



Galileo Performance Workshop 2021: All you need to know about the performance of Europe's GNSS

ICG-15, hosted by United Nations Office for Outer Space Affairs,
Vienna International Centre (VIC)

Peter BUIST, Marco PORRETTA, Alvaro MOZO (EUSPA), Hillar TORK (EC)



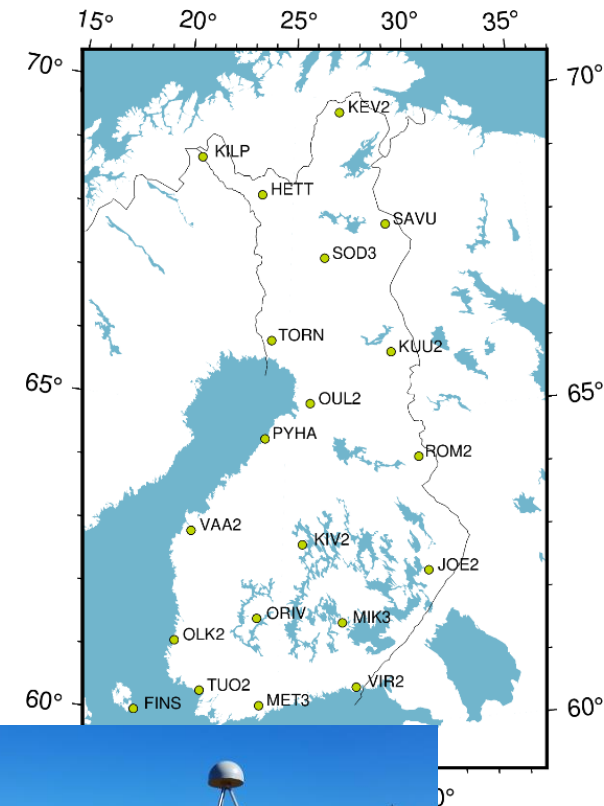
Background and scope of workshop (1/2)

- GNSS provide services to billions of users around the world for various applications.
- This has resulted in the need for monitoring the performance of GNSS as part of the service provision under responsibility of the service provider or as part of the need of specific users' groups.
- The European Union Agency for the Space Programme (EUSPA, former European GNSS Agency (GSA)) organised an online workshop on 3 March 2021 to provide an
 - in-depth analysis of the performance of Galileo,
 - show how this performance is evaluated and
 - how it is crucial for service provision in every user application.

Background and scope of workshop (2/2)

The workshop

- also involved representatives of the European Commission, the European Space Agency (ESA) and of the EU Member States (Czech Geodetic Observatory of Pecny, French CNES, Dutch NLR, Finish FGI and Swedish Chalmers),
- gathered nearly 500 participants and
- was, due to COVID-19 situation, conducted online.



Webinar topics

- This webinar introduced:
 - the Galileo programme needs for performance monitoring
 - the Galileo services as defined in service definition documents (SDD)
 - the Minimum Performance Levels (MPLs), the SDD presents the targets for services and defines the conditions under which such MPLs can be reached
 - Key Performance Indicator (KPI) which are quantifiable measures used to evaluate the performance
 - publicly available data, products and tools which can be used for GNSS monitoring
 - a set of monitoring and assessment guidelines for the implementation of a solution able to monitor the Galileo system performance based on publicly available data, products, and tools.

Agenda

14:00 Welcome by moderator, Alvaro Mozo (EUSPA) Hillar Tork (EC)

14:10 Overview Galileo, Service Provision and the GRC, Peter Buist (EUSPA)

14:30 pm Monitoring and assessment guidelines, Peter Buist

- Service Definition Document and Minimum Performance Levels: Marco Porretta (EUSPA)
- Performance monitoring and assessment needs: Lennard Huisman (EUSPA)
- Reference products generation: Andrea Nardo (EUSPA)

15:45 pm Service performance monitoring

- Galileo Reference Centre: Marco Porretta
- ESA: Gaetano Galluzzo
- Geodetic Observatory of Pecny: Jan Dousa
- CNES: Bernard Bonhoure
- NLR, FGI and Chalmers: Hein Zelle & Heiko Engwerda

17:25 pm Conclusions: Hillar Tork and Alvaro Mozo

Example 1: GRC Performance & cross check reports



European Global Navigation Satellite Systems Agency

GALILEO REFERENCE CENTRE MONTHLY REPORT
MAY 2019
GRC

UNCLASSIFIED

Galileo Performance Signal Monitoring

NLR
May 2019
Kadaster

CHALMERS
UNIVERSITY OF TECHNOLOGY

NLS
NAVIGATION SOLUTIONS PROVIDED BY EUROPE

nlr

WP3.1 – Galileo OS Navigation Performance
Synthesis Report
2019 Quarter 2

GRC MS

crnes MGR Kartverket

Code:
Version:
Date:

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European Global Navigation Satellite Systems Agency

GALILEO REFERENCE CENTRE SERVICE PERFORMANCE MONTHLY REPORT
GRC

SENSITIVE NON-CLASSIFIED

NAME
Prepared by: GRC Operations Team
Approved by: Cristina GARCIA
Authorized by: Guillermo TORRES
Customer Approval: Peter BUST

Code:
Date:
Version:
Internal:

CHALMER
GSA/GRANT/04/2016

WP4 - SIS Monitoring

Report on SIS campaign
GSA001
2018-12-18/19

June 2019
Rüdiger Haas

ASTRON
European Institute for Space Research

EI Quality Report
March 25, 2019

Satellite: PRN-30
Signal: L1
Sampling Frequency: 60 MHz
Modulation Type: CBOC
Date and time of data recording: 07:00:2019 23:15:39

1 Acquisition

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GALILEO REFERENCE CENTRE SERVICE PERFORMANCE MONTHLY REPORT
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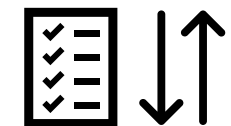
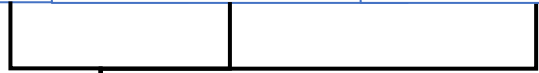
NAME
Prepared by: GRC Operations Team
Approved by: Cristina GARCIA
Authorized by: Guillermo TORRES
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GRC MS

WP3.4 – NeQuick G performance summary report Q2 2019

Kartverket CBK TU WIEN U PORTO

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EUROPEAN GNSS (GALILEO) INITIAL SERVICES

OPEN SERVICE
QUARTERLY PERFORMANCE REPORT
APRIL - JUNE 2019

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EUROPEAN GNSS (GALILEO) INITIAL SERVICES

OPEN SERVICE
SERVICE DEFINITION DOCUMENT

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EUROPEAN GNSS (GALILEO) OPEN SERVICE

SIGNAL-IN-SPACE
INTERFACE CONTROL DOCUMENT

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EUROPEAN GNSS (GALILEO) OPEN SERVICE

IONOSPHERIC CORRECTION
ALGORITHM FOR GALILEO SINGLE FREQUENCY USERS

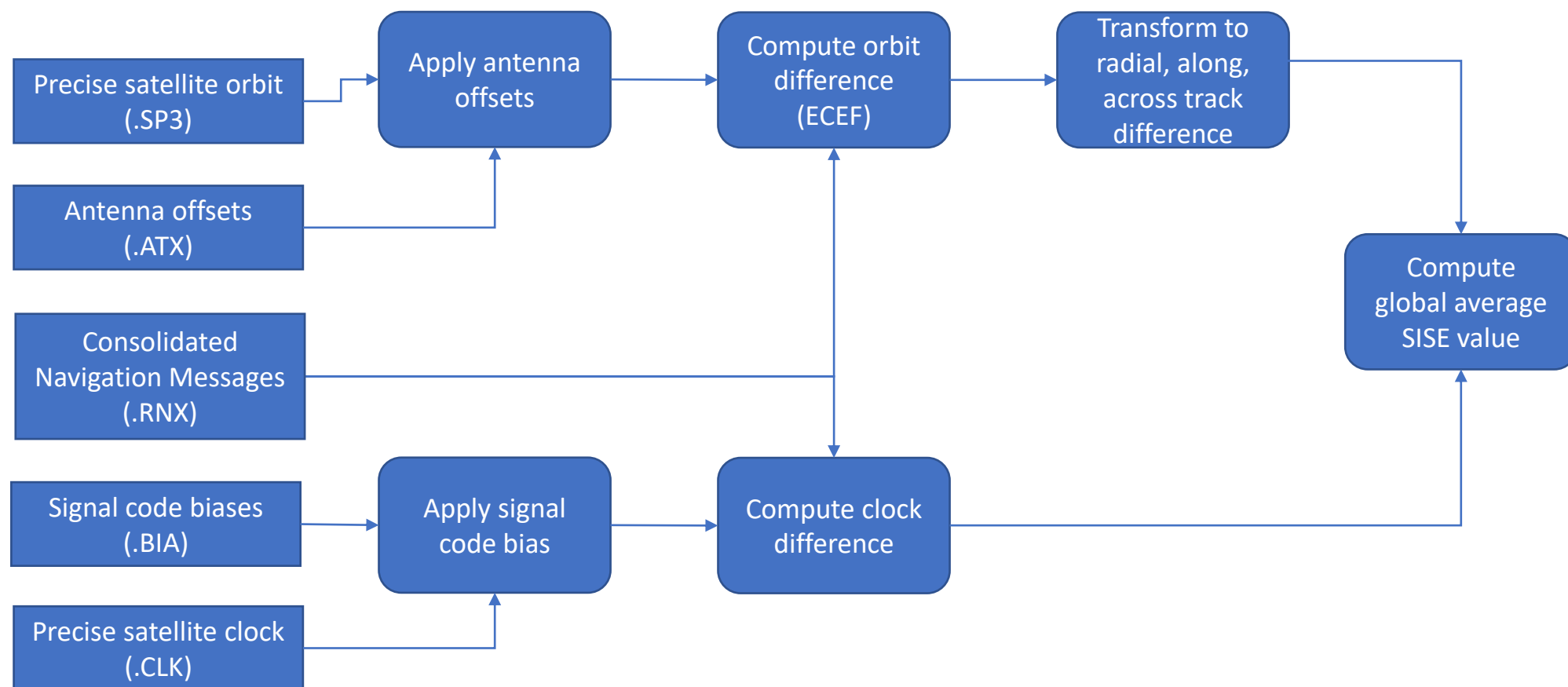
NAVIGATION SOLUTIONS PROVIDED BY EUROPE

Example 2: Tools for navigation messages and reference products

- Navigation file QC and merge:
 - Gnut Anubis (<https://gnutsoftware.com/software/anubis>)
 - GFZRNX (<https://dataservices.gfz-potsdam.de/panmetaworks/showshort.php?id=escidoc:1577894>)
- Reading files and streams, compute satellite positions, clock offset, biases, health status, receiver positioning,
 - Several open source tools available that contain library functionality
 - RTKLIB (<http://www.rtklib.com/>) *
 - BKG NTRIP Client (BNC) (<https://igs.bkg.bund.de/ntrip/download>) *
 - G-Nut Anubis (<https://gnutsoftware.com/software/anubis>)
 - goGPS (<https://gogps-project.github.io/>)
 - ...

*) Supports real-time streams

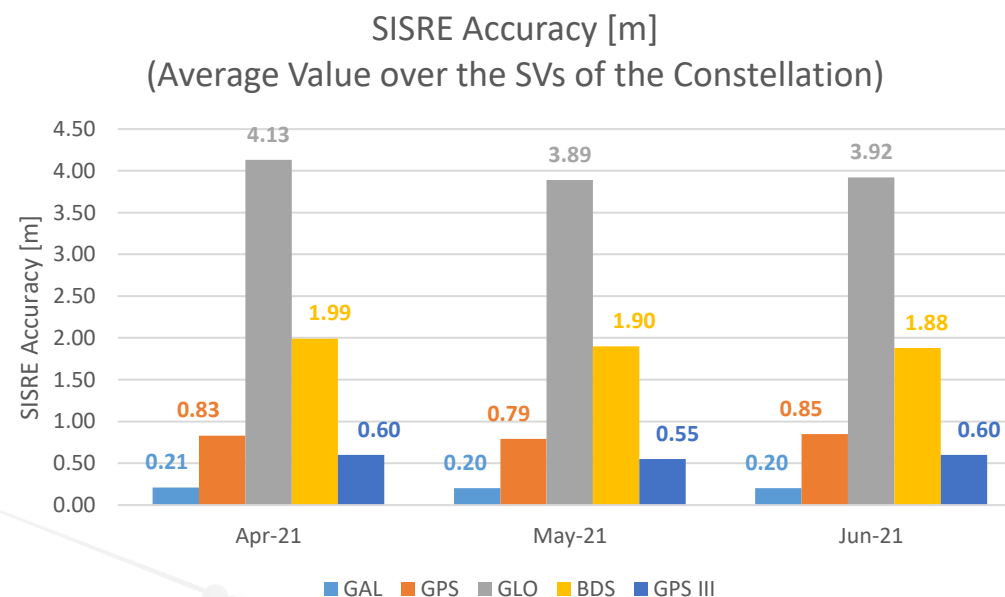
Example 3: Performance monitoring using reference products (orbit, clock, BGD, ANTEX)



Workshop outcome (1/4)

At the workshop, a number of technical topics were addressed.

- All presenters confirmed that the Galileo Initial Services commitments as described in the OS SDD are met, some events were observed and discussed, but the Galileo performance, also compared to other GNSS especially in terms of accuracy, is good.
- When monitoring the performance of Galileo, it is important that the satellite health status should be verified for F/NAV and I/NAV ephemerides using broadcast navigation data consolidated from a global network.
 - However, there is no standard on how to generate a consolidated navigation message from publicly available data– the quality and availability depends on latency of this data.



Typical performance for all constellations observed at GRC

Workshop outcome (2/4)

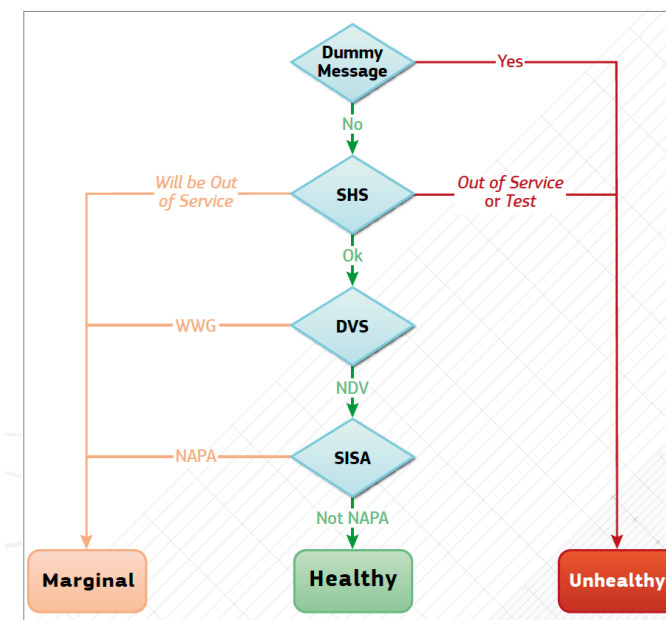
- It is important for users to check the status of the navigation messages as specified in the Galileo OS Signal-in-Space (SiS) Interface Control Document (ICD) and the SDD.
 - This requires that the receivers monitor the Signal-in-Space health flags: signal health status (SHS), data validity status (DVS) and Signal-In-Space accuracy (SISA).
 - The Galileo system uses these three SiS health flags to protect users, and all of them need to be monitored and appropriate actions taken as specified in the ICD.
 - Both the ICD and SDD are available for download on the website of the GSC.

SIGNAL HEALTH STATUS (SHS)	DEFINITION
0	Signal OK
1	Signal out of service
2	Signal will be out of service
3	Signal component currently in Test

DATA VALIDITY STATUS (DVS)	DEFINITION
0	Navigation data valid
1	Working without guarantee (WWG)

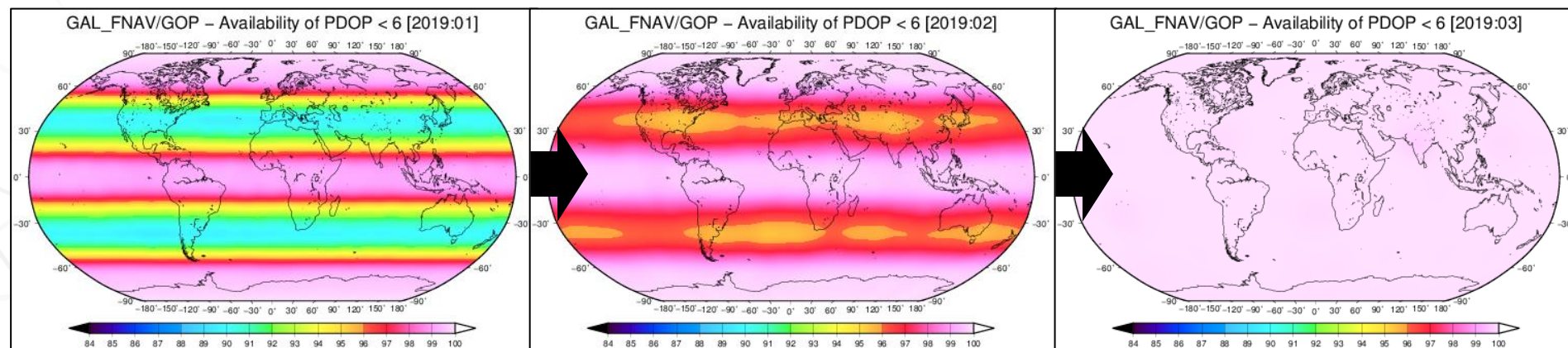
SISA INDEX	SISA VALUE
255	No Accuracy Prediction Available (NAPA)
0.....254	Not NAPA

		USERS			F/NAV				I/NAV			
		E5a _{HS}	E5a _{DVS}	SISA(E1, E5a)	E1B _{HS}	E1B _{DVS}	E5b _{HS}	E5b _{DVS}	SISA(E1, E5b)			
SINGLE FREQUENCY	E1				X	X					X	
	E5a	X	X	X								
	E5b						X	X	X			
DOUBLE FREQUENCY	E1/E5a	X	X	X	X	X						
	E1/E5b				X	X	X	X	X			



Workshop outcome (3/4)

- With respect to using reference stations for performance monitoring, it is recommended to use a geodetic grade receiver connected to a geodetic antenna.
 - This generates high-quality data using multiple frequencies and signals.



Global PDOP < 6 availability over 24 hours after activating 4 new Galileo satellites [Geodetic Observatory of Pecny]

Workshop outcome (4/4)

- Real-time data provides an overview of GNSS status in nominal situations.
 - However, not all information from the signals required for monitoring is available in the real-time streams using the RTCM standard.
 - Some sources also provide real-time broadcast orbit and clock corrections in the state space representation (SSR) format, yet unusual events and anomalies might not be reflected properly in these streams, as the underlying processing software might not be able to handle those events well.
- The Galileo Service Operator runs the system to maintain the performance specified in the SDD.
 - Performance may vary within set margins due to operational, maintenance or deployment constraints.
 - In light of this, interpretation of results is key for proper GNSS performance monitoring. It is good practice to make use of redundancy and always to confirm results with other sources, when possible.
- Positive feedback received from participants.
- Follow-up workshop is planned (potential hybrid: online and physical).

More information

Presentations are available at:

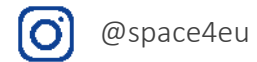
- <https://www.euspa.europa.eu/newsroom/european-space-expo/webinar-%e2%80%9call-you-need-know-about-performance-europe%e2%80%99s-global-navigation>



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