EU SPACE

THE GALILEO PROGRAMME

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European Commission
Directorate-General for Defence Industry and Space

"Workshop on GNSS Data Processing for High-Accuracy Positioning using Low-Cost Receiver Systems"
Thailand, 19 January 2021

GALILEO EGNOS
NAVIGATION MADE IN EUROPE

Galileo

- Accurate, global navigation
  - < 1m position
  - < 5ns timing
- Almost 2 billion devices
  - Probably in your phone!
- First global mass-market dual frequency GNSS (E1/E5)
  - 1164-1215 and 1559-1591 MHz
- Search and Rescue service integrated into Cospas-Sarsat (has saved lives!)

- Coming, Navigation Message Authenication
- Coming, 20cm service in third frequency (E6/L6)
  - 1260-1300MHz)
- Coming, unique authentication (E6/L6)
- Next generation already planned

2020 Where are we?

- World class space programme
  - Copernicus
  - EGNOS
  - Galileo

- Managed by European Commission's new **Directorate General for Defence Industry and Space**

- And newly created:
  EU Space Programme Agency (EUSPA)
  - formerly the GSA

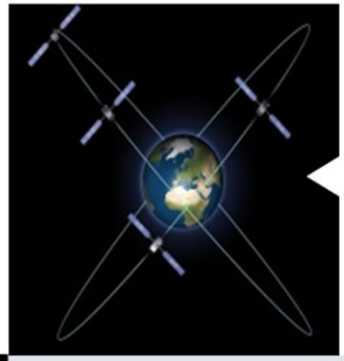
- System design by ESA

- New budget (under discussion in European Parliament) about €13bn
  - Operational
  - Developmental
  - Research

Galileo Deployment History

GALILEO

2005
DEVELOPMENT SYSTEM TESTBED
GIOVE A/B



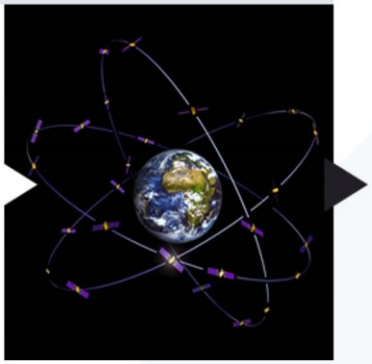
2013
IN-ORBIT VALIDATION
4 satellites
initial ground infrastructure

2015/2016
INITIAL GALILEO SERVICES
OS, SAR, PRS, CS demonstrator

2017/2019
EXPLOITATION PHASE
FOC1 System

2020 +

24 operational satellites
and complete ground infrastructure



After 2020++
TOWARD GALILEO 2nd GENERATION

G2G

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Galileo Constellation Status: STABLE

Plane A **Plane B** **Plane C**

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

- 26 satellites in orbit
- L3 sats
- 1 spare
- 1 unavailable
- 2 no SAR (by design)

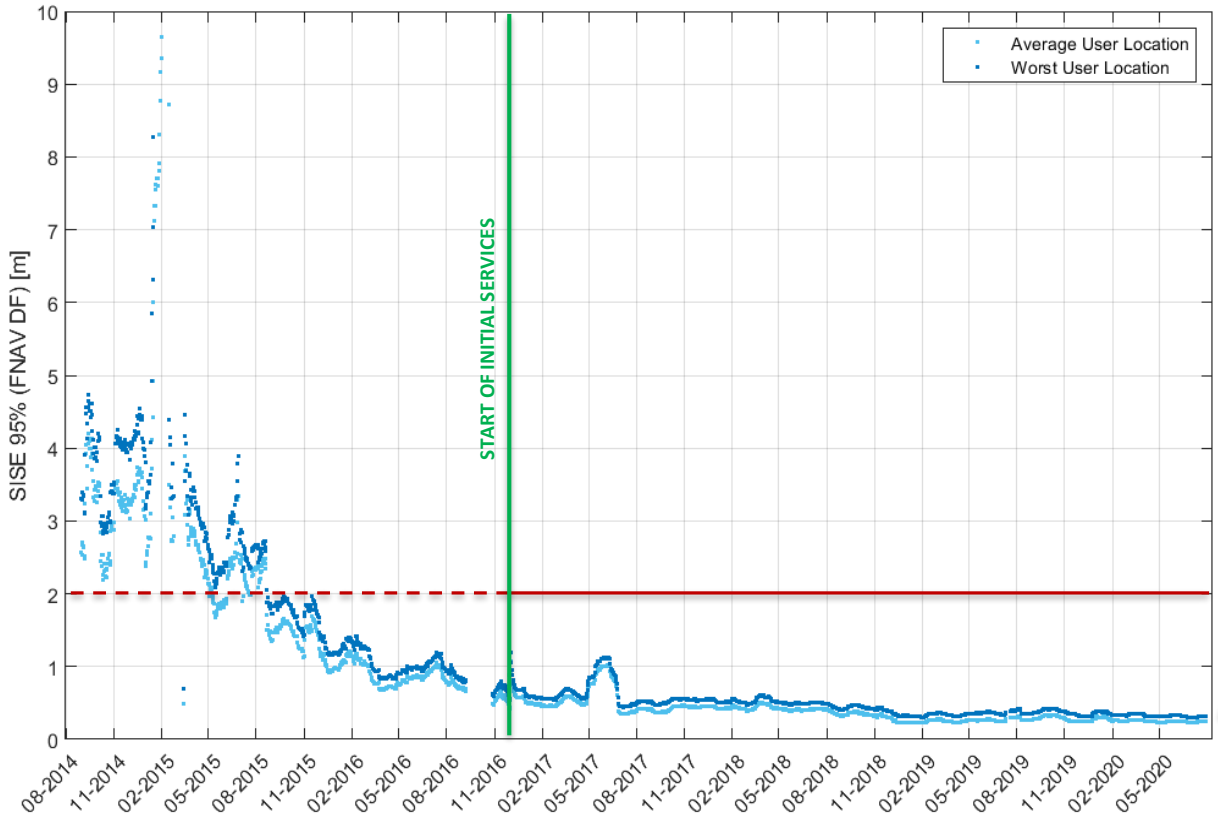
EGNOS SBAS

- Augments GPS
- Provides integrity data for Safety of Life applications
  - precision landings
  - rail/road tolling/RPAS
- Enables affordable precision farming
  - < 0.5m accuracy
- In service since 2011
- Covers EU+
  - Extensions planned

- EGNOS/Galileo alone estimated to bring net benefits €60bn+ to EU economy (up to 2027)

Pinpoint

Galileo Ranging Performance

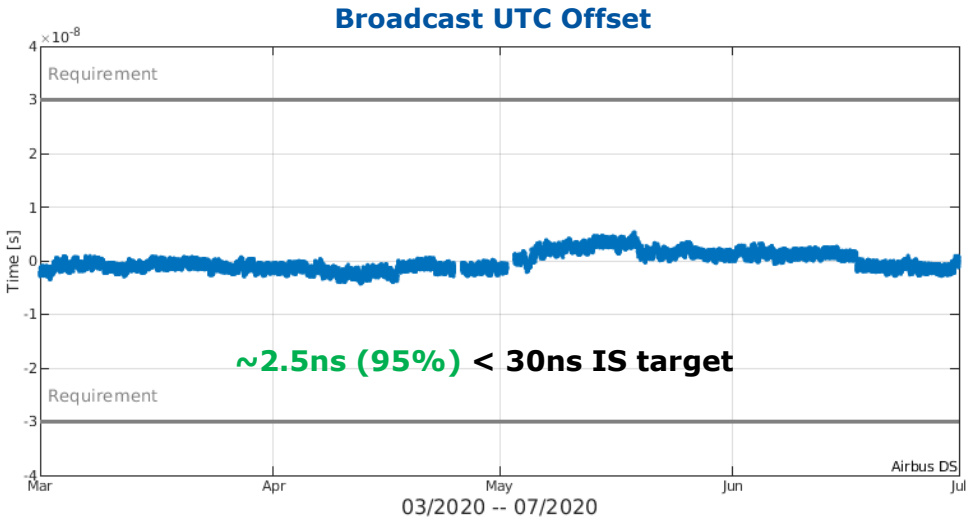


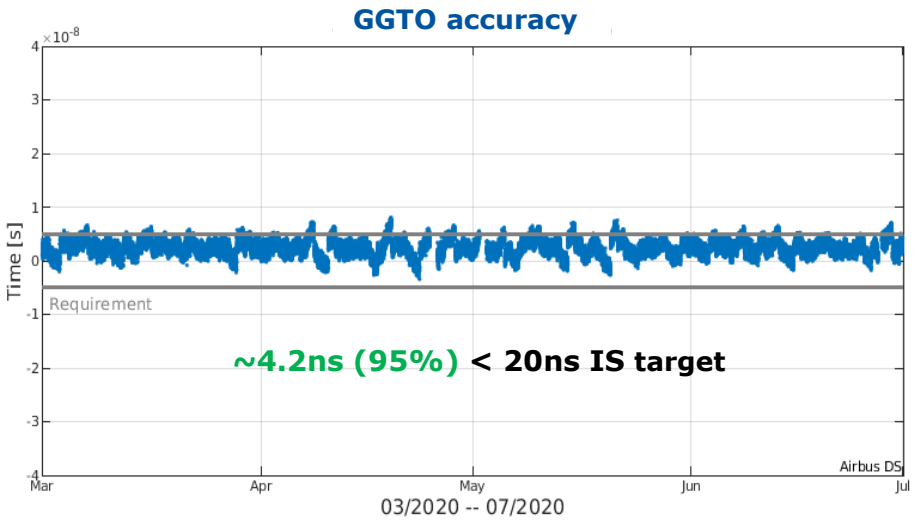
STABLE ACCURACY
~25cm

- Decreasing ranging error trend due to increasing number of satellites and ground infrastructure improvements
- **Ranging accuracy (95%) 0.25 m** all satellites in July 2020 (FNAV)

Like clockwork

Galileo Timing Performance

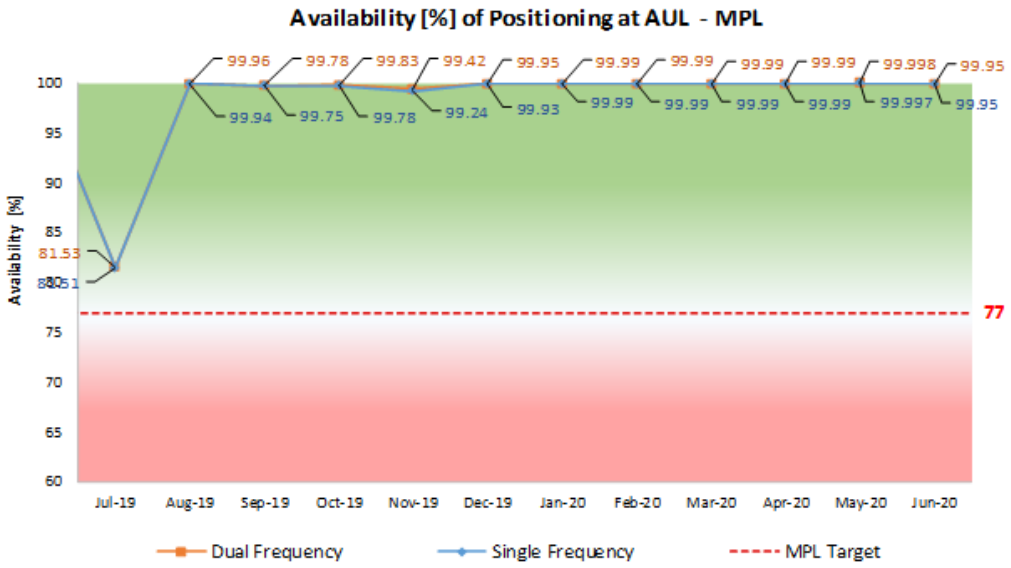


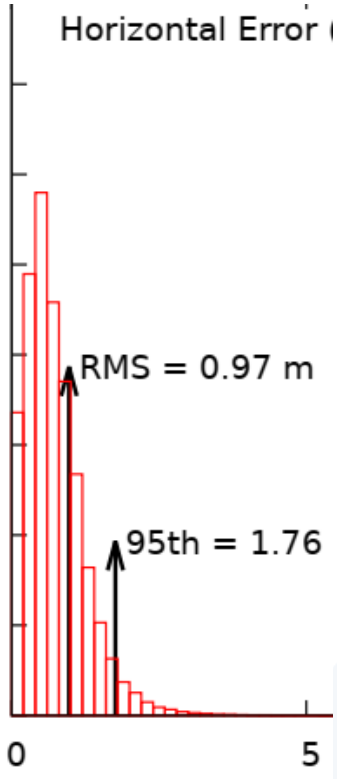


- Evaluated with calibrated timing GPS/Galileo receiver operated at a European UTC(k) laboratory (PTB, INRIM)

Reliable (mostly)

Service Availability





- And under scrutiny !
  - GRC and EU Member States Networks
  - IGS
  - IGMA
  - www.galmon.eu

Performance in detail

Definition		Committed Target	Worst Case from Oct 2019 to Jun 2020	Jul 2020	Aug 2020	Sep 2020
Ranging accuracy (DF, 95%)	Worst Satellite month	**< 7.0 m**	**0.45**	**0.29**	**0.29**	**0.41**
	Constellation Average	**< 2.0 m**	**0.22**	**0.15**	**0.16**	**0.21**
Ranging accuracy (SF, 95%)	Worst Satellite month	**< 7.0 m**	**0.75**	**0.56**	**0.61**	**0.58**
	Constellation Average	**< 2.0 m**	**0.45**	**0.31**	**0.31**	**0.34**
Availability of F/NAV Global PDOP ≤ 6		**≥ 77%**	**98.40%**	**99.999%**	**99.94%**	**99.86%**
Availability of Positioning at Average User Location*	Dual Frequency	**≥ 77%**	**99.42%**	**100%**	**99.94%**	**99.96%**
	Single Frequency	**≥ 77%**	**99.24%**	**100%**	**99.99%**	**99.95%**
Availability of Positioning at Worst User Location*	Dual Frequency	**≥ 70%**	**97.47%**	**100%**	**99.94%**	**99.66%**
	Single Frequency	**≥ 70%**	**96.98%**	**100%**	**99.91%**	**99.61%**
"Per Slot" Availability of SiS (monthly, OS, healthy SF/DF – OS-SDD MPL)		**> 87%**	**≥ 96.29%**	**≥ 98.10%**	**≥ 98.17%**	**≥ 98.35%**
UTC Time Diss. Uncertainty (DF, 95% over last 12 months – OS SDD MPL)		**< 30 ns**	**14.4**	**14.4**	**13.6**	**12.6**
Availability of UTC dissemination (%)		**> 87%**	**100%**	**100%**	**100%**	**100%**
GST-GPS time offset uncertainty (95% over last 12 months – OS SDD MPL)		**< 20 ns**	**13.7**	**13.4**	**12.4**	**11.2**

Accurate, *and precise*

HAS (High Accuracy Service)

Current

- **Defined**:
  - HAS SIS ICD
  - Based on RTCM format with Galileo-specific features
  - Launching “Phase 1” EU coverage
  - “Phase 2” improves performance with more stations, ionospheric corrections for better global service
- **Infrastructure**: HAS Data Generator module at CDR phase and progressing steadily
- **Testing:** Promising performance in tests using current Galileo monitoring stations

Next Steps

- SIS testing with HAS Demonstrator.
- HAS Data Generator completion
- Begin operational validation
  - phase 1 service declaration 2022-23

Trusted

OSNMA
(Open Service Navigation Message Authentication)

Current

- **Defined** OSNMA scheme
- **Infrastructure:** OSNMA module qualified and integrated
- **Testing**: Internal testing
- **Receivers and Applications**:
  - Receiver Guidelines produced
  - OSNMA receivers and software available
  - OSNMA is a cornerstone of newly drafted **Smart Tachograph Regulation**

Next Steps (2021)

- **Infrastructure**: consolidate to ensure high robustness before Declaration
- **Testing**: open testing before service and operational validation
- **Receivers and applications**: Publication of official SIS ICD and Receiver Guidelines

Secured

CAS (Commercial Authentication Service)

- Stronger protection than OSNMA
  - Eg for insurance, financial transactions
- Encrypted navigation signal
- System capabilities and timeline agreed
- Feasible service concept proposed and under discussion

Protected

- Search And Rescue localisation service
  - Up and Running with excellent performance
  - detection in <5 minutes, not 4 hours; and 500m, not 5 km
- Return Link Service
  - Service Declaration on 21st January 2020
  - Compatible beacons – already half of manufacturers
  - Worldwide service – already 18 states, beacon approval
- eCall (automatic call localisation for car accidents)
  - In service for more than 2 years (now fitted to all new cars)
- Galileo used in E112 emergency call location (E911)

Resilient

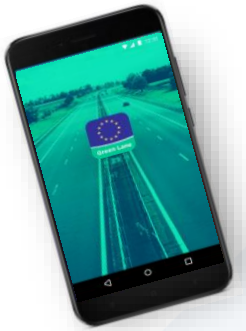
- Robust timing service under definition
- Resilience - the key principle for G2G

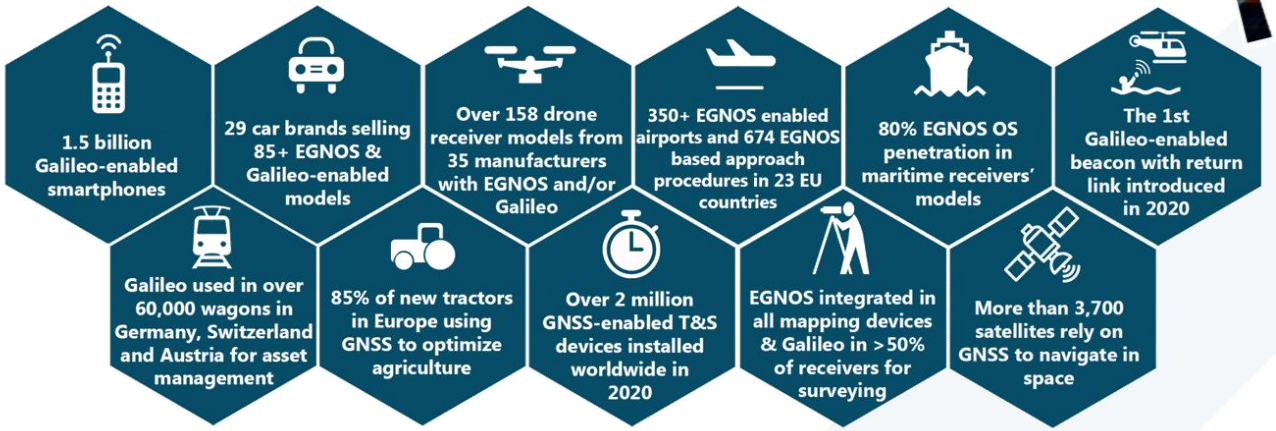
- July 2019 Event - Inquiry board recommendations
- Substantial programme steering
  - Maintain navigation in case of multiple element failure – **graceful degradation**
  - Improve upgrade deployment capabilities
  - **Review redundancy** for some elements of the service delivery in the light of existing and new services
  - Review **operational processes** and procedures
  - Continuous **reinforcement** of cyber security

Applied

USEGALILEO.EU

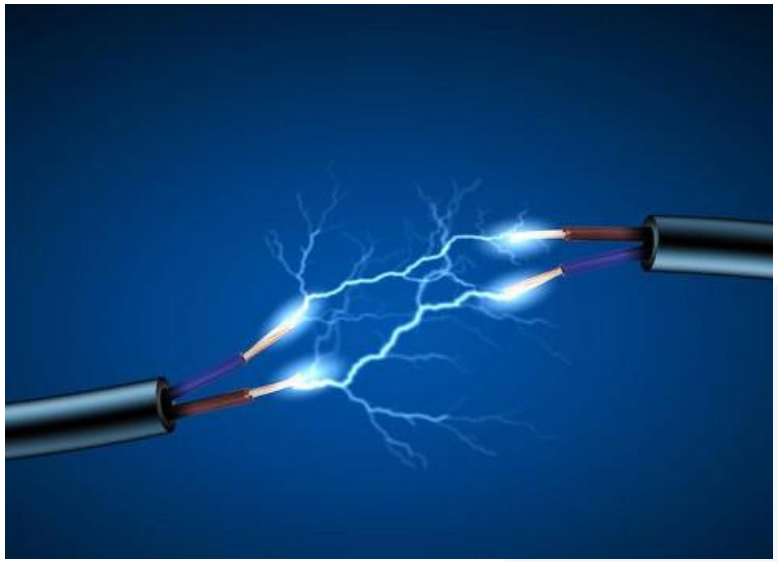
- Customer centric approach
- GSC registered users still on the rise
- GSA Market Teams in continuous exchange with user communities
  - Market Report (Oct 2019) and User Technology Report (End 2020)
  - Power-efficient positioning for The Internet of Things
  - Guidelines for rail receivers supporting EGNSS in ERTMS
  - Adoption of Galileo in Prague public transport
  - SAR beacons remote activation for fishing vessels
  - Galileo Green Lane App (COVID border crossing)





Defended

- Working with EU Member States to keep GNSS spectrum free from interference
  - European GNSS Interference Task Force (~~plug-in jammers~~)
- Working with international partners to defend GNSS spectrum and monitor GNSS performance (UN-ICG)
- Working (with BeiDou) towards better co-existence between GNSS and amateur radio users (WRC-23 AI 9.1b, 1240-1300MHz)



Accelerated

- L3 satellites have joined the operational constellation
- OS SISI ICD 2.0 with new features (backward compatible)

G2G

G2G Service Portfolio and High Level Mission Objectives agreed with Programme Stakeholders

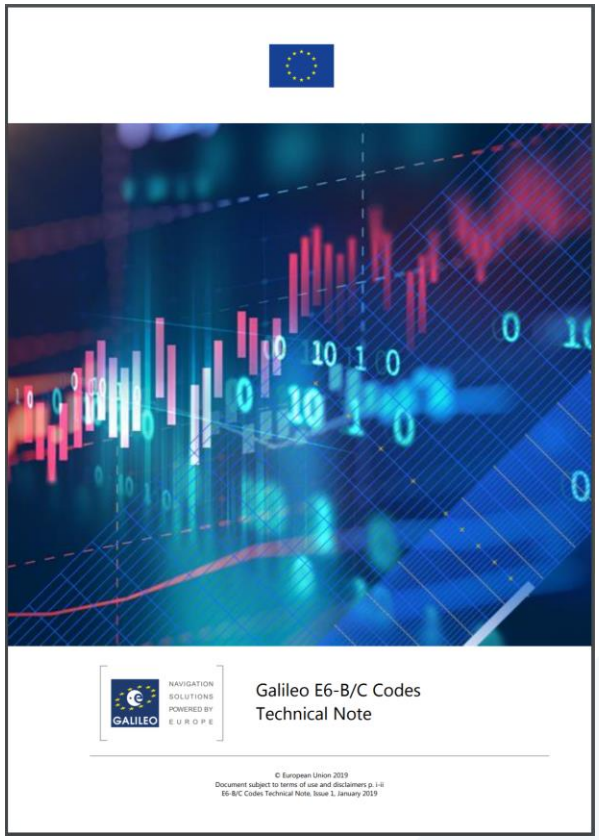
Service evolutions include:

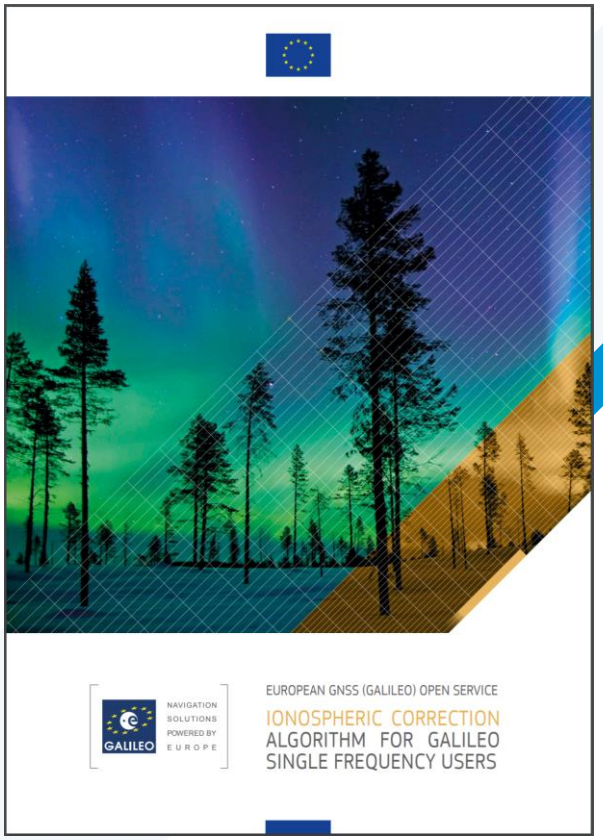
- Advanced Timing Services
- Space Service Volume
- ARAIM – coming back to serving SoL communities
- Emergency Warning Services
- Search And Rescue – Innovative service based on the return link
- Ionosphere Prediction Service
- Signals Evolution – increased performance at user level (reduced power consumption,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

Documented

- https://www.gsc-europa.eu/electronic-library/programme-reference-documents

VERSION 2.0
JUST RELEASED!





Optional Slide

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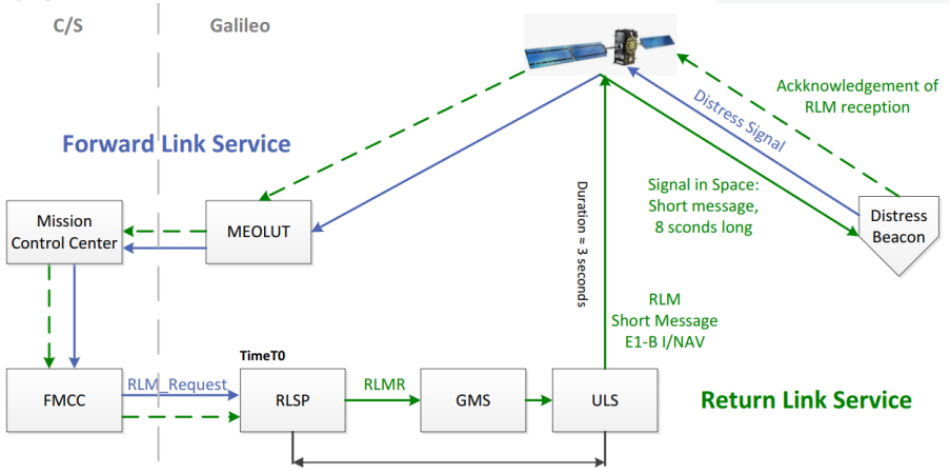
SEARCH AND RESCUE Service

- MEOSAR operational as part of
  COSPAS SARSAT in December 2016
  - Detects standard 406 MHz emergency beacons
  - Faster beacon detection (was 4hrs, **now <5mins**)
  - Better position accuracy (was 10km, **now <1km**)
  - Major contribution by Galileo

- EU Coverage 3 MEOLUTs
- 4th station in Indian Ocean



- Return Link Service ready

Successful performance – remarkable latency

Manufacturers building RLS capable beacons

Successfully tested at sea with US Coastguard, near Maryland

Optional Slide

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Galileo SAR

Galileo SAR Performance

Definition			Committed Target	Worst Case from Oct 2019 to Jun 2020	July 2020	August 2020	Sept. 2020
Valid message detection probability			≥ 99%	96.5%	100%	100%	100%
Localisation probability (1 burst)			≥ 90%	99.1%	100%	99.7%	99.9%
Localisation probability (up to 12 bursts)			≥ 98%	99.7%	≥ 99.9%	100%	99.9%
Localisation success within 5 km (1 burst)			≥ 90%	98.1%	≥ 99.5%	≥ 99.6%	99.2%
Localisation success within 5 km (up to 12 bursts)			≥ 95%	99.1%	≥ 99.9%	≥ 100%	99.9%
Minimum SAR Transponder Avai. (Worst Case)			> 95%	52.35%	91.90%	92.91%	93.70%
MEOLUT Availability	in "Nominal" status	LNC	≥ 95%	98.4%	99.5%	100%	99.60%
		MSP	≥ 95%	99.2%	99.6%	100%	99.70%
		SBG	≥ 95%	98.7%	99.7%	100%	99.70%
	in "Nominal + Degraded" status	LNC	≥ 97.5%	99.2%	99.6%	100%	99.80%
		MSP	≥ 97.5%	99.4%	99.6%	100%	99.80%
		SBG	≥ 97.5%	98.8%	99.7%	100%	99.80%
SAR Forward Link Service Availability			≥ 99%	99.85%	99.90%	99.91%	99.87%
SAR Return Link Service Availability			≥ 95%	100%	100%	99.99%	99.99%
SAR RLM Delivery Latency < 15 [min]			≥ 99%	99.70%	99.97%	99.97%	99.83%

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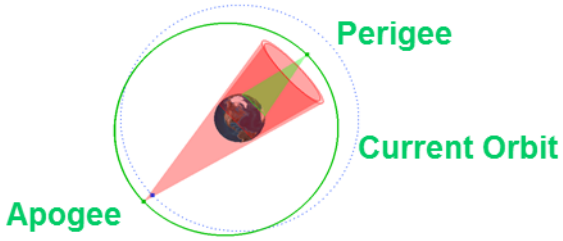
GSAT201/202 entry into Service

- Satellites GSAT201/202 ('L3' satellites), launched 22 August 2014, did not reach nominal orbit
- Partial orbit recovery performed by ESA in 2014/2015



- System and satellite S/W updated to handle the different orbit
- L3 have broadcast navigation messages since August 2016;
  - no degradation observed/reported by users
  - majority of user segment already track these satellites
  - user feedback indicated eagerness for healthy flag to enable use in PVT solutions
- Ranging performance is in line with those observed for the other satellites,
- L3 almanac information not included in the OS Navigation Message broadcast by any Galileo satellite - L3 satellites information published by the GSC

- **L3 satellites declared operational 30 November 2020**