



EU SPACE

University of Tokyo/
UNOOSA ICG

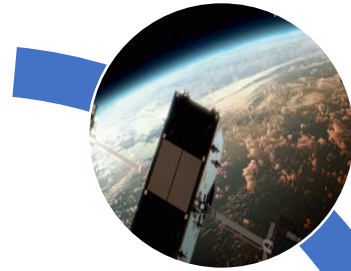
GNSS Training
January 2022

GALILEO Status Update

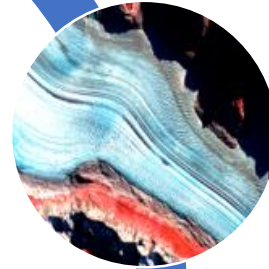
Dominic Hayes
European Commission

Expanding Horizons

New integrated EU Space Programme established by the new **Space Regulation** covering the period up to 2027



Galileo / EGNOS



Copernicus

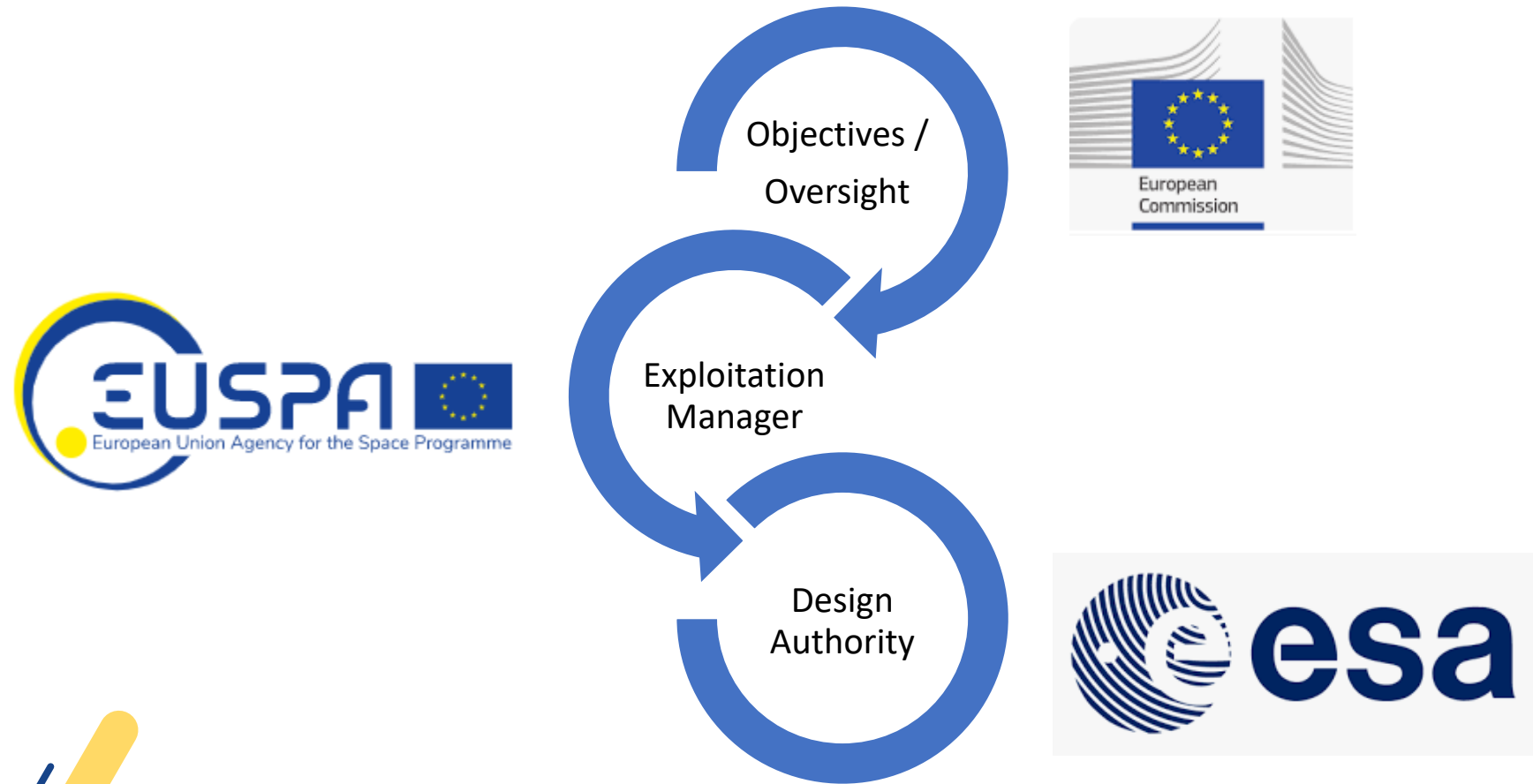


Secure Connectivity



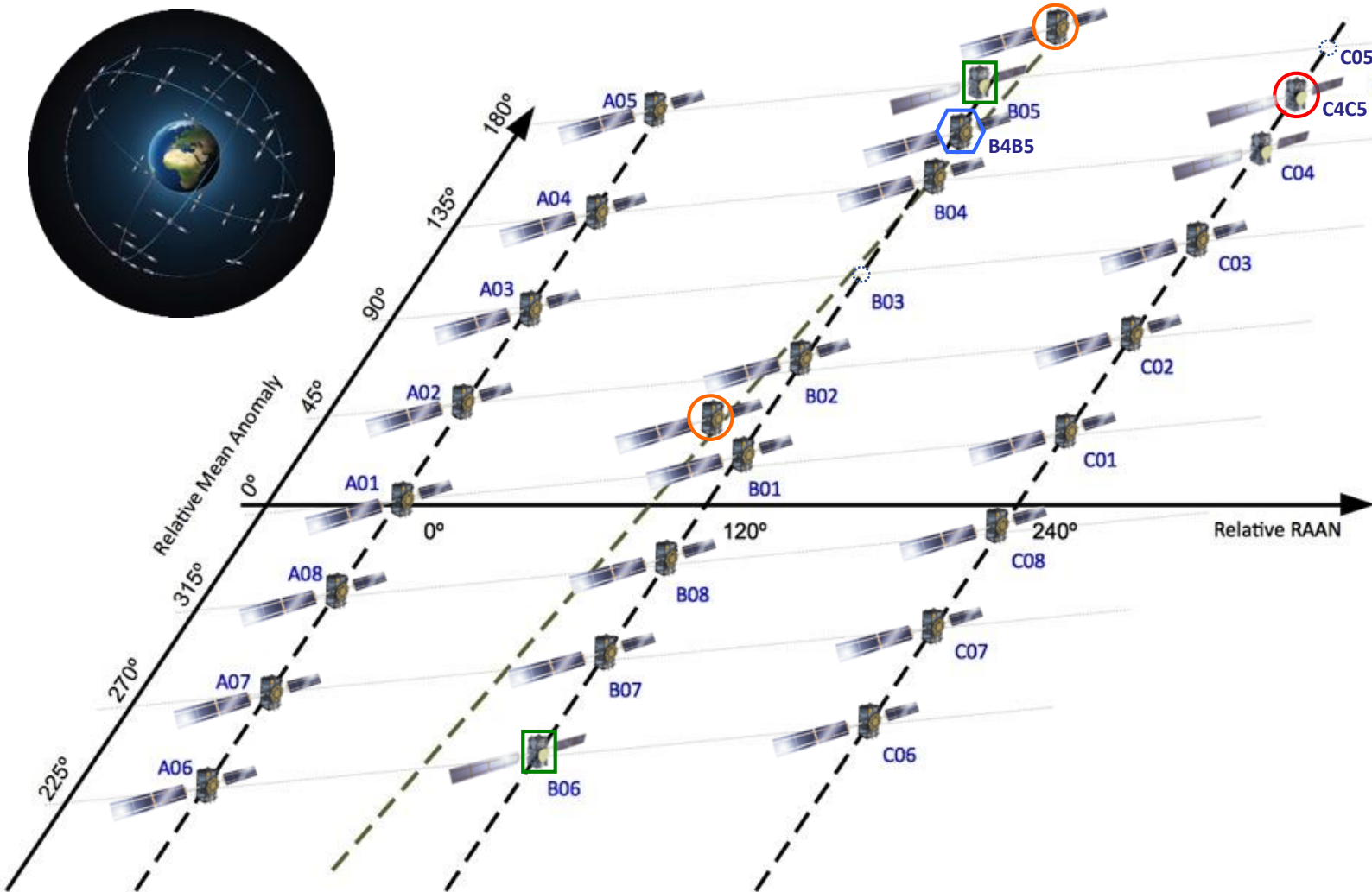
Space Awareness

Partners Working Together




Framework
Partnership
Agreement

Galileo Constellation Status



Navigation (22 in service)
Search and Rescue (24 in service)

-  26 satellites in orbit
-  2 unhealthy (NAV P/L only)
-  1 spare
-  1 unavailable
-  2 no SAR (by design)

GSAT 104 (Spare, NAVANT failure), relocation from C05 to C4C5 completed on 12/05/2021

GSAT 204 (Spare, SAR operational), relocation from B03 to B4B5 completed on 06/05/2021

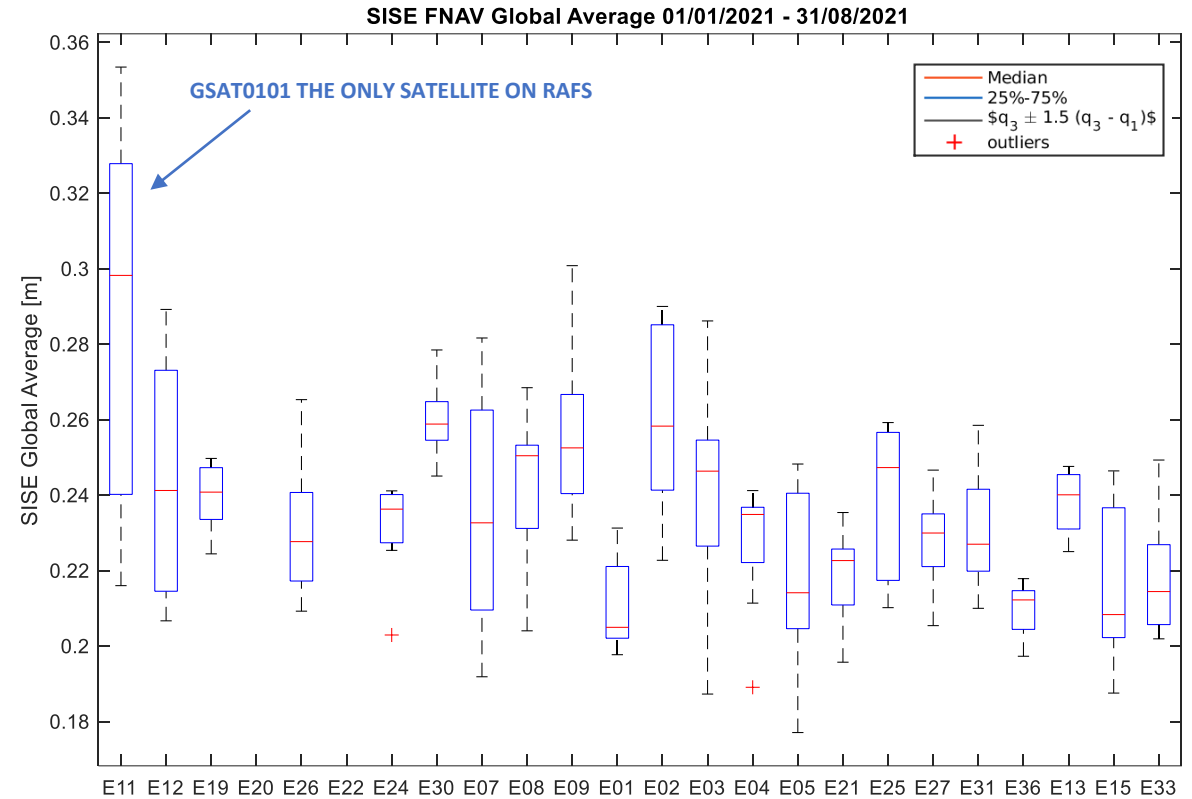
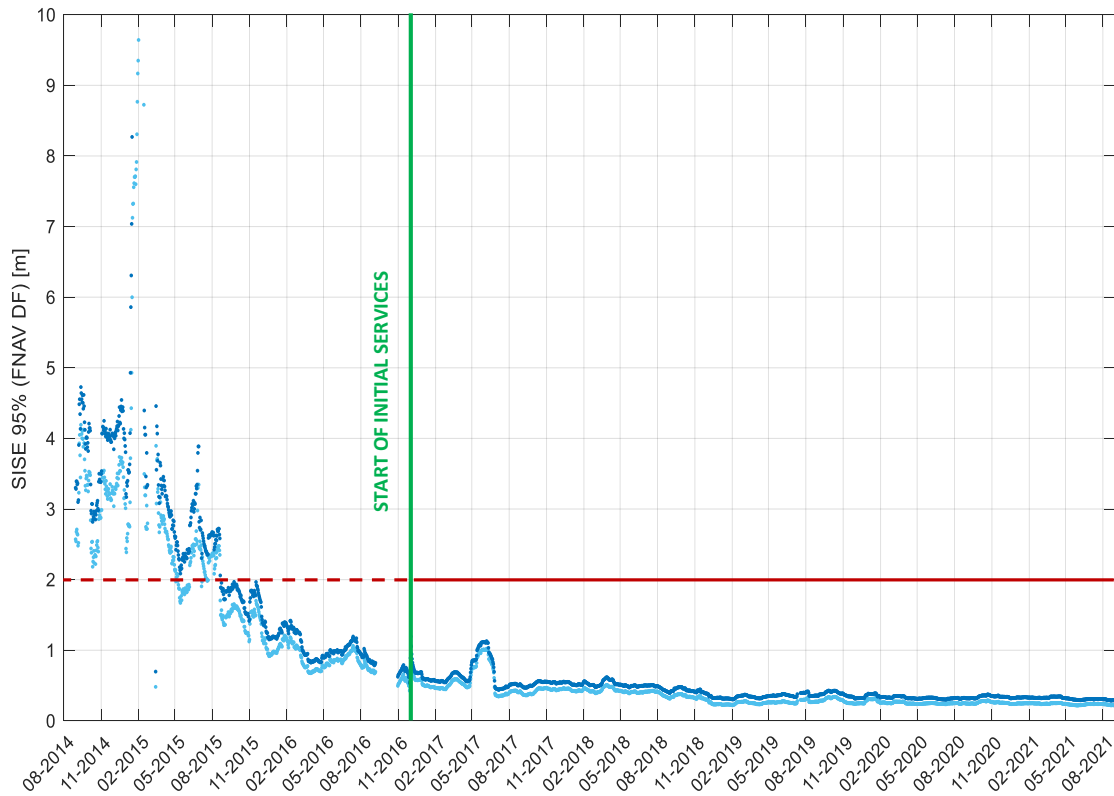
GSAT 201/202 (set to unhealthy)

L11 slots in Plane B: B03, B5B6

GSAT 227/228 launched 04 Dec 2021:
LEOP and testing proceeding well

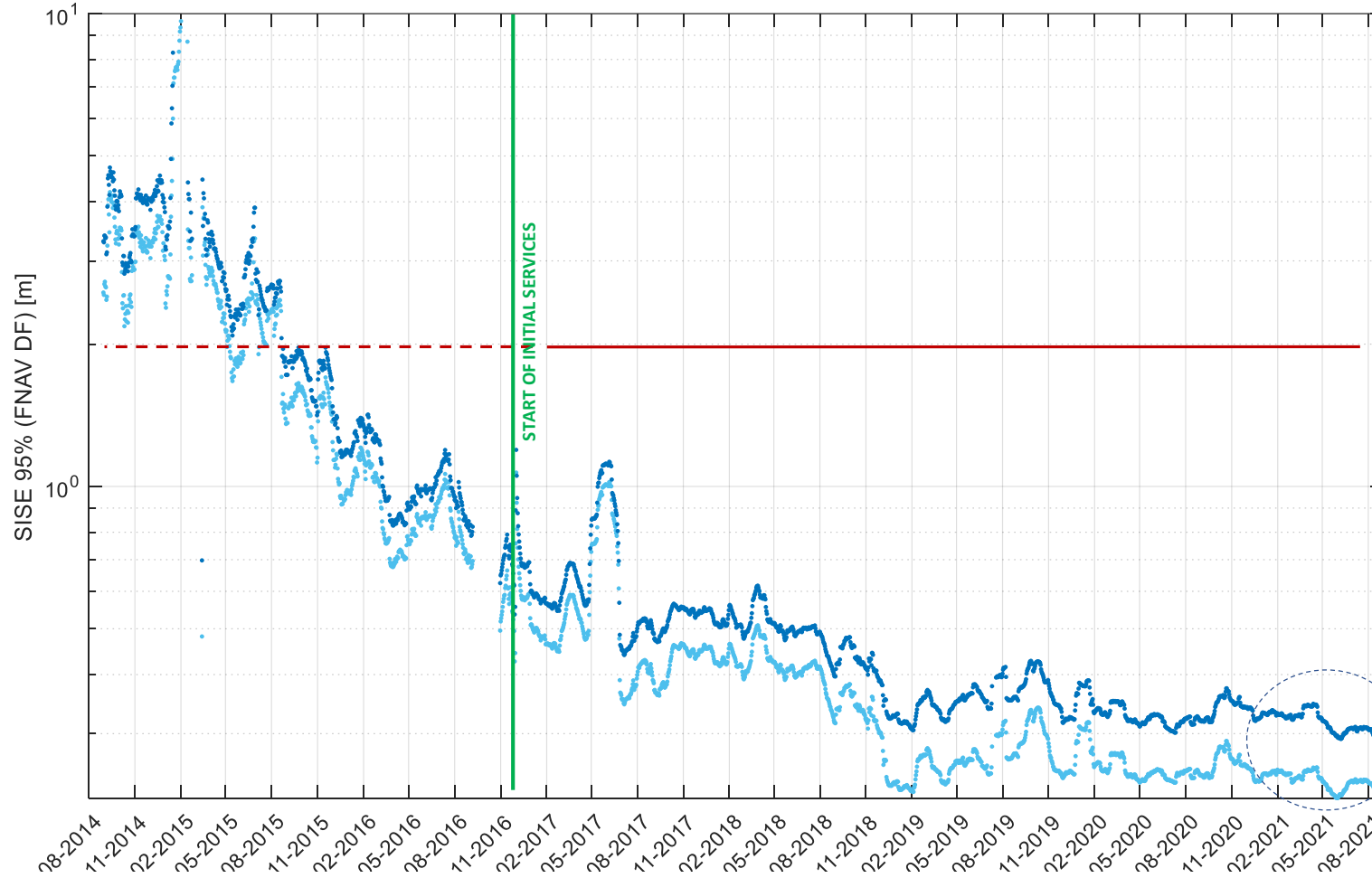


Stable As-observed Ranging Performance



- Decreasing Ranging Error trend due to increasing number of Satellites and G/S improvements
- **Ranging accuracy (95%) 0.22m** all satellites, in **August 2021** (FNAV)

Ranging Performance (Log scale)



NEW MINIMUM reached since GSS sites consolidated!

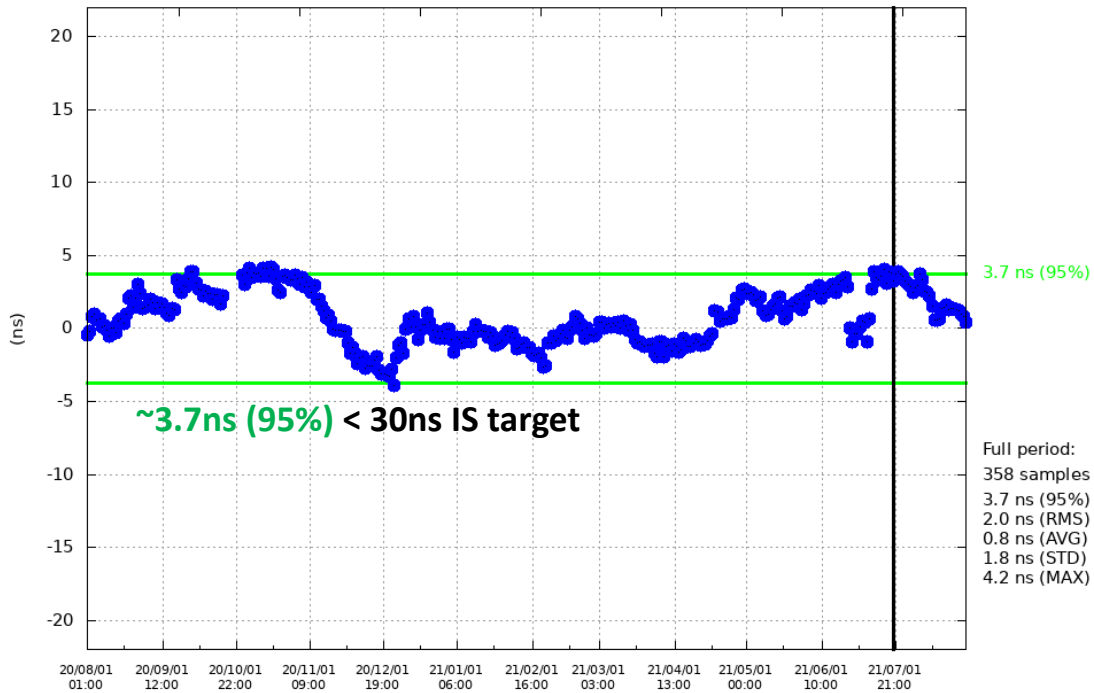
Improved OSPF robustness and GSS data availability

- SISE Constellation Average computed as 30 days moving average
- Decreasing Ranging Error trend due to increasing number of Satellites and G/S improvements
- **Ranging accuracy (95%) 0.22m** all satellites, in **August 2021** (FNAV)

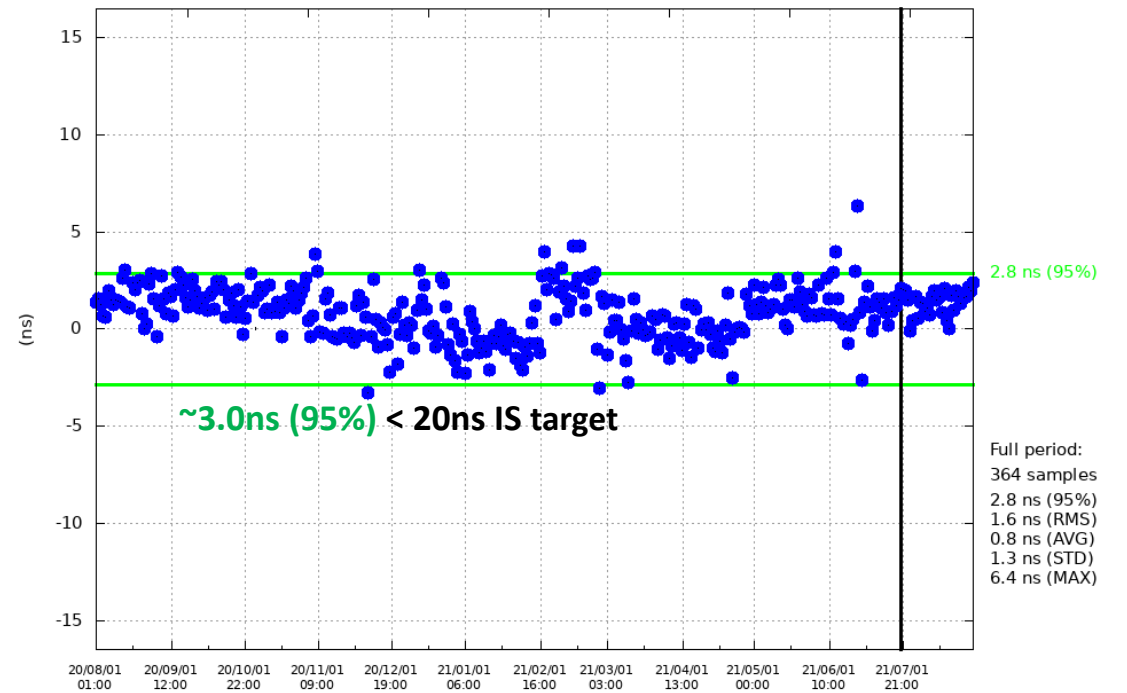
Best Satellite GSAT0214 (PHM-A) **16cm (95%)** in May 2021 | Worst Satellite GSAT0101 (RAFS-A) **40cm (95%)** in Jan 2021

Galileo Timing Availability **STABLE**

Broadcast UTC Offset



GGTO accuracy

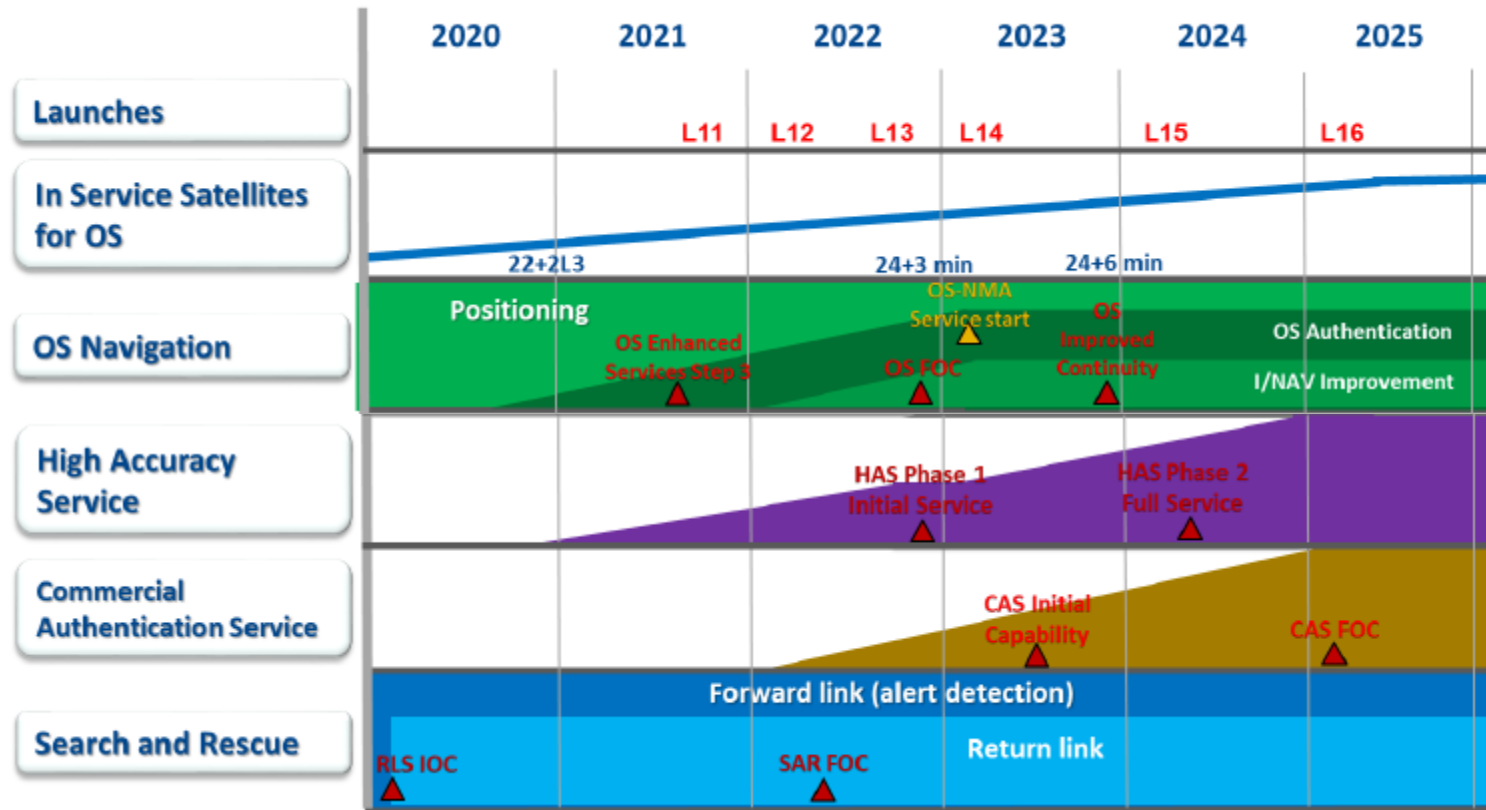
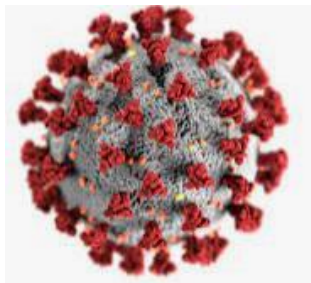
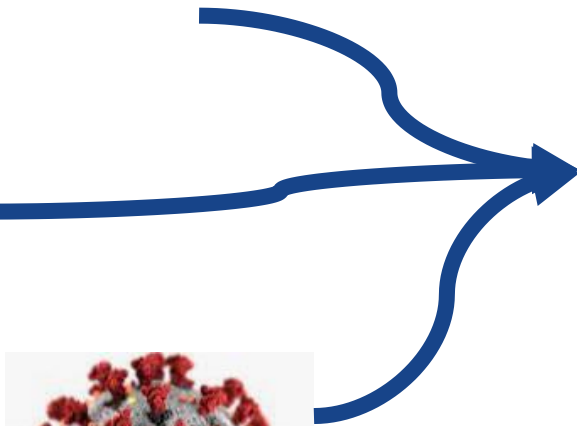


- Evaluated with calibrated timing GPS/Galileo receiver operated in UTC(k) laboratory (PTB, INRIM)
- Deployment of new V2B.08.01.00 in all 4 GSS PTFs, including GRCPs
- GSSPTFs delay calibration complete for GRCNs and GRCPs

Progress Pushed by Pandemic



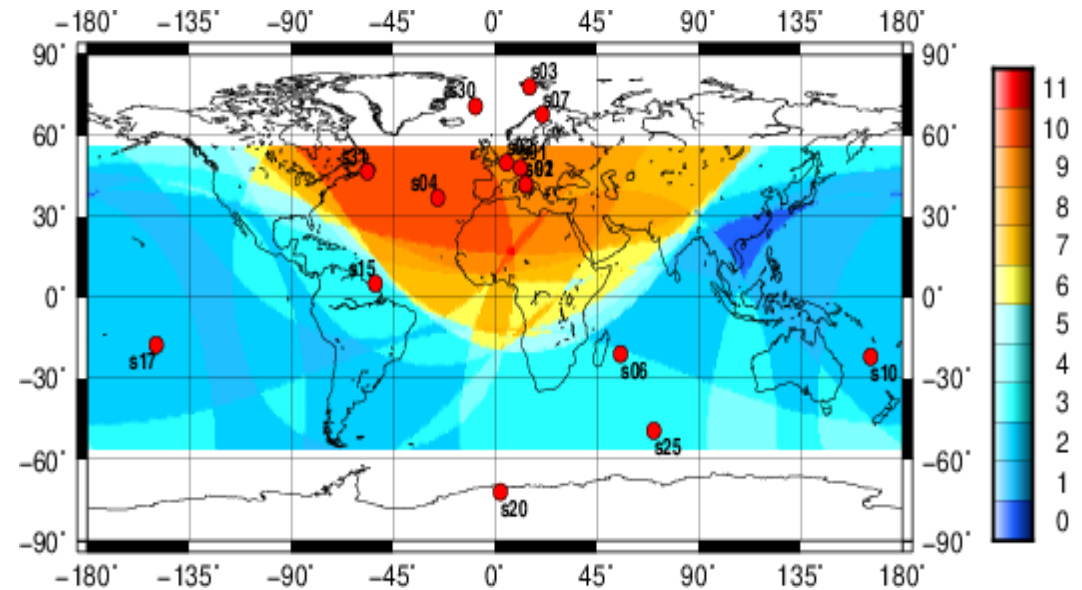
July 2019



Galileo, HAS... started testing

Configuration	Orbital Error components [cm], RMS			Total orbital error [cm]*	clock error [ns], RMS
	Radial	Along	Cross		
GPS L1-L2	3.2	9.9	4.9	6.6	0.26
Galileo E1-E5b	3.2	6.9	5.1	5.3	0.15

- Preliminary results from HAS Phase 0 (demonstration phase).
 - September 2020, 14 stations (not so many!)
 - 15-min orbit prediction, 3-day arcs.
- Main difference wrt standard ODTs:
 - Continuous clock estimation
 - IAR for ODTs satellite-station measurements
- User receiver PPP results promising.



*: 1D mean RMS; Reference: CNES products from IGS; Source: AALECS & MAGICGNSS, GMV

Galileo HAS... even better accuracy

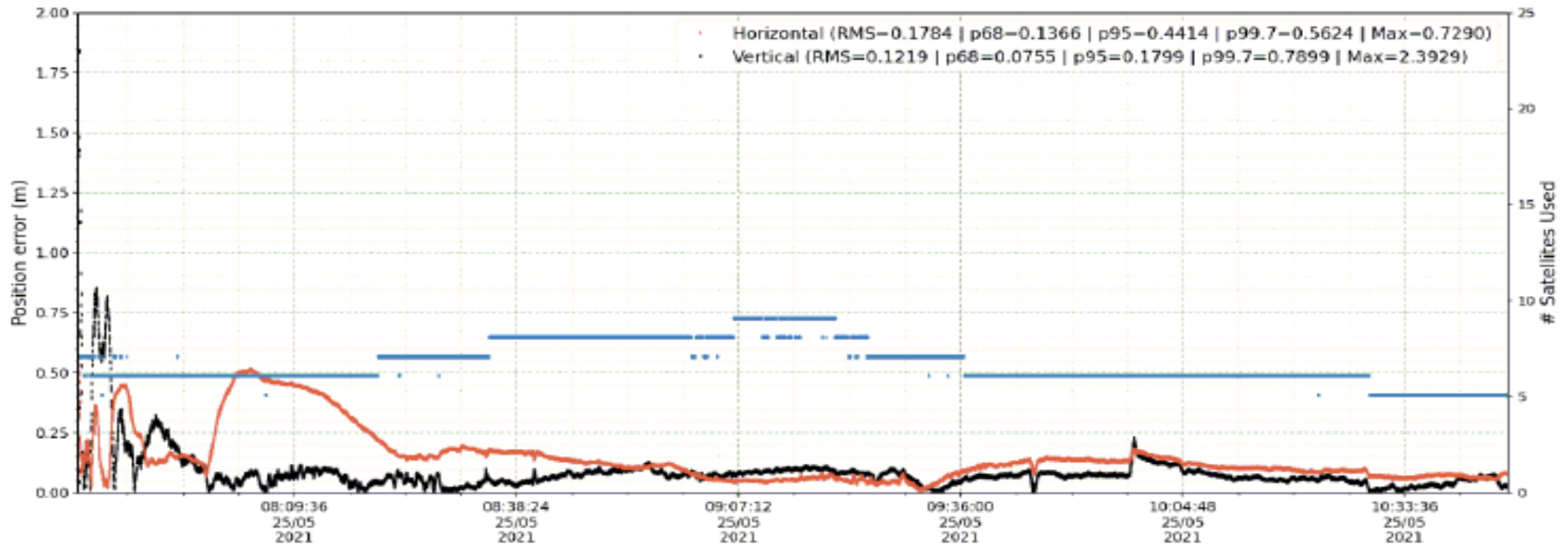
- HAS SIS testing started with CS Demonstrator on May 2021 (Phase 0), under EUSPA coordination. Early results promising
- The European Commission expects HAS signal to continue with a high availability for next steps (Call For Interest, ICD publication), until HAS Initial Service declaration (2022)

	Phase 0 (Testing)	Phase 1 (Initial Service)	Phase 2 (Full Service)
Target Date	Q1 2021	Q3 2022	Q2 2024
GSC	V 1.2	V 1.3	V 2.0
Service Area	Test	Europe	Worldwide
Targeted Accuracy	N/A	> 20 cm	< 20 cm
HAS Infrastructure	CS-Demo Platform	HADG	HADG V2

Source: Galileo FOC roadmap

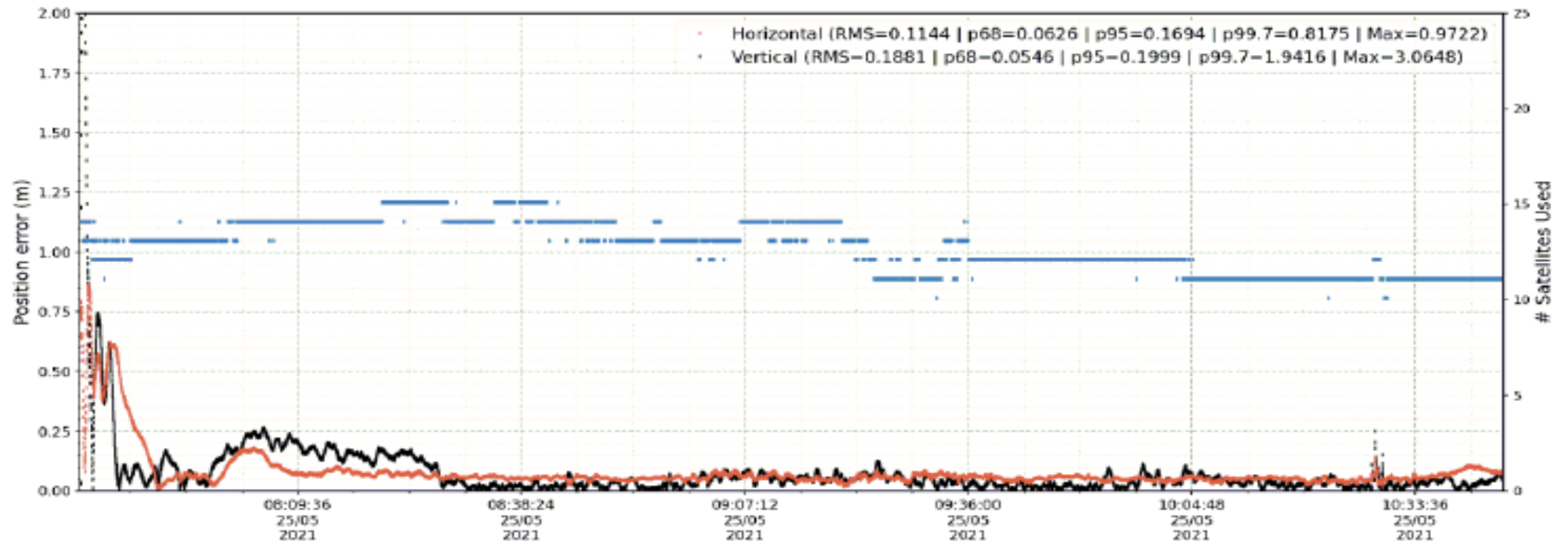
HAS First Test Results (1/2)

- Results from signal-in-space test on 25/5/21
 - Horizontal/vertical error below 20/40 cm 95% , after convergence
 - Technical configuration: Galileo-only, dual-frequency (E1-E5b, iono-free), floating PPP solution, at Tres Cantos, Spain, static, open sky; Septentrio AsteRx4 receiver and MagicPPP; no code/phase biases transmitted.



HAS First Test Results (2/2)

- Results improve by combining Galileo + GPS (L1CA-L2P)
- Phase 1 will assume no iono model, even Nequick not sufficiently accurate
- Phase 2 will use an updated Nequick model (Europe) to further improve accuracy



Source: GMV, MagicPPP; NB: RMS/p68-95-99 values cover both convergence and stationary state

Galileo HAS... moved forward



MILESTONE

User Consultation Platform

- The User Consultation Platform (UCP) is a forum for interaction between users of position, navigation and time solutions and the organisations and institutions dealing, directly and indirectly, with Galileo and EGNOS. The platform serves as a key tool for gathering user requirements and validating the Galileo HAS target performance
- The UCP 2020 will be held during European Space Week on 7-11 December 2020 (<https://www.eu-spaceweek.eu/>)

Call for Expression of Interest

- Participating in the HAS SiS ICD public consultation
- Expressing interest in participating in ad-hoc HAS SiS testing campaigns
- Providing feedback on specific HAS user requirements

HAS PO Testing

HAS SiS ICD Publication

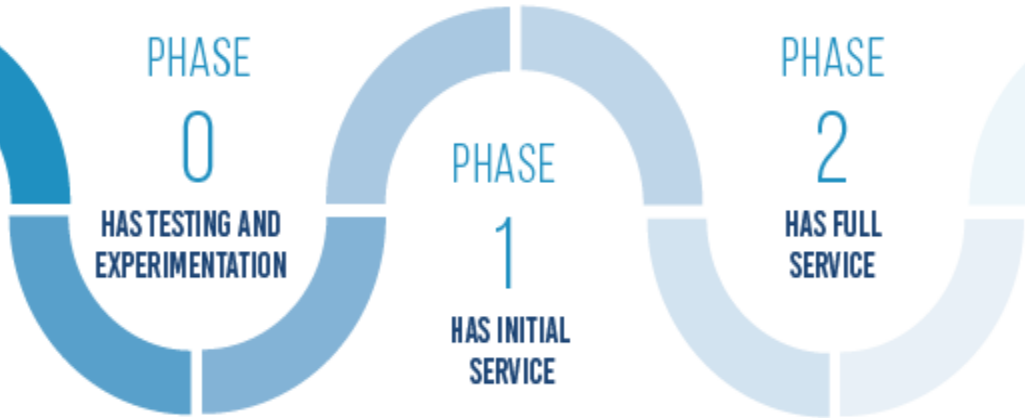
- Following the finalisation of the testing phase, the first version of the HAS message specification document is planned to be published

HAS Initial Service Declaration

- After the necessary service validation activities, the HA Service will be declared available and the HA Service Definition Document will be published

HAS Full Service Operational Capability

2020
2021
2021
2021
2022
> 2024



Validate dissemination capabilities

HAS SiS tests and experimentation

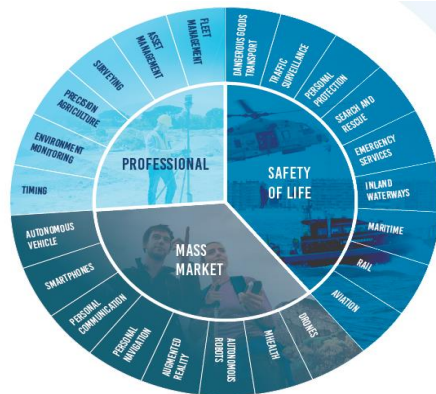
Leverage lessons learned for following phases

Use Galileo system data only (GSS)

Relaxed performance targets

Improved design / infrastructure

Additional data (stations) to improve the performance



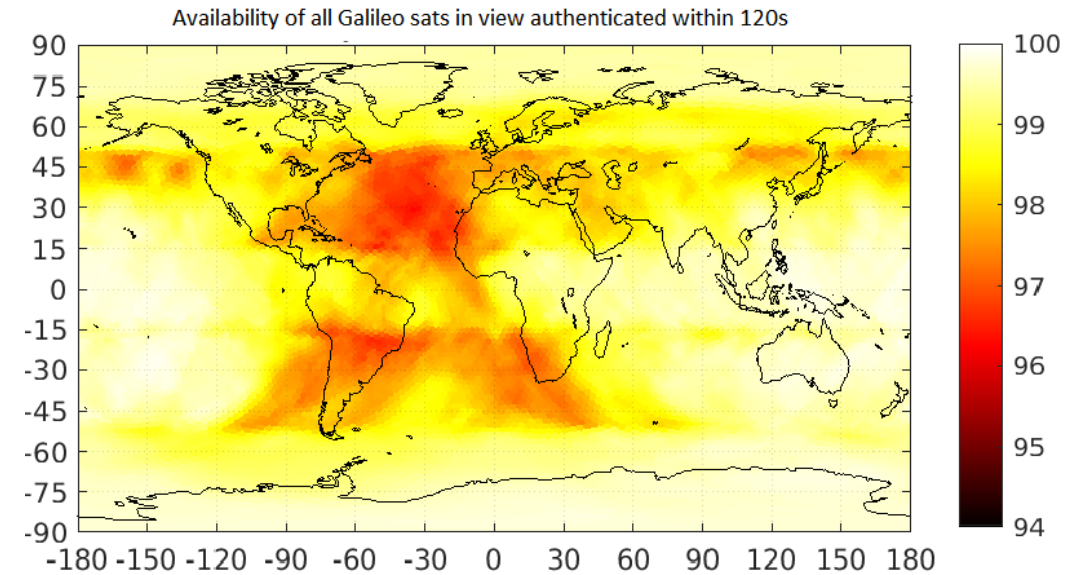
PROFESSIONAL

SAFETY OF LIFE

MASS MARKET

It's a matter of Trust

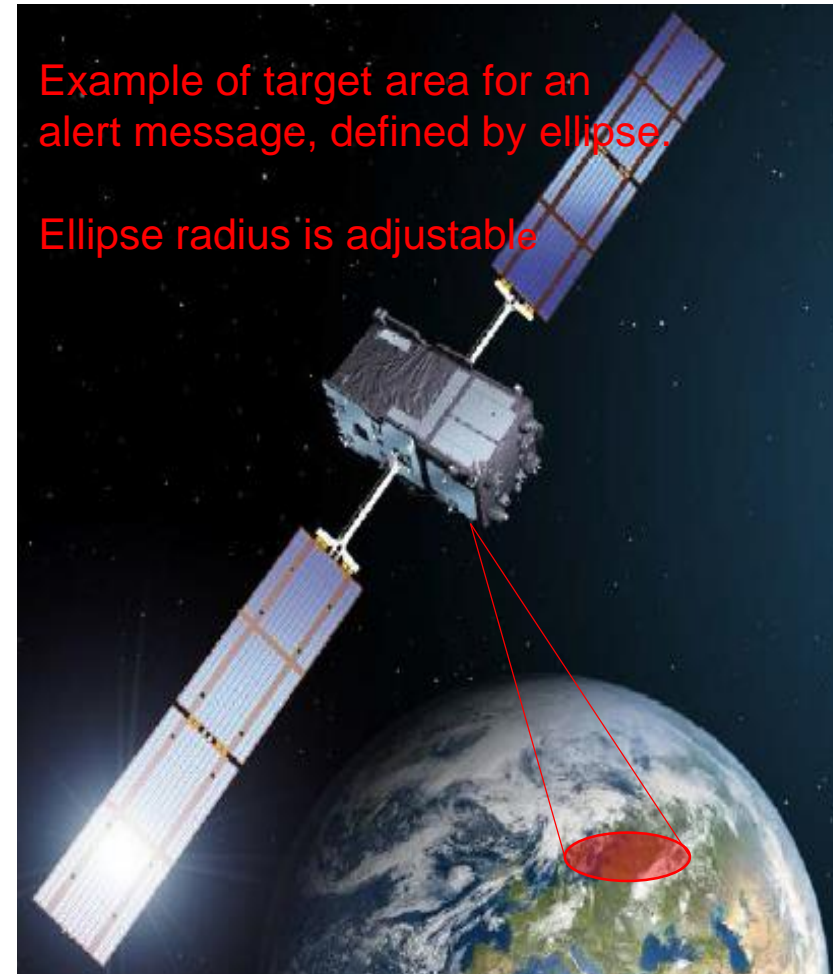
- OSNMA **over-the-air testing** since November 2020 without affecting standard OS users. Different OSNMA configurations and processes (key renewal, revocation, etc.) have been successfully tested.
 - ✓ Worldwide dissemination with up to 20 connected satellites and "cross-authentication" concept
 - ✓ No degradation of OS PVT accuracy
 - ✓ Availability of authentic PVT equivalent to standard OS for users with synchronisation requirements better or equal to 30 seconds (works for receiver with time reference up to 5-min error)
- Next steps: OSNMA ICD/guidelines/keys publication and start of "Public Observation Phase"
- Commercial Authentication Service (including signal authentication) assisted concept consolidated and under prototyping



...stay tuned!

The Galileo Emergency Warning Service...

- Global coverage
- No 'mobile' connection required - Resilience to ground destruction
- Uses existing Open Service signal spare capacity
- Multi-hazard (tornadoes, earthquakes, nuclear disaster or industrial disaster, terrorist attacks, ...)
- On-demand broadcast of an alert message + associated guidance by Local Civil Protection Authorities
- Complementary to existing systems
- Reach out population in a timely manner (2-3 minutes), whatever the size of the area
- Geo-location information encoded in the message to target only the relevant population
- Synergies with Copernicus Emergency Management Service and its other system capabilities
- An interoperable solution studied in cooperation with Japan and India



SAR ...The Return

• Remote Activation of Beacons

✓ *Under "MRD" formalisation*

✓ *EUROCAE standard approved*

• RCC (or airline) can contact Galileo to remotely activate a beacon via the RLM of Galileo

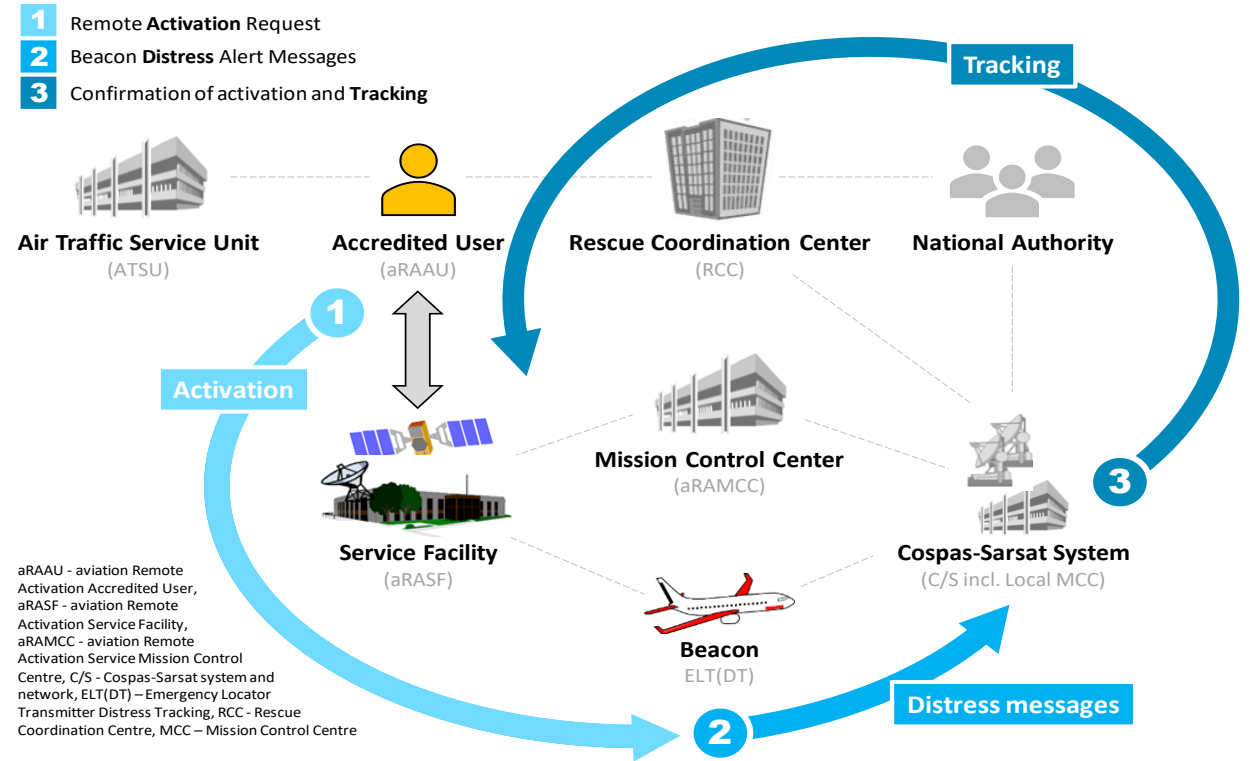
• Use cases: **Aviation**: aircraft disappearance, Un-responsive crew; **Maritime**: overdue vessel

• Two-way (distress) communication

• Enabled by the long Return Link Message; based on **predefined Q&A helping the rescue mission**

• Distress Position Sharing

• RCC can contact Galileo to share the position of a beacon user in distress with other nearby users



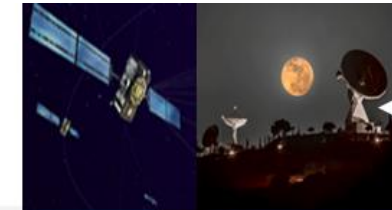
Fast...but not Furious !

G2G Service Portfolio and High Level Mission Objectives adopted

- Advanced Timing Services
- Space Service Volume
- ARAIM – coming back to serving SoL
- Emergency Warning Services
- Search And Rescue – Innovative services
- Ionosphere Prediction Service
- Signals Evolution – increased performance at user level (reduced power consumption, TTFF, accuracy, authentication, etc.)
- SAR 2nd Generation Beacons
- PRS evolutions



2013-2019
EGEP & H2020
Technologies and
System Studies



2020
System, Satellite and
Ground Procurements

2024-2025
First G2G Satellites &
G2G IOV



2027
G2G Initial Operational
Capability



2030+
G2G Full Operational
Capability

Far and Beyond



Horizon Europe

THE NEXT EU RESEARCH & INNOVATION PROGRAMME (2021 – 2027)



As One Among Others

- **Bilateral Cooperation** with other core constellation providers
- Define new services collaboratively
 - SAR / RLS / 2-way COM
 - Emergency Warning Distribution
 - Advanced RAIM for Safety of Life
 - Authentication solutions



International/multi-lateral

- ITU: Coordinate and defend GNSS Spectrum
- UN-ICG: service provision and performance monitoring
- ICAO: Galileo standards adopted in Nov 2020

Additional General GNSS Topic

Interference to GNSS

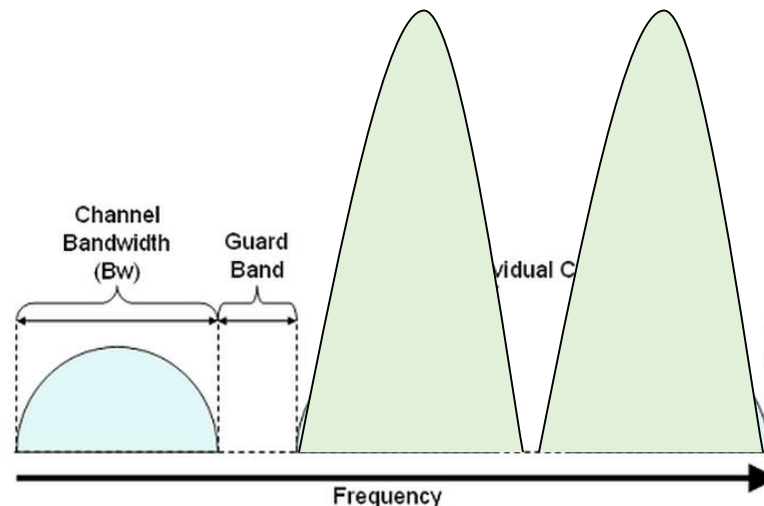
Radio Frequency Interference

- RF interference is an electromagnetic disturbance generated by an external source that affects the RF receiver's circuitry
 - Can be unintentional or intentional, from sources in-band or out-of-band
- RF interference between GNSS systems are carefully managed through bilateral coordination process set up by the ITU
- However, recent trend with technology is creating to higher spectrum demand
 - Increased potential for RF interference from sources other than GNSS systems



Optimizing spectrum allocations

- ITU Radio Regulations divide radio spectrum into separate "allocations" to reduce the potential for interference between different types of radio use
 - eg GNSS and TV have separate frequencies
- To minimize interference, "guard bands" between very different services have been used in the past



Why manage spectrum?

- If GNSS signals share frequencies with high power terrestrial systems, eg mobile phones, GNSS reception would not be possible
- To avoid interference, the **Radio Regulations** separate different service types (eg terrestrial mobile, satcoms, TV) into different frequency bands or "**allocations**", eg,
 - mobile at 900MHz
 - TV at 600MHz
 - satcoms at 1650MHz
 - GNSS at 1575MHz

Terrestrial transmitter next to a GNSS receiver

- Imagine a GNSS receiver operating a short distance from a base station or mobile phone
- the terrestrial signal levels could be many billion times larger than the GNSS signals
- if the frequency separation is insufficient, there is a real risk that frequency edges of the terrestrial system will swamp the GNSS receiver
- the ITU spends many years working out the appropriate frequency separations to reduce interference
- and, to prevent interference between systems, national regulators apply ITU recommendations

Minimise interference, maximise benefits

- The Radio Regulations are the result of many decades of compatibility studies
- Experts at the ITU consider the specific characteristics and operational aspects of systems
- the experts evaluate whether systems can either share the same frequencies or use frequencies adjacent to each other
 - these are the **radio compatibility studies**
- the experts also define recommendations to facilitate harmonious use of the spectrum
- The Radio Regulations generally work!



EU SPACE

Happy to answer questions