

NAVISP-EL2-054 EPIC: An ITU ePRTC Clock Standard with Advanced GNSS Capabilities

FINAL PRESENTATION

Webex

JULY 11, 2022

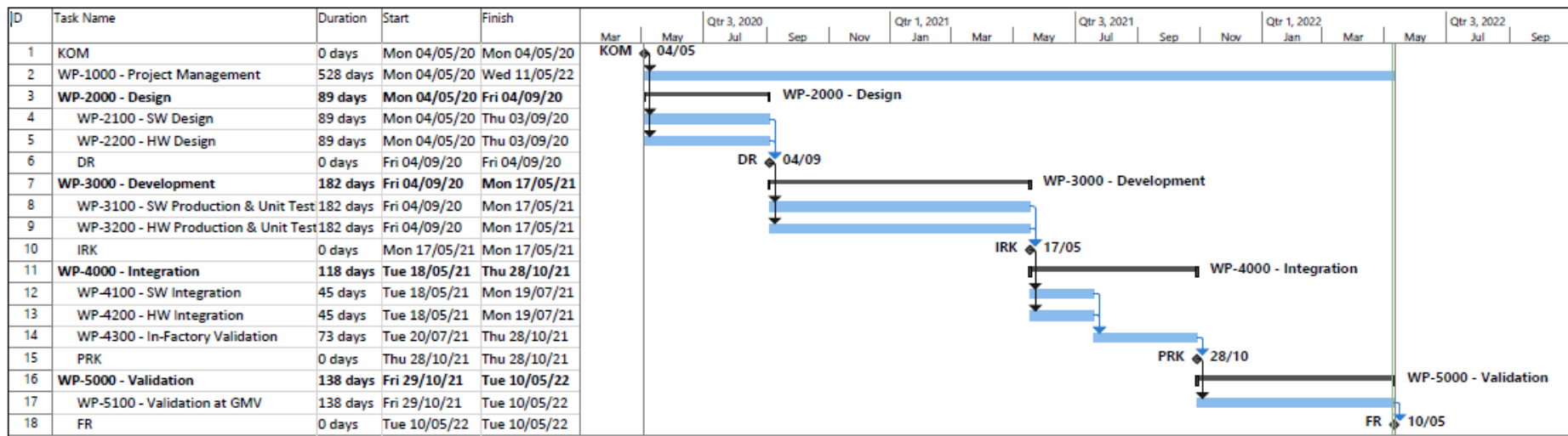
Agenda

- ❑ EPIC Project Objectives
- ❑ EPIC Phases and Schedule
- ❑ EPIC Architecture
- ❑ EPIC Key Issues
 - GNSS Calibration
 - UTCO RINEX
 - Timing Integrity
 - Micro-stepper
 - UTC Time Scale
 - PHM Holdover
- ❑ Project Outcome
- ❑ Conclusions

EPIC Project Objectives

- ❑ The objective of the EPIC project was to design, develop and implement an enclosed solution for the new ePRTC (enhanced Primary Reference Time Clock) standard, implementing additional features to enhance the robustness and quality of the solution, considering the most advanced techniques available in the timing community.
- ❑ The ITU-T ePRTC standard defines a synchronization source, which provides the necessary precision, robustness and reliability required by today's and next-generation telecom, banking, data centres and energy distribution networks. The ePRTC system generates its own independent time scale that is aligned to UTC and reduces its dependency on GNSS by means of an atomic clock. With ePRTC, a maximum time error of 30 ns w.r.t. to UTC in nominal working mode and a maximum time error of 100 ns w.r.t. to UTC after 14 days of holdover (without GNSS input) is guaranteed.

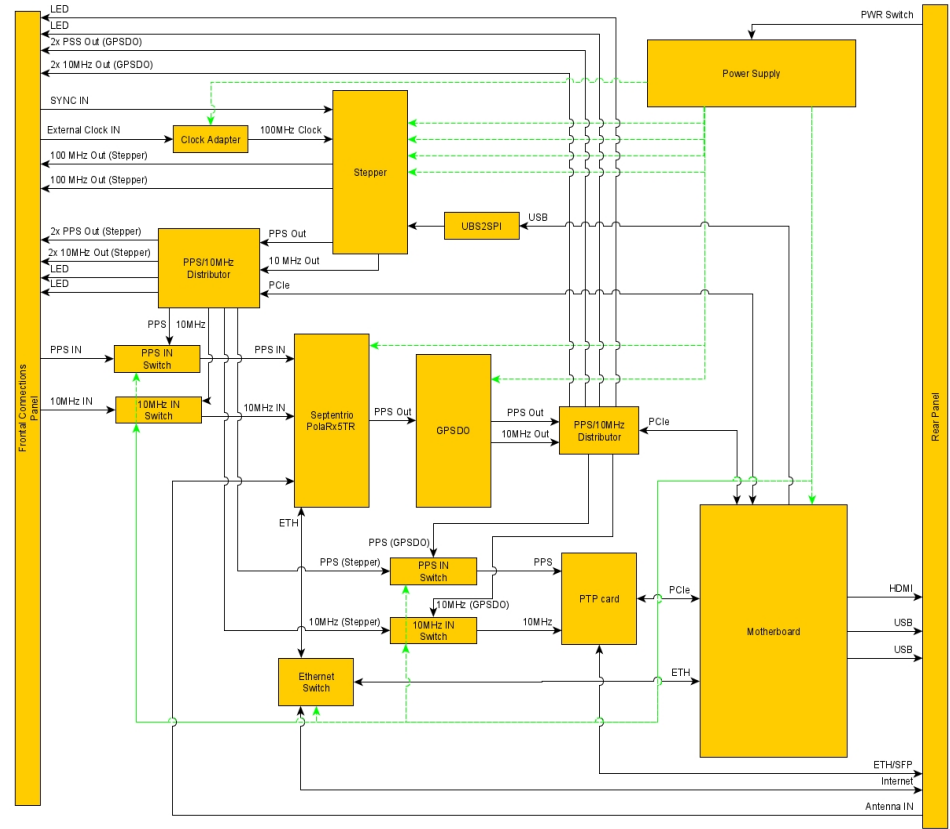
EPIC Phases and Schedule



EPIC HW Architecture

EPIC is composed by the following HW elements:

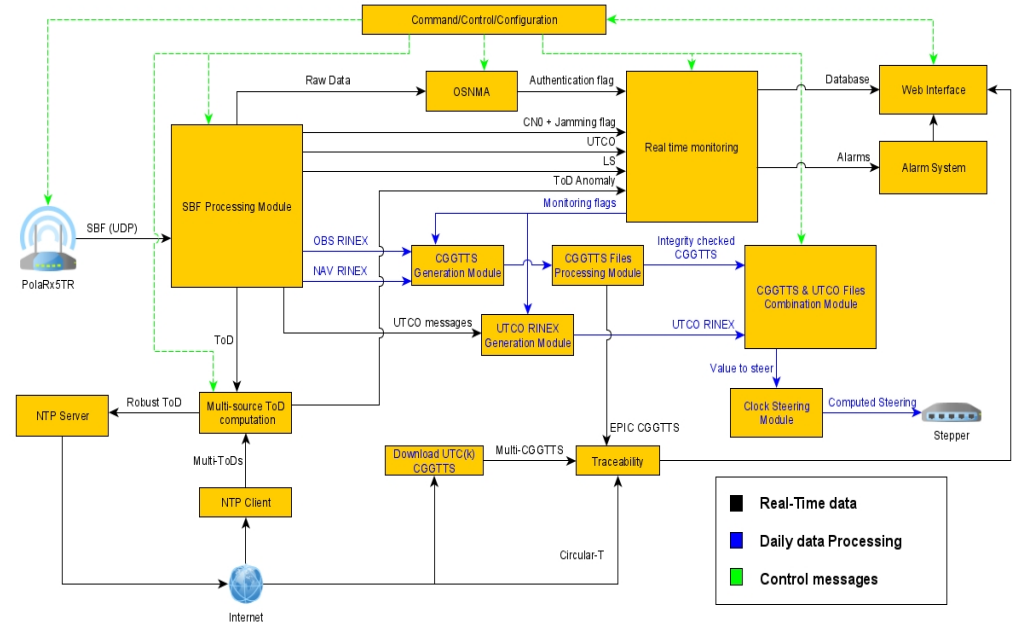
- External Passive Hydrogen Maser
- Clock Adapter
- Frequency micro-stepper
- GNSS receiver and antenna
- GPSDO
- Processing unit
- 1PPS/10MHz switches
- 1PPS/10MHz distributor



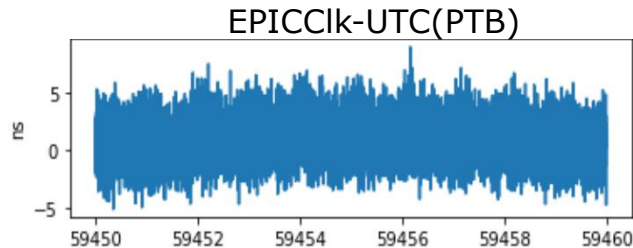
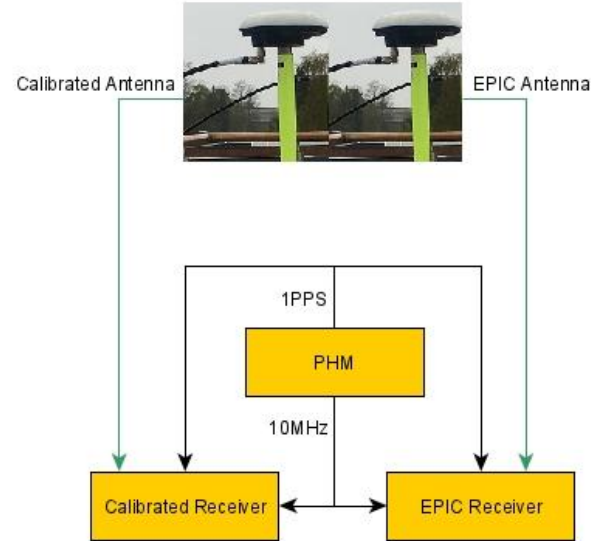
EPIC SW Architecture

□ The EPIC processing chain is composed by 3 main elements:

- Access to UTC via UTCO+CGGTTS combination.
- Computation of clock model and steering from the UTCO+CGGTTS data.
- Alarms monitoring the continuity and accuracy of the data.



EPIC GNSS Calibration



GNSS Signal	Calibrated Receiver Delay [ns]	Relative Diff. [ns]	EPICA TOTAL delay [ns]	Uncertainty* [ns]
'L1P'	15.45	2.06	17.52	1.5
'L2P'	14.94	0	14.94	
'E1C'	17.67	2.18	19.85	
'E5Q'	17.05	0.18	17.23	

GNSS Signal	EPICA TOTAL delay [ns]	Relative Diff. [ns]	EPICB TOTAL delay [ns]	Uncertainty* [ns]
'L1P'	17.52	-1.61	15.91	1.5
'L2P'	14.94	1.06	16.00	
'E1C'	19.85	-1.56	18.29	
'E5Q'	17.23	0.37	17.60	

GNSS Signal	EPICA TOTAL delay [ns]	Relative Diff. [ns]	EPICC TOTAL delay [ns]	Uncertainty* [ns]
'L1P'	17.52	-1.00	16.52	1.5
'L2P'	14.94	1.69	16.63	
'E1C'	19.85	-0.72	19.13	
'E5Q'	17.23	0.42	17.65	

*The 1.5ns uncertainty is the typical uncertainty assumed by the BIPM when performing this type of calibration.

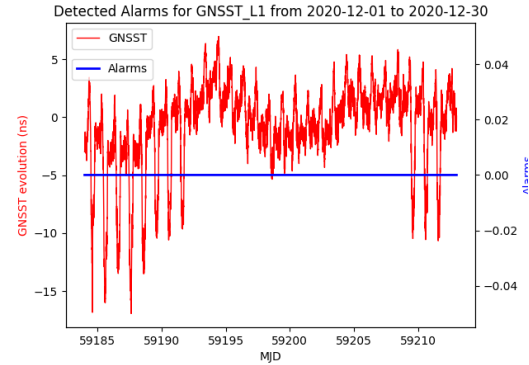
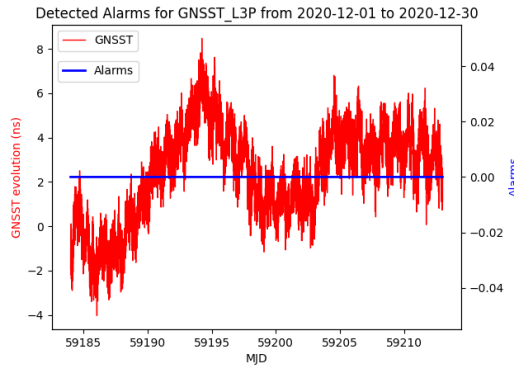
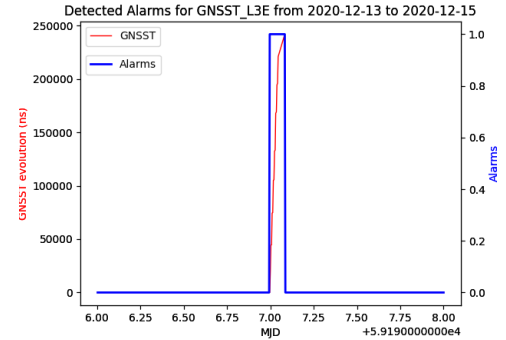
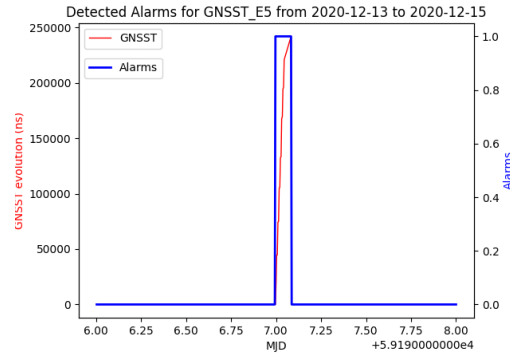
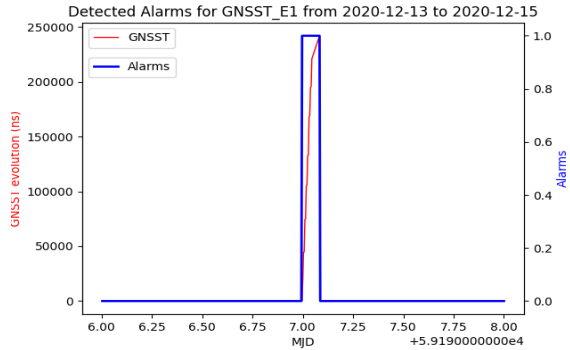
New UTCO RINEX

- ❑ The proposed UTCO RINEX format provides detailed information related to UTCO and leap seconds, which allows easily analysing, process and detecting any anomaly that affects any system using GNSS as a timing reference.
- ❑ The "u" extension is not taken in the existing RINEX convention, we could use it for our new RINEX UTCO files. For example, for the following file sample, the file name will be EPIC0110.22u

```
1          1.00          UTCO DATA M          RINEX VERSION / TYPE
2 G = GPS R = GLONASS E = GALILEO S = GEO M = MIXED          COMMENT
3 EXAMPLE OF VERSION 1 FORMAT          COMMENT
4 > EPOCH PRNs WN Te Selected_UTCO_GPS Selected_UTCO_GAL          EPOCH LINE FORMAT
5 PRN AO AI Tot WNT computed_UTCO Flag          PRN LINE FORMAT
6 0 - Invalid data set          FLAG INDICATOR
7 1 - Valid data set          FLAG INDICATOR
8 2 - Two or more valid data sets          FLAG INDICATOR
9 Summary of UTC Parameters          COMMENT
10 AU          seconds          UTC PARAMETER/ UNITS
11 AI          sec/sec          UTC PARAMETER/ UNITS
12 Tot          seconds          UTC PARAMETER/ UNITS
13 WNT          weeks          UTC PARAMETER/ UNITS
14 Te          seconds          UTC PARAMETER/ UNITS
15 WN          weeks          UTC PARAMETER/ UNITS
16          18          LEAP SECONDS
17          5          MIN ELEVATION
18 2022 1 11 00 00 00.000000          TIME OF FIRST OBS
19          END OF HEADER
20 > 2022 01 11 00 00 00.00000000 21 2192 172818 -2.691957069460e-09 -4.426345782280e-09
21 G01 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.963114179000e-09 2
22 G03 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.963114179000e-09 2
23 G08 -3.725290000000e-09 -4.440890000000e-15 405504 2192 -2.691957069460e-09 1
24 G10 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.963114179000e-09 2
25 G14 -5.587940000000e-09 -1.154630000000e-14 319488 2192 -3.894444179000e-09 2
26 G16 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.963114179000e-09 2
27 G21 -3.725290000000e-09 -4.440890000000e-15 405504 2192 -2.691957069460e-09 1
28 G22 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.963114179000e-09 2
29 G23 -3.725290000000e-09 -5.329070000000e-15 319488 2192 -2.943675303100e-09 0
30 G27 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.963114179000e-09 2
31 G32 -3.725290000000e-09 -4.440890000000e-15 405504 2192 -2.691957069460e-09 1
32 E01 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
33 E07 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
34 E08 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
35 E12 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
36 E13 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
37 E18 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
38 E24 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
39 E26 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
40 E31 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
41 E33 -4.656610000000e-09 2.664540000000e-15 86400 2192 -4.426345782280e-09 1
42 > 2022 01 11 05 00.00000000 21 2192 173118 -2.693289336460e-09 -4.425546420280e-09
43 G01 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.966578069000e-09 2
44 G03 -4.656610000000e-09 -1.154630000000e-14 319488 2192 -2.966578069000e-09 2
```

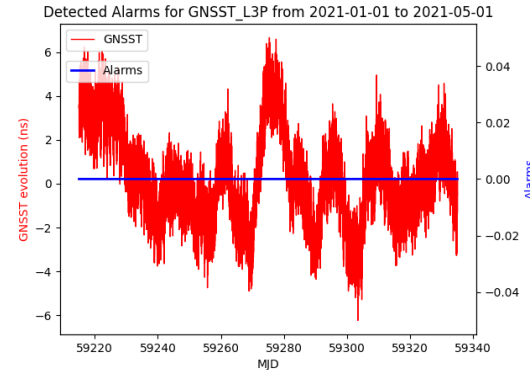
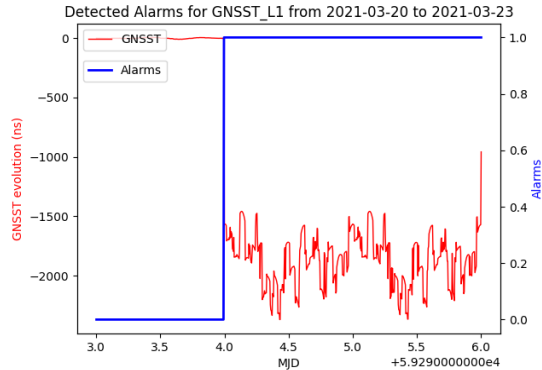
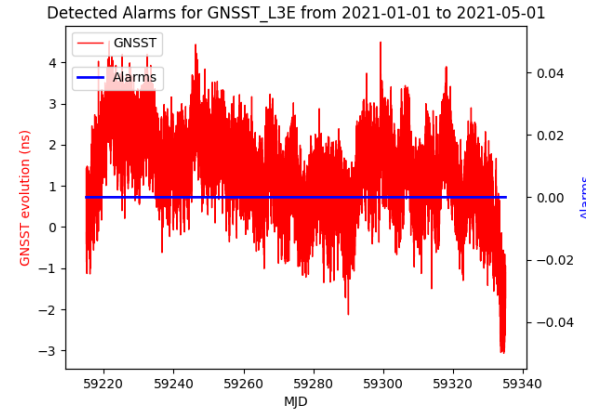
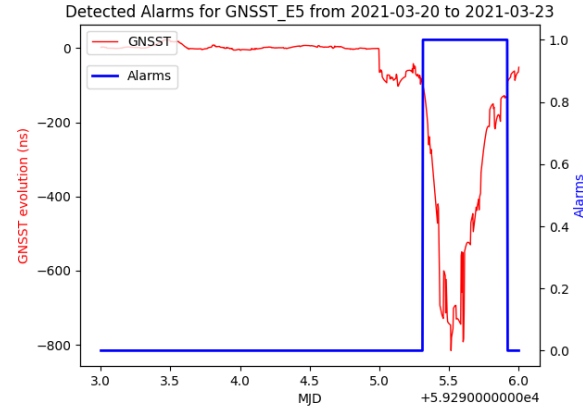
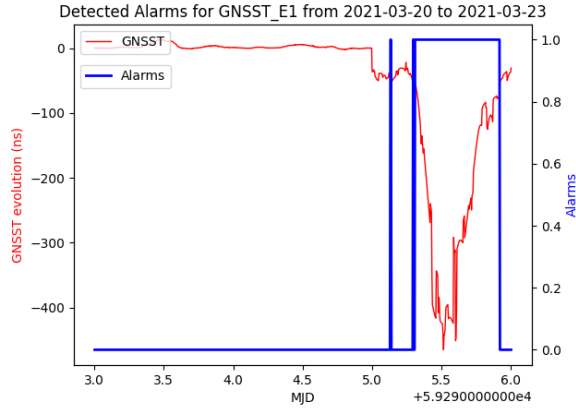
EPIC Timing Integrity – Data Anomalies

- ❑ NAGU 2020021 - 14th of December 2020 - Degradation of service on all Galileo satellites



EPIC Timing Integrity- Data Anomalies

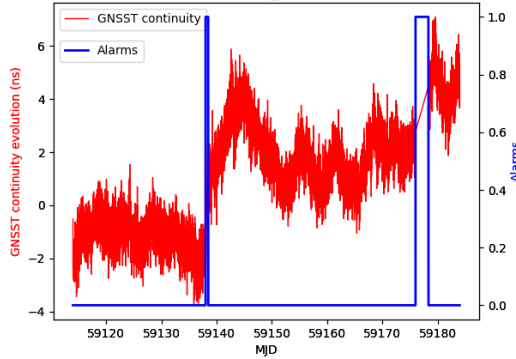
□ Induced ionospheric errors



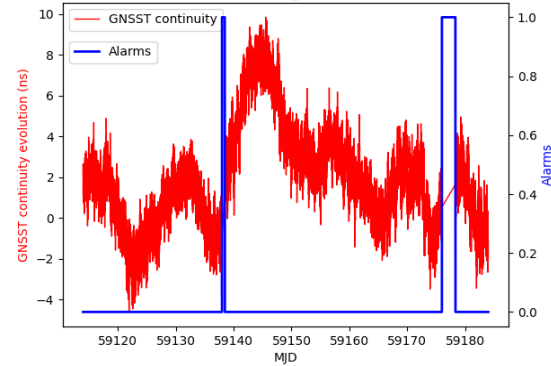
EPIC Timing Integrity – Data Continuity

- ❑ The first alarm from 2020-10-16 00:00:00 to 2020-10-16 05:00:00
- ❑ The second alarm from 2020-11-22 to 2020-11-25

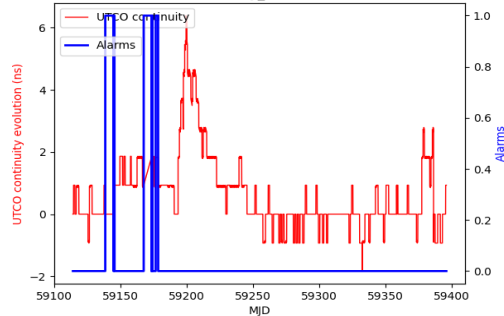
Detected Alarms for GNSST continuity_L3E from 2020-09-22 to 2020-12-01



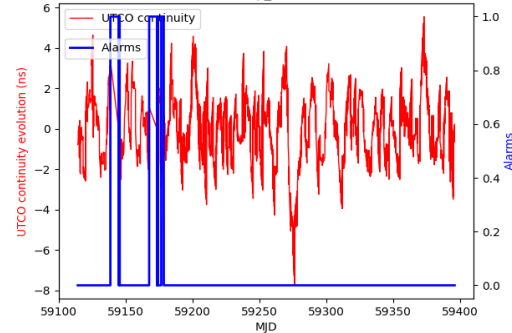
Detected Alarms for GNSST continuity_L3P from 2020-09-22 to 2020-12-01



Detected Alarms for UTCO continuity_GAL from 2020-09-22 to 2021-07-01

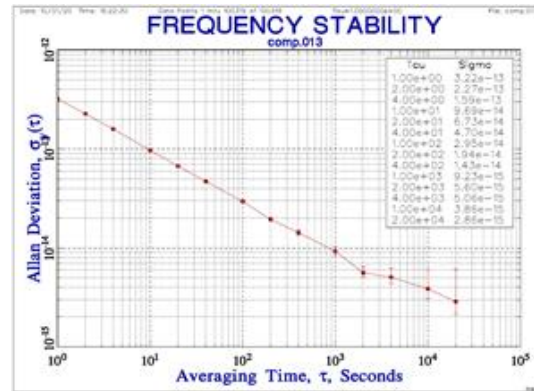
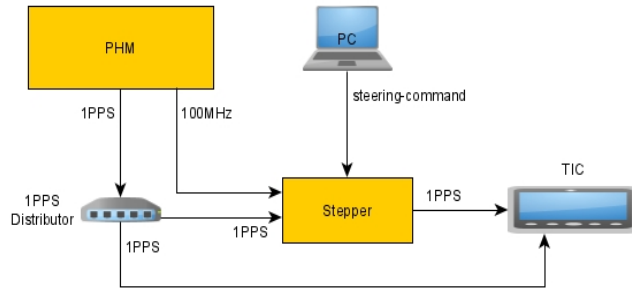
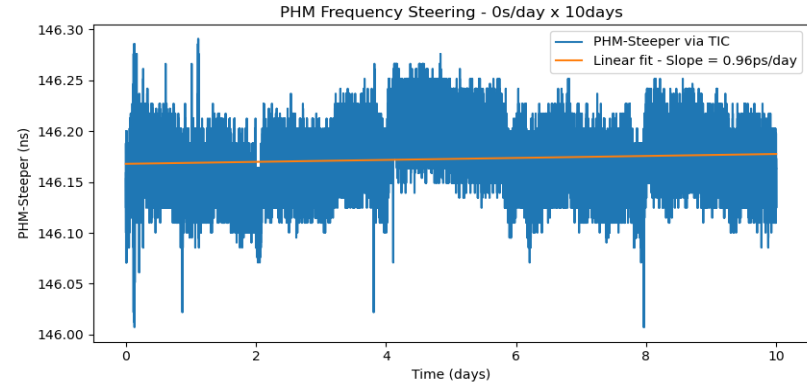
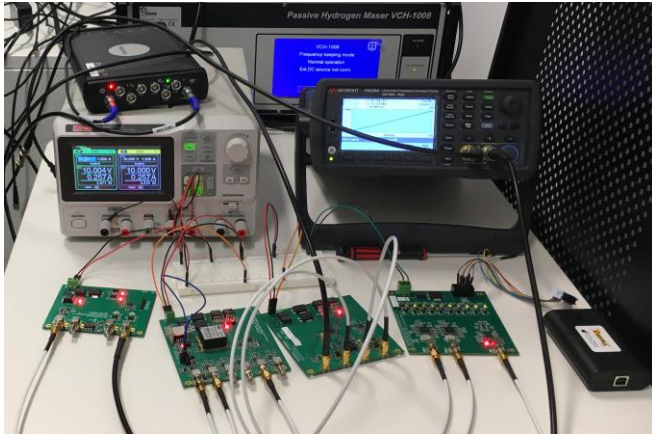


Detected Alarms for UTCO continuity_GPS from 2020-09-22 to 2021-07-01

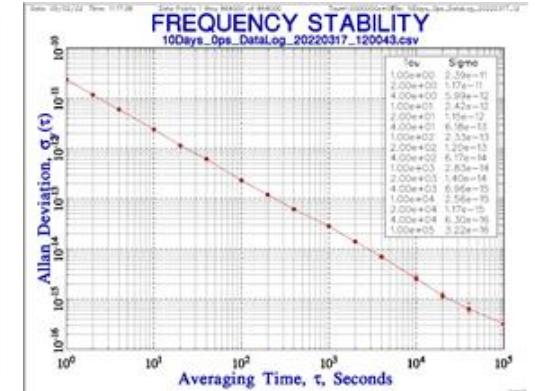


EPIC Micro-stepper

- ❑ Zero steering
- ❑ 10 days recording
- ❑ Slop of 0.96ps/day

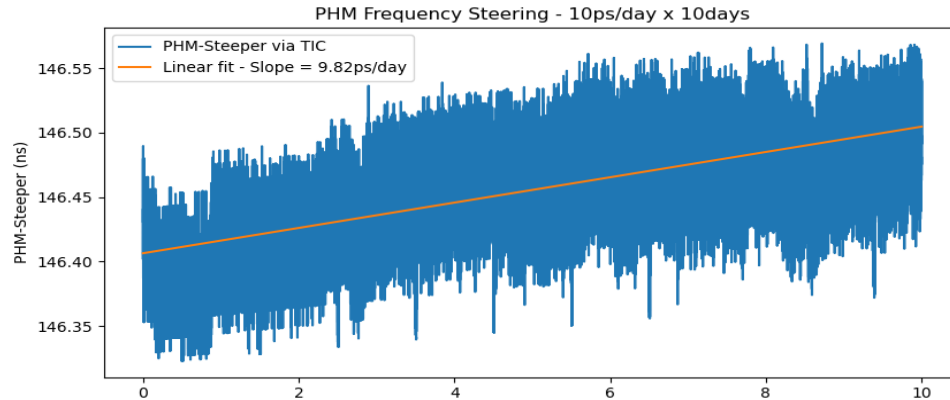


PHM ADEV

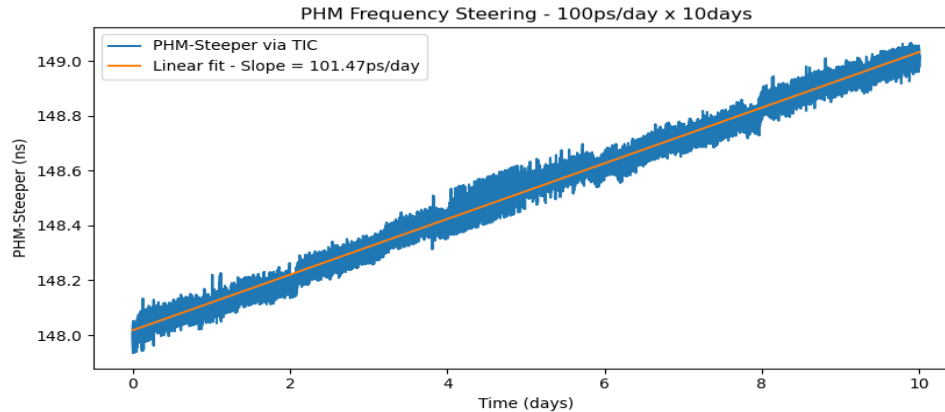


Micro-stepper ADEV
with 0 steering

EPIC Micro-stepper



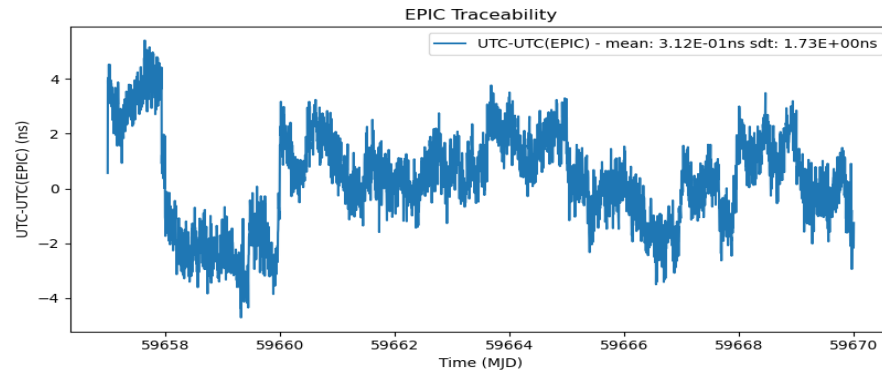
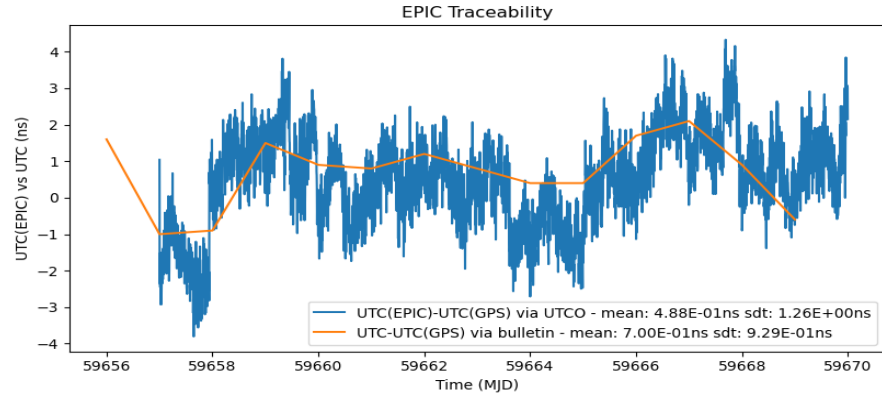
- 10ps/day steering
- 10 days recording
- slope of 9.82ps/day



- 100ps/day steering
- 10 days recording
- Slope of 101.47ps/day

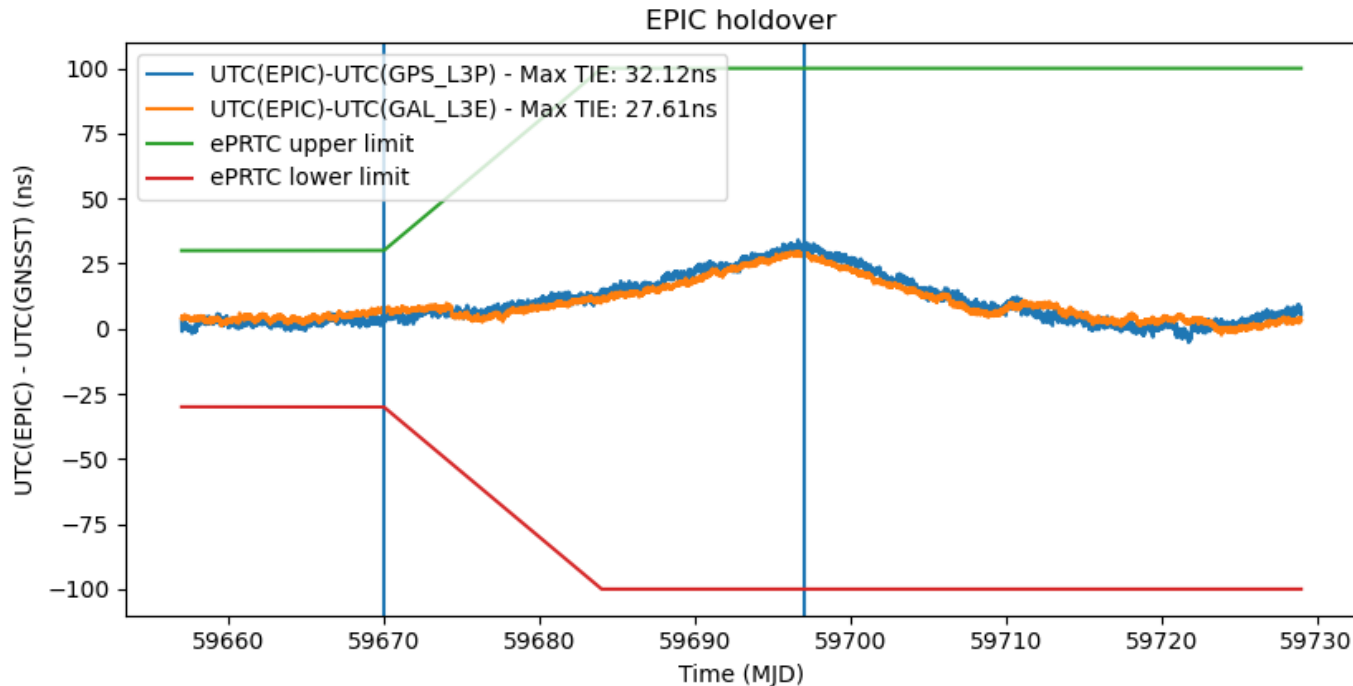
EPIC UTC Time Scale

- Comparison of the UTC(EPIC)-UTC(GPS) vs Circular-t UTC-UTC(USNO)_GPS data from 18/03/2022 to 31/03/2022 (14 days).



EPIC PHM Holdover vs ePRTC requirements

- Holdover from the 1st of April 2022 at 12pm to the 27th of April 2022 at 12pm (27 days).




Project Outcome - WANtime station - HW

The product generated during the EPIC project is now being offered by GMV, under the name of **WANtime station**. **WANtime** is now a registered trademark at European and UK level (<https://trademarks.ipo.gov.uk/ipo-tmcase/page/Results/1/UK00918074643>).




Project Outcome - WANtime station - GUI

Welcome admin! [Logout](#)
Welcome admin! [Logout](#)



- Status
- ≡ Graphs
- Traceability
- ⚙ Configuration
- Logs

Status		Traceability		Current steering	
Global Status	Operational	UTCEPIA - UTC	09:43:56	MJD	59730
GNSS Interference	OK	UTCEPIA - GPST	5.33 ns	Phase	-1.378E-15
CNO level	OK	UTCEPIA - GST	3.52 ns	Frequency	-2.52E-14
UTC status	OK	UTCEPIA - UTCGPS	4.13 ns	Total	-2.66E-14
		UTCEPIA - UTCGAL	4.43 ns		



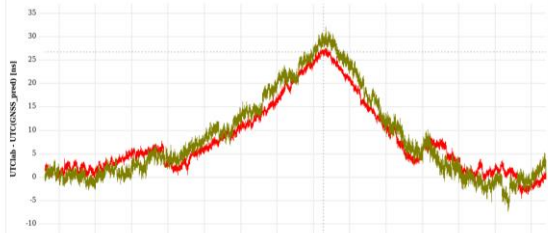
- Status
- ≡ Graphs
- Traceability
- ⚙ Configuration
- Logs

Graphs


From 20-03-20 to 29-05-2022

UTCEPIA - UTC(GNSS Pred) EPIA Steering UTCEPIA - GNSS

UTC(GNSS_pred)



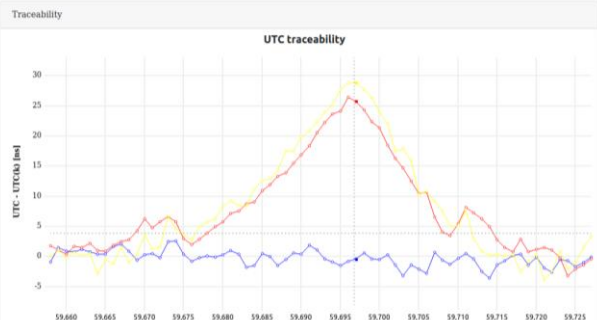
MJD: 59,696.360 EPIAL3E: 30.530 ns EPIAL3E: 26.696 ns EPIAL3E: 34.400 ns EPIAL2: 30.830 ns EPIAL3E: 33.896 ns
EPIAL3E: 28.138 ns EPIAL3E: 30.820 ns EPIAL3P: 28.994 ns EPIAL3P: 37.394 ns EPIAL3E: 32.494 ns EPIAL2: 42.904 ns
EPIAL3Q: 44.504 ns EPIAL2: 30.204 ns



- Status
- ≡ Graphs
- Traceability
- ⚙ Configuration
- Logs

Traceability

UTC traceability



MJD: 59,697 CIR-T: -0.400 ns EPIAL3E: 25.784 ns EPIAL3P: 28.857 ns

Project Outcome - WANtime station - Configuration

Welcome admin! [Logout](#)



- Status
- Graphs
- Traceability
- Configuration
- Logs

Configuration - Receiver

GNSS Constellations GPS Galileo GPS + Galileo

Time base UTC GPST GST
 1PPS delay [ns]

Antenna position Free Fixed
 X [m] Y [m] Z [m]

Save



- Status
- Graphs
- Traceability
- Configuration
- Logs

Configuration - Alarms

UTC warning [ns]	<input type="text" value="10"/>
UTC error [ns]	<input type="text" value="30"/>
UTC critical error [ns]	<input type="text" value="100"/>
Continuity limit [min]	<input type="text" value="60"/>
Quadratic clock model limit [ns/ns^2]	<input type="text" value="0.2"/>
Linear clock model limit [ns/ns]	<input type="text" value="2"/>
Constant clock model limit [ns]	<input type="text" value="10"/>

Save

Welcome admin! [Logout](#)



- Status
- Graphs
- Traceability
- Configuration
- Logs

Configuration - Calibration

EPIA

RCVR	SEPT	CH	20
Lab name	EPIA	Ref	UTC(EPIA)
X	3970564.3810	Y	-90929.4080
Z	4974181.4710		
Comments	NO COMMENTS		
Antena cable delay	385.89	Clock cable delay	10
GALE1	19.85	GALES	17.85000038147
GALE5a	17.85000038147	GALESb	17.85000038147
GPSC1	17.52	GPSP1	17.52
GPSP2	14.94	GPSP5	17.23
GPSC2	14.94		

Update **Delete**



- Status
- Graphs
- Traceability
- Configuration
- Logs

Configuration - NTP

Name	IP	Port	NTS	NTS Port
hora.roa.es	123	<input type="checkbox"/>	<input type="button" value="✎"/>	<input type="button" value="🗑"/>
ntp1.npl.co.uk	123	<input type="checkbox"/>	<input type="button" value="✎"/>	<input type="button" value="🗑"/>

Add New Server **Save**

Welcome admin! [Logout](#)

Conclusions

- ❑ The EPIC project has designed, developed and implemented an enclosed solution for the new ITU ePRTC (enhanced Primary Reference Time Clock) standard.
- ❑ The product generated during the EPIC project is now being offered by GMV, under the name of **WANtime station**. **WANtime** is now a registered trademark at European and UK level (<https://trademarks.ipo.gov.uk/ipo-tmcase/page/Results/1/UK00918074643>).
- ❑ The **WANtime station** generates its own independent time scale that is aligned to UTC and reduces its dependency on GNSS by means of an atomic clock. A maximum time error of $\pm 5\text{ns}$ w.r.t. to UTC in nominal working mode (i.e., when using GNSS signals in nominal conditions) and a maximum time error of $\pm 15\text{ns}$ w.r.t. to UTC after 14 days of holdover (i.e., after a total loss of GNSS signals) is guaranteed.
- ❑ The **WANtime station** provides a synchronization source, which provides the necessary precision, robustness and reliability required by today's and next-generation telecom, banking, data centres and energy distribution networks.

gmv.com

Thank you

Daniel Chung

Daniel.chung@gmvnsi.com