Galileo High Accuracy Service
Groupe de travail GNSS et Positionnement (G&P)

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- What is Galileo HAS

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# Galileo OSNMA/HAS/CAS Background

EC Imp Decision (EU) 2017/224 (8-02-2017) amended by (EU) 2018/321 (2-03-2018)

Implementation of the Galileo Commercial service as:

- **CS High Precision or HAS Service:** Free service. High Accuracy corrections, accuracy down to 20 cm using E6-B.

- **CS Authentication**
  - **OSNMA:** authentication data broadcast in E1-B through the EDBS field
  - **CAS Service:** Authentication through access to encrypted codes (using a private crypto key), using E6-B for the access data and E6-C component (pilot).
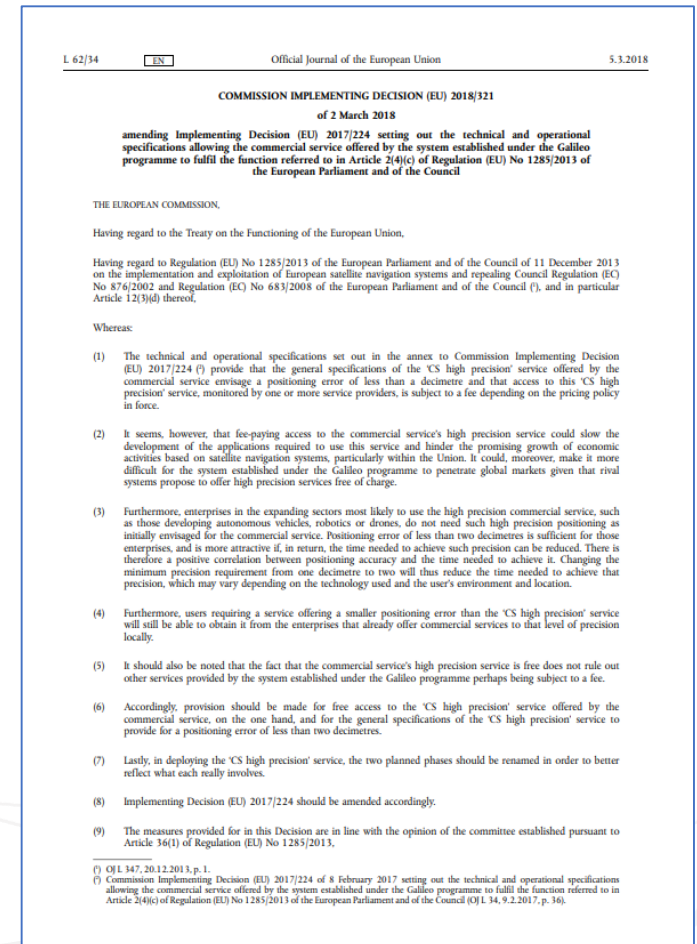
Galileo High Accuracy Service (HAS)
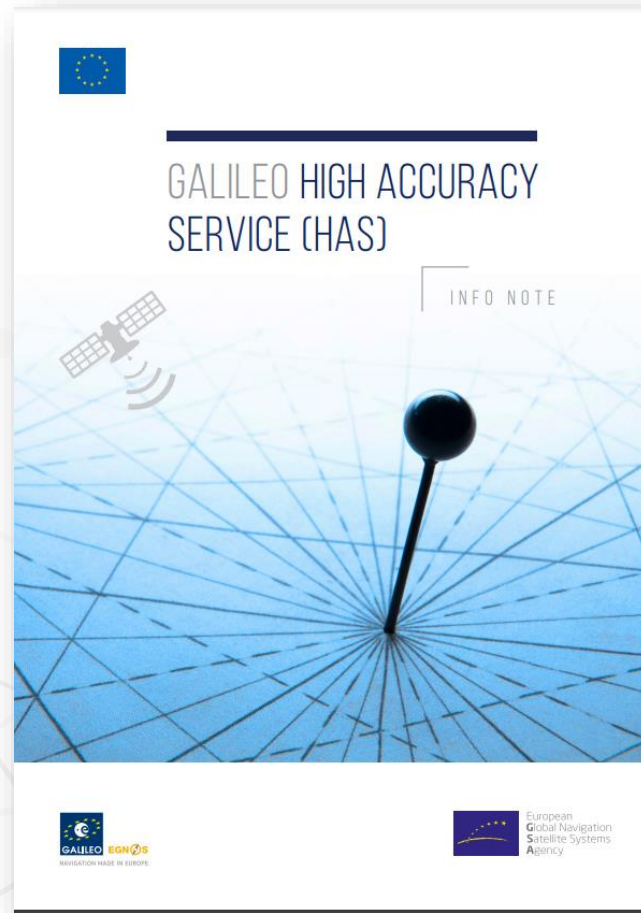
Overview of the **main characteristics of the service**, along with information on features such as **service levels, target performance, an implementation roadmap**, and an **overview of the target markets for the service**
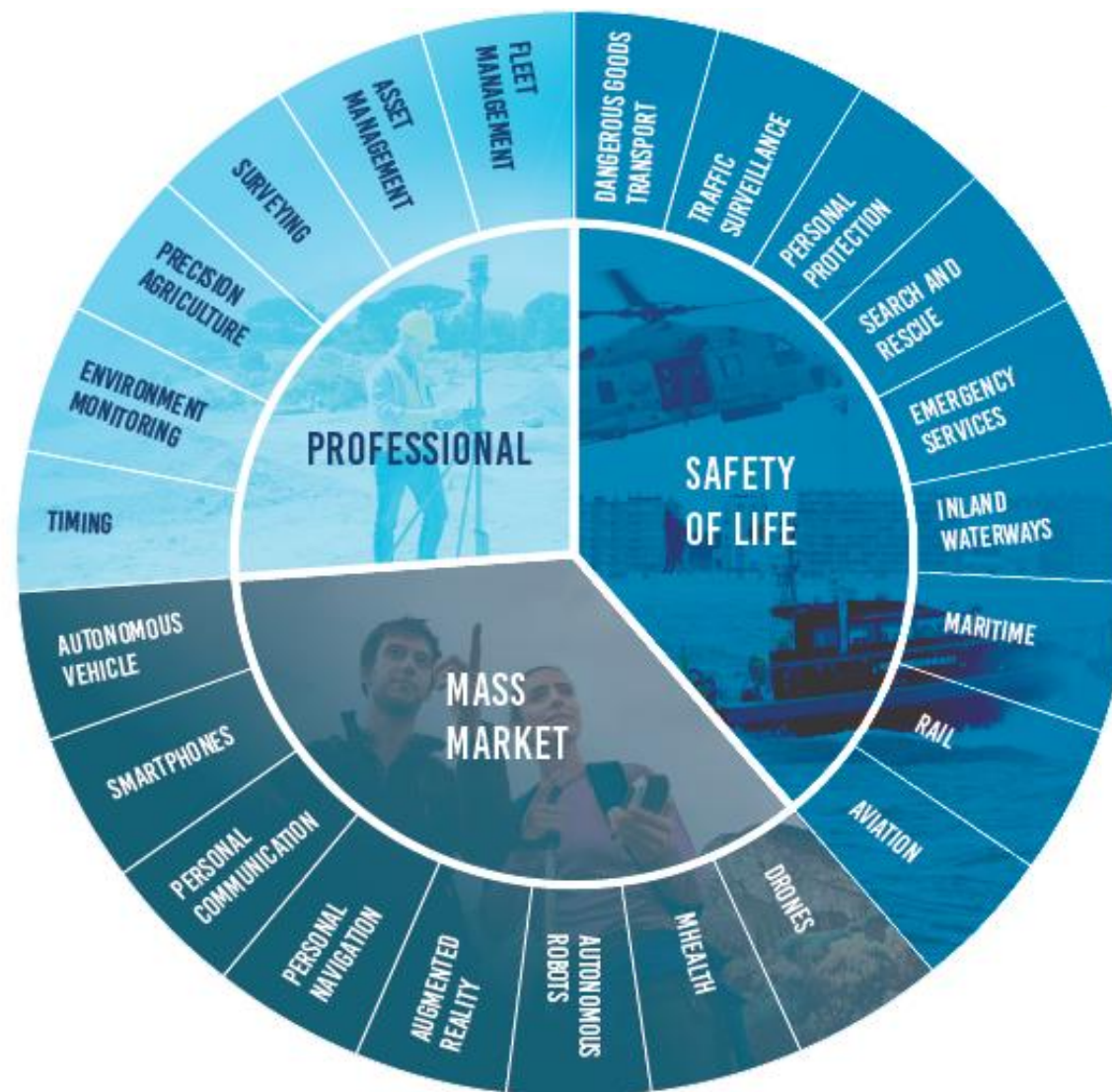
Target applications

Galileo HAS addresses both traditional and emerging markets and applications

Galileo HAS concept

- HAS is a Galileo service aimed at enabling PPP positioning worldwide and for free

- HAS provides orbit, clock, code and phase biases for Galileo and GPS

High Accuracy Service main features:

- Collection of GNSS observations from a reference stations network

- Product Generation for global PPP and Ionospheric products to enable faster regional PPP

- SIS dissemination through E6B (1278.75 MHz) and terrestrial (internet) distribution in RTCM-like format
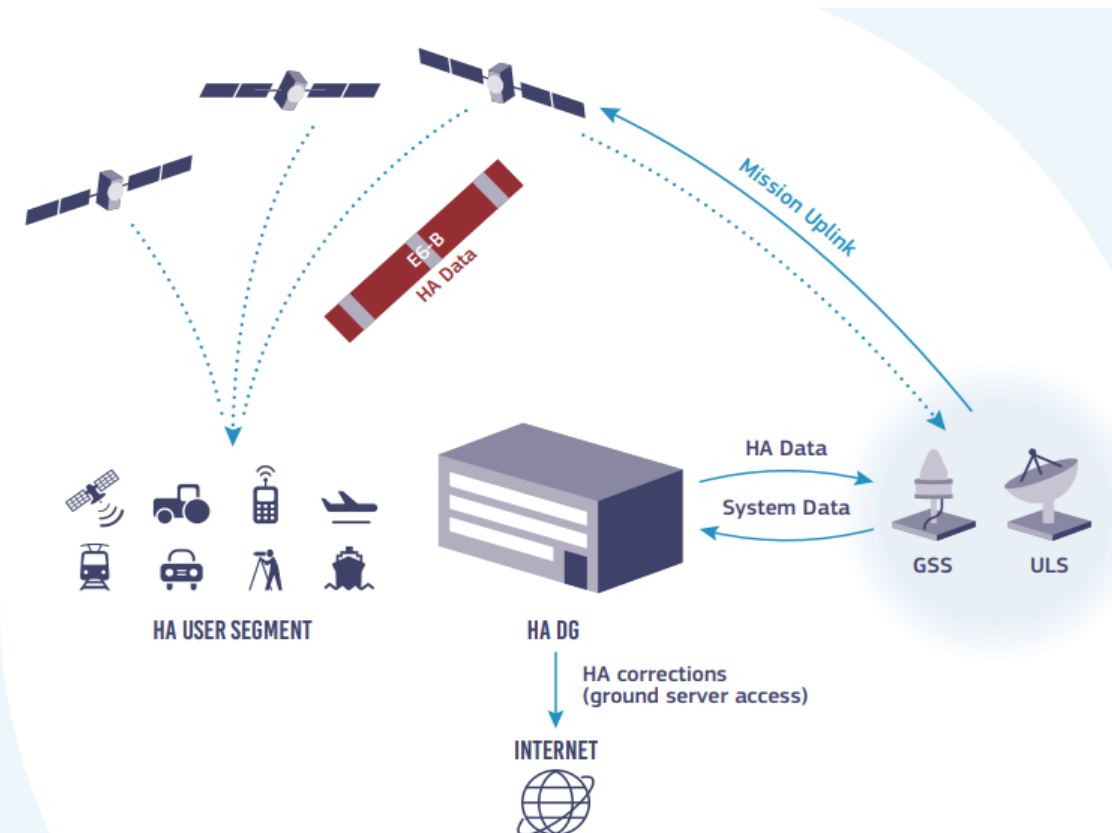
HAS Main characteristics

HAS	SERVICE LEVEL 1	SERVICE LEVEL 2
COVERAGE	Global	European Coverage Area (ECA)
TYPE OF CORRECTIONS	PPP - orbit, clock, biases (code and phase)	PPP - orbit, clock, biases (code and phase incl. atmospheric corrections
FORMAT OF CORRECTIONS	Open format similar to Compact-SSR (CSSR)	Open format similar to Compact-SSR (CSSR)
DISSEMINATION OF CORRECTIONS	Galileo E6B using 448 bits per satellite per second / terrestrial (internet)	Galileo E6B using 448 bits per satellite per second / terrestrial (internet)
SUPPORTED CONSTELLATIONS	Galileo, GPS	Galileo, GPS
SUPPORTED FREQUENCIES	E1/E5a/E5b/E6; E5 AltBOC L1/L5; L2C	E1/E5a/E5b/E6; E5 AltBOC L1/L5; L2C
HORIZONTAL ACCURACY 95%	<20 cm	<20 cm
VERTICAL ACCURACY 95%	<40 cm	<40 cm
CONVERGENCE TIME	<300 s	<100 s
AVAILABILITY	99%	99%
USER HELPDESK	24/7	24/7

Galileo HAS roadmap & perf targets
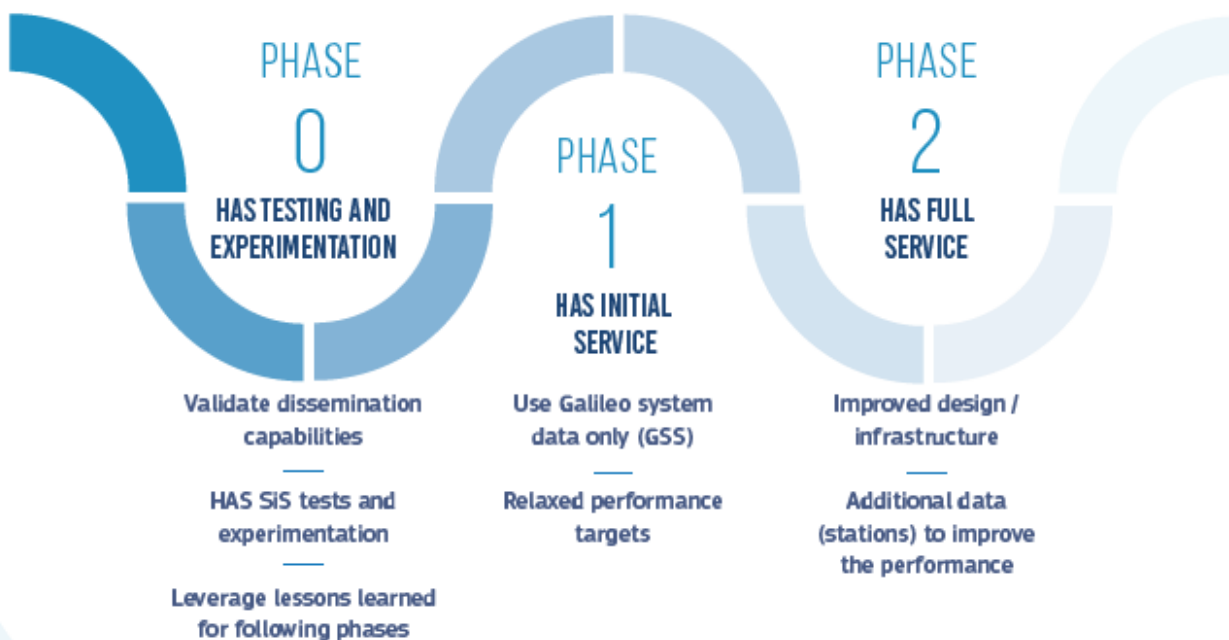
	Phase 0 SIS Testing	Phase 1 Initial Service	Phase 2 Full Service
Coverage	EU+	EU+	Global
Code biases	Y	Y	Y
Phase biases	N	Y	Y
Galileo corrected signals	E1, E5a, E5b, E6	E1, E5a, E5b, E6	E1, E5a, E5b, E5, E6
GPS corrected signals	L1, L2P	L1, L2P, L2C	L1, L2C, L5
Horizontal accuracy 95%	N/A	<20 cm TBC	<20 cm
Vertical accuracy 95%	N/A	<40 cm TBC	<40 cm
Availability	N/A	99% TBC	99%
SL1 (Global) Conv. time	N/A	<300 s TBC	<300 s
SL21 (EU) Conv. time – Ionosphere corrections	N/A	N/A	<100 s
Internet Data Distrib (Ground channel)	N	Y	Y
Authentication	N	N	Y
Start	2020	2022	2024+

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HAS Initial Service is coming...

CURRENT STATUS

HAS

1ˢᵗ ever free of charge global High Accuracy Service test signal broadcast by a GNSS!!!

Tested by Key stakeholders from MS (>15 companies – including CNES) promising initial results

2022   **>2024**

PHASE 0 — HAS TESTING AND EXPERIMENTATION
Validate dissemination capabilities

PHASE 1 — HAS INITIAL SERVICE
Use Galileo system data only (GSS)

PHASE 2 — HAS FULL SERVICE
Improved design / infrastructure

NEW GALILEO HAS SIS ICD PUBLISHED
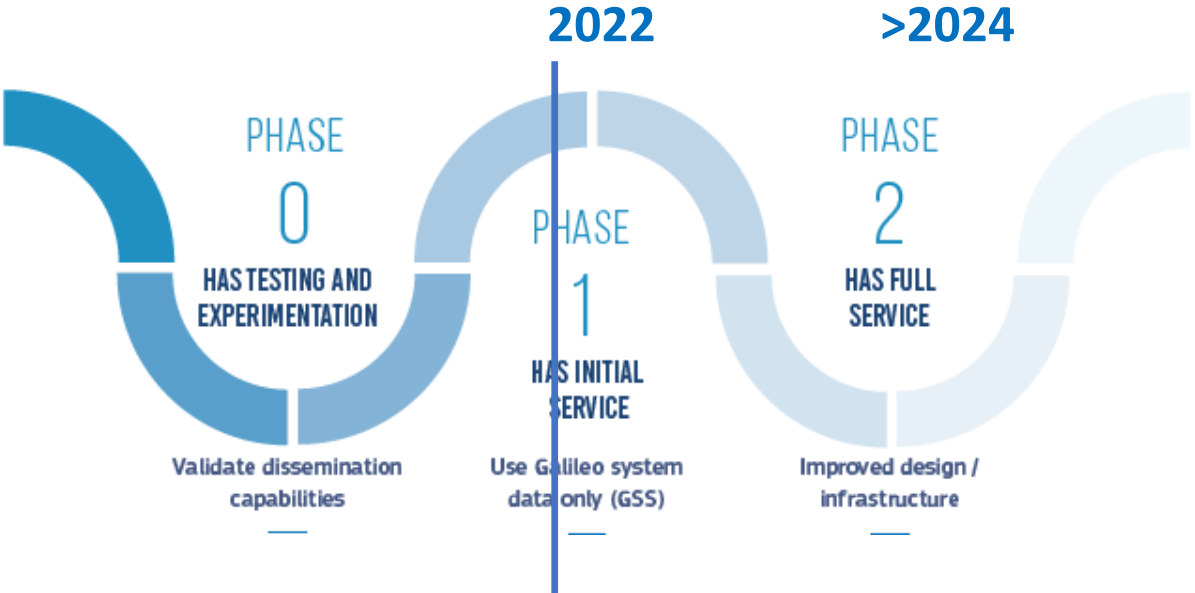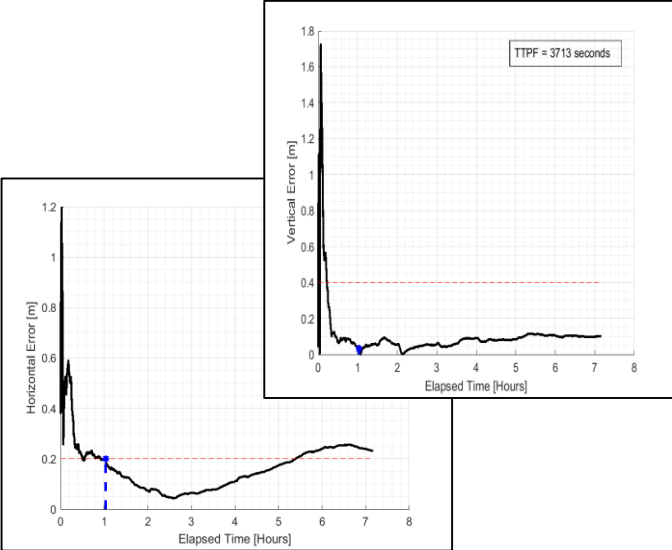
▪ HAS SIS ICD available since May 22

https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_HAS_SIS_ICD_v1.0.pdf

▪ SIS available worldwide (HAS Status flag = 'test' mode)

▪ Initial Service available by the end2022

11

HAS SIS ICD message structure

Sync	Symbols	Total (symbols)
16	984	1000

C/NAV Page				Total (bits)
Reserved	HAS Page	CRC	Tail	
14	448	24	6	492

Table 3: C/NAV Page Layout

HAS Page		Total (bits)
HAS Page Header	HAS Message	
24	424	448

Table 5: HAS Page Layout

Galileo HAS fields (Phase 1)

Correction	Range	Scale factor	Unit	Size (bits)
Orbit: delta radial	± 10.2375	0.0025	m	13
Orbit: delta in-track	± 16.376	0.0080	m	12
Orbit: delta cross-track	± 16.376	0.0080	m	12
Delta clock	-10.2375 to $+10.2350$	0.0025	m	13
Code bias	± 20.46	0.02	m	11
Phase bias	± 10.23	0.01	cycles	11

HPVRS encoding/decoding

| H | Mask, Orbit Corr., Code Bias | HAS Msg. |

| M_1 | M_2 | … | | M_k | HAS Msg. to encode ($k<32$ blocks) |

| C_1 | C_2 | … | | C_n | Encoded HAS Msg. ($n<255$ blocks) |
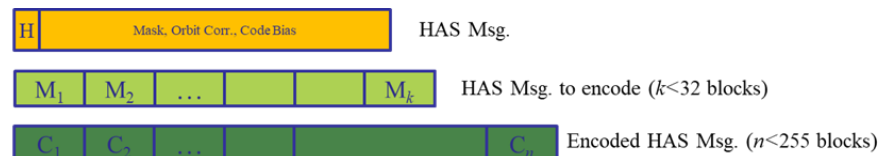
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Galileo HAS test campaign

OBJECTIVES

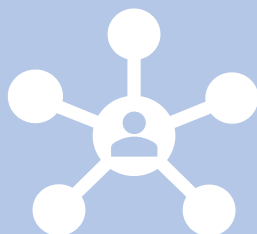## PROMISING RESULTS

- Validation of critical HAS service elements (ICD).
- Independent assessment of performance*

- Engage stakeholders
- Build a strong relationships with future HAS users
- Foster HAS adoption

- Gather lessons learned and recommendations towards HAS Full Service

*Test campaign is supported by a demonstrator which is not fully representative of the future operational service infrastructure, thus, **the tests performed and results obtained will not represent the performance of the final service**

High Accuracy Reference Algorithm: Under development by EUSPA (ad-hoc contract). Foreseen to be available to any interested user when the Service is declared available.

PPP User performance (GAL E1-E5a, M1, 24/06/2021), PolaRx

TTPF = 3713 seconds
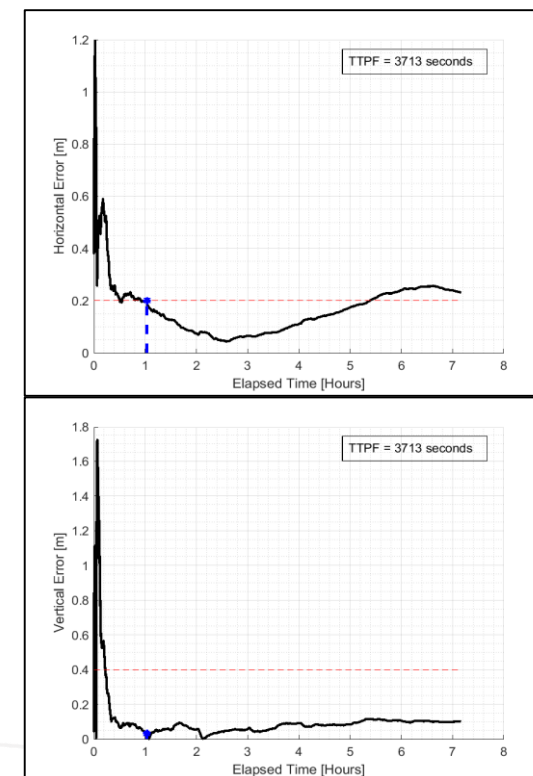
Orbit & Clock Accuracy with HAS Live Signals

- HAS Orbit and Clock with live signals between May 2021 and June 2022

- Septentrio PolaRx5S rx with Trimble Zephyr 2 antenna @JRC EC (Italy)

- HAS broadcast test signals and performance might not be representative of final service ones

I. Martini, M. Susi, I. Fernandez-Hernandez, "PPP and Galileo High Accuracy Service with Satellite Selection Strategies for Kinematic Applications", IONGNSS+2022

Orbit & Clock Accuracy with HAS Live Signals

I. Martini, M. Susi, I. Fernandez-Hernandez, *"PPP and Galileo High Accuracy Service with Satellite Selection Strategies for Kinematic Applications", IONGNSS+2022*
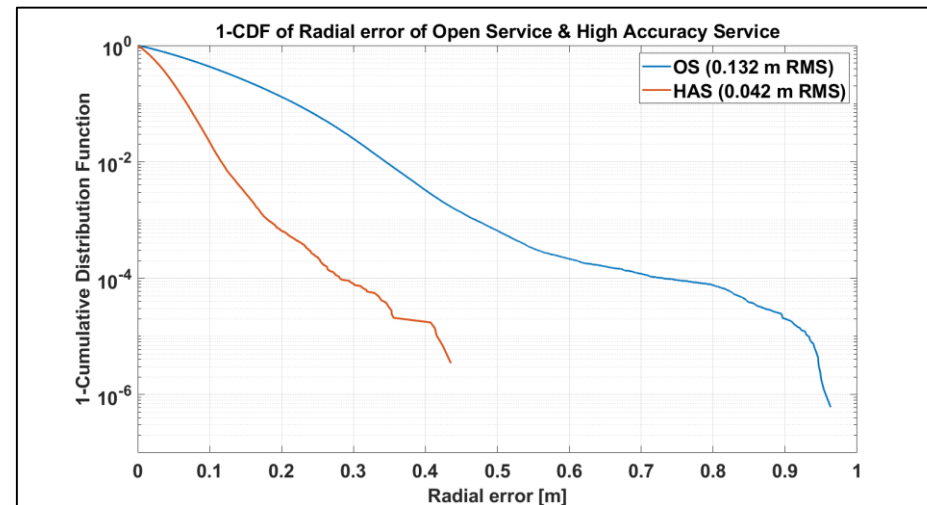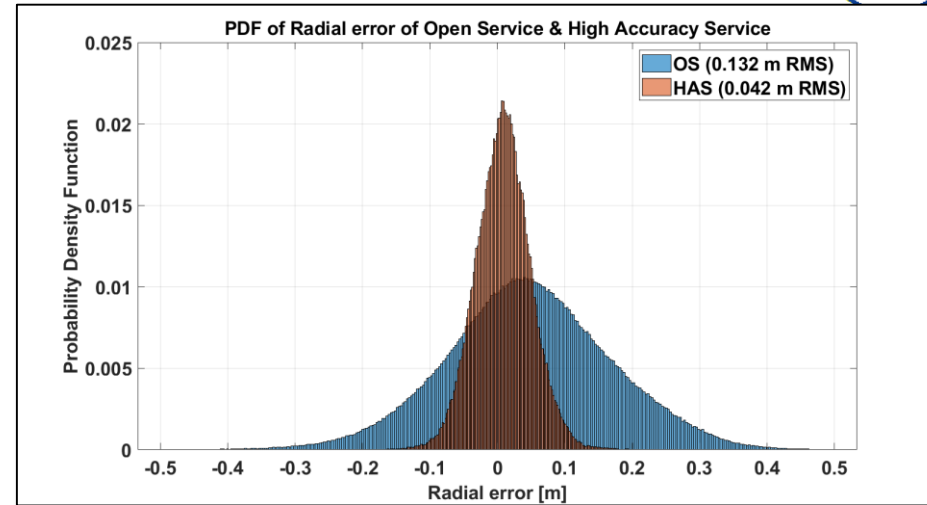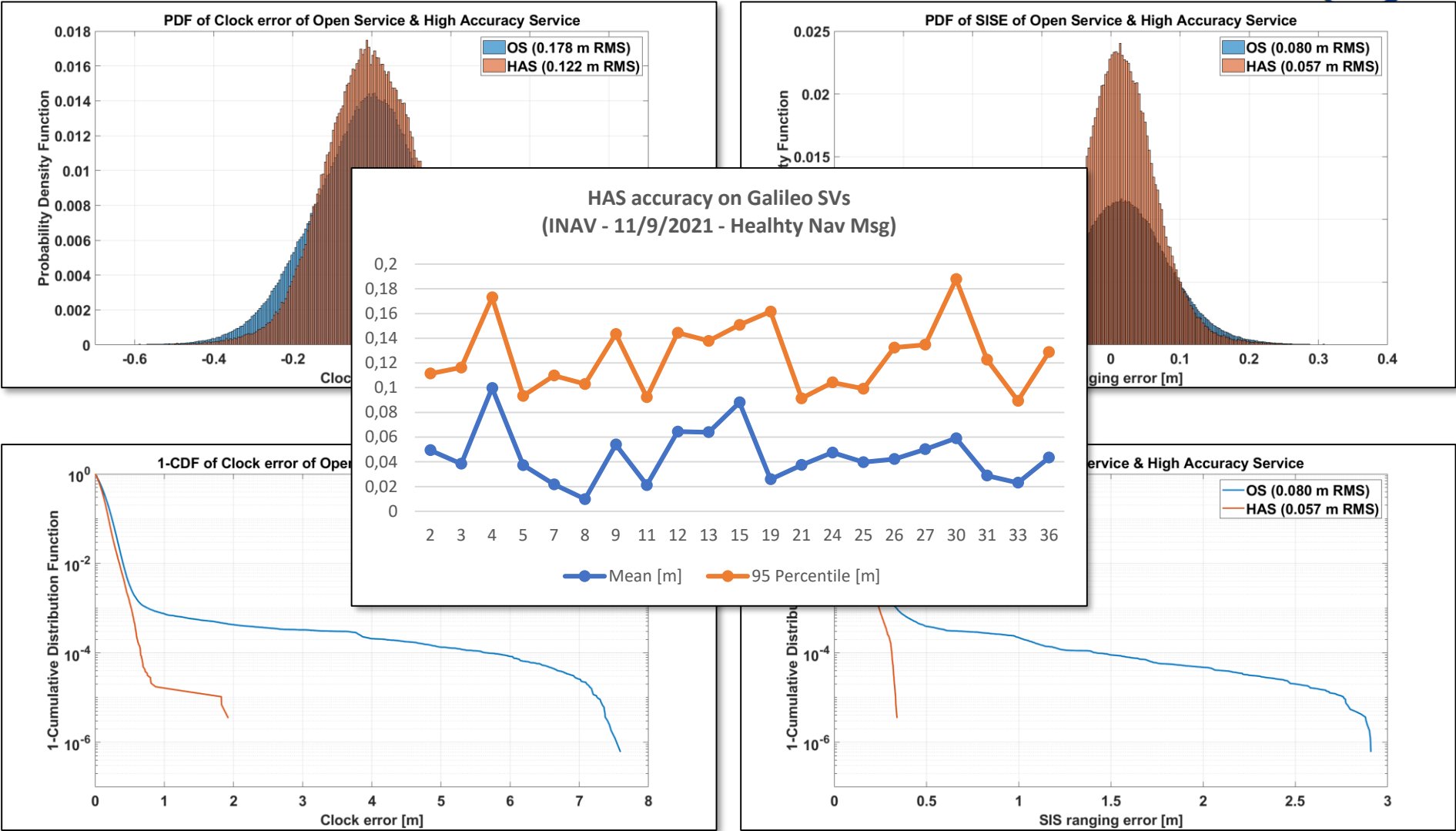
HAS-PPP ACCURACY PERFORMANCE

Initial considerations:

- Monitoring stations are a subset of GMV's GGRN (Global GNSS Reference Network)

- Open sky conditions for all the stations (see picture)

- Punctual local or receiver effects also contribute to error statistics

- Performance measured in stationary mode after convergence

- PPP configuration used:
  - Multiconstellation GAL+GPS
  - Double frequency E1-E5a and L1C/A-L2CL (Iono-free + ionospheric estimation)
  - PPP float

- RMS and 95th percentile of errors from the 6 days of scenarios have been obtained for all the stations

A. Chamorro, et al. "Early Demonstration of Galileo HAS user Performances", IONGNSS+ 2022

HAS-PPP ACCURACY PERFORMANCE

Positioning error performance for Europe and Africa

- Best performance expected for Europe due to the GSS network distribution

- Performance of the station in Africa is similar to performance of stations in Europe

Europe & Africa	Errors RMS (cm)		
	North	**East**	**Height**
SPTR	4.5	6.6	13.8
ROBU	5.7	6.6	14.0
SWOJ	6.5	6.1	14.6
NAWI	4.0	5.3	14.4

Europe & Africa	Errors p95 (cm)	
	Horizontal	**Vertical**
SPTR	19.5	26.5
ROBU	17.3	26.8
SWOJ	13.5	28.3
NAWI	18.1	25.3

A. Chamorro, et al. "Early Demonstration of Galileo HAS user Performances", IONGNSS+ 2022

EUROPEAN STATION (SWEDEN)

RT_Error_File_HAS_SIS_E1_E5A_noIAR_SWO1

RT_Error_File_HAS_SIS_E1_E5A_noIAR_SWO1

Height (RMS=10.40)
North (RMS=6.13)
East (RMS=6.57)
Sats

Height (RMS=11.77)
North (RMS=3.99)
East (RMS=4.20)
Sats

Height (RMS=12.12)
North (RMS=4.78)
East (RMS=2.94)
Sats

Height (RMS=12.90)
North (RMS=4.77)
East (RMS=4.89)
Sats

Height (RMS=20.64)
North (RMS=9.96)
East (RMS=9.61)
Sats

Height (RMS=16.96)
North (RMS=7.61)
East (RMS=6.09)
Sats

HAS-PPP ACCURACY PERFORMANCE

Positioning error performance for America

- Slight difference in accuracy between North America and South America/Pacific

America	Errors RMS (cm)		
	North	**East**	**Height**
USNA	6.0	8.3	17.5
CABU	6.1	9.0	21.9
CHSA	8.8	13.7	24.0
FRTA	9.1	9.7	24.2

America	Errors p95 (cm)	
	Horizontal	**Vertical**
USNA	19.8	32.9
CABU	21.4	38.1
CHSA	26.5	36.1
FRTA	27.0	40.7

A. Chamorro, et al. "Early Demonstration of Galileo HAS user Performances", IONGNSS+ 2022

HAS-PPP ACCURACY PERFORMANCE

Positioning error performance for Asia

- Some degradation starts to appear for most eastern stations

- 95th percentile affected by punctual reconvergences due to lower corrections availability

- However, accuracy is similar to other regions when sufficient corrected satellites are available (reflected in RMS)
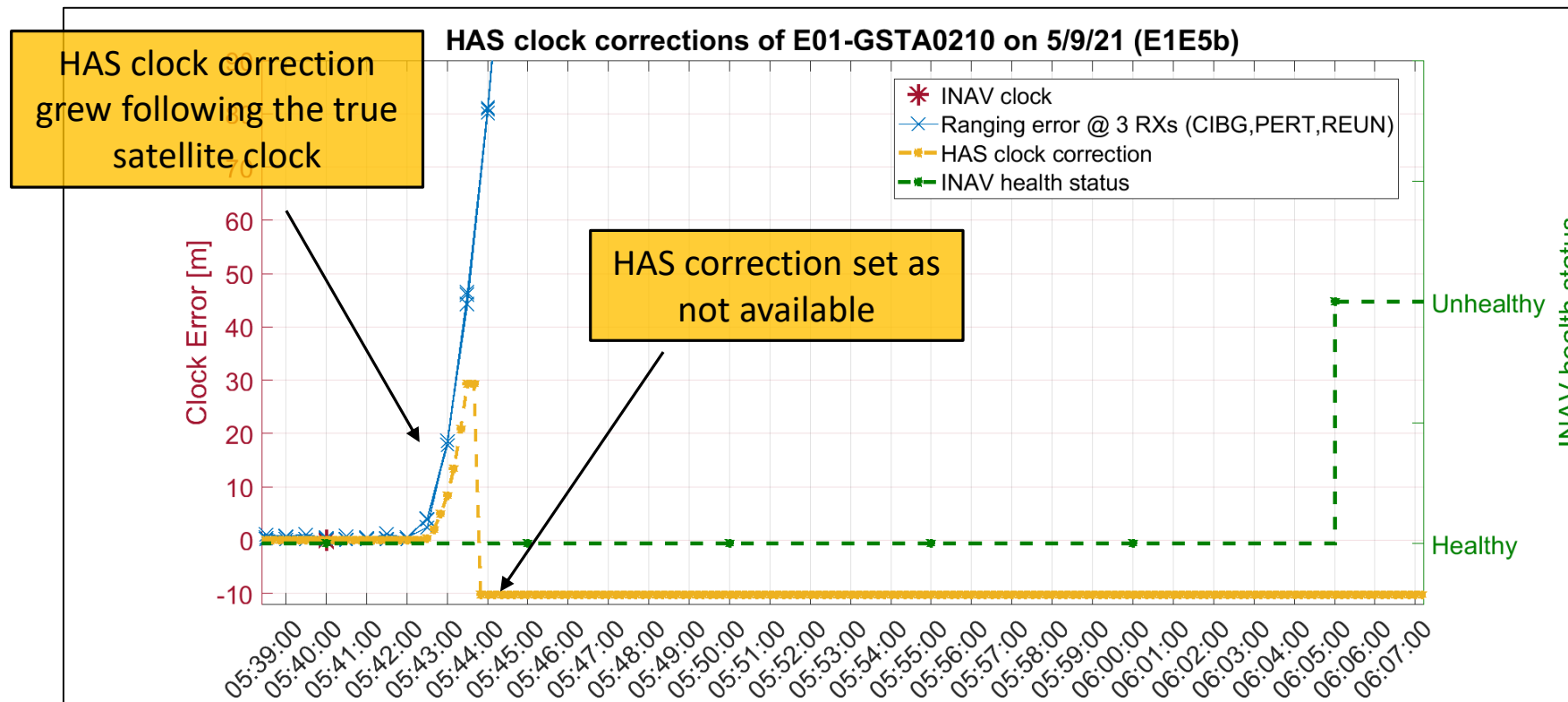
Asia	Errors RMS (cm)		
	North	East	Height
INKO	5.8	8.7	21.8
TATA	8.6	15.9	27.0

Asia	Errors p95 (cm)	
	Horizontal	Vertical
INKO	19.1	35.7
TATA	33.1	52.2

A. Chamorro, et al. "Early Demonstration of Galileo HAS user Performances", IONGNSS+ 2022

HAS and fault detection

- If the HAS correction value grows and shows a degradation of the orbit and/or clock error, the user excludes the satellite to avoid impact on the position performance

- In addition, the HAS message informs the user that the satellite shall not be used

HAS clock corrections of E01-GSTA0210 on 5/9/21 (E1E5b)

HAS clock correction grew following the true satellite clock

HAS correction set as not available

Legend:
- INAV clock
- Ranging error @ 3 RXs (CIBG,PERT,REUN)
- HAS clock correction
- INAV health status

Clock Error [m]: 60, 50, 40, 30, 20, 10, 0, -10

INAV health status: Unhealthy, Healthy

Time axis: 05:39:00 – 06:07:00

I. Martini et al. "Satellite Anomaly Detection with PPP Corrections: A Case Study with Galileo's High Accuracy Service" ION ITM January 2022

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Next Steps

Short term:

- Finish Validation phase
- Declare HAS Initial Service (SiS and internet distribution)
- Develop user segment
  - More E6 receivers
  - EUSPA R&D actions
  - HAS Reference algorithm and HASlib

Mid-long term:

- **Improve the HAS performance** towards full Service:
  - Improve SL1: Complete infrastructure with more stations
  - Enable HAS SL2: ionosphere correction message in Europe
- **New HAS features**: Add authentication and error characterization to HAS message (support to integrity models)
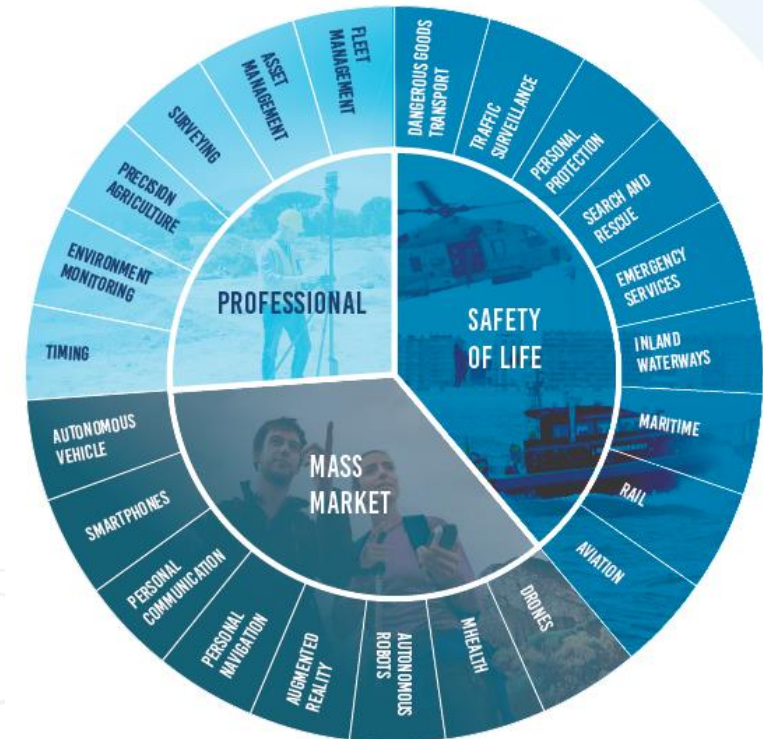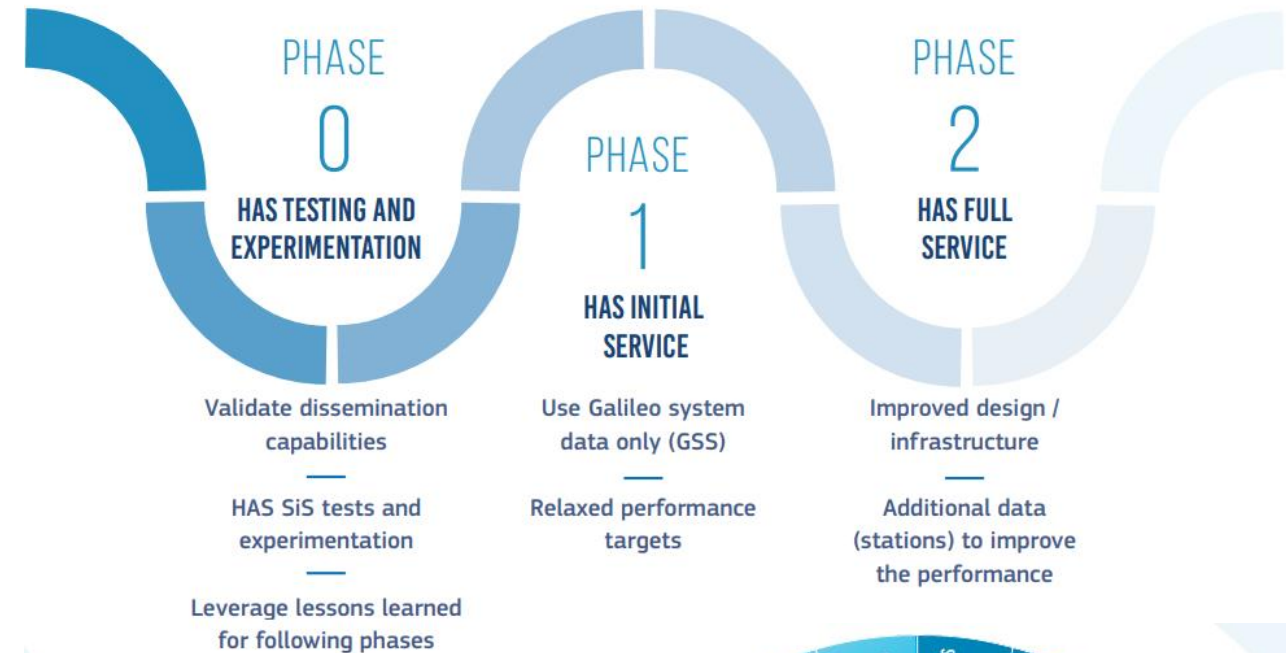
Linking space to user needs

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