

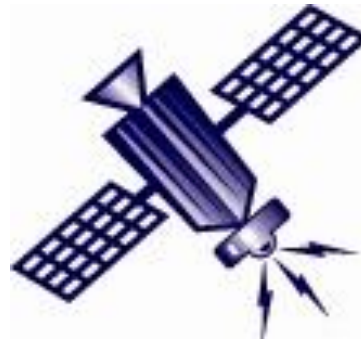


## The European Satellite Navigation Programmes EGNOS and Galileo

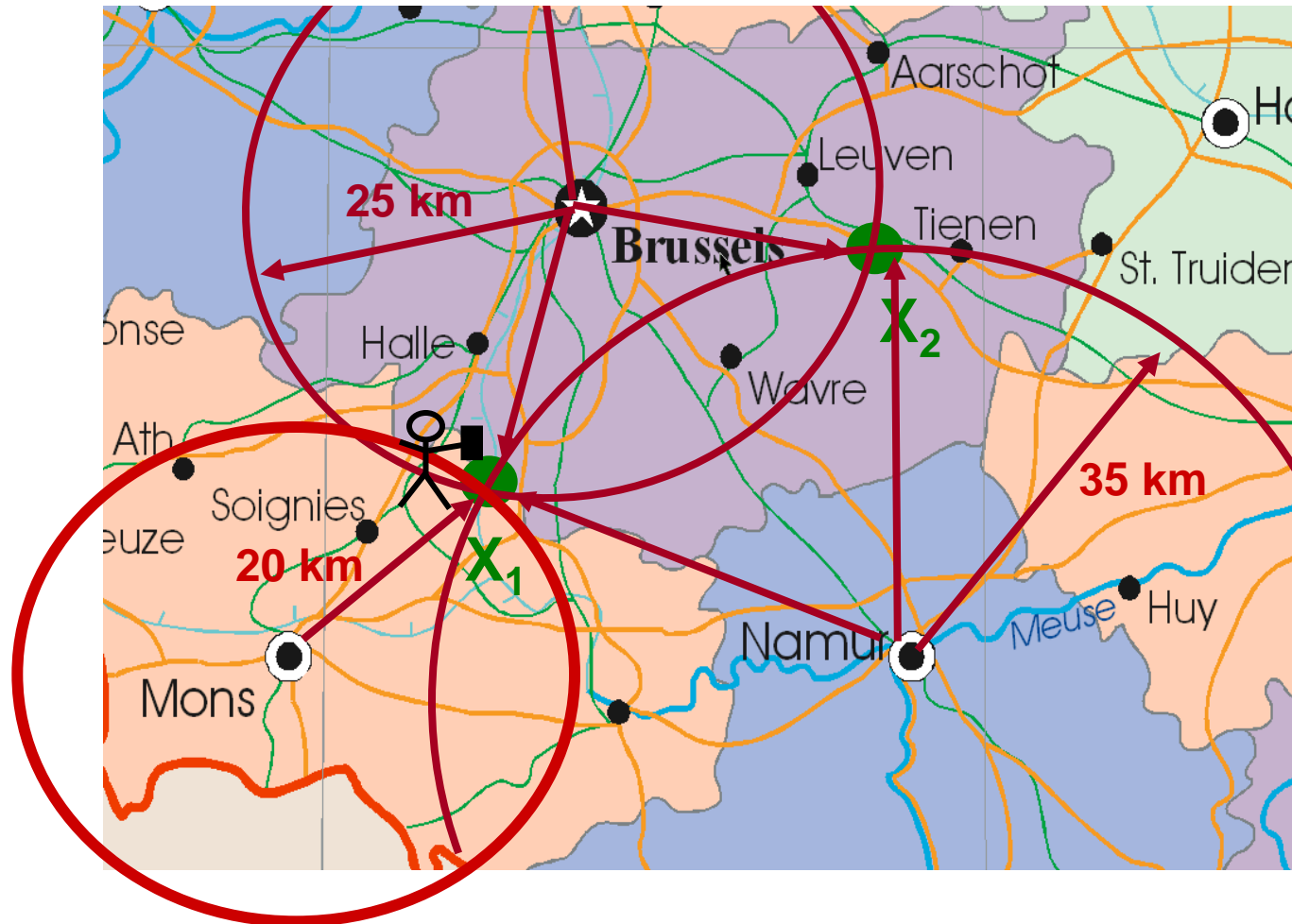
Olivier Crop – European GNSS Agency (GSA)  
Paris, 17 March 2014



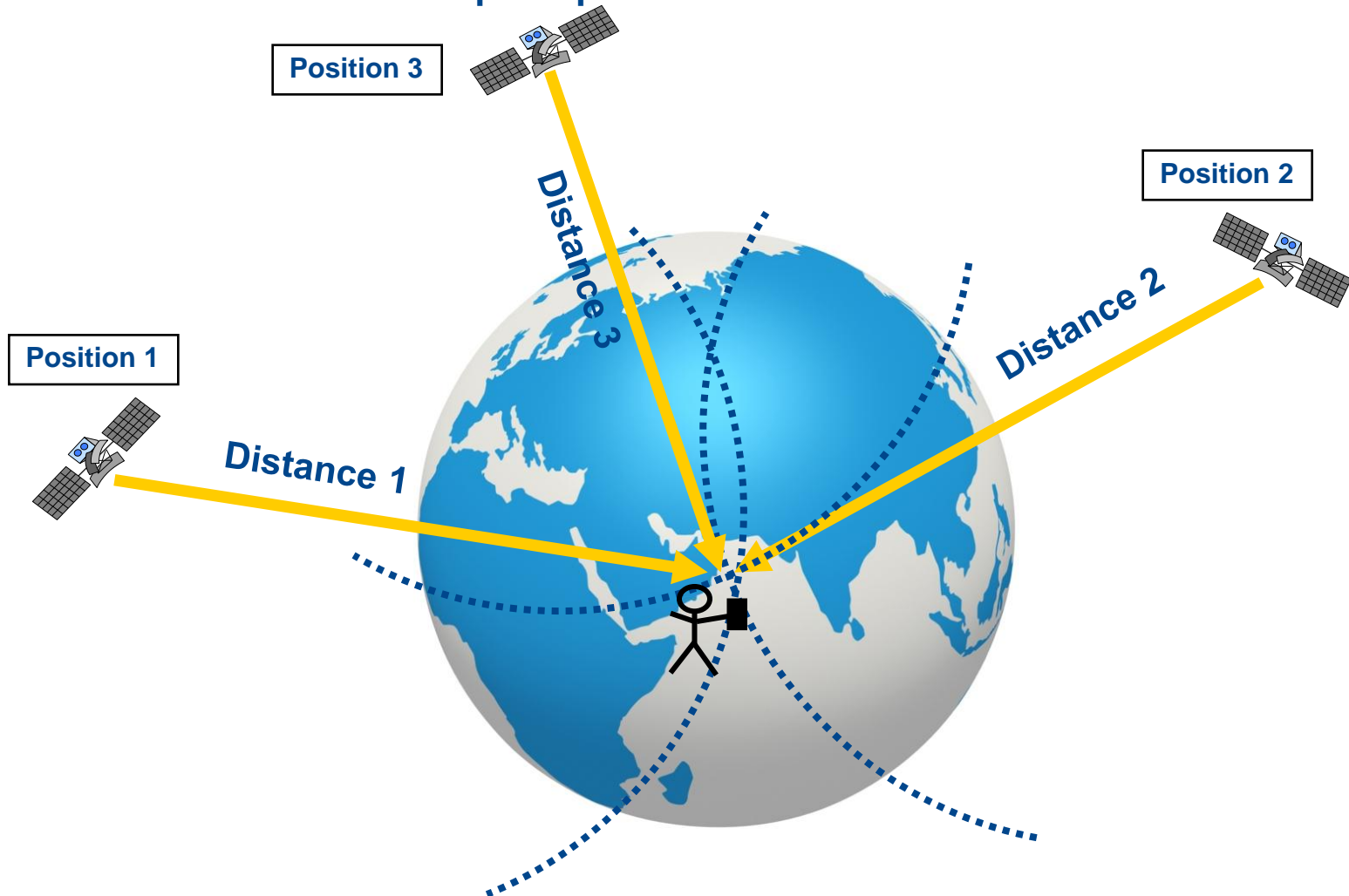
## Basics of Satellite Navigation



**The principle of Trilateration: If I know my distance from three different points, I can calculate my exact position**

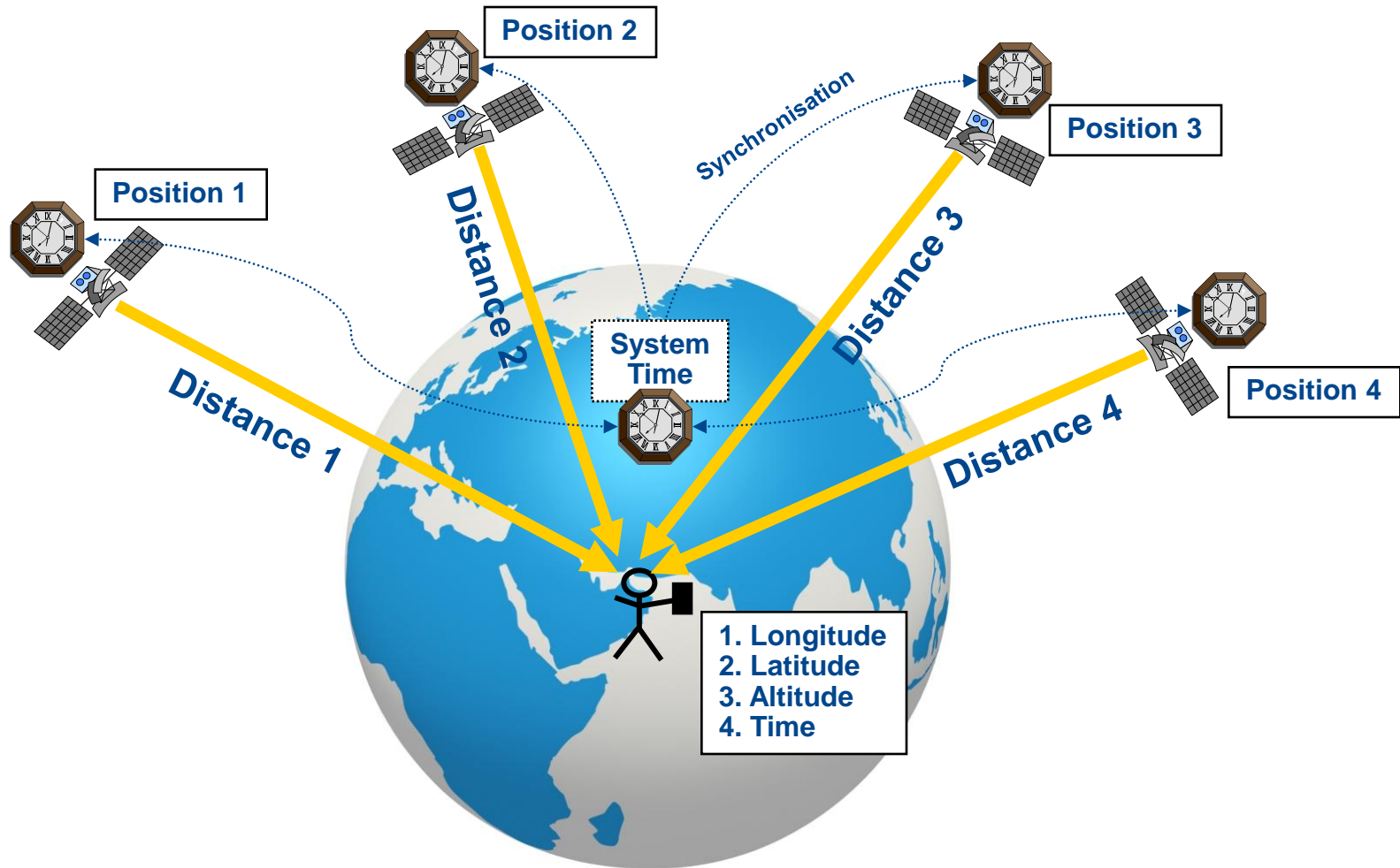


The Galileo satellite navigation system is built around the very same basic principle of Trilateration





## 4 satellites in view are necessary



**In order to get an accurate position, you need extremely accurate timing**

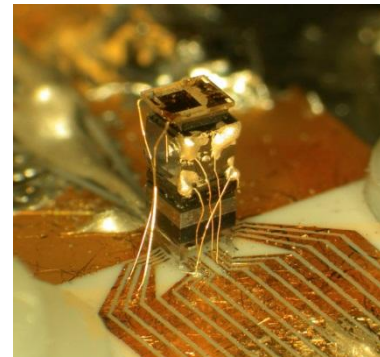
Error in time	Error in distance
1 second	300 000 000 m
1 micro-second	300 m
1 nano-second (0,000000001 seconds)	0,3 m



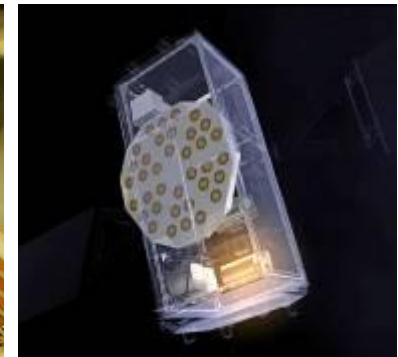
Rubidium clock  
(GIOVE-A)



Hydrogen Maser  
clock (GIOVE-B)



Chip-scale atomic  
clock (2005)



Passive Hydrogen  
Maser clock  
(Galileo IOV)

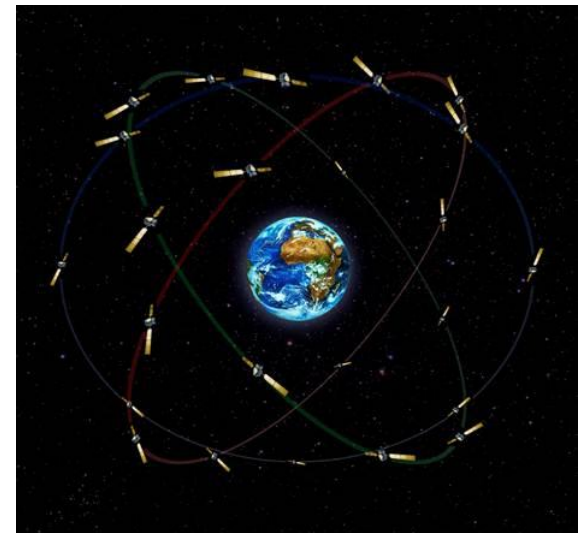


European  
Commission



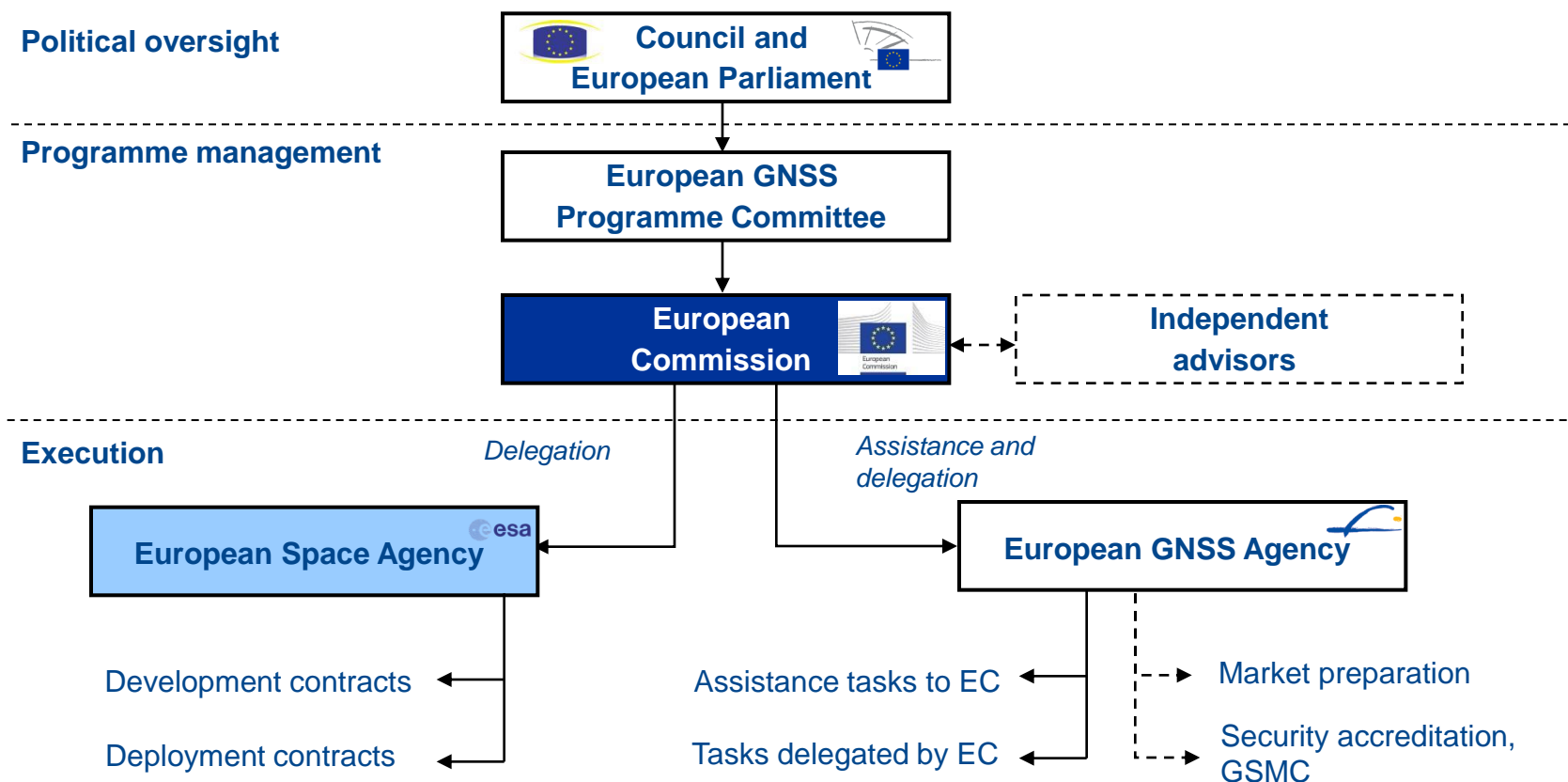
## Galileo enhances Europe's technological independence

- ★ The first global satellite positioning, navigation, and timing system, designed and operated under civil control
- ★ As of 2008, financed entirely by the European Union and managed by the European Commission
- ★ Provides Europe independence from other similar systems and greater robustness
- ★ Targeted to be interoperable with other GNSS to facilitate their combined use and to offer better performances for all kinds of user communities worldwide

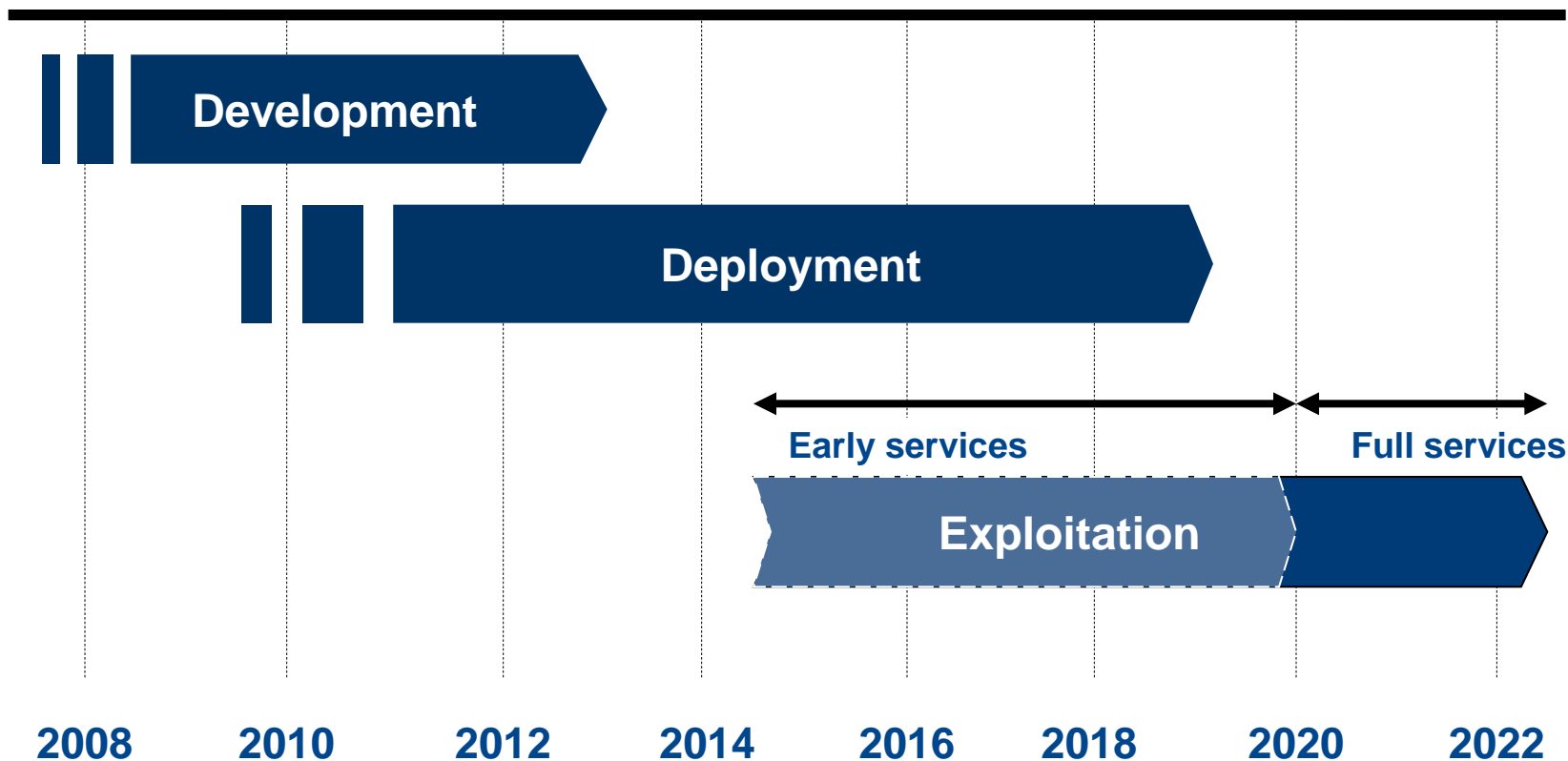




## The GNSS Regulation entrusts the European Commission with the role of programme manager



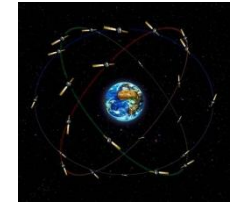
## Galileo is moving from the development phase to the deployment phase



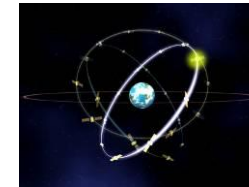
## Galileo is implemented in a step-wise approach

**Full Operational Capability**  
Full services, 30 satellites

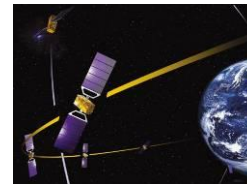
**Initial Operational Capability**  
Early services for OS, SAR, PRS,  
and demonstrator for CS  
**2014**



**In-Orbit Validation**  
4 fully operational satellites  
and ground segment  
**2013**







**GIOVE A/B**  
2 test satellites  
**2005/2008**




**Galileo System Testbed v1**  
Validation of critical algorithms  
**2003**



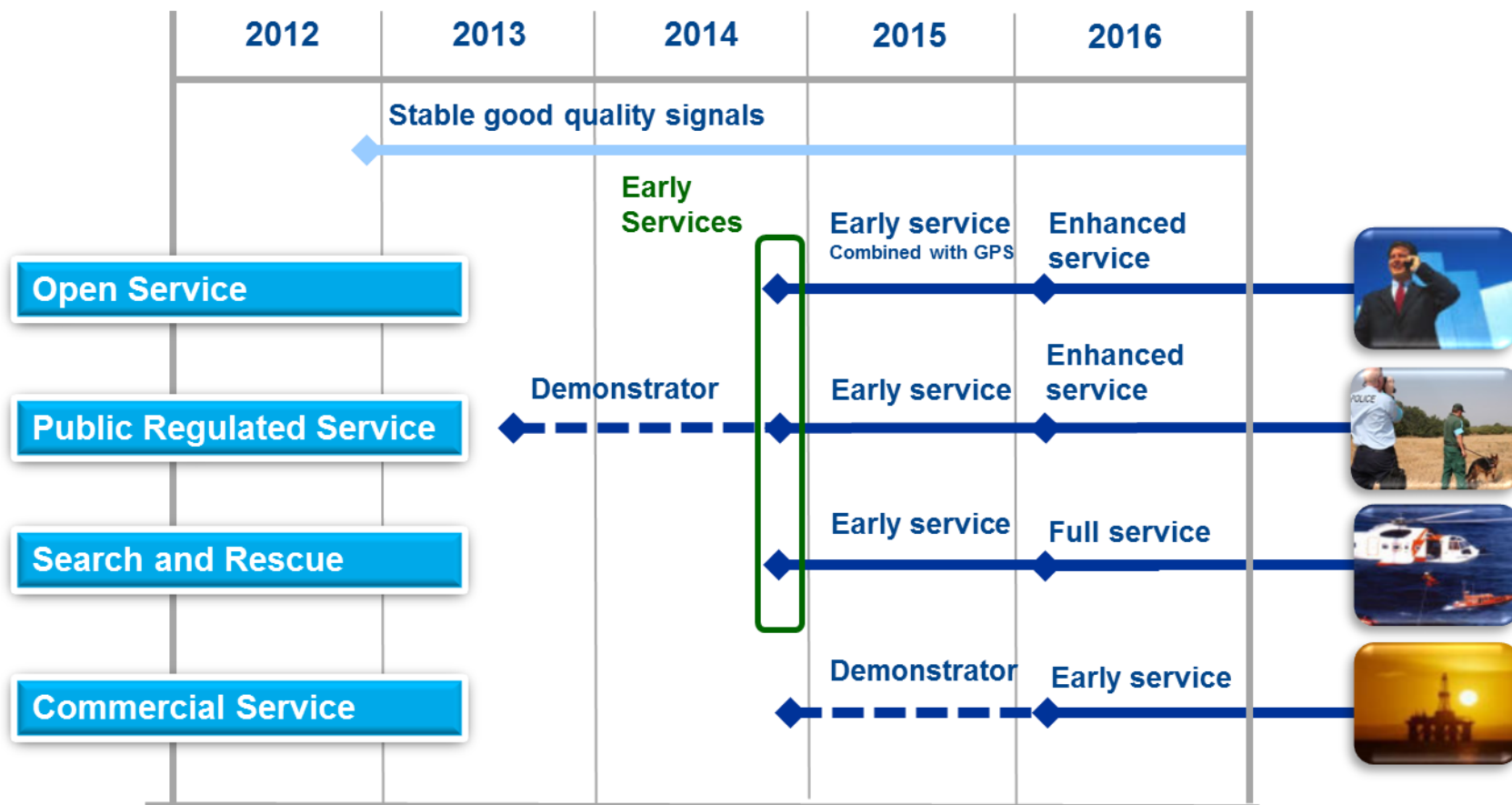
## Early services for OS, SAR and PRS will be provided from end of 2014

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

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

<b>Integrity Monitoring Service</b>	Provides vital integrity information for life-critical applications	
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**Early services will be provided from end of 2014 with a gradual transition towards full services as more satellites become available**





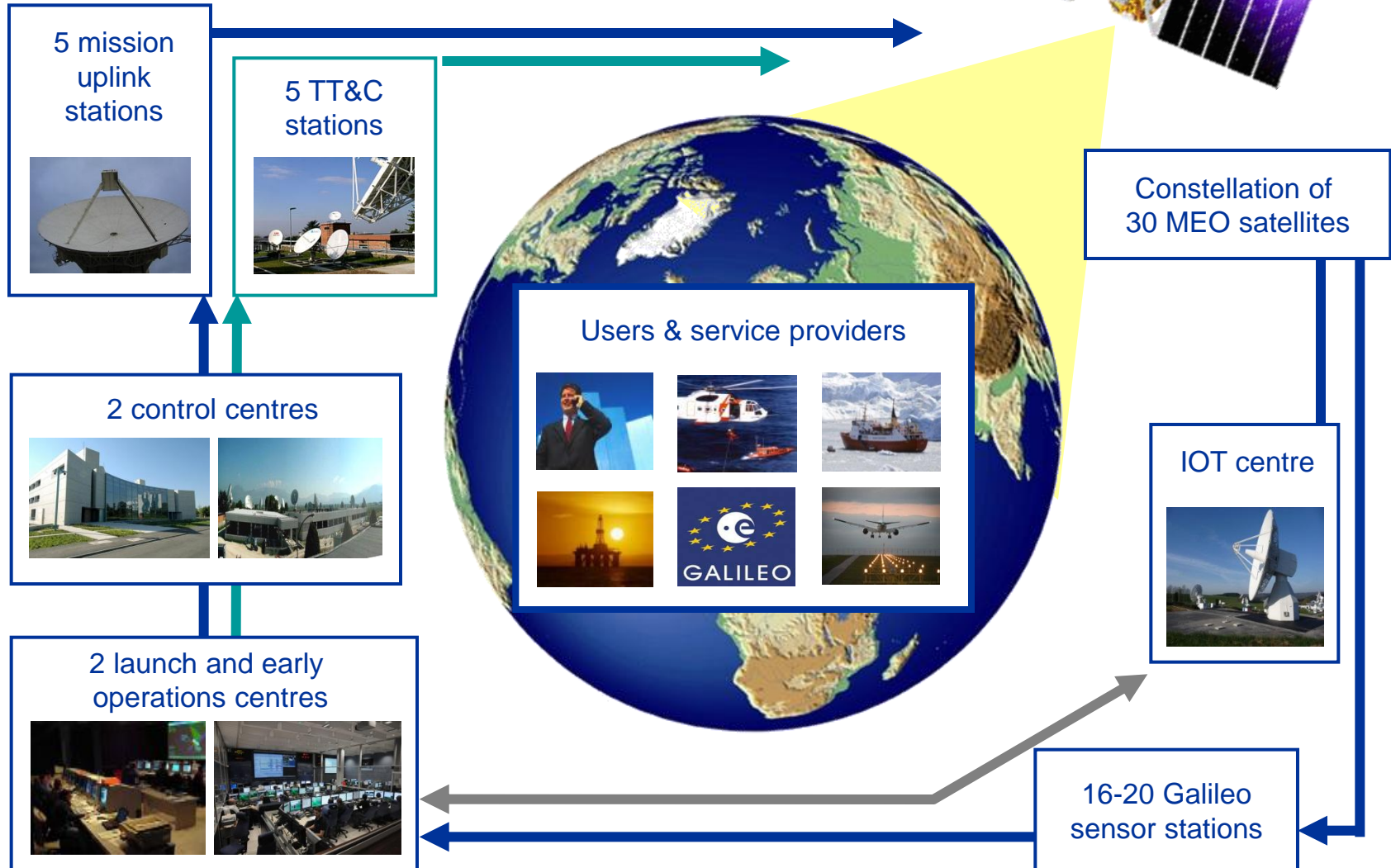
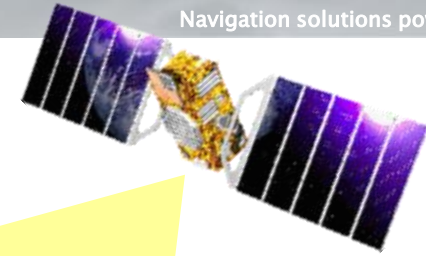
## The Galileo services will offer unprecedented accuracy and reliability




Service	Horizontal accuracy (95%) *	Vertical accuracy (95%) *	Availability for global coverage	Integrity
Open Service (OS)	4 m	8 m	99.5%	not applicable
Commercial Service (CS)	under definition			
Integrity Monitoring Service	under definition			
Public Regulated Service (PRS)	4 m	8 m	99.5%	not applicable

\* Including system margins

Based on dual frequency data. Guaranteed performance in the worst case situation. Actual measured performance is expected to be higher than these requirements

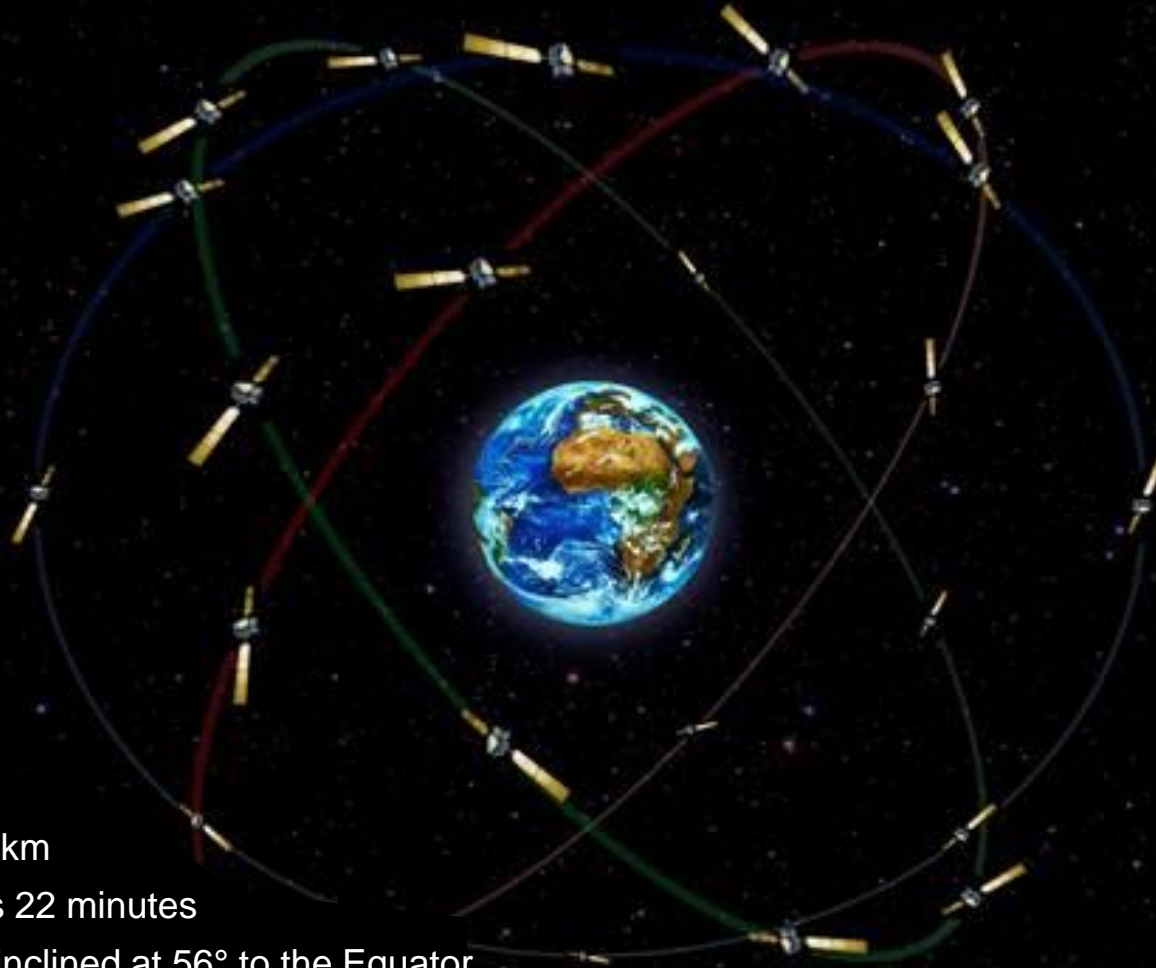
# Galileo system architecture



Space Segment		GPS 	Glonass 	Galileo 
<b># Orbital planes</b>		6	3	3
<b># Spacecraft</b>	<i>Baseline</i>	24	24	30
	<i>Status</i>	30	22	2
<b>Altitude (km)</b>		20 160	19 100	23 200
<b>Inclination</b>		55°	65°	56°
<b>Period</b>		12 h	11 h	14 h

Ground Segment		GPS 	Glonass 	Galileo 
# Control Centres		2	2	3
# Monitoring Stations	<i>Baseline</i>	6	4	20 to 30
	<i>Plans</i>	17	10	-
# Uplink Stations		3	3	9
# Telemetry, Tracking and Control		4	5	5

## 30 satellites in Medium Earth Orbit (MEO)



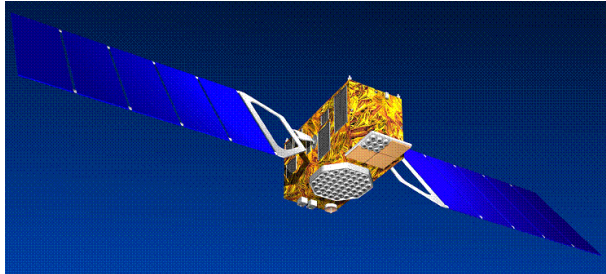
Altitude: 23 222 km

Period: 14 hours 22 minutes

3 orbital planes inclined at  $56^\circ$  to the Equator

2 spare satellites in each plane

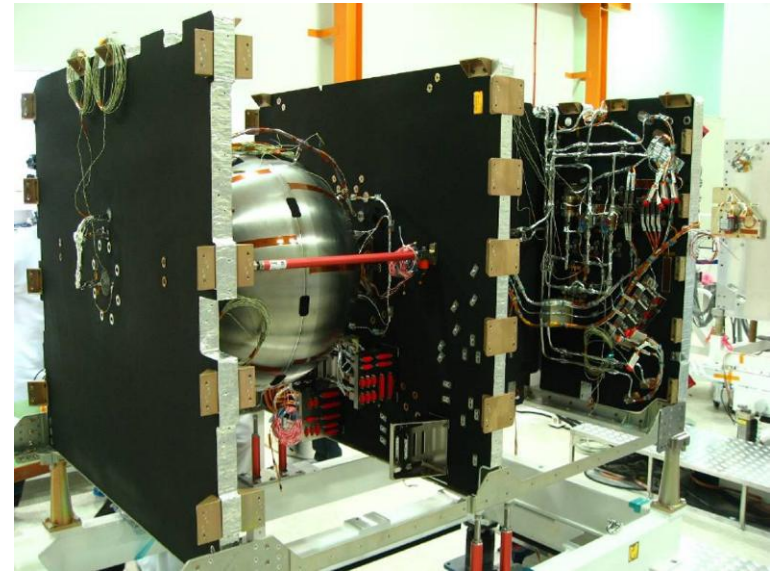




- ★ Overall Spacecraft: 730 Kg / 1.6 kW
- ★ Navigation payload: 115 kg
- ★ Launcher: Dual Launch with Soyuz from Kourou



Soyuz launch pad in Kourou



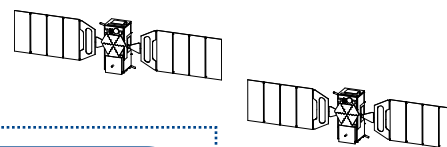
Proto-Flight Model in Assembly



Kiruna



Kourou



**TT&C S-band  
Up-link**


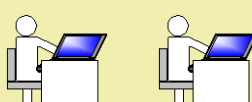
**5 Telecommand  
Stations**

## Oberpfaffenhofen GCC



**GALILEO Control Centre  
(GCC-1)**

**Satellite  
Operations**

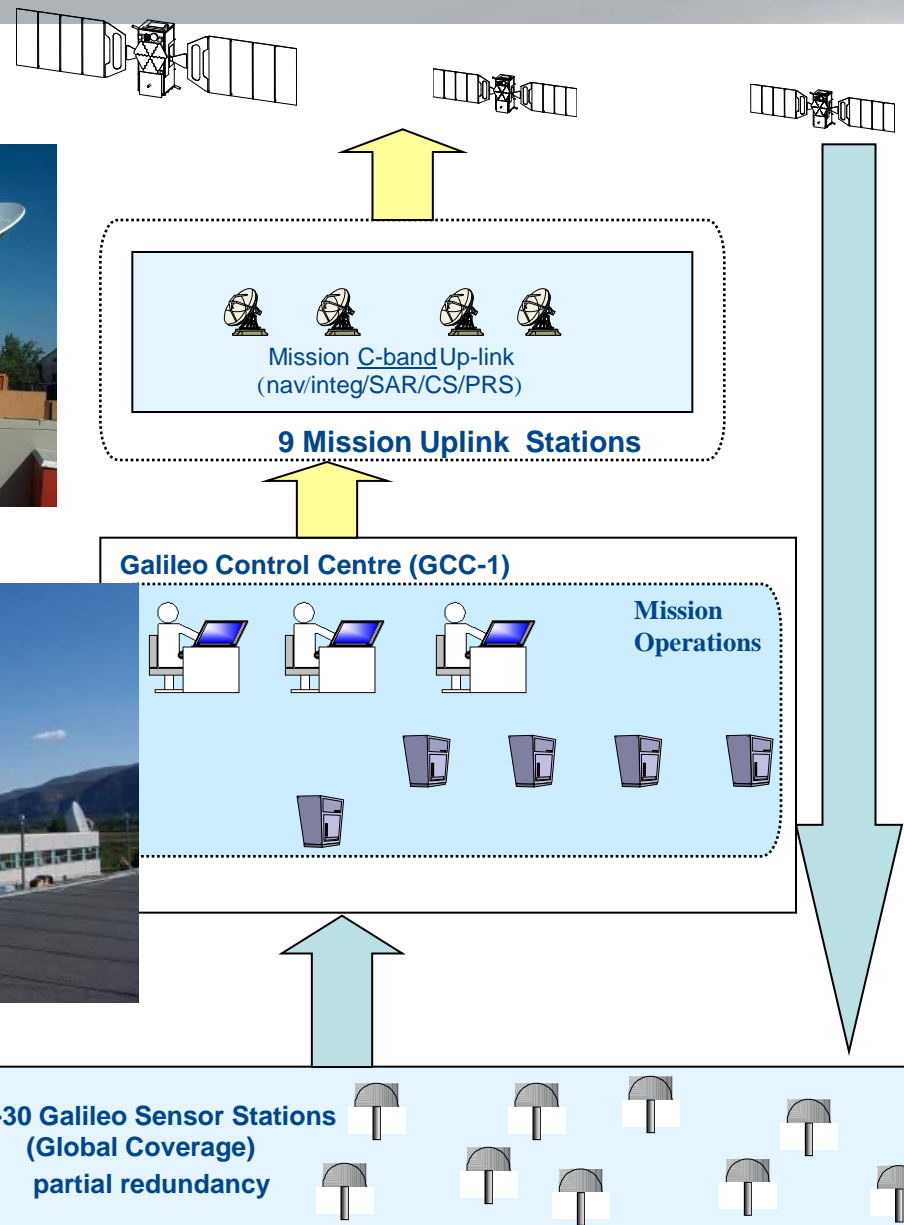


**GALILEO Control  
Centre (GCC-2)**



# Galileo Ground Mission Segment

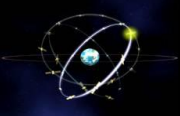




ULS  
In test



Fucino GCC



The full system will consist of 30 satellites, 2 control centres in Europe and a network of sensor, uplink and TT&C stations around the globe

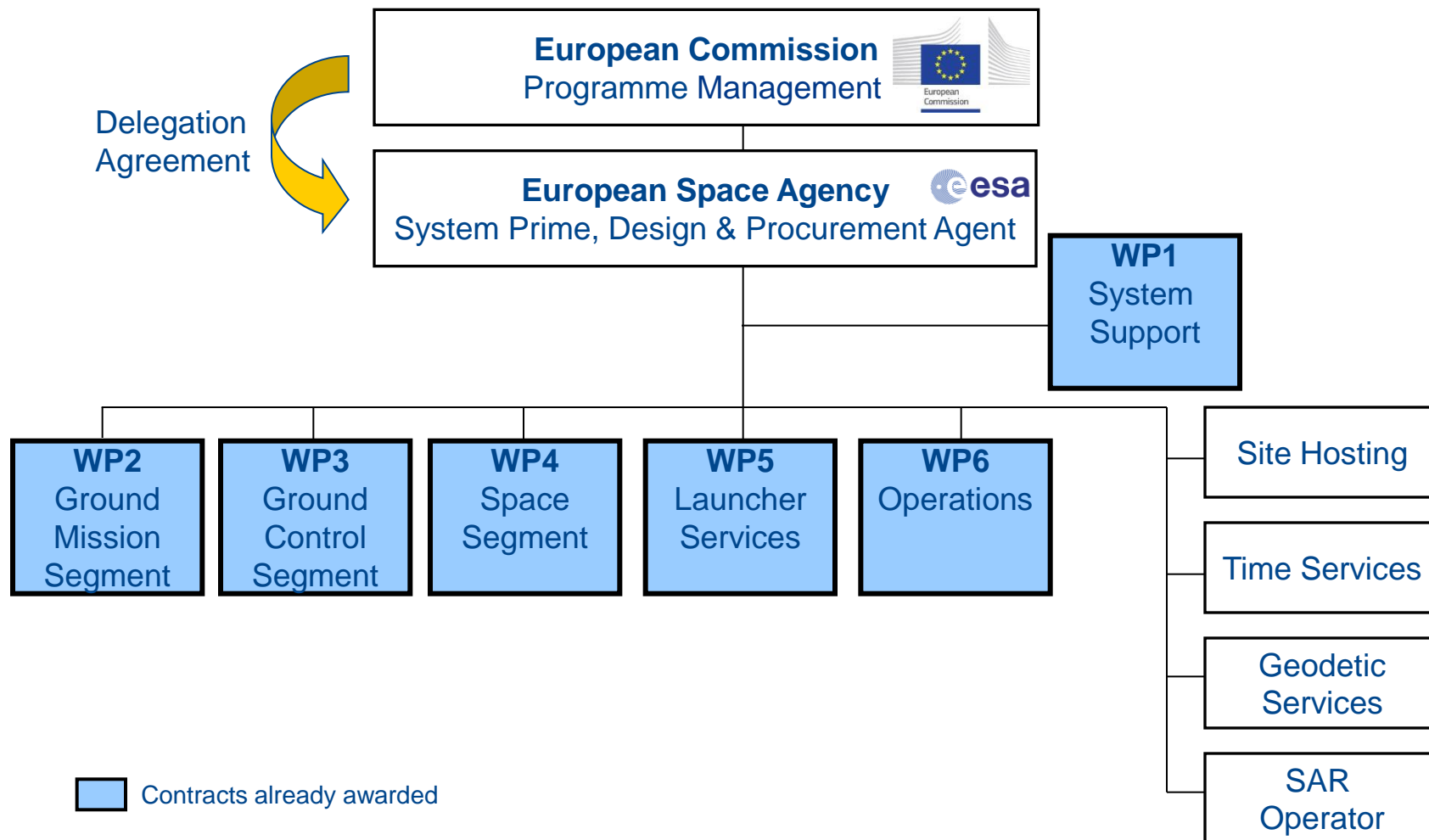
		IOV	IOC	FOC
	<b>Satellites</b>	4 (deployed Oct 2012)	12	30
	<b>Control Centres</b>	1/2 + 1/2 (deployed)	2	2
	<b>Mission Uplink Stations</b>	5 (deployed)	5	5
	<b>TT&amp;C Stations</b>	2 (deployed)	3	5
	<b>Sensor Stations</b>	12 (11 deployed)	16	16-20

**All six contracts for system support, ground segment, the construction of 22 satellites, the launch of 10 satellites and the operations were awarded**

Work Package	Contract Signature Date	Contract awarded to
WP1 System Support	January 2010	<b>Thales Alenia Space</b> (Italy)
WP2 Ground Mission Segment	June 2011	<b>Thales Alenia Space</b> (France)
WP3 Ground Control Segment	June 2011	<b>Astrium</b> (UK)
WP4 Space Segment	January 2010 February 2012	<b>OHB System</b> (Germany) for 14 satellites <b>OHB System</b> (Germany) for 8 additional satellites
WP5 Launcher Services	January 2010	<b>Arianespace</b> (France)
WP6 Operations	October 2010	<b>SpaceOpal</b> (Italian-German joint venture)



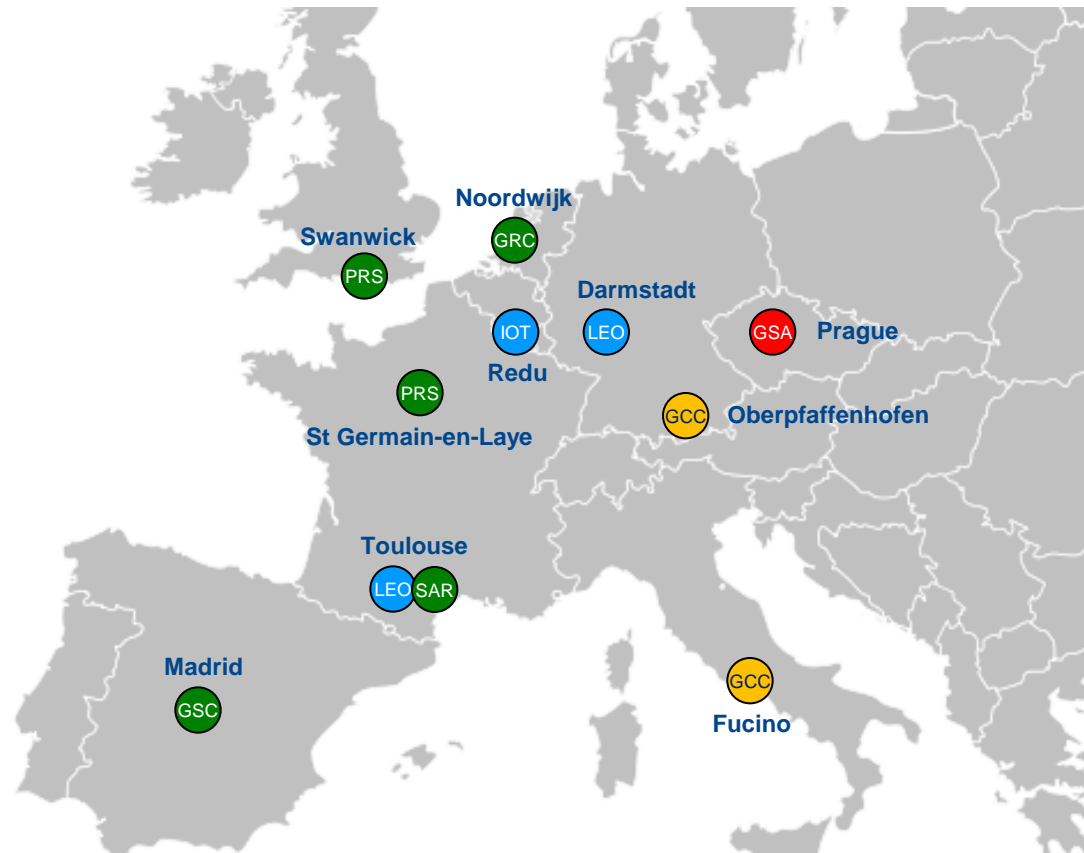
## The contracts for the main work packages and services were awarded











WP: Work Package

SAR: Search And Rescue

## Major Galileo centres and facilities are located throughout Europe



-  **European GNSS Agency**
-  **Galileo Control Centre**
-  **Galileo In-Orbit Testing Centre**
-  **LEOP Centre**
-  **Galileo Reference Centre**
-  **Galileo Security Monitoring Centre (PRS)**
-  **Galileo Service Centre (OS/CS/Integrity)**
-  **SAR Data Provider Centre**

Note: Only major centres, facilities and stations are shown. Not all of them are (fully) implemented yet.

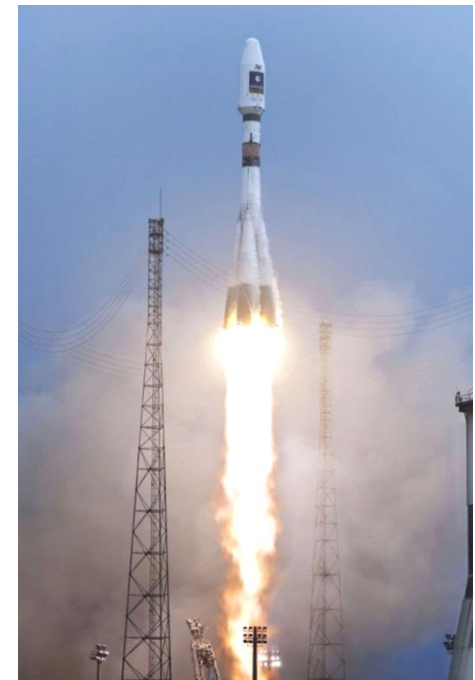
# Galileo ground segment for IOC



Note: Target set-up for IOC. Not all facilities are shown. USNO to host the Galileo to GPS time offset facility. IOC: Initial Operational Capability

## Deployment of the infrastructure

- ★ Completion of the first wave of procurement of the services and components required for the deployment of the system, June 2011.
- ★ Completion of the second procurement wave, February 2012, including:
  - ★ the order of 8 additional satellites to OHB
  - ★ securing Ariane 5 launches for four Galileo satellites at a time.
- ★ Launch of the four in-orbit validation satellites (2 on 21 October 2011 and 2 on 10 October 2012);
- ★ Deployment of ground infrastructure.
- ★ Opening of the GNSS Service Centre in Madrid, May 2013.
- ★ Signature of the GSMC hosting agreement with France in June and with the UK, July 2013.



## Delivery of Galileo services

- ★ Signature of the SAR operations contract with CNES, February 2013.
- ★ First computation of an autonomous Galileo position, March 2013.
- ★ PRS tests since July 2013.
- ★ Commercial Service demonstrator contract signature, December 2013.

## International Cooperation

- ★ Signature of the GNSS Cooperation Agreement with Norway, May 2011.
- ★ Signature of an administrative agreement with the United States Naval Observatory (USNO) improving interoperability between GPS and Galileo.
- ★ Signature of an administrative arrangement on GNSS cooperation with Israel, October 2013.
- ★ Signature of the GNSS Cooperation Agreement with Switzerland, December 2013.

## ★ EGNOS is operational

- ★ EGNOS OS since October 2009
- ★ EGNOS SoL service since March 2011
- ★ EGNOS Data Access Service since July 2012



## ★ Galileo is taking off

- ★ All procurement contracts awarded
- ★ First four operational Galileo satellites launched in October 2011 and in October 2012
- ★ Deployment is being accelerated
- ★ Early Galileo OS/SAR/PRS services from 2014
- ★ Early Galileo CS services from 2016

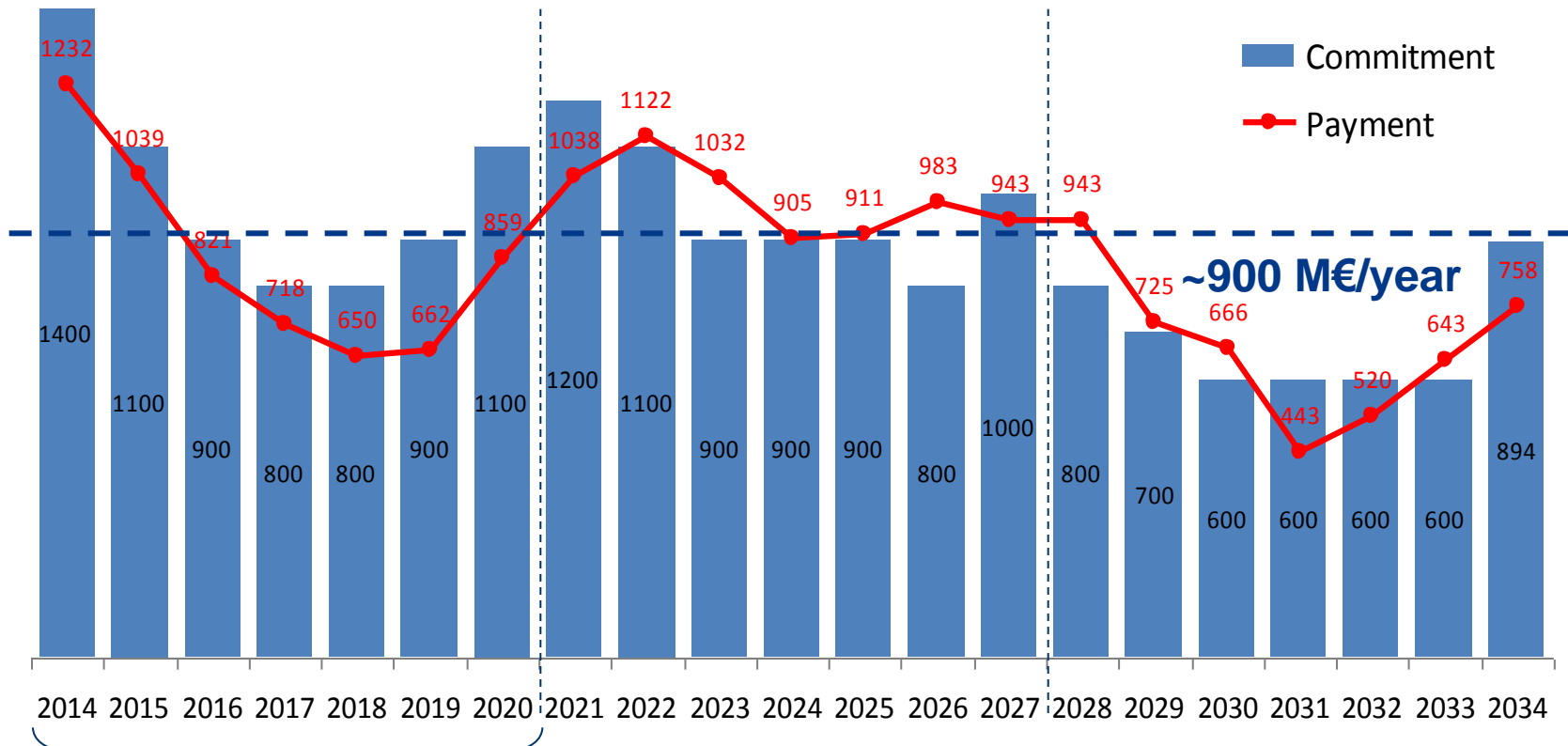


## ★ International coordination is key

- ★ Ensure compatibility with other GNSS as a minimum
- ★ Achieve interoperability when desired



## Long-term costs for the exploitation of Galileo and EGNOS are estimated at ~900 M€ per year on average without escalation



$\Sigma$  PA = 5950  
 $\Sigma$  CA = 7000

Total budget in payment and commitment appropriations in M€



Navigation solutions powered by Europe

**Thank you for your attention**

<http://ec.europa.eu/galileo>  
<http://ec.europa.eu/egnos>