

Introduction to Galileo PRS

Fabio Covello

20/09/2017

- **The Galileo Space Segment:**

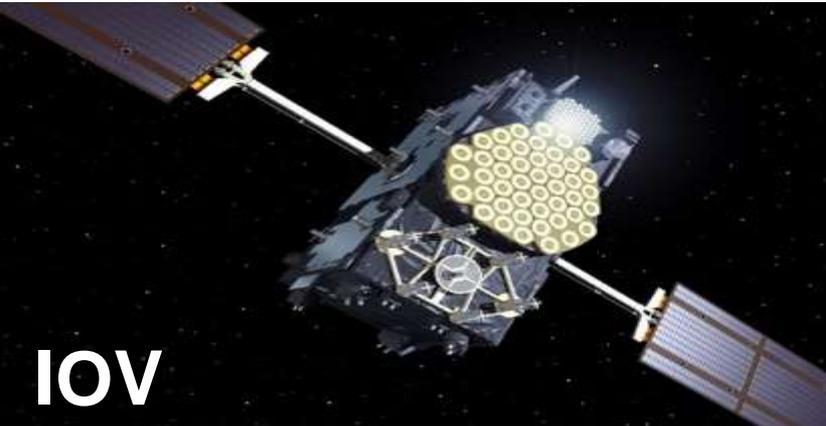
- 30 satellites (full constellation) Walker 24/3/1 constellation + 6 spares
- Altitude of 23222 km (MEO)
- 3 orbital planes, inclination of 56°
- 14 hours to orbit the Earth
- Payload: Highly stable atomic clocks

- **The Galileo Ground Segment :**

- two Ground Control Centers (GCC),
- five Telemetry, Tracking and Control (TT&C) stations,
- nine Mission Uplink Stations (ULS),
- a global network of 16 Galileo Sensor Stations (GSS)
- the European GNSS Service Centre (GSC).



Constellation Satellites

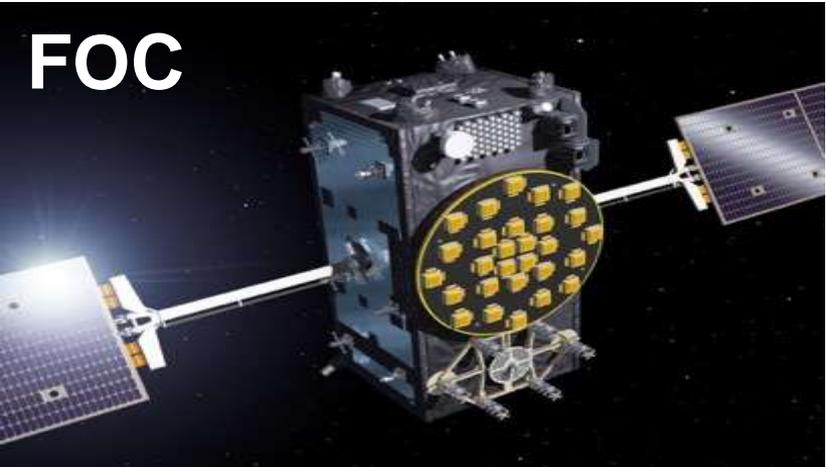


IOV

**S/C Prime Contractor Astrium GmbH
(now Airbus Defence & Space)**

4 satellites – 4 In-Orbit

Mass at Launch	700kg
Power Consumption	1420W
Dimensions	2.7 x 1.6 x 14.5 m
Orbit Injection	Direct into MEO orbit
Attitude Profile	Yaw Steered



FOC

**S/C Prime Contractor OHB Systems GmbH
P/L Prime Contractor SSTL Ltd**

22 satellites – 14 In-Orbit

Mass at Launch	733kg
Power Consumption	1900 W
Dimensions	2.5 x 1.1 x 14.7 m
Orbit Injection	Direct into MEO orbit
Attitude Profile	Yaw Steered



→ GALILEO GROUND SEGMENT OVERVIEW



Papeete

LEGEND

- GCC: Ground Control Centre
- GSS: Ground Sensor Station
- ULS: Uplink Station
- TTCF: Telemetry, tracking and Command
- SAR MEOLUT: Search and Rescue - Medium Altitude Earth Orbit Local User Terminal
- GSMC: Galileo Security Monitoring Centre
- TGVF: Timing and Geodetic Validation Facility
- IDT: In Orbit Test Centre
- LEDPCC: Launch and Early Operations Control Centre

Falkland Islands

Troll

Jan Mayen

Svalbard

ESTEC Noordwijk

Redu

Swanwick

Kiruna

Darmstadt

Saint-Germain-en-Laye

Oberpfaffenhofen

Azores

Fucino

St Pierre et Miquelon

CNES, Toulouse

Larnaca, (Cyprus)

Maspalomas (Canary Islands)

Kourou

Ascension Island

Reunion

Wallis and Futuna

Noumea

Kerguelen

Services to be provided by Galileo:

- Open Service (OS)
- Commercial Service (CS)
- Public Regulated Service (PRS)
- Search And Rescue Service (SAR)

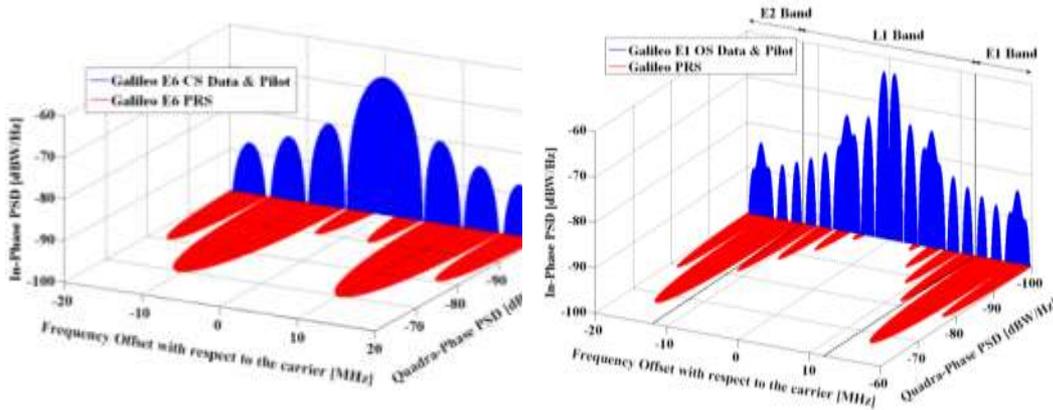


What is PRS



Galileo Service Restricted to government-authorized users, intended for security and strategic infrastructure. It provides the outstanding Positioning, Velocity and Timing (PVT) performance of Galileo with:

- High level of service continuity
- Higher level of protection (confidentiality)
- Robustness against unintended and intended interferences



Frequency Band	E1	E6
Centre Frequency	1575.42	1278.75
Access Technique	CDMA	CDMA
Spreading Modulation	$BOC_{cos}(15,2.5)$	$BOC_{cos}(10,5)$
Subcarrier frequency	15.345 MHz	10.23 MHz
Code Frequency	2.5575 MHz	5.115 MHz



How to get these characteristics

Service continuity is granted at system level via the adoption of engineering measures to minimize the probability of service interruption



Confidentiality is implemented via the adoption of encryption schemas allowing only the authorized user to access the service.



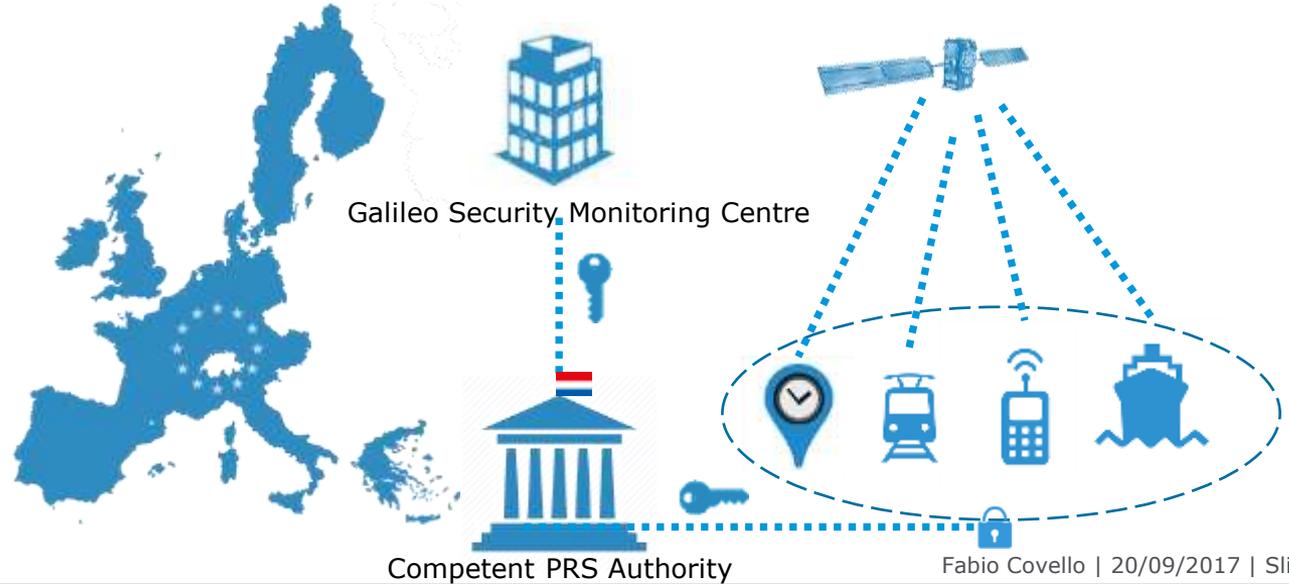
Robustness against interference is implemented via the selection of appropriate Signal characteristics and technical measures limiting the overlapping of the Spectrum with other signals and the possibility to counterfeit the signal.

Legal framework

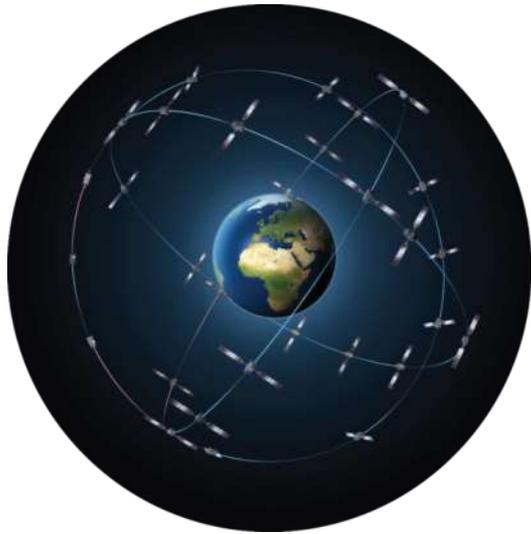
The Rules for access to the public regulated service provided by the global navigation satellite system established under the Galileo program are defined in:

DECISION N. 1104/2011/EU

OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 25 October 2011



Deployment / Exploitation Plan



FOC2
Full Services



2020

Exploitation Phase



2017-2019

FOC1
Initial Services



2014-2016

In-Orbit Validation



Development
GIOVE A & B



2011-2013

2005 & 2008

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European Space Agency

Launch Plan



IOV

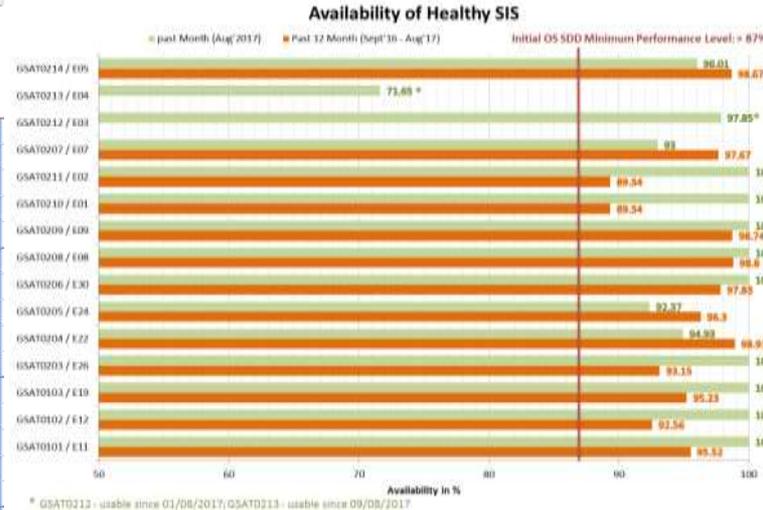
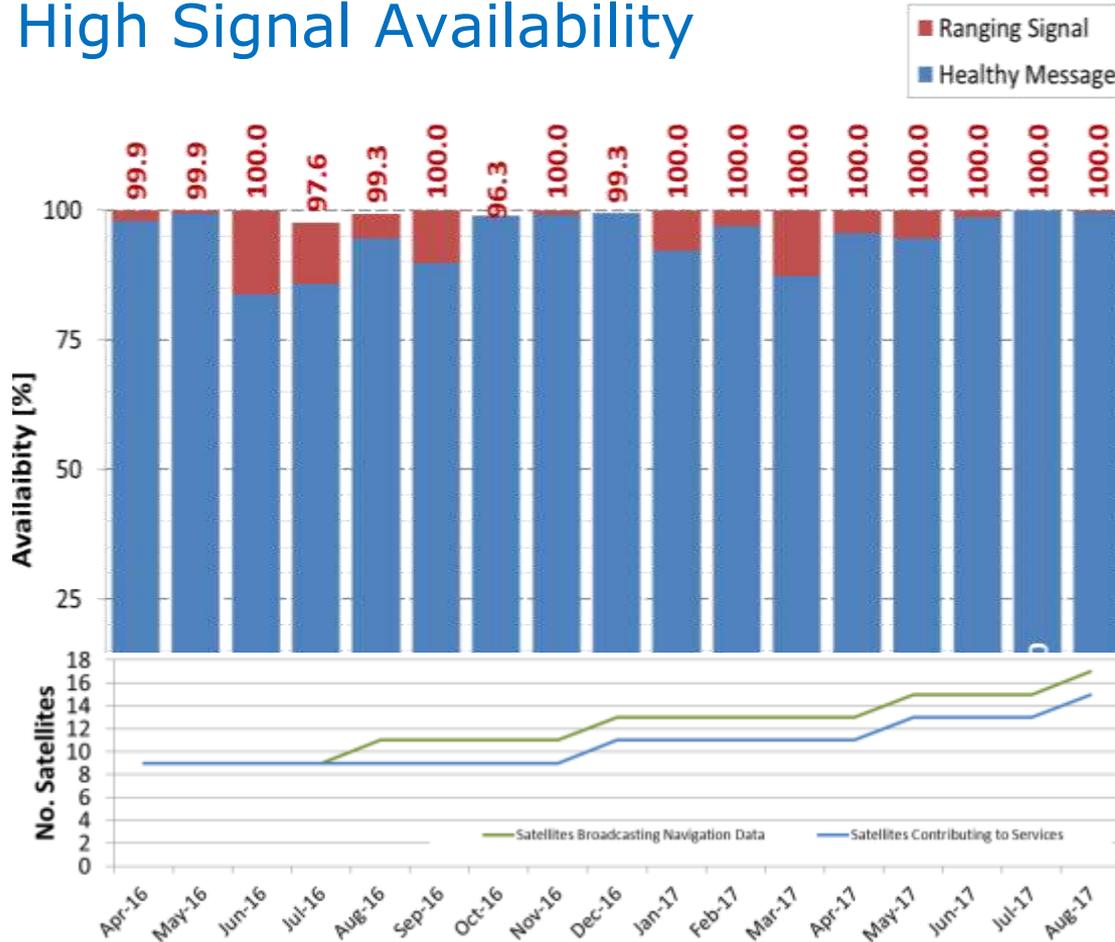
FOC



Number of satellites launched



High Signal Availability



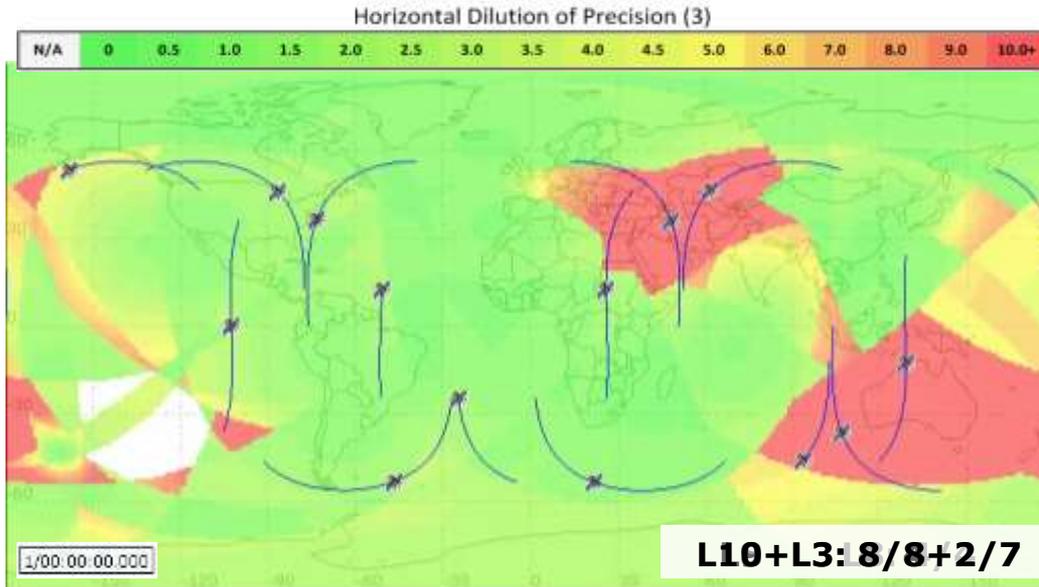
Availabilities reported since first complete month in operation.

Availability reduced by

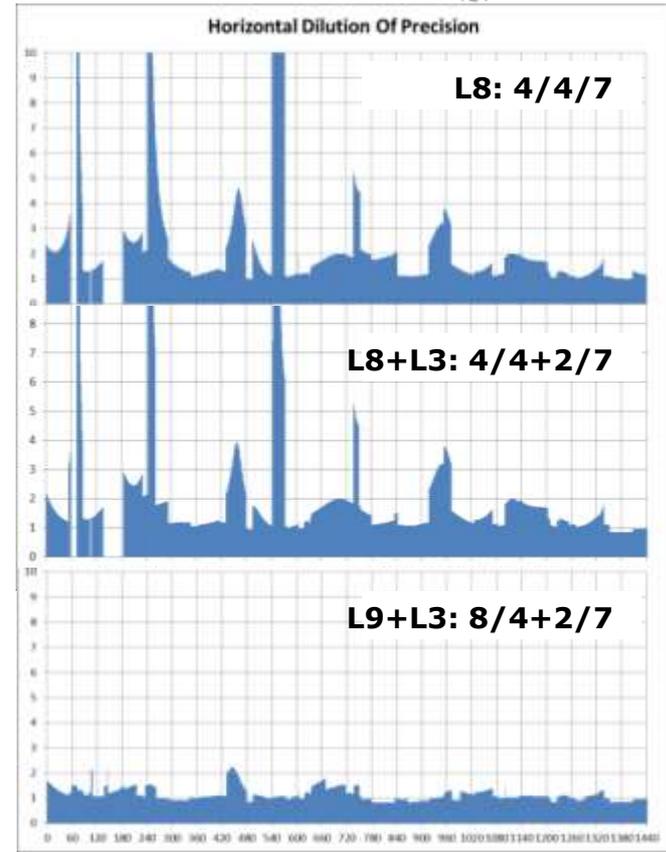
- On Board S/W upgrades
- On Board Clocks maintenance
- Station keeping manoeuvre



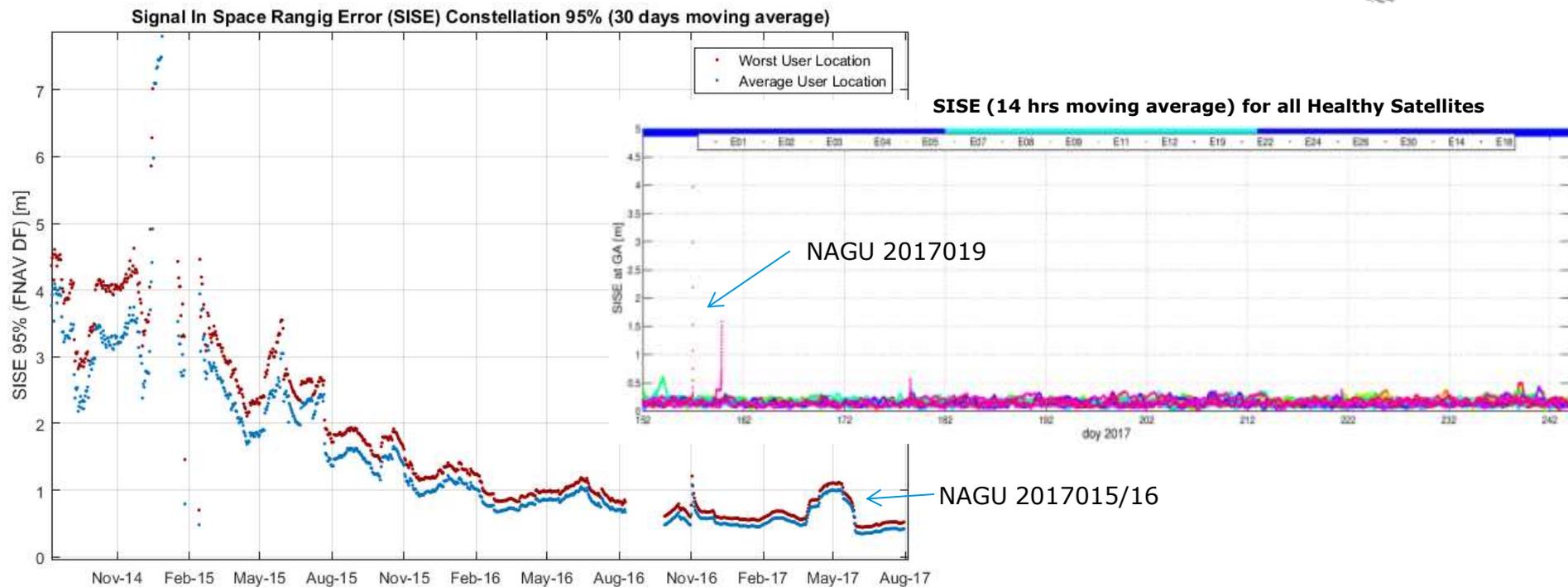
Increased Availability of Positioning



Central European User (@ 5deg masking)			
Launch	Constellation configuration	Availability of PDOP < 5	PVT Opportunities over 10 days/ average duration
L8	4/4/7	79.6%	74 / 2.58 hrs
L8 + L3	4/4/7+2	86.0%	62 / 3.33 hrs
L9	8/4/7+2	99.8%	4 / 59.89 hrs (~8 min average time with insufficient geometry)



As-observed Ranging Performance - OS



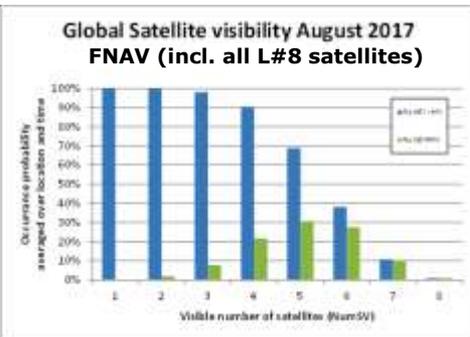
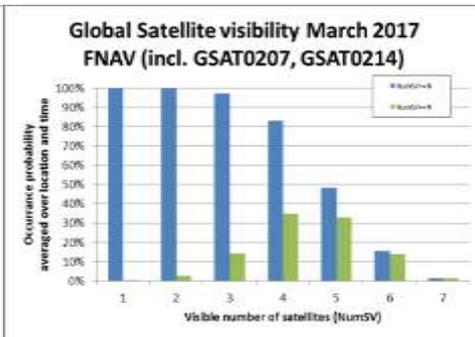
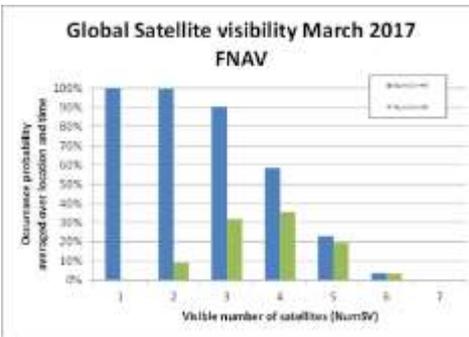
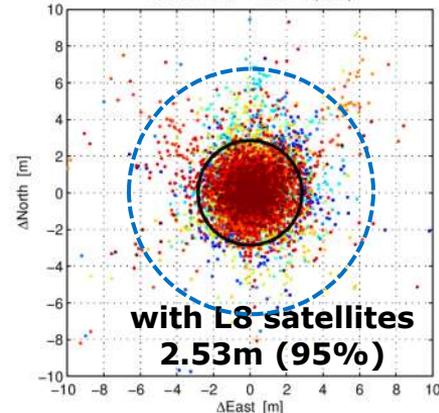
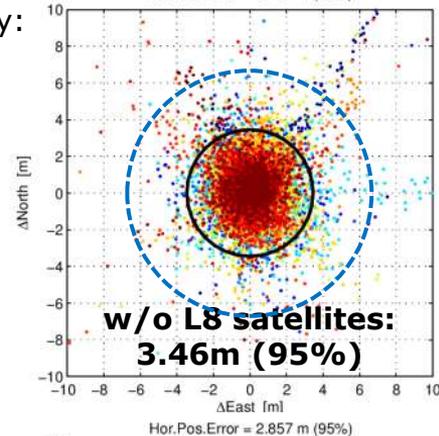
- ★ Decreasing Ranging Error trend due to increasing number of satellites and improvements in the Ground Segment
- ★ Ranging accuracy Constellation Average $\sim 0.20\text{m}$ and 0.24m Worst Healthy Satellite

Positioning Performance & Availability - OS



Horizontal accuracy of global stations on a sample day:
 Hor.Pos.Error = 3.457 m (95%)

- ★ 4 more satellites operational: in May/June 2017
- ★ Satellites in operational constellation 11 → 13 → 15
- ★ Availability of H Accuracy <10 m 89% → 96% → 98%
- ★ Global PDOP ≤6 availability 41% → 60% → 78%



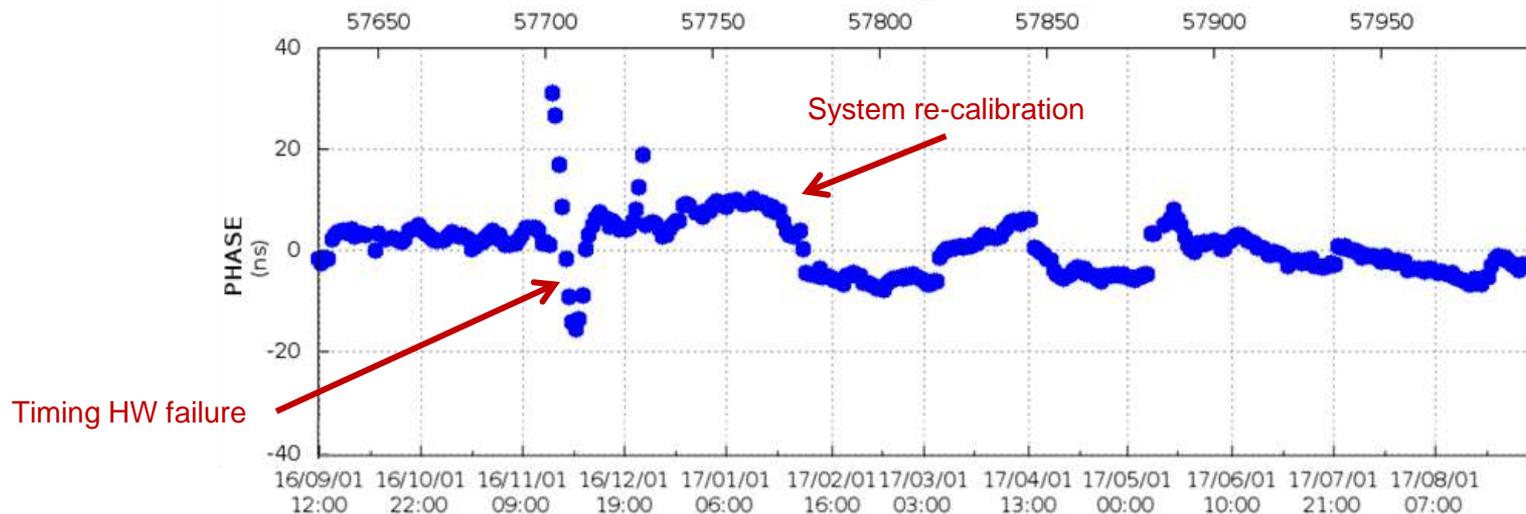
ESA UNCLASSIFIED - For Official Use



European Space Agency

UTC(SIS)-UTCr
57632-57996
2016/09/01-2017/08/31

MD



★ Overall good performance of 9.3 ns (95%)

★ Initial Services target: 30 ns (95%)

SISRE Overview (April 2017) – (source DLR*)

Constellation	Type	Group	SISRE [cm]	SISRE(orb) [cm]
GPS	LNAV	all	50	22
		Rb	45	22
		IIF/Rb	40	24
	CNAV	all	53	22
		IIF/Rb	39	23
GLONASS		all	309	51
Galileo	INAV	all	14	14
	FNAV	all	15	14
BeiDou-2		all	162	66
		MEO	86	63
		IGSO	100	35
		GEO	198	84

(*) ref: Multi-GNSS SISRE Monitoring – Methodology and Results - P. Steigenbergen, O. Montenbruck (GSOC)
<http://www.igs.org/assets/pdf/W2017-PY01-02%20-%20Steigenberger.pdf>

GSA for PRS Preparation:

GSA supports Member States and EC agencies in the preparation and development of their PRS receivers.

Also GSA support MS CPA using the service (providing training and grants like JTA giving MS opportunity to exploit the service).



European
Global Navigation
Satellite Systems
Agency

ESA PRS Receiver compatibility test program

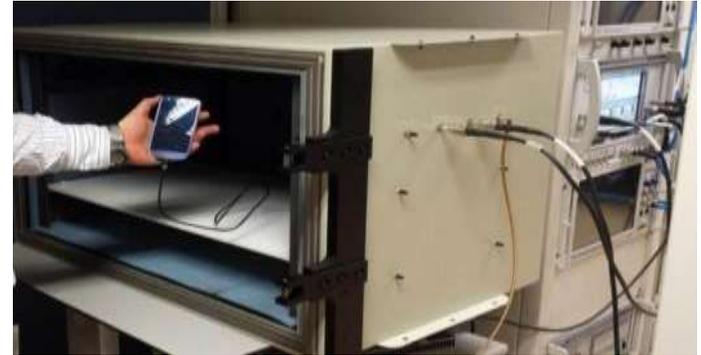


- ❑ Testing PRS receivers with the Galileo navigation system
 - Foster the use of Galileo PRS
 - Support MS and manufacturers
- ❑ Early product testing
 - Get the best products for Galileo
 - Receive early real world feedback

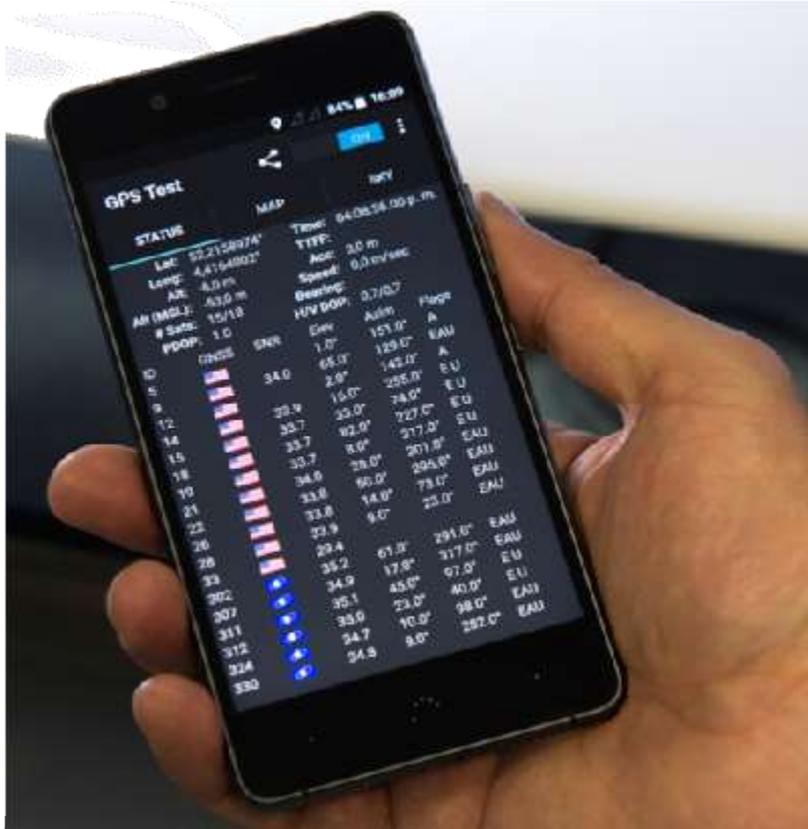


What and how we test

- Security Module
 - PRS user test bench
 - Interfaces
 - Security Implementation
 - Key Management
 - User access control
- Receiver performances
 - Real signal
 - Rooftop antennas
 - Mobile test vehicle, blue van ->
 - Simulated signal
 - Radio Frequency Constellation Simulator



OS 2017 ACHIEVEMENT = PRS 2020 AIM



Brand	Type
Apple	iPhone 8 Plus
Apple	iPhone 10/X
Apple	iPhone 8
BQ	Aquaris X5 Plus
BQ	Aquaris X
BQ	Aquaris X Pro
Huawei	Mate 9 pro
Huawei	P10
Huawei	P10 plus
Huawei	Mate 9
Mediatek	Meizu Pro 7 Plus
Mediatek	Meizu Pro 7
Oneplus	Oneplus5
Samsung	S8
Samsung	S8+
Sony	Xperia XZ Premium
Vernee	Apollo 2



Thank you

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