WELCOME TO
Galileo: At the Dawn of a New Age of GNSS Services

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Who's In the Audience?

A diverse audience of over 700 professionals registered from 57 countries representing the following industries:

16% **GNSS Equipment Manufacturer**

16% **System Integrator**

15% **Professional User**

15% **Product/Application Designer**

14% **Government**

24% **Other**

Welcome from *Inside GNSS*

Glen Gibbons
Editor and Publisher
Inside GNSS

Galileo: At the Dawn of a New Age of GNSS Services

Demoz Gebre-Egziabher
Aerospace Engineer and Mechanics Faculty
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Galileo: Towards Initial Services

Marco Lisi, Dr. eng.
Senior Manager
European Space Agency

Galileo System Essentials

- Galileo is Europe's initiative for a state-of-the-art global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control;

- While providing autonomous navigation and positioning services, Galileo will at the same time be interoperable with GPS and GLONASS, the two other global satellite navigation systems;

- Two major implementation phases:
  - the In-Orbit Validation phase (IOV);
  - the Full operational Capability phase (FOC);

- The fully deployed Galileo system will consist of 30 satellites (24 plus 6 spare) and the supporting ground infrastructure.

Early services for OS, SAR and PRS will be provided from 2014

Open Service (OS)	Freely accessible service for positioning, navigation, and timing	
Public Regulated Service (PRS)	Encrypted service designed for greater robustness and higher availability	
Search and Rescue Service (SAR)	Assists locating people in distress and confirms that help is on the way	
Commercial Service (CS)	Delivers authentication and high accuracy services for commercial applications	

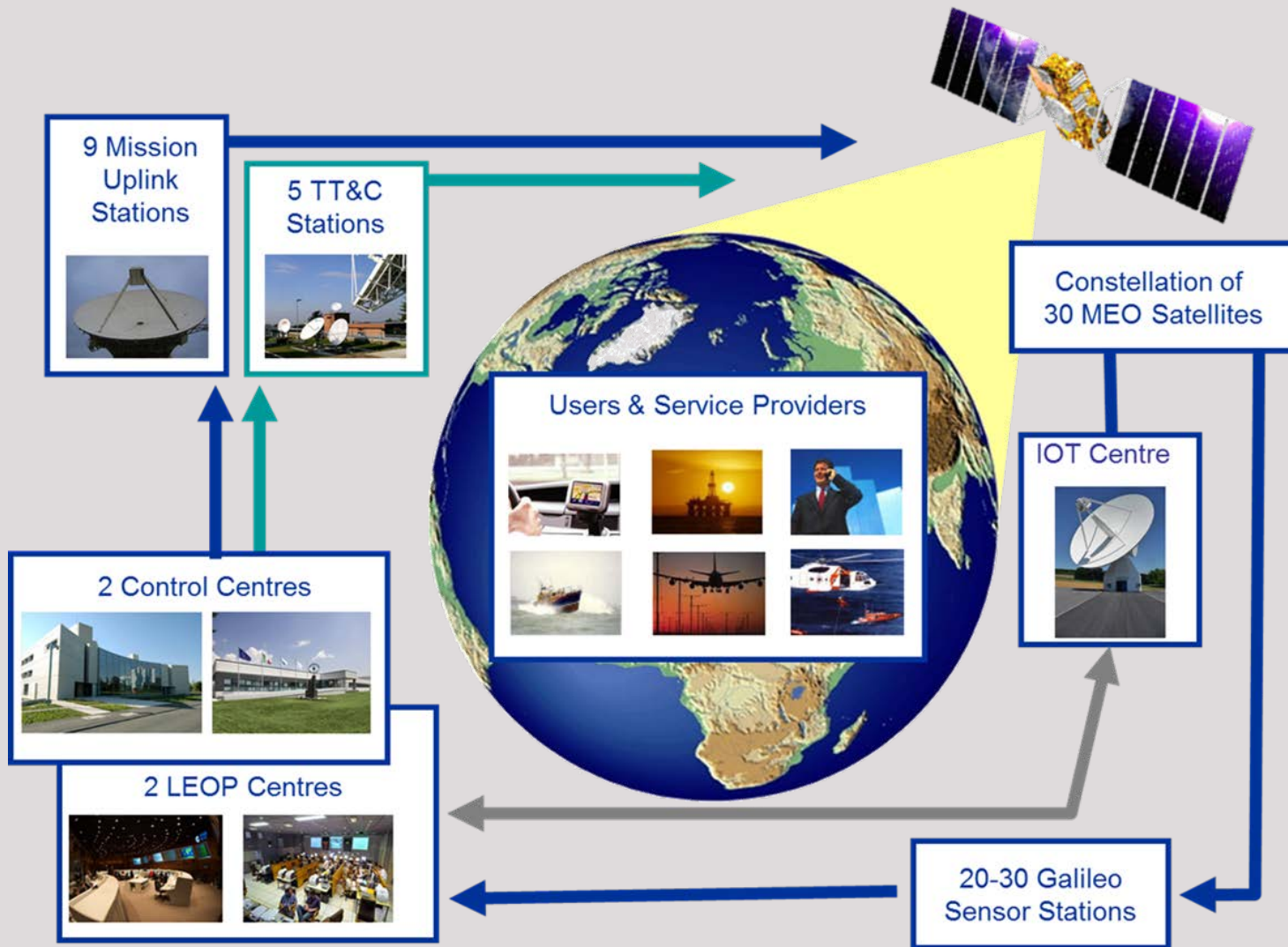The former "Safety-of-Life" service is being re-profiled:

Integrity Monitoring Service	Provides vital integrity information for life-critical applications	

Walker 24/3/1
Semi-major Axis: 29,600 km
Circular Orbit
Inclination: 56°

Galileo FOC Satellite
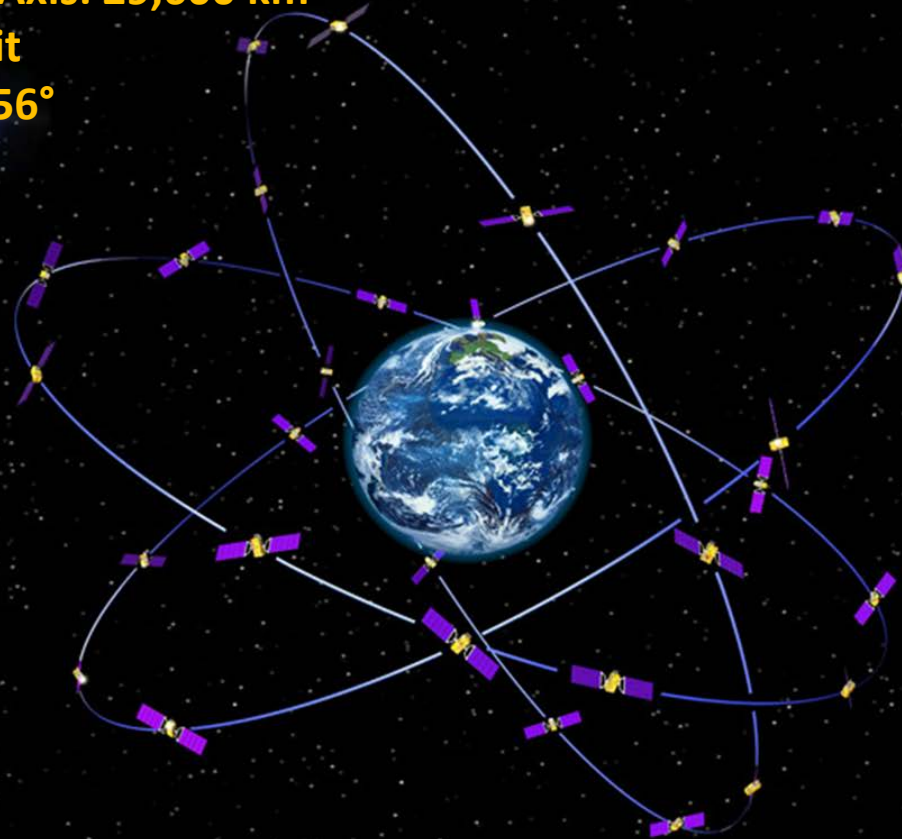
Launch Mass: 733 kg
Total Power: 1900 W
Size: 2.5 x 1.2 x 1.1 m^3
Solar Wing Span: 14.7 m
Design Lifetime: 12 years

Galileo On-Board Atomic Clocks

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inside
unmanned systems
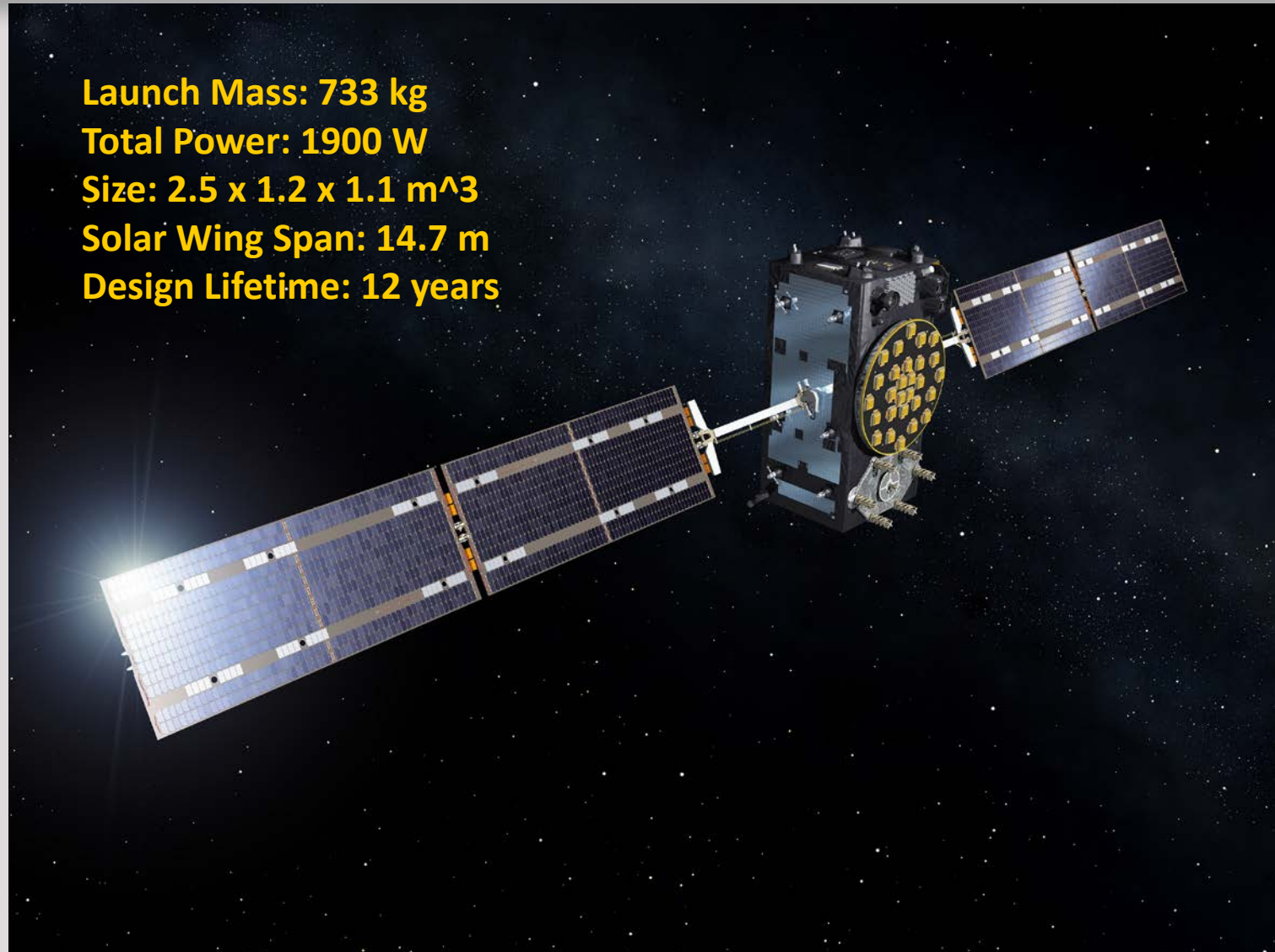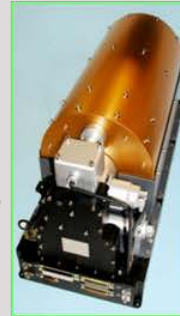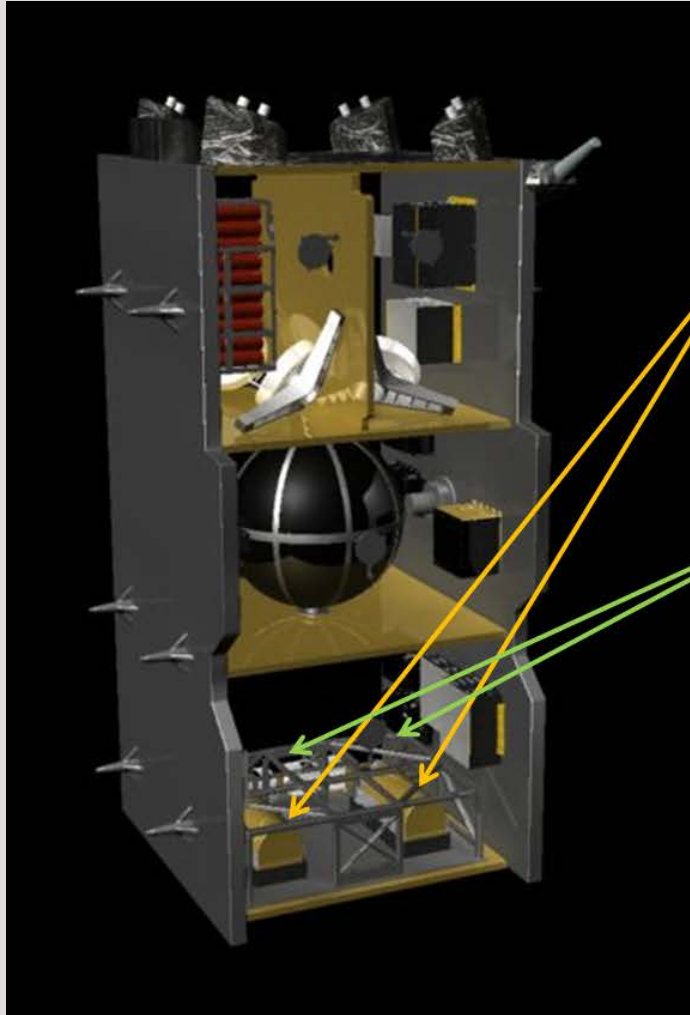
Passive Hydrogen Maser
The most stable and accurate
→ Looses no more than 0.5 ns in 12h, i.e. 1s over 3 million years
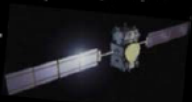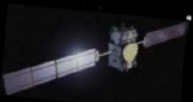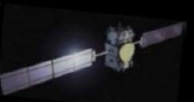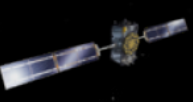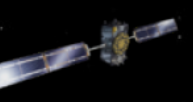
Rubidium
→ Looses 3s over 1 million years

Error in time	Error in distance
1 s	300 000 000 m
1 ms (0.001 s)	300 m
1 ns (0.000000001 s)	0.3 m

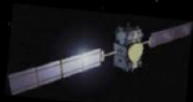|	GSAT0101	GSAT0102	GSAT0103	GSAT0104	GSAT0201	GSAT0202
Launch Date	21 Oct. 2011	21 Oct. 2011	12 Oct. 2012	12 Oct. 2012	22 Aug. 2014	22 Aug. 2014
SV ID	11	12	19	20	18	14
Orbital Slot	B05	B06	C04	C05	Ext01	Ext02
Clock	RAFS	RAFS	PHM	RAFS	PHM	PHM
Technical Status	Nominal	Nominal	Nominal	Unavailable (NAGU 2014014)	Testing	Testing
EIRP (wrt Public OS SIS ICD)	All bands aligned	All bands aligned	All bands in temporary back-off	E1 only E5 + E6 permanently unavailable	All bands aligned	All bands aligned
SAR Transponder	N/A	N/A	Nominal	Nominal	Nominal	Nominal

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	GSAT0203	GSAT0204	GSAT0205	GSAT0206	GSAT0208	GSAT0209	GSAT0210	GSAT0211
Launch Date	27 Mar. 2015	27 Mar. 2015	11 Sep. 2015	11 Sep. 2015	17 Dec. 2015	17 Dec. 2015	24 May 2016	24 May 2016
SV ID	26	22	24	30	08	09	01	02
Orbital Slot	B08	B03	A08	A05	C07	C02	A02	A06
Clock	PHM	RAFS	PHM	PHM	PHM	PHM		
Technical Status	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	**Commissioning completed Operational since December 8th, 2016**	
EIRP (wrt Public OS SIS ICD)			← All bands aligned →					
SAR Transponder	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal		

	GSAT0207	GSAT0212	GSAT0213	GSAT0214
Launch Date	17 Nov. 2016	17 Nov. 2016	17 Nov. 2016	17 Nov. 2016
SV ID	07	03	04	05
Orbital Slot	C06	C08	C03	C01
Clock				
Technical Status	Under Commissioning (NAGU 2016050)			
	In Orbit Test Review planned April 2017	In Orbit Test Review planned June 2017	In Orbit Test Review planned June 2017	In Orbit Test Review planned April 2017
EIRP (wrt Public OS SIS ICD)				
SAR Transponder				

Galileo Launch Schedule

IOV   **FOC** →

2011	2012	2013	2014	2015			2016		2017	2018
							24 May 17 Nov			
2	4		6	8	10	12	14	18	22	26
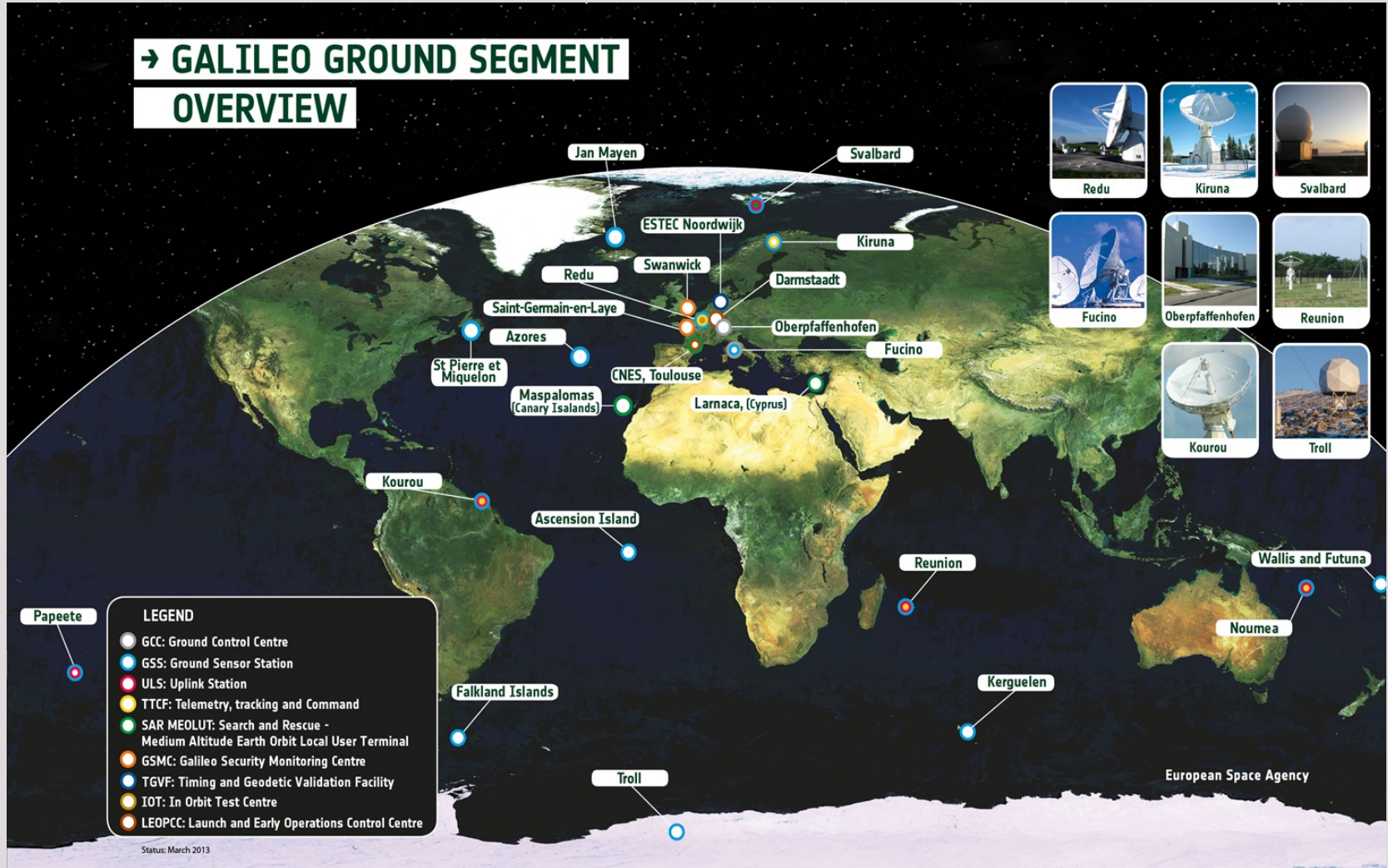
Major Galileo centres and facilities are located throughout Europe
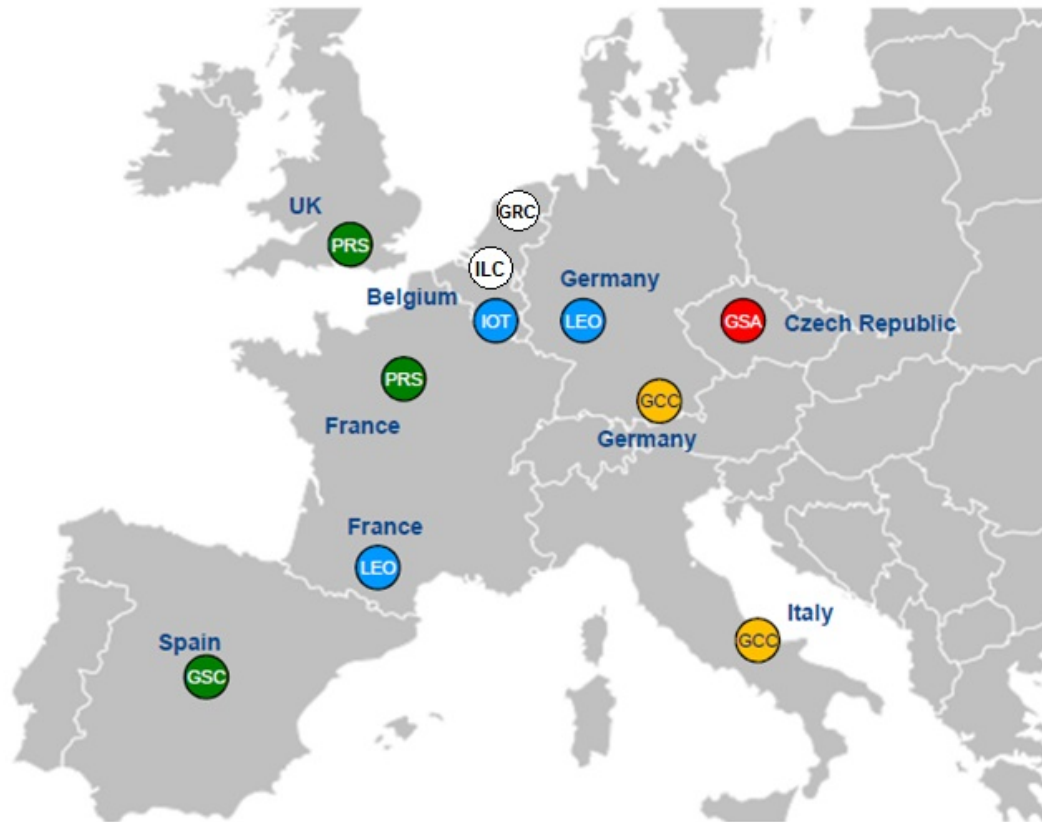
Note: Only major centres, facilities and stations are shown. Not all of them are (fully) implemented yet.

2 Complementary Control Centres:

**• Ground Mission Segment (GMS)
in Fucino (Italy) has the responsibility
for the mission aspects;**

**• Ground Control Segment (GCS)
in Oberpfaffenhofen (Germany), to
control and monitor the constellation.**

**Both centres are being completed
to become fully redundant.**
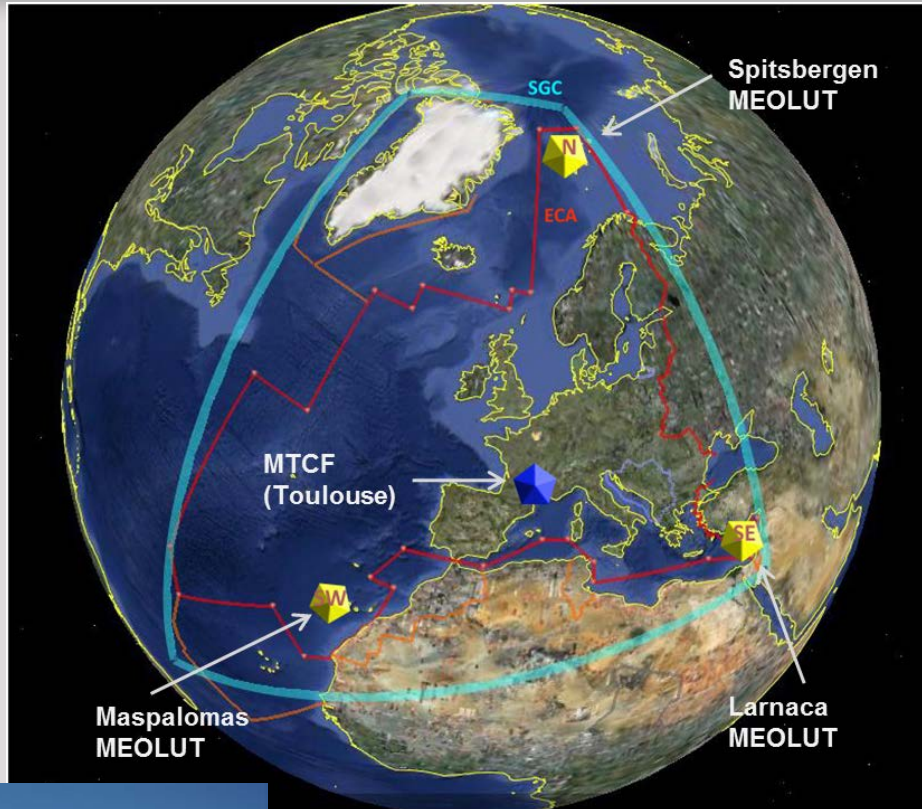
Galileo Service Center (Madrid)
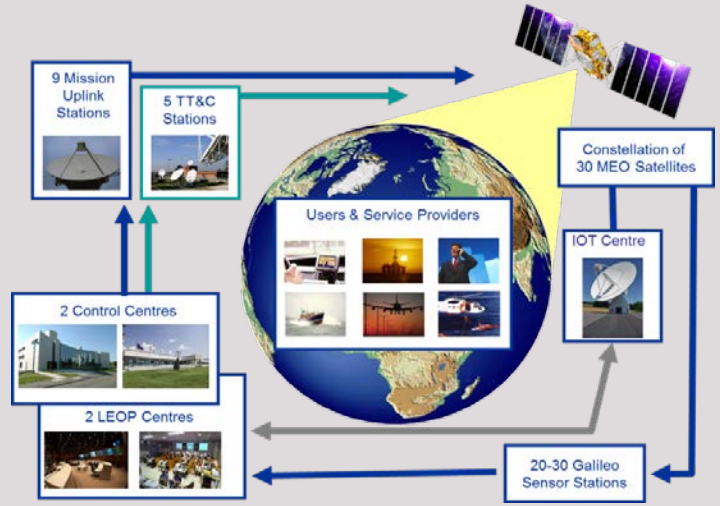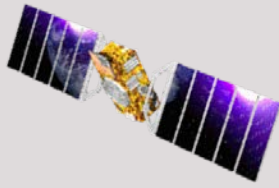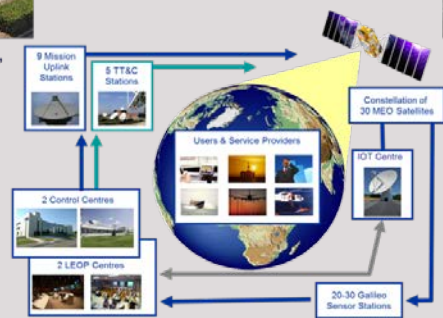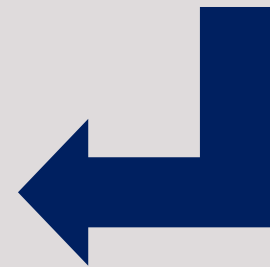
Galileo:
eager to serve

GALILEO INITIAL SERVICES

Jeremie Godet
Head of Sector, Galileo
Implementation, DG GROW
European Commission

26 October 2016

- 1- Maximise benefits of space for Society and EU
  - → Market uptake
  - → **EU delivers!**

- 2- Foster competitiveness and innovation

- 3- Autonomy and access to space

- 4- Promote International cooperation

- Copernicus

- **Galileo** and EGNOS

Naukluft Park - Namibia
Data provided by Sentinel-2
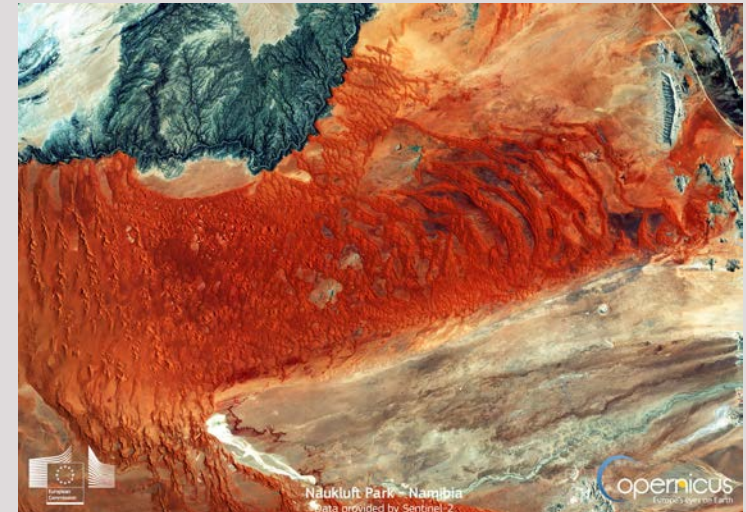
15 December 2016

- **Open Service**
    - free and interoperable with other GNSS
    - world-wide access

- **Public Regulated Service**
    - access authorised and controlled by Competent Authorities
    - world-wide coverage

- **Search and Rescue**
    - free
    - world-wide, under the international organisation Cospas- Sarsat
    - locate emergency beacons and communicate the distress to Search & Rescue centers

Infrastructure tested: **excellent Performances**

Constellation of satellites:	18 in orbit today
Ground segment:	world-wide
Last launch 17-11-2016:	Ariane-5: success!

For the Initial Services:

11 sat for OS/PRS

12 sat for SAR

... not yet including the 4 satellites launched on Nov.17

Stay posted!   **www.gsc-europa.eu**

... delivering high performance services

~ 0.8 meters (avg. ranging, 95%)

~ 3/~8 meters (avg. H/V accuracy, 95%, when PDOP<6)

~ 9.5 nanosec (UTC dissemination accuracy, 95%)

~ 7 nanosec (Galileo-GPS time offset, 95%)

SAR location probability within 10 minutes above 98%

Horizontal Deviations from Position Solutions to Receiver Positions at 27-10-2016 (day)

95%ile: 3.2m

deviations in northern direction [m]
deviations in eastern direction [m]

as-observed

67%ile GSAT0209 / E09
67%ile GSAT0208 / E08
67%ile GSAT0206 / E30
67%ile GSAT0205 / E24
67%ile GSAT0204 / E22
67%ile GSAT0203 / E26
67%ile GSAT0103 / E19
67%ile GSAT0102 / E12
67%ile GSAT0101 / E11

Ranging Accuracy [m]
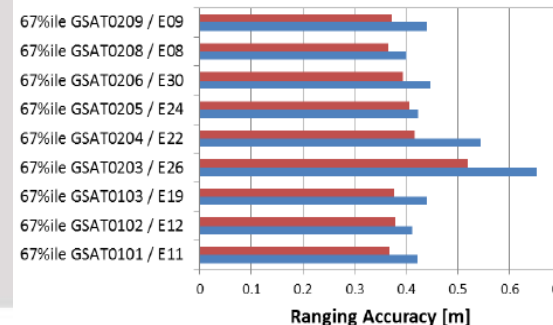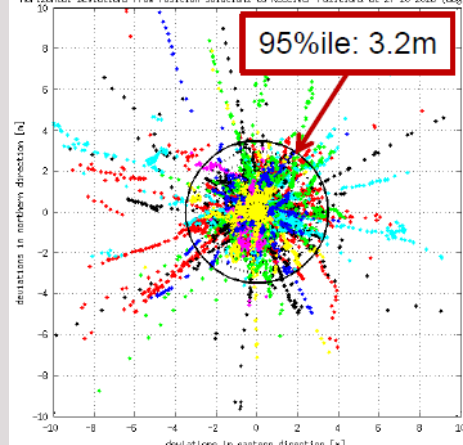
- Documents ready for OS, PRS and SAR
- Published: 15/12/2016
- Based on predefined Minimum Performance Levels (MPL)
- Include additional technical information and expected evolution of services

The conditions under which the Galileo Initial Services will be delivered, including their expected performance (accuracy, etc) and availability, have been published on the website of the European Service Centre found here: www.gsc-europa.eu

Open Service Definition Document

| Performance parameter	MPL Value	observed
Ranging Accuracy for any satellite (SF/DF, monthly)	≤ 7 m (95%)	1.4 m
Ranging Accuracy over all satellites (SF/DF, monthly)	≤ 2 m (95%)	0.81 m
UTC Time Dissemination Accuracy (SF/DF, annually)	< 30 ns (95%)	9.5 ns
UTC Frequency Dissemination Accuracy (SF/DF, annually)	< 3E-13 (95%)	2.15E-14 ns
Per-Slot Availability (SF/DF, annually)	≥ 87%	95.1%
Availability of the Ranging Service (SF/DF, monthly)	≥ 87%	99.6%
Availability of the UTC Time Determination Service (SF/DF, monthly)	≥ 87%	99.6%
Galileo GST-GPS Time Offset Determination Accuracy (annually)	< 20 ns (95%)	6.8 ns
Galileo GST-GPS Time Offset Determination Availability (annually)	≥ 80%	82%
Timely publication of NAGUs (planned events)	≥ 24 hours	100%
Timely publication of NAGUs (unplanned events)	< 72 hours	100%

- Galileo Initial Services offer:
  - up to 3 frequencies for Open Service (E5a, E5b, E1B/C)
  - 2 frequencies for Public Regulated Service (E6A, E1A)

- First Open Service Definition Document with global coverage multiple frequencies navigation signals

- Open Service
- (test) Commercial Service
- Public Regulated Service
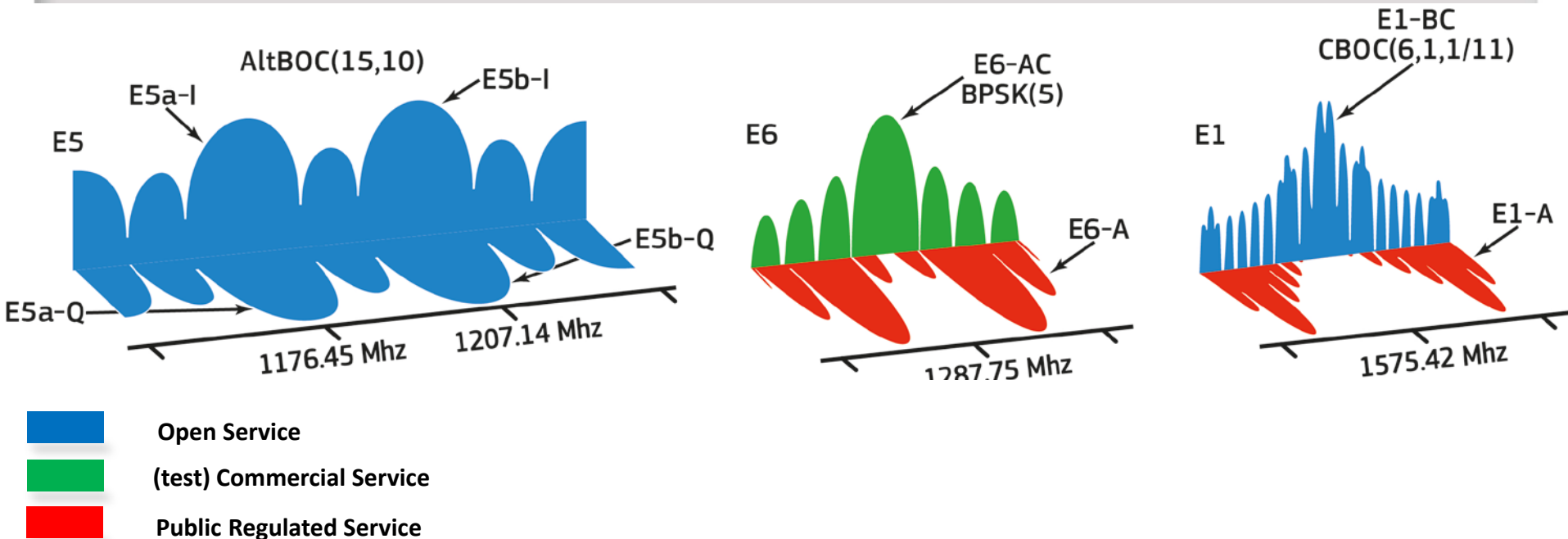
Galileo SAR Initial Service offers:

- Cospat Sarsat (C/S) MEOSAR Ground Segment Early Operational Capability (EOC) over SAR Galileo Service (SGS) coverage and Global Space Segment coverage
- Endorsed by C/S Council Decision
- Based on Galileo L-band SAR repeaters and GPS S-band experimental repeaters
- EOC to FOC: Full space segment coverage with operational L-band SAR repeaters
- Observed performance for all MPL above FOC targets in the SGS coverage

Performance parameter	MPL Value	observed
% of transmitted bursts that are detected by at least one MEOLUT	>99%	99.5%
Location probability after 1 transmitted burst	>75%	97%
Location probability after 12 transmitted burst **~10 min**	>98%	99%
Location accuracy (within 5km) after 1 transmitted burst	>70%	96%
Location accuracy (within 5 km) after 12 transmitted burst **~10 min**	>95%	96.5%
Location accuracy (within 2 km) after 12 transmitted burst **~10 min**	>80%	88%

- Search and Rescue is now…
  much faster (->3h to <10 minutes)
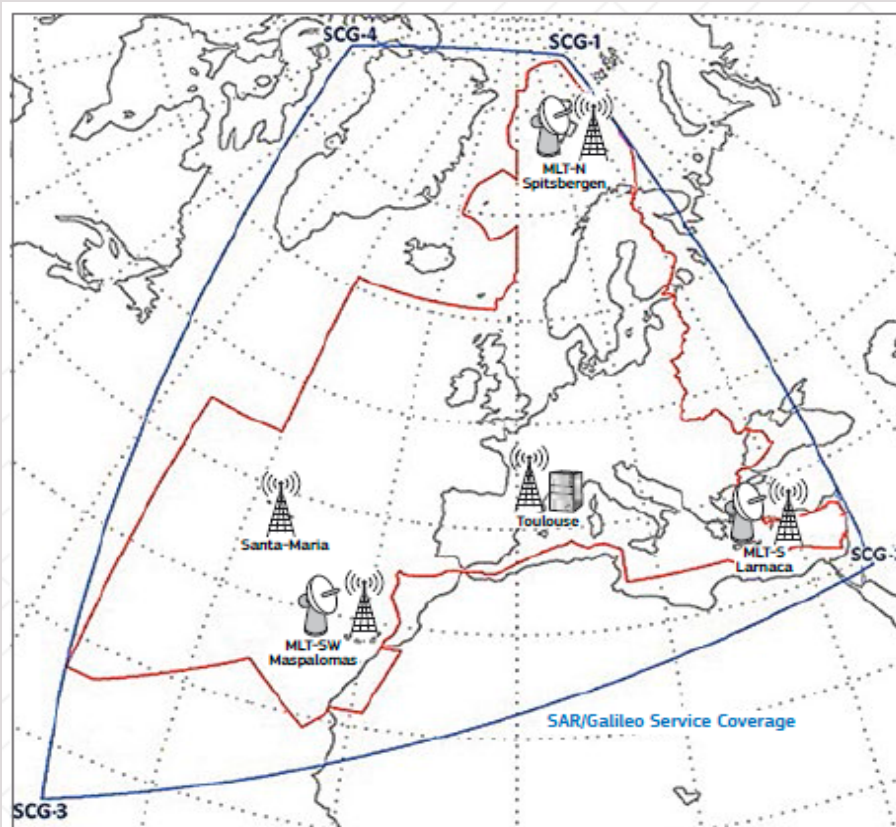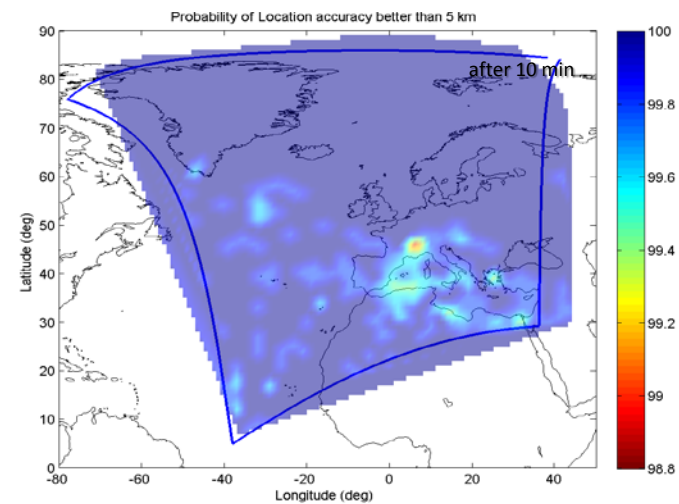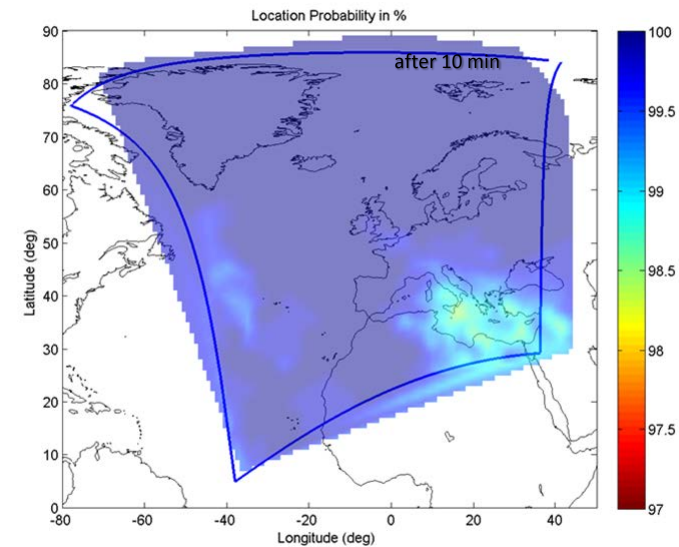 more accurate (10 km to 5 km)

Figure 7. SAR/Galileo Service Coverage and SAR/Galileo Sites

- **Galileo Initial Services** are the first step towards reaching Full Operational Capability by end of 2020

- Infrastructure :   Complete the constellation

- Operations: Ensure that performances are maintained
                          New operator ("GSOp")

- Services   - Open Service Navigation Message Authentication
  Differentiators   - Commercial Service High Accuracy
  (target 2018)   - Search And Rescue Return Link

- Improvements   OS Navigation Message improvement for TTFF,
                          robustness, synchronisation for LBS

- Markets: Uptake in different sectors of the economy
                          Available for use in EU policies

Ask the Experts – Part 1

Marco Lisi, Dr. eng.
Senior Manager
European Space Agency

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Head of Sector
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DG GROW
European Commission

Fiammetta Diani
Deputy Head of Market
Development Department
European GNSS Agency

Peter Grognard
CEO
Thales Alenia
Space Belgium

Poll #2

Approximately, how many major vendors provide Galileo-capable receivers today?(Please select one)

- 3
- 10
- 17
- 30
- None.

GALILEO and initial services: the users perspective

European GNSS Agency - GSA

Fiammetta Diani
Deputy Head of Market
Development Department
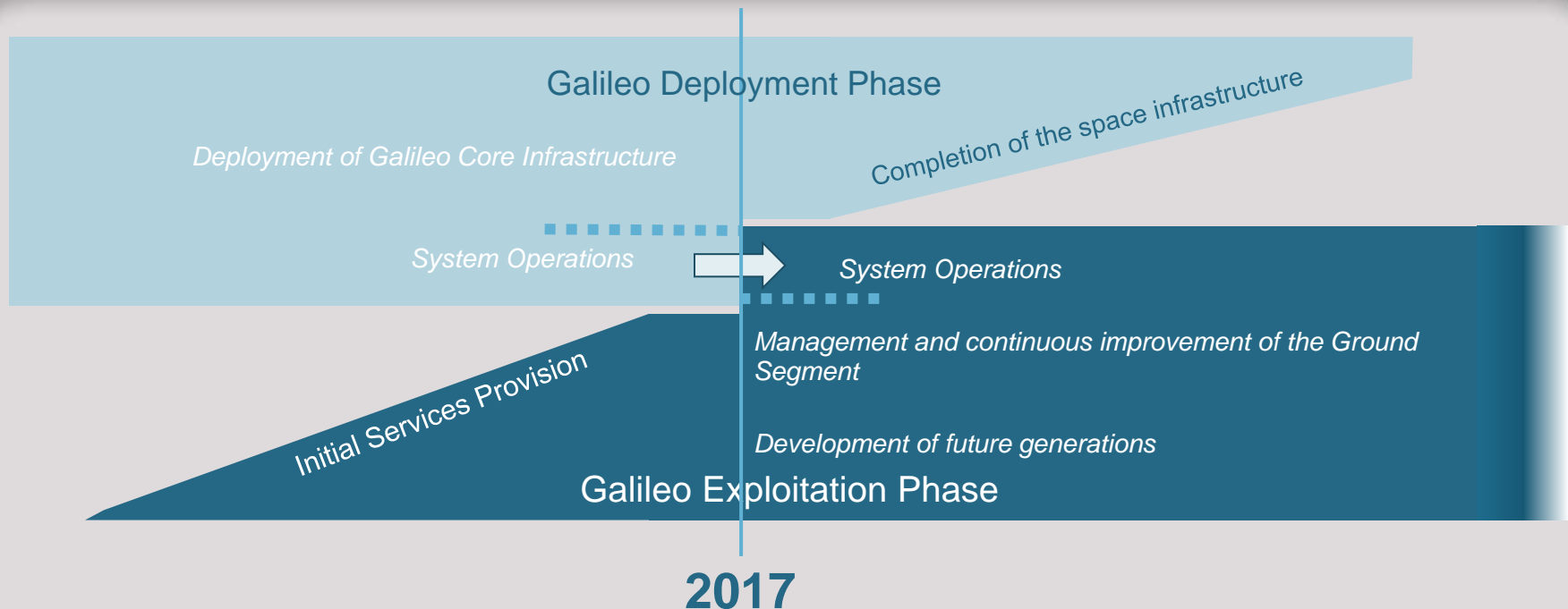**European GNSS Agency**

The Galileo initial services: benefits for the users and readiness of receivers

Galileo ready to use: from smartphones to transport

An outlook on the future and current R&D opportunities

Galileo Deployment Phase

Deployment of Galileo Core Infrastructure

Completion of the space infrastructure

System Operations → System Operations

Management and continuous improvement of the Ground Segment

Development of future generations

Initial Services Provision

Galileo Exploitation Phase

2017

- European GNSS Agency (GSA) to progressively manage exploitation activities delegated by European Commission acting as programme supervisor

- European Space Agency (ESA) to continue with its role for the system design and development

Better availability of satellite signals:

Being compatible and interoperable with GPS, all Galileo-enabled
navigation devices are capable to 'see' more satellites
→ especially important in urban environments where the presence of high
buildings can prevent signal reception.

Improved Search and Rescue service:

SAR services enhanced with Galileo will improve:
→ Detection time of a person in distress (3 hours vs 10 minutes)
→ Accuracy of position of the distress beacon (10km range vs 5 km range)

Very precise timing:

Galileo timing will provide very high accuracy and resilience, e.g. in
combination with GPS, needed for infrastructure synchronisation.

→ The timing of Galileo can be used with only one satellite in view

… and let's not forget the benefits of Galileo dual frequency

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Advantages of dual frequency

Better accuracy
- Ionosphere error correction
- Faster and more reliable carrier phase ambiguity resolution
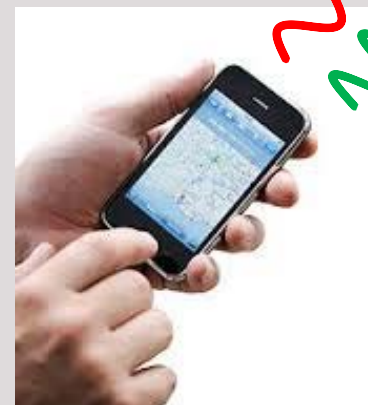
Increased robustness
- Reduce vulnerability risks of GNSS signals to jamming and/or spoofing

Why L5/E5 is the best solution for a second frequency?

- A protected frequency

- There will be soon more L5/E5 satellites than L2C satellites

- Shared by all GNSS and all SBAS

- More widely separated from L1, thus minimising the iono-free linear combination errors
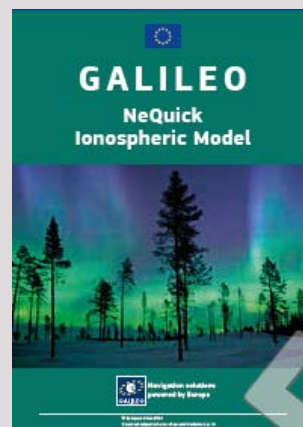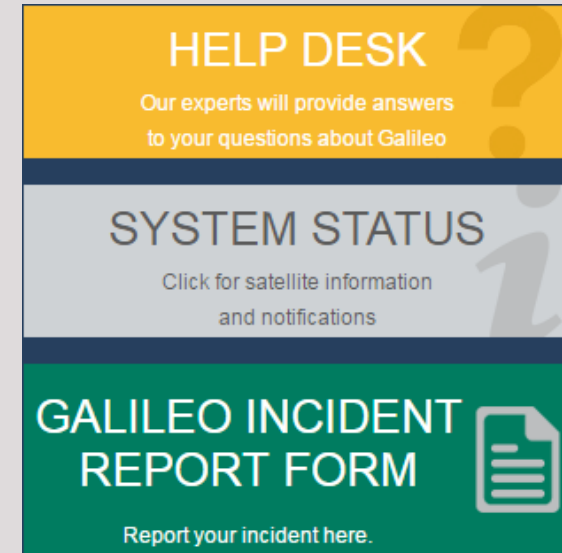
Specific key advantages of L5/E5 signal

- Better multipath mitigation and better accuracy using L5/E5 signals vs using L2C

- Higher received power for L5/E5 vs L2C

The GNSS service center: the interface of Galileo with the users!

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The European GNSS Service Centre (GSC) is **the single interface between the Galileo system and the users** of the Galileo Open Service (OS), and the Galileo Commercial Service (CS)

www.gsc-europa.eu

HELP DESK
Our experts will provide answers to your questions about Galileo

SYSTEM STATUS
Click for satellite information and notifications

GALILEO INCIDENT REPORT FORM
Report your incident here.

European GNSS (Galileo) Open Service

Signal-In-Space Operational Status Definition

Navigation solutions powered by Europe

GALILEO
NeQuick
Ionospheric Model

European GNSS (Galileo) Open Service Service Definition Document

Navigation solutions powered by Europe

European GNSS (Galileo) Open Service

Signal In Space Interface Control Document

Is it possible to use Galileo in receivers?

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From 3 manufacturers adopting Galileo in 2010 to 17 in 2016, representing more than the 95% of global supply

2016 TIMING spectracom
Synchronizing Critical Operations

SMARTPHONES/MASS MARKET

intel QUALCOMM BROADCOM MEDIATEK

AUTOMOTIVE **UAVs**

STMicroelectronics CSR QUALCOMM ublox

HIGH PRECISION THALES FURUNO

NovAtel JAVAD Trimble Leica Geosystems

TOPCON septentrio

2010

ublox
septentrio ST STMicroelectronics

The Galileo initial services: benefits for the users and readiness of receivers

Galileo ready to use: from smartphones to transport

An outlook on the future and current R&D opportunities

USEGALILEO.EU

Galileo Initial Services triggered many forward-looking companies to create Galileo-enabled receivers, chipsets and modules and launch them in the market.

Users can keep track of **Galileo-enabled devices in the different market segments**, and be informed as soon as new ones become available.

- Launched in July 2016 it features a Galileo enabled Qualcomm Snapdragon 652 chip

- Today, thanks to the release of the new firmware, the smartphone is capable to track Galileo satellites

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From April 2018

Galileo compatibility required in every new car/van model sold in Europe

② **Positioning**
Via satellite positioning and mobile telephony caller location, the accurate position of the accident scene is fixed and then transmitted by the eCall to the nearest emergency call centre. More information is given in the eCall, e.g. the direction of travel and the vehicle type.

③ **Emergency call centre (PSAP)**
The eCall's urgency is recognized, the accident's location can be seen on a screen. A trained operator tries to talk with the vehicle's occupants to get more information. If there is no reaction, emergency services are sent off without delay.

① **Emergency Call**
A 112 emergency call (eCall) is made automatically by the car as soon as on-board sensors (e.g. the airbag sensors) register a serious accident. By pushing a dedicated button in the car, any car occupant can also make an eCall manually.
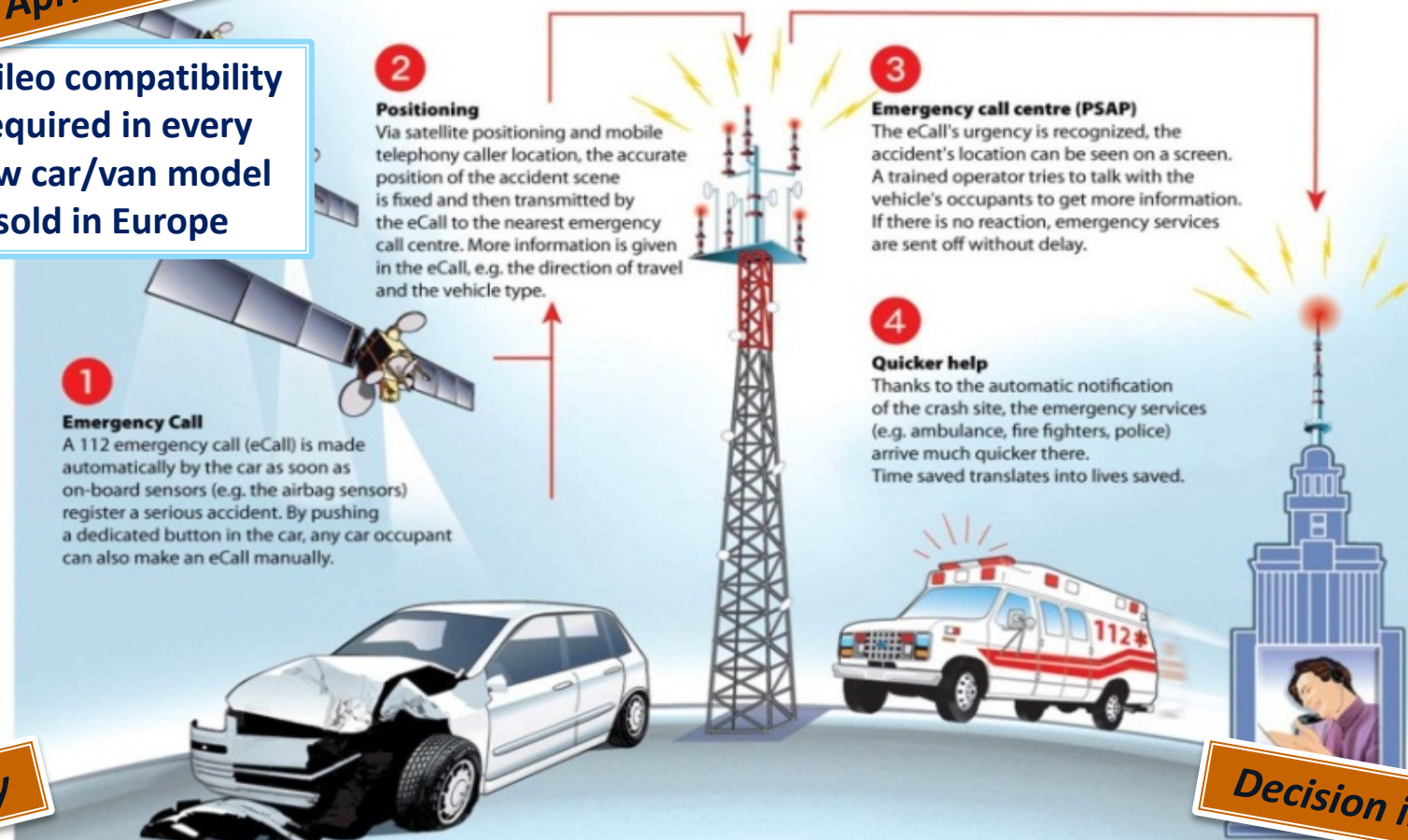
④ **Quicker help**
Thanks to the automatic notification of the crash site, the emergency services (e.g. ambulance, fire fighters, police) arrive much quicker there. Time saved translates into lives saved.

Today

Decision in 2017

13 Millions of light vehicles sold every year in EU

United Nations Economic Commission for Europe (UNECE) working in a eCall harmonised regulation

Digital Tachograph (DT) is the early driver of Galileo Authentication

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From June 2019

- **Digital Tachograph** (DT) improves road safety, supporting the respect of time of drive and rest rules.

- The new amended **EU legislation** is proposing GNSS inside the new generation of Digital Tachograph requiring in particular Galileo compatibility.

- The need for **increased robustness and trustability** is opening new opportunities for Galileo OSNMA Authentication!

Galileo IMO recognition opens Galileo market in commercial shipping

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Galileo recognised as part of World Wide Radio-Navigation System during the 96th session of the Maritime Safety Committee in London on 17 May 2016

- A huge **milestone enabling Galileo adoption in commercial shipping** worldwide

- A **potential ~110 m€ market enabled** with relevant positive effect on recreational market segment

The Galileo initial services: benefits for the users and readiness of receivers

Galileo ready to use: from smartphones to transport

An outlook on the future and current R&D opportunities

- Galileo will provide an **efficient**, **resilient** and **low-cost solution** against spoofing attacks

Authentication

- Ability of the system to guarantee to the users that they are utilizing signals from the Galileo satellites and not from any other source

→ CS (SCE) authentication: E6C

→ OS (NMA) authentication: E1B

- Expected availability:
  - ✓ OS E1B with OSNMA starting 2018, at very low cost. (*)
  - ✓ CS E6 signals with Spreading Code Encryption/Authentication by 2020

- OSNMA receiver implementation efforts/HW are low.

(*) Source: EC. Current OSNMA proposed in "Reserved 1" field (20bps) of E1-B through TESLA protocol. Analyses and simulations incl. degraded environments show no performance degradation wrt. standard PNT.

The 1st edition of the GSA's GNSS User Technology Report provides an overview of the state-of-the-art of GNSS receiver technology

Including:
- General overview of the latest GNSS receiver technology common to all application areas

- An in-depth analysis of GNSS user technology as it pertains to three key macrosegments:
  - ✓ Mass market solutions
  - ✓ Transport safety and liability-critical solutions
  - ✓ High precision, timing and asset management solutions

- Supplement on location technologies that looks beyond GNSS in the positioning landscape

Available for download here:

HTTP://BIT.LY/2CGARXF

GNSS USER TECHNOLOGY REPORT
ISSUE 1

2016   Issue 1

European Global Navigation Satellite Systems Agency

Funding mechanisms promote the development of Galileo compatible solutions

HORIZON 2020

Fundamental Elements

Applications Development:
- Going beyond state-of-the-art
- With effective business plan
- Exploiting the Galileo initial services and differentiators

Receivers Development:
- Innovative receivers, chipset devices valorising Galileo and its signal
- Addressing main market segments (mass market, automotive, maritime, timing, etc.)

40 projects already running

Third Call open now: **33 millions euros**
Deadline: **1st March 2017**

Overall budget (EGNOS and Galileo):
111.5 millions euro

7 new calls by end of 2017.

http://www.gsa.europa.eu/r-d/gnss-r-d-programmes

Galileo Initial Services: Perspective from a User

Peter Grognard
CEO
Thales Alenia Space
Leuven, Belgium

Galileo Initial Services
Congratulations to the Galileo Programme!

InsideGNSS
GPS|GALILEO|GLONASS|BEIDOU
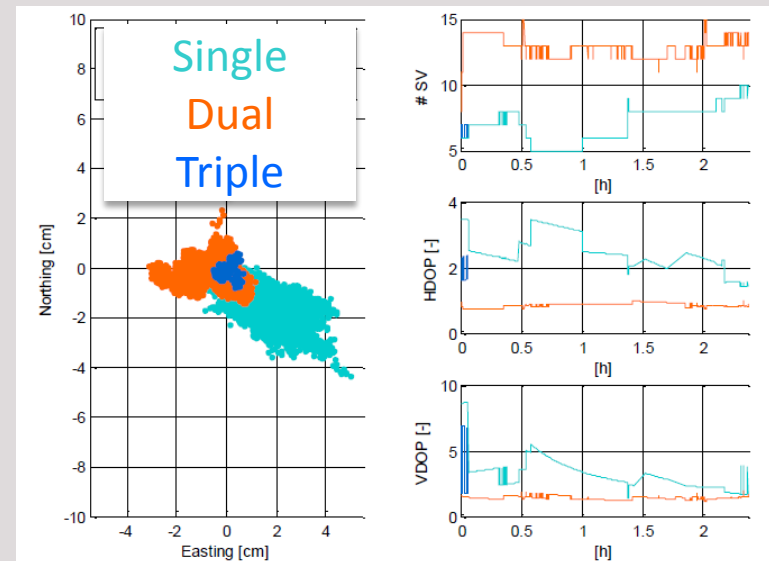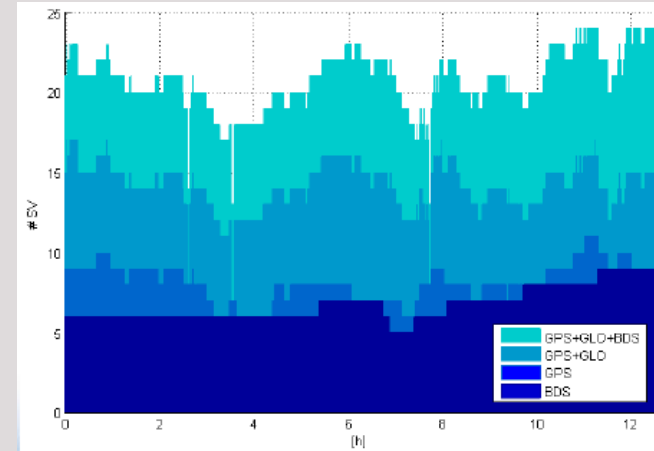
NovAtel

inside
unmanned systems

- We have come a long way since the first signal reception on January 12, 2006 from GIOVE-A, the first Galileo satellite.

- *Eighteen Galileo satellites are now orbiting the Earth…. Galileo is now ready to be used.* Source GSA

- Almost there: 16 more satellites to go!
  - 4 S/C in 2017, 4 S/C in 2018
  - 8 S/C there after!

Multi-System – Multi-Frequency Approach
Addressing the Needs of Professional Users… so far

InsideGNSS
GPS | GALILEO | GLONASS | BEIDOU

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unmanned systems
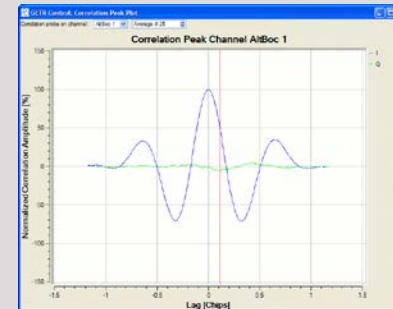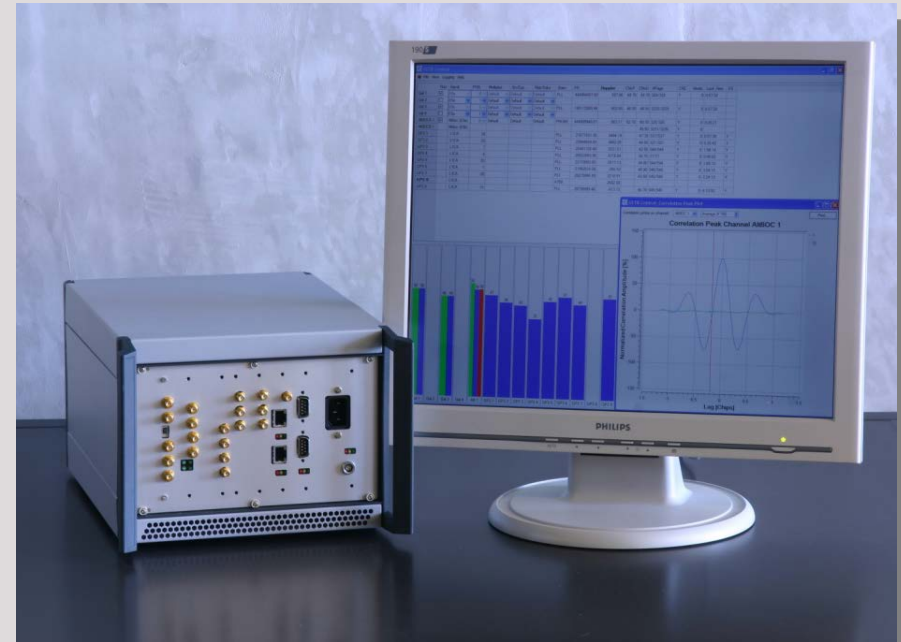
- Mass market / professional: today's market is a two-dimensional world

  - Accuracy: low/high

  - Integrity (or cost) : low/high

- For **professional** users, accuracy and availability key – integrity for aviation users

  - Traditional multi-system/multi-frequency approach works

- For **mass market** users, cost, power consumption, size.
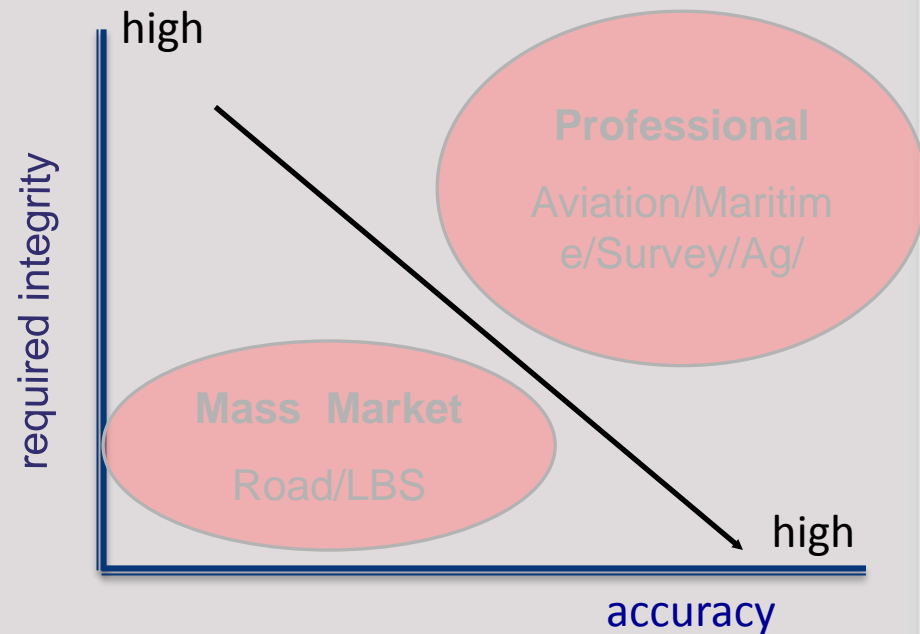
high

required integrity

Professional

Aviation/Maritime/Survey/Ag/

Mass Market

Road/LBS

high

accuracy

Source: Septentrio

ASECNA Test Campaign


Source ASECNA – TAS-F – Pildo - SSN

- Market segmentation will be along three axes tomorrow:
  - Accuracy: low/high
  - Integrity (or cost) : low/high
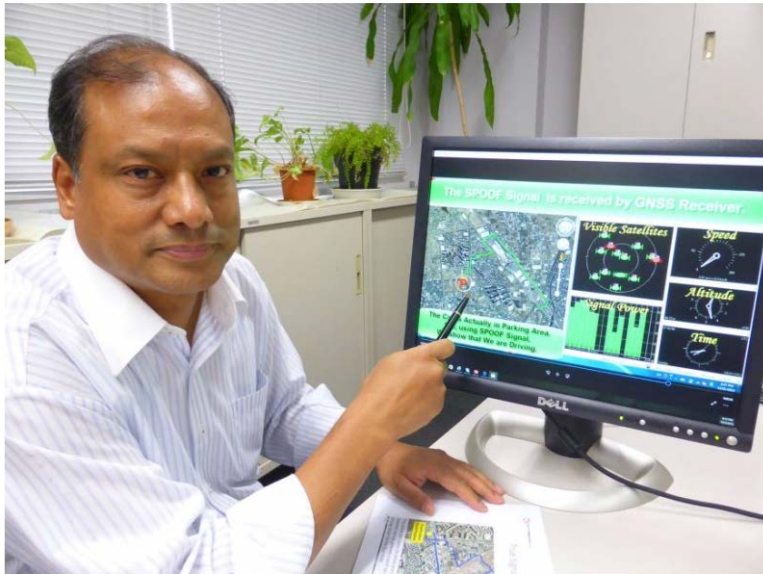 - Authentication

- Road becoming the biggest professional segment (?) – safety and security become key requirements, too
  - Accuracy
  - Integrity
  - Authentication – spoof-proof?
    You'll need it all

high

Professional

Road

required integrity

Mass Market

Road/LBS

high

accuracy

authentication
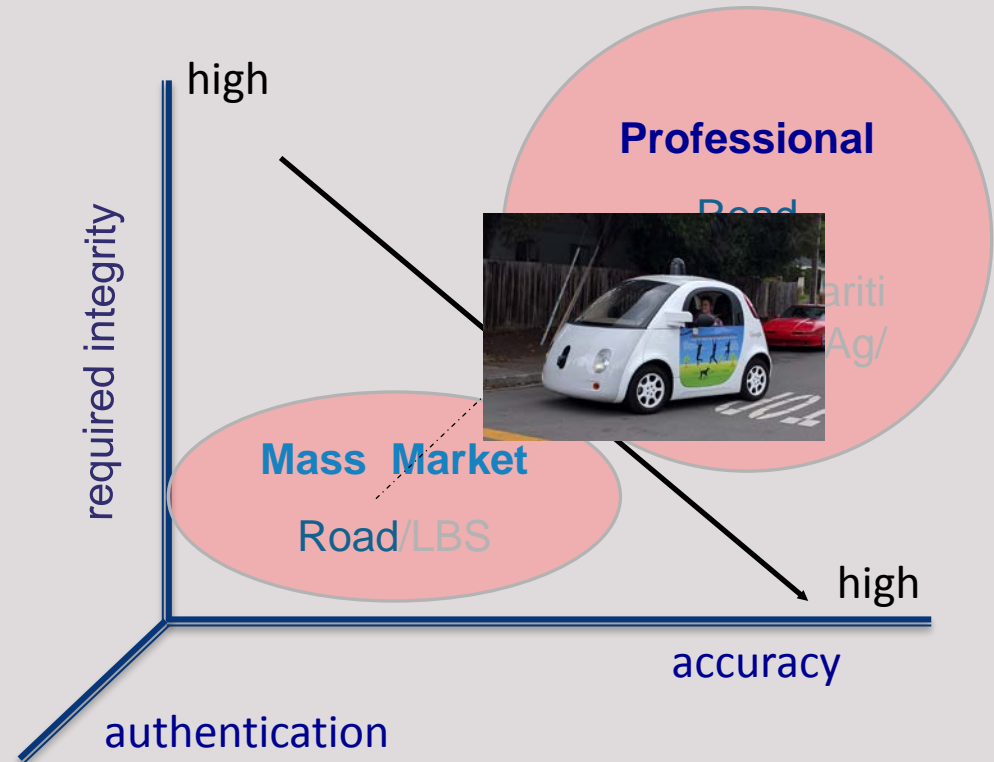
"Spoofing will attain virus status"

Faking of GPS data a growing and potentially lethal danger, expert warns

Source: The Japan Times

- Several layers of defense against spoofing
  - Open Service
  - Commercial Service
  - PRS

- Galileo proposes new solutions - on other GNSS systems too?

- Integrity Monitoring Service
  - Providing integrity information for safety-critical applications

Visit **www.insidegnss.com/webinars** for:

- PDF of Presentations

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Poll #3

Now that Galileo is here, our (my) company (organization) plan is:
(Please select all that apply)
- Develop, purchase, and/or use Galileo-capable solutions
- Evaluate future use of OS capabilities
- Evaluate future use of PRS capabilities
- Evaluate future use of the SAR capabilities
- None of the above