calibrated both by CNES and ESA

Significantly different setups

ESA	CNES
Spirent simulator	Spectracom simulator
Simulator calibration with one data set for all codes	Simulator calibration with one data set for each code
ESA correlation software	CNES correlation software

Consistency

- **0.4 to 1.1 ns for PolaRx5**
- **0.6 to 2.7 ns for PolaRx4 (using ESA “old” procedure)**

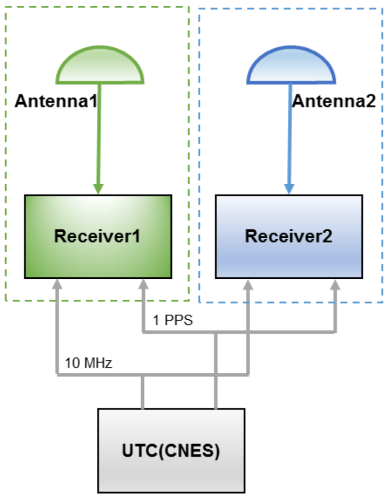
for GPS and Galileo codes

All details in
Waller P, Valceschini R, Delporte J, Valat D, “Cross-calibrations of multi-GNSS Receiver Chains”, *Proc. of IFCS-EFTF 2019*

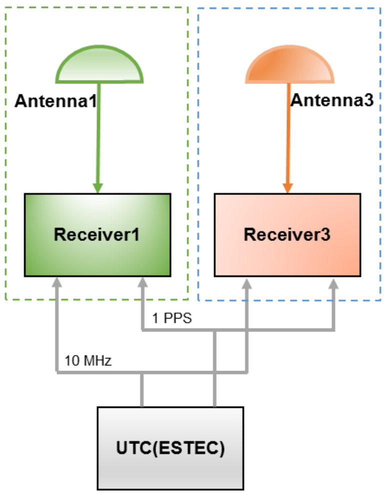
Validation with another absolute calibration [3/3]

Full receiver chains with real signals @ CNES and @ ESA

CNES site



ESA site



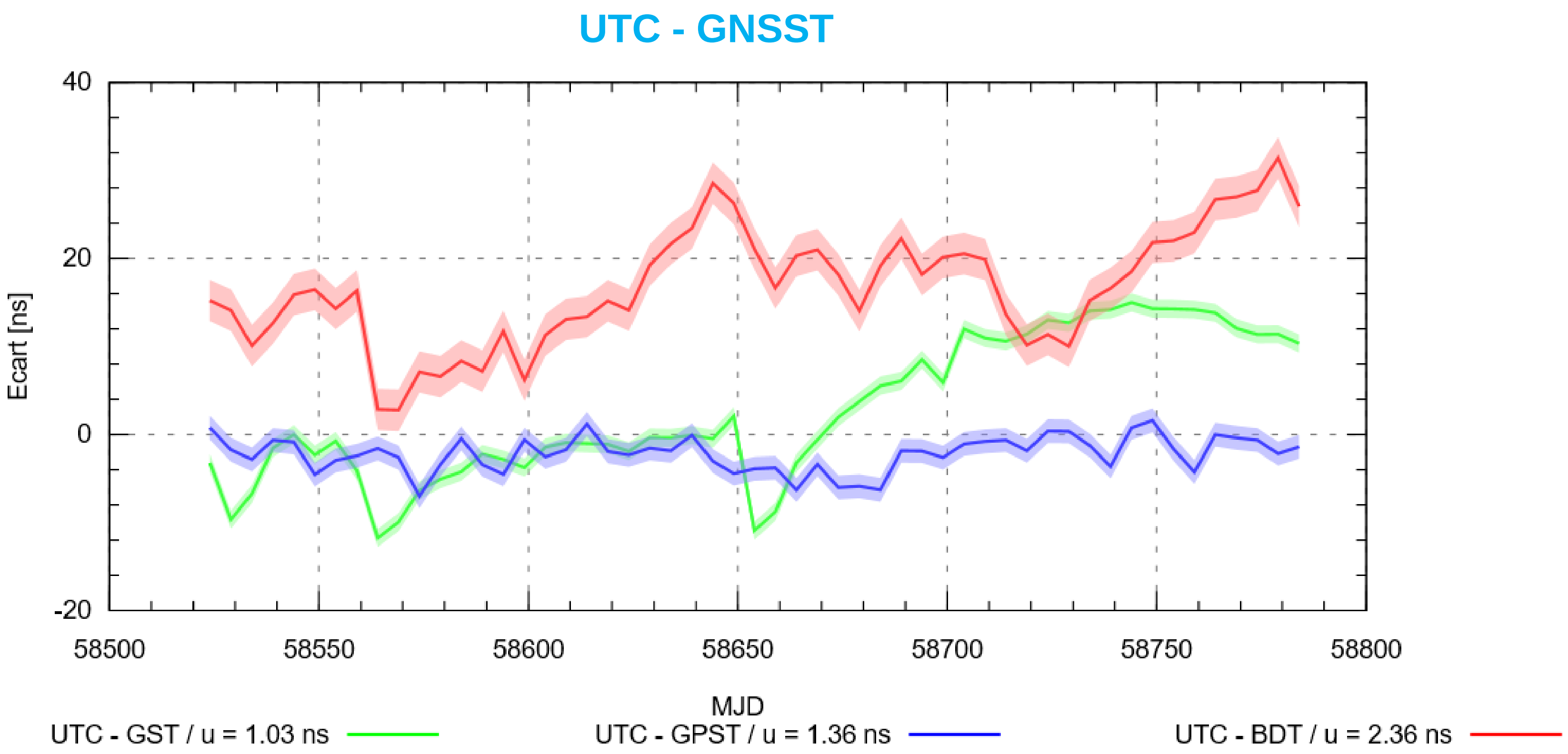
Consistency : 1-3 ns on both CNES and ESA sites

for GPS and Galileo codes

Similar to previously reported results

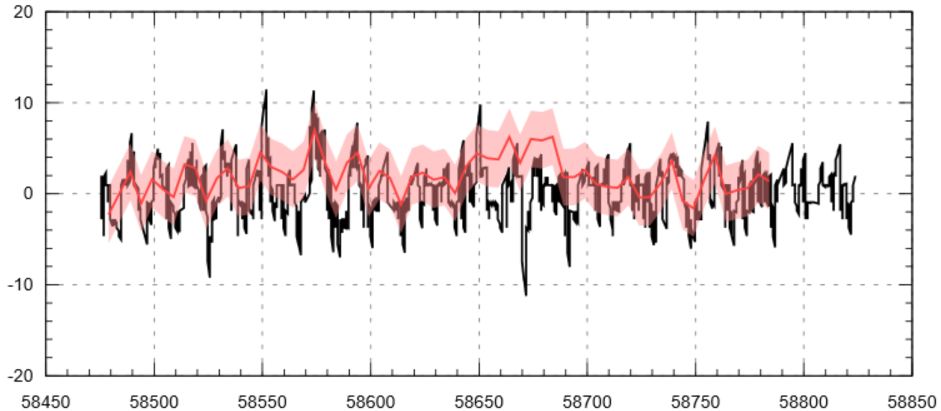
All details in
Waller P, Valceschini R, Delporte J, Valat D, "Cross-calibrations of multi-GNSS Receiver Chains", *Proc. of IFCS-EFTF 2019*

Monitoring of GPST, GST and BDT

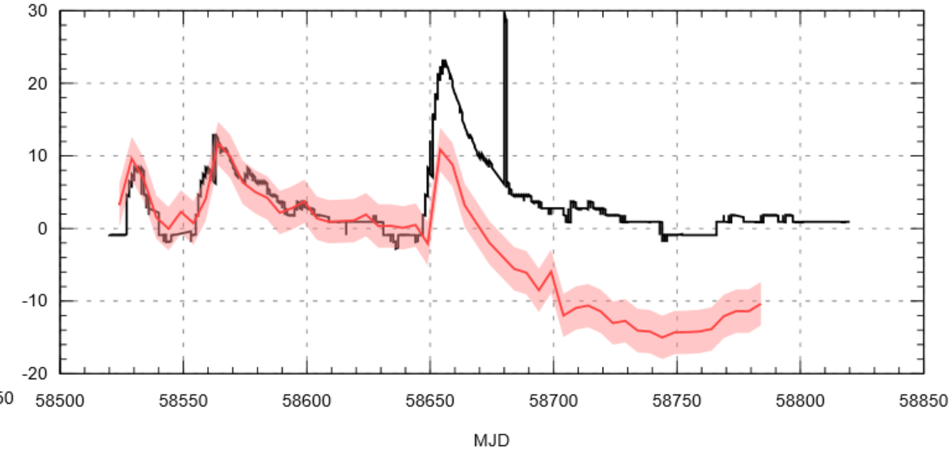


Comparison with UTC broadcast information

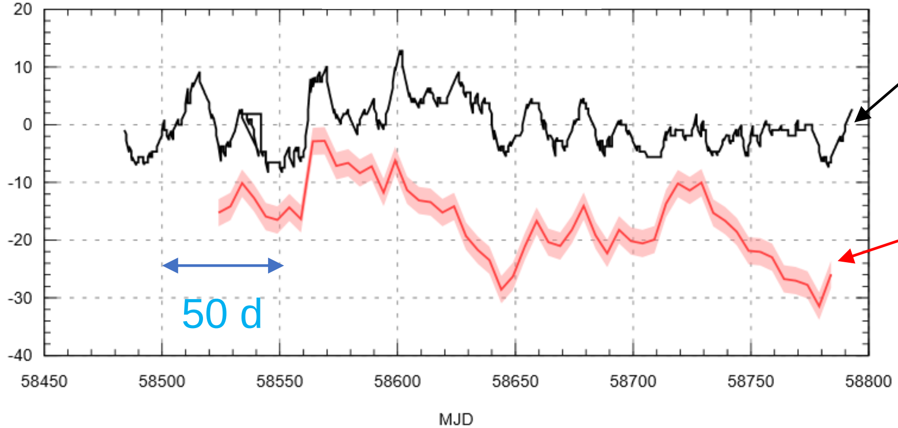
GPST - UTC



GST - UTC



BDT - UTC



broadcast UTC information

Local evaluation
GNSST – UTC =
GNSST – UTC(CNES) + UTC(CNES) - UTC

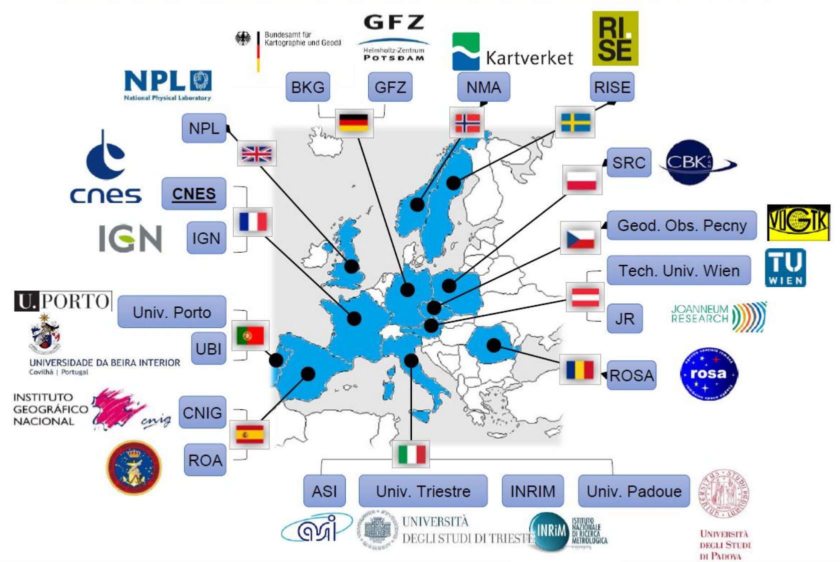
GRC and GRC-MS

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)

Objective: monitoring of Galileo timing performances

- ✓ offset between UTC and Galileo System Time : UTC – GST
- ✓ UTC dissemination accuracy : UTC – UTC_SiS
- ✓ Frequency of UTC dissemination accuracy : freq(UTC – UTC_SiS)
- ✓ GGTO accuracy
- ✓ availability of GAUT and GGTO information

Conclusions

- Absolute calibration is essential to monitor GNSS_time – UTC
- It is also a possible means to determine/monitor the XYTO
- Cross-calibration campaign successfully carried out between ESA and CNES
- More cross-calibration activities should be performed with interested parties and involving if possible all GNSS signals

Thank you for your attention

Questions ?

jerome.delporte@cnes.fr