EU SPACE

Galileo
High Accuracy Service

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European Commission
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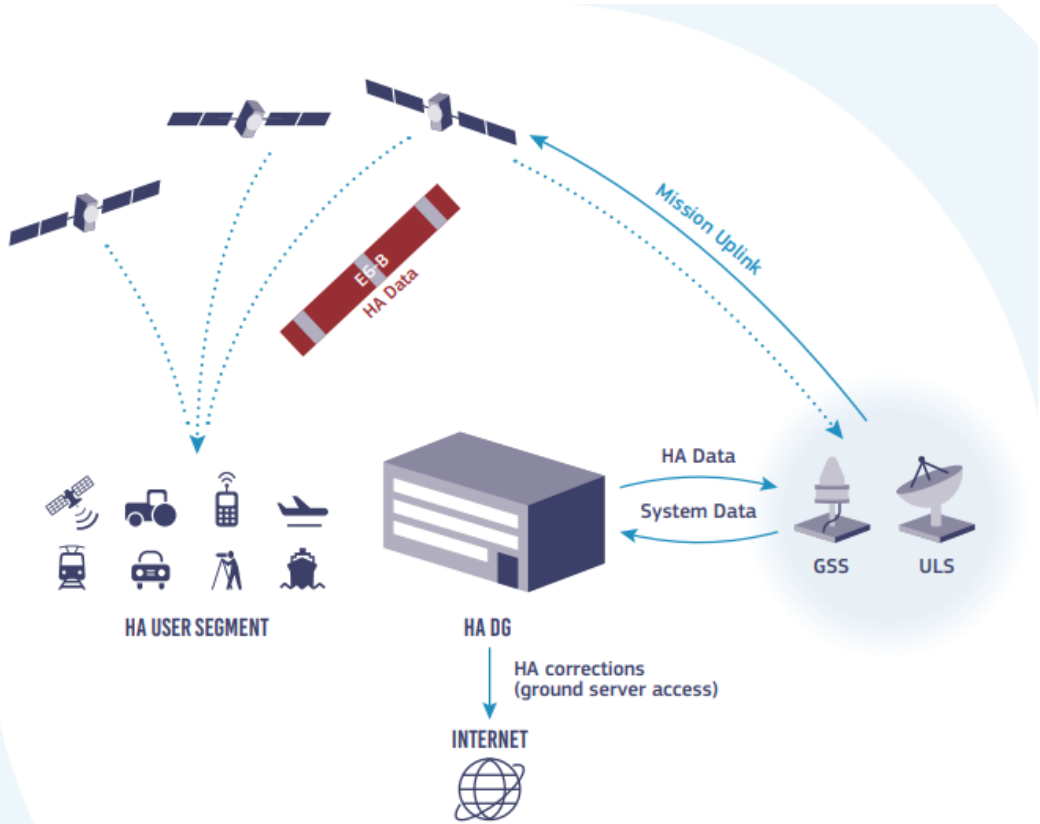
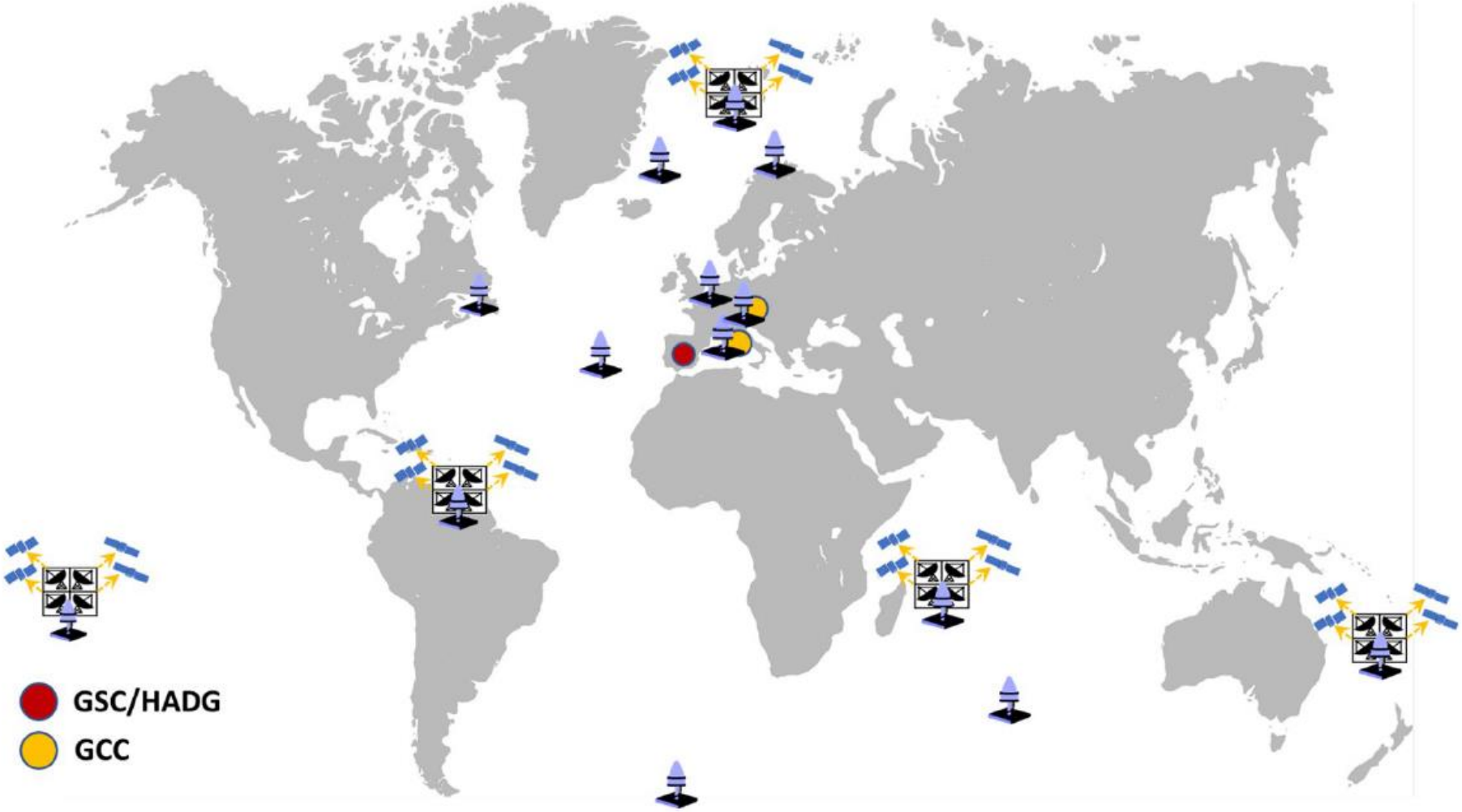
Overview of Galileo High Accuracy Service (HAS)

- Galileo HAS is a Galileo service aimed at providing precise corrections, allowing PPP positioning worldwide and for free
- Galileo HAS provides orbit, clock, code and phase biases for Galileo and GPS (I/NAV & CNAV iono-free and Galileo E1, E5a,E5b, E6B/C and GPS L1C/A, L2C, L2P signals)
- SIS dissemination through E6B (1278.75 MHz) and ground dissemination channel through a real-time connection in RTCM-like format



European Union Agency for the Space Program (EUSPA), "Information Note on Galileo High Accuracy Service," 2020. [Online]. Available: https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_HAS_Info_Note.pdf.

Galileo HAS infrastructure



Galileo HAS Phase 1 architecture. The 14 GSS (Galileo Sensor Stations) are depicted with a single antenna, and the five ULS (Up-Link stations) are depicted with four antennas

Fernandez-Hernandez, I., et al., "Galileo high accuracy service: initial definition and performance". GPS Solutions, 26(3), 1-18, 2022

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

Galileo HAS phases and performance targets

	Phase 0 SIS Testing	Phase 1 Initial Service	Phase 2 Full Service
Coverage	EU+	EU+	Global
Clock 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 requirement 95%	N/A	<20 cm TBC	<20 cm
Vertical accuracy requirement 95%	N/A	<40 cm TBC	<40 cm
Availability	N/A	99% TBC	99%
Convergence time requirement Global, no ionosphere (SL1)	N/A	<300 s TBC	<300 s
EU, Ionosphere corrections (SL2)	N/A	N/A	<100 s
Ground channel	N	Y	Y
Authentication	N	N	Y
Start	2020	2022-23	2024+

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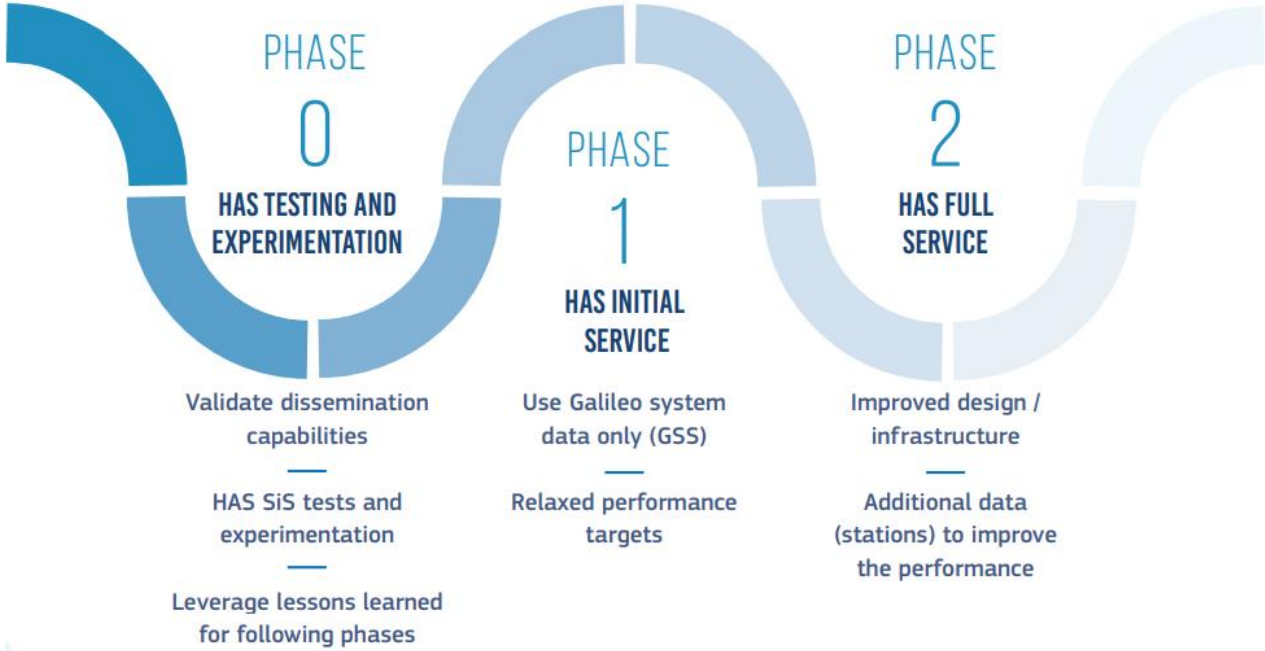
HAS current status

- Three phases:
  - Phase 0 (testing)
  - Phase 1 (initial service)
  - Phase 2 (full service)

- Current status: Finishing Phase 0
  - HAS SIS ICD available since May 22*
  - SIS readily available worldwide (HAS Status flag = ‘test’ mode)

- Initial Service declaration by end2022/early2023



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

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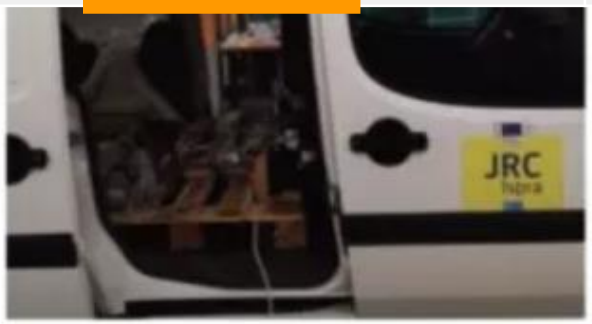
HAS Target Performance

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

Time To Receive Data (HAS message)

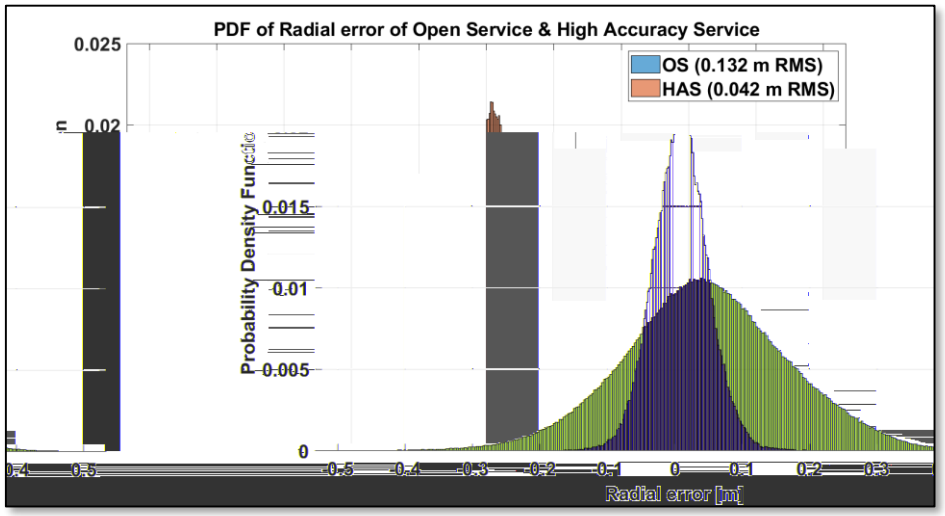
	Mean [s]	Mode [s]	Median [s]	95% Quantile [s]	Max [s]	Min [s]
FEB 27A	8.46	7	8	13	33	6
FEB 27B	8.71	7	7	17	65	4
FEB 28A	11.16	7	8	32	152	4
FEB 28B	7.61	6	6	14	36	5

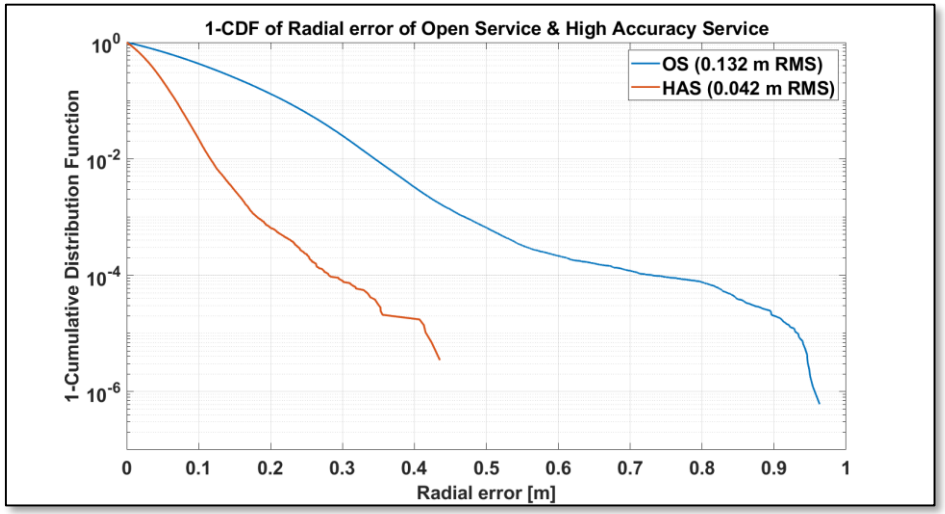


https://insidegnss.com/galileos-high-accuracy-service-field-experimentation-of-data-dissemination-schemes/

Galileo orbit&clock accuracy with HAS live signals

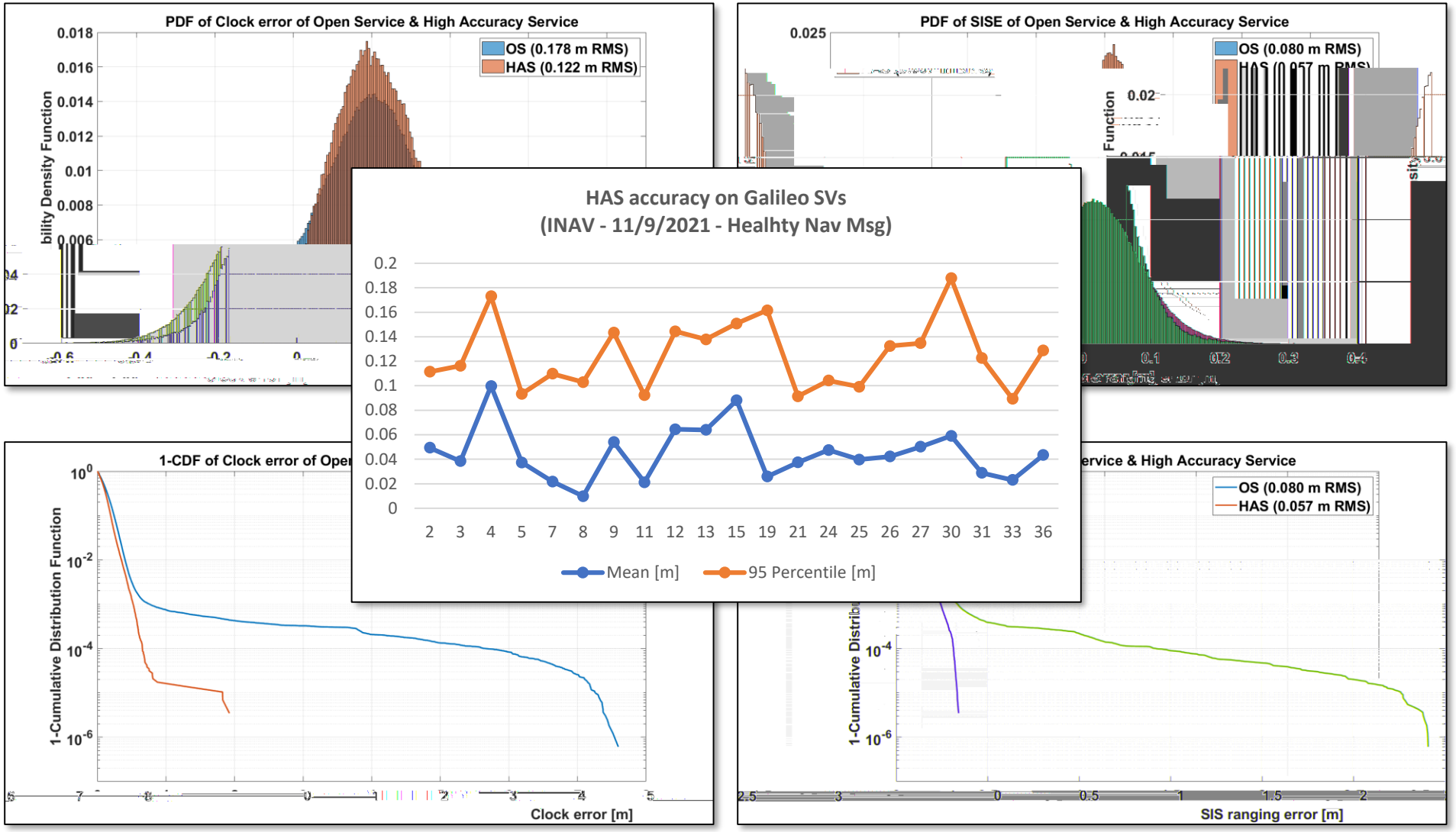
- HAS Orbit and Clock with live signals between May 2021 and June 2022
- Septentrio PolaRx5S rx with Trimble Zephyr 2 antenna @JRC EC (Italy)
- HAS broadcast test signals and performance might not be representative of final service ones





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

Galileo 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

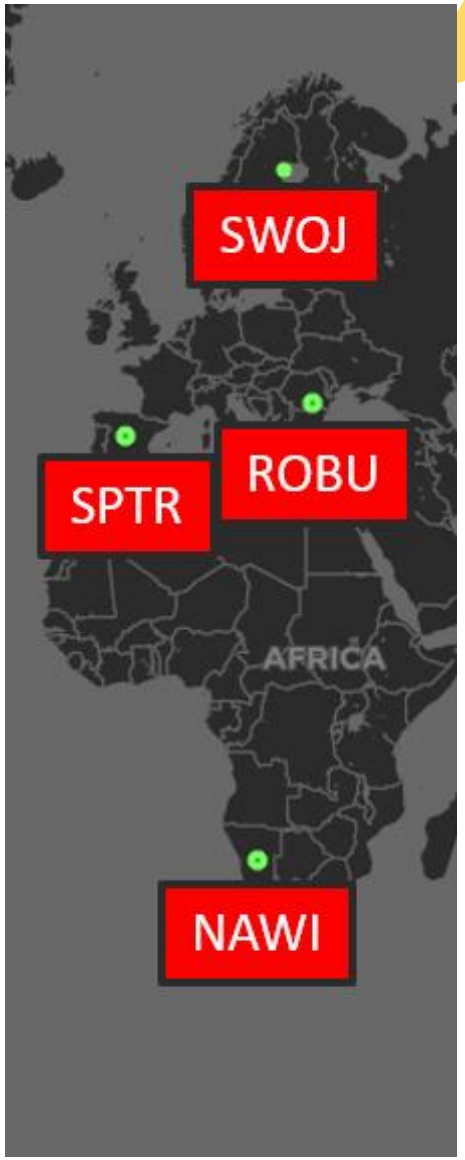
HAS-PPP ACCURACY PERFORMANCE

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

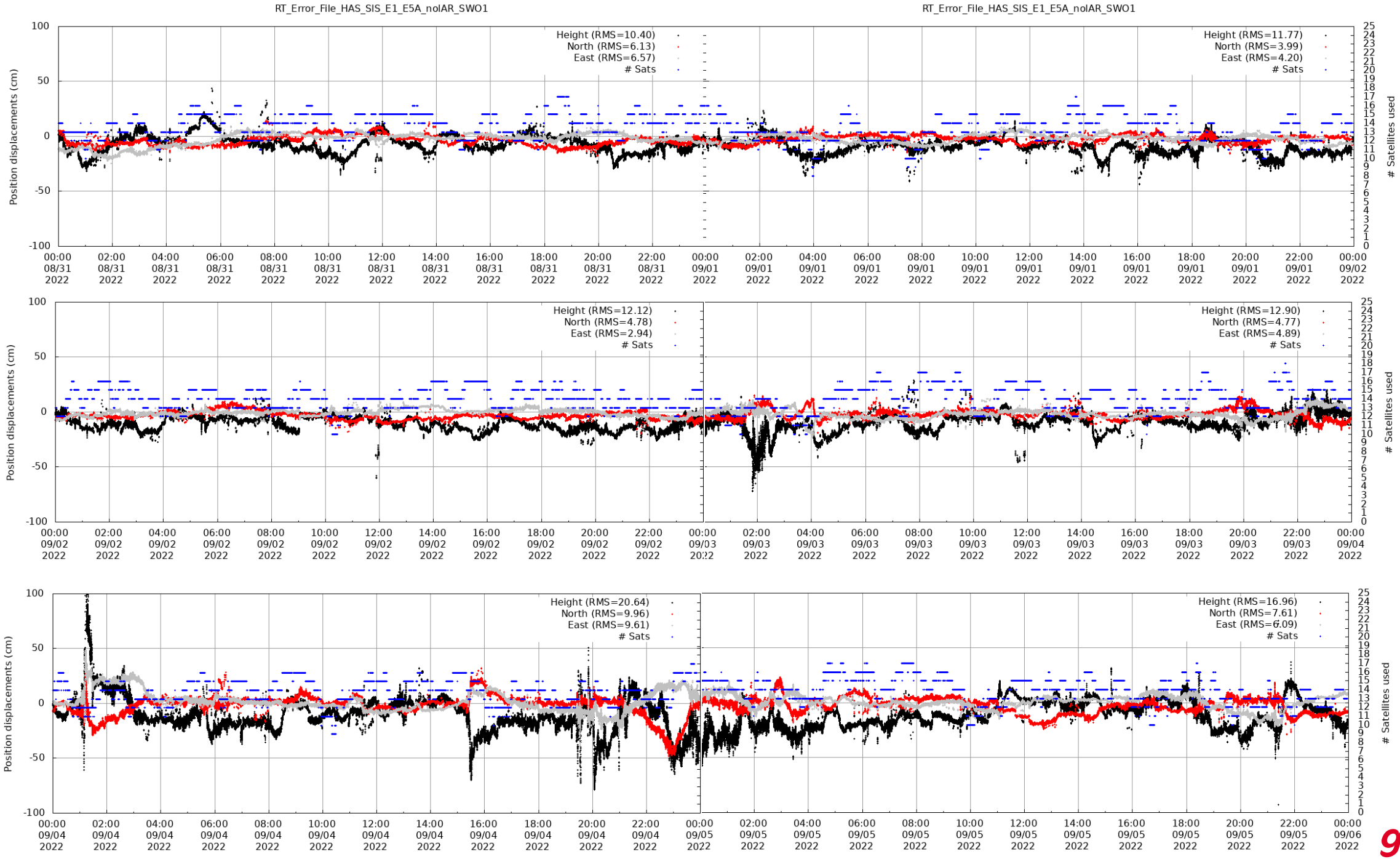
Europe & Africa	Errors RMS (cm)		
	North	East	Height
SPTR	4.5	6.6	13.8
ROBU	5.7	6.6	14.0
SWOJ	6.5	6.1	14.6
NAWI	4.0	5.3	14.4

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)



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)

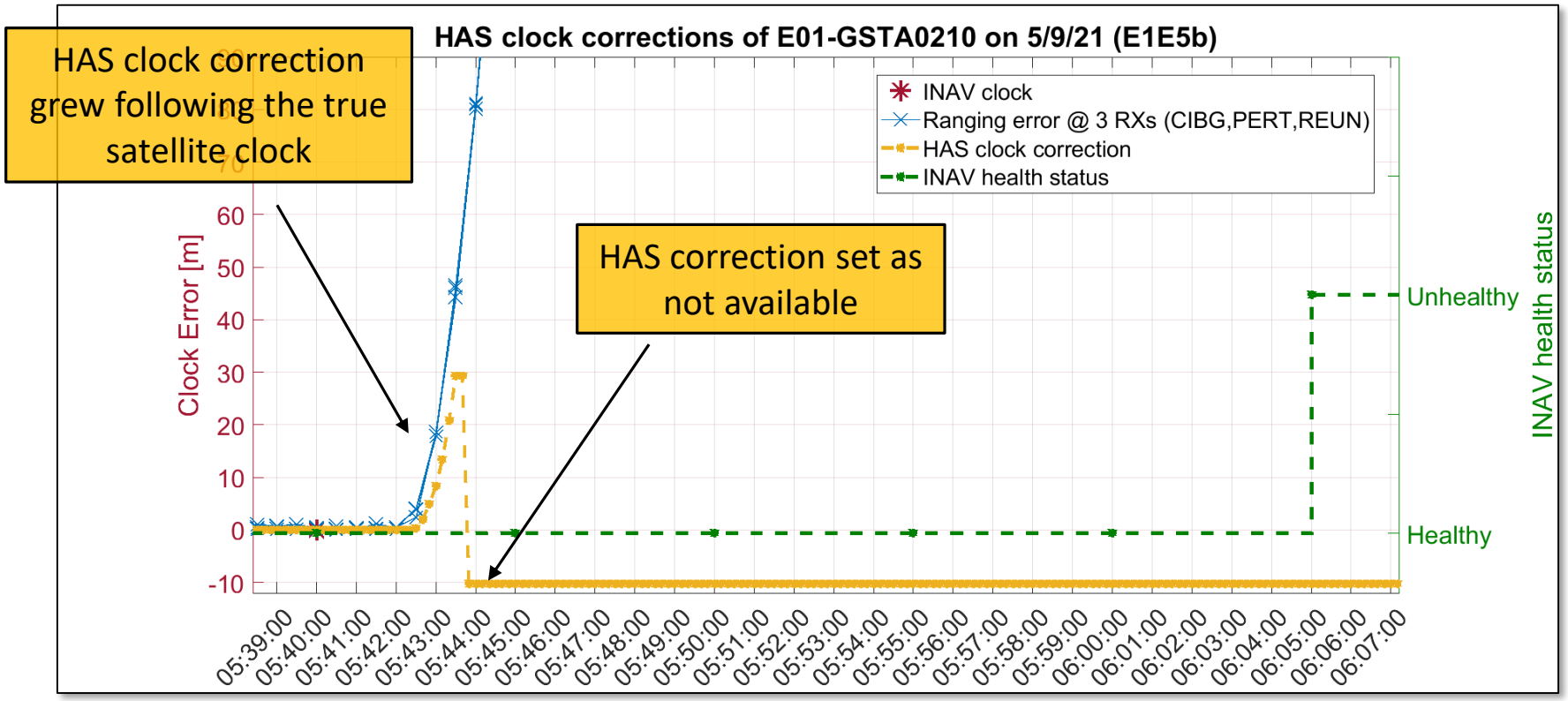
Asia	Errors RMS (cm)		
	North	East	Height
INKO	5.8	8.7	21.8
TATA	8.6	15.9	27.0

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



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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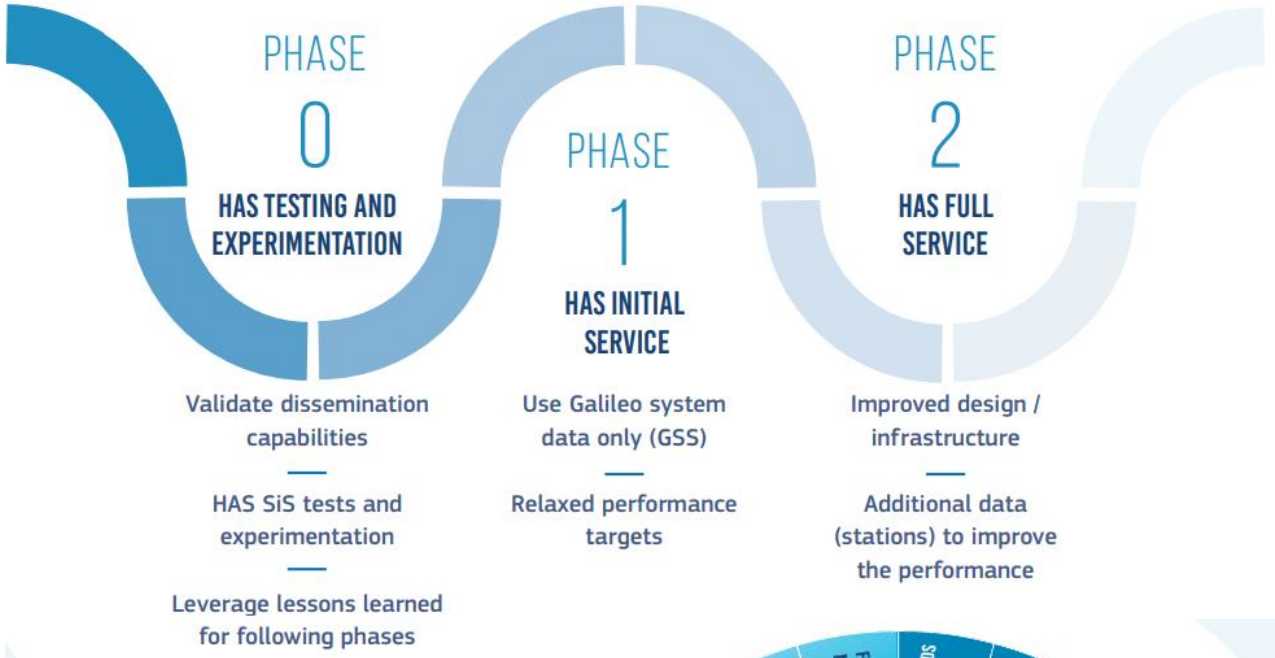
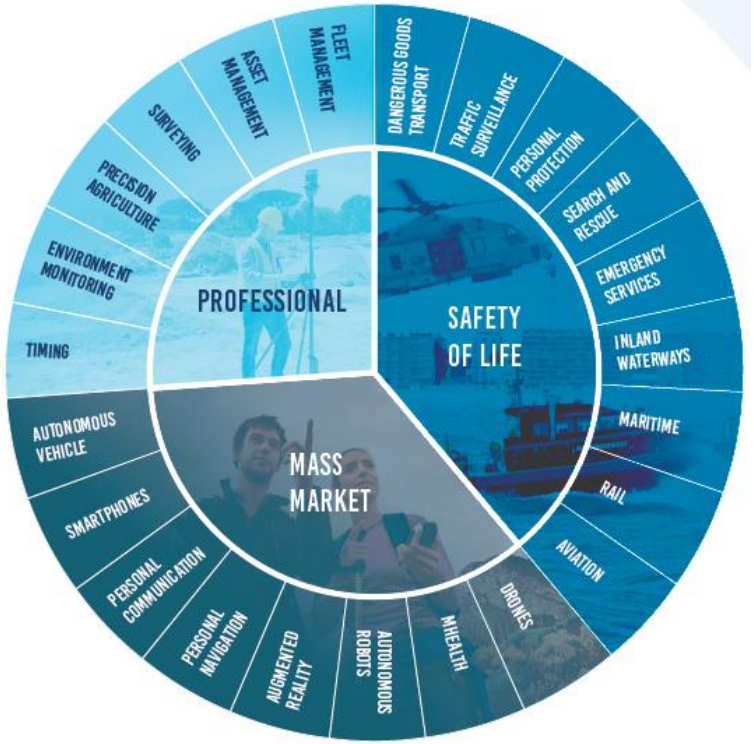
Next steps

Short term:
- Finish Validation phase
- Declare HAS Initial Service
- Open ground correction channel
- Develop user segment
  - More E6 receivers
  - EUSPA R&D actions
  - HASlib

Mid-long term:
- Add authentication and error characterization to HAS message
- Complete infrastructure with more stations
- Add ionosphere correction message in Europe





Thank you for your attention!

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