European GNSS Programmes

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Second meeting of the International Committee on Global Navigation Satellite System (ICG-02), Sept.4-7, 2007, Bangalore, India

Overview

- Introduction
- EGNOS & Galileo System Descriptions
- EGNOS & Galileo Services
- GNSS signals compatibility and interoperability
- International Activities
- Conclusions

Introduction

- **Early Political Milestones:**
  - **Launch of Galileo programme**
    - **5 April 2001 through a EU Council Resolution, following the Nice European Council**
  - **Following Key assumptions confirmed by subsequent EU Councils**
    - **Galileo definition and development phase to be co-financed by the European Commission and ESA**
    - **Later phase to be implemented as a Public Private Partnership**
    - **Civil system under civil control**
    - **EGNOS integration into Galileo programme**
    - **Five Services: Open Service, Safety of Life Service, Commercial Service, Public Regulated Service, Search & Rescue Service**

Introduction (2)

- **Key Programme Implementation Milestones:**
  - **Creation of the Galileo Joint Undertaking in 2003**
  - **Creation of the GNSS Supervisory Authority in 2005**
  - **June 2007: stop of negotiations with candidate consortium, due to lack of progress**

- **Revision of Key Programme Assumptions**
  - **EU Council takes note of concession negotiations failure**
  - **Re-profiling of the Galileo programme proposed by the EC:**
    - **Galileo infrastructure to be fully taken over by public sector: 2,5 B€ already financed by the public sector**
    - **Galileo to be operational in 2012 preceded by EGNOS in 2008**
    - **Assessment of financial means through the EU budget to be proposed in late September**
  - **Integrated decision on the European GNSS programmes expected in EU Council in Autumn 2007**

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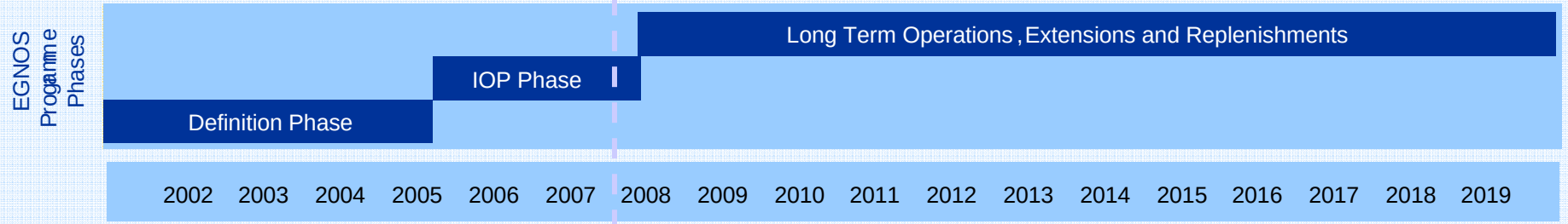
The EU GNSS Programmes

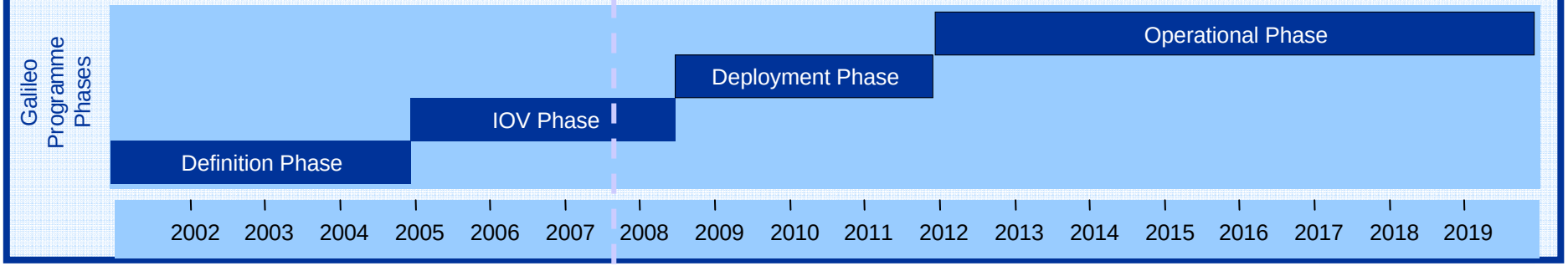
1) EGNOS

Regional Infrastructure & Services

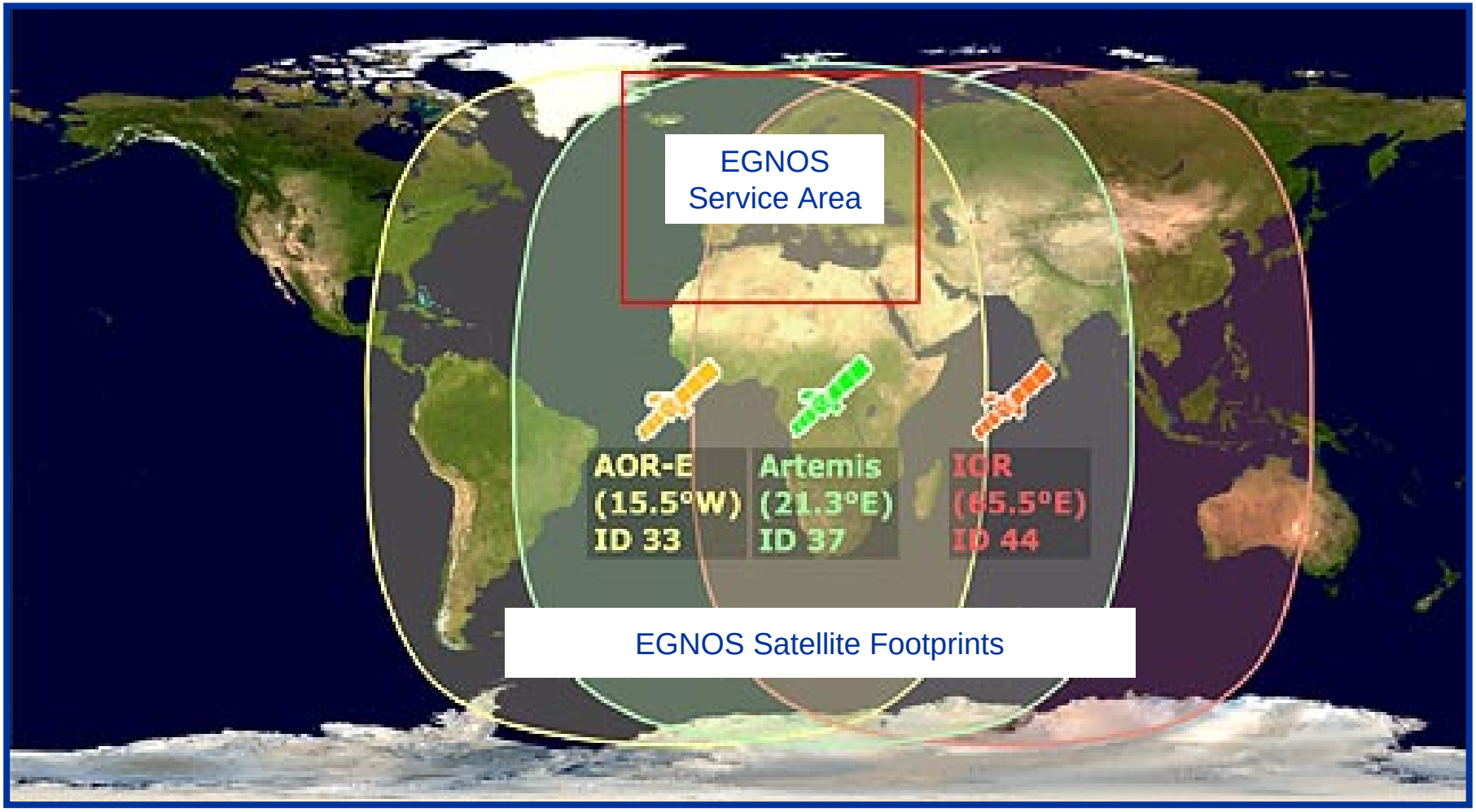


2) Galileo

Global Infrastructure & Services

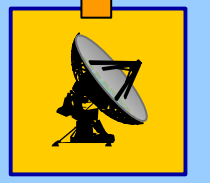


EGNOS Overview



EGNOS System Architecture

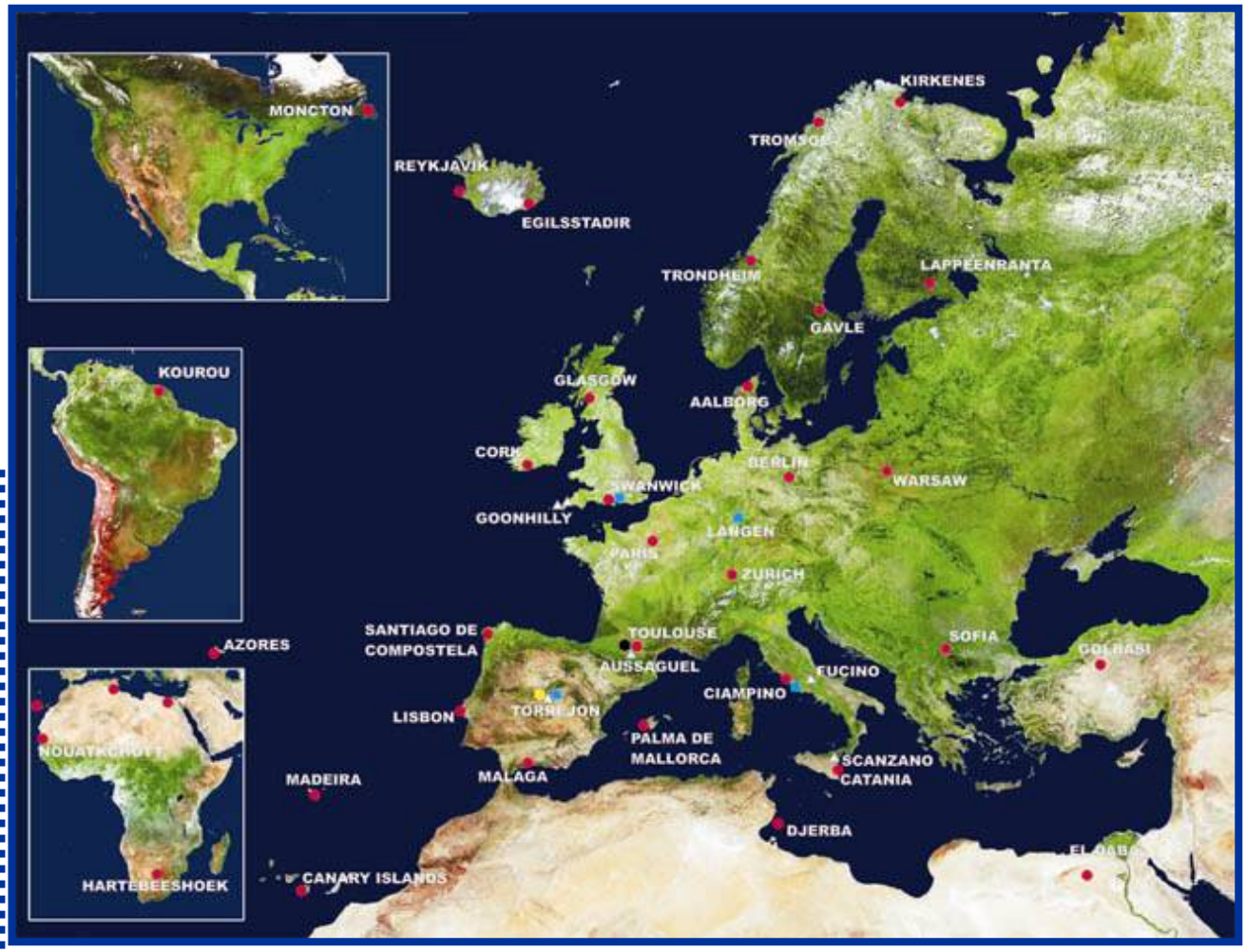
Users

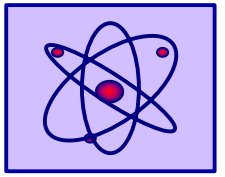


△ 6 NLES Navigation Land Earth Stations

● 2 Support ○ Facilities

□ 4 MCC Mission Control Centers





● 34 RIMS Ranging & Integrity Monitoring Stations

EWAN

EGNOS Performance

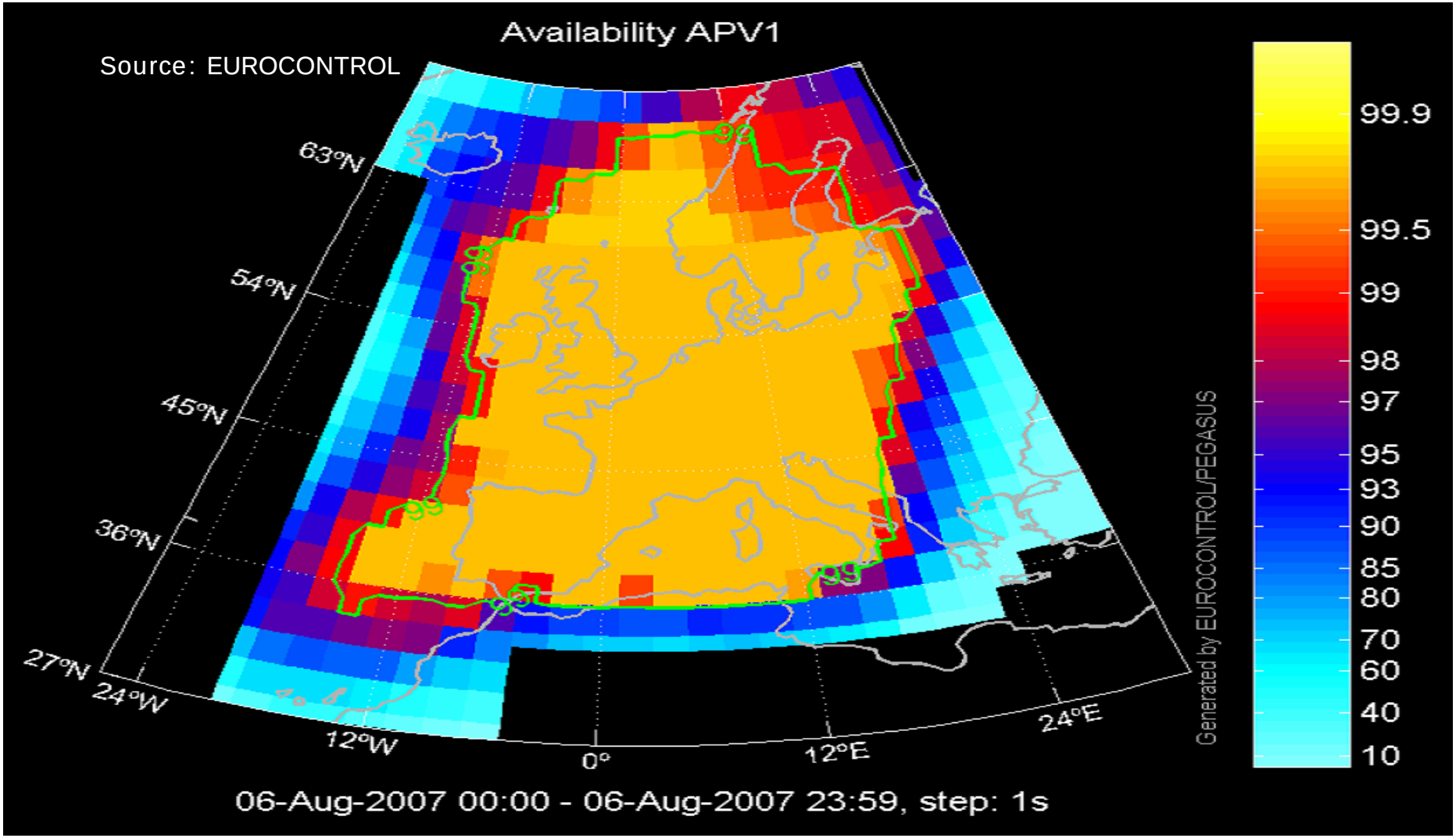
Standards v Actual Performance (5-11 August, 2007)

	APV-1 requirement	Measured at Toulouse (France)	Measured at Warsaw (Poland)	Measured at Brussels (Belgium)
Horizontal Accuracy	16 m	0.91 m (95% HNSE)	2.23 m (95% HNSE)	0.91 m (95% HNSE)
Vertical Accuracy	20 m	1.34 m (95% VNSE)	2.58 m (95% VNSE)	1.34 m (95% VNSE)
Availability	99%	99.9049%* (worst day: 99.33%)	97.6457%* (worst day: 95.08%)	99.9049%* (worst day: 98.219%)
Continuity	$1\text{-}8.10^{-6}$ / 15s	Not measured	Not measured	Not measured

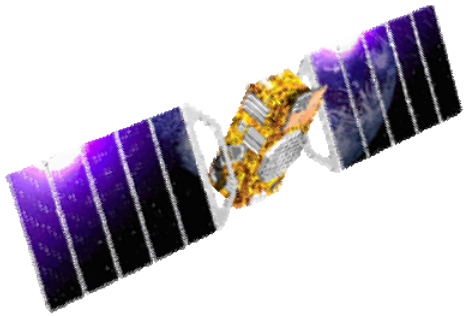
* Availability computed from data collected when EGNOS SiS is available.

Source: ESA EGNOS Real-Time Performance: http://www.egnos-pro.esa.int

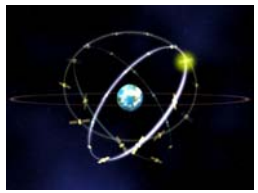
EGNOS Performance (ECAC area)



Galileo Programme



Full Operational Capability
27 (+3) Galileo Satellites



In-Orbit Validation
4 satellites plus
ground segment

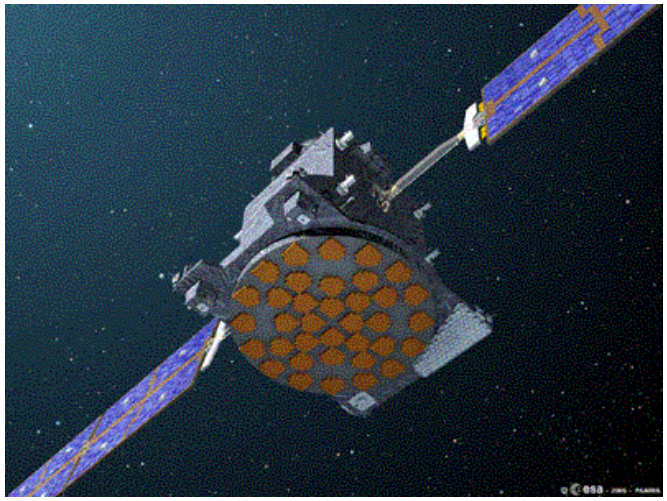
Galileo System Testbed v2
Initial Test Satellites

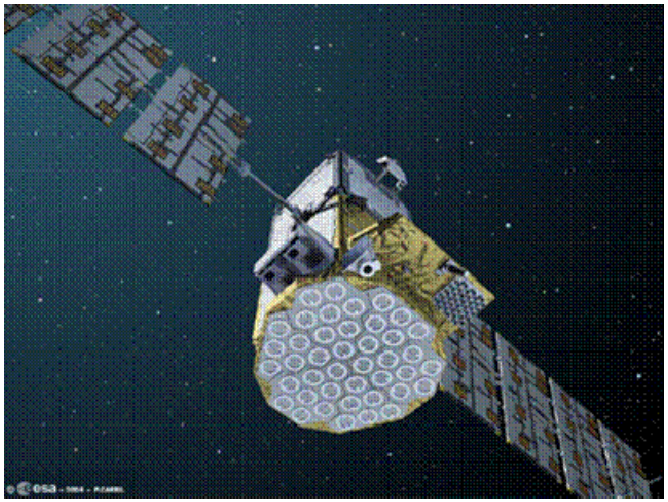
GALILEO
GIOVE

Galileo System Testbed v1
Validate critical algorithms

GALILEO
GSTB-V1

GIOVE Objectives

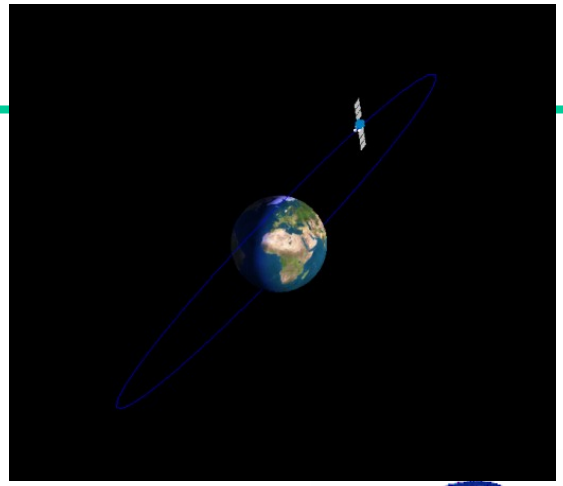




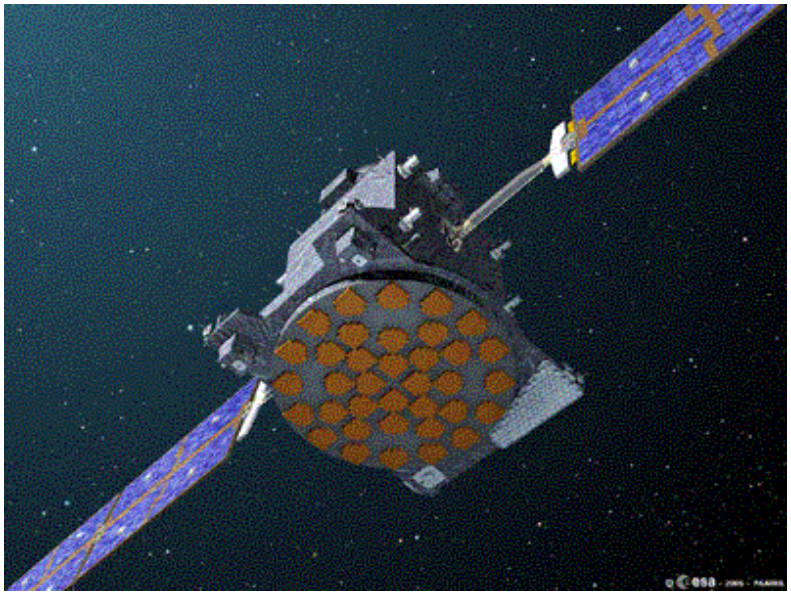
To secure the Galileo frequency filings allocated within the International Telecommunications Union (ITU)

To characterize the MEO orbits to be used by the in-orbit validation satellites

To test some of the critical technologies, such as the atomic clocks

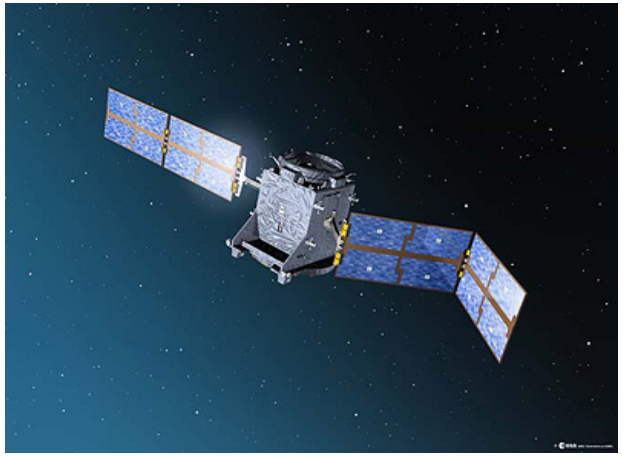


GIOVE-A / GIOVE-A2

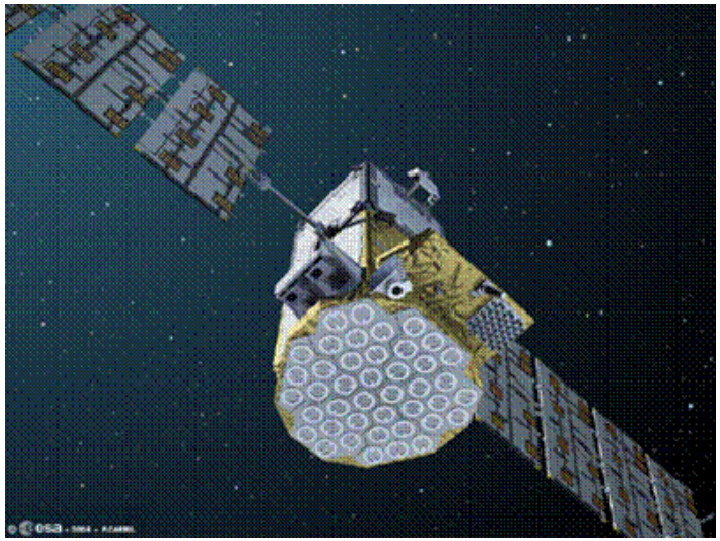


- GIOVE-A is Europe's first MEO satellite
- Launched on 28 December 2005
- The GIOVE-A satellite:
  - Transmits the Galileo signals
  - Tests critical technologies
    - rubidium atomic clock
    - signal generator
  - Measures environment for FOC

- GIOVE-A2 risk mitigation activities started in March 2007
  - Secure in-orbit presence
  - Continue experiments
  - Monitoring of the MEO environment
  - Support EU / US L1 Open Service common baseline



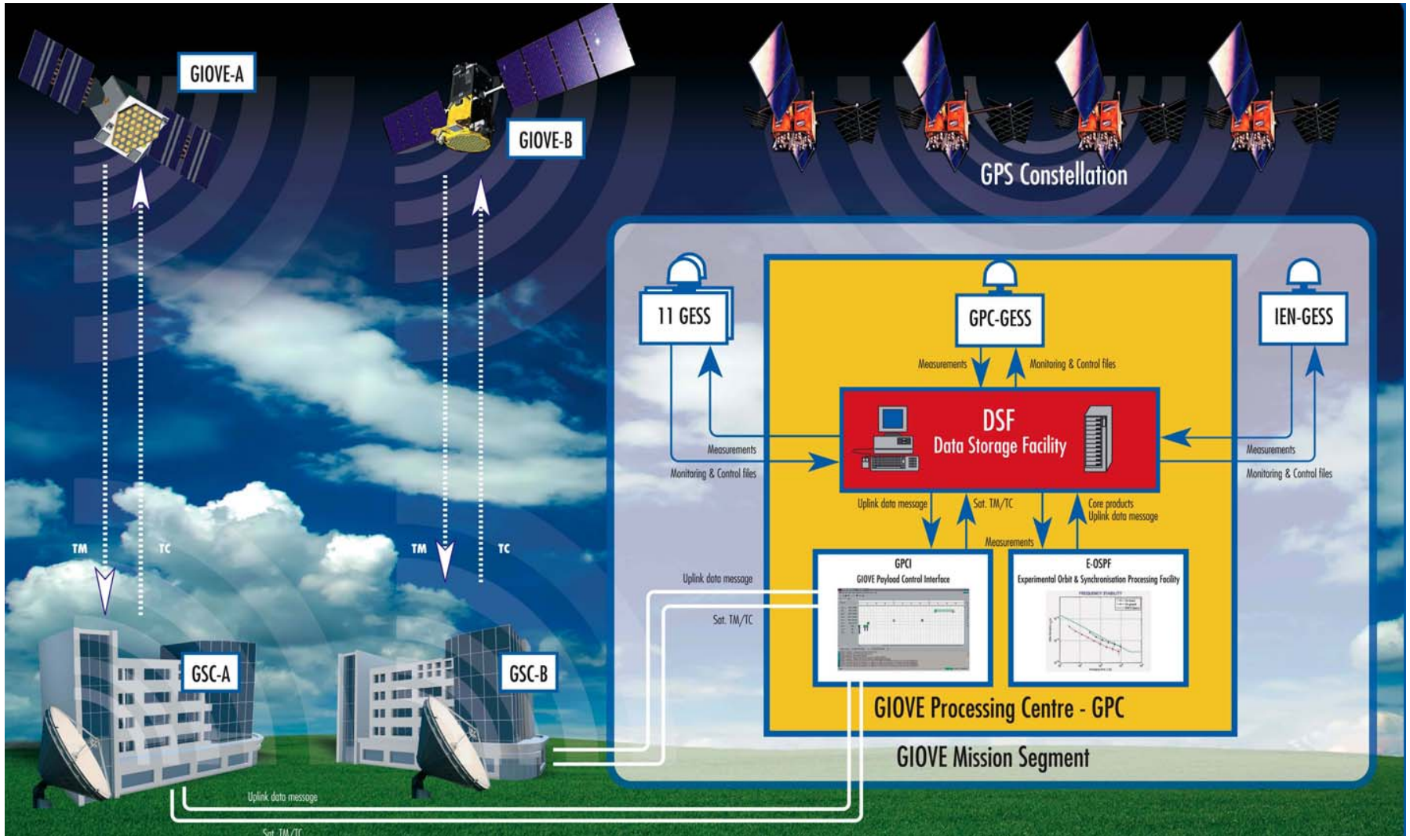
GIOVE-B



Constructed by Galileo Industries
Lift-off mass: 485 kg
Power demand: 940 W
Stowed Dimensions: 1 m x 1 m x 2.4 m

- **The GIOVE-B satellite will:**
  - **Transmit the Galileo signals**
  - **Test critical technologies: passive hydrogen maser clock, rubidium atomic, signal generator**
  - **Measure environment for future constellation**
- **GIOVE-B is expected to be launched in December 2007**

GIOVE Architecture



Galileo Performances
Dual Frequency

Galileo Service	Horizontal Accuracy (95%)	Vertical Accuracy (95%)	Availability	Integrity
Open Service	4 m	8 m	> 99.8%	NO
Safety of Life	4 m	8 m	> 99.8%	YES
Commercial Service	Detailed performance requirements under elaboration			
Public Regulated Service	4 m	8 m	> 99.8%	YES

GIOVE Experimentation 1/2

Space Segment

- Payload performance in orbit correlates with laboratory tests
- Results agree with specifications
- Lessons learned through GIOVE are contributing to Space Segment on-board units predevelopment and in-orbit operations
- On board clock specification appears feasible and with margin (in nominal conditions)

Ground Mission Segment

- GIOVE models/data have been used to validate/calibrate Galileo Raw Data Generator (Simulation Tool)
- Galileo sensor station tracking error specification has been evaluated
- System Performance Budget File will be updated
- Lessons learned in GIOVE are contributing to Ground Mission Segment development

GIOVE Experimentation 2/2

MEO Radiation Environment

- **Measurements are above model predictions**
- **GIOVE-A results in line with GIOVE-B/IOV requirements**

Signal in Space (SIS)

- **Experimentation confirms that GIOVE-A SIS is fully representative of GALILEO SIS**
- **Receiver measurements confirm Galileo performance and indicate AltBOC offers best performance**
- **One-year operation allowed full characterisation of the RF chain**
- **SIS ICD and technical information is publicly available:**

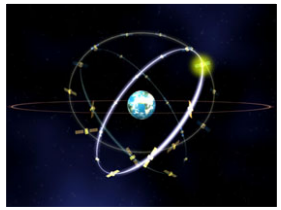
www.giove.esa.int

Galileo IOV & FOC

	Component	IOV Phase	FOC Phase
	Satellites	4	27(+3)
	Control Centres	1	2
	Mission Uplinks	5	10
	TT&C	2	5
	Sensor Stations	20	30-40

Galileo System

30 satellite Constellation

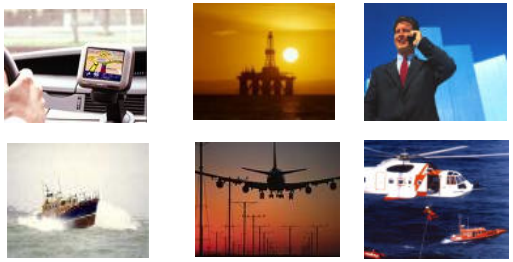


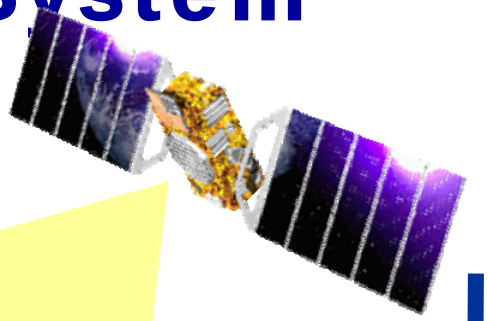
5 TT&C Stations

10 mission Uplink stations

2 Control Centres

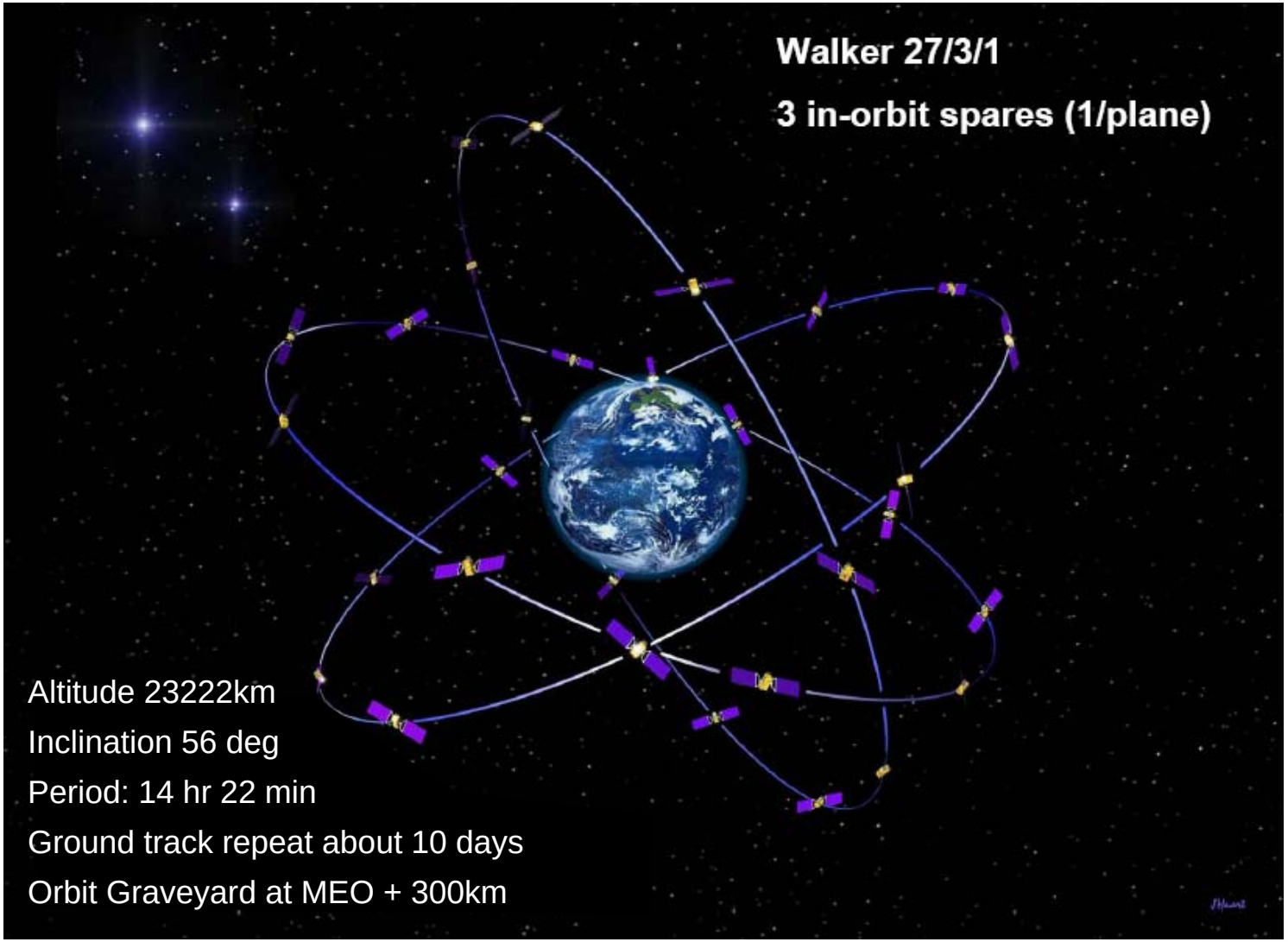
Users & Service Providers





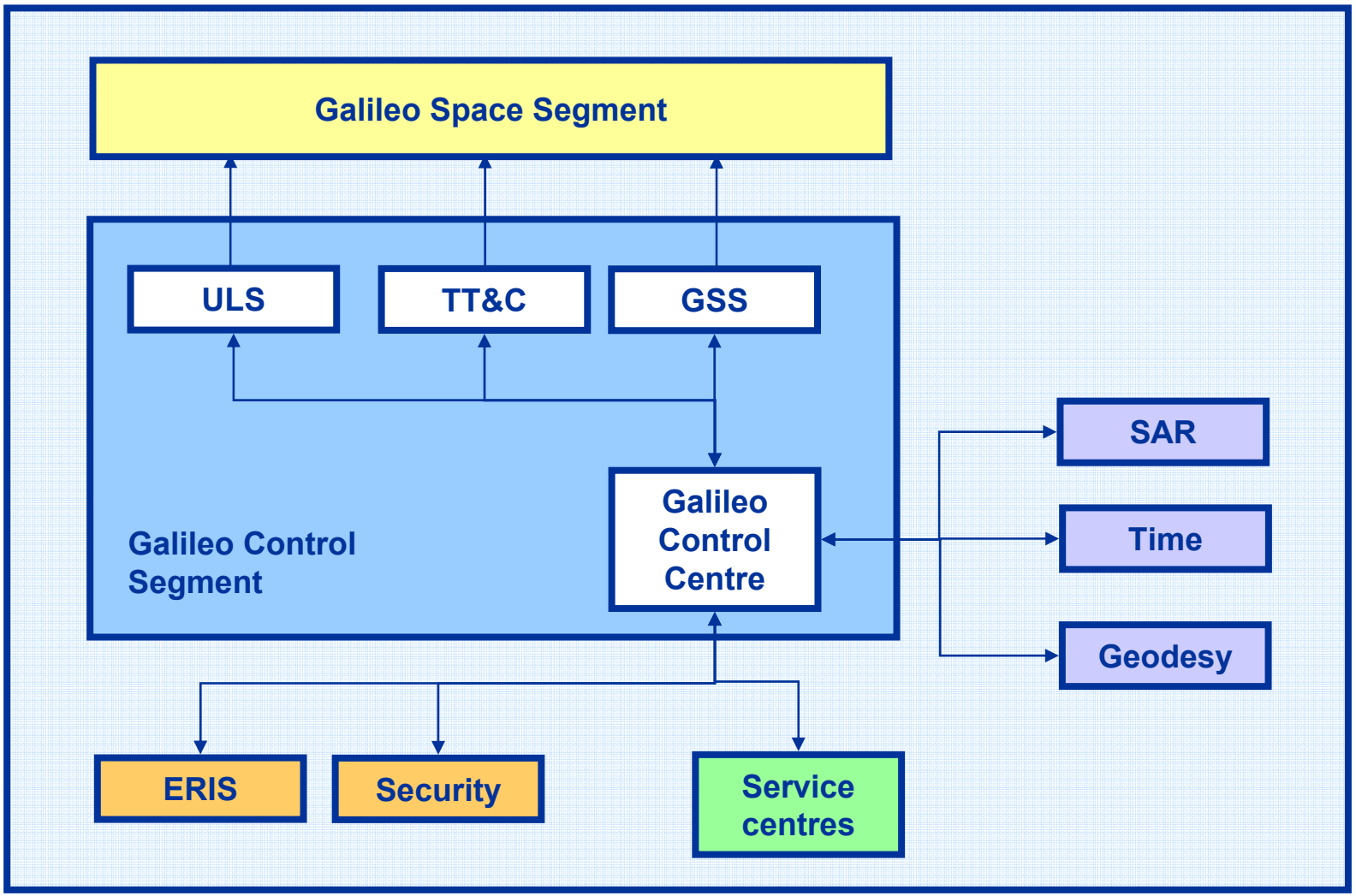
30-40 Galileo Sensor Stations

Galileo Orbits



Altitude 23222km
Inclination 56 deg
Period: 14 hr 22 min
Ground track repeat about 10 days
Orbit Graveyard at MEO + 300km

Galileo Interfaces



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- **EGNOS & Galileo Services**
- GNSS signals compatibility and interoperability
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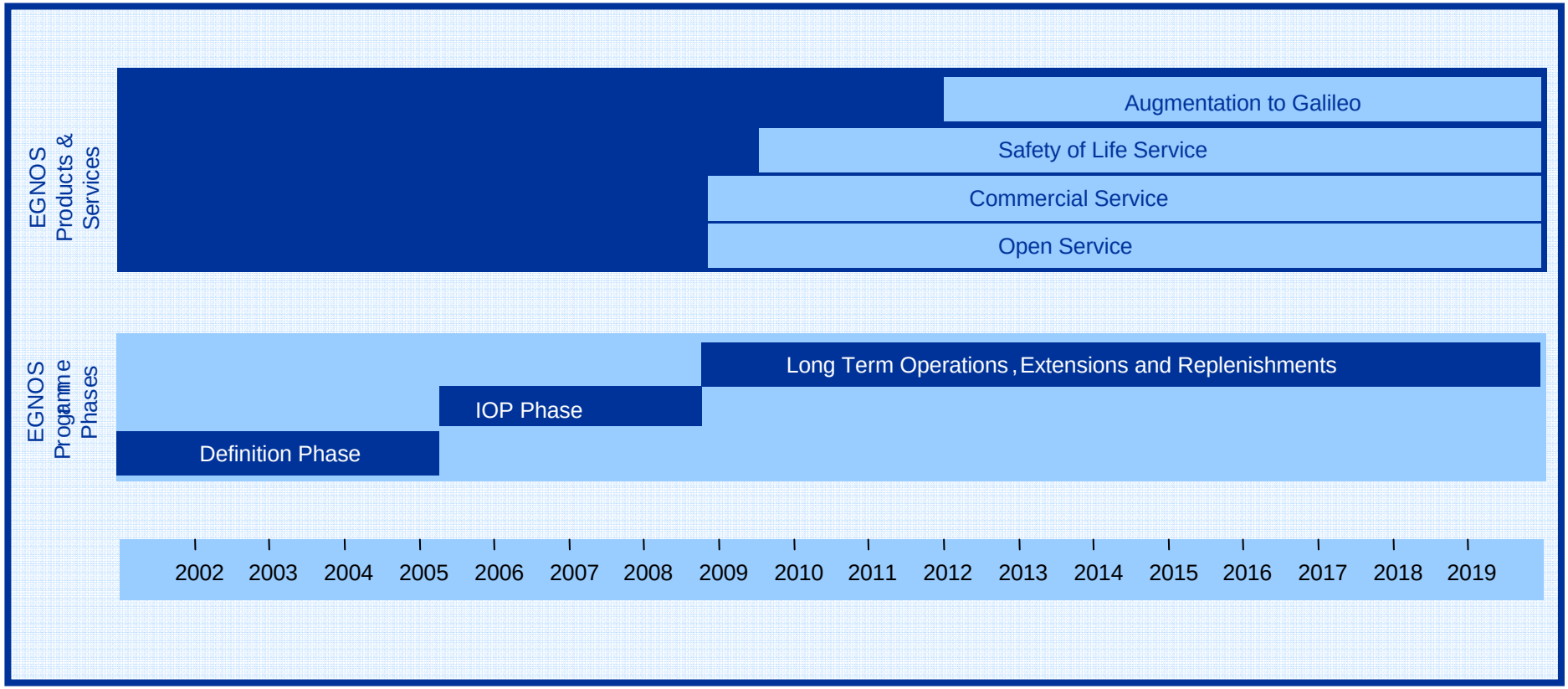
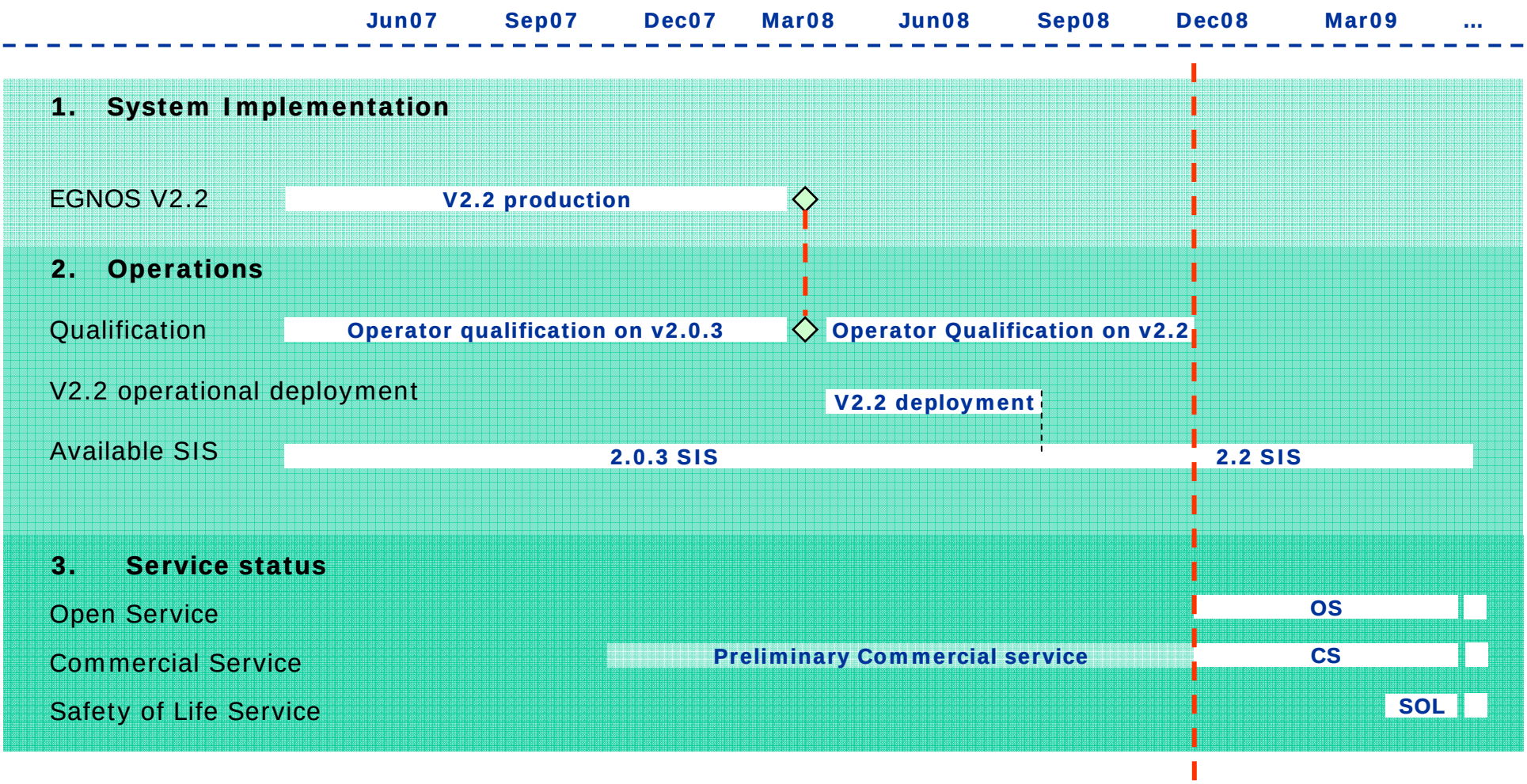
EGNOS Plans


EGNOS Products & Services
Augmentation to Galileo
Safety of Life Service
Commercial Service
Open Service
EGNOS Programme Phases
Long Term Operations , Extensions and Replenishments
IOP Phase
Definition Phase
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

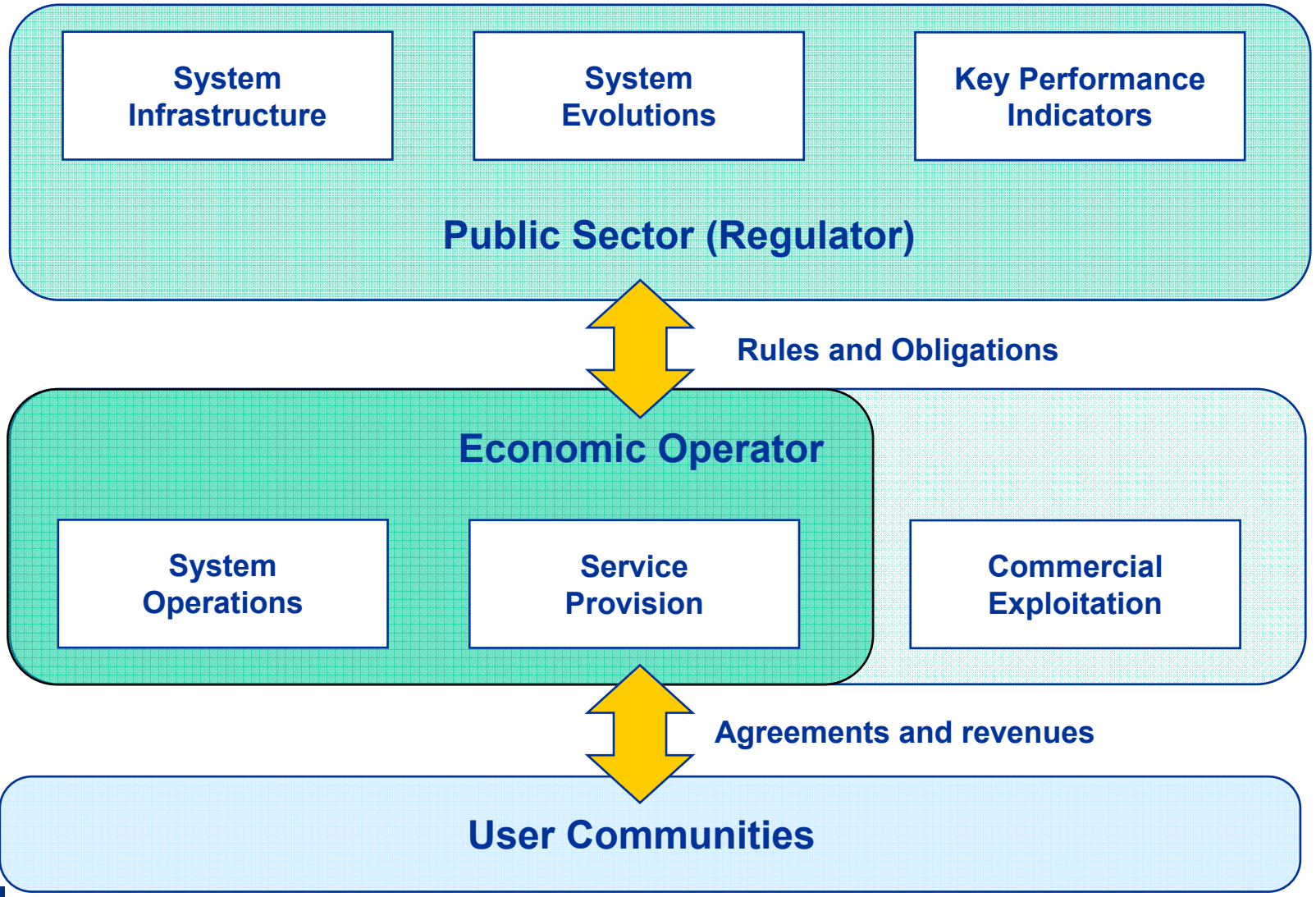
EGNOS Schedule



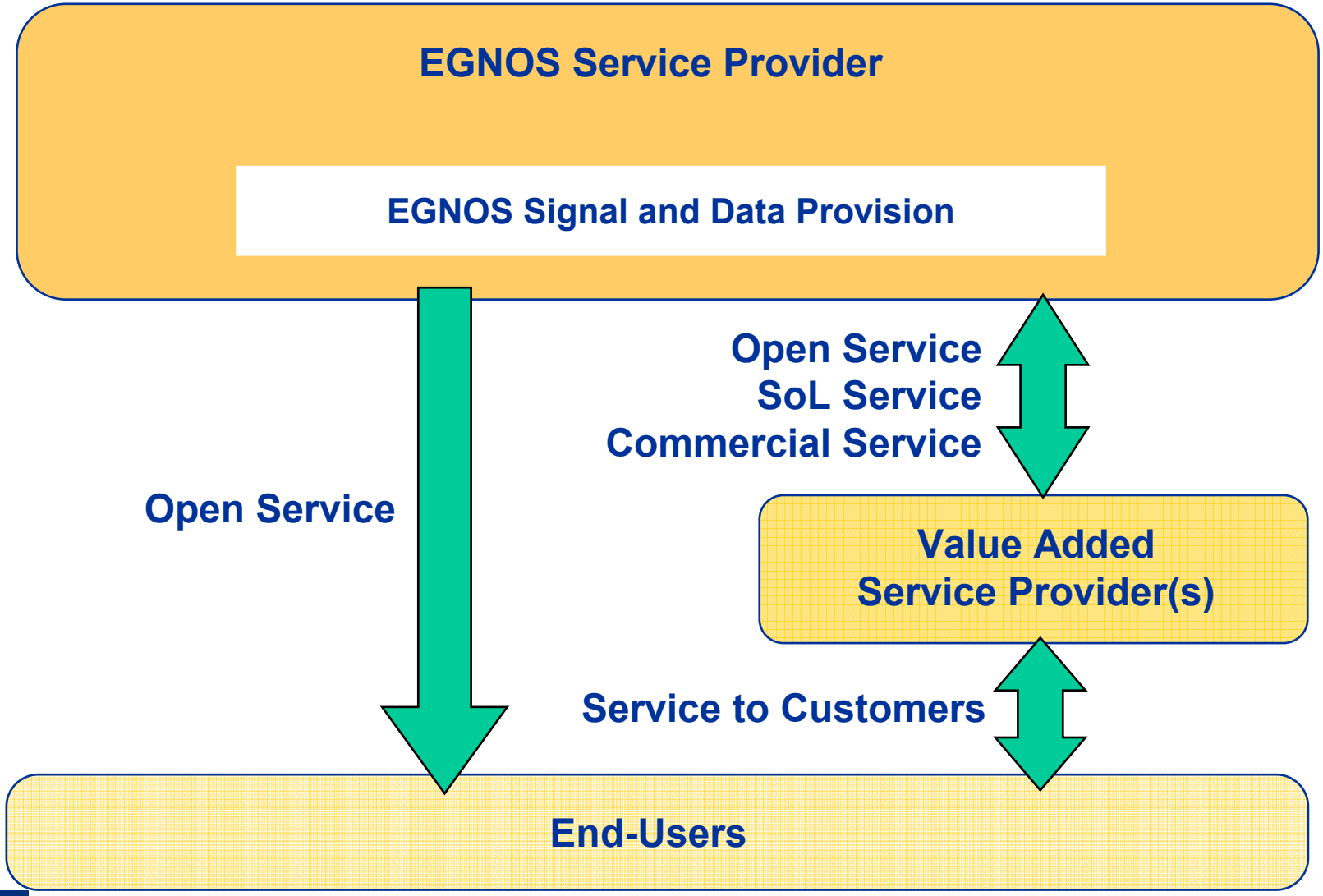
EGNOS Services

	Open Service	Safety Of Life	Commercial Service
Transmission means	RF signal (L1 frequency)	RF signal (L1 frequency)	Ground network
Reference	EGNOS MRD	EGNOS MRD	EGNOS MRD
Guarantee of Service	None	Guarantee of compliance to ICAO standards (certification)	Guarantee of compliance to SLA
Definition of the Service	SIS only (free-to-air)	SIS + Guarantee of compliance to ICAO standards (certification)	EGNOS data + Guarantee of compliance to SLA
Typical user communities	Pedestrian, in-car navigation	Aviation, Maritime, railway, road (tolling), emergency services	Pedestrian, in-car navigation, research (e.g. atmospheric, tectonics), high-precision GNSS

EGNOS Management Structure



EGNOS Service Provision



EGNOS Service Evolutions

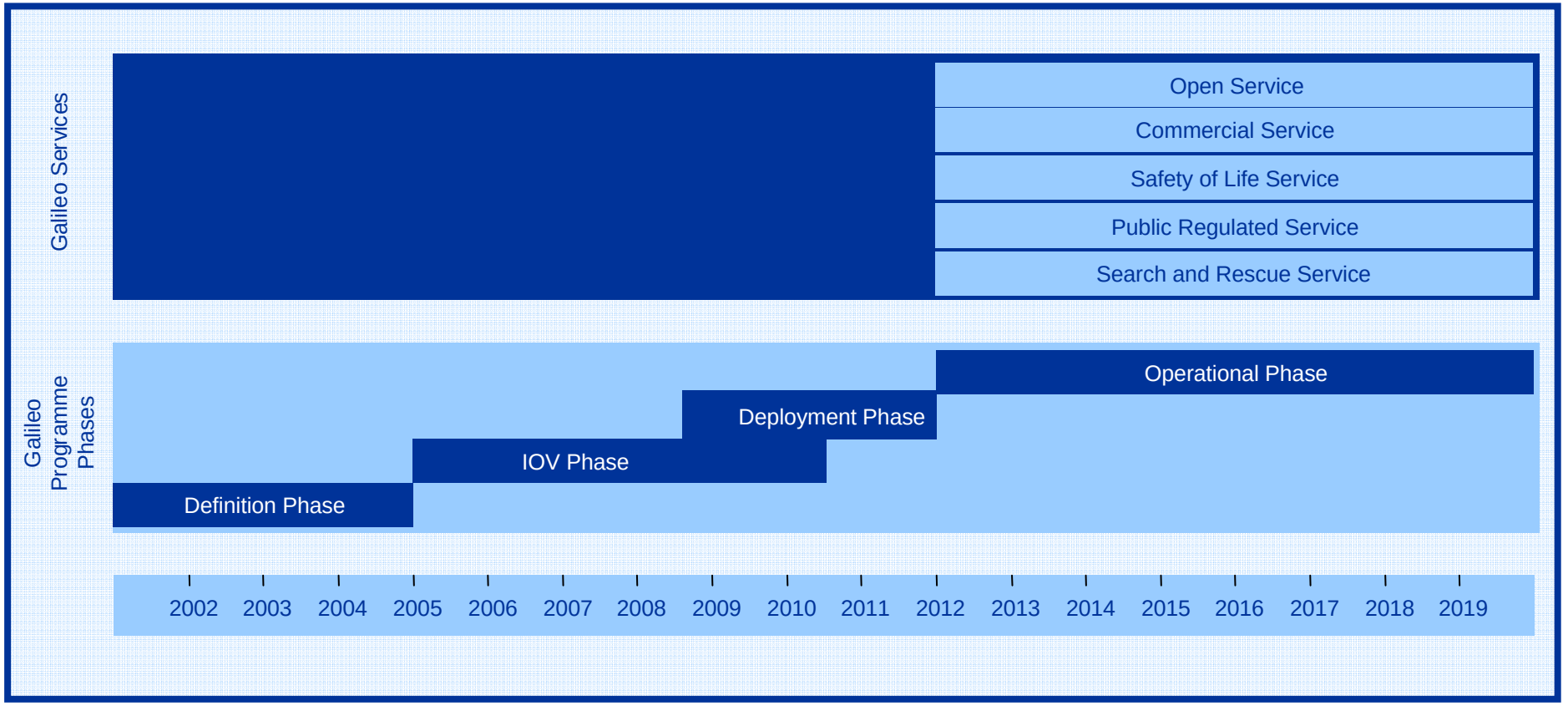
Coverage Evolution
- Enlargement (Eastern Europe, MEDA)
- Extensions (Africa, Middle East)
- Regional extension module

Standard Evolution
- SBAS L5, Galileo SOL standards
- Multi-constellation, multi-frequency Regional System (MRS)

Infrastructure Evolution
- Augmentation to Galileo
- Augmentation to modernized GPS

Additional services
- EGNOS Time Service
- Critical Communication message (ALIVE concept)

Galileo Plans



Galileo Services

Service			Receiver	Benefits	Target user groups	Availability
Open Service	OS		**Single frequency**	• **Additional satellites for better multi-system coverage (e.g., deep urban)** • **Coding and modulation advances for increased sensitivity and multi-path mitigation** • **Pilot signal for fast acquisition**	• **Low end mass market (e.g., LBS, outdoor)**	**Open**
			**Double frequency**	• **As above + increased accuracy with 2nd frequency**	• **High end mass market (e.g., car navigation, maritime)**	**Open**
Commercial Service	CS		**Double frequency**	• **Increased accuracy using additional frequencies and signals** • **Additional features under investigation (e.g., data rate capacity)**	• **Professional markets (e.g., surveying, precision agriculture)**	**Commercial basis**
Safety of Life Service	SoL		**Single frequency (Level B)**	• **As OS +** • **Integrity and authentication of signal** • **Continuity and service guaranty**	• **Aviation (en route)**	**Certified receivers**
			**Double frequency (Level A and C)**	• **As above at higher performance levels suitable for stringent dynamic conditions**	• **Aviation (A)** • **Maritime (C)** • **Road, Train (A)**	**Certified receivers**
Public Regulated Service	PRS		**Dual frequency**	• **As OS +** • **High Continuity (in times of crisis)** • **Improved Robustness (vs jamming, spoofing)**	• **Law enforcement** • **Strategic infrastructure**	**Regulated**
Search and rescue	SAR		**Single frequency**	• **Almost instantaneous reception of emergency calls** • **Exact positioning of emergency beacon**	• **Emergencies**	**Certified & registered beacons**

Supporting Service Provision

Market	Target User group	R&D Project
Transport	Road	GIROADS
	Rail	GRAIL
	Aviation	GIANT
	Maritime	MARUSE
Mass Market	Mobile Location Based Services	AGILE
Public	Emergency management, Humanitarian aid, law enforcement	HARMLESS
	Public regulated Services	PACIFIC
	Emergency Services	MAGES
Professional	Multimodal Freight Transportation	MTRADE
	Energy, geo-reference	GIGA
	Agriculture	FIELDFACT
	Cultural heritage	CUSPIS
	Surveying & Engineering	MONITOR
	Timing and synchronisation	HARRISON
	Scientific research	GEO6

SIXTH FRAMEWORK PROGRAMME

SEVENTH FRAMEWORK PROGRAMME

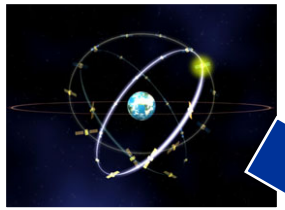
€110m invested, €350 planned

- Applications development
- Introduction of Services
- Receiver development
- Technology demonstrations
- End-to-end demonstrations
- Pilot projects
- Awareness
- Dissemination of results
- Standardisation
- International Activities

Note: see www.galileoju.com for more information on these projects

Galileo Regional System (ERIS)

Global Message



Galileo Satellites

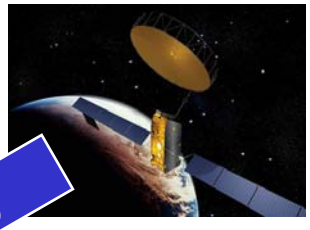
Integrity Uplink

Galileo Integrity

Global Integrity

Regional Integrity

Regional Message



ERIS Satellites

Integrity Uplink

Regional Integrity

Global Network
Of Galileo Stations

Regional Network
Of GNSS Stations

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- **GNSS signals compatibility and interoperability**
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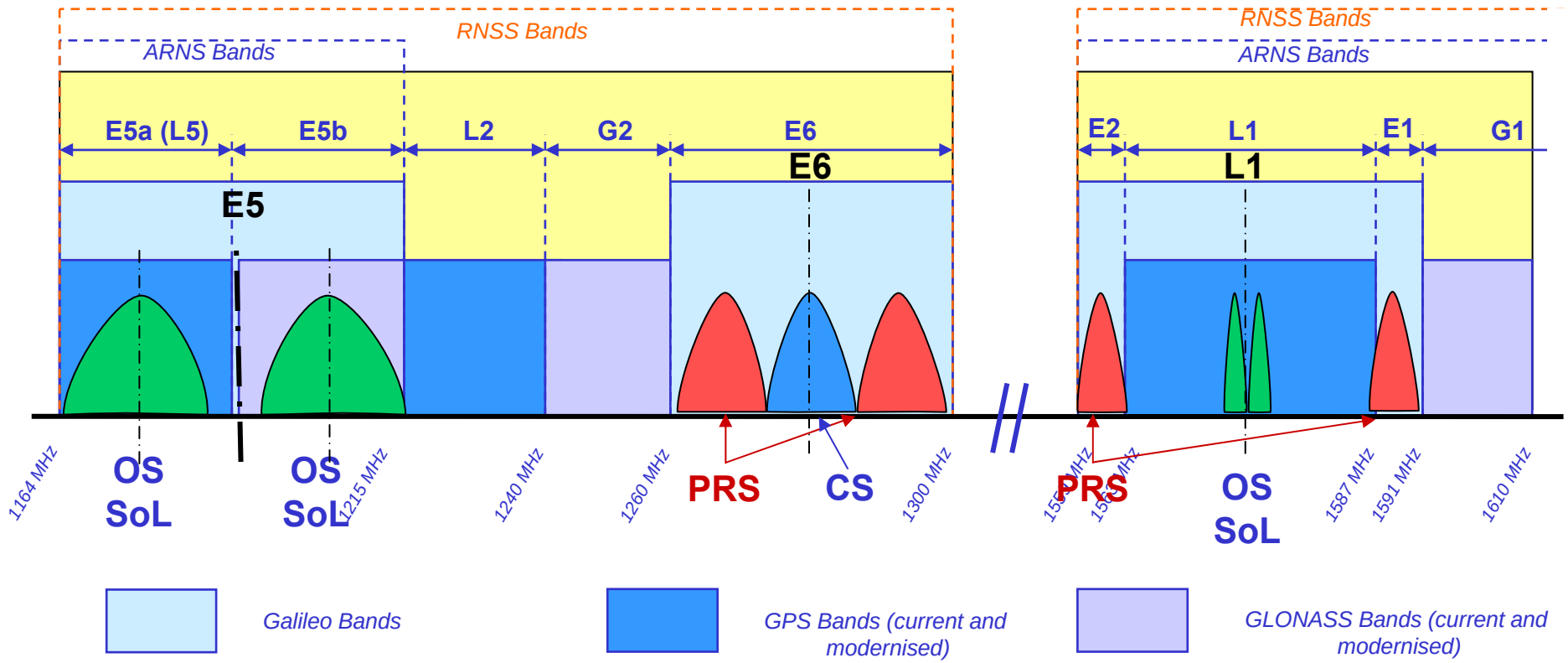
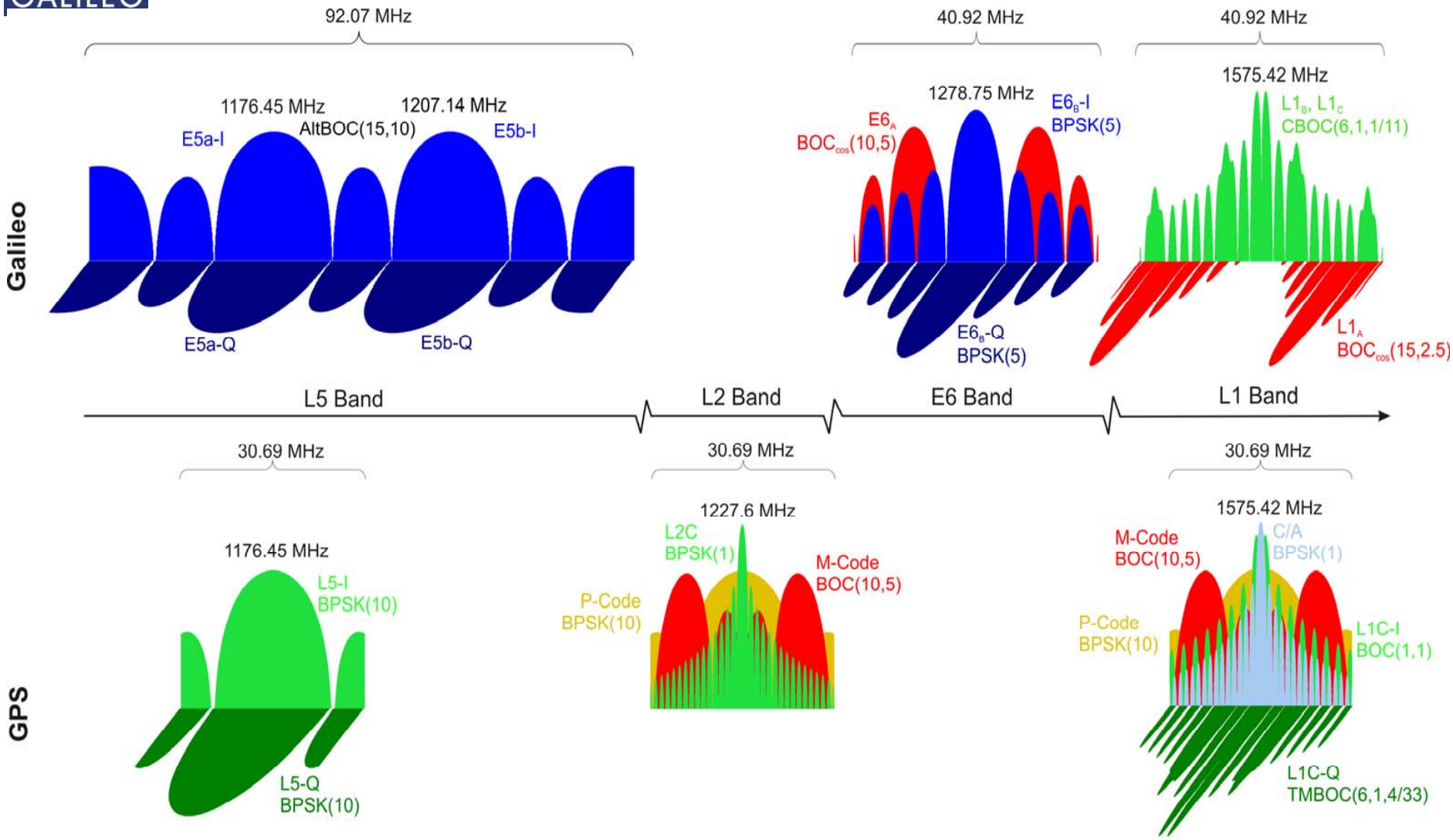
Galileo Signal and Frequency Plan

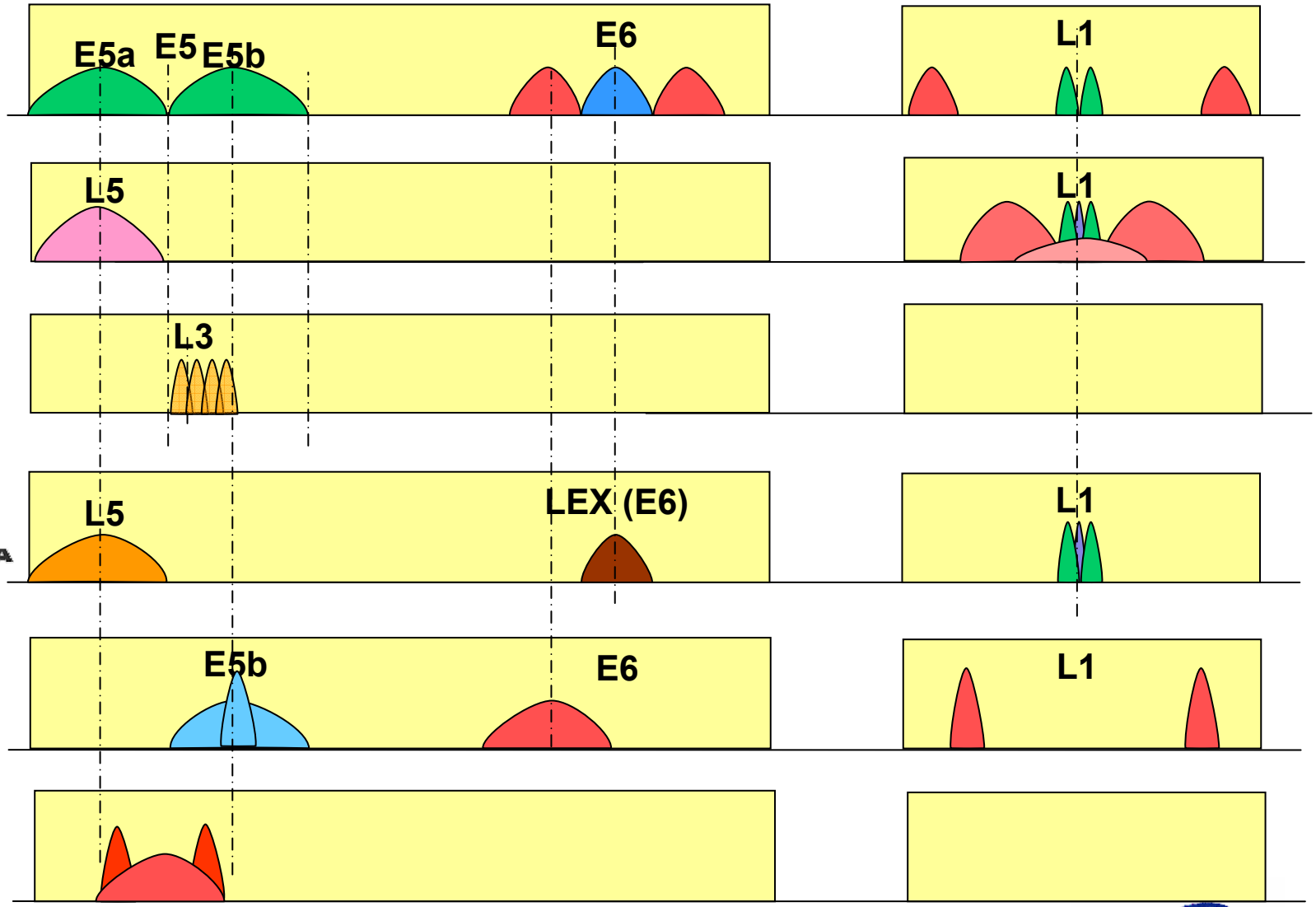


Not to scale

Galileo and GPS signal structure



Compatibility & interoperability with other GNSS



Compatibility & interoperability with other GNSS (2)

- Galileo and..
  - GPS:
    - EU-US Agreement signed on June 2004
    - 6 Working Group meetings on compatibility and interoperability (WGA) in 2005-2007
  - GLONASS:
    - 3 Technical Group meetings in 2004-2005; restarted in 2007
  - QZSS:
    - 6 Technical group meetings in 2004-2007
  - Nigcomsat:
    - 1 coordination meeting in 2007
  - COMPASS:
    - 1 coordination meeting in 2007

Compatibility & interoperability with other GNSS

- ***Compatibility*** **refers to the ability of space-based positioning, navigation, and timing services to be used separately or together without interfering with each individual service or signal, and without adversely affecting national security.**

- ***Interoperability*** **refers to the ability of civil space-based positioning, navigation, and timing services to be used together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal.**

ITU - WRC and Spectrum Issues

- **Agenda item 1.6**
  - **Aviation bid for AM(R)S allocation (5000-5030 MHz) jeopardises ubiquitous deployment of evolved satnav operations, severe interference to RNSS**
  - **CEPT (supported by APT, RCC, Arab group) does not support allocation**
- **Agenda item 1.21**
  - **Potential restrictions to protect Radioastronomy**
  - **(−194dBW/m²/20kHz pfd limit proposed by CEPT for RNSS emissions into 1610.6-1613.8 MHz at single dish RAS sites, integrated over 2000s)**
- **Agenda item 1.12**
  - **Looking to rationalise/simplify some aspects of filings/coordination procedures (and tidy Radio Regulations): eg CEPT proposes to remove a particular ambiguity in 9.11A to 9.16 so that coordination is only required between services with equal rights**

ITU - WRC and Spectrum Issues

- **Interference to radar 1215-1300MHz**
  - **Non WRC issue. ITU-R WP 8B continuing to assess the issue**
  - **Galileo analysis shows that RNSS and radars already coexist happily**
  - **As new signals will be within the same PFD range, Galileo supports ongoing work to develop ITU-R Recommendations for continued radar and RNSS operations within the whole band**

- **ITU-R RNSS System Recommendations**
  - **WP8D continues to develop RNSS specific Recommendations for use in compatibility studies – Galileo supports and actively contributes to this work**

- **Res609 and bi-laterals**
  - **Galileo will participate in the Res 609 Consultation group and continue bi-lateral negotiations with other RNSS systems**
  - **Galileo welcomes the multilateral framework introduced by ICG**

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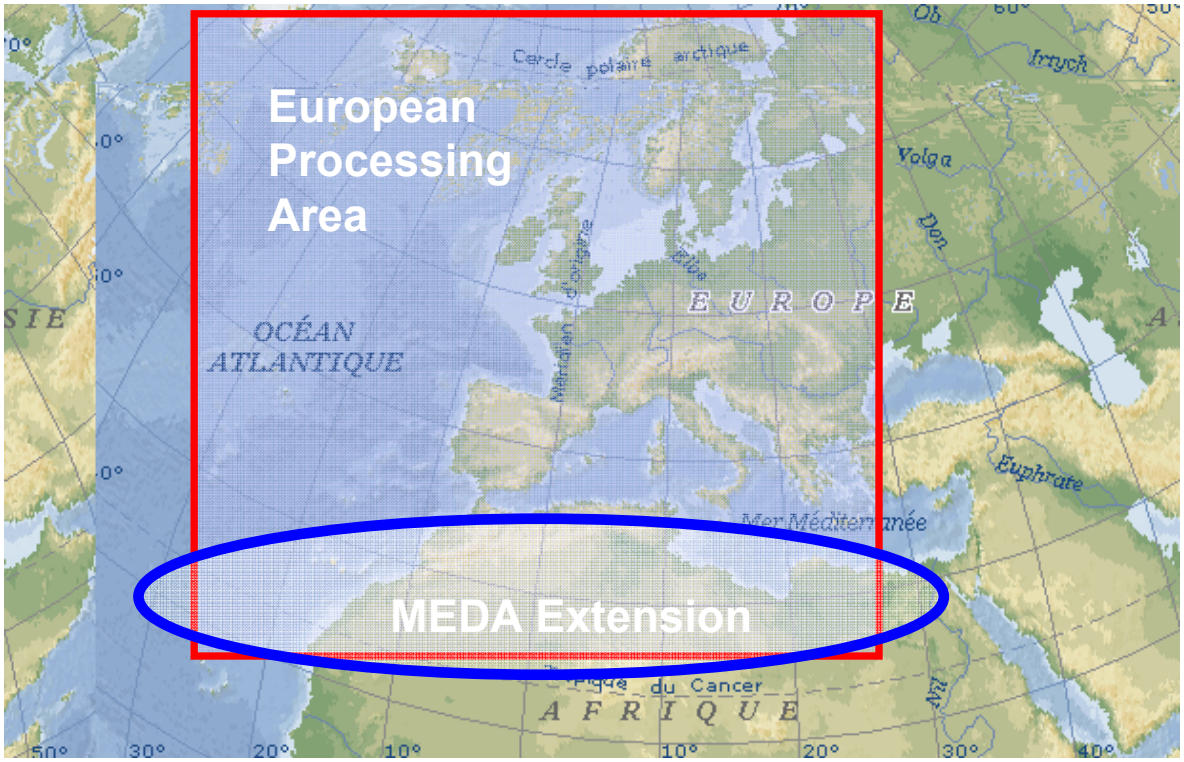
EGNOS Trials in Africa

- EGNOS trials have been carried out in Senegal and Kenya
- EGNOS has demonstrated benefits of precision approach with vertical guidance without any specific infrastructure on the ground
- Especially beneficial at secondary airports that would be too costly to equip with conventional landing aids
- An ongoing programme of work has ensured the installation of EGNOS reference stations in several African countries:
  - Chad, Cameroon, Central African Republic, Congo, Ethiopia, Kenya, Zambia, Namibia and South Africa

EGNOS Extensions - MEDA



MEDA region falls within the EGNOS European Processing Area

- **Homogeneous extension**
- **Extension of EGNOS network (Addition of 4-6 RIMS)**
- **EGNOS Central processing**

EGNOS Extensions - ACAC

ACAC region falls outside the EGNOS European Processing Area

- **Regional extension**
- **Extension of GPS integrity monitoring**
- **Additional ionospheric monitoring**

Galileo International Activities

Perspectives

- New worldwide infrastructure
- Regional & Local components
- Research & technology
- Industrial cooperation
- Market development and Trade
- Global Standards and certification

Galileo Centres

- China
- Egypt (Mediterranean Region)
- Latin America

Agreement EU-MS and..	Signed / Initialed
U.S.A.	✓
China	✓
Israel	✓
India	✓
Morocco	✓
South Korea	✓
Ukraine	✓

***Exploratory talks on going with other countries, including Russian Federation and Japan**

Galileo International Board

To be set up in order to associate non EU partner countries in the management structures of the Galileo programme

International Projects

Mediterranean Region (METIS Project)

- **The goal is to promote GNSS services in the MEDA area. Its outcome gives relevant support for Euro-Med cooperation and a common policy regarding the use of EGNOS and GALILEO in the Mediterranean region.**

Latin America Region (LATINO Project)

- **Galileo Information Centre (Brazil)**

Latin America Region (CELESTE Project)

- **CELESTE will build on the results of previous EGNOS trials in the region and to provide the guidelines and recommendations to define future activities and projects to be carried out in the region**

Overview

- Introduction
- EGNOS & Galileo System Descriptions
- EGNOS & Galileo Services
- GNSS signals compatibility and interoperability
- International Activities
- Conclusions

Conclusions

EGNOS is in its Operational Validation Phase

- **Initial Commercial Services starting in 2007**
- **Open Service in 2008**
- **Safety of Life Service in 2009**

Galileo is in its Development Phase

- **GIOVE-A mission on-going**
- **GIOVE-B will be launched in December 2007**
- **Initial 4 satellites by 2010**
- **Full Operational Capability by 2012**

International Cooperation is an important feature within both the EGNOS and Galileo programmes:

- **Infrastructure & Services**
- **Research & Development**
- **Market Development**

thank you for your attention

further information can be found at:

http://ec.europa.eu/dgs/energy_transport/galileo/documents/index_en.htm
gsa.europa.eu
www.esa.int
www.giove.esa.int