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Galileo

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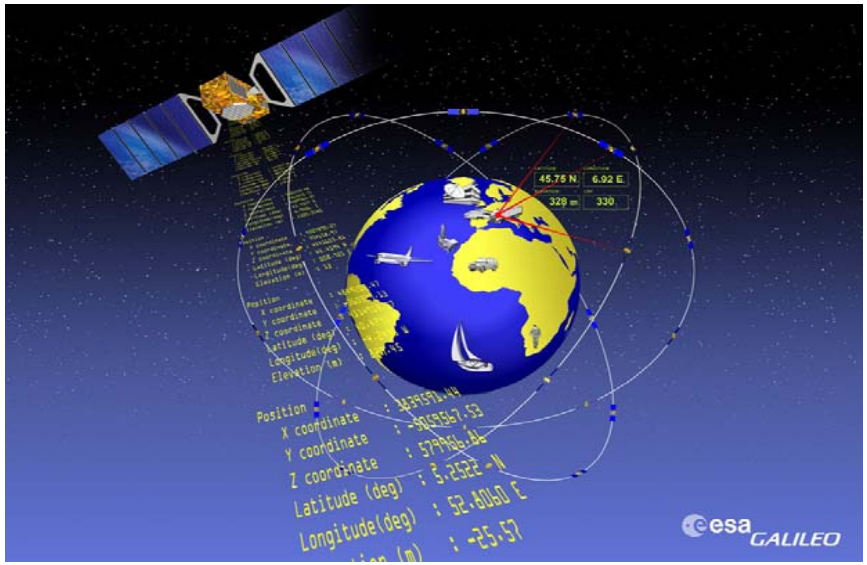
KAYSER-THREDE

Outline

- Motivation
- System Architecture
- Signals and Services
- Implementation
- Summary



Galileo – Why? (1/2)

- Ever increasing dependence of economy and social life on globally uniform navigation and timing infrastructure
- GPS proved to be a massive technological and economical factor
- Europe needs control over an independent system and its technology

Galileo – Why? (2/2)

- Decision in 2001 to implement an independent, but compatible and interoperable system

- Improved performance with minimum impact on user equipment cost:
  - Better performance (modern signal codes for reduced multipath)
  - Additional services (5 vs. 2 in GPS)
  - Integrity feature (new; N/A in GPS)
  - Service guarantee (civil system; N/A in GPS)

- GPS + Galileo = double number of satellites (improves both accuracy and robustness)

Galileo System

MEO constellation

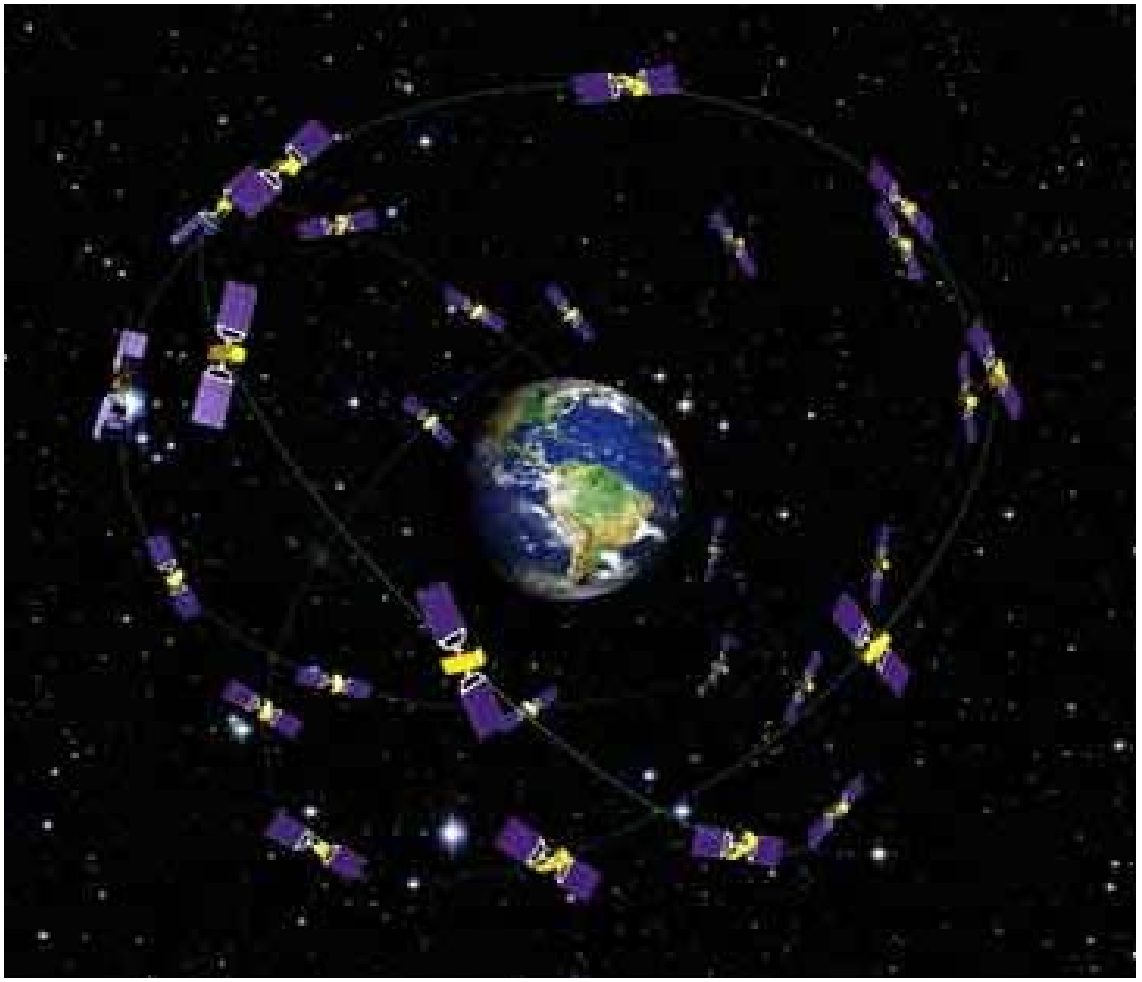
- 23200 km altitude (29600 km radius)
- 14h 05m (17 revs in 10 d)
- 56° inclination
- 3 orbital planes

30 satellites

- 27 operational
- 3 spares
- 9 + 1 per plane

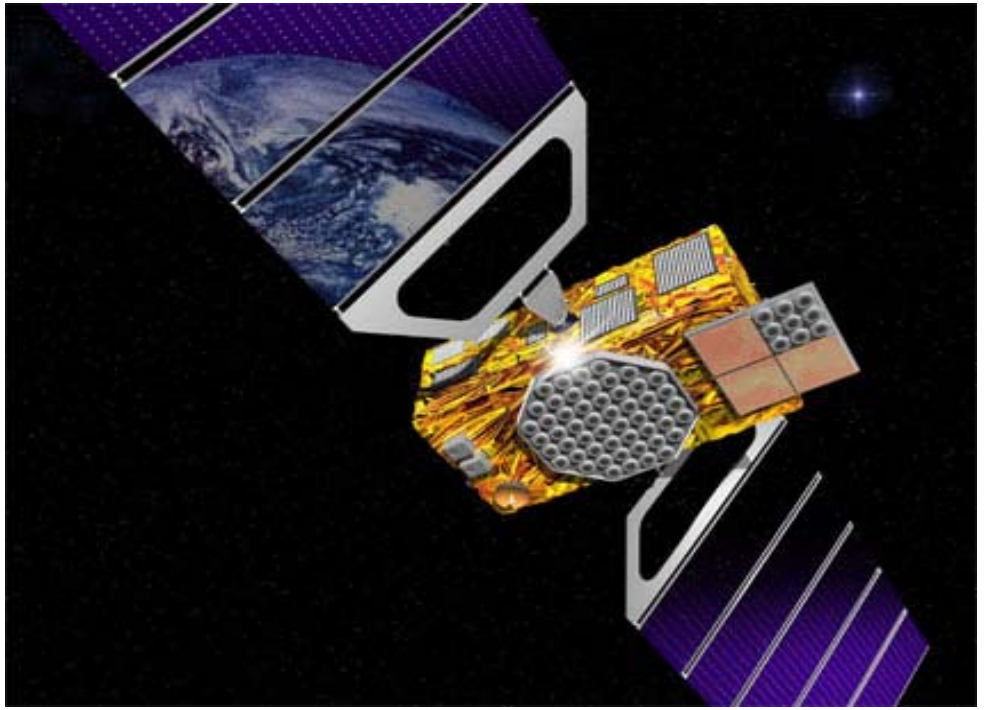
Two launchers

- Soyuz (2 S/C)
- Ariane-5 (4 S/C)

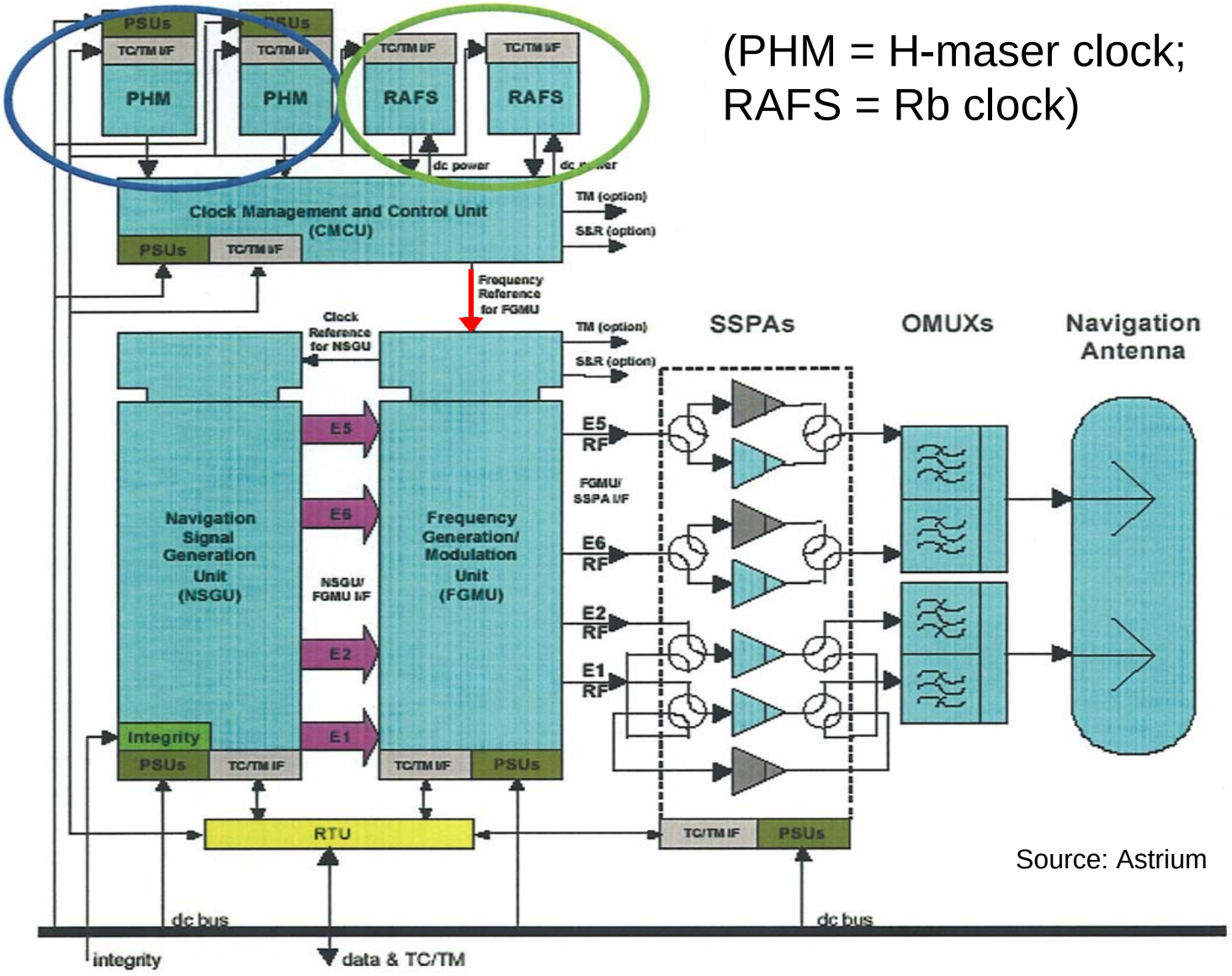


Galileo Satellites

- Mass 680 kg (launch mass)
- 1.5 kW electrical power
- Size 1.2m x 1.1m x 2.7m
- Lifetime >12 Jahre
- 3-axis stabilized
- 4 reference clocks
  - 2 x Rb ($5 \cdot 10^{-13}$/100s)
  - 2 x H-Maser ($5 \cdot 10^{-14}$/10000s)
- Laser retro reflector
- Navigation payload ~80 kg (850W)
- SAR transponder ~20 kg



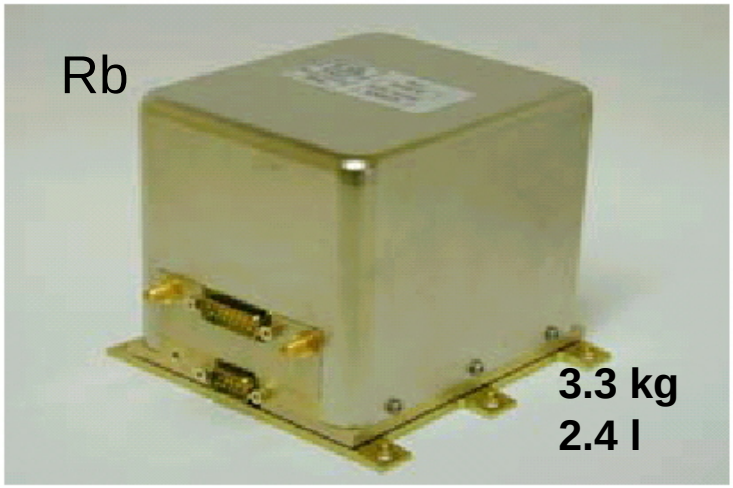
Navigation Payload

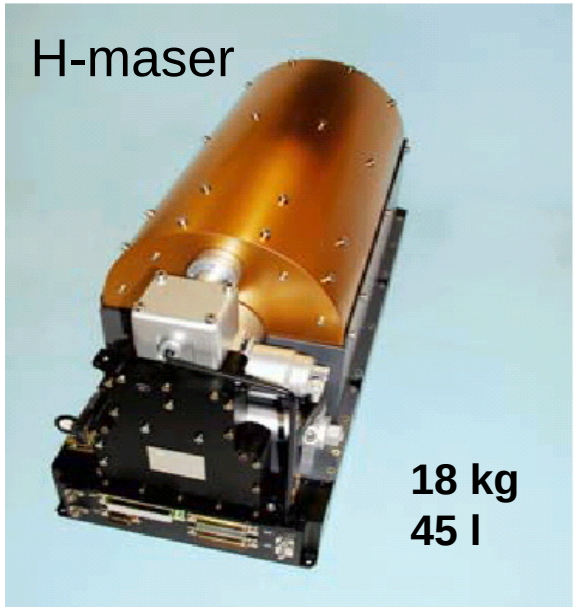


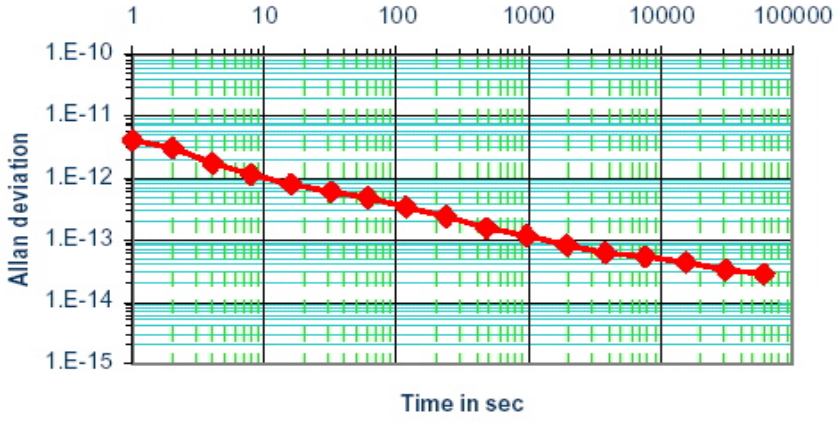
(PHM = H-maser clock;
RAFS = Rb clock)

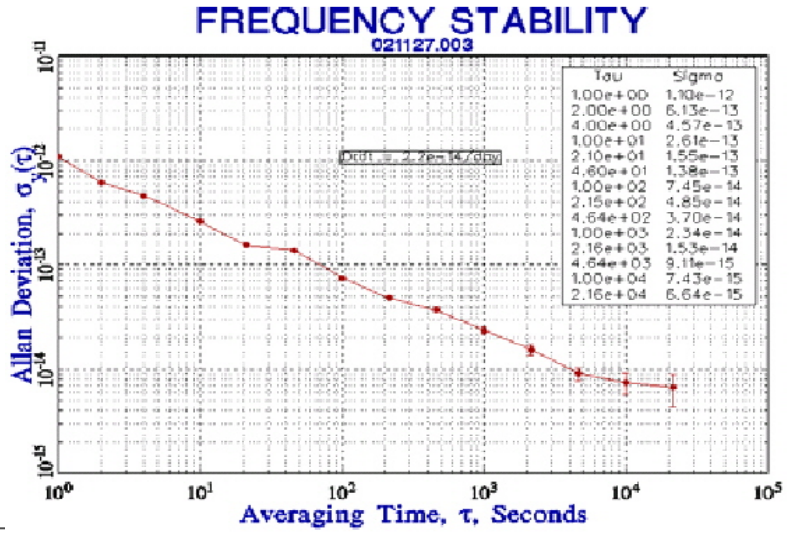
Source: Astrium

Onboard Clocks



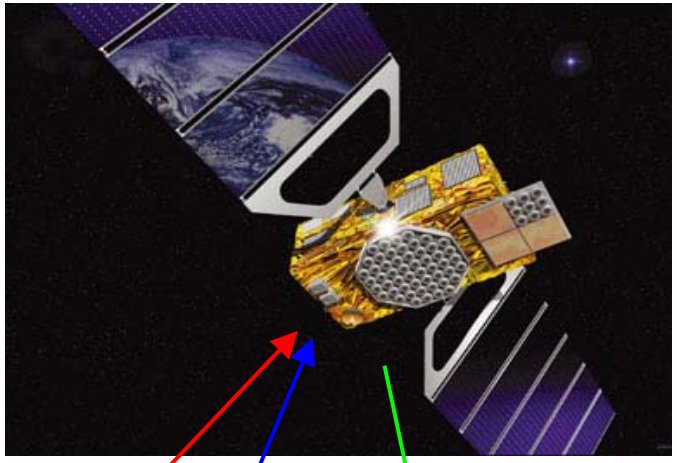


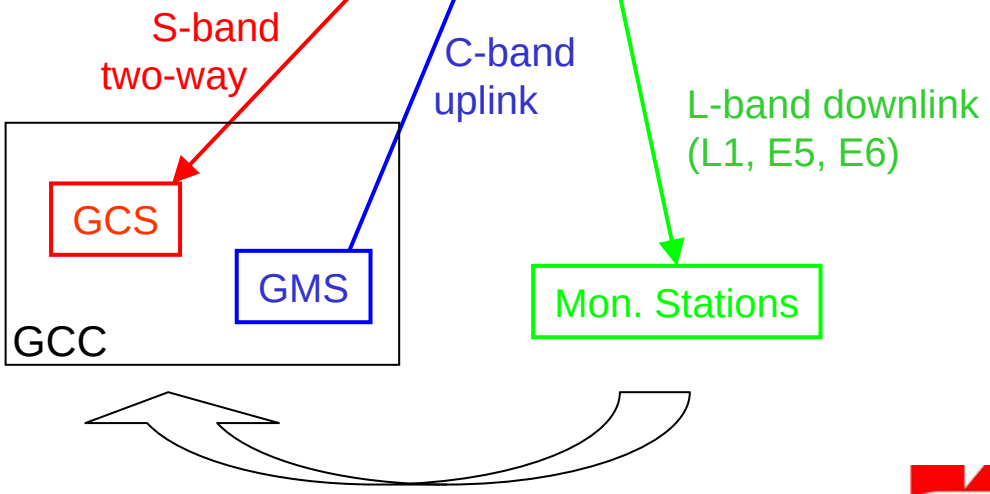




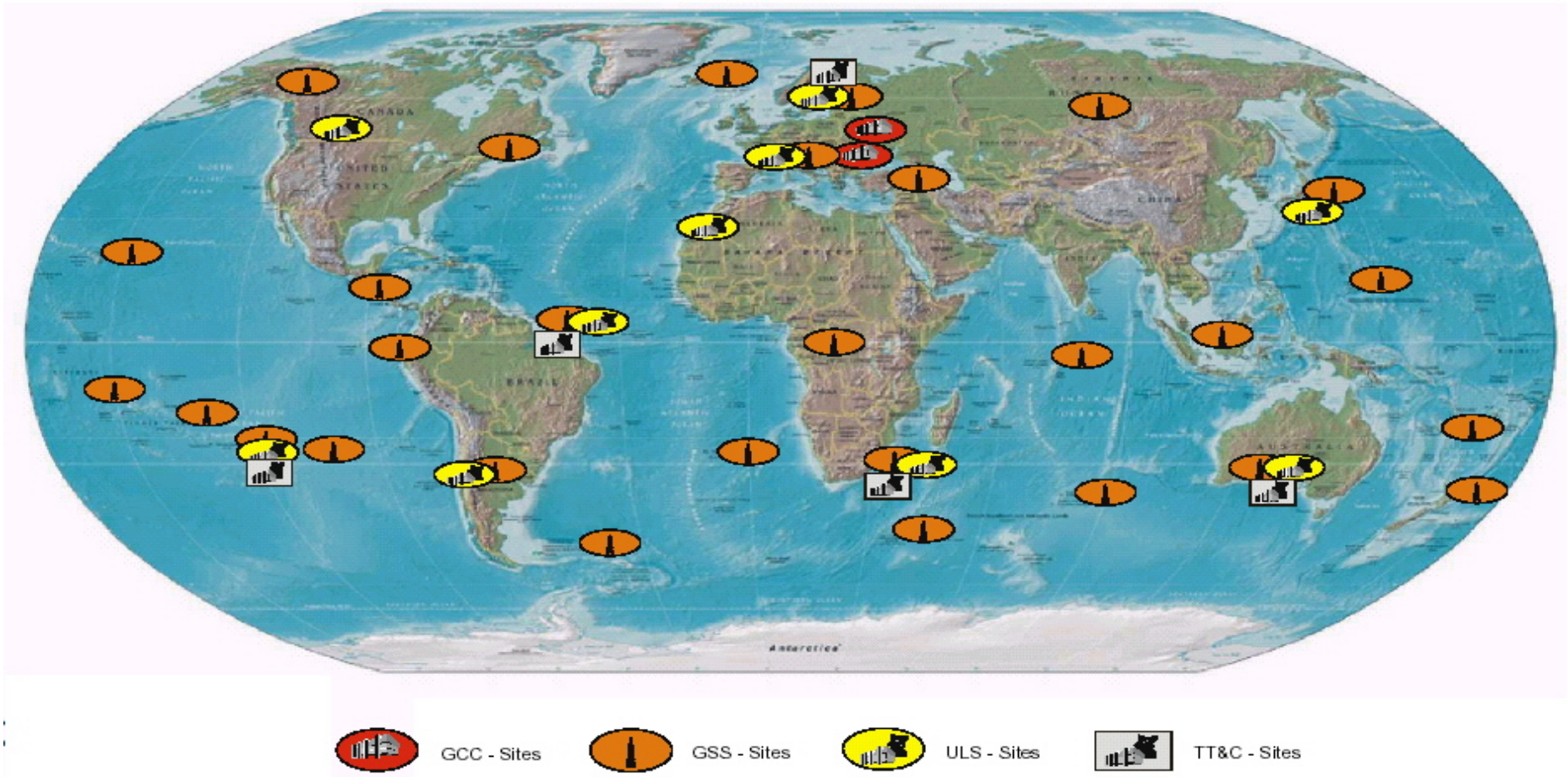
Closed-Loop System Architecture

1. Ground Control Segment (GCS) manages Galileo **spacecraft** (orbits, relative spacing, health status, …)
2. Ground Mission Segment (GMS) manages **payload** (navigation signal power levels, coding, encryption, …)
3. World-wide network of fixed signal monitoring stations (GSS, > 30) monitors navigation **signals**
4. Data are fed back by terrestrial links in real-time from monitoring stations to control center (GCC)
5. Two redundant GCCs: Oberpfaffenhofen/D, Fucino/I





Galileo Ground Segment

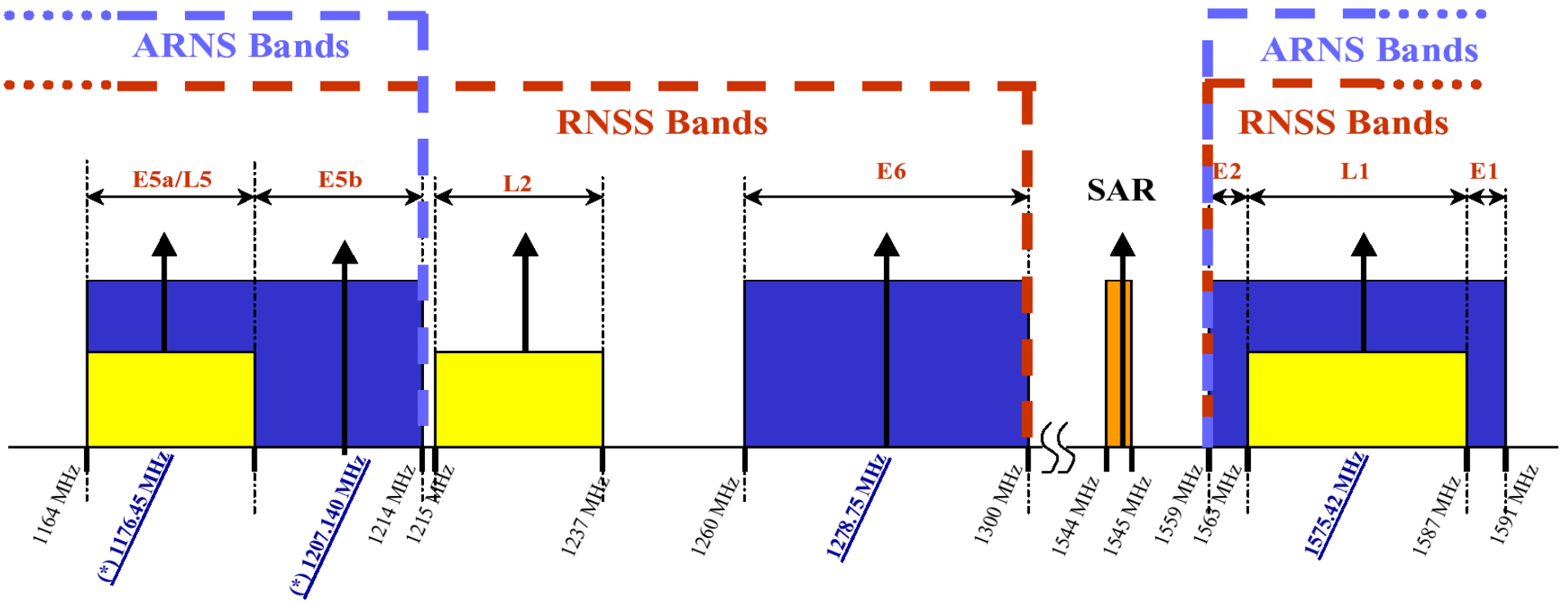


Source: ESNIS

Ground Control Centre (GCC) Oberpfaffenhofen

- Located on campus of DLR (German aerospace research centre) in Ober-pfaffenhofen (25km southwest of Munich)
- Inauguration September 2008
- Staff ca. 100 people
- Installation of all technical equipment (servers, consoles, antennas) on-going
- Operational since mid 2009 to support launch and operations of IOV satellites
- Dimensioned to fully support FOC phase as one of two redundant GCC‘s

Galileo Frequency Bands: E5, E6, L1

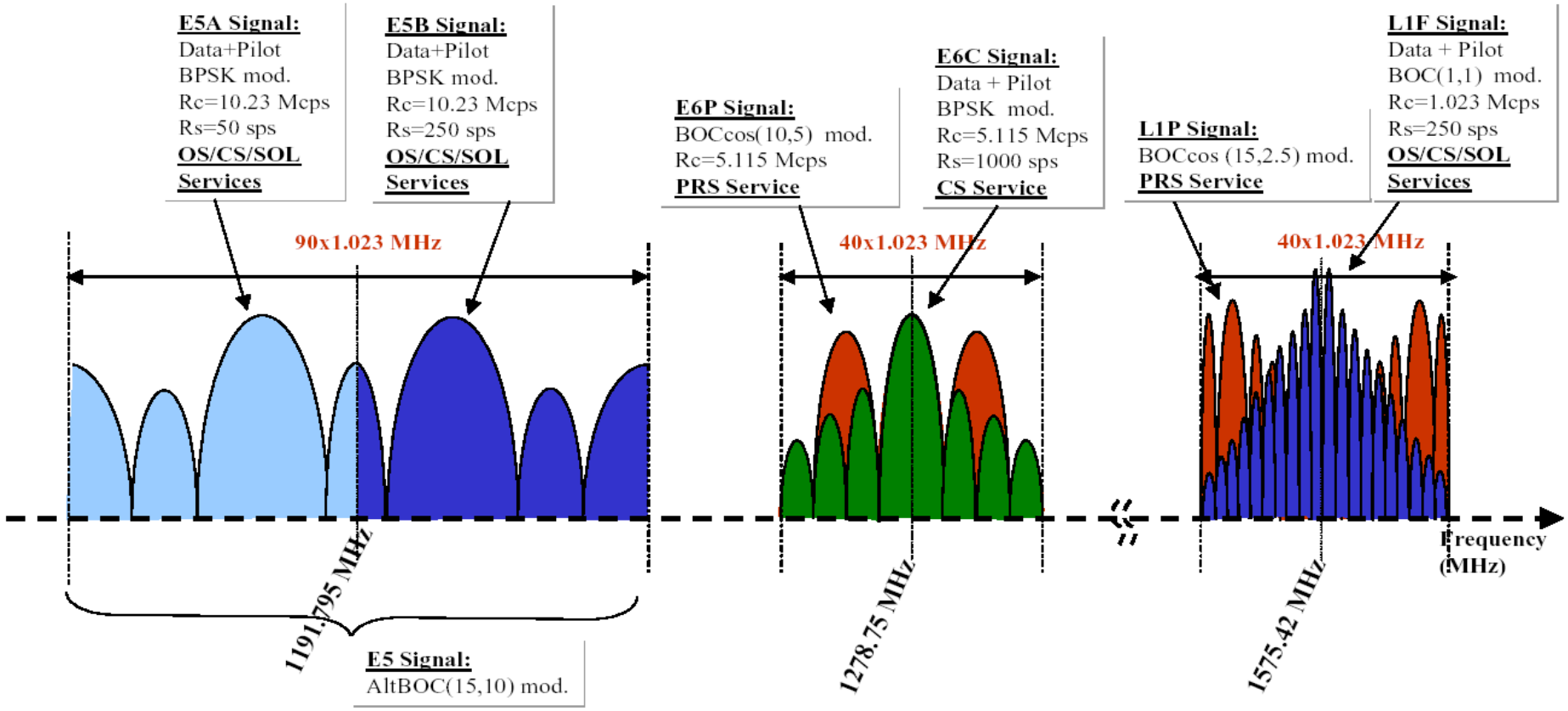


Notes:

ARNS = Aeronautical Radio Navigation Service
RNSS = Radio Navigation Satellite Service
SAR = Search and Rescue Service

Source: GJU (2005)

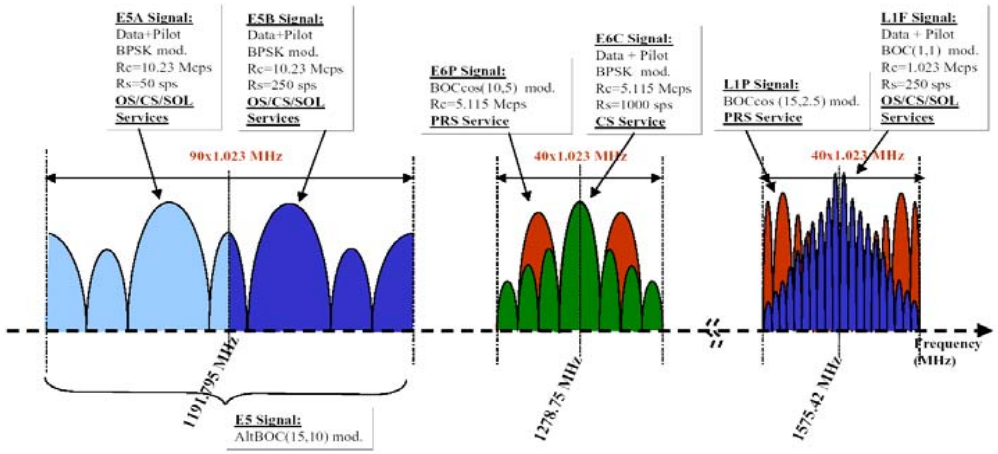
Galileo Signal Structure



Source: GJU (2005)

Open Service (OS)

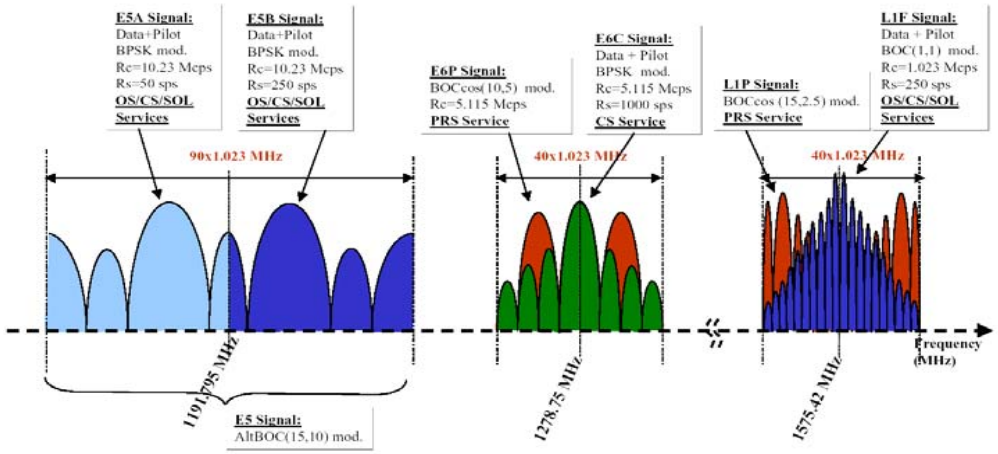
- For mass market users
- Global availability
- One or two frequencies usable
- No fees



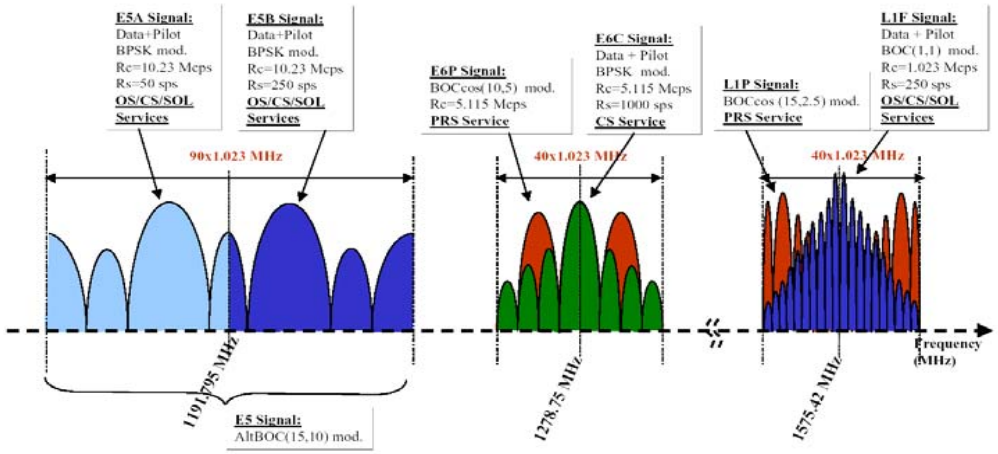
	Single frequency	Dual frequency
Horizontal positioning (95%)	15 m	4m
Vertical positioning (95%)	35 m	8m
Velocity (95%)	0.5 m/s	0.2 m/s
Time (relative to UTC)	30 ns	30 ns
Availability (global)	99.5%	99.5%

Commercial Service (CS)

- For commercial market/users (upon registration)
- Same basic performance as Open Service
- Supplementary: guarantee of service (availability)
- User fees
- Controlled access to CS codes and NAV messages by encryption



Safety-of-Life Service (SoL)

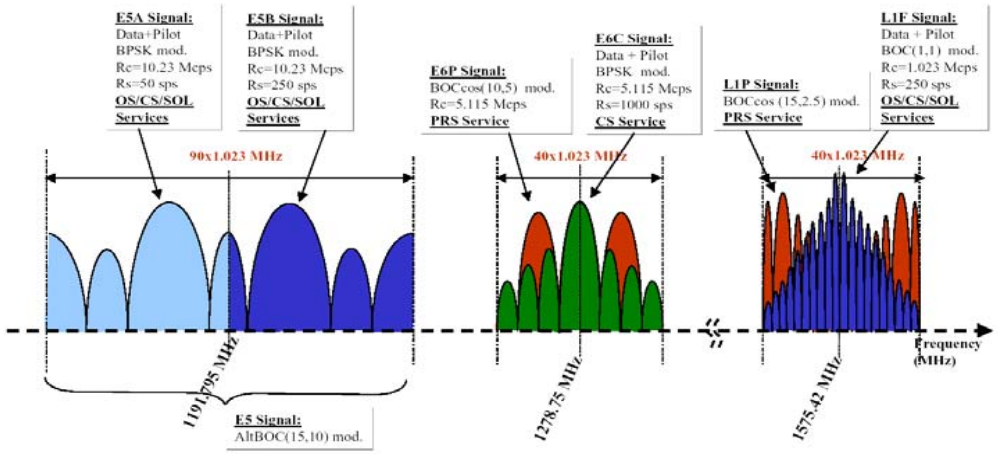


- For Safety of Life market/users
- Same basic performance as Open Service
- Supplementary: integrity information
- User fees under discussion
- Controlled access to SoL codes and NAV messages by authentication (certified receivers)

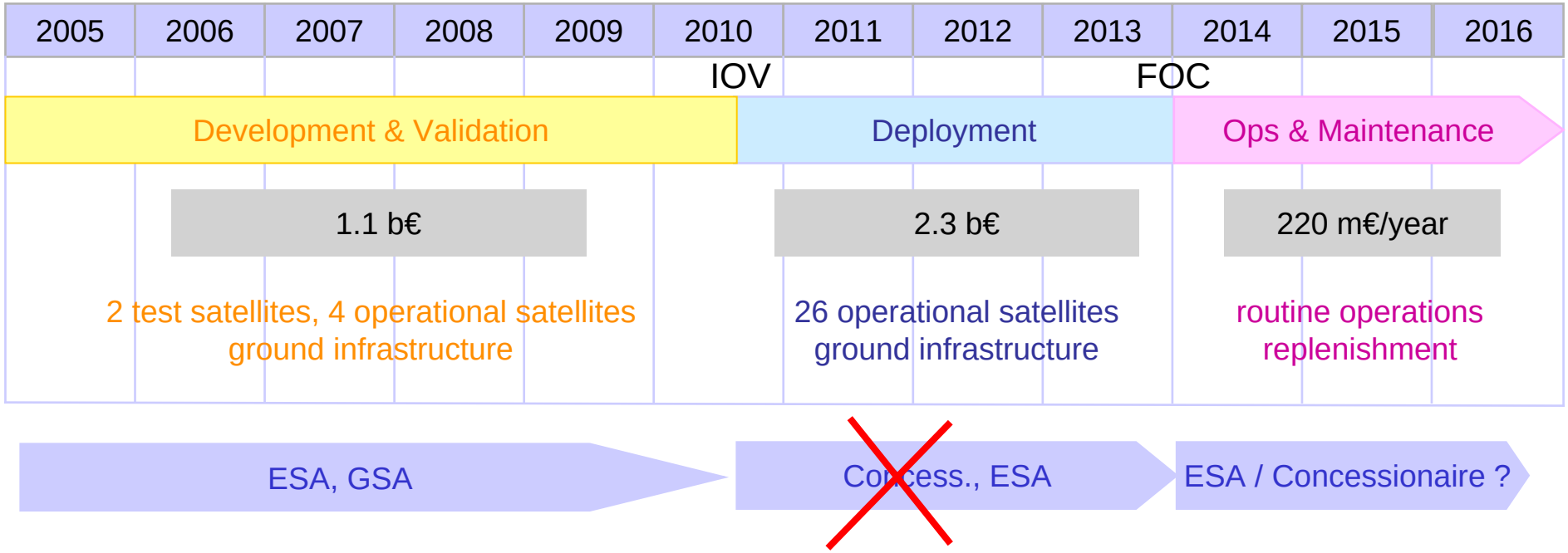
	Single frequency
Alert limit (horizontal)	12 m
Alert limit (vertical)	20 m
Time to alert	6s
Integrity risk	$2 \cdot 10^{-7}$ / 150s
Continuity over 15s	99.999%

Public Regulated Service (PRS)

- For public authorities (government, police, military, …)
- Same basic performance as Open Service
- Supplementary: integrity information + service guarantee („PRS has it all“)
- User fees under discussion
- Controlled access to PRS codes and NAV messages by encryption and authentication



Galileo Project Phases and Cost



Same cost as for other infrastructure projects:

- Tunnel for TGV train Lyon-Torino
- 250 km new highway

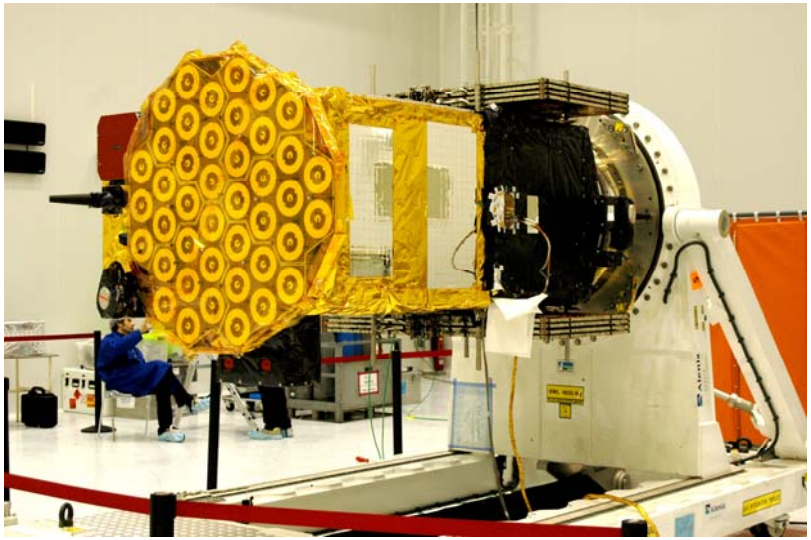
GIOVE-A

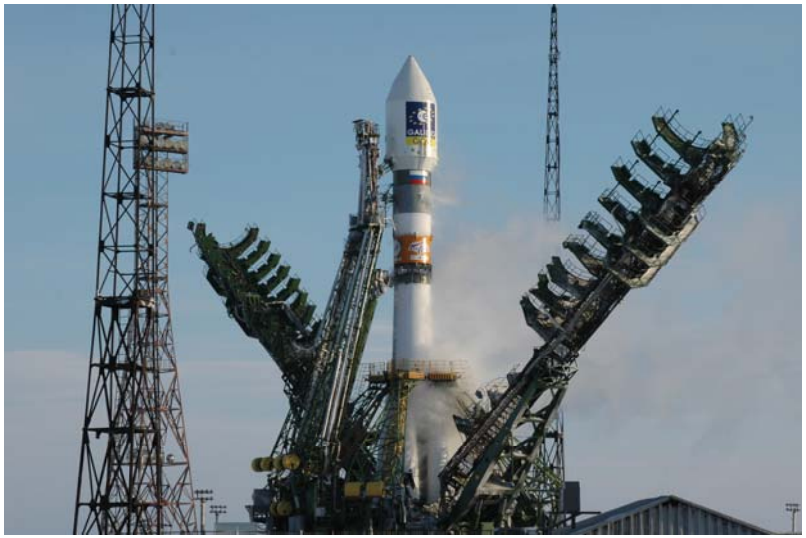
- First Galileo Test Satellite
  - 600 kg, 700 W
  - Body 1.3x1.6x1.8 m^3; 3.5m^2 solar panels
  - Built by SSTL UK (30 Mio€)
- Purpose
  - Frequency filing
  - Navigation signal assessment
- Activities
  - Launched 28 Dec. 2005
  - First signals 12 Jan. 2006
  - Orbit determination and clock validation started in May/June 2006

GIOVE-B

- Second Galileo Test Satellite
  - 523 kg, 940 W
  - Body 1x1x2.4 m^3; 3m^2 solar panels
  - Built by Galileo Industries (130 Mio€)
- Purpose
  - Technology verification
  - MEO radiation assessment
- Activities
  - Launched 26 April 2008
  - First signals 7 May 2008
  - Experimentation program started in June/July 2008

GIOVE Launch Preparations





Source: ESA

GIOVE User Equipment

- GIOVE Experimental Sensor Station (GESS)
- GeNeRx Test Receiver (Septentrio)
- NovAtel L1/E5a card

Summary

- Increasing demand for navigation related tasks and worldwide services
  - Mass market (car and mobile phone)
  - Safety critical navigation (aeronautics, safety-of-life)
- Galileo will provide new powerful signals and services
  - Three frequencies, large bandwidths
  - More and better codes
  - Increased data rates
- Galileo is on its way
  - GIOVE-A and GIOVE-B launched
  - IOV satellites launch due Dec 2010
  - FOC contracts under negotiation