



# Galileo is here! Where are you?

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*ITSF Bucharest 2018*

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European Space Agency

# Initial Services started 15<sup>th</sup> Dec 2016



Almost 2 years of  
initial services  
providing Open  
Service, PRS and SAR



## L10 (25/07/18) – Completed initial deployment!



26 satellites in orbit



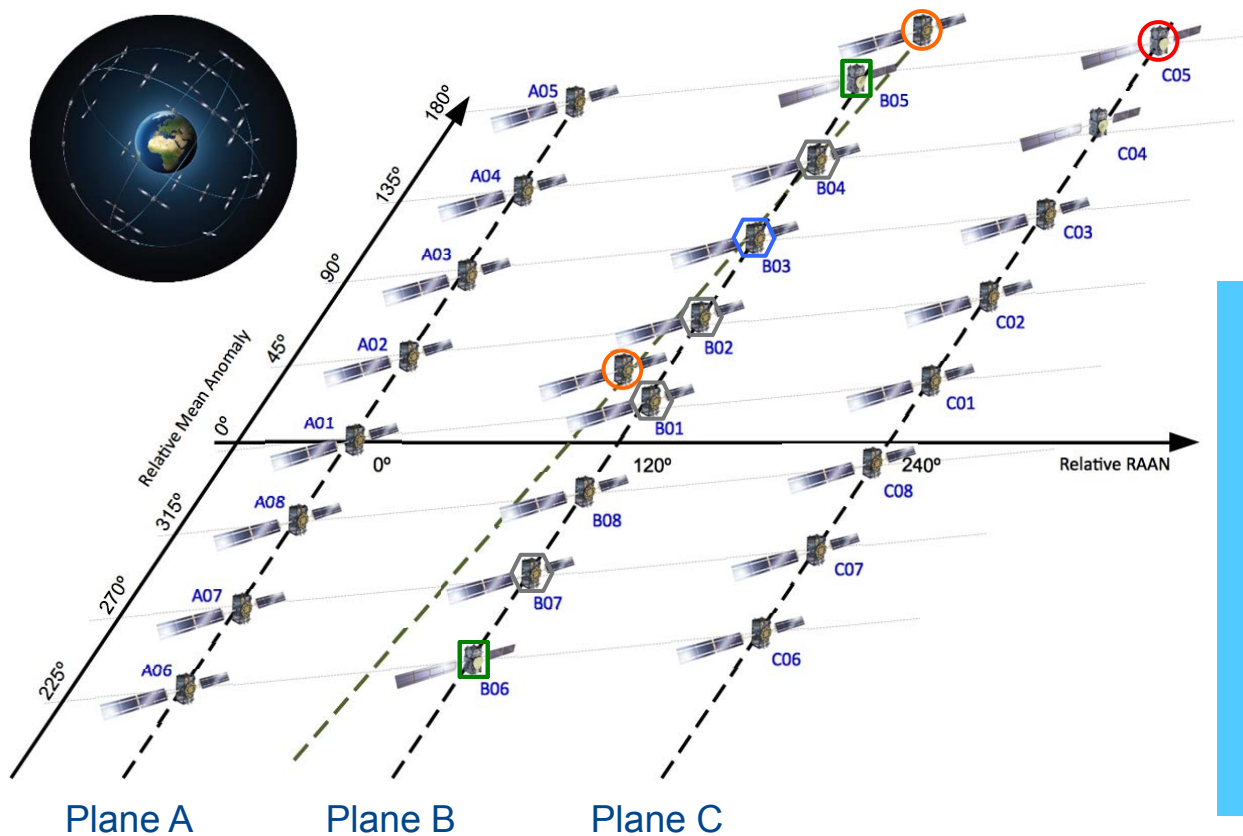
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# Galileo Constellation Fully Populated !



**Navigation (18 in service)**  
**Search and Rescue (19 in service)**



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

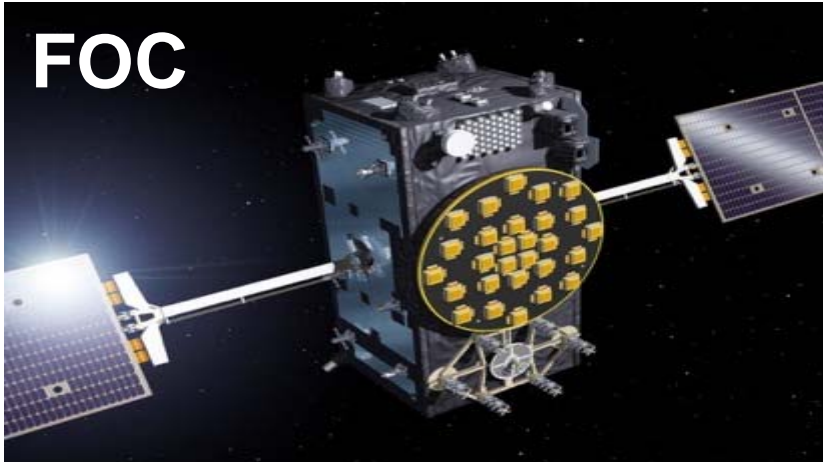
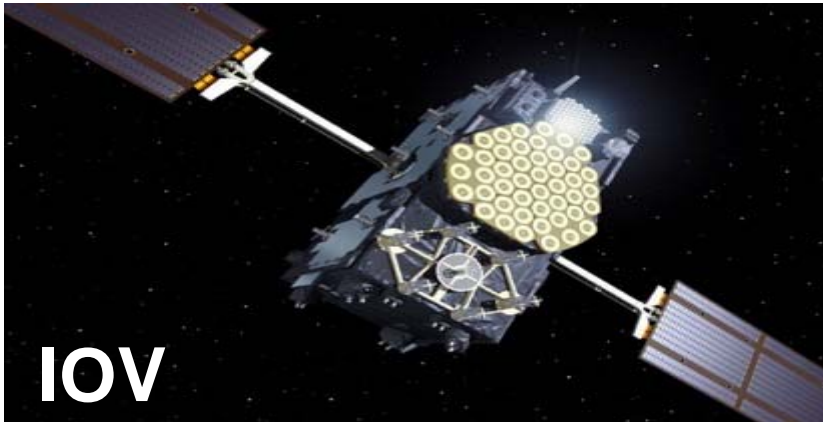
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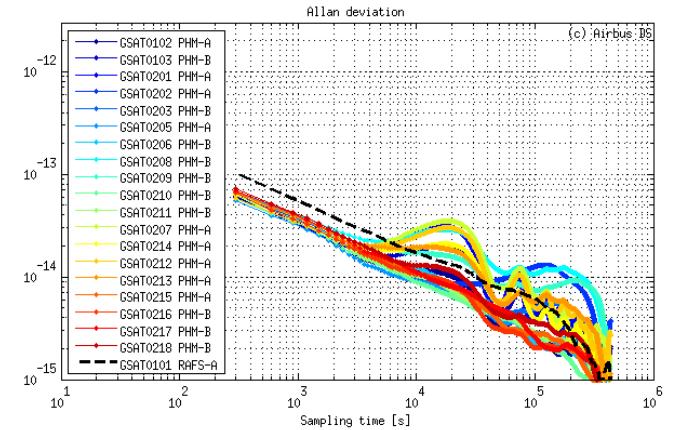


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# Constellation Satellites



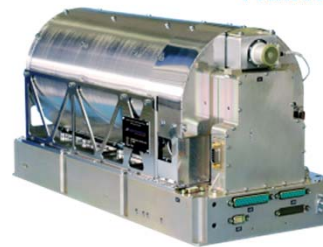
**Airbus Defence & Space**  
4 satellites



**Embarked Clocks:**

**Rubidium Atomic Frequency Standard**

**Passive Hydrogen Maser**



**OHB Systems GmbH**  
**SSTL Ltd**

22 satellites

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# Galileo Precise Time Facility



- Dual Redundant PTFs
- Triple Redundant Maser
- Quad Redundant Cs
- TSP provides link to UTC



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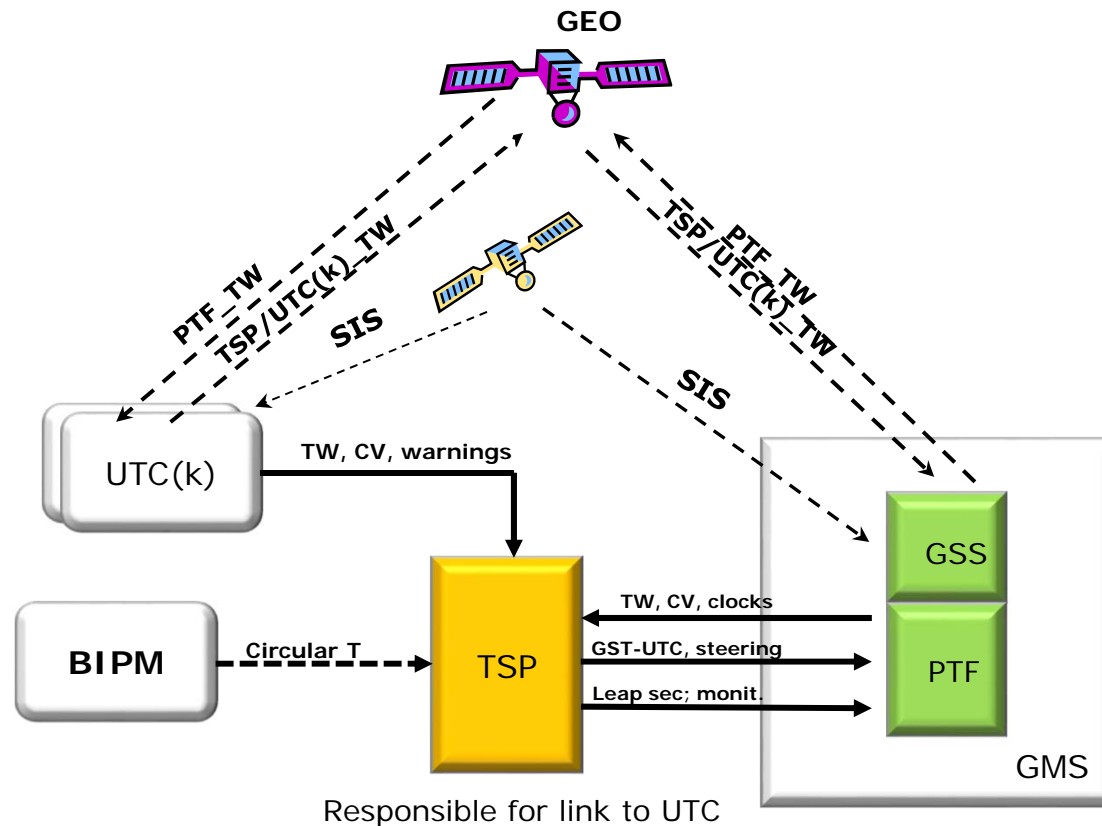
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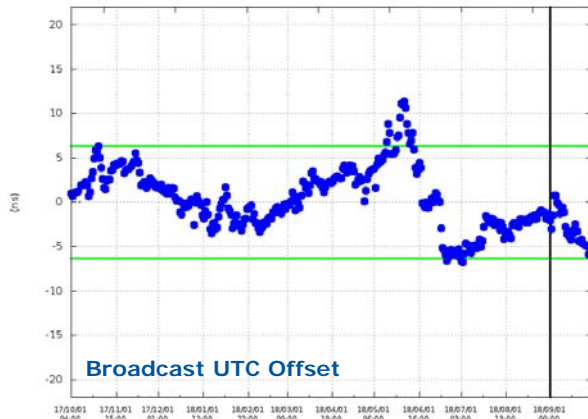


# Galileo Time Service Provider

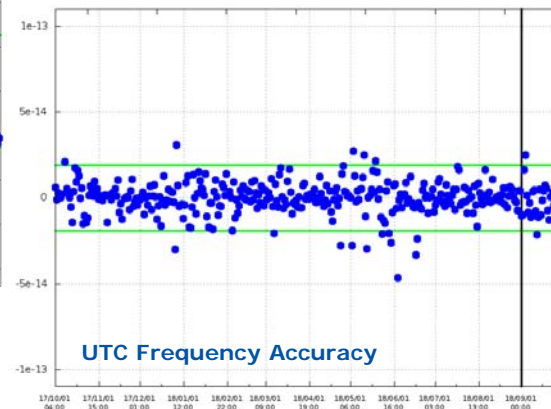


- Dual Redundant TSP service based on hardware installed at GCC-I & D
- UTC realisation is based on a network of connected timing laboratories
- TSP receives the PTF time and provides corrections steering GST

# Outstanding UTC dissemination performance



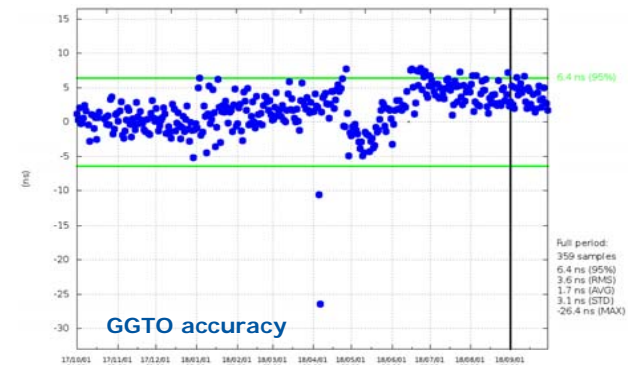
**6.4ns (95%)**  
**< 30ns IS target**



**1.92E-14 (95%)**  
**< 3E-13 IS target**

→ evaluated with **calibrated timing GPS/Galileo receiver** operated in a UTC(k) laboratory (PTB, INRIM).

- Galileo will continue to broadcast the **Galileo-GPS Time Offset** in order to actively contribute to interoperability



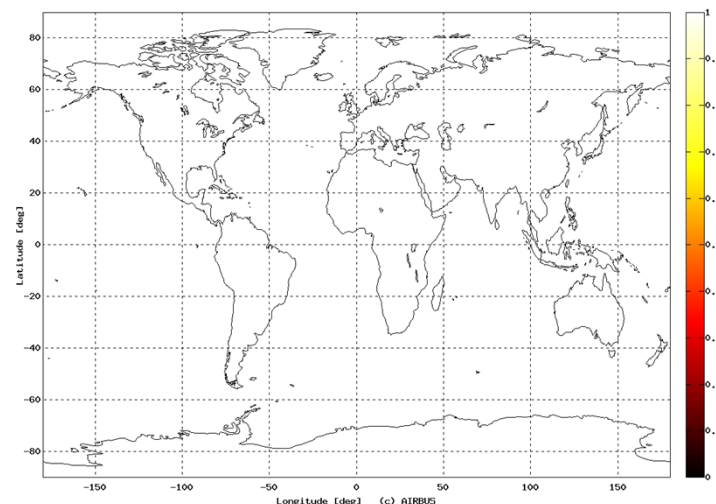
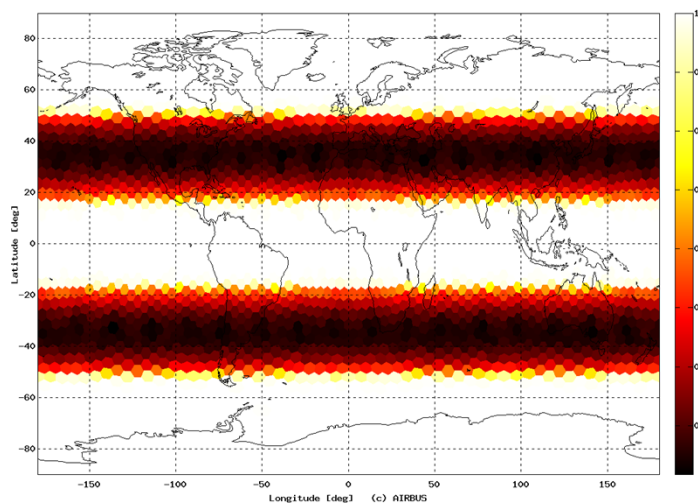
**6.4ns (95%)**  
**< 20ns IS target**



# High Availability of Signals for Timing Applications

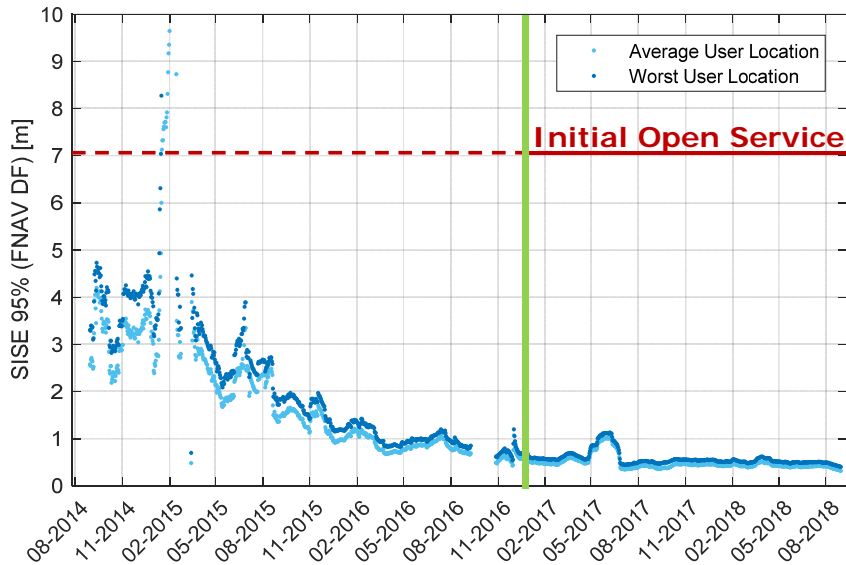


- 4 more satellites operational since Q3 2018
- Satellites in operational constellation: 18 → 22
- Availability of H. Accuracy <10 m 96% → **100%** (Average User Location)
- Global PDOP ≤6 availability 95% → **99.99%** (Average User Location)
- Availability for Timing Service **100%**



Availability of Horizontal Position Accuracy < 10 m for 18 satellites (left) and 22 satellites (right)

# Excellent As-observed Ranging Performance

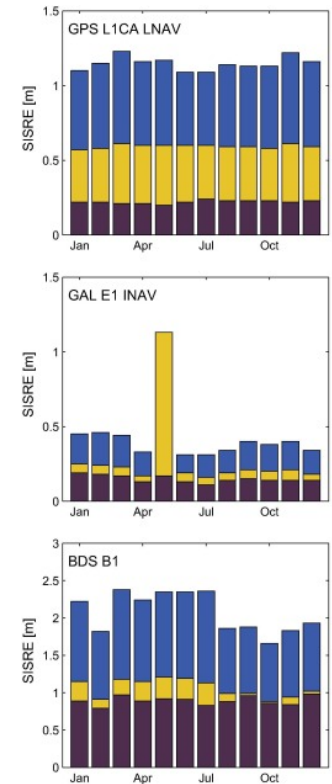


- Decreasing Ranging Error trend due to increasing number of Satellites and G/S improvements
- **Ranging accuracy (95%) 0.38m** all satellites, 0.45m worst satellite in September 2018 (FNAV)

■ Extract from “Multi-GNSS signal-in-space range error assessment – Methodology and results” by DLR, DE.

■ <https://doi.org/10.1016/j.asr.2018.03.041>

➤ Fundamental for timing service



# First mass-market dual frequency GNSS receiver



- World's first mass-market, dual frequency GNSS receiver device for smartphones
- Usage of E1/L1 and E5/L5 frequencies benefit from better accuracy, ionosphere error cancellation, improved code tracking pseudorange estimates and faster transition from code tracking to phase tracking



**18 operational Galileo satellites (E1/E5)**



**+ 12 operational GPS Block IIF satellites (L1/L5)**



Future GNSS/RNSS common frequencies, showing the potential of E5a/L5 and of E1/L1 combination

	L5 / L5OC / E5a / B2a	L2 / L2C / L2OC	E6 / LEX	L1 / L1OC / E1 / B1
GPS	30	30		30
GLONASS	24	24		24
Galileo	30		30	30
BeiDou	35		35	35
QZSS	3	3	3	3
IRNSS	7			
	129	← ARNS* Bands →		122

Frequency band used by the system, with N = number of satellites  
 Frequency band not used by the system

\* ARNS = Aeronautical Radio Navigation Service: Frequency bands allocated worldwide to GNSS on a primary basis, granting a better protection against interference

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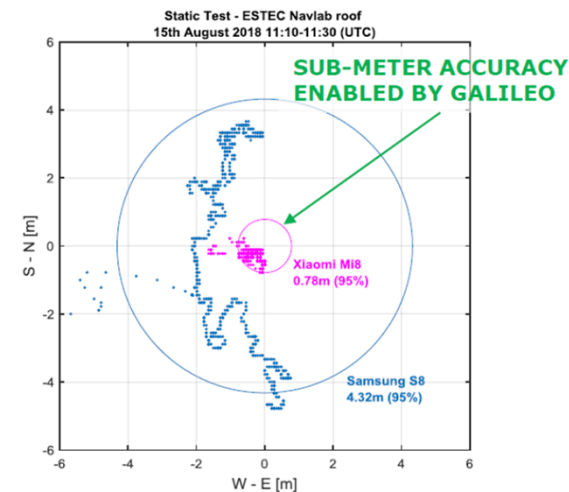


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# Opens Sky Pedestrian Test SF vs DF GNSS chipsets



TEST #1 15-08-2018  
6-8 Galileo satellites in view during the test



→ Dual Frequency (DF) measurements along with GNSS chipset algorithmic enhancements enable a significant reduction of positioning error



## Towards 2020 and Beyond



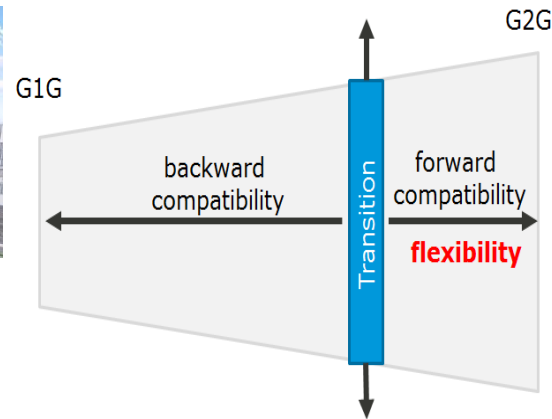
- Open Service Full Operational Capability (mass market) incl. **I/Nav message (improving Time to First Fix)**
- **OS Navigation Message Authentication**
- SAR Full Operational Capability
- **High Accuracy Service**



## High Accuracy Service

- System is under definition
- **Commission Implementing Decision (EU) 2018/321 of 2 Mar 2018**
  - Better than two decimetre level of performance
  - Free of charge
  - Complementary to fee paying systems which provide better than decimetre level performance
  - Initial signals supply phase between 2018 and 2020' and '— Full service supply phase expected post 2020'
- Allows for global distribution from connected Galileo Satellites
- **Provides Real Time corrections of Orbits, Clocks, Signal biases and Ionospheric data.**

# Designing the Future (towards 2030) Galileo Transition System & G2G Phase B



**GALILEO  
EVOLUTIONS  
HAVE  
ALREADY  
STARTED**



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# EGEP & H2020 AS EVOLUTIONS ENABLERS

ESA EGEP (ongoing closure) & EC H2020 HSNVAV Programmes are investing up to 2020 around 340M€ (150+ contracts) in GNSS R&D

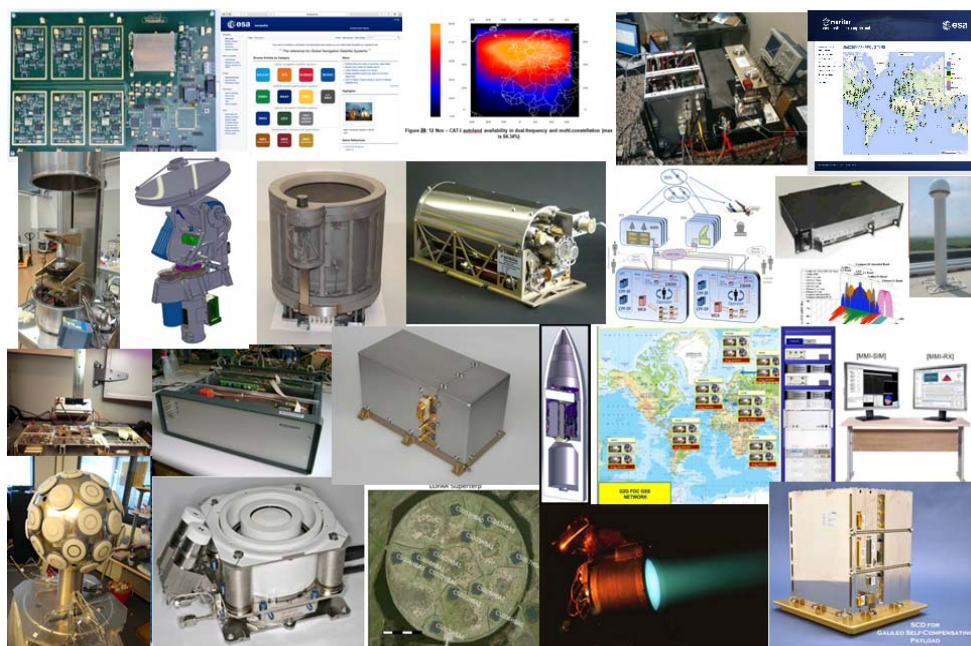


Galileo & EGNOS Evolutions Phase 0/A/B

Galileo & EGNOS novel technologies

GNSS Science & Transversal Activities

Exploratory studies and EGNOS GALILEO Synergies



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# Galileo APPs

GNSS Compare

GalileoPVT

CALLISTO

ENGLISH (EN)

## USE GALILEO.EU

FIND A GALILEO-ENABLED DEVICE TO USE TODAY

Galileo is Europe's Global Satellite Navigation System (GNSS), providing users with improved positioning and timing information.

*Click on the icons to find Galileo-enabled devices.*

ON THE ROAD

ON THE WATER

ON THE TRAIN

IN THE AIR

GOING MOBILE

ON THE FARM

ON THE MAP

DURING AN EMERGENCY

## CALLISTO

Galileo's Spaceship

Discover Galileo with Callisto's navigation game!

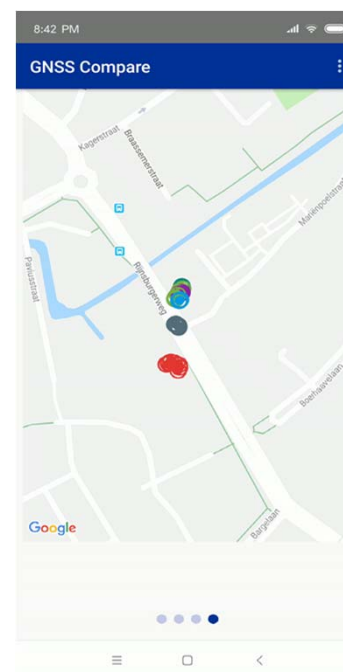
GET IT ON Google Play

powered by

GNSS Compare

created by the Galileo team

sponsored by



## GalileoPVT

svID	Type	C/N0	Azm	Elev	FP Meas	Sync	Mag	Age
3	FOC	37	194° 10'	1°	F-804	1/1	0	0.8 Live
8	FOC	35	242° 36'	1°	F-805	KT/KT	0	78.1 Live
2	FOC	32	295° 78'	1°	F-805	KT/KT	0	77.8 Live
11	IOV	29	80° 32'	1°	F-799	2/2	0	85.3 Live
30	FOC	20	269° 25'	1°	F-797	0/KT	0	- Live
12	IOV	18	28° 13'	1°	F-764	0/2	0	- Live
7	FOC	13	304° 29'	1°	F-795	0/2	0	- Live
24	FOC	9	0° 1'	1°	F-761	0/0	0	- 4:42

7 live Galileo signals (11 live GPS)

Sky plot

C/N0

Fix availability history

Android location known

SUPL ephemerides/coefficients up to date

MAP 7 visible 0 used 7 Fix Logging

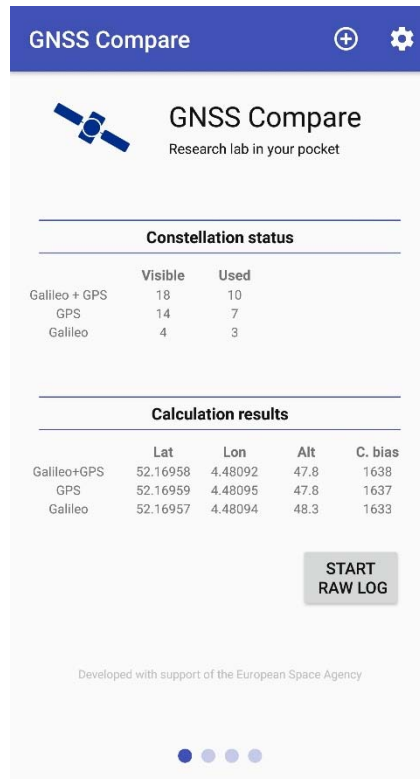
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# Challenging Opportunities for Young Engineers!



## ESA APP Competition

### Supported constellations:

- Galileo, GPS (separate or combined)

### Implemented PVT estimators:

- Weighted Least Squares
- Extended Kalman Filter (*initialized with Android FINE location*)

### Data logging formats:

- Simple logger (UTC timestamp, X, Y, Z)
- NMEA (UTC timestamp, lat, lon, alt, CN0)

### Available on Google Play:



→ [Online documentation](https://gnss-compare.readthedocs.io) <https://gnss-compare.readthedocs.io>



ESA YGT winning team, "The Galfins": Mareike Burba, Sebastian Ciuban, Dominika Perz, Mateusz Krainski

# Challenging Opportunities for Young Engineers!



## NEW ESA APP Competition

Proposal Submission by 12 November 2018



[www.esa-jrc-summerschool.org](http://www.esa-jrc-summerschool.org)  
for 2018 programme

We look forward to your most innovative ideas!



<http://www.esa.int/GalileoAppCompetition>



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# Challenging Opportunities for Young Engineers!



## OPPORTUNITIES to Kick Start your Career

Post Docs: Research Fellowship

PhD students: Network/Partnering Initiative

Graduates: Young Graduate Trainees

Graduates: National Trainees

Student Internships



[https://www.esa.int/About\\_Us/Careers\\_at\\_ESA](https://www.esa.int/About_Us/Careers_at_ESA)



## Highlights to Take Away

- **Galileo is available and contributes! Let's use it!**
- **Outstanding timing performance for GNSS & clock stability demonstrated with UTC (SIS) better than 10ns**
- Proven Accuracy of Positioning and Timing
- Galileo has entered the Single Frequency mass-market
- Galileo is the de facto standard for Dual Frequency applications
- Galileo is here and will stay for the future (more satellites under procurement)

### Where to get the data?

- <https://www.gsc-europa.eu/>



# Galileo is ready for you!

## Are you Ready for Galileo?

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