



European
Global Navigation
Satellite Systems
Agency



GALILEO Status & High Accuracy

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The EU Satellite Navigation Programmes

Europe's contribution to satellite navigation consists of **two** systems

EGNOS

- An overlay system
- Improves GPS performance
- European coverage
- Three services, including the Safety of Life service (mainly for aviation users)



Galileo

- An autonomous infrastructure
- Services similar to those of GPS
- ...but with unique features
- Global coverage
- Five services



Owned by the European Union

Programme Political Oversight:
European Council and Parliament

Programme Manager:
European Commission

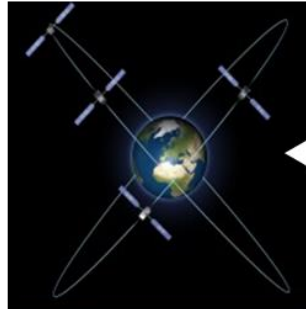
Programme Architect and Deployment:
European Space Agency

Exploitation:
European GNSS Agency

Galileo moving ahead ...



2005
DEVELOPMENT
SYSTEM TESTBED
GIOVE A/B



2013
IN-ORBIT VALIDATION
4 satellites
initial ground
infrastructure

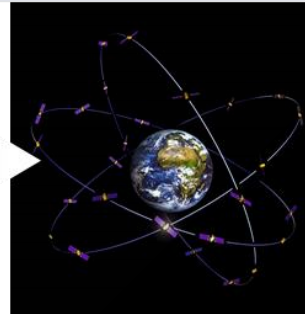


2015/2016
INITIAL GALILEO SERVICES
OS, SAR, PRS, CS demonstrator

2017/2019
EXPLOITATION
PHASE
FOC1 System

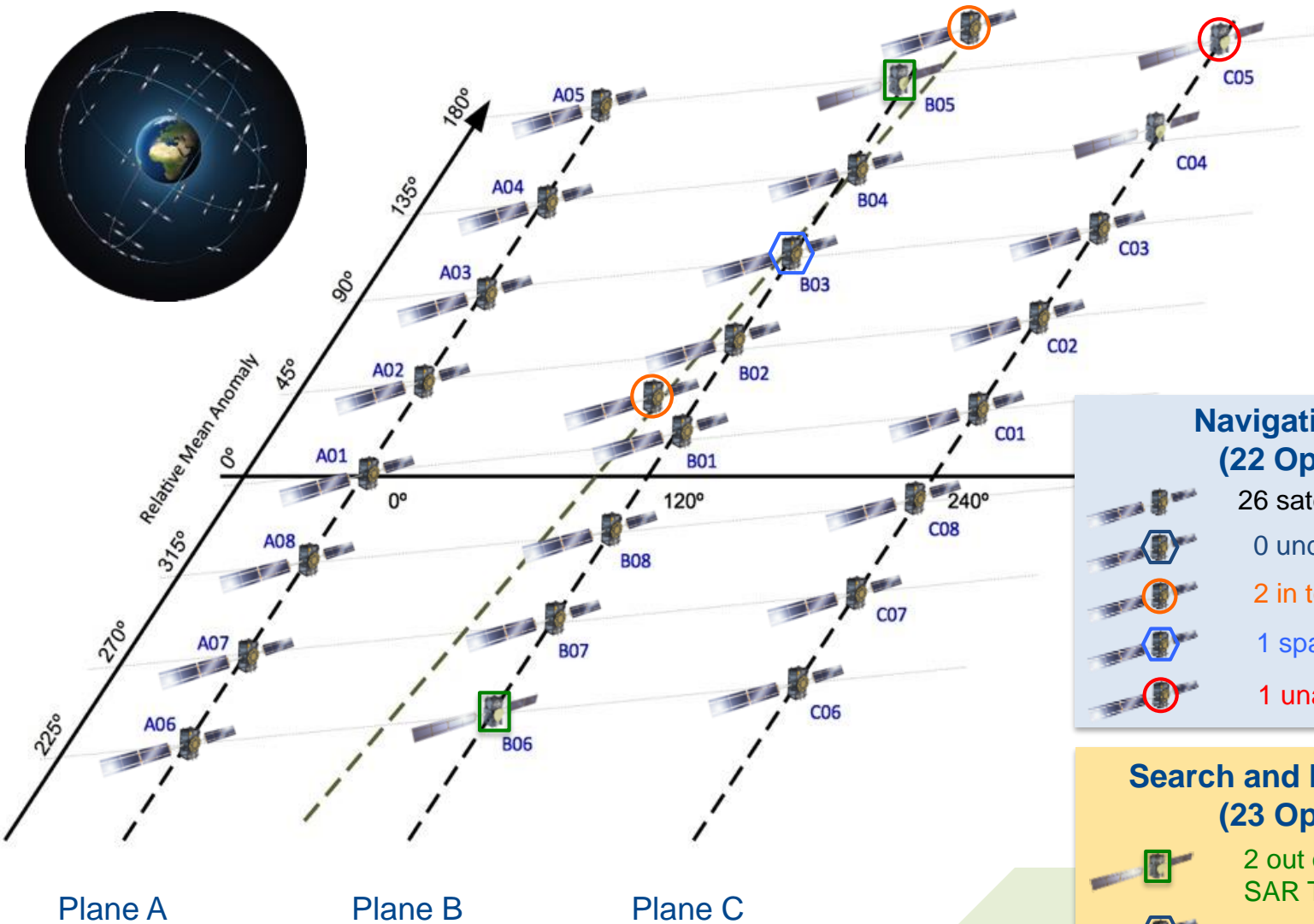


2020
FULL OPERATIONAL
CAPABILITY
24 operational
satellites
and complete ground
infrastructure








After 2020
TOWARD
GALILEO 2nd
GENERATION

Galileo Constellation Status



Navigation Payload (22 Operational)

-  26 satellites in orbit
-  0 under commissioning
-  2 in testing
-  1 spare
-  1 unavailable

Search and Rescue Payload (23 Operational)

-  2 out of 26 satellites with no SAR Transponder
-  0 under commissioning
-  1 spare

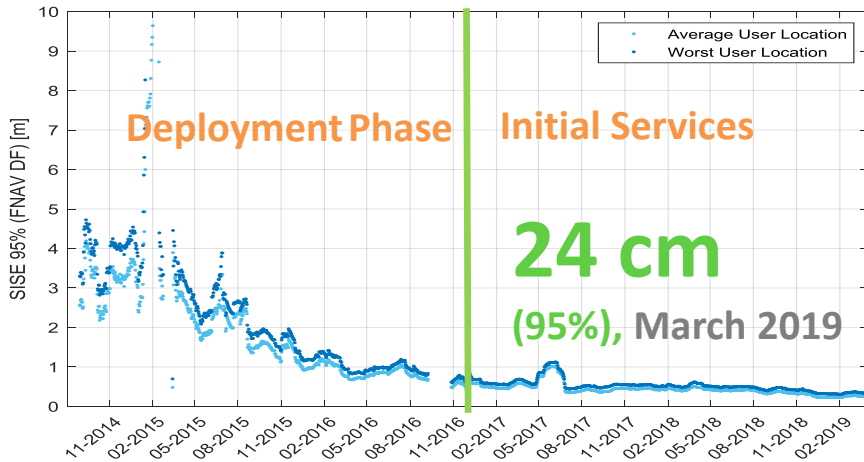
Galileo began offering Initial Services on 15th December 2016



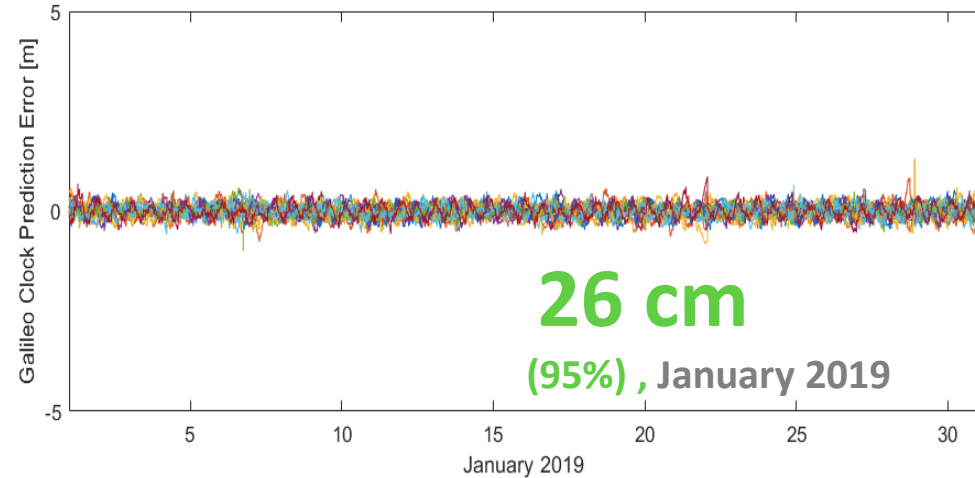
- ★ Open Service: open and free of charge service for users with Galileo enabled devices
- ★ Public Regulated Service: encrypted, robust service for government-authorized users
- ★ Search and Rescue Service: Europe's contribution to COSPAS-SARSAT, an international satellite-based search and rescue distress alert detection system

“Accuracy matters” – OS Ranging and Timing Performance

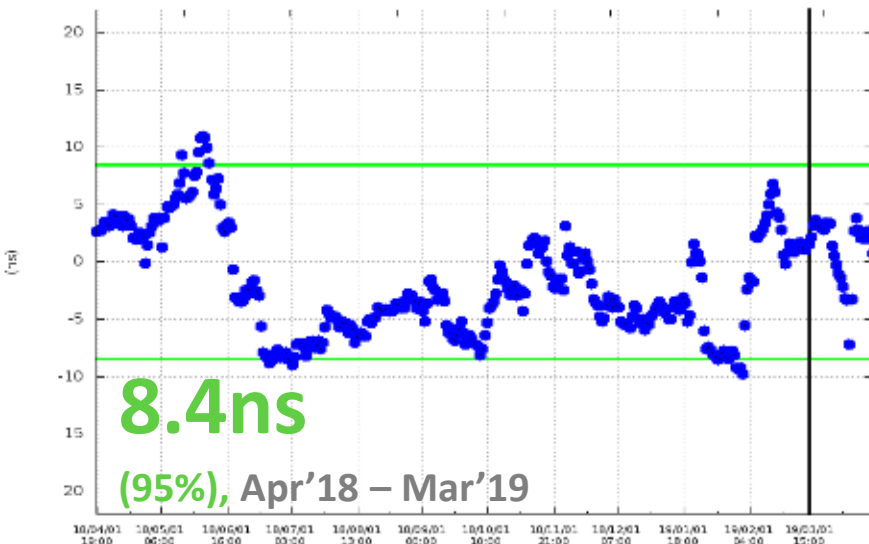
Ranging Error and Timing Performance



Clock Prediction Performance



Broadcast UTC Offset accuracy

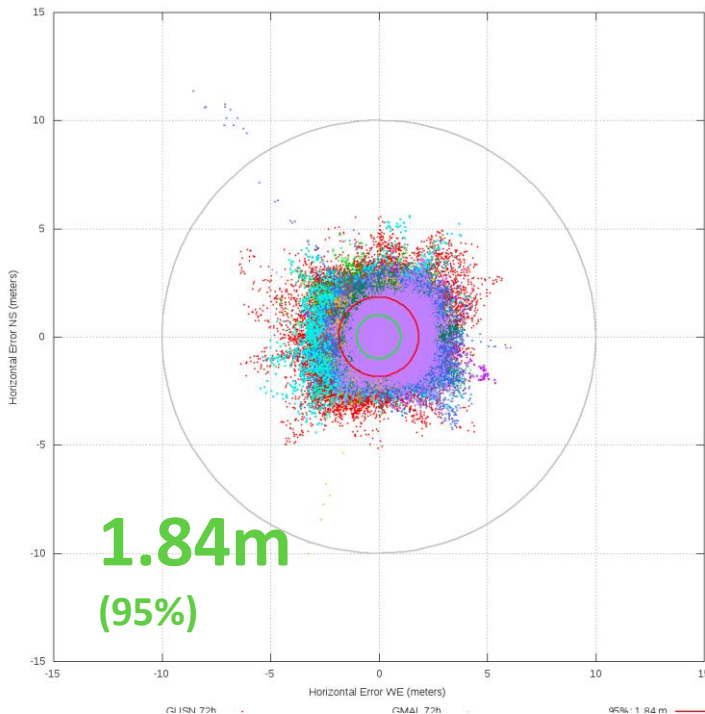


- Galileo broadcast clock predictions accuracy as observed at user level is **outstanding**
- In January 2019, the measured **Galileo clock prediction accuracy was 0.26m (95%) for Galileo.**
- The better performance of Galileo is obtained through a combination of excellent clock stability and high uplink rate of the navigation messages

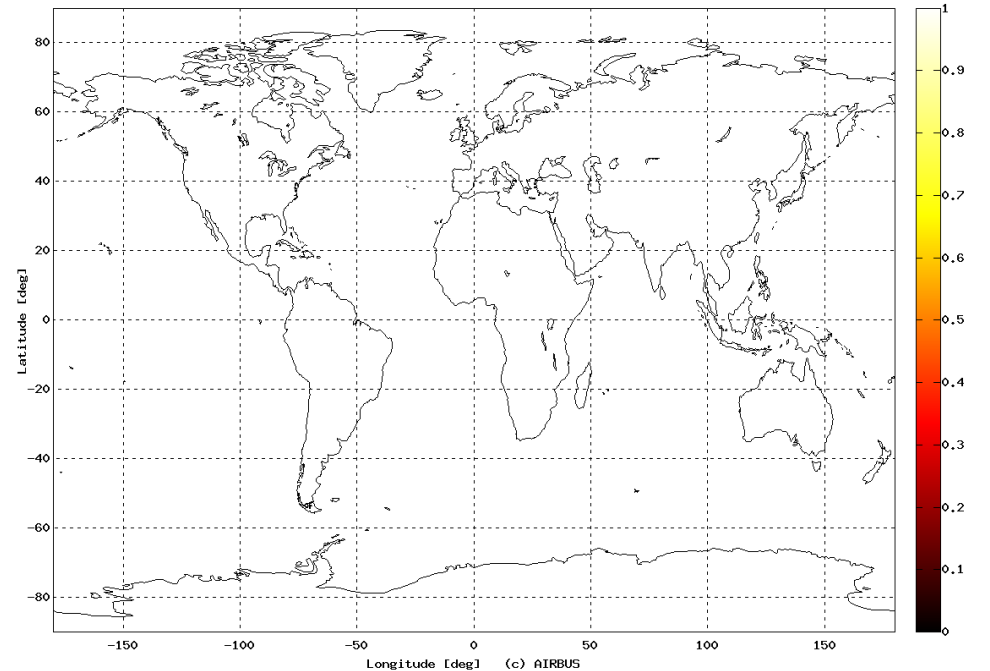
“Accuracy matters” – OS Positioning and Availability

Operational Satellites :
Availability of H. Accuracy <10 m
Global PDOP <=6 availability
Availability for Timing Service

22
100% (Average User Location)
99.99% (Average User Location)
100%



Measured Horizontal Positioning Accuracy
(Source TGVF)



Availability of Horizontal Position Accuracy
< 10 m for 22 satellites

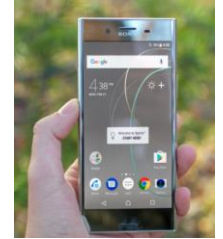
2010



BQ Aquaris X5 July 2016



iPhone



Sony



Samsung



Huawei

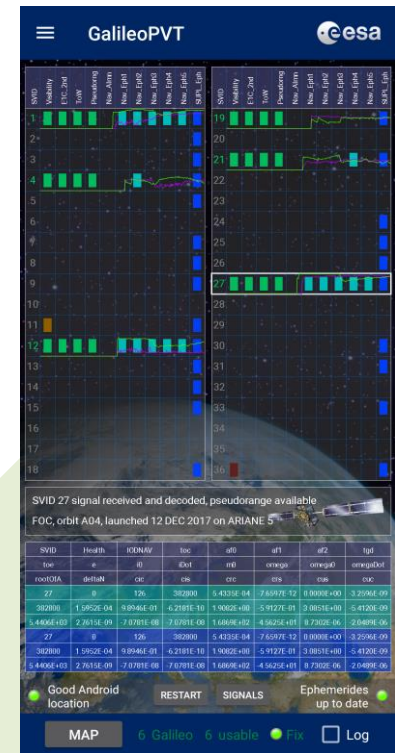
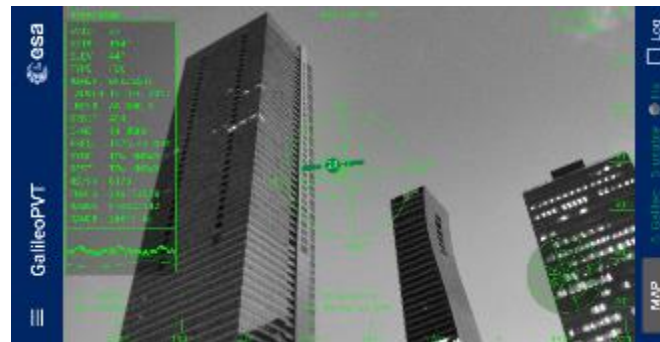
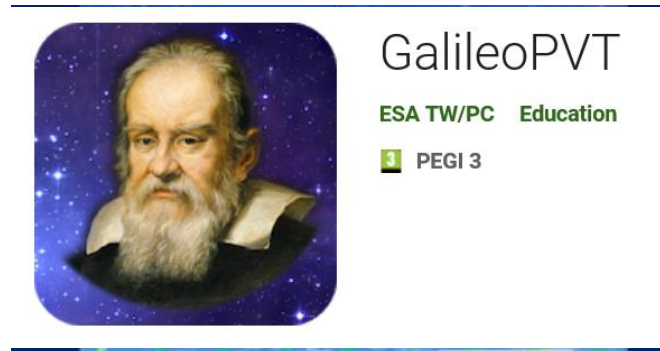
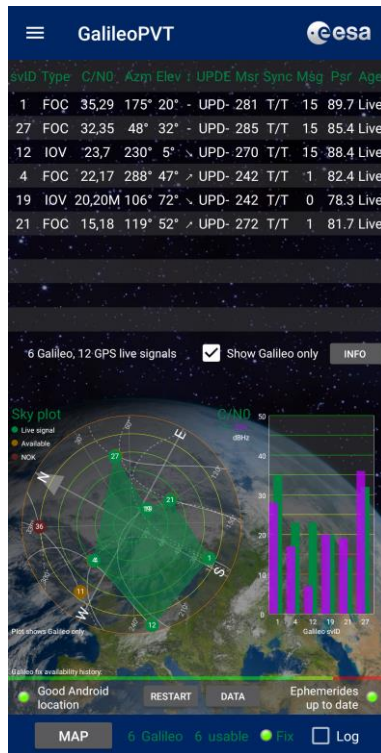
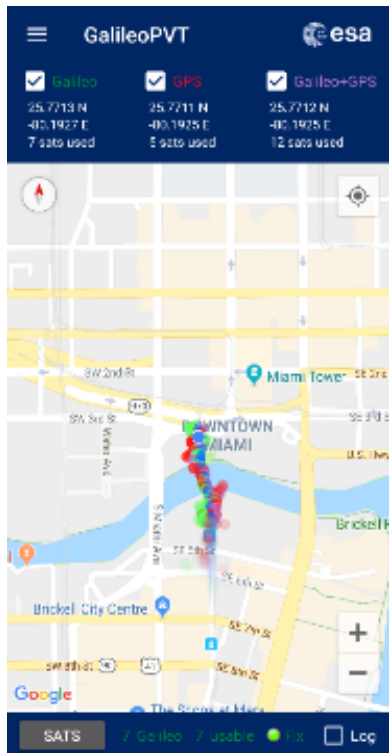
2018

95+% of global suppliers



Xiaomi Mi8 May 2018 Dual Frequency

GalileoPVT Android App by ESA



E5a for user ROBUSTNESS



2f, GPS+GAL Code-only
– PVT w/o PPP
corrections -



1f & 2f, GPS+GAL Code smoothed Carrier -
PVT w/o PPP corrections -



GPS+GAL Dual Frequency - PVT w/o and with PPP corrections -

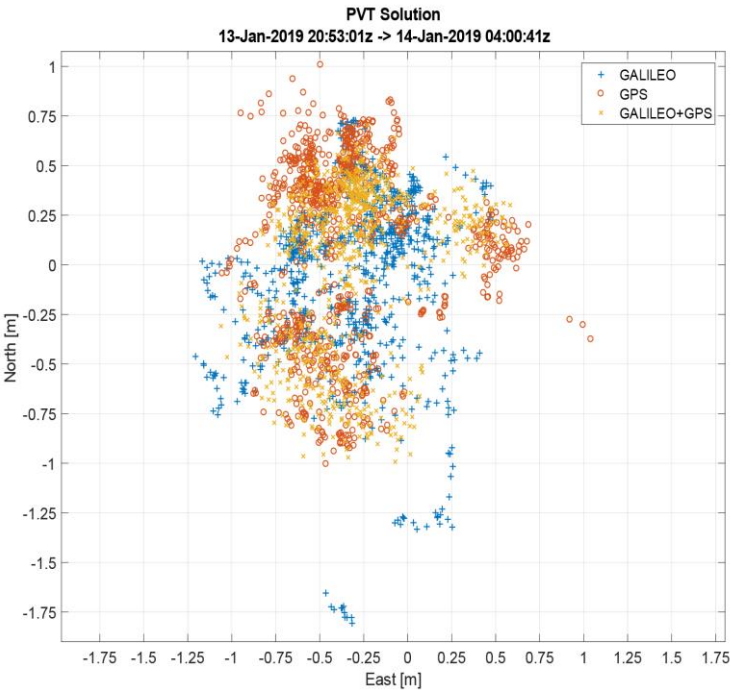


**E5a/L5
measurements
boost PVT
performances!**

**Galileo leads
E1/E5a market**

Galileo Navigation Performances at 80 degrees South

Galileo Experimentation and Scientific Test in Antarctica (GESTA) performed by ESA between Nov 2018 and Feb 2019, dedicated notably to the ionospheric modelling at low latitudes.



Horizontal/Vertical Position Accuracy

Gal: 0.55 m/ 1.08 (1 σ)



Southern most Galileo Position Fix:
Lat/Long: -79.637335 deg/ 46.081265 deg

GALILEO providing excellent performance

- **Galileo Services are a reality**
 - Initial Services provided since 15th December 2016
 - Open Service and SAR/Galileo Forward Link Service
- **Galileo offers excellent overall performance**
 - High “Per satellite” availability 99.42%
 - **Continuous SISE improvement due to ongoing deployment;** Currently observed SISE value <0.50m 95% **Global Average** (constellation average)
 - **UTC(SIS) dissemination** accuracy is below **8.4ns (95%)**
 - **GGTO dissemination** accuracy is below **6.9ns (95%)**
- **Galileo provides Dual Frequency** capability to users

More Information on Galileo



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OUR EXPERTS WILL PROVIDE ANSWERS TO YOUR QUESTIONS ABOUT GALILEO



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CLICK FOR SATELLITE INFORMATION AND NOTIFICATIONS



GALILEO INCIDENT REPORT

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Galileo High Accuracy Service

- Galileo has been designed to allow for provision of a **Commercial Service (CS)** intended for broadcast of value added data, such as **high accuracy** and **authentication**.
- In March 2018, the European Commission adopted an implementing decision whereby the **High Accuracy** feature of the Galileo CS shall be provided **free of charge to Galileo users**.
- The European Commission's goal with offering a free High Accuracy signal is to allow **innovation** to flourish in both consolidated and emerging **markets**, while **minimising** as far as possible any **disruption** to the current business models of established providers.
- While high accuracy services are already widespread in professional sectors, providing them on a worldwide basis is a novel service that Galileo will begin to offer as of 2020/21.

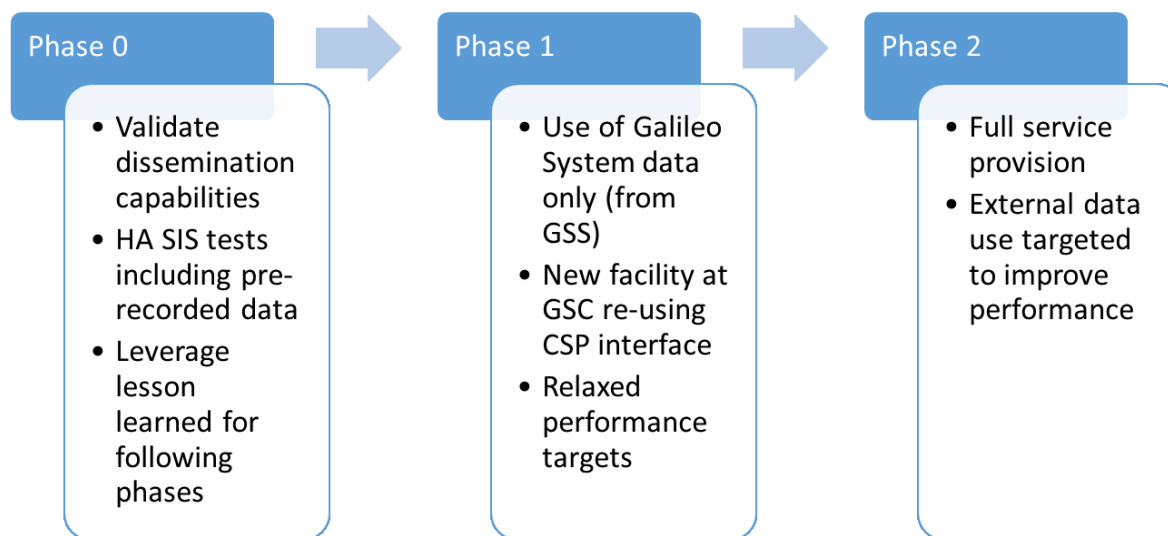
Galileo High Accuracy - continued

- **Galileo** will be the first constellation able to provide such **High Accuracy service globally**.
- **Galileo High Accuracy Service** will be based based on the provision of accurate satellite data (clocks, orbits and biases) and atmospheric data (mainly ionospheric corrections) to enable **PPP**
- Galileo **High Accuracy Data** will be transmitted through an **open format** in the **Galileo E6B signal**, using **448 bits** per satellite per second.
- The format of HA corrections, considering the available bandwidth and Galileo uplink capability, are critical for maximising user performance. The format is based on RTCM-CSSR adapted to the Galileo E6B channel.

Galileo High Accuracy Service Key Features

- Galileo HAS will provide 2 Service Levels:
 - **Global Service Area (SL1)** and
 - **Regional Service Area (SL2)**
- Enabling Positioning with Accuracies < **20 cm (H)/ 40 cm (V)**
- **Improved Convergence** for the Regional Service
- **Multi** Constellation (at least Galileo + GPS)
- **Multi** Frequency
- Correction Data broadcast through **Galileo E6B Signal in Space** at 448 bps
- Correction Data also planned to be available through auxiliary channels
- Corrections provided in **Galileo Terrestrial Reference Frame** and **Galileo System Time**

High Accuracy Service Plan



- **HAS Phase 0:** Tests started by mid Feb'19 and continued.
- **HAS Phase 1:** under procurement. Based on existing infrastructure.
 - Will provide HAS by 2020 (signal)/2021 (service).
 - Not global - relaxed performances.
- **HAS Phase 2:** under design. Global (SL1), full accuracy service, possibly including ionospheric information to improve convergence regionally (SL2).

High Accuracy Service – Take away

- Galileo High Accuracy Service:
 - will be **free of charge** to Galileo Users
 - will enable **20 cm PPP** positioning on a **global scale**, with regionally improved convergence
- The Galileo HAS data will be **transmitted openly, for free**, and through an **open standard format**.
- The Galileo High Accuracy Service will be **gradually rolled out** as of 2020
- Galileo HAS **Tests are already carried out** and will feed into design of the Final HAS Service.

THANK YOU

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Technical Consideration for PPP Interoperability

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PPP Interoperability Considerations

- The call for the PPP Workshop contained the following topics which are of interest for the meeting:
 - PPP activity updates and plans from different GNSS/RNSS providers (addressed in previous presentation)
 - efficiency of PPP products transmission which includes the types of satellites, augmentation signal frequencies and bandwidth; as well as ground augmentation transmission
 - timing and geodetic references for satellite orbits and clock parameters
 - interoperability of PPP products in particular signal biases and atmospheric corrections
 - message data formats, structures, contents for transmission
 - definition of PPP integrity and continuity needs
 - performance level of the PPP services, e.g., minimum PPP standard

- **HAS Product Transmission by Galileo**
 - Galileo HAS will be provided through the Galileo MEO constellation Galileo in the E6B signal (1278.75 MHz) with 448bits per satellite per second.
 - Complementary dissemination channels are under consideration e.g. EGNOS GEOs, terrestrial dissemination,...
- **Timing and geodetic references**
- Galileo HAS corrections will be provided in:
 - Galileo Terrestrial Reference Frame (GTRF) for the Satellite Orbits (independent realization of International Terrestrial Reference System)
 - Galileo System Time (GST) for Satellite Clock parameters

Galileo HAS corrections

Draft HAS SIS ICD for Phase 1 is available but not yet in public domain.

Based on RTCM-CSSR adapted to the Galileo E6B channel.
Some parameters and messages are still under consolidation.

E6 Signal in Space and RTCM-CSSR structure is also used by QZSS

The following parameters are envisaged:

| Parameter | HAS Global Service Level 1 | HAS Regional Service Level 2 |
|-------------------------------|----------------------------|------------------------------|
| Satellite Orbit Corrections | X | X |
| Satellite Clock Corrections | X | X |
| Code Biases | X | X |
| Phase Biases | (X) TBC | (X) TBC |
| Ionospheric delay corrections | | X |

Interoperability of products

- Interesting feature for users using several different correction origins
- Not deemed to be of critical importance as long as the broadcast correction parameters are well defined in User Interface documents
- Likewise for the Atmospheric corrections a clear description of the provided corrections and the applied model is important

Interoperability could be ensured **by sharing a common terminology** when describing the services

Questions to the participants

- **Question:** Should there be a common terminology used for **defining the parameters and performance** statements?
Is there a need for a commonly agreed set of definitions similar to those currently discussed for the GNSS Open Services in the context of ICG?
- **Question:** Should users be able to account for the differences in the Atmospheric parameters or should the PPP corrections be based on the same model?
- **Question:** Are there common parameters that open PPP services could provide/broadcast to support interoperability?
- **Question:** What are the use cases that benefit from Open PPP services? What could be future complements to such services e.g.: should integrity and continuity be considered as part of the evolution of the open PPP services?

THANK YOU

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