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University of Tokyo/ UNOOSA ICG

GNSS Training January 2022

GALILEO Status Update

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European Commission

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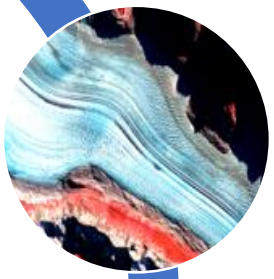
Expanding Horizons

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

Galileo /
EGNOS



Copernicus

Secure
Connectivity

Space
Awareness

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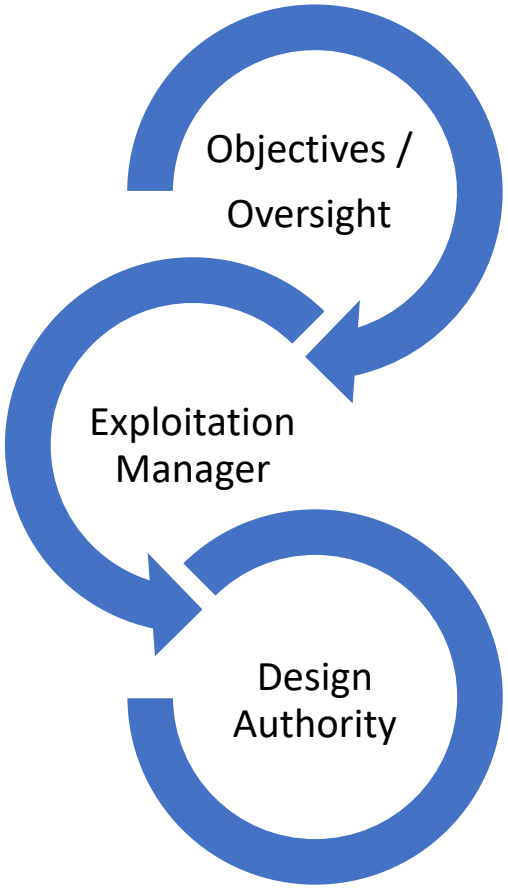
Partners Working Together



European Commission

EUSPA
European Union Agency for the Space Programme

esa

Framework Partnership Agreement

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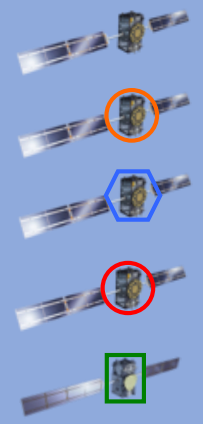
Galileo Constellation Status

Plane A Plane B Plane C

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

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)

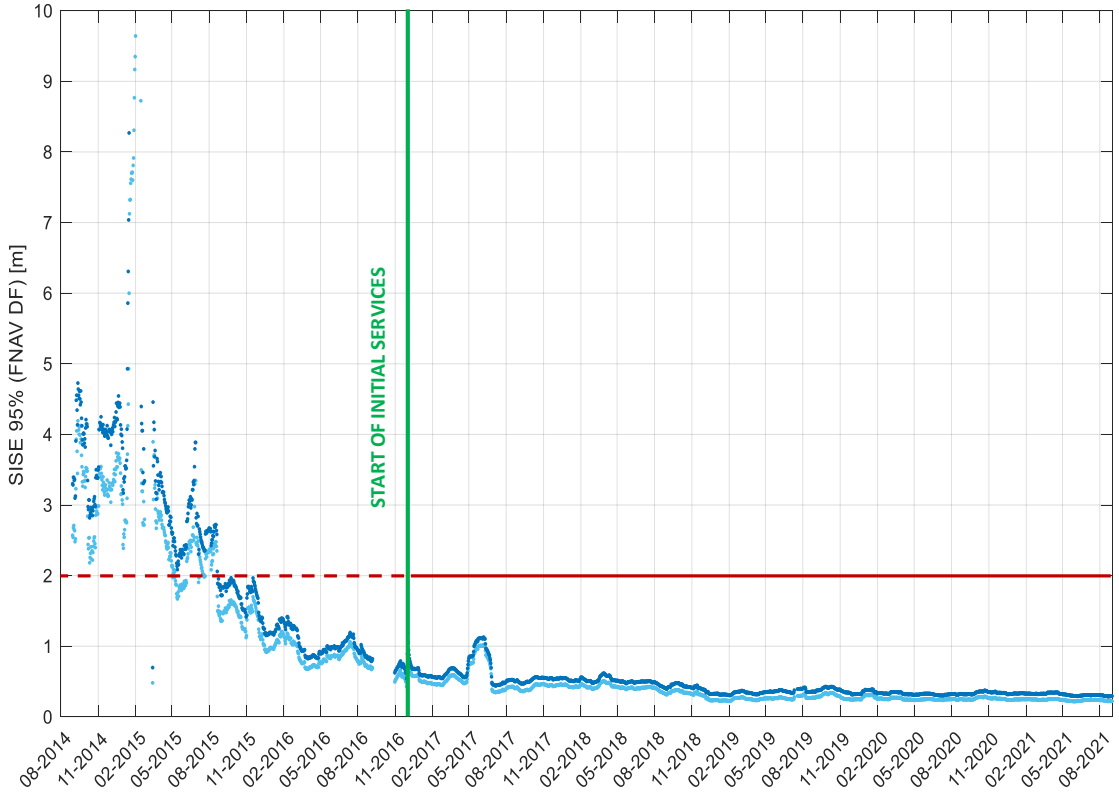
GSAT 104 (Spare, NAVANT failure), relocation from C05 to C4C5 completed on 12/05/2021

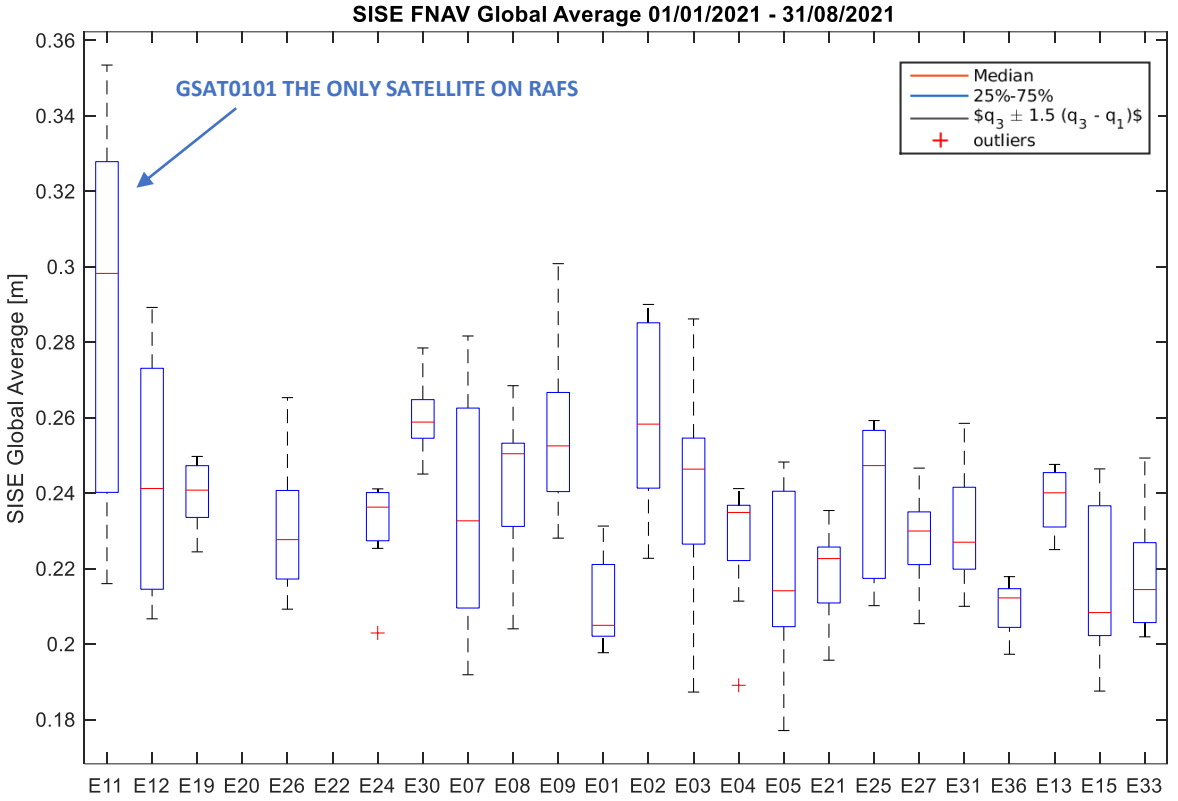
GSAT 204 (Spare, SAR operational), relocation from B03 to B4B5 completed on 06/05/2021

GSAT 201/202 (set to unhealthy)

L11 slots in Plane B: B03, B5B6

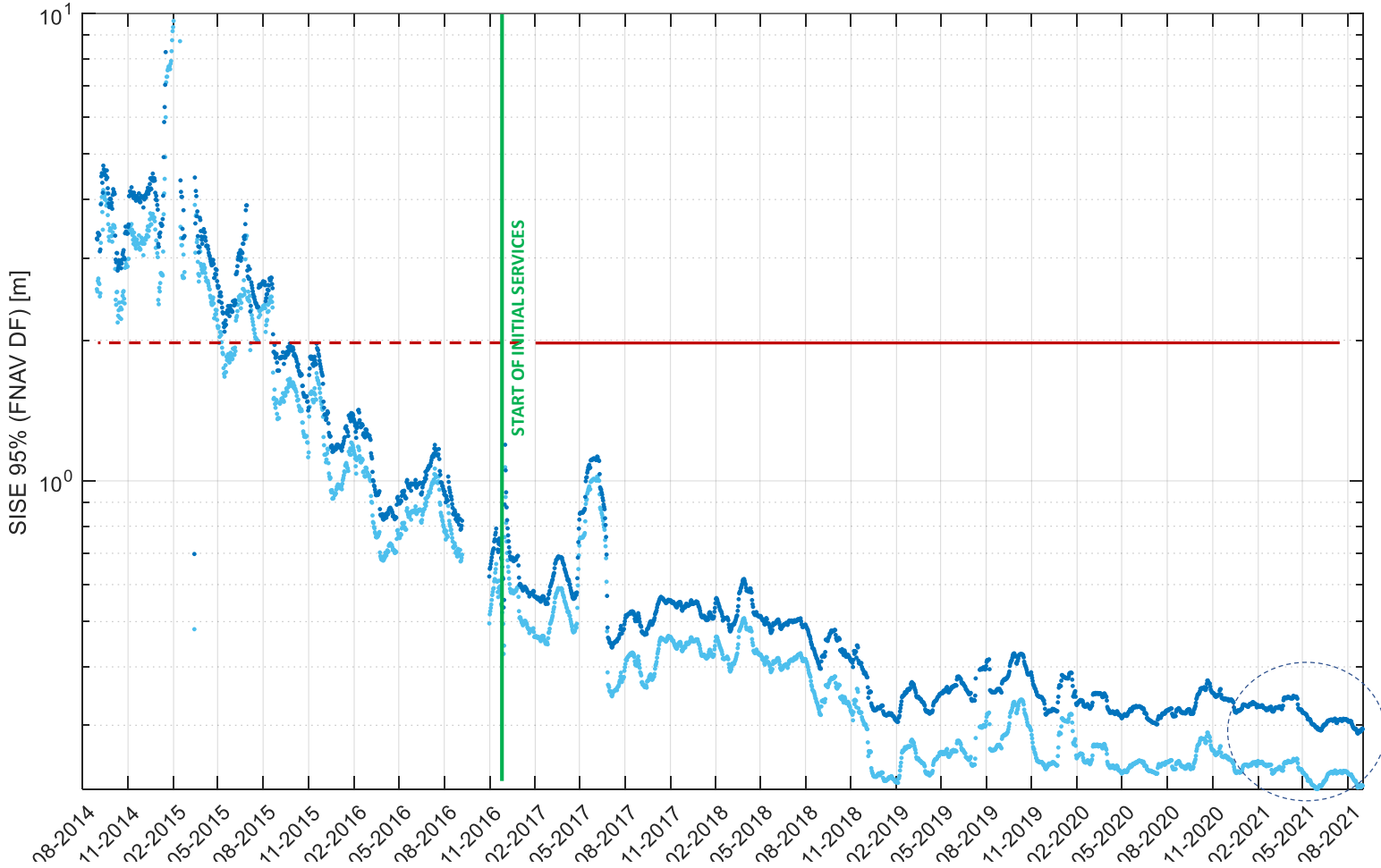
Stable As-observed Ranging Performance





- 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!

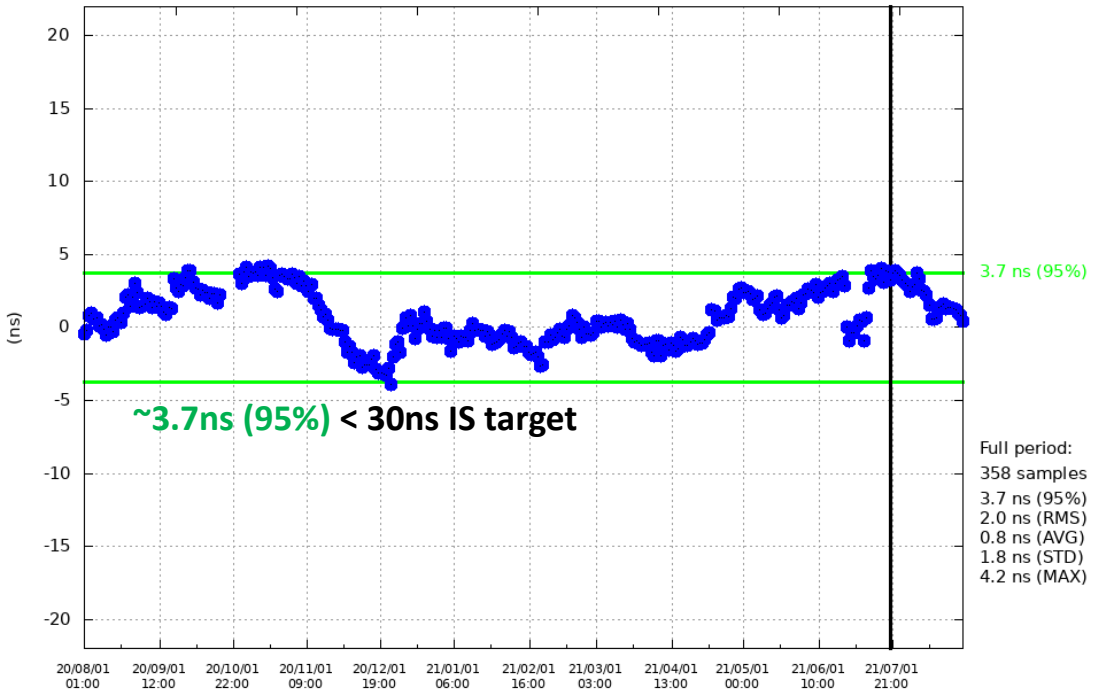
Improved OSPF robustness and GSS data availability

- 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)

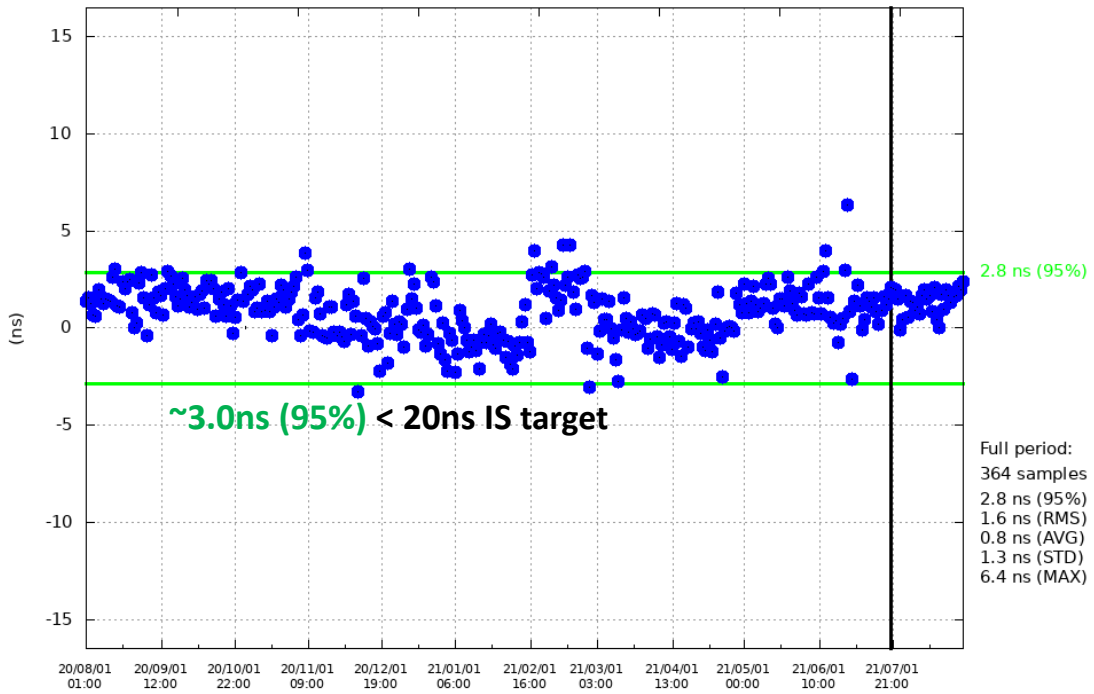
  Best Satellite GSAT0214 (PHM-A) **16cm (95%)** in May 2021 | Worst Satellite GSAT0101 (RAFS-A) **40cm (95%)** in Jan 2021

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

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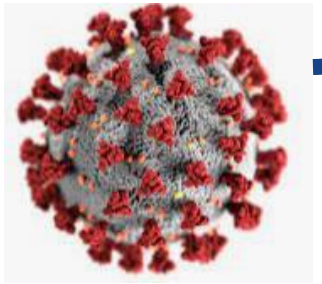
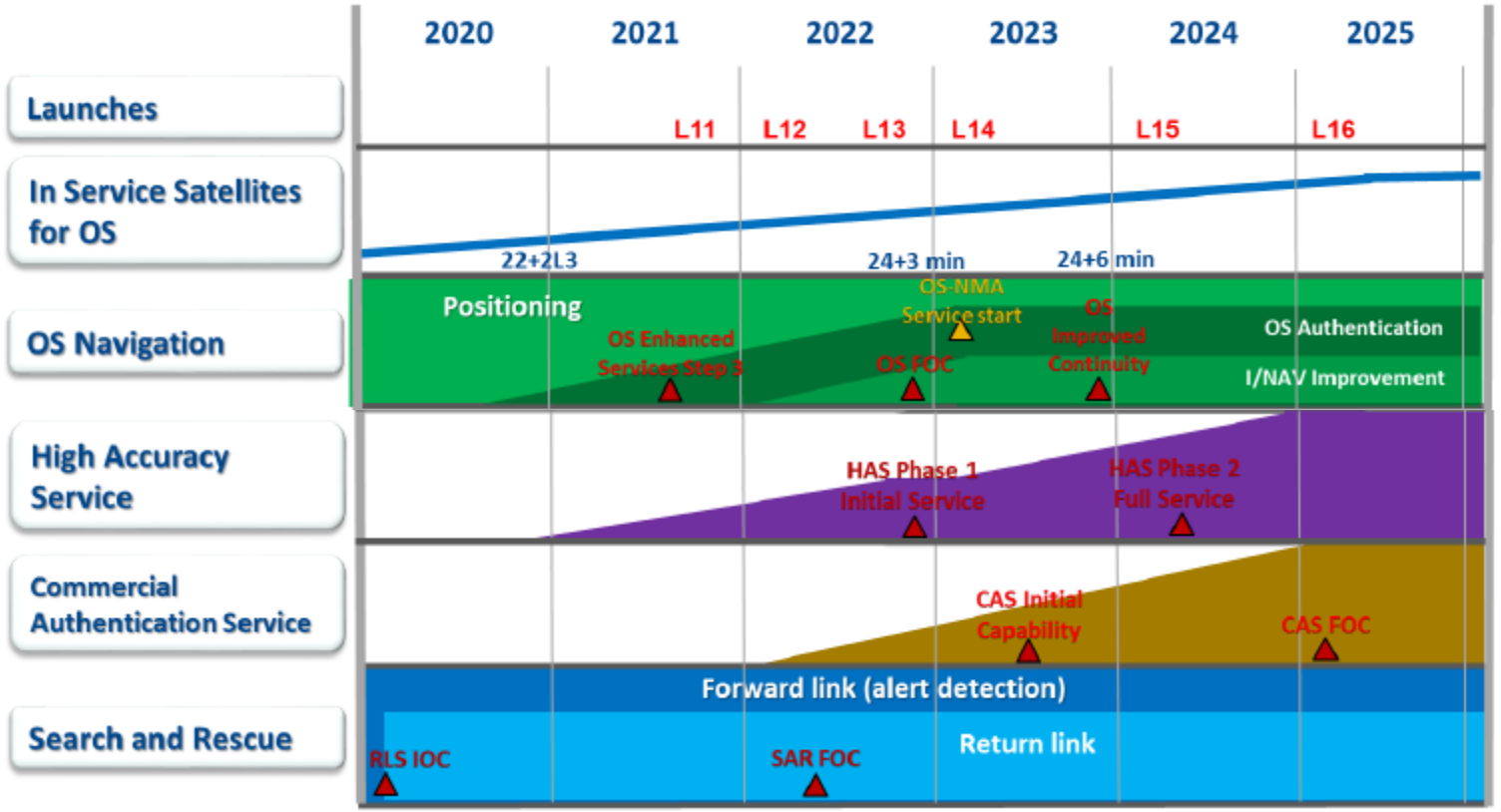
Progress Pushed by Pandemic

July 2019

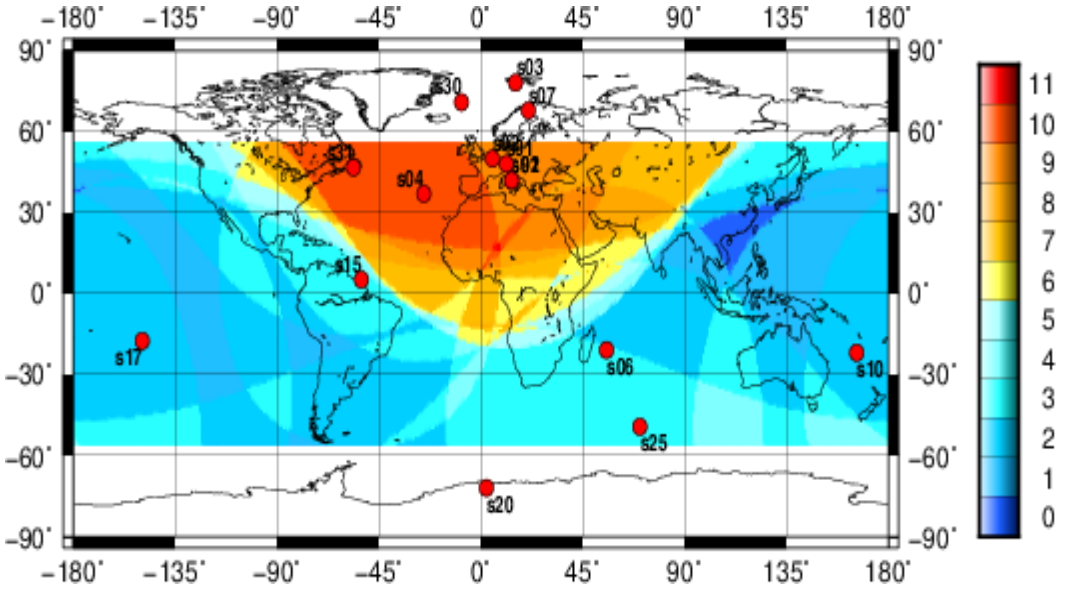




Galileo, HAS… started testing

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:
  - Continous 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

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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

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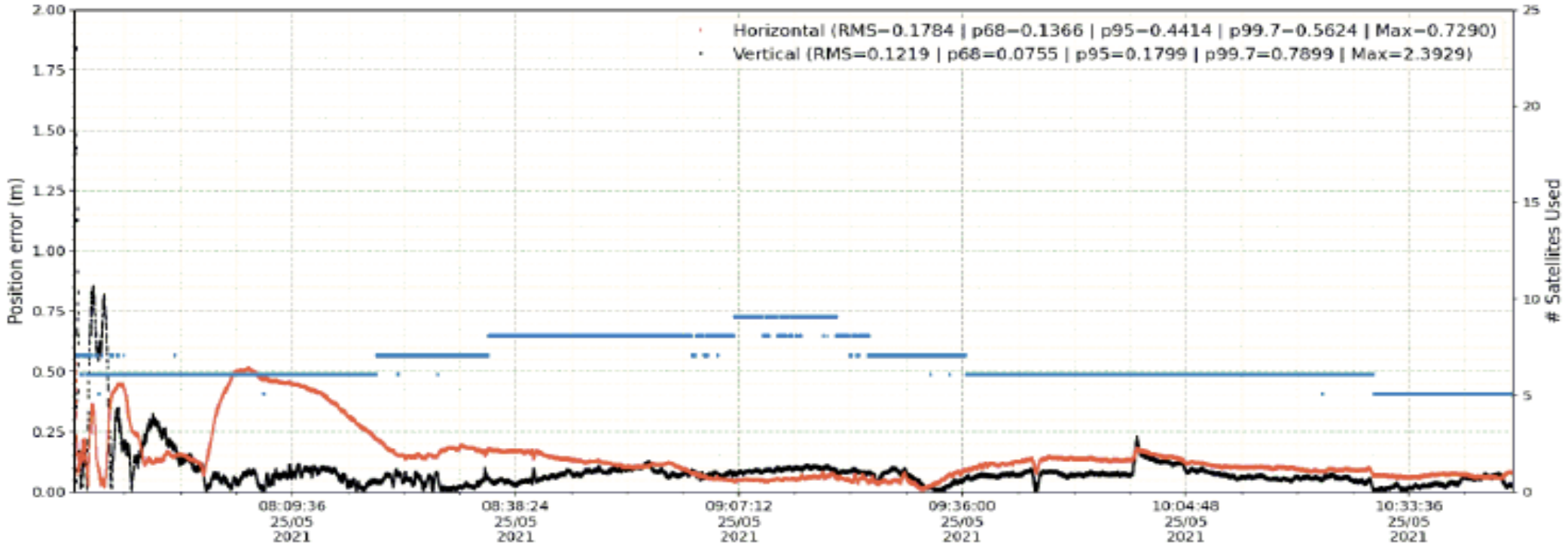
HAS First Test Results (1/2)

- 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.



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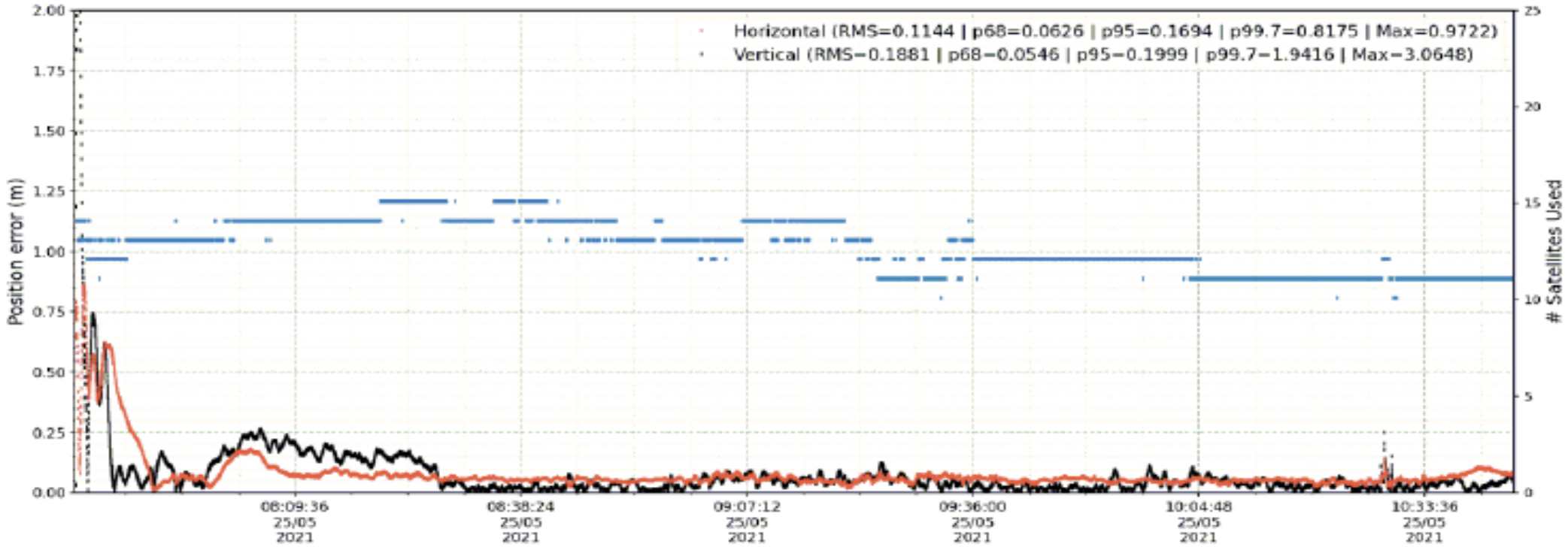
HAS First Test Results (2/2)

- 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

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Galileo HAS… moved forward

PHASE 0
HAS TESTING AND EXPERIMENTATION

Validate dissemination capabilities

HAS SiS tests and experimentation

Leverage lessons learned for following phases

PHASE 1
HAS INITIAL SERVICE

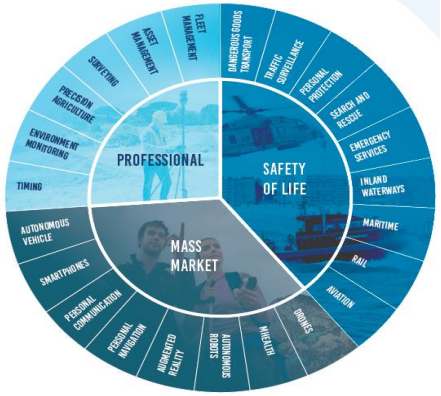
Use Galileo system data only (GSS)

Relaxed performance targets

PHASE 2
HAS FULL SERVICE

Improved design / infrastructure

Additional data (stations) to improve the performance



2020

2021

2021

2021

2022

> 2024

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.euspaceweek.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

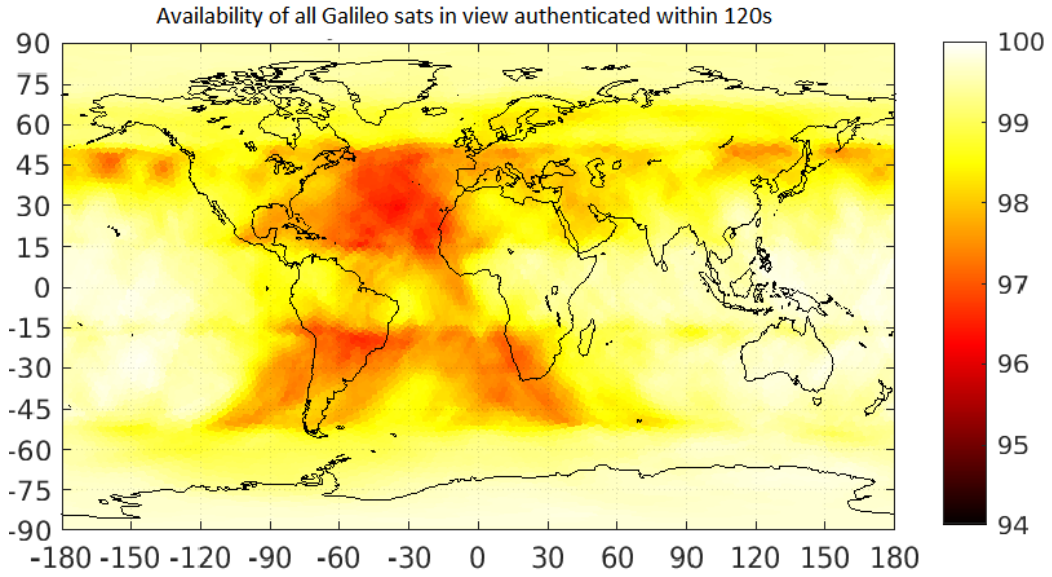
HAS Initial Service Declaration

- 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

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!

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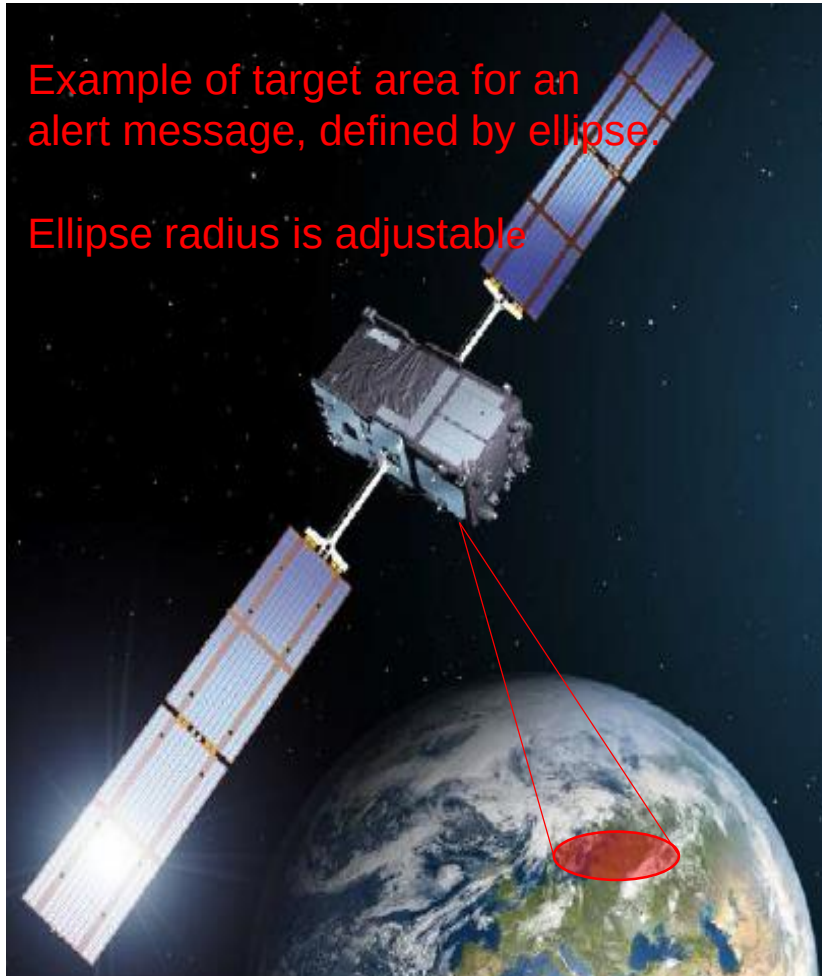
The Galileo Emergency Warning Service…

- 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



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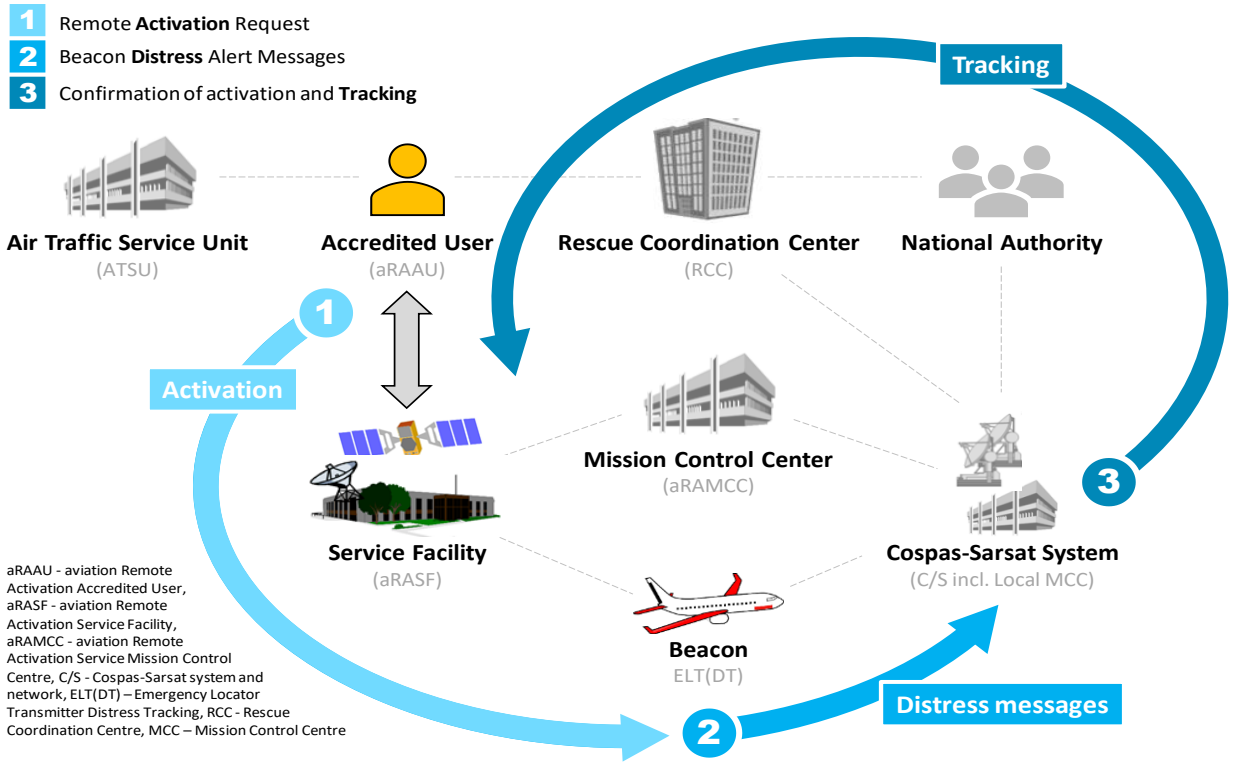
SAR …The Return

- **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



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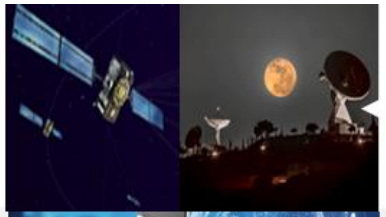
Fast…but not Furious !

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

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Far and Beyond

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

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Additional General GNSS Topic

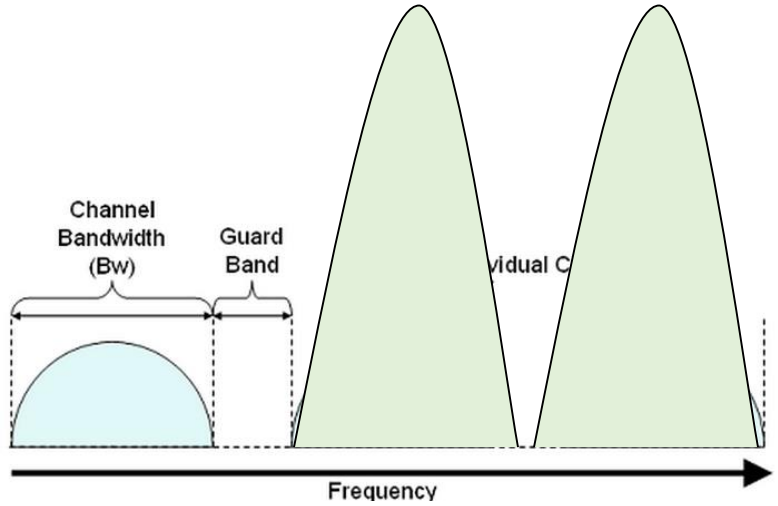
Interference to GNSS

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

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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!

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Happy to answer questions