



European
Global Navigation
Satellite Systems
Agency



Galileo High Accuracy Service



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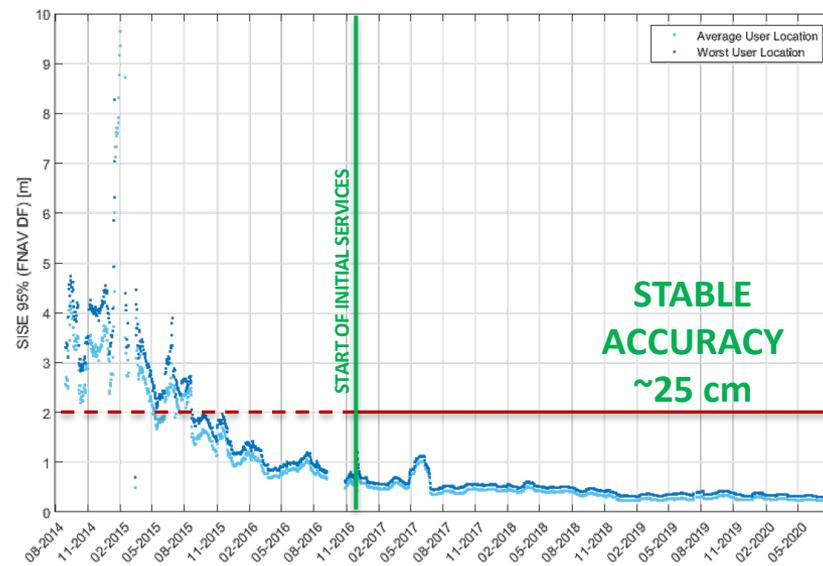
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Presentation Outline

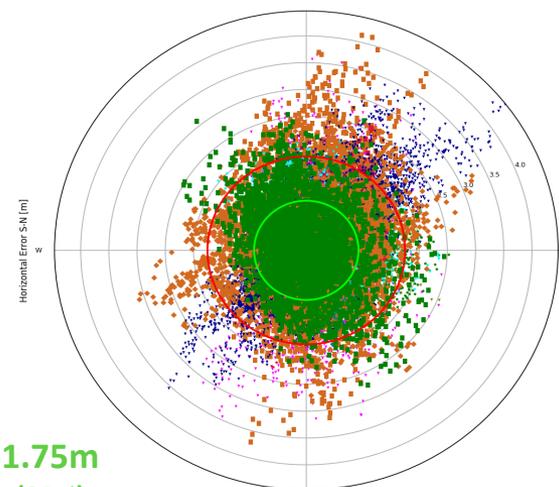
- Galileo High Accuracy Service Background
- Galileo High Accuracy Service Roadmap
- Galileo High Accuracy Service Target User Markets
- Galileo High Accuracy Service Characteristics & Targets
- Galileo High Accuracy Service High Level Architecture
- Galileo High Accuracy Service Initial Performance Predictions
- Galileo High Accuracy Service High Accuracy Service Context

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;**
 - observed SISE value ~0.25 m 95% Global Average (July 2020)
 - UTC(SIS) dissemination accuracy is ~ 2.5 ns (95%)
 - GGTO dissemination accuracy is below ~4.2 ns (95%)
- **Galileo provides Dual Frequency capability to users**



Measured Horizontal Positioning Accuracy (TGVF-X)



**1.75m
(95%)**

Horizontal Error S.M. [m]
 • GCAL • GIKOU • GIMIZ • GOTA • GTHT
 • GIEN • GLPG • GNNO • GOUS • GUSN
 • GKIR • GMAL • GNOR • GPTB • GVES
 — RMS: 0.93 m
 — 95%: 1.75 m
 — Avail 10m: 100.00%

Galileo High Accuracy Service – Programmatic Background

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⁽¹⁾ whereby the **High Accuracy** feature of Galileo CS shall be provided **free of charge to Galileo users**.

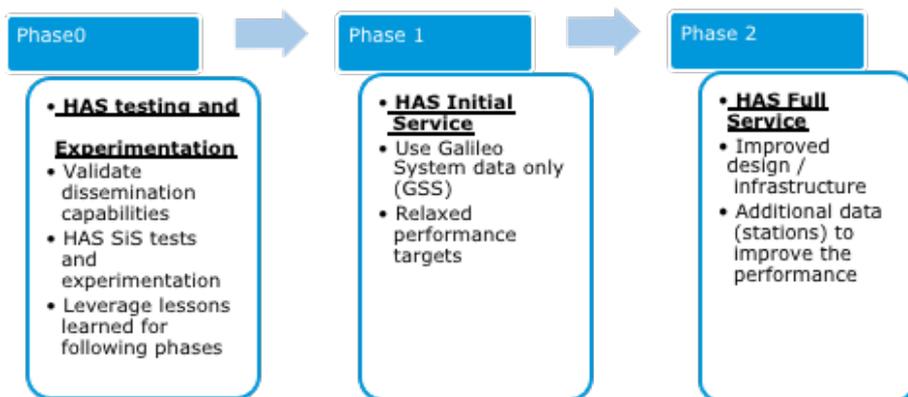
- The **Galileo High Accuracy Service** :

- Broadcast globally and **free of charge to Galileo users**
- using the E6 signal to broadcast corrections to Galileo Navigation messages
- Enable PPP for global users and fast PPP for regional users through additional corrections.

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.

Galileo High Accuracy Service – Roadmap

HAS Service rolled out in Phases:



Phase 0: Testing has started and will continue

Phase 1: HAS Initial Service

Corrections to enable PPP to users

Targeting EU coverage

Performance close to final targets

(as close as feasible with the limitations of the infrastructure).

Phase 2: HAS Full Service

=> **Service Level 1**

Corrections to allow PPP-AR globally with 20 cm/40 cm (H/V) with <5 min convergence time

=> **Service Level 2**

Regional atmospheric corrections (EU) to enable PPP with 20 cm/ 40cm (H/V) with improved convergence (100s)

HAS Target Markets

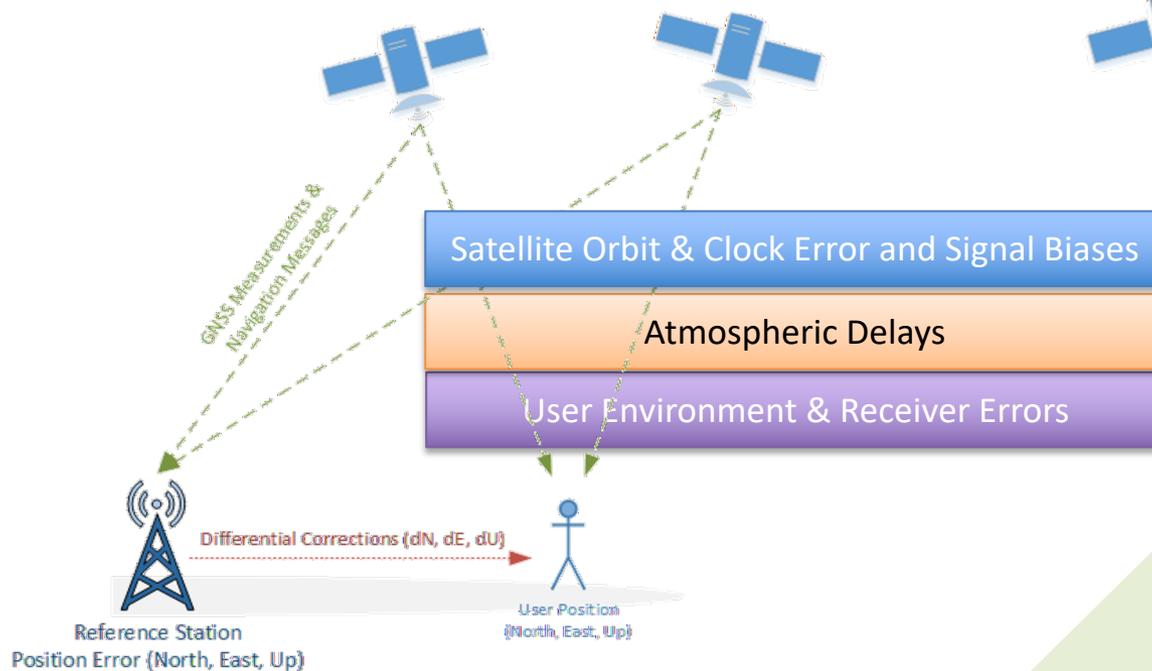
| HAS TARGET MARKETS | | | |
|---------------------------|---|---------------------------|---|
| Geomatics | <ul style="list-style-type: none"> GIS/Mapping Cadaster in rural areas (Land consolidation) Hydrographic survey and Vessel navigation Off-shore exploration | Rail | <ul style="list-style-type: none"> Cold Movement Detection Odometer Calibration Door Control Supervision Infrastructure surveying Gauging surveys Structural monitoring |
| Agriculture | <ul style="list-style-type: none"> Guidance VRA-Low applications Farm machinery positioning Site-specific data analysis applications | Aviation | <ul style="list-style-type: none"> Drones: Positioning/Nav System (Urban) Drones: Geo-awareness System Integrated Surface Management |
| Road | <ul style="list-style-type: none"> Autonomous driving (contribution to) Safety-critical applications | Consumer Solutions | <ul style="list-style-type: none"> LBS Gaming Health AR for leisure Commercial (Geo marketing and advert) AR Professional Robotics- High GNSS use |

* Descriptions of these applications can be found in the GSA GNSS Market Report or the User Requirement Documents

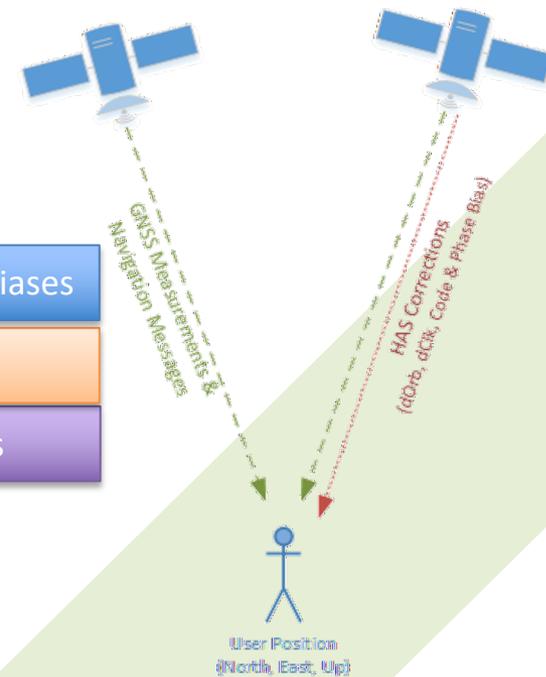
HAS enabling Precise Point Positioning

- Galileo HAS data in combination with OS signals will enable accurate positioning capability based on PPP technique.
- Providing Precise Corrections to broadcast GNSS Navigation Messages

Differential Techniques



Precise Point Positioning Techniques

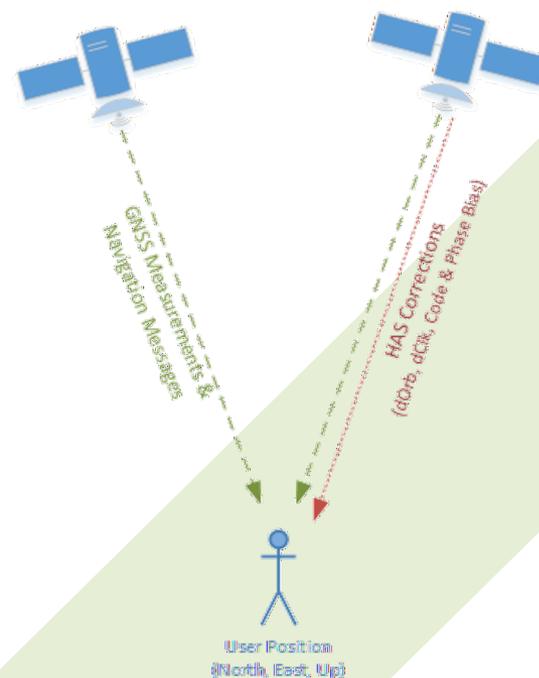


HAS enabling Precise Point Positioning

- Galileo HAS data in combination with OS signals will enable accurate positioning capability based on PPP technique.
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| | Advantage vs. PPP | Correction for |
|----------------------------|---------------------------------------|---|
| PPP | | Orbit & Clock |
| PPP – Ambiguity Resolution | Better Accuracy | Orbit & Clock Signal Biases |
| Fast PPP | Better Accuracy Faster Convergence | Orbit & Clock Signal Biases Atmospheric Delay |

Precise Point Positioning Techniques



Galileo HAS Message and Correction Parameter

Galileo High Accuracy Data transmitted through an open format in the Galileo E6B signal.

Galileo HAS SIS Message Definition supporting Initial HAS is available – not yet in public domain.

Based on RTCM-CSSR adapted to the Galileo E6B channel.

The following correction parameter 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 | X |
| Ionospheric delay corrections | | X |

For the full HAS service, additional parameter and message content are under consolidation. (e.g. Correction Quality Indicators)

HAS Service Characteristics

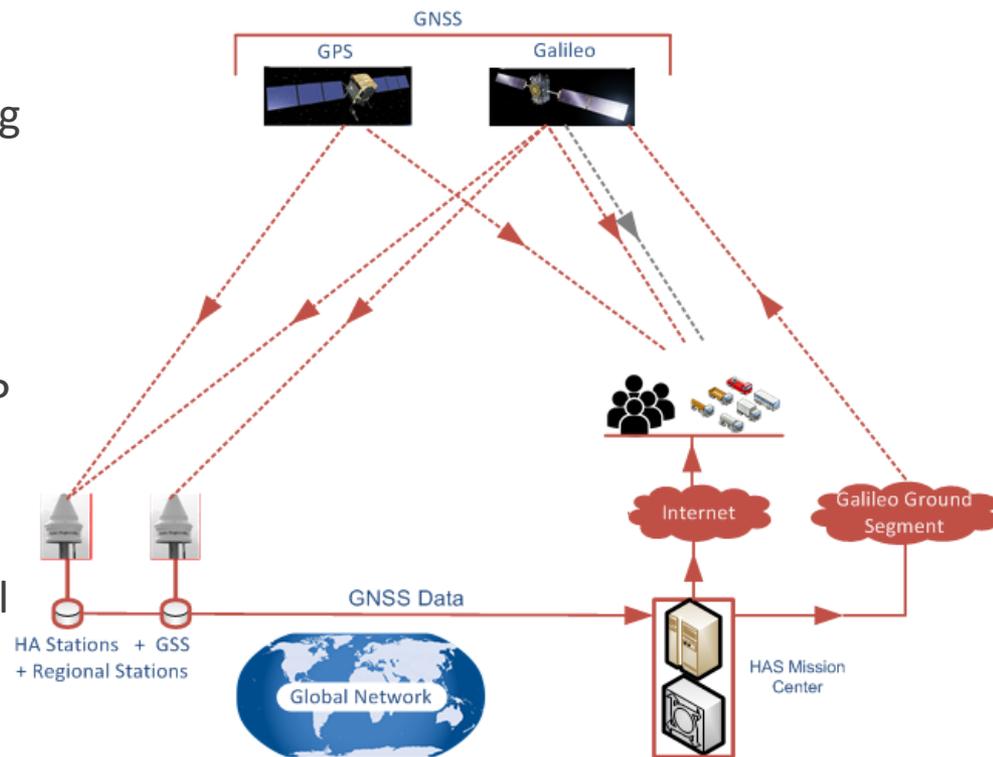
Provision of accurate satellite data (clocks, orbits and biases) and atmospheric data (mainly ionospheric corrections) to enable **Precise Point Positioning**.

| HAS | SERVICE LEVEL 1 | SERVICE LEVEL 2 |
|--|--|--|
| COVERAGE | Global | European Coverage Area (ECA) |
| CORRECTIONS DISSEMINATION | Galileo E6B using 448 bits per satellite per second / terrestrial (internet) | Galileo E6B using 448 bits per satellite per second / terrestrial (internet) |
| SUPPORTED CONSTELLATIONS & FREQUENCIES | Galileo E1/E5a/E5b/E6; E5 AltBOC GPS L1/L5; L2C | Galileo E1/E5a/E5b/E6; E5 AltBOC GPS L1/L5; L2C |
| HORIZONTAL ACCURACY 95% | <20 cm | <20cm |
| VERTICAL ACCURACY 95% | <40cm | <40cm |
| CONVERGENCE TIME | <300 s | <100 s |
| USER HELPDESK | 24/7 | 24/7 |

HAS High Level Architecture

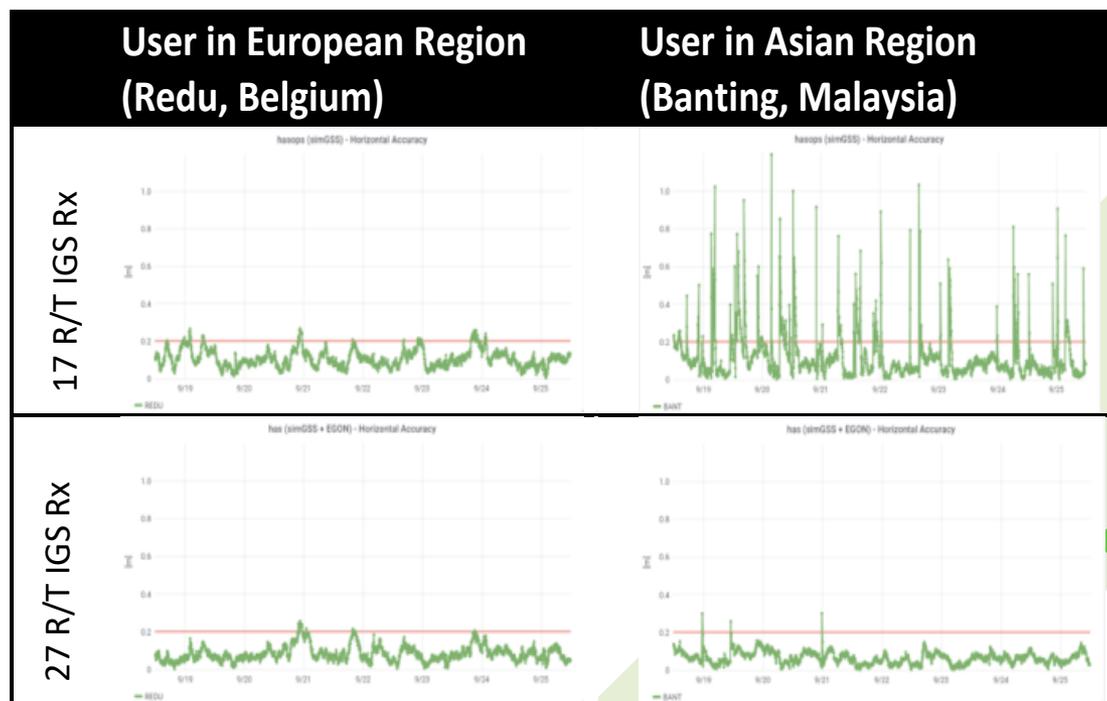
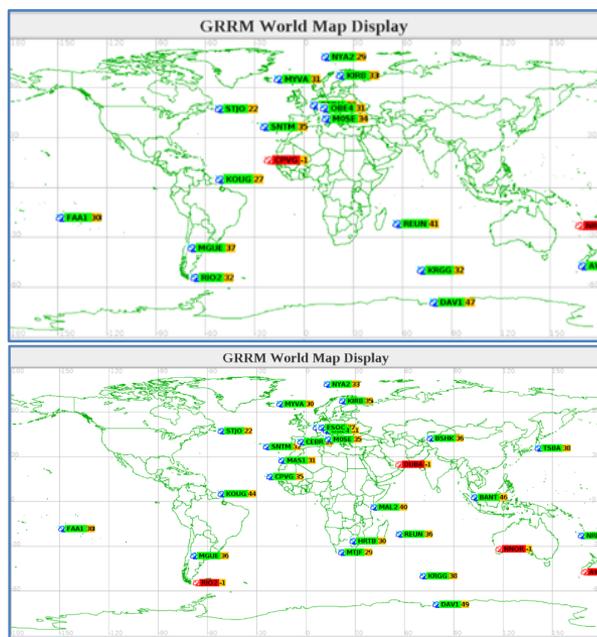
Main Features:

- Collection of GNSS observations utilizing reference network of Global and Regional Receivers
- Product Generation enabling global PPP and regional fast PPP (incl. Ionosphere)
- Dissemination through Galileo E6 Signal complementary terrestrial distribution channel (internet).
- Reception and Processing by User Terminals



HAS User Performance – Effect of Receiver Network

Dense Reference Receiver Network to achieve geometric diversity of the observations to provide stable service for the global service area



Sample PPP results from 2 different regions (2D error in cm)

Results illustrate the dependency based on Time Series of the Horizontal Accuracy obtained by emulation with two different Networks of IGS R/T receivers.

(PPP, GAL&GPS, BKG Client, ESOC Corrections)

HAS User Solution Convergence Time

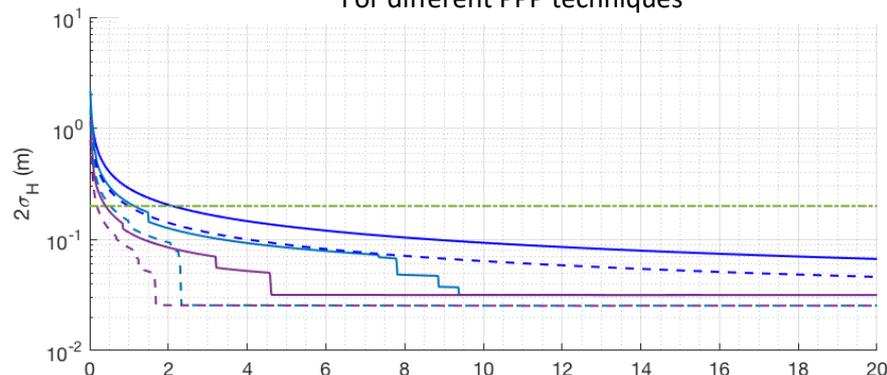
Convergence Time depends on:

- Quality of Corrections (Residual Error/Age)
- Enabled/User PPP Technique
 - classical PPP
 - PPP with Ambiguity Resolution
 - fast PPP
- Number of Corrected Satellites in local geometry (Single Constellation, Multi Constellation)

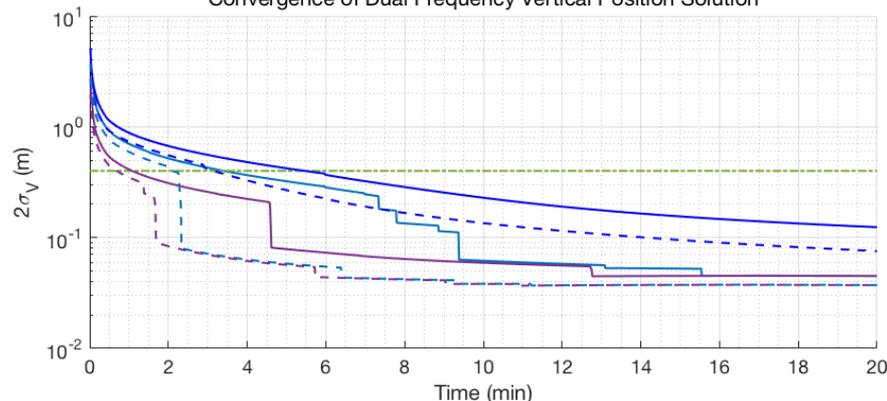
Challenge for HAS is the Convergence of the Vertical Solution:

- to the target of 40 cm within 300 second for global Service Level 1
- to the target of 40 cm within 100 seconds for regional Service Level 2

Simulation of PPP convergence for Static User
For different PPP techniques



Convergence of Dual Frequency Vertical Position Solution



- PPP Float Solution - E1/E5a, (Corrections: Orb, Clk)
- PPP Partial AR - E1/E5a, (Corrections: Orb, Clk, Co/Ph Bias)
- PPP Partial AR - E1/E5a, (Corrections: Orb, Clk, Co/Ph Bias, Iono)
- - PPP Float Solution Multi-Constellation - E1/E5a + L1/L5, (Corrections Orb, Clk)
- - PPP Partial AR Multi-Constellation - E1/E5a + L1/L5, (Correction: Orb, Clk, Co/Ph Bias)
- - PPP Partial AR Multi-Constellation - E1/E5a + L1/L5, (Corrections: Orb, Clk, Co/Ph Bias, Iono)
- - Convergence Target

Galileo High Accuracy Service – International Context

Other GNSS and RNSS gradually introduce similar capabilities in the near future, e.g. QZSS is providing already similar services on a Regional Scale (CLAS & MADOCA)

 International Committee on Global Navigation Satellite Systems

GNSS System Provided PPP Services

| System | Coverage | Format | Supported GNSS/RNSS | Service |
|------------------|--------------------|----------------|----------------------|---------------------------------------|
| Galileo | Global Regional | Open (CSSR) | | PPP (global) SSR-RTK (regional) |
| GLONASS/ SDCM | Regional | | GPS, GLO, GAL, BDS | |
| BeiDou-3 | Regional | Open | | |
| QZSS | Regional | Open (CSSR) | GPS, QZSS, GLO & GAL | PPP, PPP-AR SSR-RTK (JAP) |
| Australia | Regional | Open | GPS & GAL | PPP |
| Korea | Regional | | | |




India and Africa as well!

←

GAL & GPS

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Source: ICG-14, "Standards and Interoperability of Precise Point Positioning Services" by Working Groups D, B and S.

Galileo HAS – the first **global** Free-of-Charge High Accuracy Service

High Accuracy Service – Take away

Galileo High Accuracy Service will enable **20 cm/40 cm H/V PPP** positioning on a **global scale, free of charge** to Galileo Users

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**, with capabilities needed to be adaptable to evolving user expectations.

Galileo High Accuracy Service documentation and available interfaces:

GNSS Service Center (GSC):

<https://www.gsc-europa.eu/>
<https://www.gsc-europa.eu/helpdesk/>

Galileo E6-B/C Codes Technical Note:

https://www.gsc-europa.eu/sites/default/files/sites/all/files/E6BC_SIS_Technical_Note.pdf

GSA Market and Technology Reports:

<https://www.gsa.europa.eu/market/market-report>
<https://www.gsa.europa.eu/european-gnss/gnss-market/gnss-user-technology-report>

GSA Reports on User needs and requirements:

<https://www.gsa.europa.eu/gnss-applications/user-needs-and-requirements>

THANK YOU

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