Satellite Navigation: the on-going revolution

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17/05/2013 - ESAC

OBJECTIVES OF THIS TALK

This talk aims at:

1. Informing about the high importance of Satellite Navigation (GNSS) in our economy and the growing perspectives of this field

2. Providing a general overview and status information of existing and planned GNSS (Global Navigation Satellite Systems) worldwide systems, with emphasis on Europe's GALILEO System

3. Starting a discussion about GNSS applications (downstream) and the role of the new Torrejón based Galileo Service Centre (GSC)

LECTURE OUTLINE

1. The importance of GNSS (10’)

2. Overview of GNSS Global Systems (30’)
   - GPS
   - Glonass
   - Galileo
   - COMPASS

3. GNSS Applications and the Galileo Service Centre (5’)

TOTAL : 45’ (letting then about 15’ for discussion)

LECTURE OUTLINE

1. **The importance of GNSS (10’)**
2. Overview of GNSS Global Systems (30’)
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3. GNSS Applications and the Galileo Service Centre (5’)
4. Summary

TOTAL : 45’ (letting 15’ for discussion)

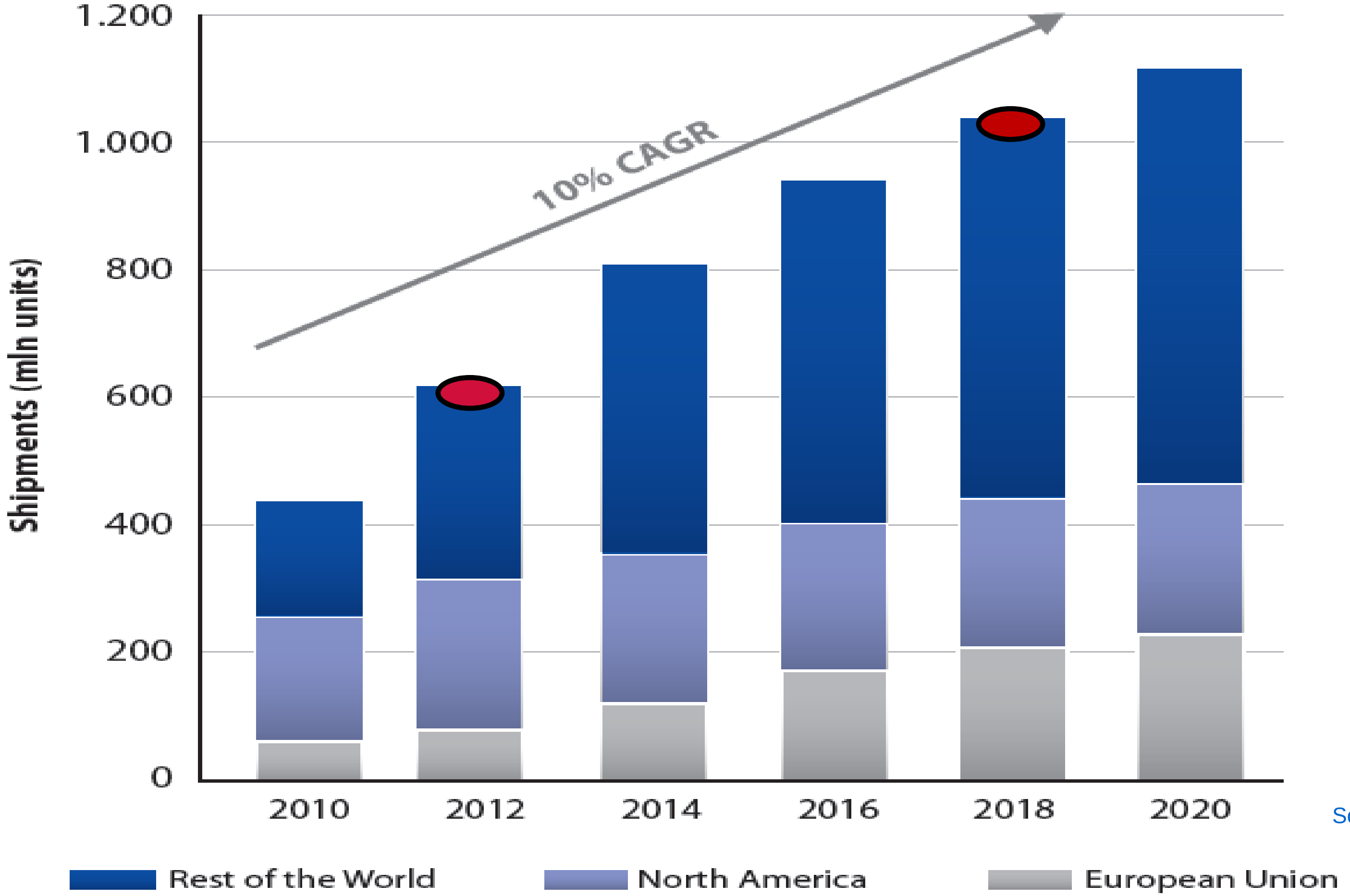
A GNSS-dependant World

- According to European Commission (Galileo mid-term review Jan 2011) it is estimated that between **6% and 7% of the European Union GDP** has a major dependence on GNSS technologies (an amount that equals **€800 billion** – about 1 trillion $).

- At worldwide level, the GNSS economic dependence is estimated **to be over 3 trillion $** (GPS World, Dec 2010)

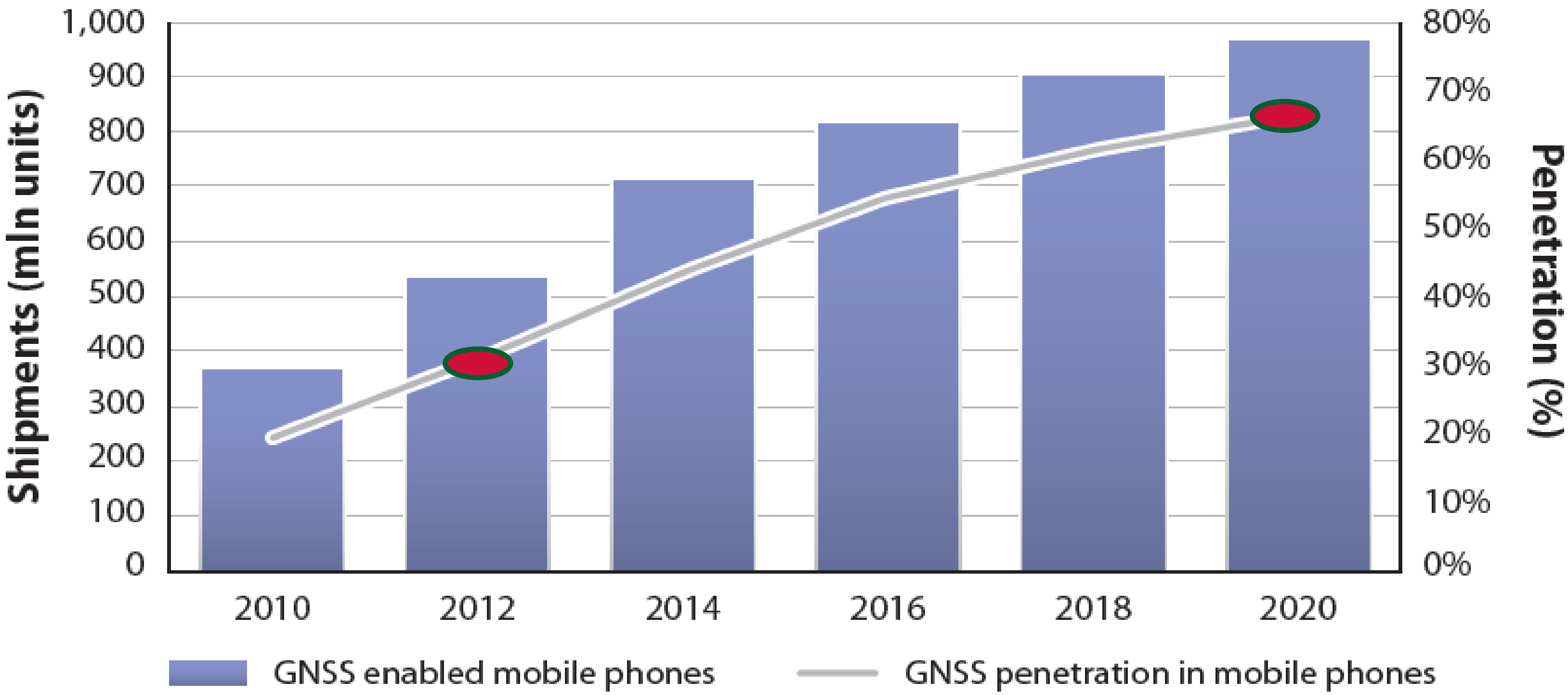
- It is estimated that today there are about **700 million** satellite navigation receivers worldwide and the figure is estimated **to exceed 1 billion in 2018** (Source: GSA GNSS Market Report, issue 2, May 2012)

GNSS devices worldwide: forecast



Source: GSA GNSS Market Report May 2012

GNSS devices in mobile Phones



Source: GSA GNSS Market Report
May 2012

GNSS is a major application and service enabler
It plays a role in almost all domains of our economy

Existing and under development GNSS Systems worldwide

esa

Global

GPS

GLONASS

Galileo

COMPASS

Regional

QZSS

IRNSS

Augmentation

WAAS

EGNOS

MSAS

GAGAN

SDCM

MASS

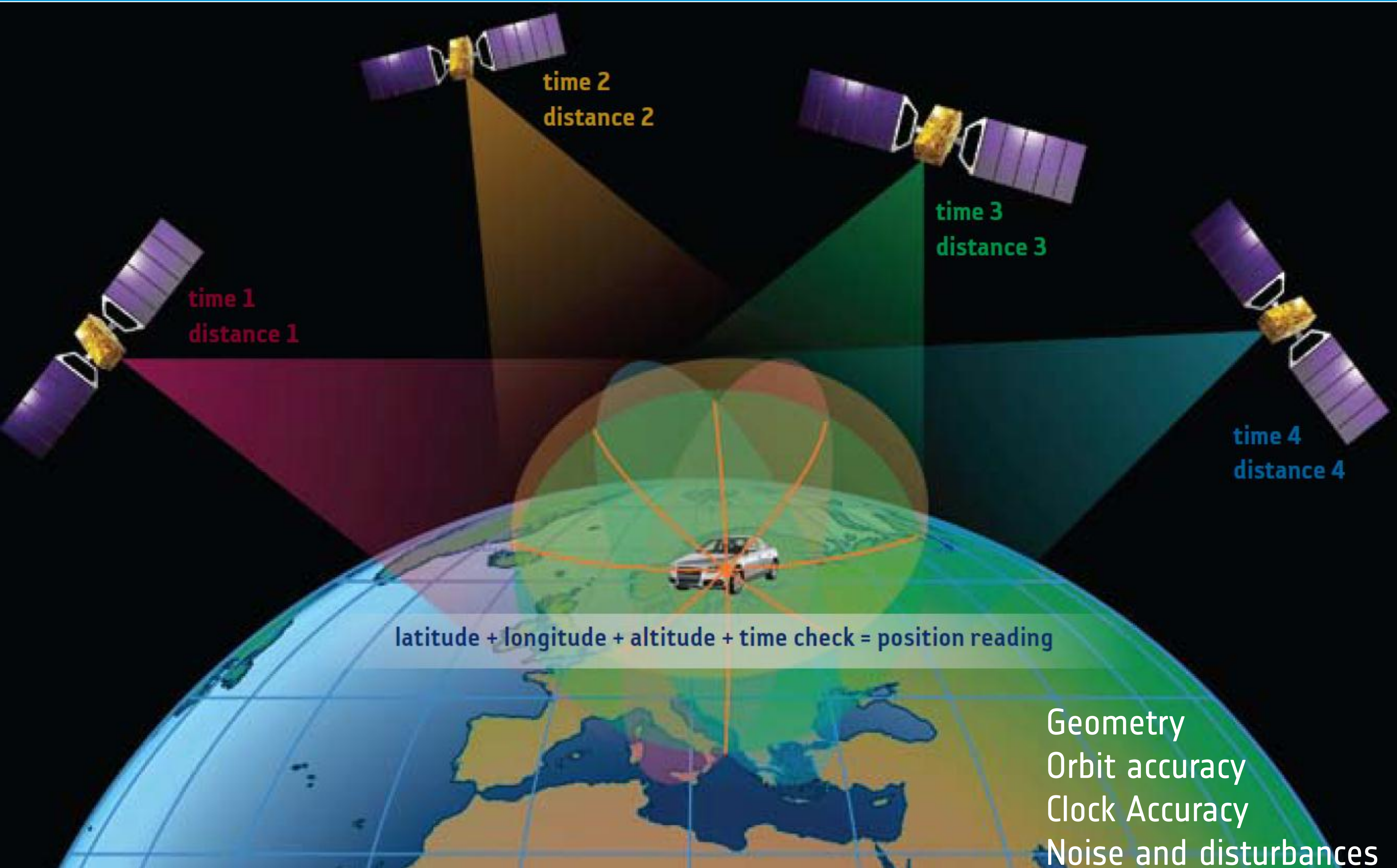
GNSS: the on-going revolution …

LECTURE OUTLINE

1. The importance of GNSS (10')
2. **Overview of GNSS Global Systems (30')**
   - **GPS**
   - **Glonass**
   - **Galileo**
   - **COMPASS**
   - **Regional Systems**
3. GNSS Applications and the Galileo Service Centre (5')
4. Summary

TOTAL : 45' (letting 15' for discussion)

ALL GNSS SYSTEMS WORK UNDER THE SAME PRINCIPLE



Geometry
Orbit accuracy
Clock Accuracy
Noise and disturbances


GPS

GPS basic data

GPS - United States of America:

- **31 satellites in operations** (May 2013)
- Status info: http://www.navcen.uscg.gov/?Do=constellationStatus
- Selective availability switched off on May 2, 2000
- Millions of civil users already
- Last launch GPS IIF-4, SVN66, PRN-27, was launched on **15th May 2013** (planned to be operational in summer 2013)
- Upgrades on-going: GPS IIF, GPS III
- Dual Civil (SPS) and Military (PPS) system

Official GPS Government website: www.gps.gov

GPS CONSTELLATION

esa

Nominal Constellation: 24 satellites

Nearly Circular Orbits (e < 0.02)
(Radius 26.560 Km)

Orbit period (close to 11 h and 58 min)

Six Orbital Planes A to F
(55 degrees inclination)

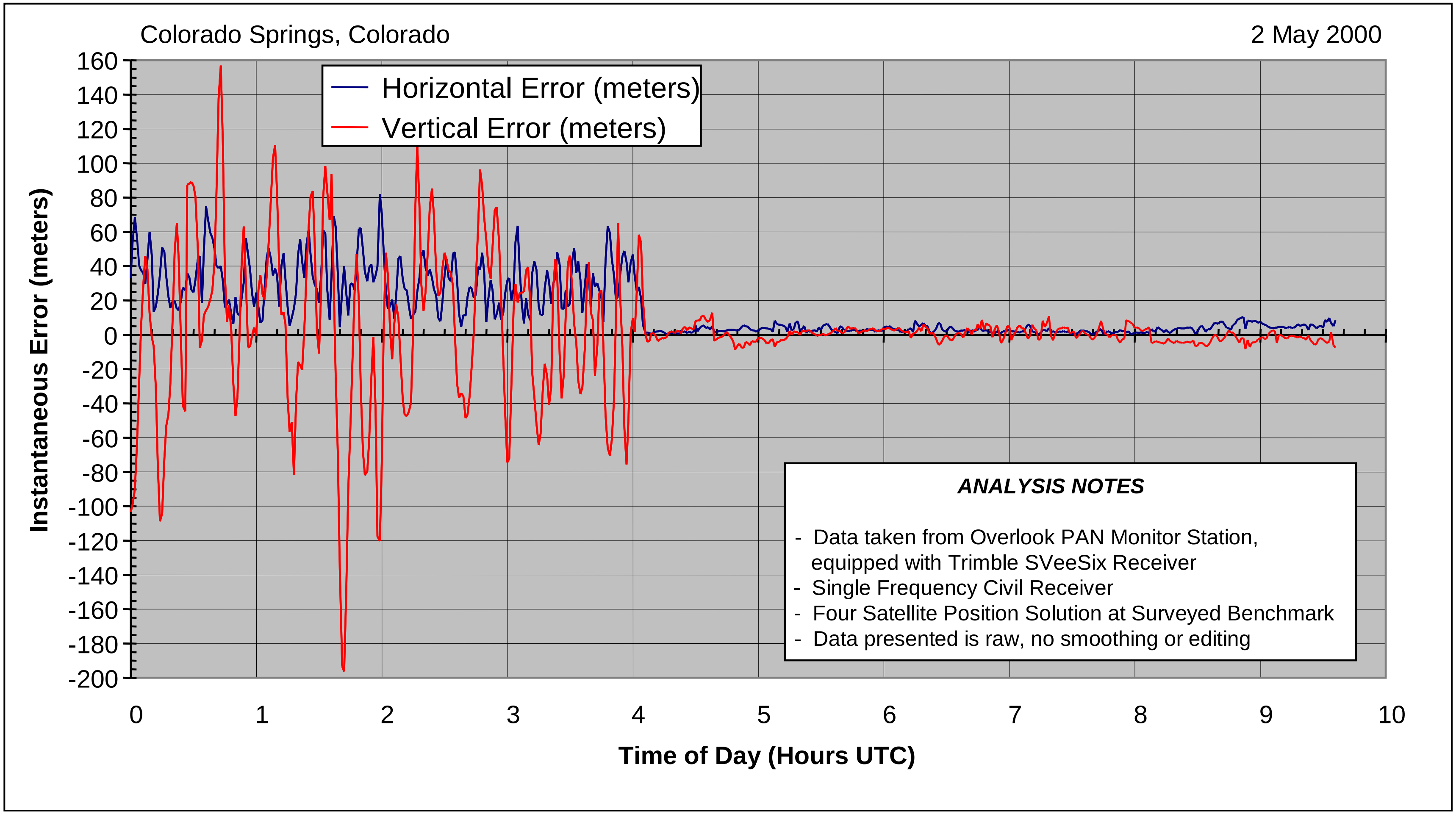
Nominally: 4 satellites per orbit unevenly distributed

This constellation guarantees that all users have a minimum of 4 satellites in view

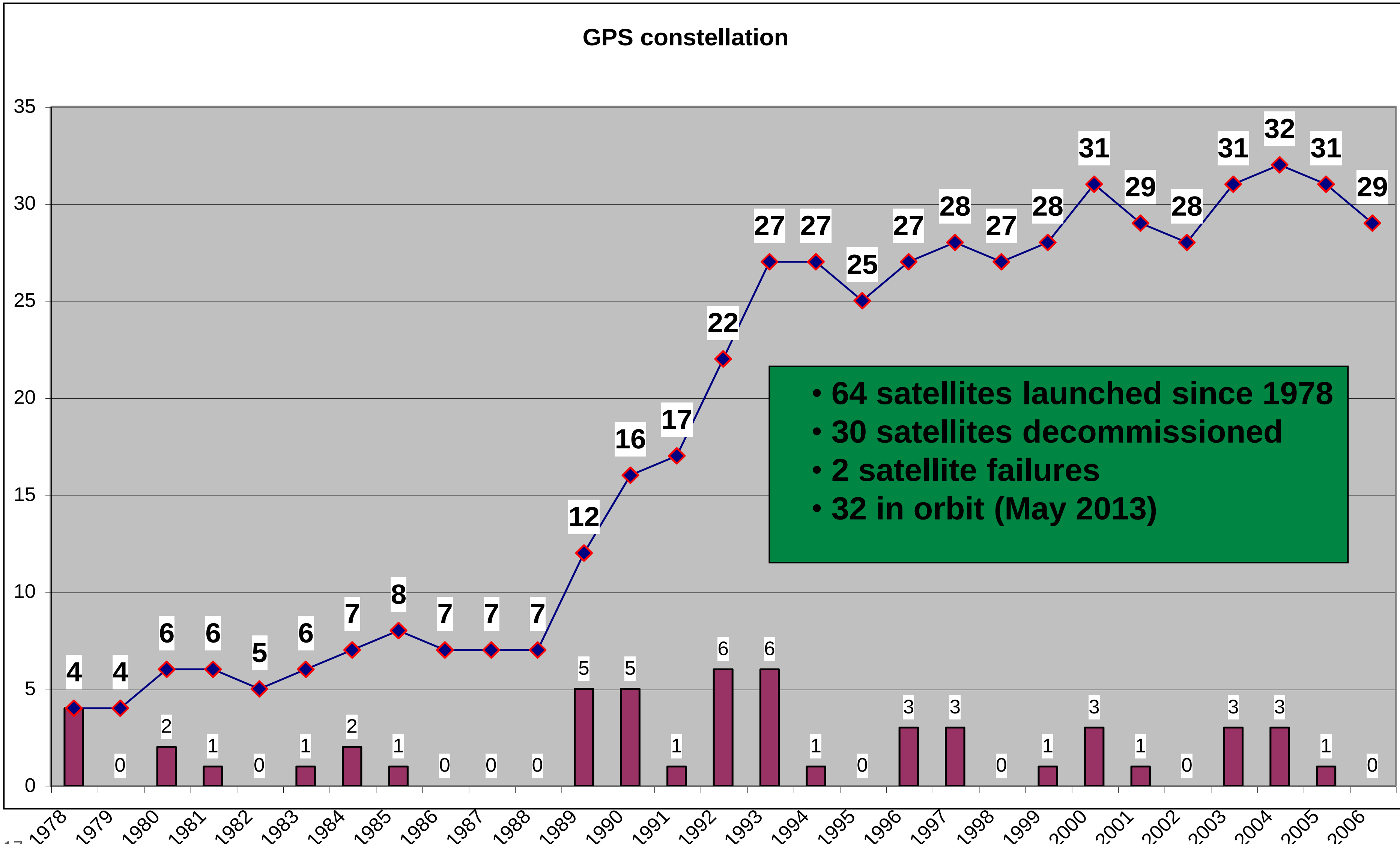
Each satellite defined by Orbit Letter and number (e.g. A3, B4, …) or PRN number (e.g. PRN 16, …)

CDMA-based

GPS SELECTIVE AVAILABILITY



GPS CONSTELLATION EVOLUTION



European Space Agency

GPS SPACECRAFTS BLOCKS

Block I - Boeing

First Launch: 22 Feb 78
11 SV's (All deactivated)

Block II/IIA - Boeing

First Launch: 14 Feb 89
28 SV's (All delivered & Launched)
9 SV in operations

Block IIR, IIR-M - Lockheed Martin

First Launch: 17 Jan 1997
19 S/C in orbit IIR-M:~9.05

Block IIF - Boeing

First Launch: 28 May 2010
4in orbit, 9 SV's more planned

+GPS-III

GPS MODERNISATION SCHEDULE

(source: ESA Navipedia: www.navipedia.net)

GPS Launches Record
(as per 15 May 2013)

Block	Launch Period	Satellites launched	Satellites Planned to be launched	Today in Operations (May 2013)
I	1978–1985	10 + 1 failure	0	0
II /IIA	1989–1997	28	0	9
IIR	1997–2004	12 + 1 failure	0	12
IIR-M	2005–2009	8	0	7
IIF	2010–2013	4	9	3
III	2014-?	0	TBD	0
TOTAL	1978-2013	64	9 GPS IIF+ GPS III	31

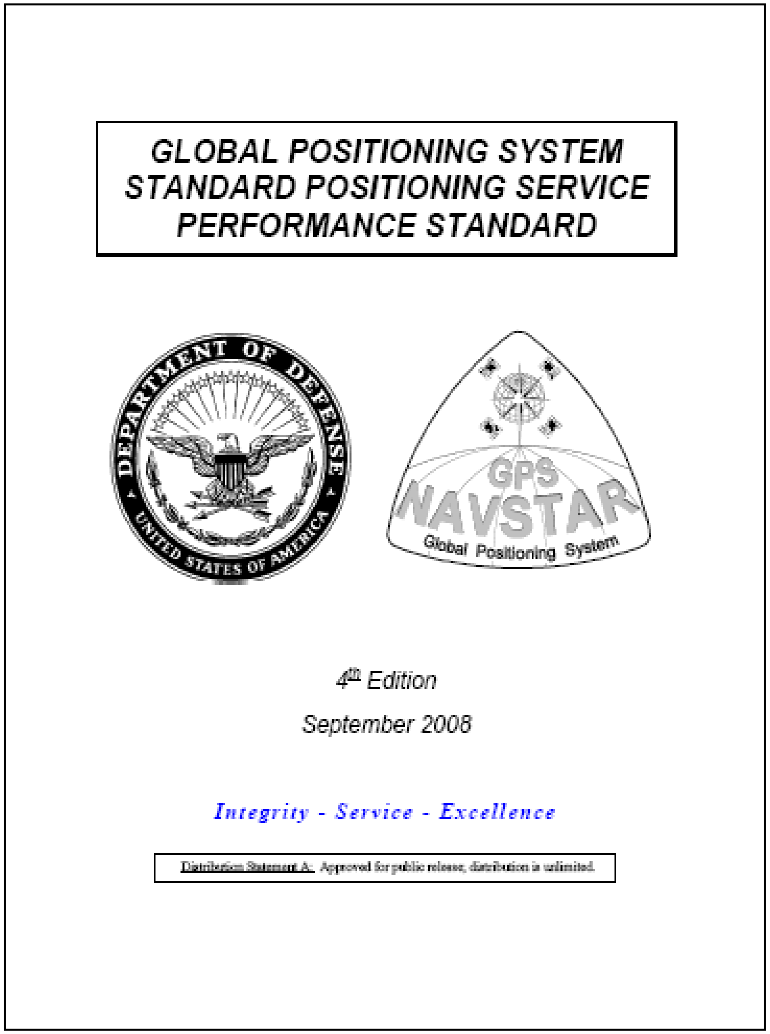

DELTA 4 Launcher
Medium+(4,2)


ATLAS V Launcher

GPS User Documents (1/3)

- GPS Standard Positioning Service (SPS), 4th Edition, September 2008: defines the level of performance U.S. Government makes Available to GPS Users on the SPS civil service (L1 signal). Approved by the DoD.

- Defines the levels of performance the U.S. Government makes available to authorized users of the GPS Standard Positioning Service Service (i.e. civil users)



GLOBAL POSITIONING SYSTEM
STANDARD POSITIONING SERVICE
PERFORMANCE STANDARD

4th Edition

September 2008

Integrity - Service - Excellence

Distribution Statement A: Approved for public release; distribution is unlimited.

GPS User Documents (2/3)

- GPS Performance Analysis report (PAN Reports) performed by the William J. Hughes Technical Centre http://www.nstb.tc.faa.gov/

- This quarterly analysis performed for the FAA (last January 2013) verify the GPS SPS performance as compared to the performance parameters stated in the SPS Specification

Global Positioning System (GPS)
Standard Positioning Service (SPS)
Performance Analysis Report

Submitted To

Federal Aviation Administration
GPS Product Team
1284 Maryland Avenue SW
Washington, DC 20024

Report #80
January 31, 2013
Reporting Period: 1 October – 31 December 2012

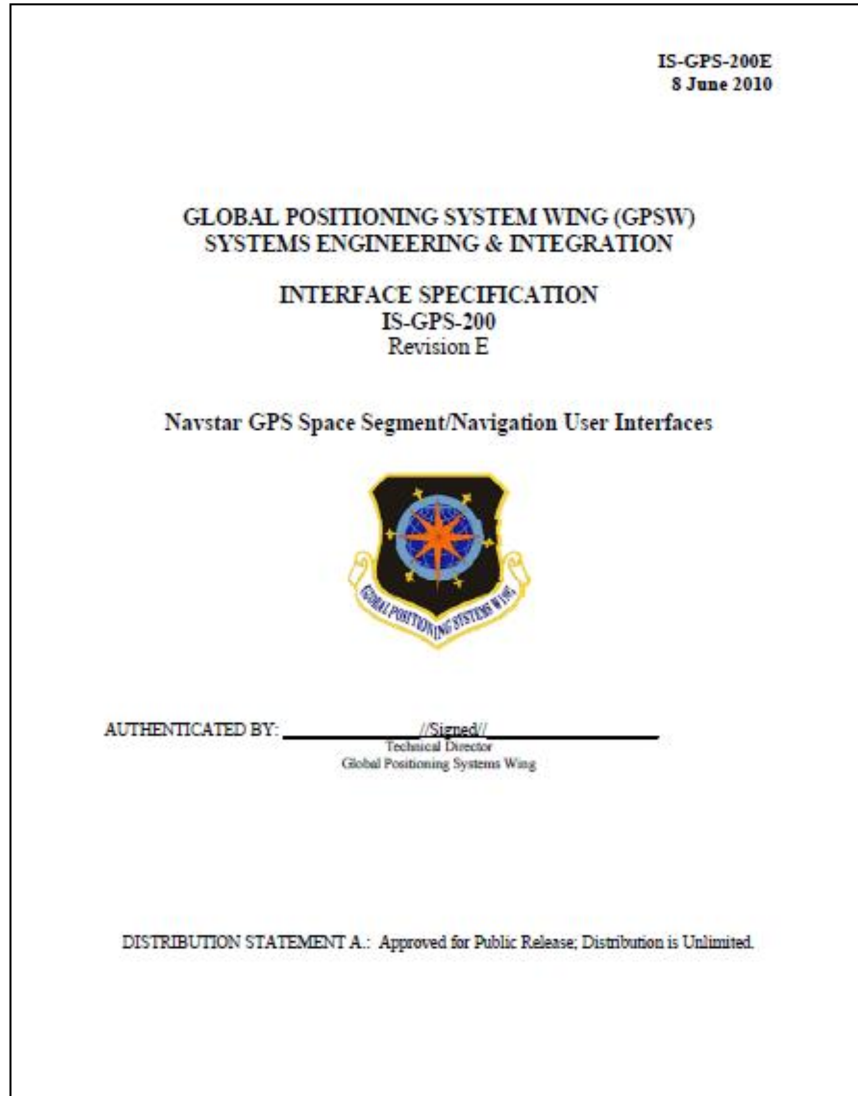
Submitted by

William J. Hughes Technical Center
NSTB/WAAS T&E Team
Atlantic City International Airport, NJ 08405

From the analysis performed on data collected between 1 October and 31 December 2012, the GPS performance met all SPS requirements that were evaluated

GPS User Documents (3/3)

- GPS SIS Interface Specification IS-GPS-200 Revision E released in June 2010 (6th revision after the first initial released document in 1983).
- This is an Interface Control Document that defines the requirements of the interface between the GPS Space Segment and the GPS user receiver.
- IS-GPS 705 (L5) and IS-GPS-800 (L1C) also available.



IS-GPS-200E
8 June 2010

GLOBAL POSITIONING SYSTEM WING (GPSW)
SYSTEMS ENGINEERING & INTEGRATION

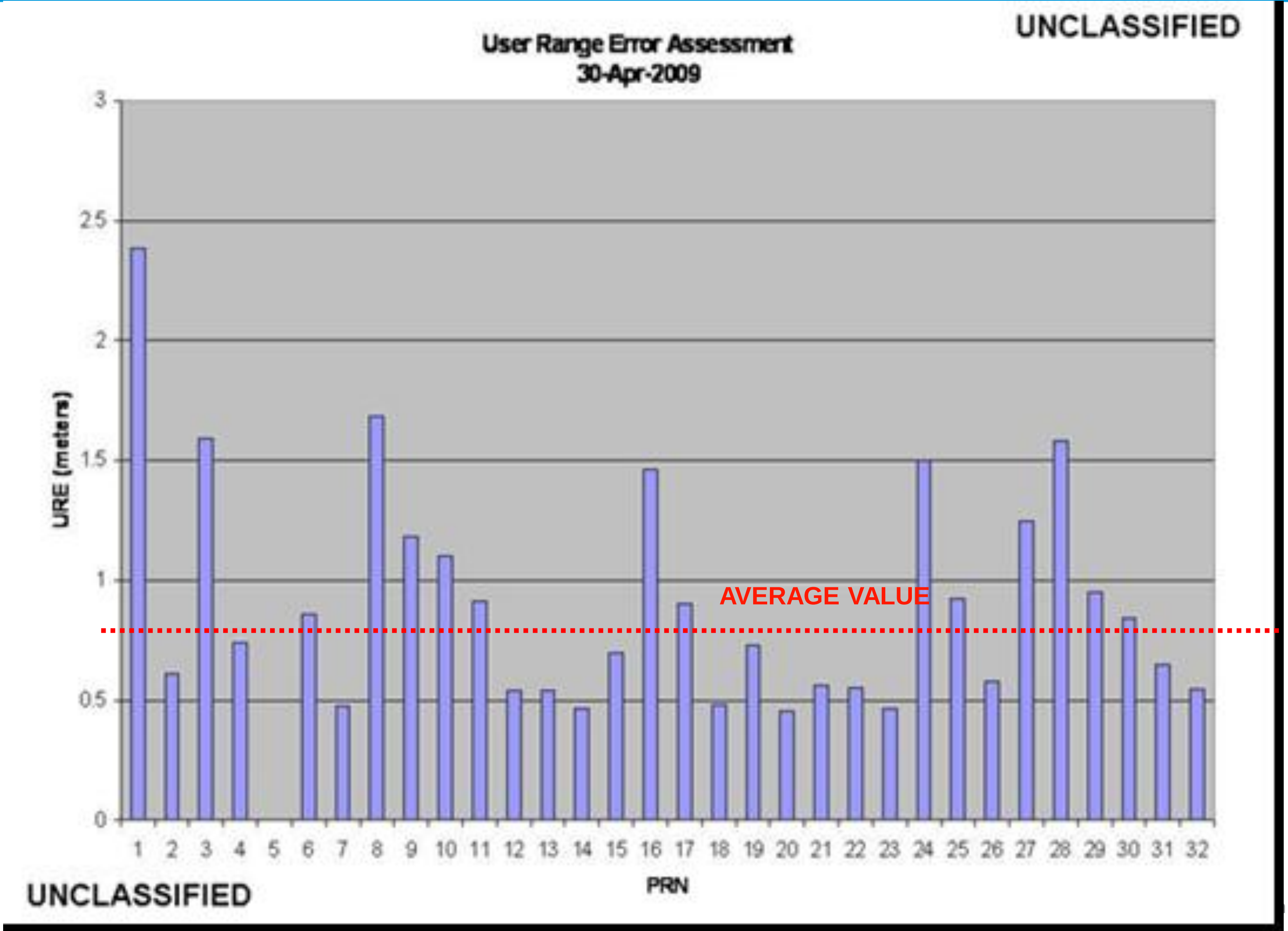
INTERFACE SPECIFICATION
IS-GPS-200
Revision E

Navstar GPS Space Segment/Navigation User Interfaces

AUTHENTICATED BY: //Signed//
Technical Director
Global Positioning Systems Wing

DISTRIBUTION STATEMENT A.: Approved for Public Release; Distribution is Unlimited.

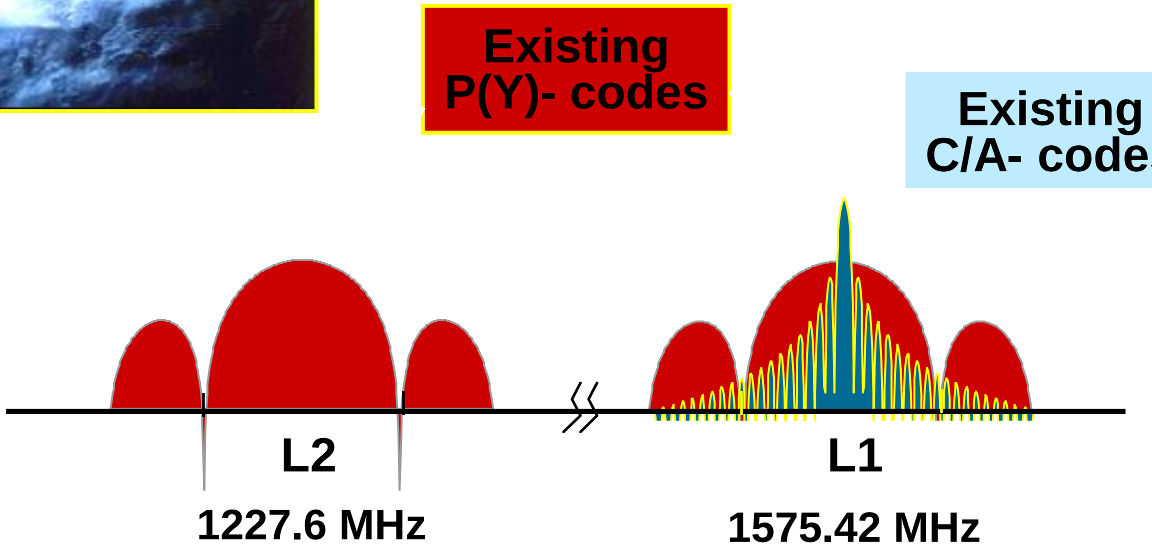
GPS User Range Accuracy Error



GPS II, IIA and IIR Satellite Signals

Spacecraft Signals:

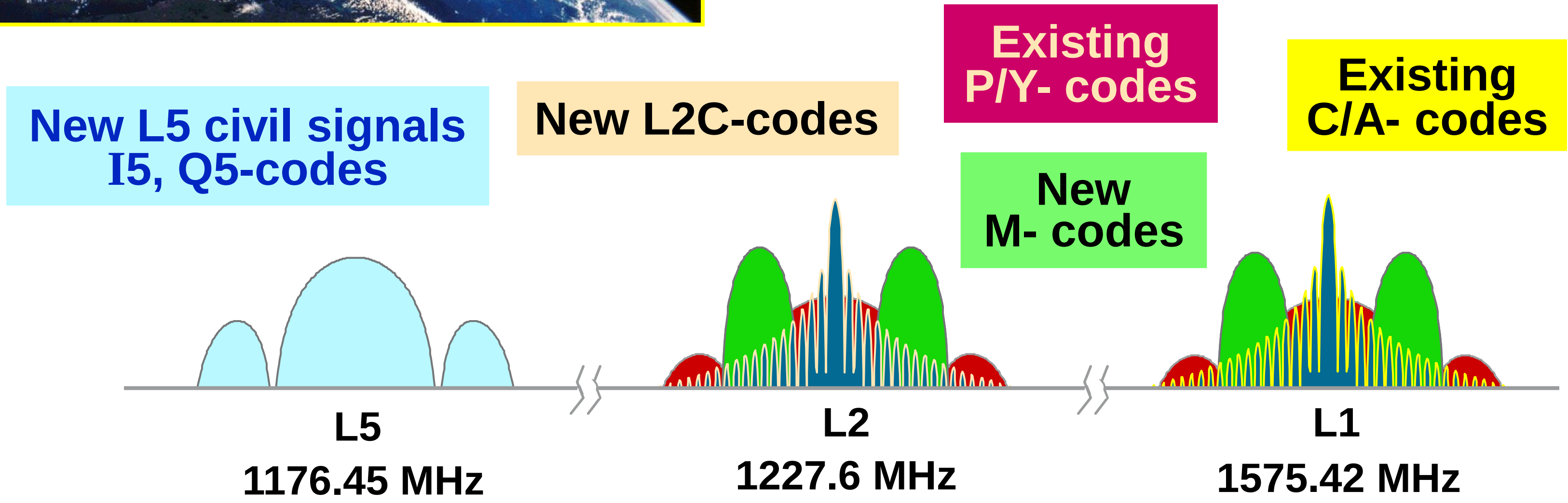
- C/A-codes on L1
- P(Y)-codes on L1 and L2



GPS IIF Satellite Modernization

IIF Modernization features:

- 2nd civil frequency (L2)
- M-codes added to L1 and L2
- 3rd civil signal (L5) with I5-codes and Q5-codes
- First launch May 2010



LECTURE OUTLINE

1. The importance of GNSS (10')
2. Overview of GNSS Global Systems (1h)
   - GPS (15')
   - Glonass (10')
   - Galileo (30')
   - COMPASS (5')
3. Overview of GNSS Regional Systems (25')
   - EGNOS and the other SBAS Systems (WAAS, MSAS, GAGAN, SDCM)
   - IRNS (India) and QZSS (Japan)
4. Overview of GNSS Applications (10')
5. Summary (5')

TOTAL : 1h 50' (letting 10' for questions)

GLONASS

GLONASS Basic data

GLONASS Russian Federation:

- **29 satellites in orbit** (Oct 2012) – 24 in operation - Status info: http://www.glonass-ianc.rsa.ru/en/
- Constellation being replenished intensively
- **Last launch April 26, 2013** (Soyuz launch), 1 Glonass-M, KOSMOS 2485, GLONASS 747, placed in orbital plane 1
- First Glonass-K1 launched Feb 26, 2011 (with L3 CDMA Transmission)
- Upgrades on-going: GLONASS-K1 and GLONASS-K2
- Nominal 24 operations constellation was reached again in 2011
- Dual Civil and Military system (**Glonass today available in a large number of mobile phones (e.g. iPhone 4S and Iphone 5**)

GLONASS CONSTELLATION

Baseline Constellation of 24 satellites.

Circular Orbits with Height (19.100 Km)

Orbit period (11h 15 min; 8/17th of a day)

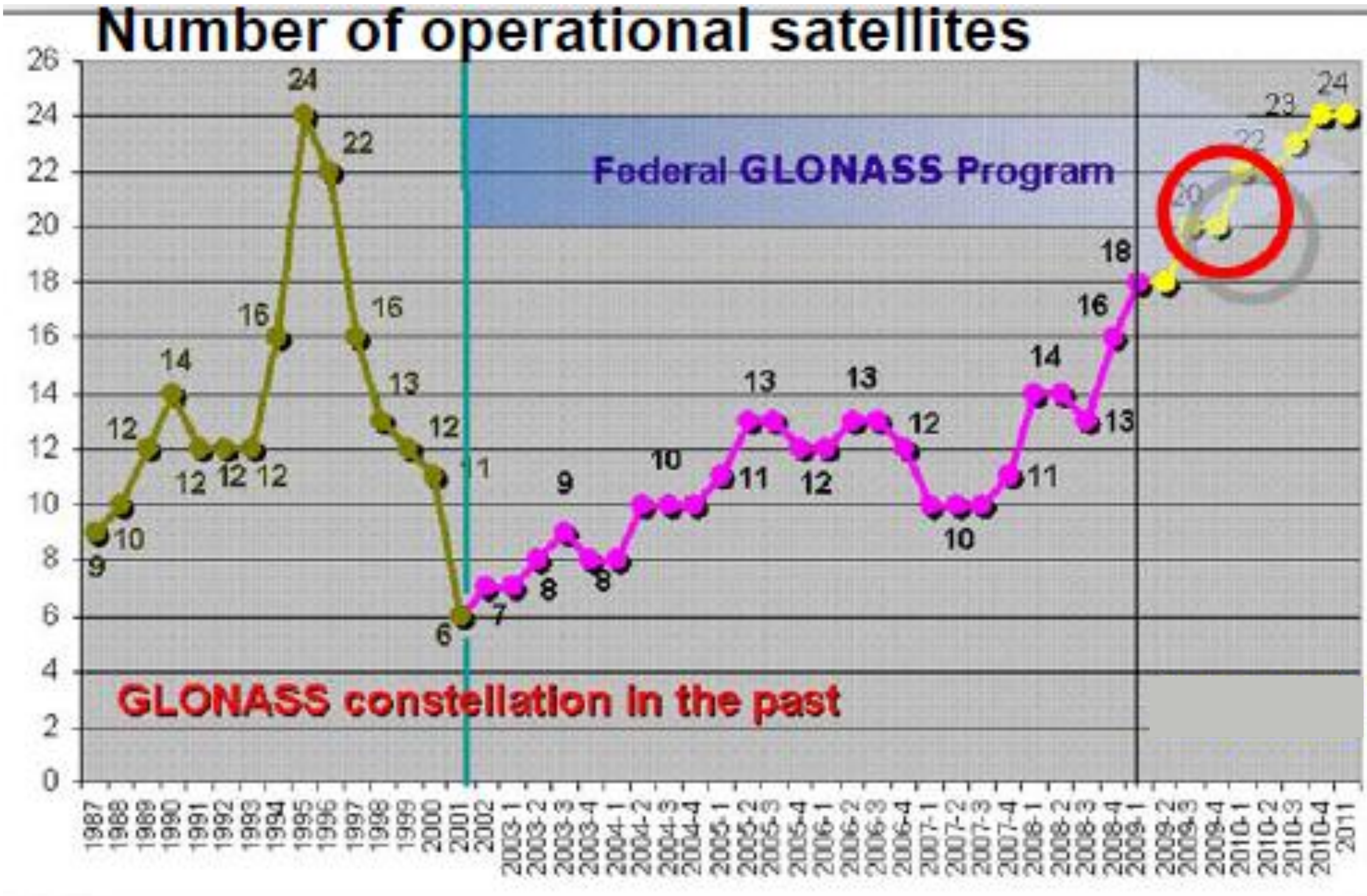
Three Orbital Planes shifted by
120 degrees (8 satellites per plane)

Nominally: 8 satellites per orbit
evenly distributed (Walker 24 / 3 / 1)

Fully deployed in 1995 but constellation
Was not duly maintained. Now fully
recovered again

FDMA-based (plan to include also CDMA
with GLONAS-K)

GLONASS CONSTELLATION

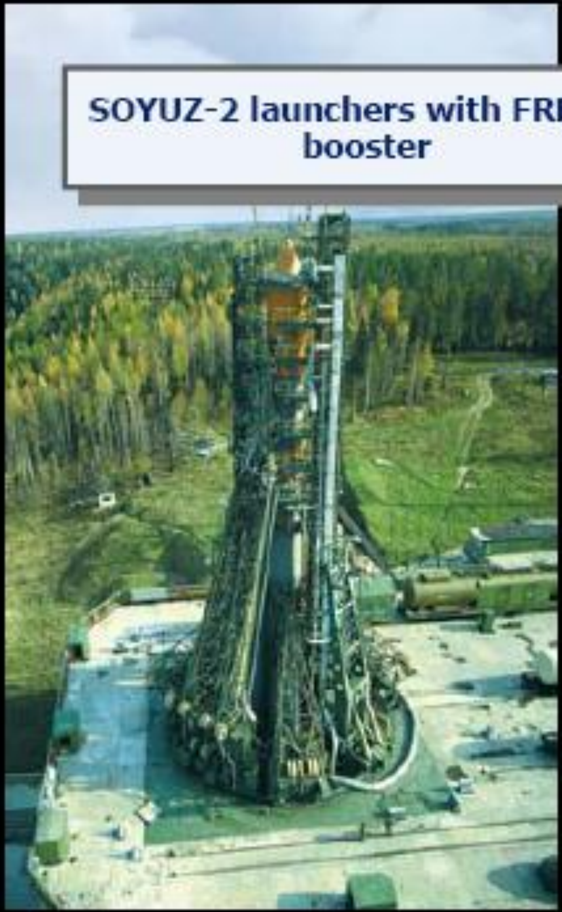


GLONASS LAUNCHERS

PROTON-K launcher with «DM» booster

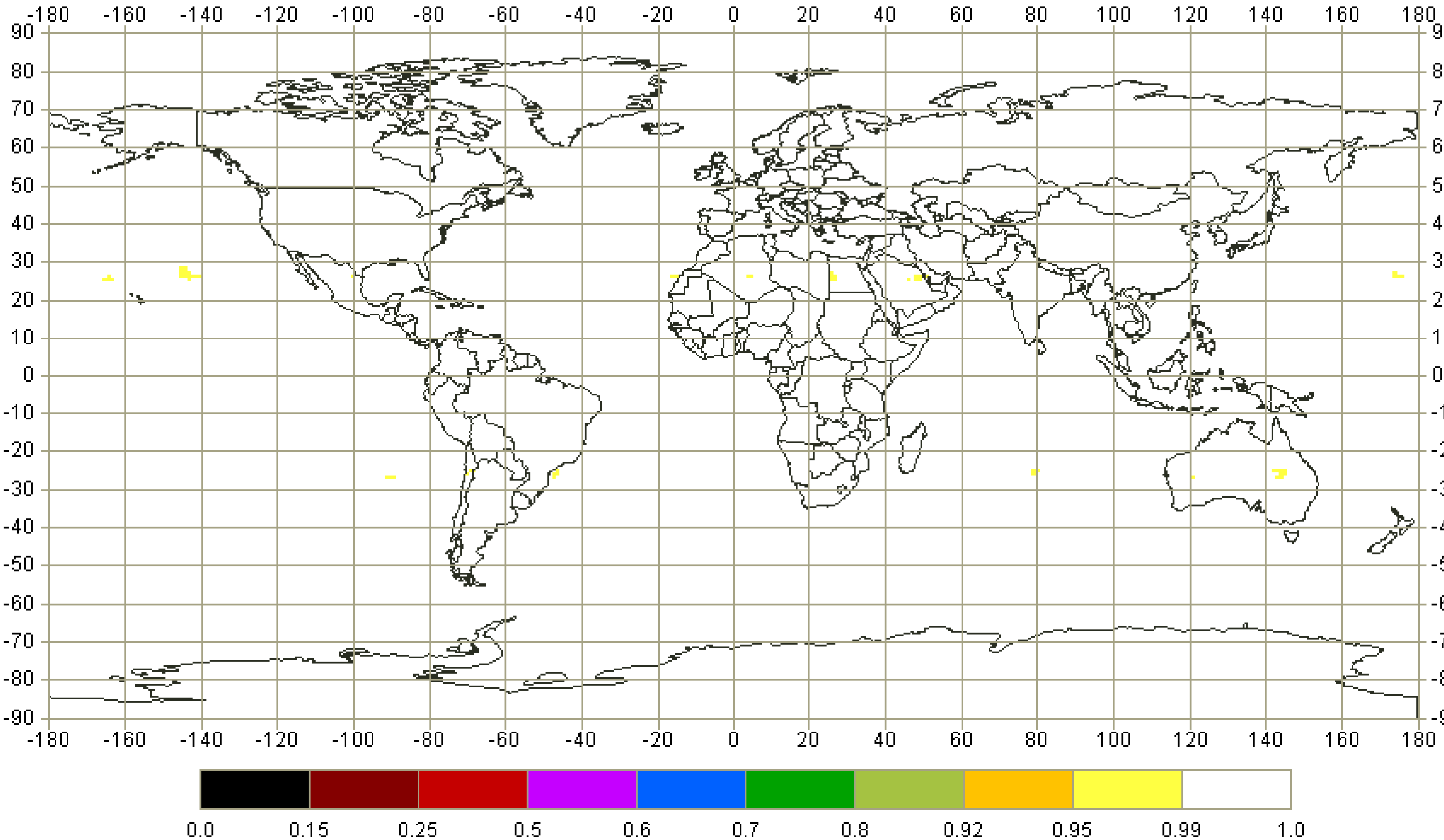
Baykonur

SOYUZ-2 launchers with FREGAT booster



Plesetsk

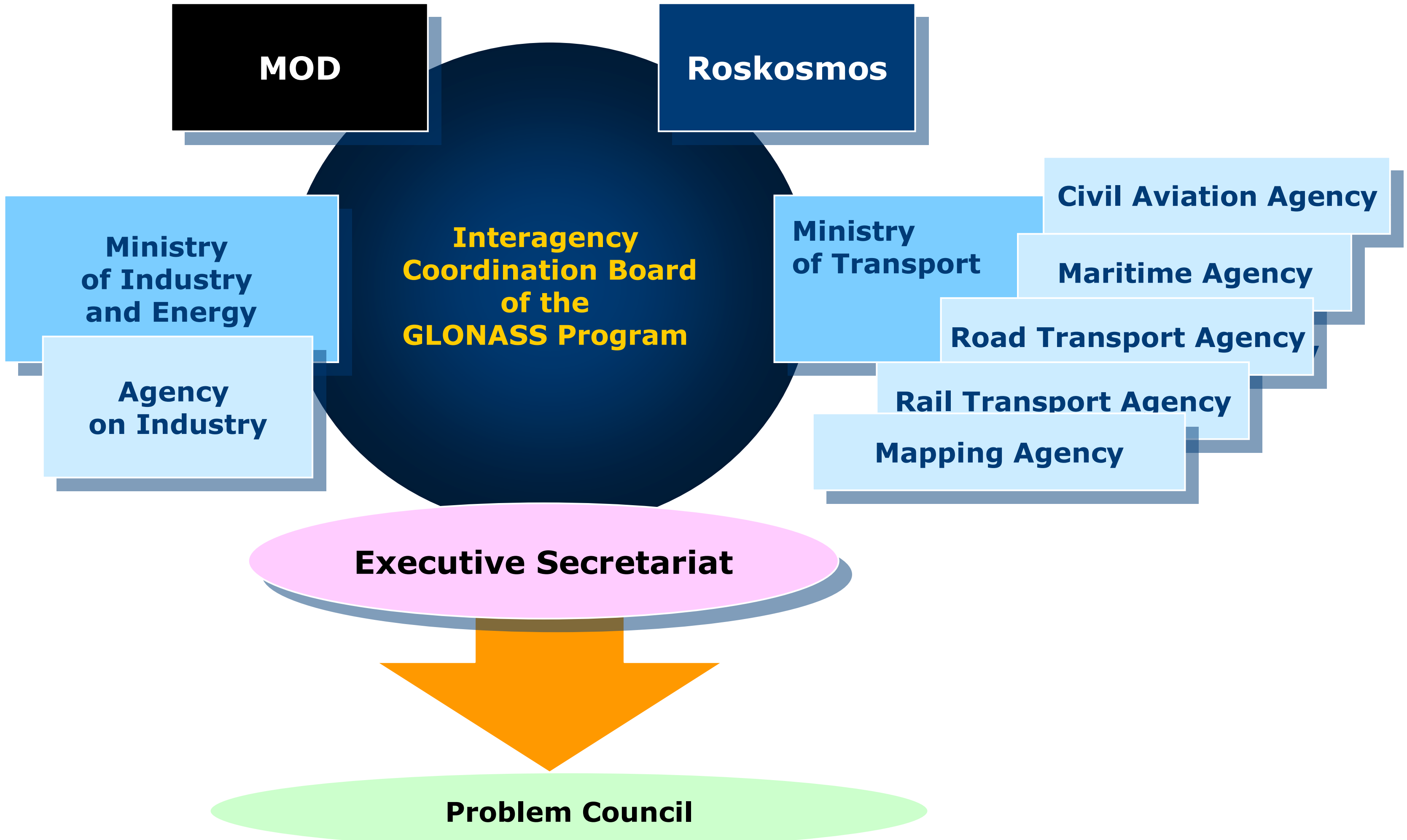
GLONASS Availability Status



Note: availability is calculated using a current almanac for the 24 hours period as percentage of time during which the condition PDOP≤6 is valid at mask angles ≥5°, where PDOP is a position (three-dimensional) dilution of precision. Step of calculation: 4 minutes in duration and 1 degree over the surface

Source: Russian Space Agency (http://www.glonass-ianc.rsa.ru/)

GLONASS Coordination Board



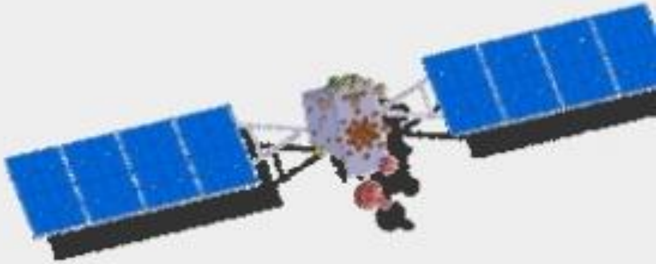
GLONASS MODERNIZATION PROGRAM

1982	2003	2011	2014
"Glonass"	"Glonass-M"	"Glonass-K1"	"Glonass-K2"

- 3 year design life
- Clock stability - $5*10^{-13}$
- Signals: L1SF, L2SF, L1OF, (FDMA)
- Totally launched 81 satellites
- Real operational life time 4.5 years

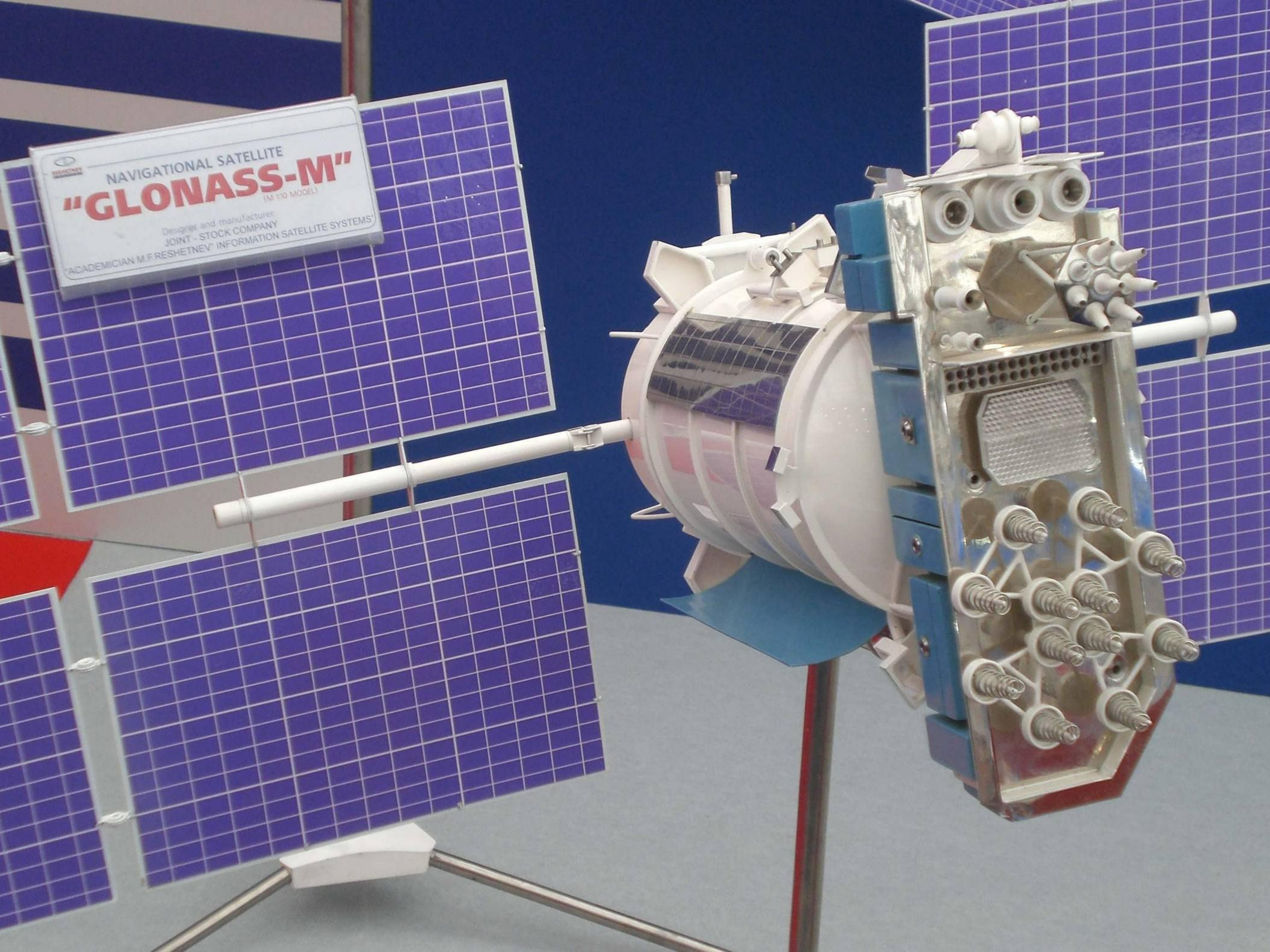
- 7 year design life
- Clock stability $1*10^{-13}$
- Signals: Glonass + L2OF (FDMA)
- Totally launched 36 satellites and going to launch 3 satellite by the end 2012

- 10 year design life
- Unpressurized
- Expected clock stability $\sim 10 \ldots 5*10^{-14}$
- Signals: Glonass-M + L3OC (CDMA) – test
- SAR



- 10 year design life
- Unpressurized
- Expected clock stability $\sim 5 \ldots 1*10^{-14}$
- Signals: Glonass-M + L1OC, L3OC, L1SC, L2SC (CDMA)
- SAR

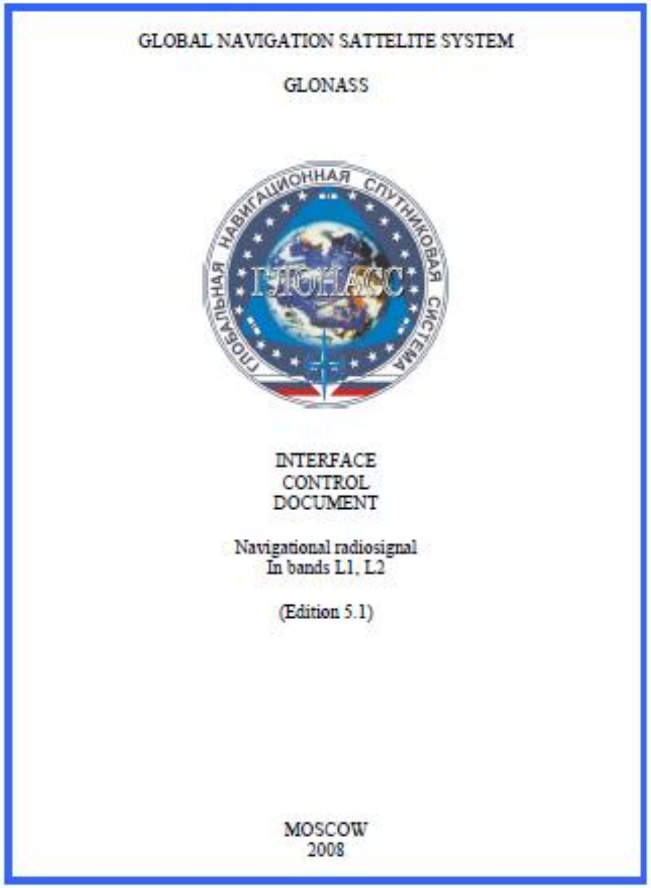
Source: Roskosmos 2012


NAVIGATIONAL SATELLITE
"GLONASS-M"
(M 1:10 MODEL)
Designer and manufacturer:
JOINT - STOCK COMPANY
"ACADEMICIAN M.F.RESHETNEV" INFORMATION SATELLITE SYSTEMS"

GLONASS-K satellite

GLONASS USER ICD

- GLONASS Interface Control Document, Version 5.1 released in 2008.
- The GLONASS Interface Control Document specifies parameters of interface between GLONASS space segment and user equipment for the Standard (ST) Open service.
- Includes Interface information for the GLONASS-M Family.


GLOBAL NAVIGATION SATTELITE SYSTEM

GLONASS

INTERFACE
CONTROL
DOCUMENT

Navigational radiosignal
In bands L1, L2

(Edition 5.1)

MOSCOW
2008

A major step of GLONASS reaching the Global Market

In 2010, Russia announced a plan to introduce a 25% import duty on all GPS-capable devices, including mobile phones, unless they are also compatible with GLONASS.

By the end of 2011, Apple adopted Glonass on its iPHONE 4s (also iPHONE 5).

But, by adding GLONASS capabilities to its iPhone line, Apple probably gave to Russian Glonass System the biggest de facto endorsement in its history.

GALILEO

esa

GALILEO: ensuring European independence on Satellite Navigation

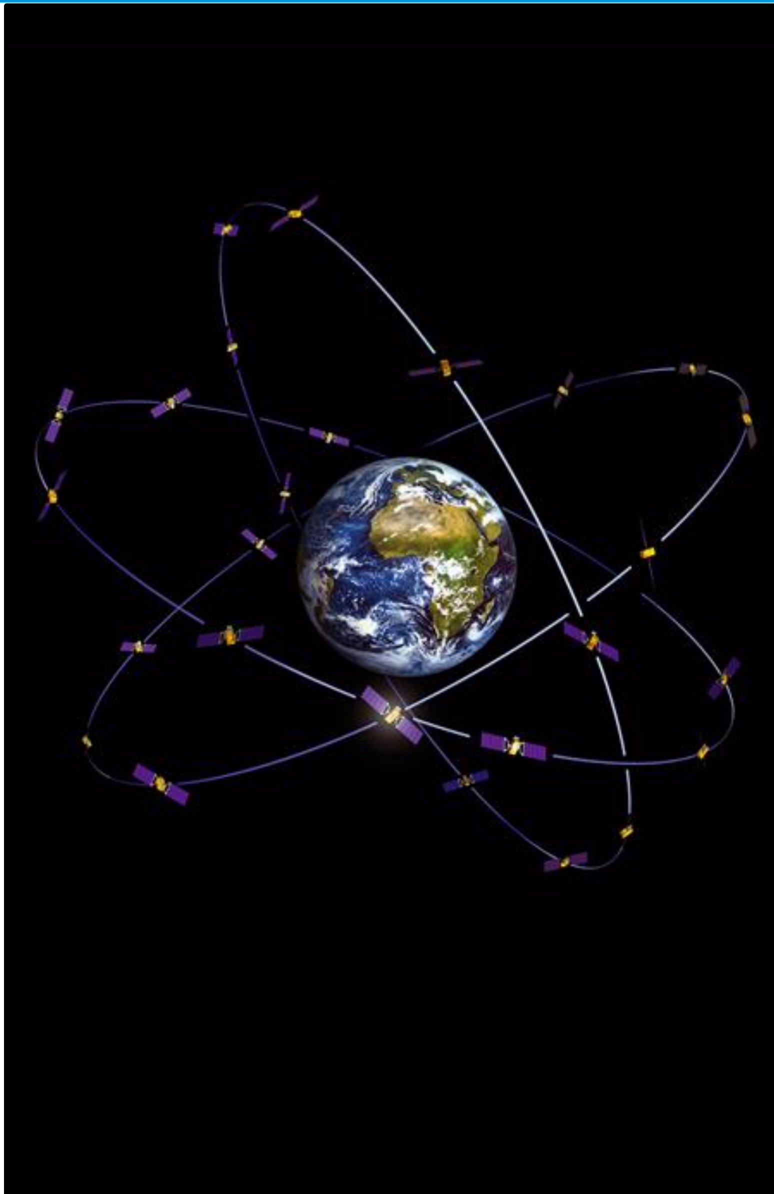
- Galileo is the global navigation satellite system of Europe, providing a highly accurate and guaranteed global positioning and timing services at worldwide level. Galileo will be under European and civilian control.

- Galileo is a joint program of the European Commission (EC) and ESA.

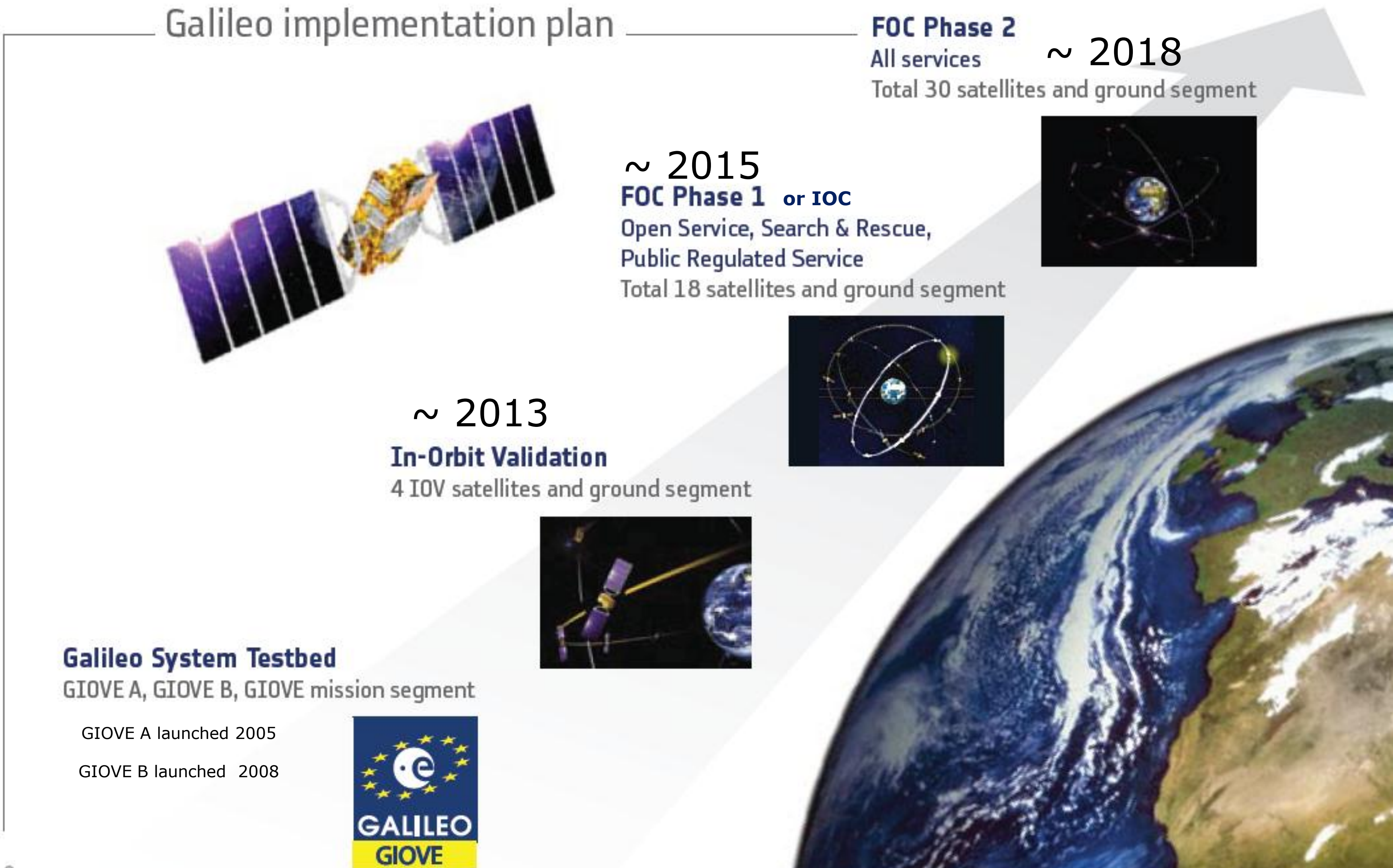
- Designed, developed and controlled in Europe, Galileo will give Europe independence in satellite navigation, a sector that has become very important for its economy (according to the EC, about 6-7% of the EU GDP in 2009 depends on GPS).

- Galileo has been conceived to be compatible and interoperable with GPS. The joint use of GPS and Galileo will offer additional important benefits to the users.

- Galileo will allow the development of a new generation of new services and applications in fields such as transportation, telecommunications, location based services, fishing, energy, etc.

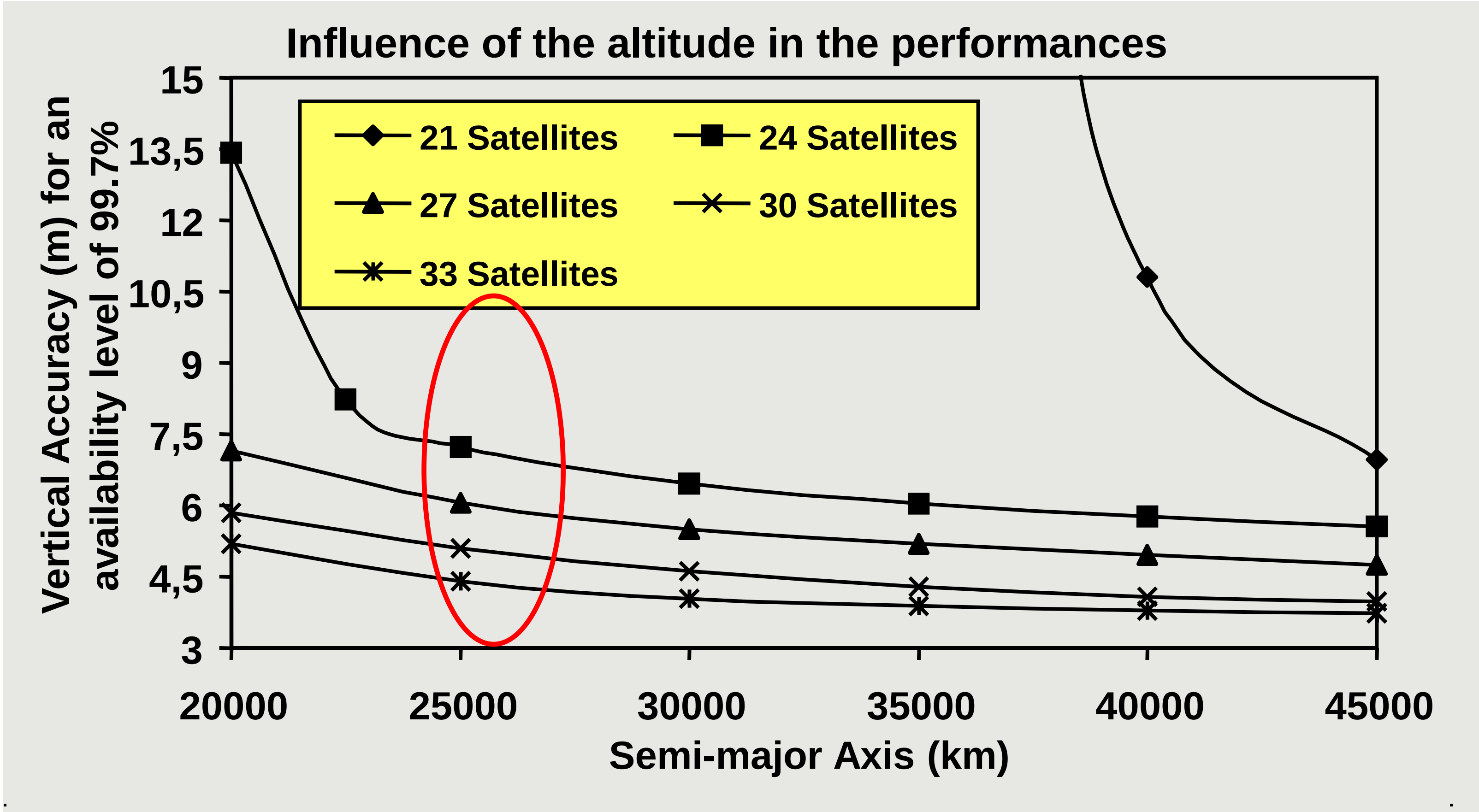


GALILEO IMPLEMENTATION PLAN

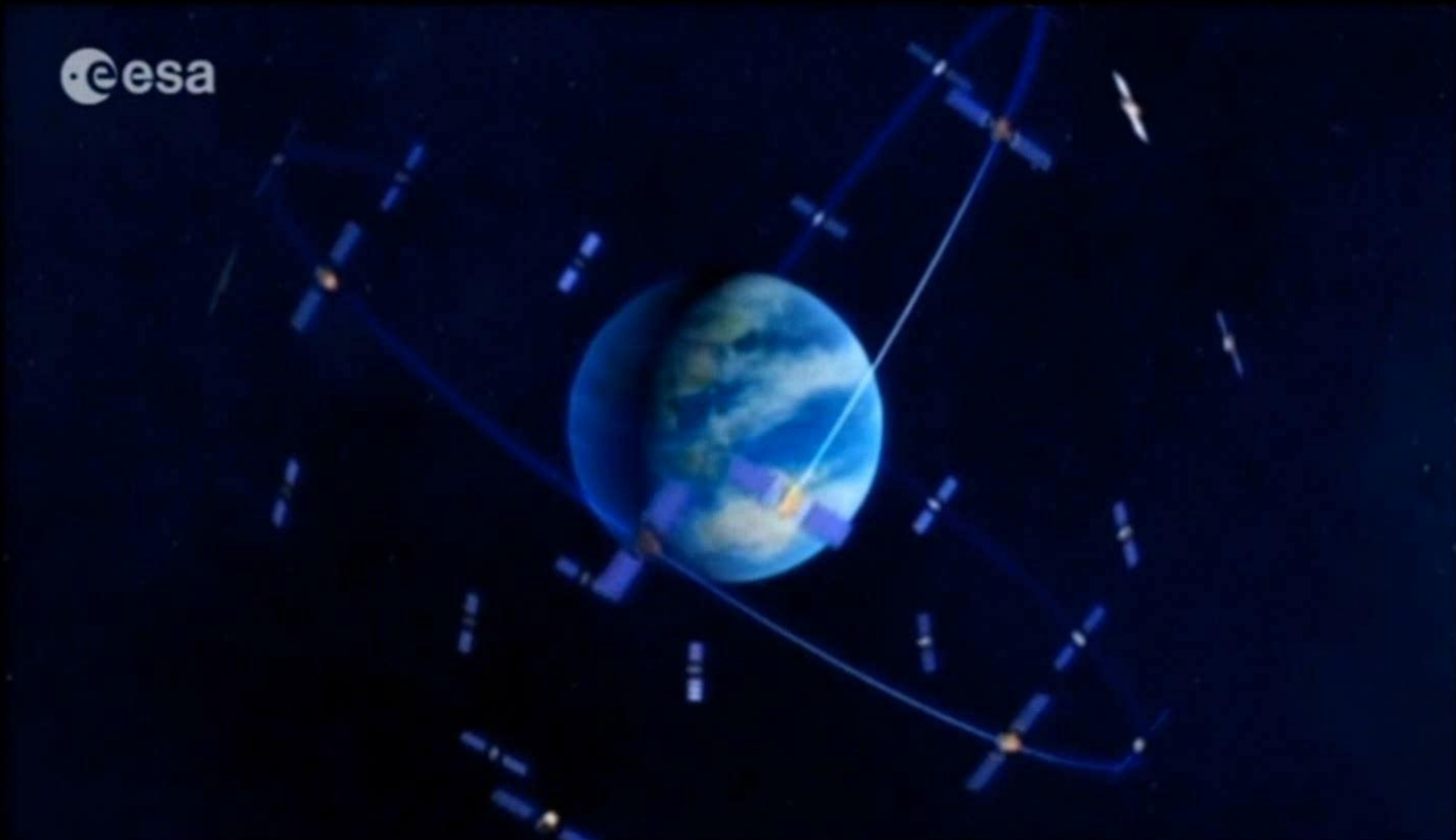


THE GALILEO CONSTELLATION

Constellation Design Trade-offs



- **For altitudes above 23000 Km and for an availability of 99.7, no major improvement in accuracy if more than 30 satellites.**
- **Minimum number of satellites is 24.**


esa

GALILEO / GPS / GLONASS

	GALILEO	GPS	GLONASS
Orbital planes	3	6	3
Number of Satellites (nominal satellites)	30	24 (32)	24 (29)
Altitude	23222 Km	20160 Km	19100 Km
Orbit inclination	56 degrees	55 degrees	65 degrees
Accuracy (95%)	< 4 metros	~ 5-10 metros	~10-15 metros

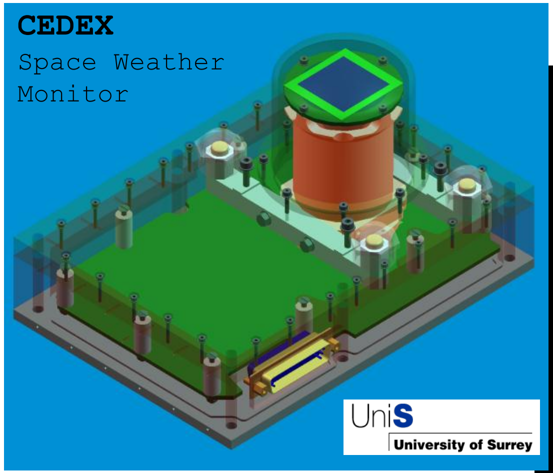
GALILEO TEST SATELLITES: GIOVE-A and GIOVE-B

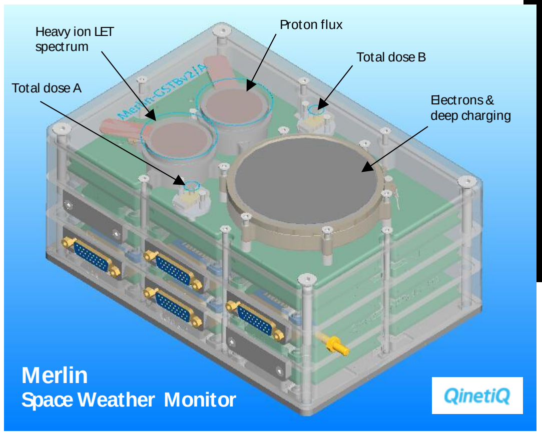
Launched on Dec 2005 (**GIOVE-A**) and April 2008 (**GIOVE-B**), these satellites have allowed to:

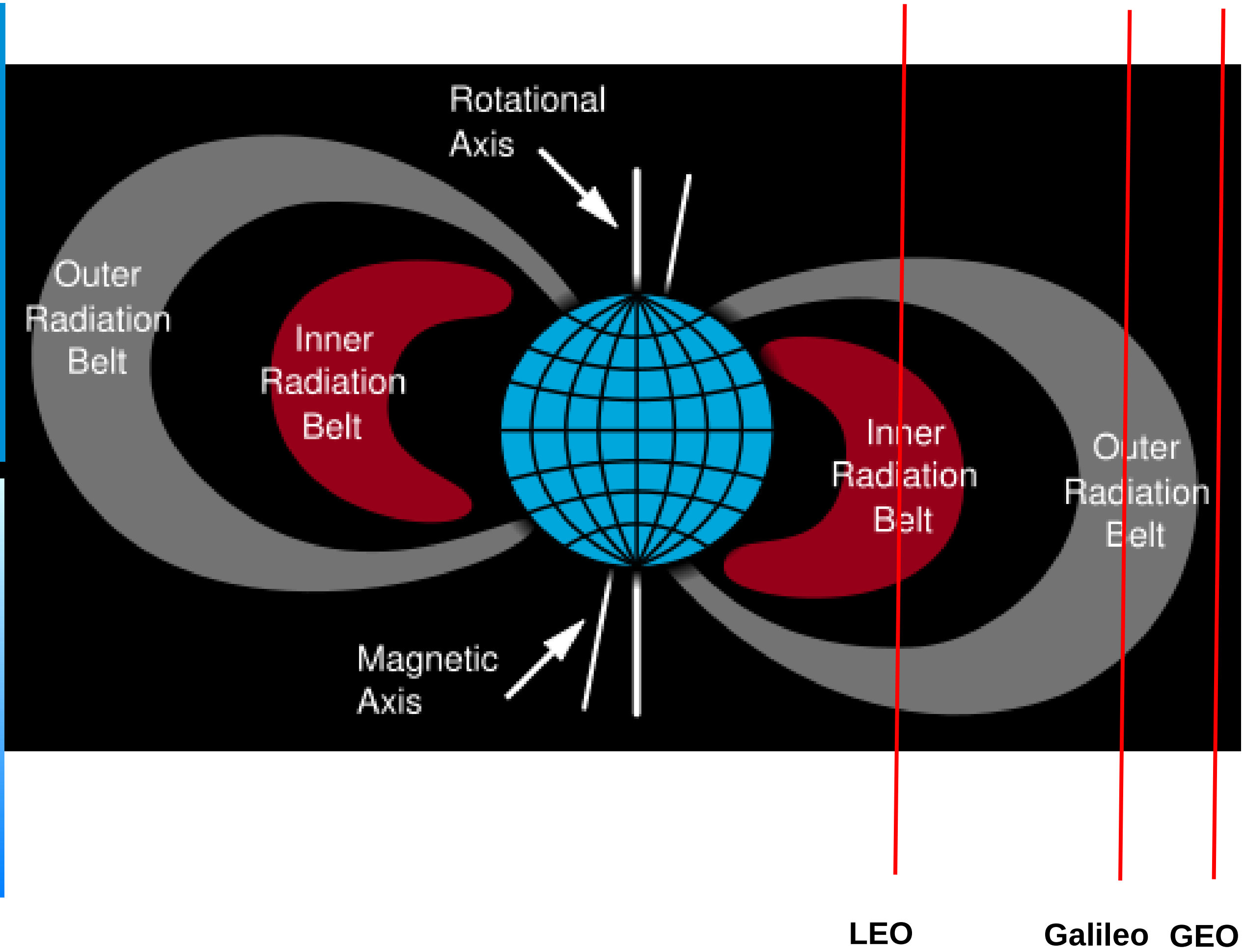
- Securing of Galileo frequencies (assigned at WRC 2000)
- MEO orbit characterisation;
- Flight-test new and critical on-board technologies:
    - Passive Hydrogen Maser atomic clock
    - On-board Galileo Signal generator
    - L-band Phased-array antenna

The GIOVE satellites have now finished their nominal operations and are moved to a graveyard orbit to avoid any disturbance to the operational Galileo satellites.

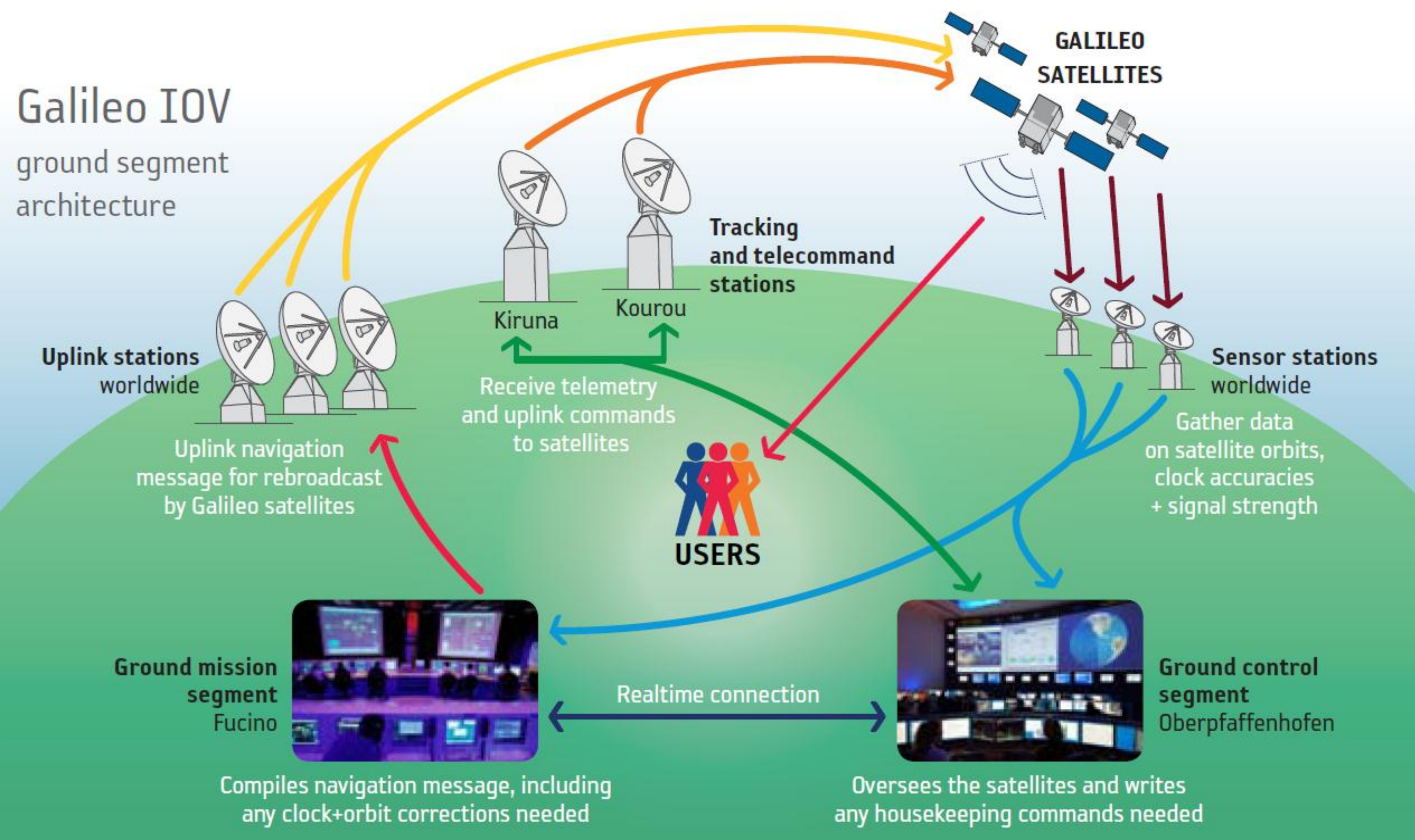
Galileo orbit and Radiation Belts



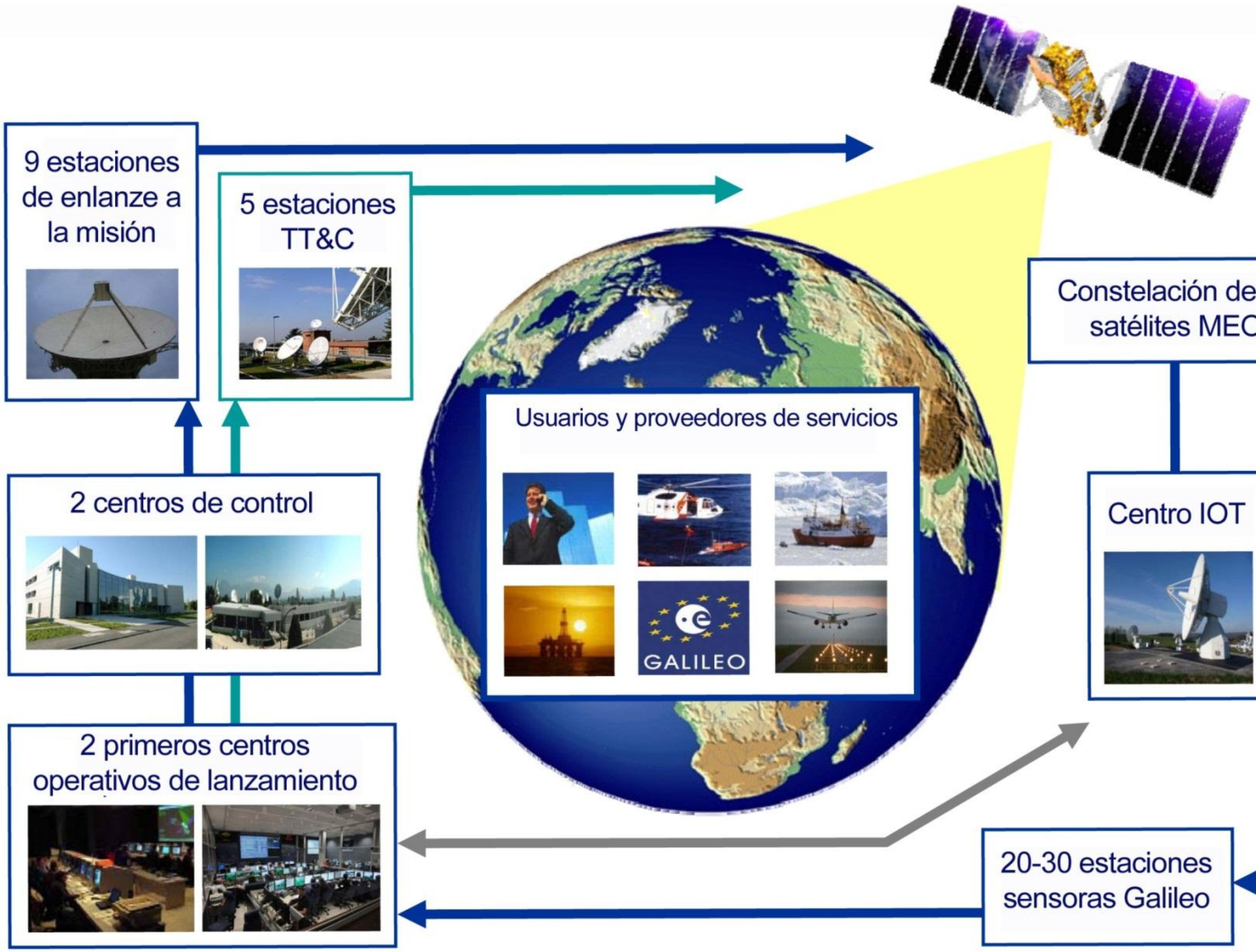




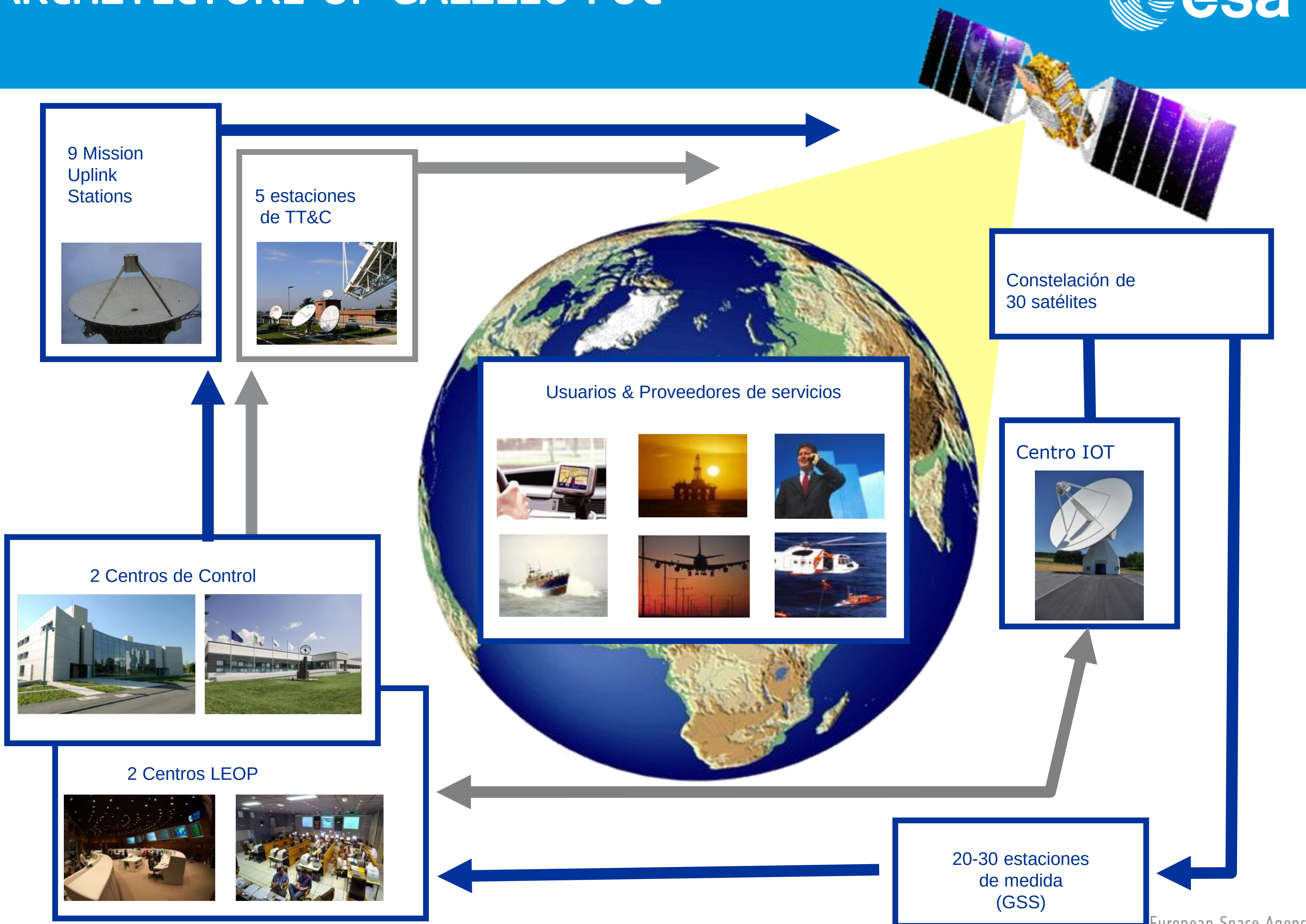
GALILEO In-Orbit validation (IOV) Phase Architecture



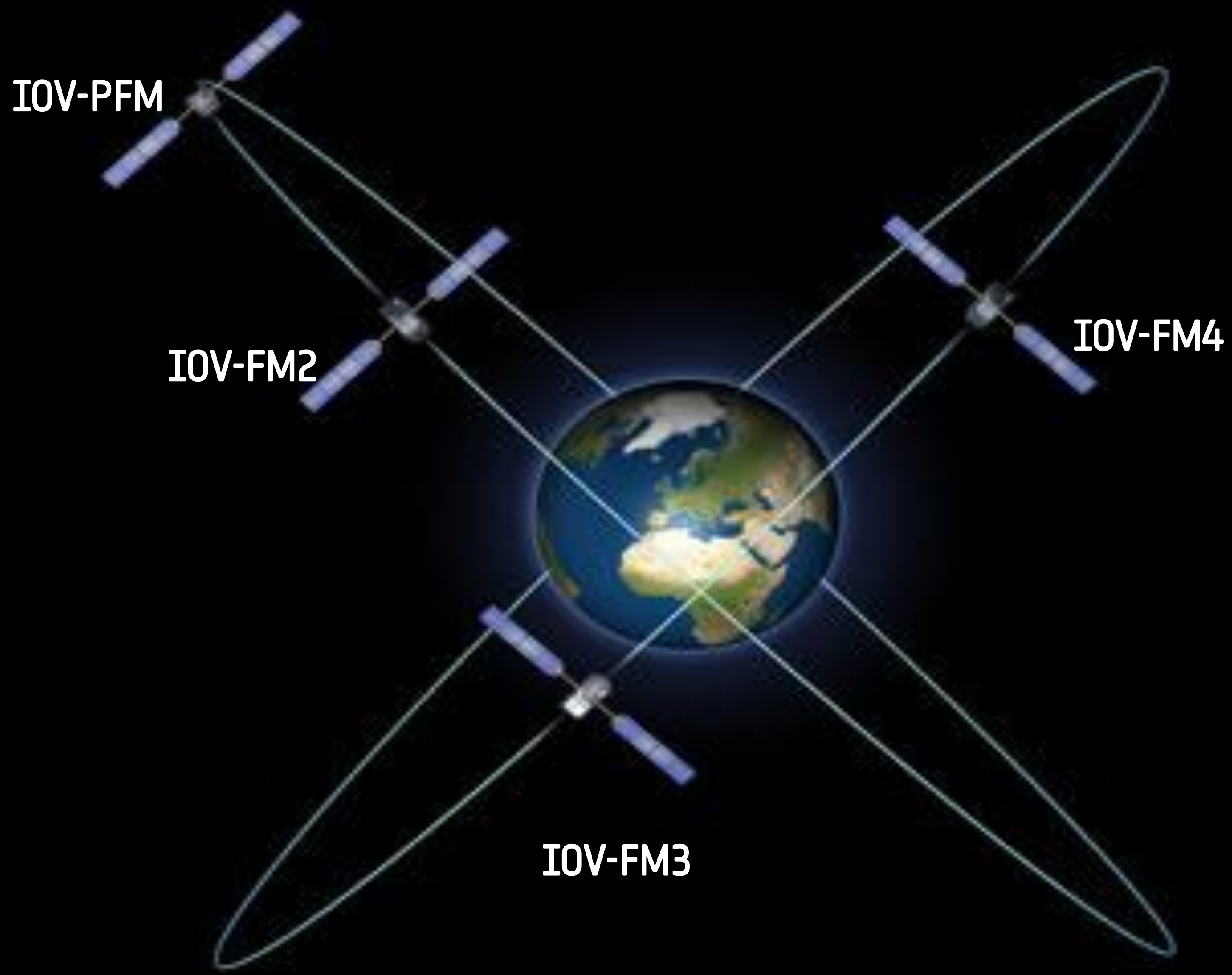
GALILEO FOC Architecture



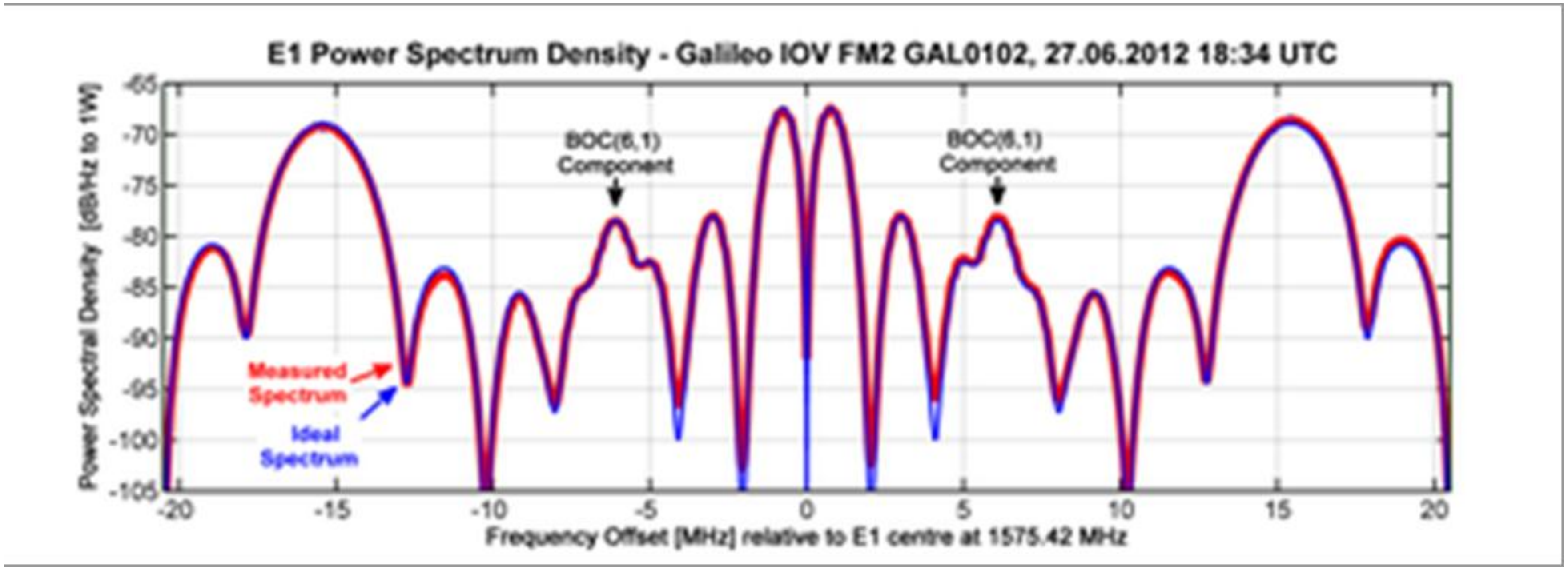
ARCHITECTURE OF GALILEO FOC



GALILEO IOV-1, IOV-2, IOV-3, IOV-4

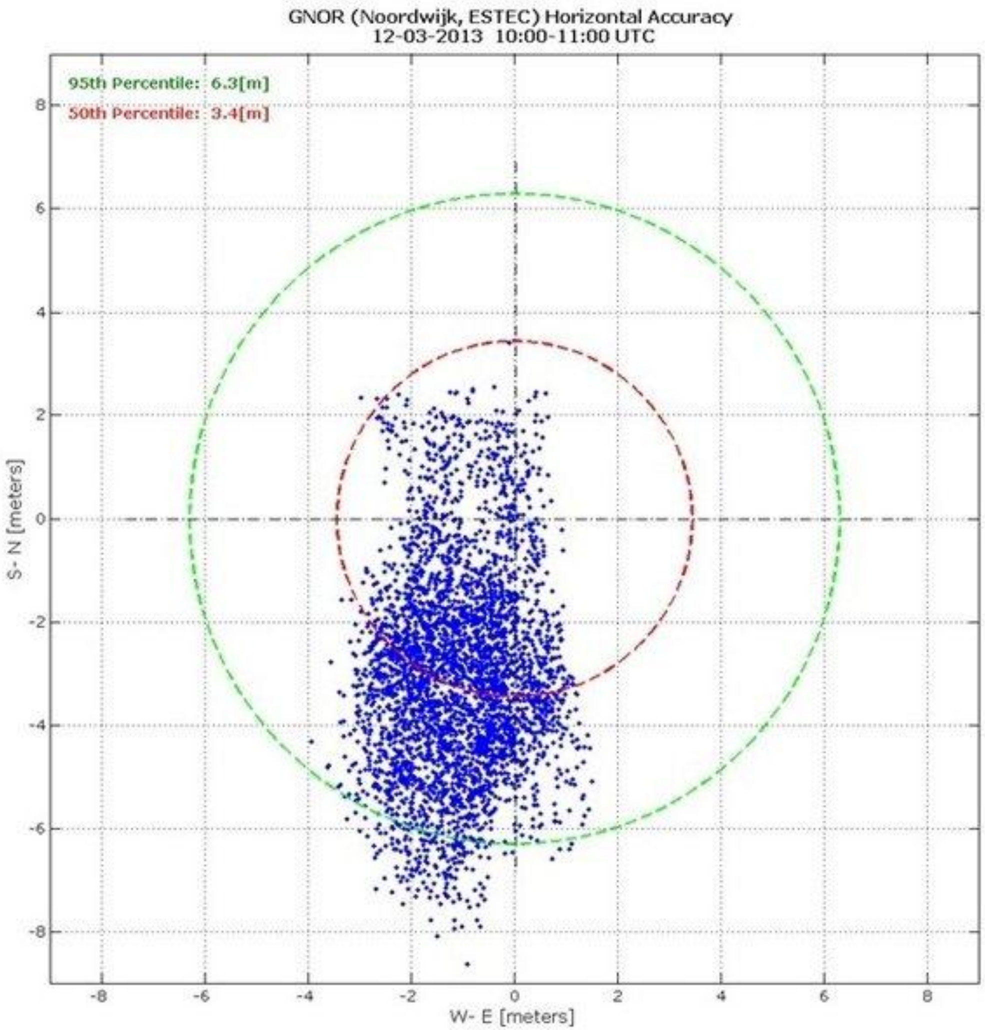


GALILEO CBOC E1 signal actually transmitted



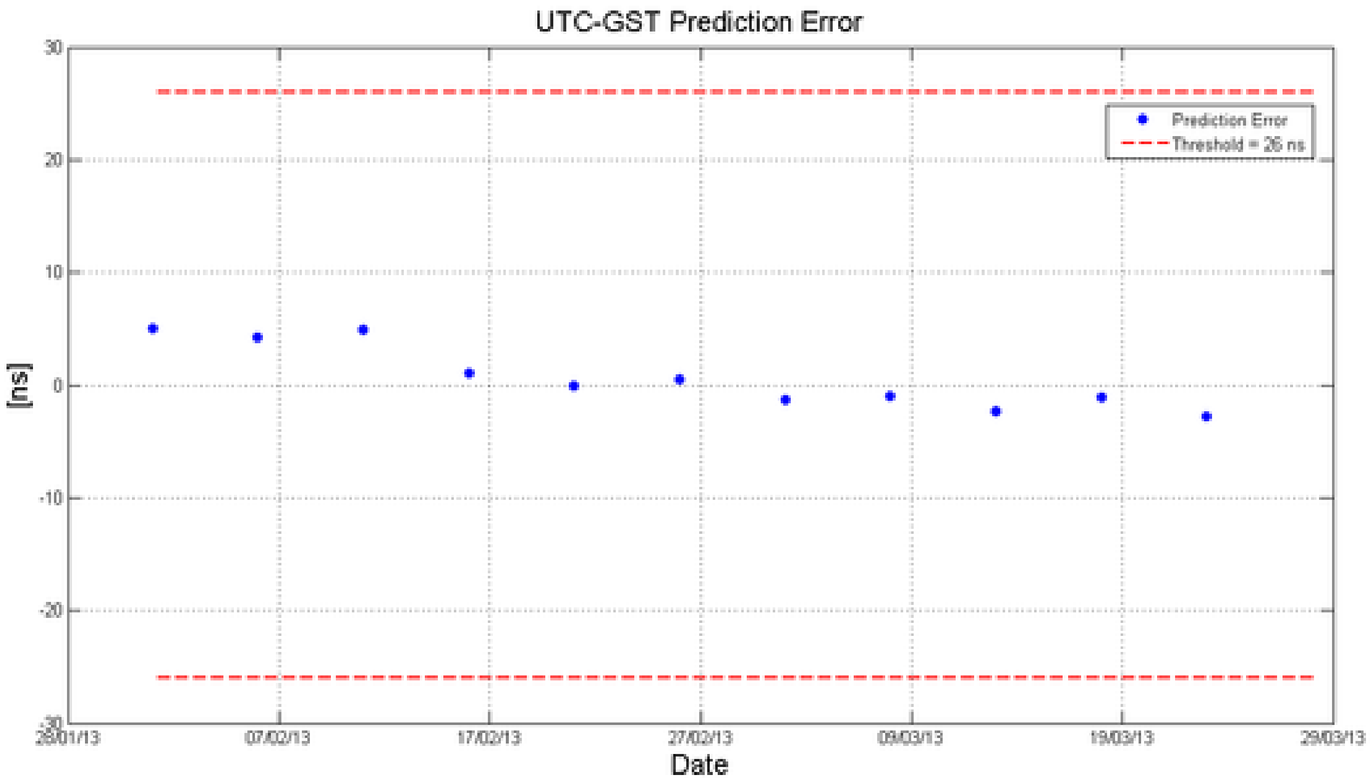
Detailed information at:
http://www.esa.int/esaNA/SEMDSAKXB4H_index_0.html

GALILEO FIRST EVER POSITION COMPUTATION !!
(12 March 2013)



Horizontal accuracy over ESTEC in Noordwijk, the Netherlands, of 6.3 m

GALILEO - UTC-time Offset first ever computation (April 2013)

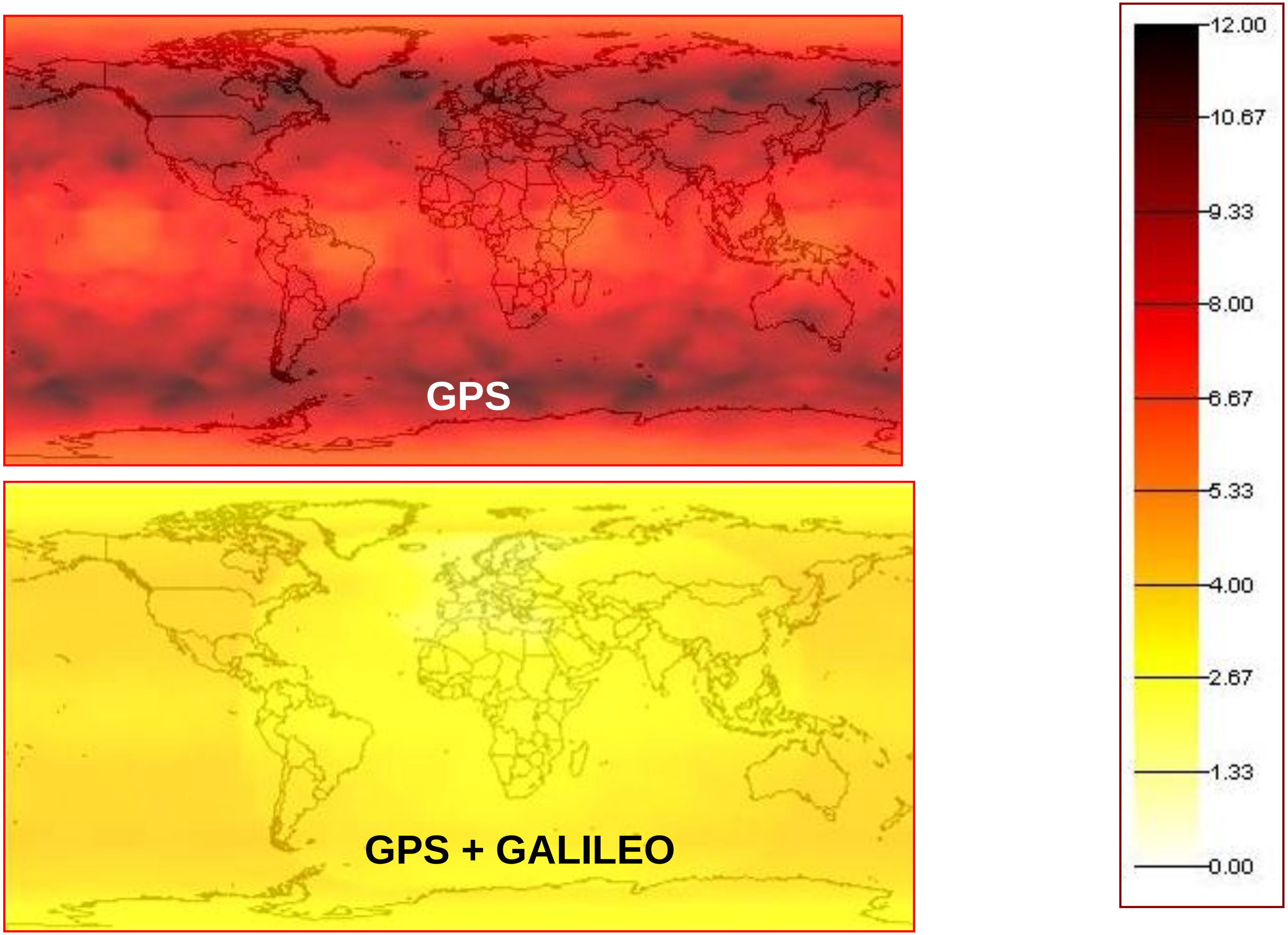


Galileo UTC's offset computed to be less than 6 ns !!

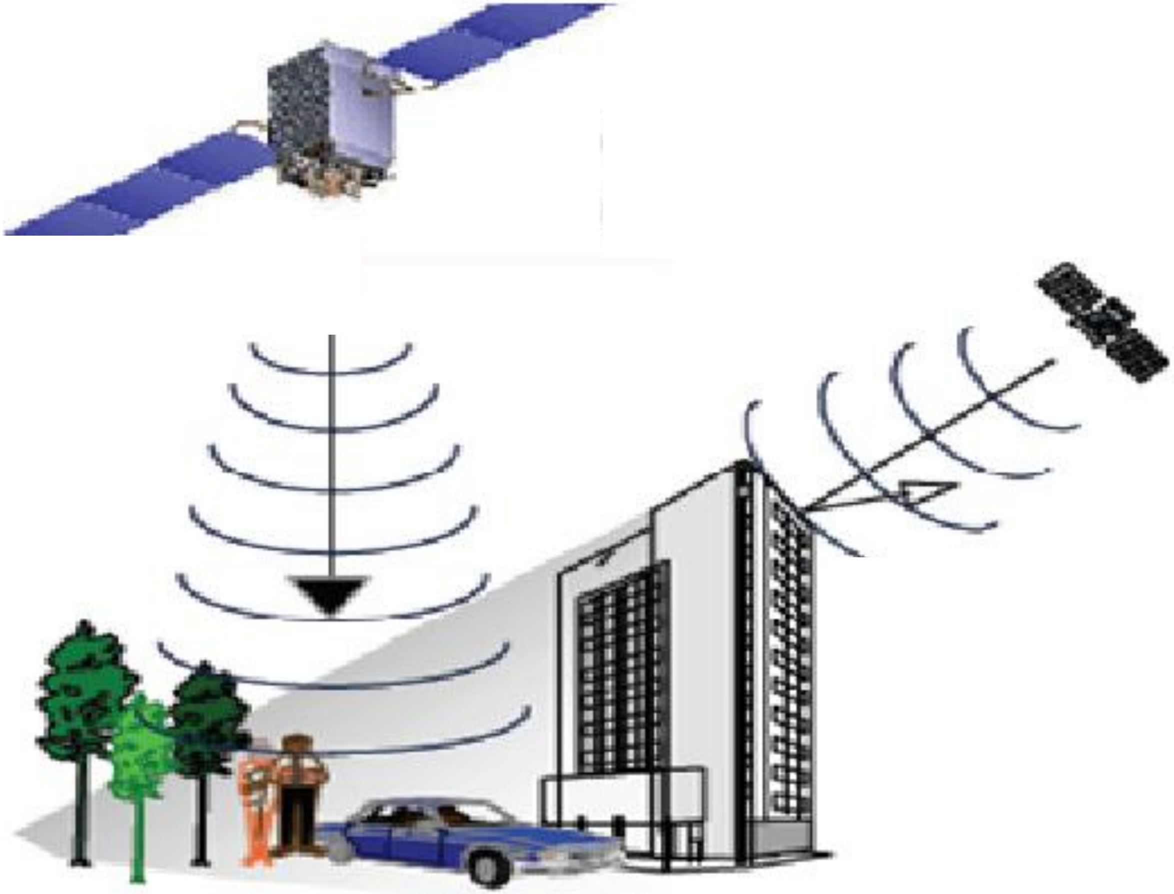
GALILEO – GPS time Offset (GGTO) computation (3 May 2013)

Excellent agreement between GGTO sent via the navigation message and actual offset:
A major step for Galileo-GPS inteoperability !!

INTEROPERABILITY GPS/GALILEO: JOINT USE



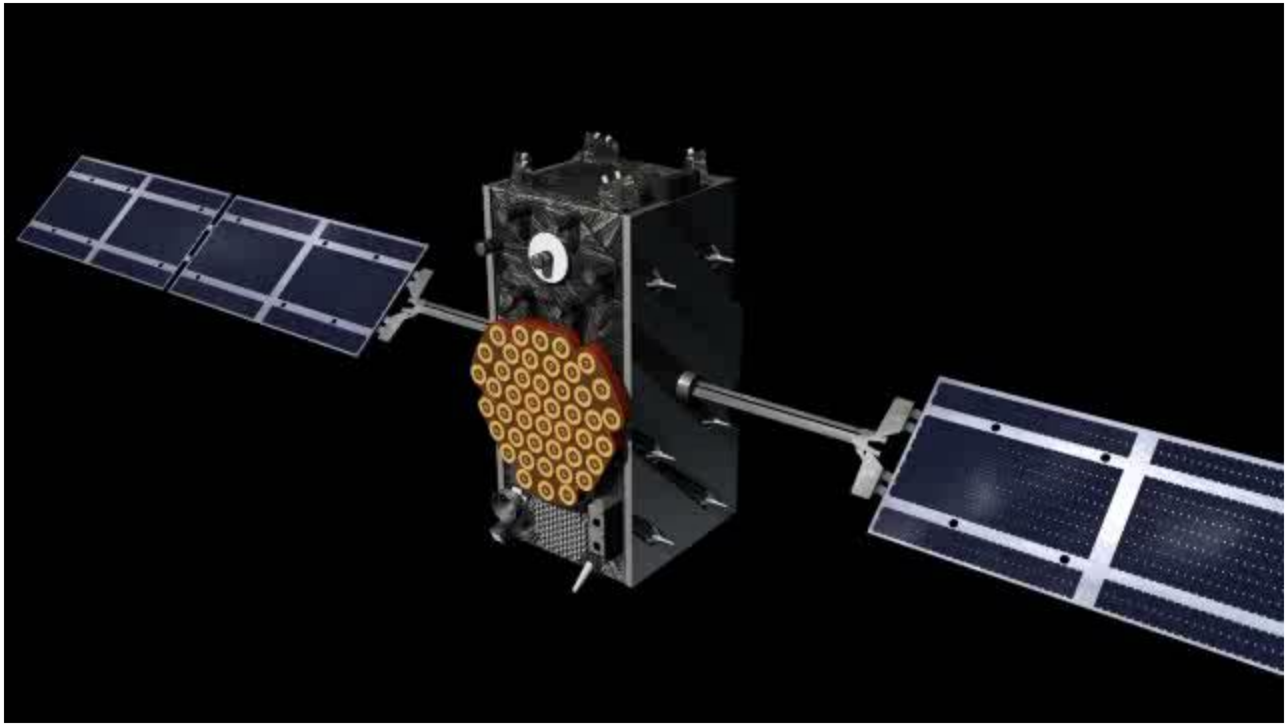
GPS/Galileo combined will significantly increase the availability of GNSS services in urban areas



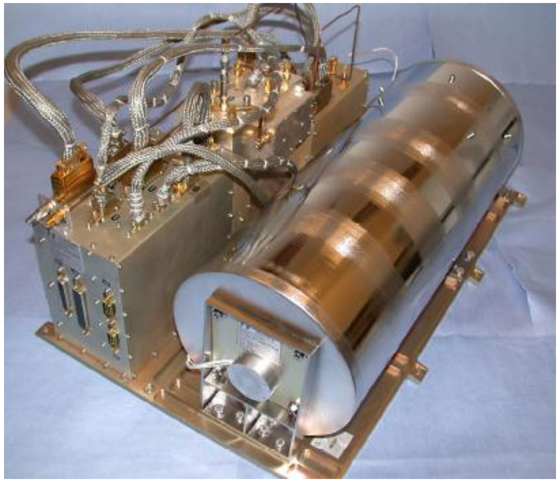
GALILEO IOV SATELLITES

Mass: 700 Kg Approx.
Dimensions: 2.74 x 14.5 x 1.59 m
Designed life time: > 12 years
Power:1420 W

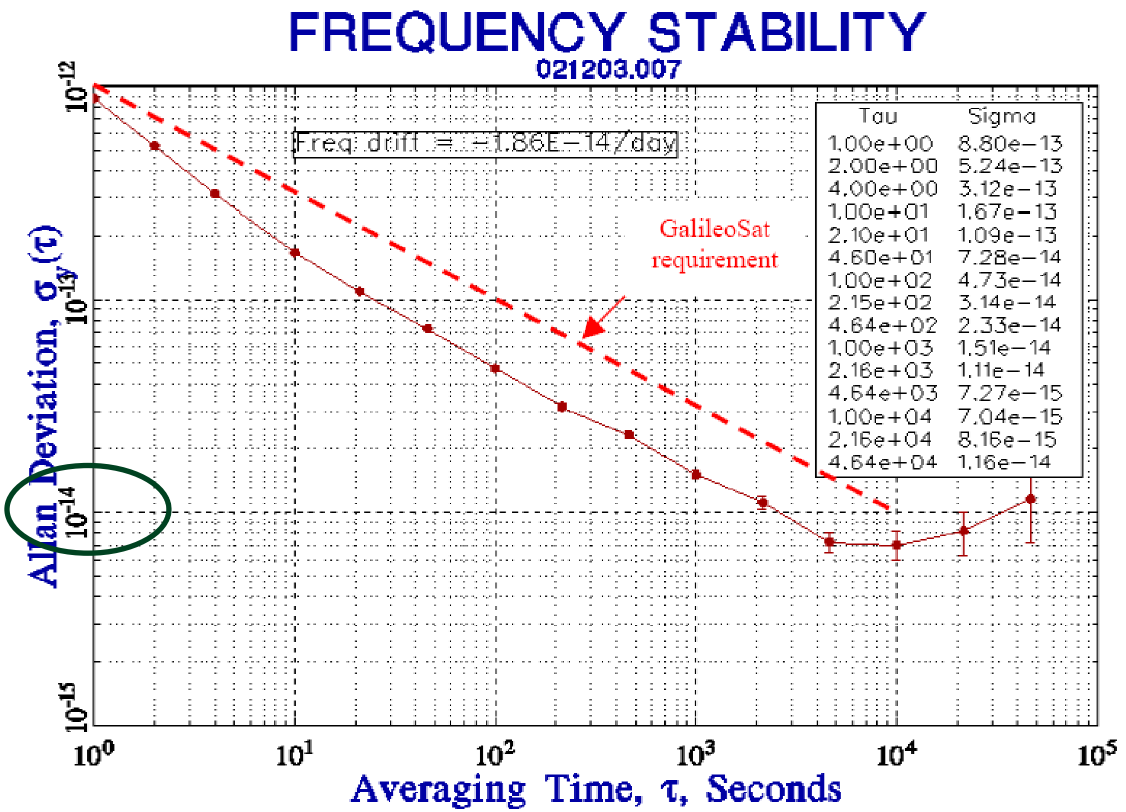
GALILEO IOV SATELLITES



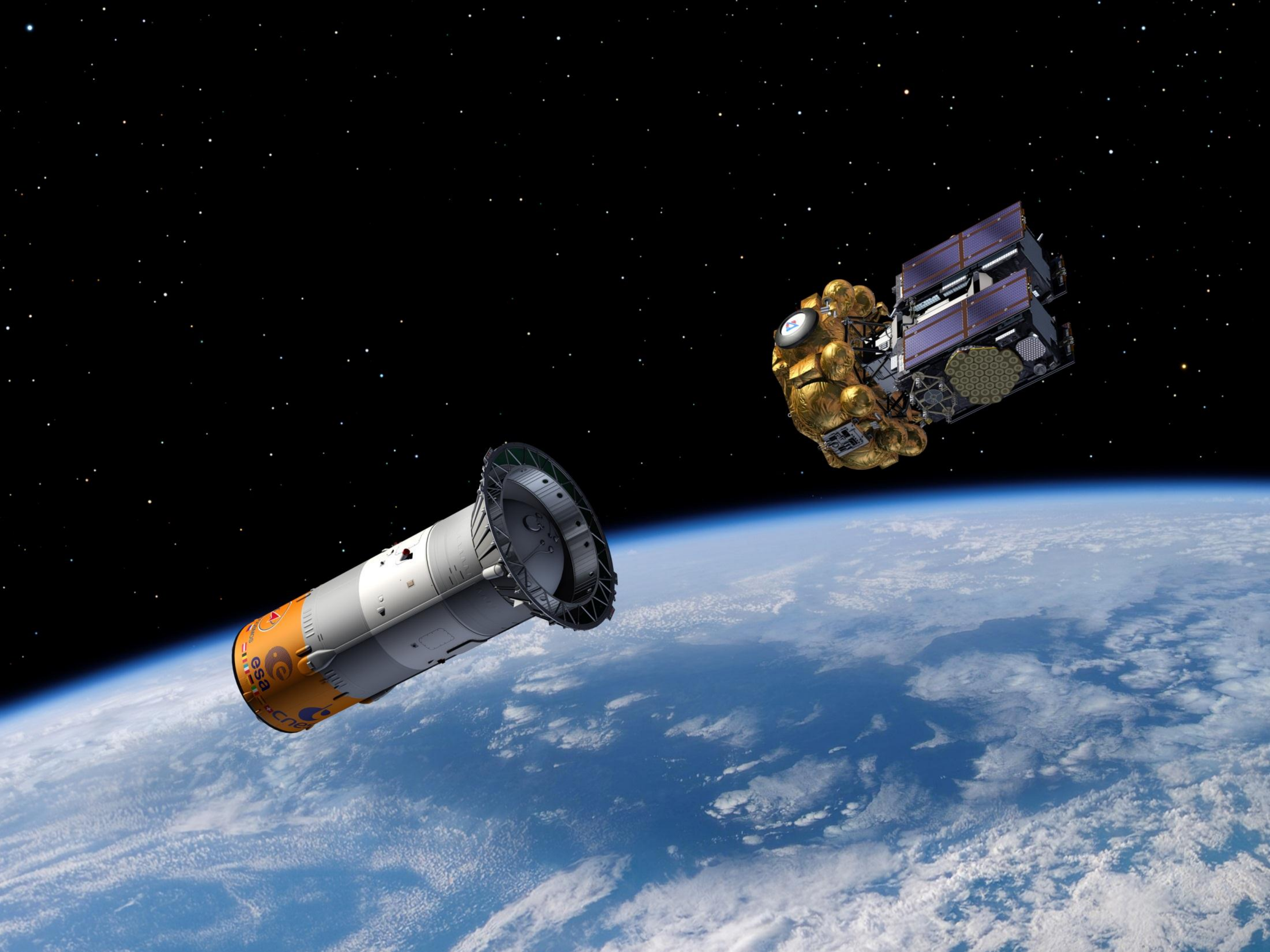
GALILEO IOV: Passive Hydrogen Maser Atomic Clock



With an accuracy of 0.45 nanoseconds over 12 hours, which translates into an accuracy of **one second in three million years !**

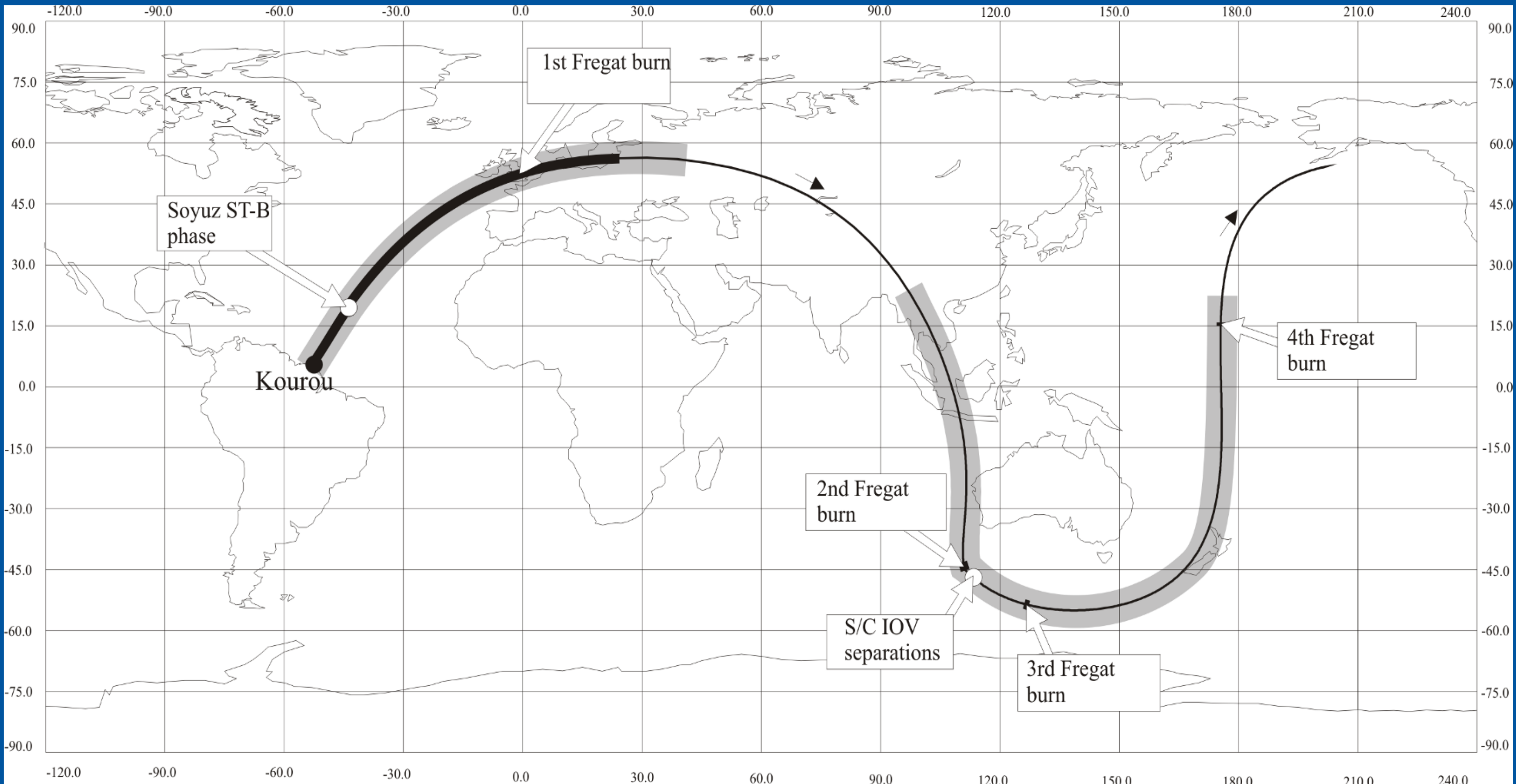


Tau	Sigma
1.00e+00	8.80e-13
2.00e+00	5.24e-13
4.00e+00	3.12e-13
1.00e+01	1.67e-13
2.10e+01	1.09e-13
4.60e+01	7.28e-14
1.00e+02	4.73e-14
2.15e+02	3.14e-14
4.64e+02	2.33e-14
1.00e+03	1.51e-14
2.16e+03	1.11e-14
4.64e+03	7.27e-15
1.00e+04	7.04e-15
2.16e+04	8.16e-15
4.64e+04	1.16e-14


esa

SOYUZ 2-1B Galileo launch ground track

esa

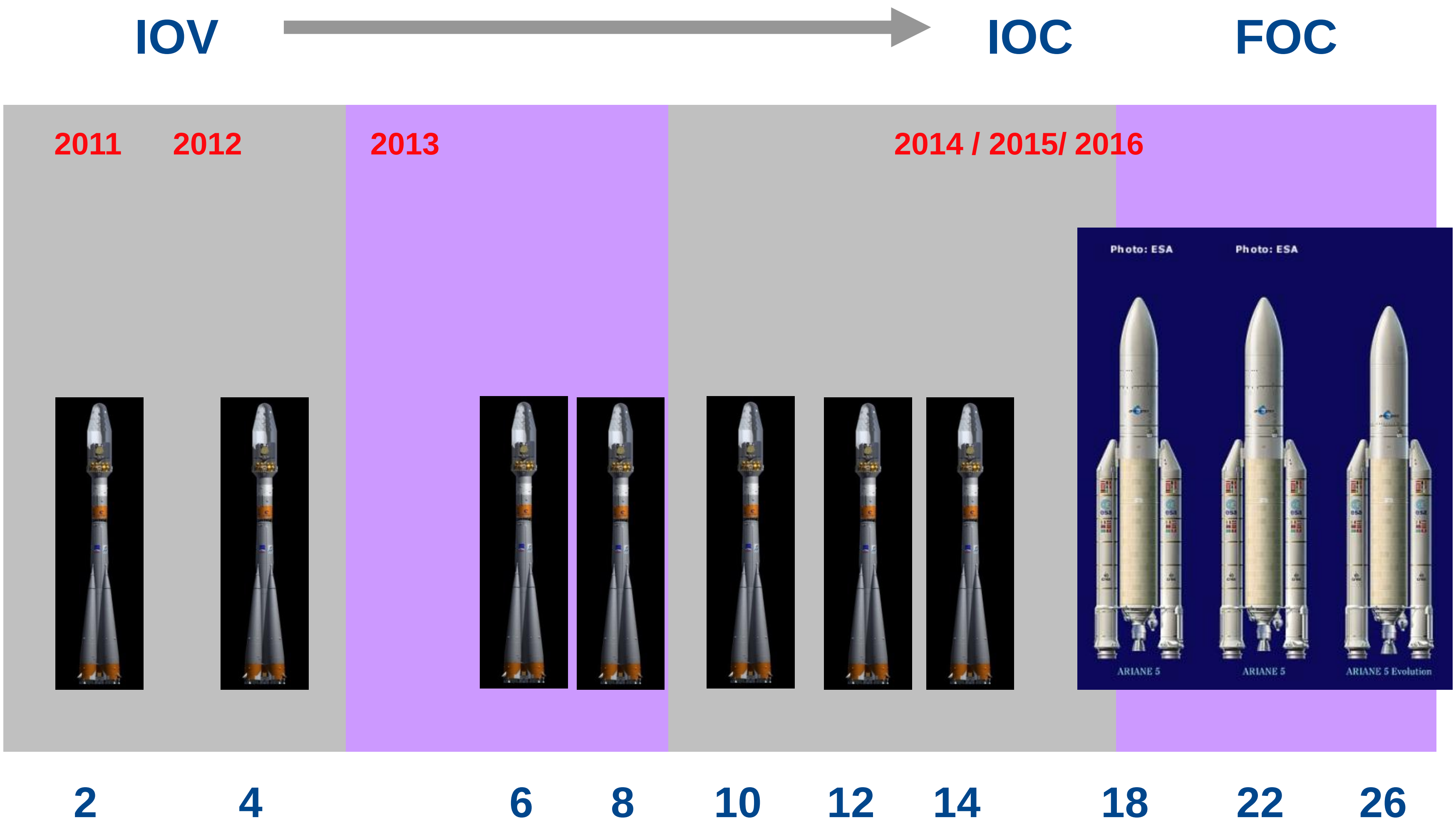


- Visibility of ground tracking stations


esa
esoc

REDU Station – Galileo IOT

GALILEO DEPLOYMENT PLAN

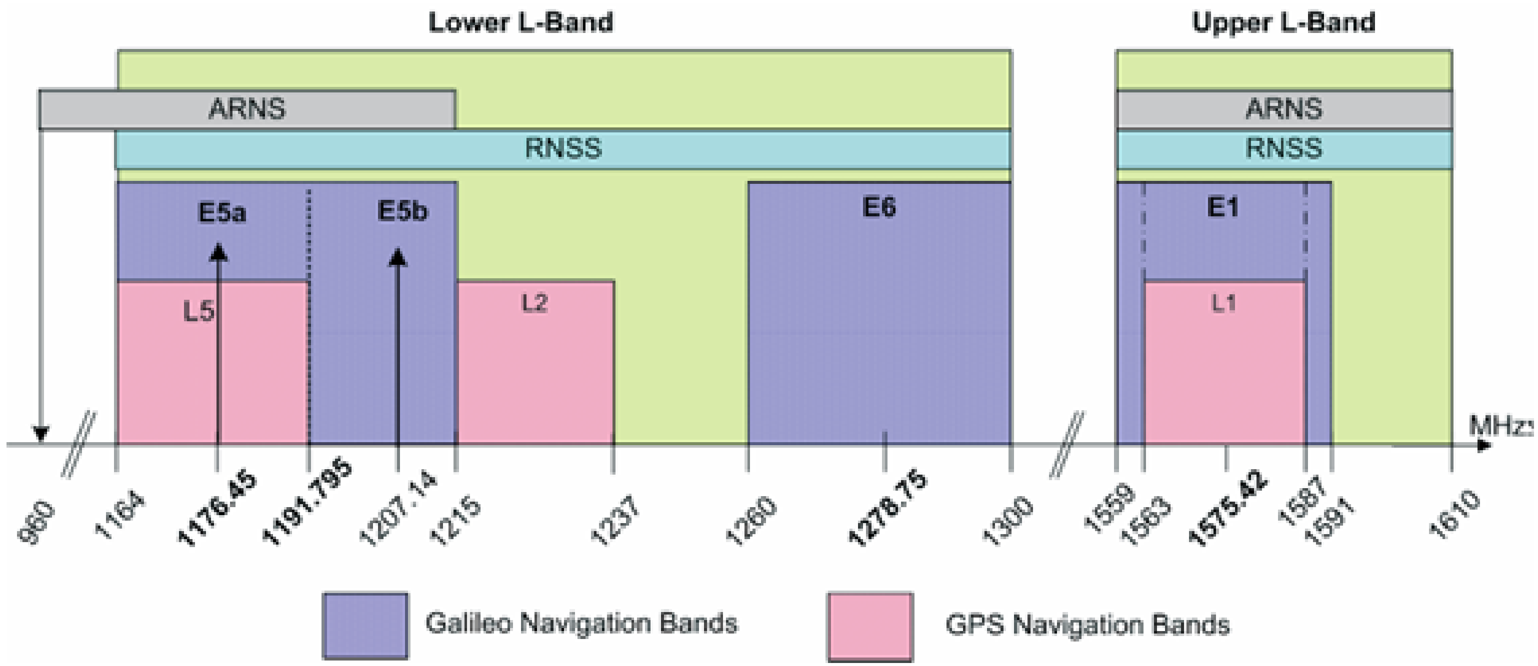


GALILEO SERVICES

Open Service	Free to air; Mass market; Simple positioning	
Commercial Service	Encrypted; High accuracy; Guaranteed service	
Safety of Life Service	Open Service + Integrity of signal	
Public Regulated Service	Encrypted; Continuous availability	
Search and Rescue Service	Near real-time; Precise; Return link feasible	

Services offered from 2015 (FOC-1 or IOC)

Galileo Frequencies and Signals



Each Galileo satellite will transmit a total of **10 satellite Navigation signals** covering through then all the GALILEO services.

Galileo is also transmitting novel signals – delivering increased robustness against interference or jamming – which have never been used before, by any navigation system

GALILEO OPEN SERVICE ICD

- ESA and the GSA have produced the Galileo open Service Signal in Space ICD and made that available on the web (http://www.gsa.europa.eu/)
- This document provides an overview of the Galileo system, the signal-in-space radio frequency characteristics, the characteristics of the spreading codes, the message structures and the characteristics of the navigation message data contents.
- It specifies the interface between the Galileo space segment and the Galileo user segment (issue 1, Revision 1, Sept. 2012)

COMPASS

COMPASS / BEIDOU

COMPASS/BEIDOU is the Chinese GNSS global/regional system consisting of:

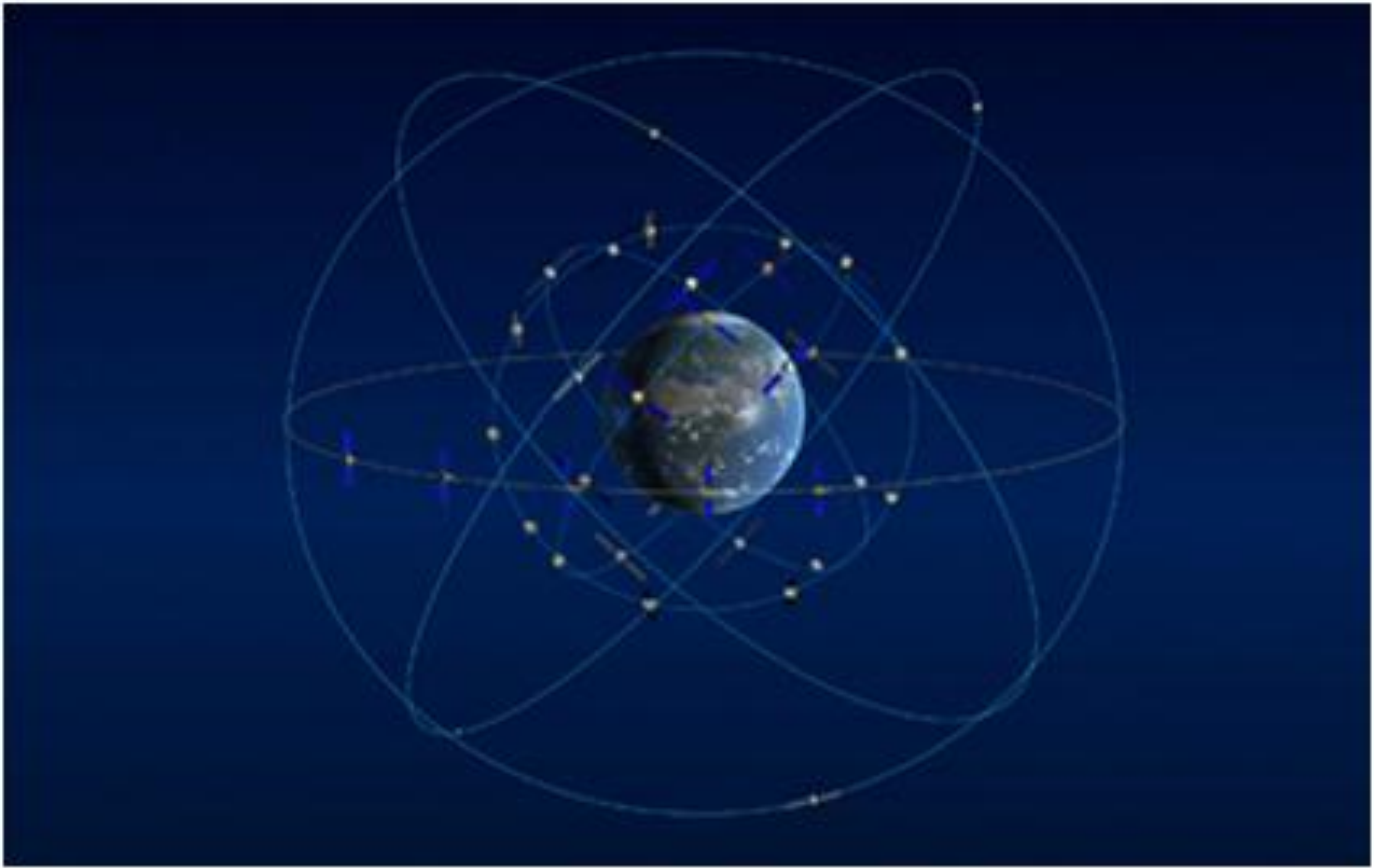
- Constellation of **35 satellites** (27MEO, 5 GEO, 3 IGSO), offering complete worldwide coverage and enhanced regional (on China)
- **Ranging signals based on the CDMA**, similar to Galileo or modernized GPS
- **16 Beidou/Compass satellites have been launched so far (May 2013)**.
- Global Open service (~10 meter accuracy) and authorised service to be provided.
- Operations started in 2012 (for Regional China service) and will be provided around 2020 for the Global worldwide service.

COMPASS Constellation

Orbit parmts.	GEO	IGSO	MEO
Semi-Major Axis (Km)	42164	42164	27878
Eccentricity	0	0	0
Inclination (deg)	0	55	55
RAAN (deg)	158.75E, 180E, 210.5E, 240E,260E	218E,98E,338E	
Argument Perigee	0	0	--
Mean anomaly (deg)	0	218E:0,98E:120,338E:240	
# Sats	5	3	27
# Planes	1	3	3

Final Compass constellation

COMPASS Navigation Satellite System



COMPASS / Beidou-2

Constellation status (Oct. 2012)

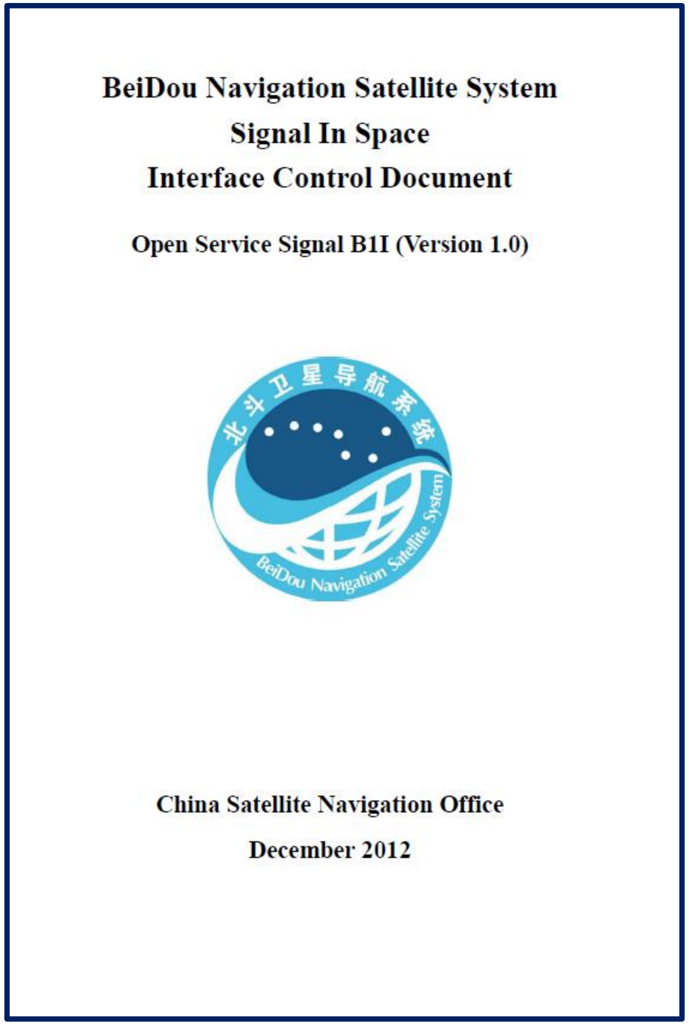
Mission	Date[41]	Name	Launch site	Launch vehicle	Bus	Orbit
07-32	2007-04-13	Compass-M1	Xichang	CZ-3C	DFH-3	MEO ~21,500 km
07-37	2009-04-14	Compass-G2	Xichang	CZ-3C	DFH-3	GEO drifting
07–38	2010-01-16	Compass-G1	Xichang	CZ-3C	DFH-3	GEO 144.5°E
07-39	2010-06-02	Compass-G3	Xichang	CZ-3C	DFH-3	GEO 84.0°E
07-40	2010-07-31	Compass-IGSO1	Xichang	CZ-3A	DFH-3	HEO ~36,000 km
07-43	2010-10-31	Compass-G4	Xichang	CZ-3C	DFH-3	GEO 160.0°E
07-45	2010-12-17	Compass-IGSO2	Xichang	CZ-3A	DFH-3	HEO ~36,000 km
07-46	2011-04-10	Compass-IGSO3	Xichang	CZ-3A	DFH-3	HEO ~36,000 km
07-49	2011-07-27	Compass-IGSO4	Xichang	CZ-3A	DFH-3	HEO ~36,000 km
07-51	2011-12-01	Compass-IGSO5	Xichang	CZ-3A	DFH-3	HEO ~36,000 km
07-53	2012-02-24	Compass-G5	Xichang	CZ-3C	DFH-3	GEO 60.0°E
07-54	2012-04-29	Compass-M3 Compass-M4	Xichang	CZ-3B	DFH-3B	–
–	2012-09-18	Compass-M5 Compass-M6	Xichang	CZ-3B	–	MEO

LONG-March 3 B last launch of BEIDOU Satellites
XiChang Satellite Launch Centre, Sept 18 2012

BEIODU ICD JUST RELEASED (DEC 2012)

- BeiDou Navigation Satellite System (BDS) Interface Control Document, Version 1.0 released in December 2012

- This ICD defines the specification related to open service signal B1I between the space segment and the user segment of the BeiDou Navigation Satellite System.



BeiDou Navigation Satellite System

Signal In Space

Interface Control Document

Open Service Signal B1I (Version 1.0)

China Satellite Navigation Office

December 2012

LECTURE OUTLINE

1. The importance of GNSS (10’)

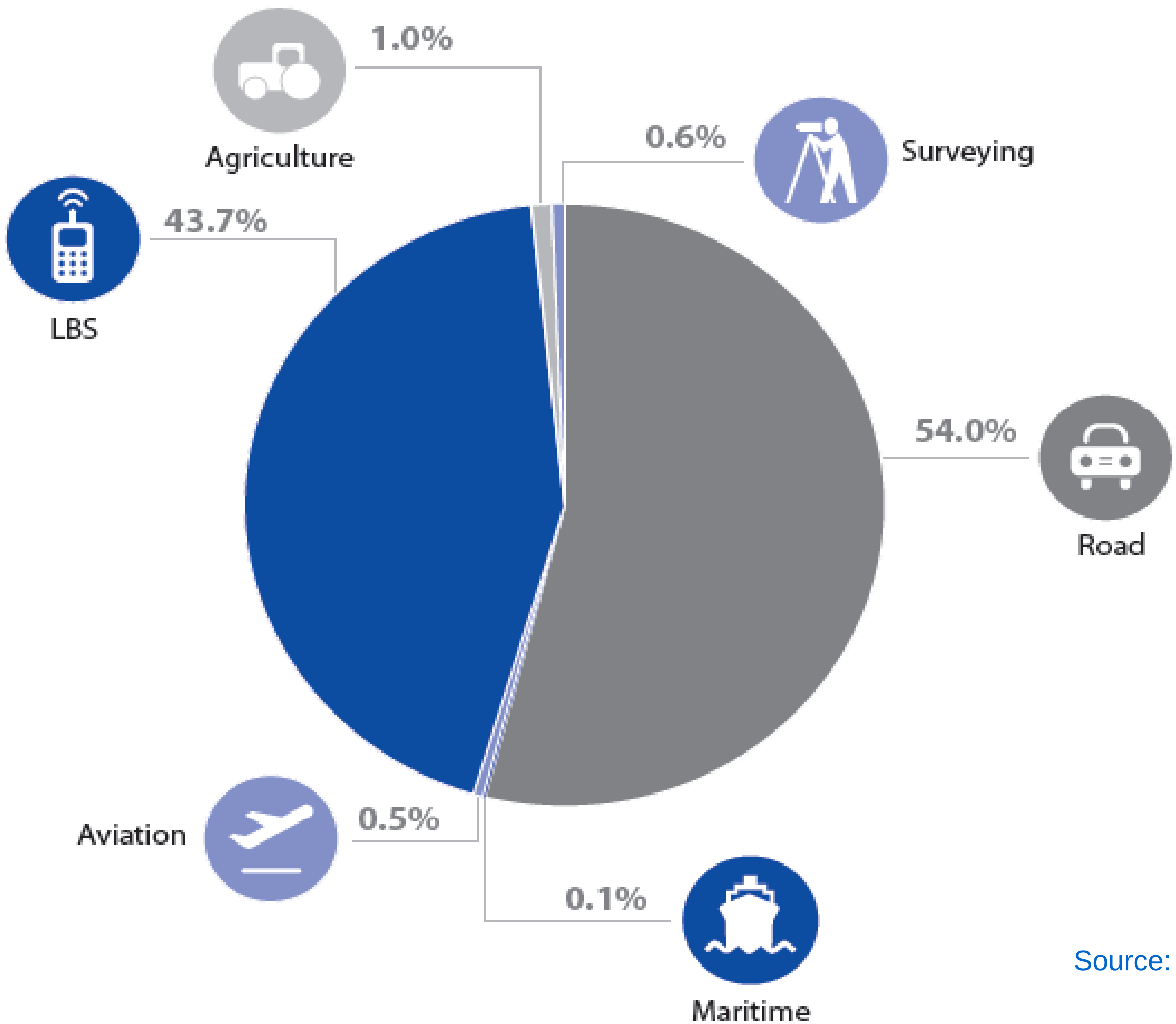
2. Overview of GNSS Global Systems (30’)
   - GPS
   - Glonass
   - Galileo
   - COMPASS

3. **GNSS Applications and the Galileo Service Centre (5’)**

TOTAL : 45’ (letting 15’ for discussion)

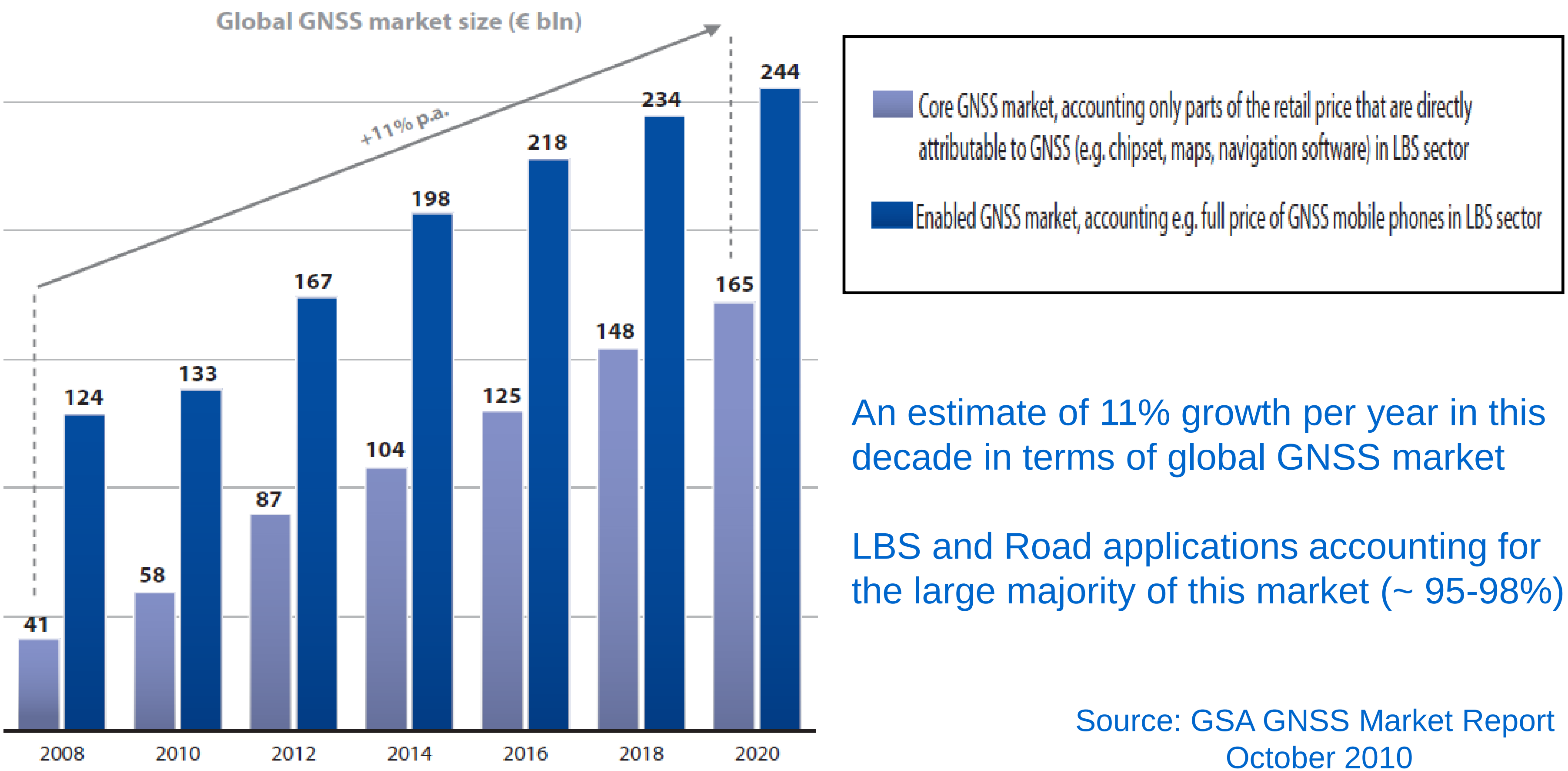
GNSS is a major application and service enabler

GNSS Market by Segment



Source: GSA GNSS Market Report
May 2012

Global GNSS Market forecast



An estimate of 11% growth per year in this decade in terms of global GNSS market

LBS and Road applications accounting for the large majority of this market (~ 95-98%)

Source: GSA GNSS Market Report October 2010

Road Applications

- Car Navigation and all associated applications (specially when linked with Internet)
- Automatic Road Tolling (towards a pan-European system)
- *Advance Driver Assistance Services, (ADAS)*
- Insurances: *Pay Per Use*
- Fleet management and public transport services (tracks, dangerous goods transportation, taxi services, information to users) ...

Aviation

- During en-route flight, the availability of 2 or more GNSS constellations will ensure high robustness through the redundancy and high reliability of the service.

- Some of the benefits of GNSS are:

  - Use in all the flight phases of commercial aircraft including critical flight phases.

  - Routes optimisation / less congestion (free flight)

  - Surface movement and guidance control

  - Helicopters (e.g. search and rescue helicopters)

  - Lower airlines cost

Maritime applications and fishering

- *Automatic Identification Services*
- Harbour operations
- Inland waterways navigation
- Commercial maritime operations (fishing; fleet management; location of containers; etc)
- Location and tracking of boats transporting dangerous goods
- improved navigation aids for fishermen (e.g. location of nets; etc)
- Search & Rescue service

Agriculture

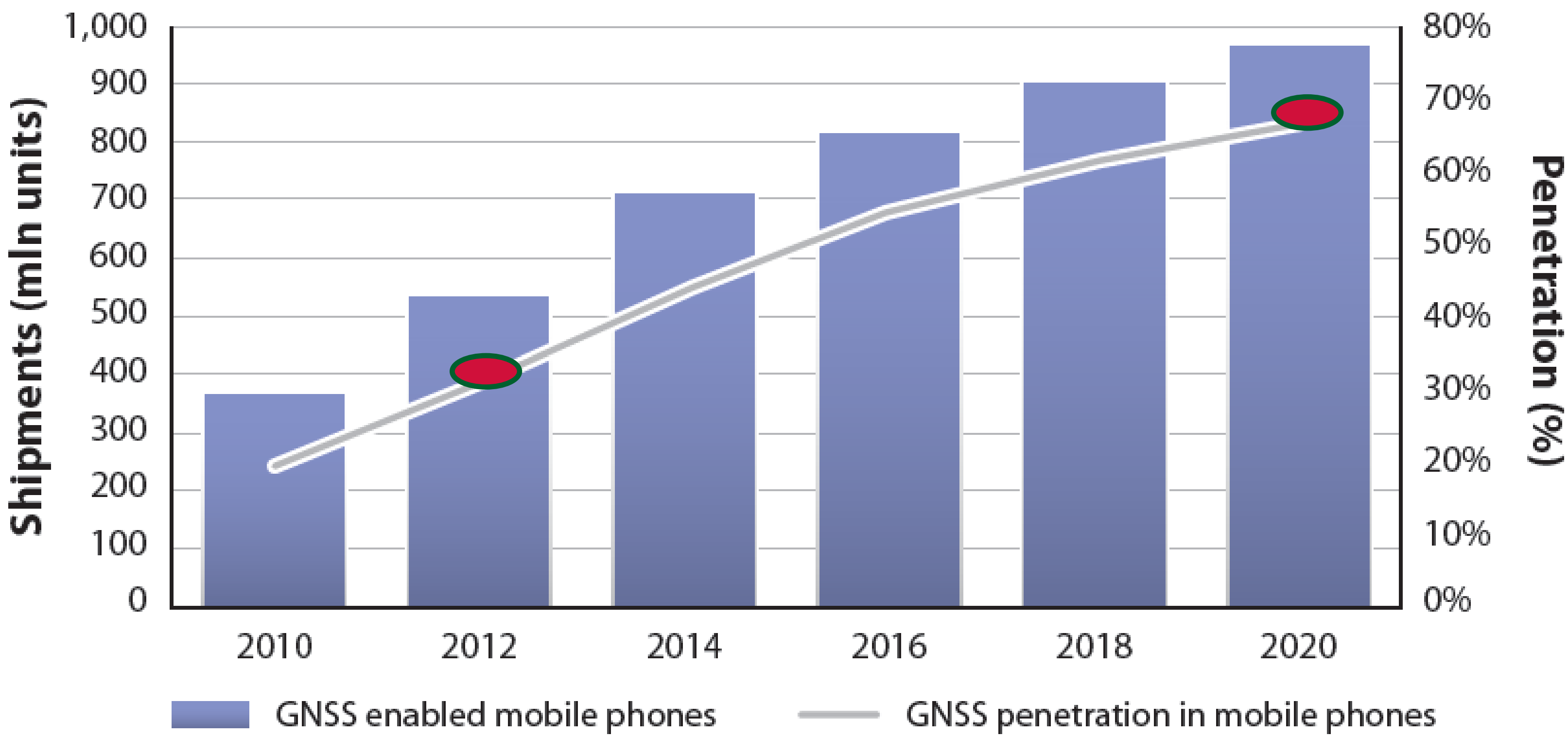
- In the European Union there are about 11 million agricultures that cultivate about 110 million hectares.

- Precise farming
  - improved monitoring of the distribution and dilution of chemicals
  - Crop yield monitoring

- Parcels measurement

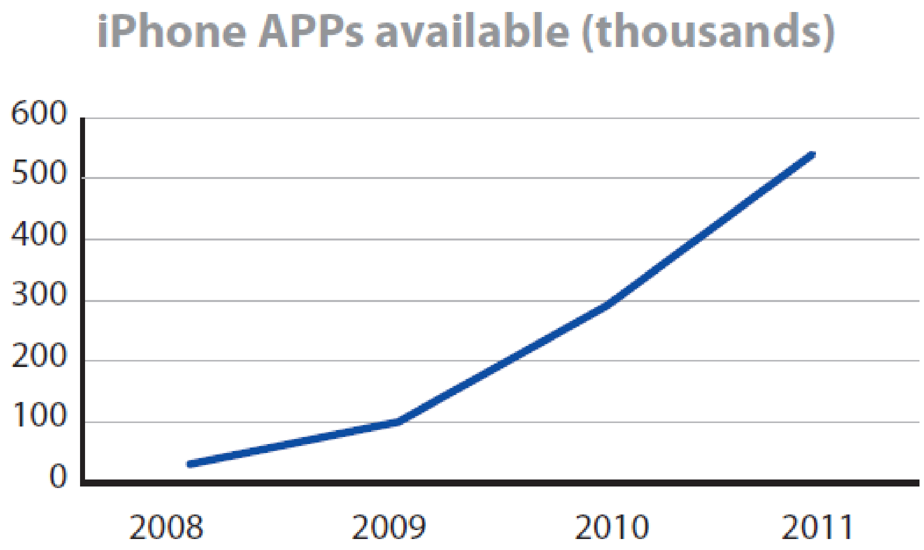
- …

GNSS-enable mobile phone: forecast up to 2020



Source: GSA GNSS Market Report
May 2012

GNSS and LBS



Source of data: http://148apps.biz/app-store-metrics

More than 30% of all APPs have access location capability

Some of the GNSS/mobile integration technology trends:

- Assisted GPS to reduce Time to First Fix
- Multi-constellation
- Highly sensitive GNSS chipset
- Wi-Fi, cellular and hybrid positioning as back-up
- Magnetic compass
- Use of Motion sensors and gyroscopes for tilt
- Integration with indoor navigation

GNSS Scientific applications

GNSS Science Activities include (non exhaustive list) the following:

Earth Sciences

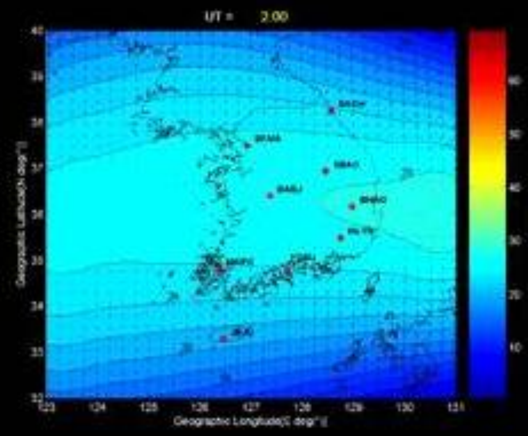
Geodesy
Geodynamics
Global Tectonics
Reference Frames
Ionosphere and space weather
Troposphere
Atmospheric tomography
Earthquakes
Gravity field
Remote sensing of Earth /Ocean
GNSS reflectometry

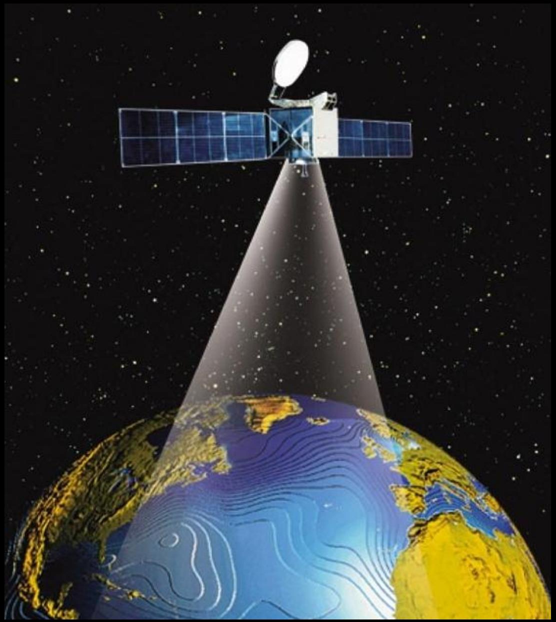
Physics

Space-Time symmetries
Fundamental constants
Relativistic reference frames
Equivalence Principle
General Relativity
Astrometry, VLBI, Pulsar Timing
Atomic physics for clocks
Astronomy and GNSS
Quantum non-locality and Decoherence

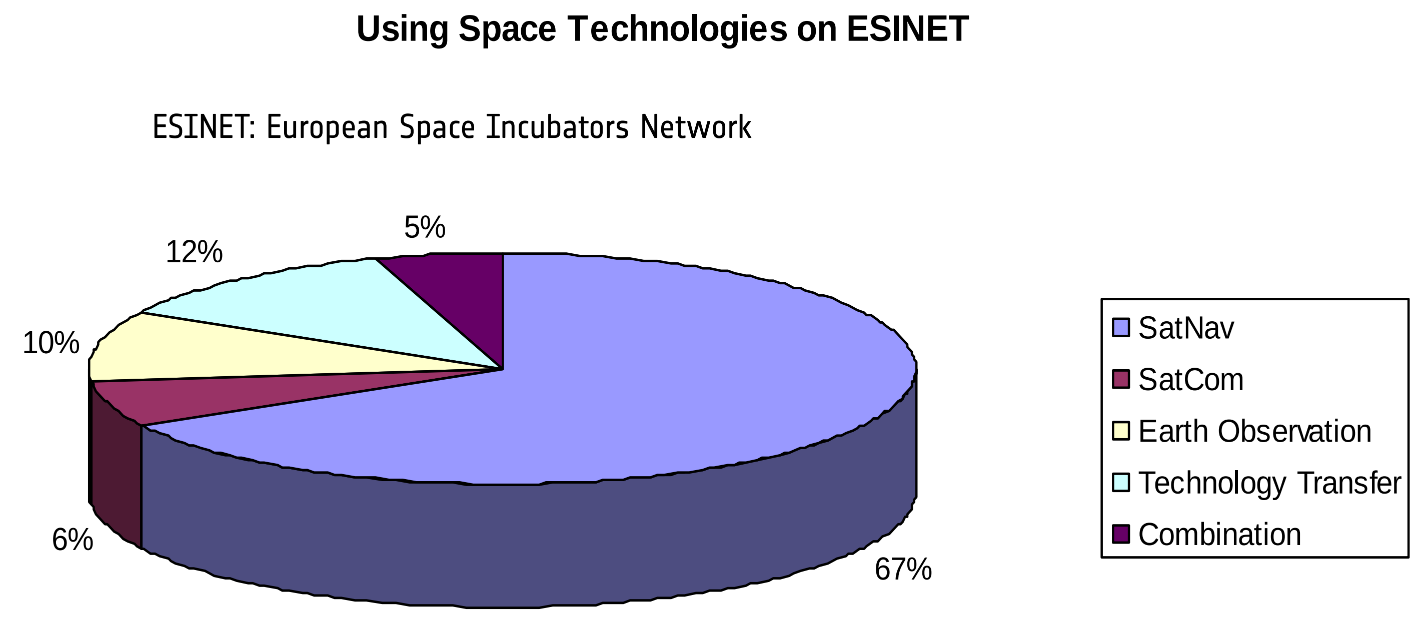
Metrology

Atomic Clocks (Optical and Maser)
Galileo timing system
Time scales and offsets
Inter-satellite links
Precise Orbit determination
Signal propagation aspects





GNSS a source of start-ups: ESINET Observatory



67% of all ESA ESINET new start-up companies are based on the use of GNSS Technologies and Applications,

Simple GNSS Applications may have a major Impact in our Society

Allows a saving, in average, of 15-25% in fuel!

GALILEO SERVICE CENTRE “LOYOLA DE PALACIO”– TORREJON (MADRID)
Formally inaugurated on 14th May 2013

GALILEO SERVICE CENTRE (GSC) "LOYOLA DE PALACIO"– TORREJON (MADRID)

SCOPE OF ACTIVITIES

- The European GNSS Service Centre (GSC), operated by the European GNSS Agency (GSA), will act as **an interface between the Galileo navigation system and user communities** for the open and commercial services.
- The **GSC's objectives** are to:

1. Provide companies and users with general information on Galileo: provide basic services to the user community via a web portal and a **user helpdesk**.
2. **Distribute timely Galileo service notices**: information on the system, system status and user notifications.
3. **Support service provision**: sharing of R&D and industry knowledge by market segment.
4. Provide up-to-date **information on Galileo programme status**
5. **Provide support to application and product developers** including access to market experts in key segments.

The GSC will employ between 35 and 50 highly skilled workers

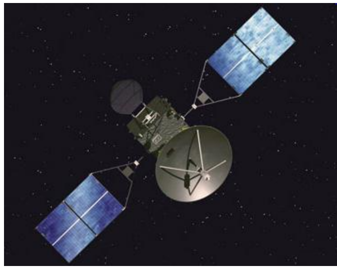
SUMMARY

- Satellite Navigation is probably **the space application sector with highest growing potential** in terms of systems, emerging applications and market opportunities (about 700 million GPS receivers worldwide today).

- On-going GNSS System initiatives today include: Modernised GPS, modernised GLONASS, GALILEO, COMPASS and a large number of Regional systems. All these Satellite Navigation Systems are or will be operational during this decade, fostering, with no doubt, **a major *GNSS market explosion* for this decade**.

- The **market perspectives for GNSS are extraordinary**, with a revenues growing of about 13% per year. Over 95% of market concentrated is in Location based Services and Road Sector. Other important GNSS sectors are agriculture, maritime, aviation, energy and GNSS science.

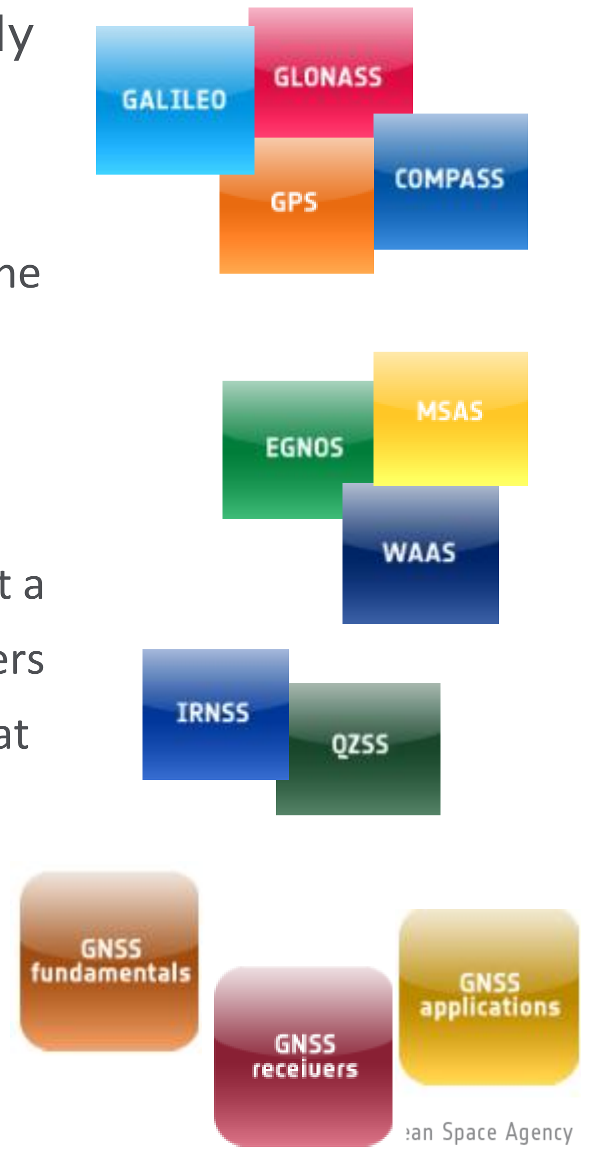
- **Spain will host the European GNSS Service Centre (GSC),** which will act as an interface between the Galileo navigation system and user communities for the open and commercial Galileo services.



To Know more: ESA navipedia initiative

esa

- ESA has launched NAVIPEDIA (GNSS wiki) , a duly updated on-line single entry point GNSS educational portal (or wiki) reliable reference.
- NAVIPEDIA enables users to access **updated information** of the **existing GNSS systems**, **applications**, **receivers** and **fundamentals**.
- NAVIPEDIA adopts the concept of wiki products - anyone can comment, propose modification to an existing article, suggest a new topic or submit a draft article. However, NAVIPEDIA differs from other wikies: there is a **robust content management** that **ensures** the **quality**, **reliability** and **consistency** of the stored **GNSS information**.



www.navipedia.org

www.navipedia.org

NAVIPEDIA: Example of topics

Pages in category "Fundamentals"

The following 181 pages are in this category, out of 181 total.

A

- ARAIM
- Accuracy
- AltBOC Modulation
- An intuitive approach to the GNSS positioning
- Antenna Phase Centre
- Antisymmetric Sequences
- Atmospheric Effects Modelling
- Atmospheric Refraction
- Atomic Time
- Autocorrelation & Power Spectral Density
- Availability

B

- Bancroft Method
- Best Linear Unbiased Minimum-Variance Estimator (BLUE)
- Binary Coded Symbols (BCS)
- Binary Offset Carrier (BOC)
- Binary Phase Shift Keying Modulation (BPSK)
- Block-Wise Weighted Least Square

C

- CBCS Modulation
- CDMA FDMA Techniques
- CEP to ITRF
- COMPASS Signal Plan
- Carrier Phase Ambiguity Fixing
- Carrier Phase Cycle-Slip Detection
- Carrier Phase Wind-up Effect
- Carrier phase ambiguity fixing with three frequencies
- Carrier phase ambiguity fixing with two frequencies
- Carrier-smoothing of code pseudoranges
- Cartesian and ellipsoidal coordinates
- Celestial Ephemeris Pole
- Clock Modelling
- Code Based Positioning (SPS)
- Code and Carrier Based Positioning (PPP)

G cont.

- GALILEO Navigation Message
- GALILEO Signal Plan
- GBAS Fundamentals
- GBAS Standards
- GBAS Systems
- GLONASS Navigation Message
- GLONASS Satellite Coordinates Computation
- GLONASS Signal Plan
- GNSS Augmentation
- GNSS Basic Observables
- GNSS Broadcast Orbits
- GNSS Interference Model
- GNSS Measurement features and noise
- GNSS Measurements Modelling
- GNSS Modulation Schemes
- GNSS Performances
- GNSS Satellites Orbit
- GNSS signal
- GNSS systems description
- GPS C1, P1 and P2 Codes and Receiver Types
- GPS Navigation Message
- GPS Signal Plan
- GPS and Galileo Satellite Coordinates Computation
- Gaussian Minimum Shift Keying (GMSK)
- Generic BCS Signals
- Geometric Range Modelling
- Ground-Based Augmentation System (GBAS)

H

- Hard Limiting

I

- ICRF to CEP
- IRNSS Signal Plan
- Instrumental Delay
- Integrity

P cont.

- Power Spectral Density of Sine-phased BOC signals
- Power Spectral Density of the AltBOC Modulation
- Power Spectral Density of the CBCS Modulation
- Precise GNSS Satellite Coordinates Computation
- Precise Point Positioning
- Precise modelling terms for PPP
- Principles of Compatibility among GNSS
- Principles of Interoperability among GNSS

Q

- QZSS Signal Plan
- Quadrature Product Sub-carrier Modulation

R

- RAIM
- RAIM Algorithms
- RAIM Fundamentals
- RTK Fundamentals
- RTK Standards
- RTK Systems
- Real Time Kinematics
- Receiver Antenna Phase Centre
- Receiver noise
- Reference Frames in GNSS
- Reference Systems and Frames
- Regional Datums and Map Projections
- Relativistic Clock Correction
- Relativistic Path Range Effect

S

- SBAS Fundamentals
- SBAS General Introduction
- SBAS Standards
- SBAS Systems
- Satellite Antenna Phase Centre


Thank you for your attention !