GALILEO
The European Satellite Navigation System

GALILEO Interim Support Structure – Brussels

Galileo mission consolidation & maritime needs:
December 18th 2002,Brussels.

Overview

1. The institutional cooperation between EC and ESA
2. The Galileo services and signals
3. The Galileo architecture
4. European standardisation activities
5. Conclusions

The European Space Strategy

In November 2000, the European Council for Research and the ESA Council approved in a joint session the European Space Strategy (ESS)

The following task share between the two organisations was agreed:

EC: **Political lead in EU Programmes**

ESA: **Implementing Agency for space related EU Programmes**

Co-operation:	**Navigation:**	**GALILEO**
	Earth Observation:	**GMES**
	Telecom:	**5th & 6th FRP & others**

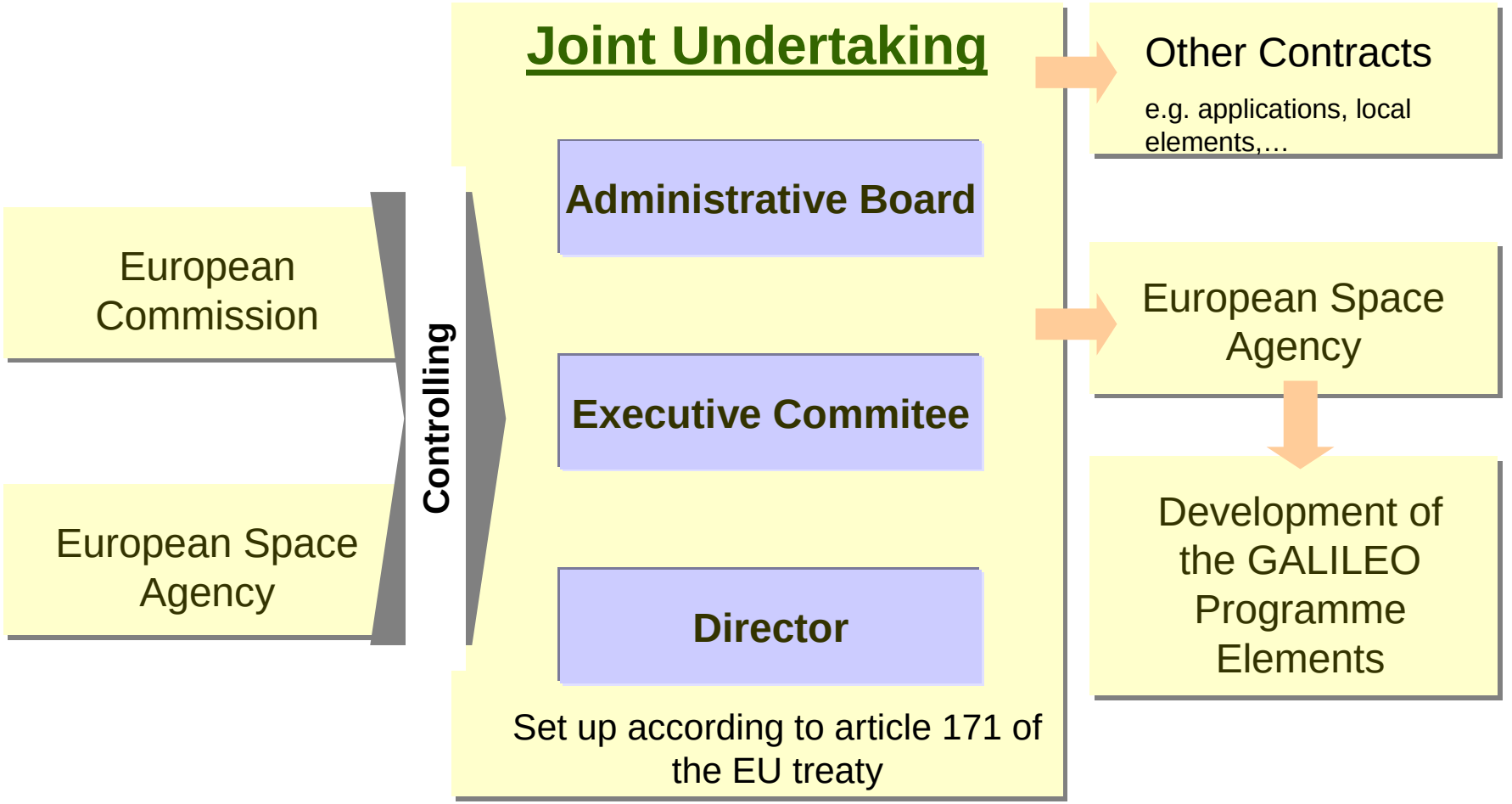
European Political Motivation For GNSS

- Sovereignty, Independence, Service Guarantee
- Implementation of European Transport Policy
- Certifiable for Safety of Life Applications
- Market share for European Industry
- Complementarity to GPS / GLONASS
- Joint actions by EU and ESA

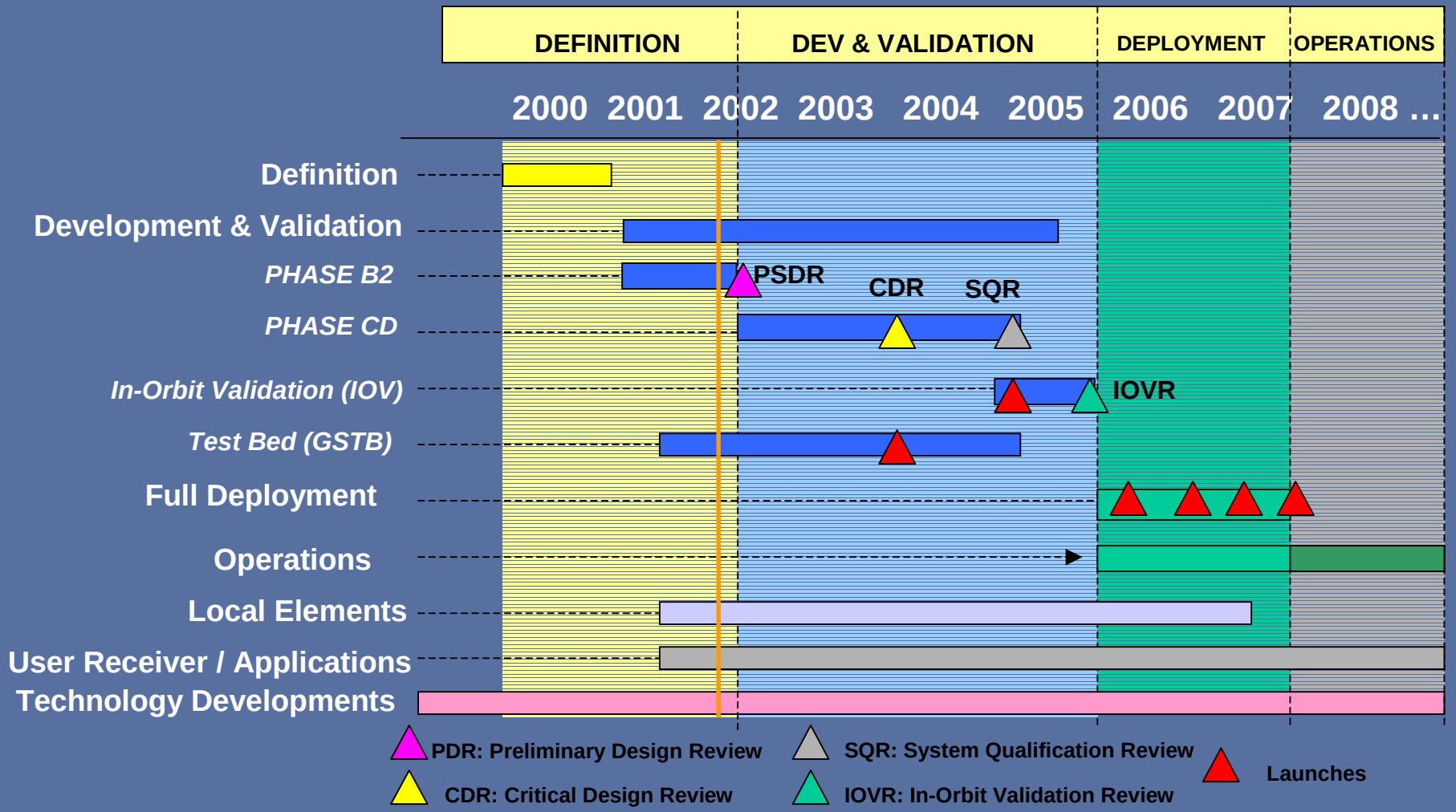
Status of Political Decision Making Process

Mid 2001	Start of ESA Phase B2
15 Nov. 2001	Approval by ESA Ministerial Council of phase C/D budget (550 M€)
7 Dec. 2001	EC Council refers decision on phase C/D (450 M€) to European Summit
14/15 Dec. 2001	European Summit provides positive signal and intends for decision in March 2002
26 March 2002	Decision of EU Transport Council to start next phase and to create the Joint Undertaking
5/6 Dec. 2002	EU Transport Council agrees on the five Galileo services, to be included in the Invitation To Tender

GALILEO Management (from end 2002 to 2005)



The GALILEO Master Schedule



The Signals and Services provided by the GALILEO System to Users

The GALILEO Services

1. **Galileo satellite only services**

   Navigation services:

   - **Open Service (OS)**
   - **Commercial Service (CS)**
   - **Safety-Of-Life Service (SoL)**
   - **Public Regulated Service (PRS)**

   Support to Search and Rescue Operations:

   - **SAR/Galileo**

2. **Locally Assisted Service**
3. **EGNOS Service**
4. **Combined Services (e.g. GPS, UMTS)**

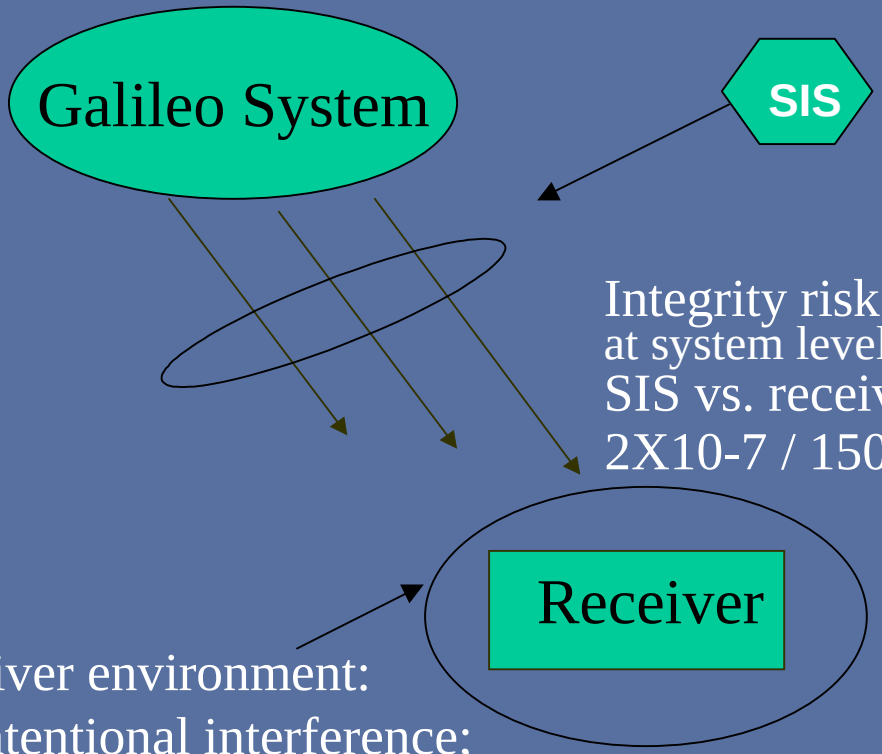
Galileo satellite only services

Position, Velocity and Time Services:

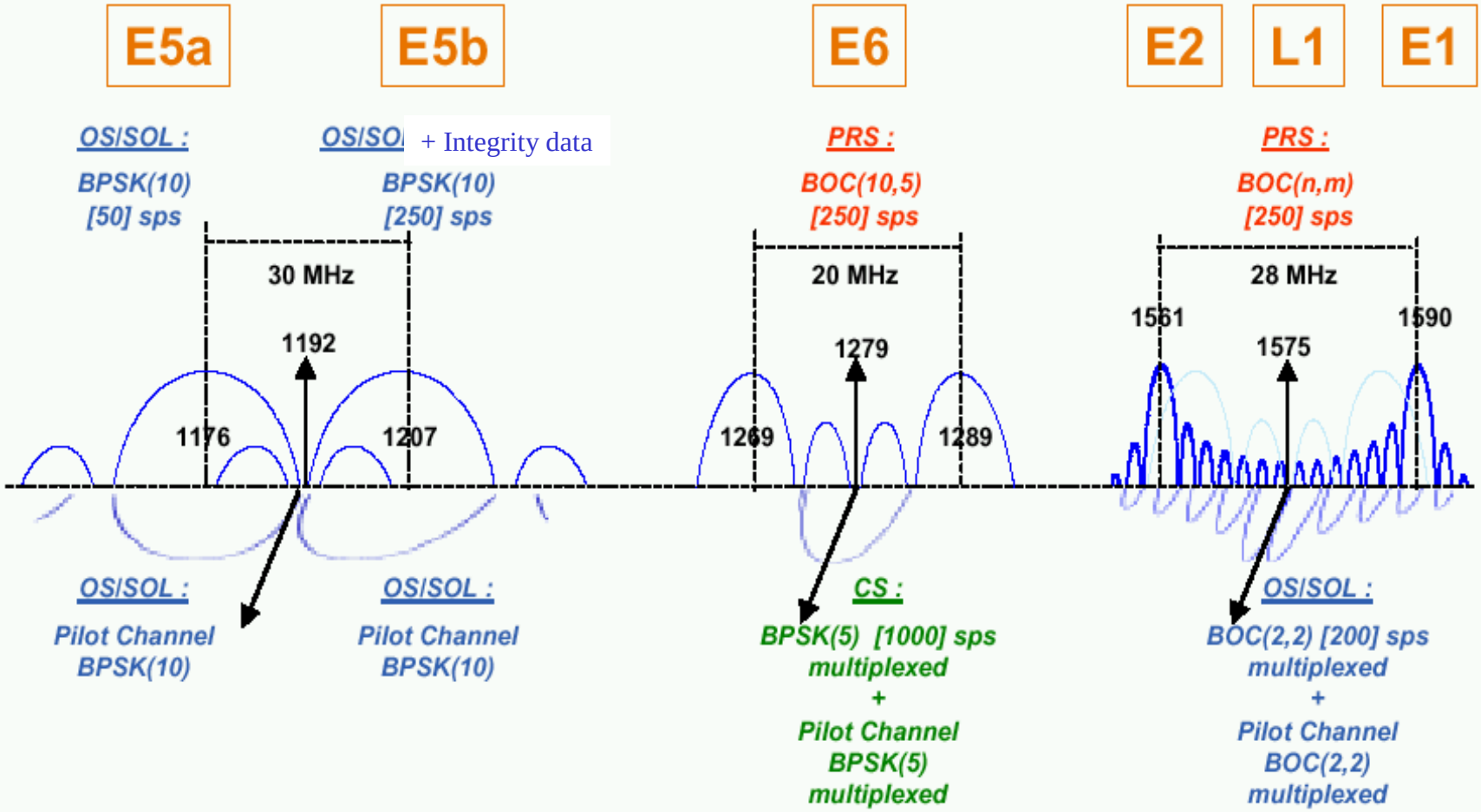
- **Open Service** - providing positioning, navigation and timing services, free of charge, for mass market navigation applications (future GPS SPS)
- **Commercial Service -** provides added value over the Open Service providing commercial revenue, such as dissemination of encrypted navigation related data (1 KBPS), ranging and timing for professional use - with service guarantees
- **Safety of Life Service** – Provides timely warnings (Integrity) and service guarantees.
- **Public Regulated Service** - for applications devoted to European/National security, regulated or critical applications and activities of strategic importance - Robust signal, under Member States control
- **Support to Search and Rescue:**

  Search and Rescue Service coordinated with COSPAS SARSAT

General approach of Galileo services



The GALILEO Signal Structure



GALILEO Open Service

Coverage		Global	
Accuracy (95%)		H: 15m V: 35m	H: 4m V: 8m
Integrity	**Alarm Limit**	**Not Applicable**	
	Time-To-Alarm		
	Integrity Risk		
Continuity Risk		8×10^{-6} / 15 sec	
Timing Accuracy wrt UTC/TAI		Not defined	50 nsec
Certification/Liability		No	No
Availability		99.8%	
		Single Freq.	Dual Freq.

GALILEO Safety Of Life Service

Coverage	Global	
Accuracy (95%)	H: 4 m V: 8 m	
Integrity **Alarm Limit**	H: 12 m V: 20 m 1	H: 556 m 2
Time-To-Alarm	6 sec	10 sec
Integrity Risk	3.5×10^{-7}/150sec	10^{-7}/hour
Continuity Risk	8×10^{-6}/15 sec	10^{-4} - 10^{-8}/hour
Timing Accuracy wrt UTC/TAI	50 nsec	
Certification/Liability/ Service guarantee	Yes	
Availability of accuracy	99.8%	

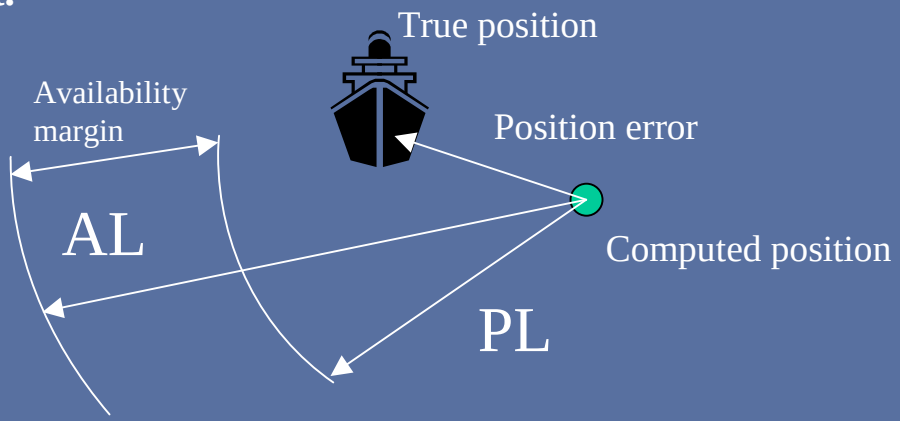
1 Integrity data for critical level
2 Integrity data for non-critical level

GALILEO Safety Of Life Service.
Integrity concepts.

Protection level

This is the value **computed by the user receiver** which estimates the confidence bound on the actual **Position error**. The user integrity monitoring function is **available** when the **protection level** is computable and is less than the **alarm limit.**

PL is continuously compared to the fixed alarm limit values AL



Alarm limit

The alarm limit is the maximum error allowable in the user computed position solution before an alarm is to be raised within the specified **time to alarm**. This **alarm limit is dependent on the considered operation**.

For a given operation (port, ocean, costal waters) alert limit values to be defined considering operational aspects.

GALILEO Safety Of Life Service.

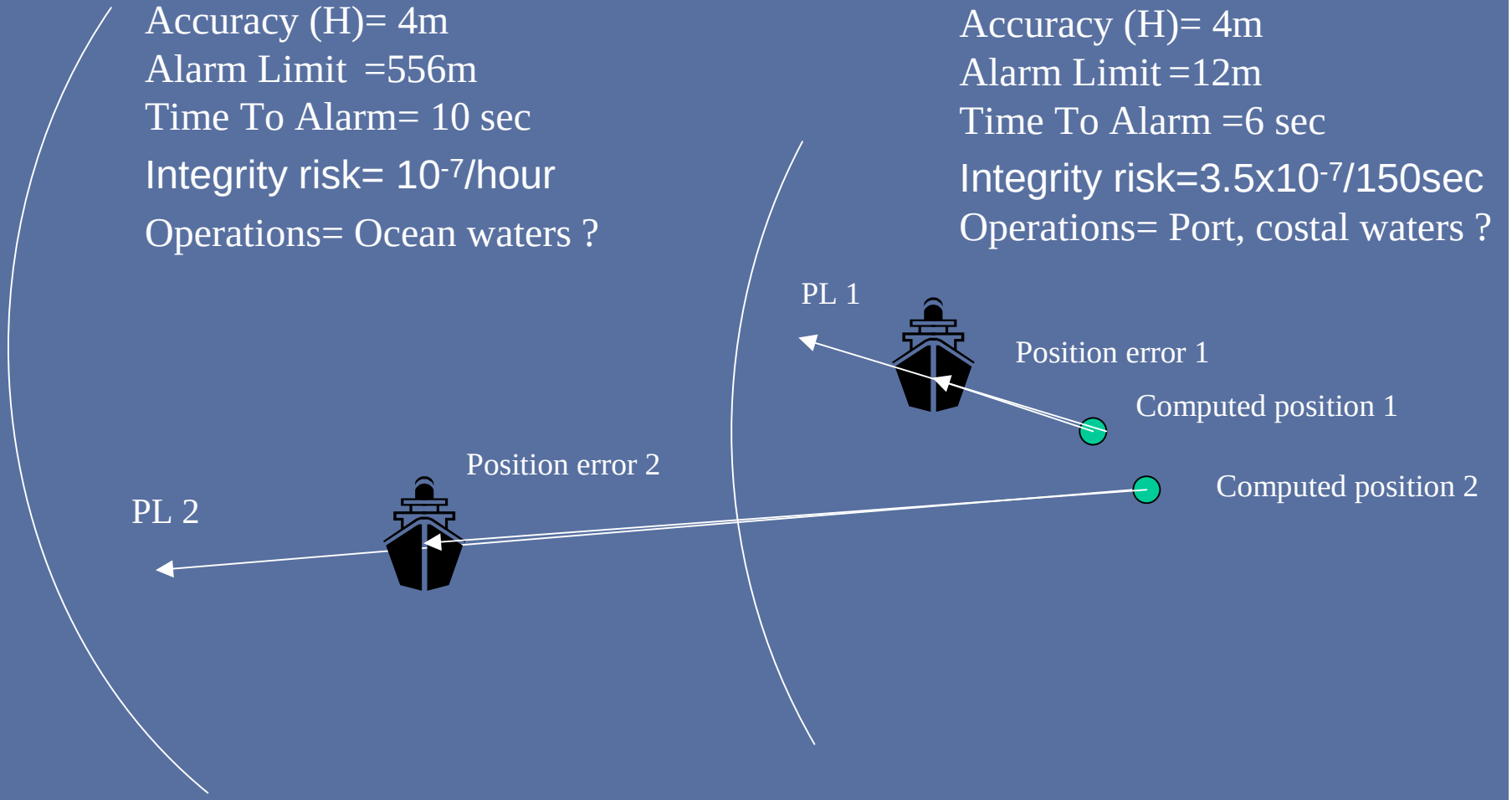
Two levels of Integrity.

Non-critical level

Accuracy (H)= 4m
Alarm Limit =556m
Time To Alarm= 10 sec
Integrity risk= 10^{-7}/hour
Operations= Ocean waters ?

Critical level

Accuracy (H)= 4m
Alarm Limit =12m
Time To Alarm =6 sec
Integrity risk=3.5×10^{-7}/150sec
Operations= Port, costal waters ?



Vessel 2 could use Galileo for ocean waters operations but not for port navigation.

GALILEO Safety Of Life Service.

Availability

Availability of integrity= 99,5 %

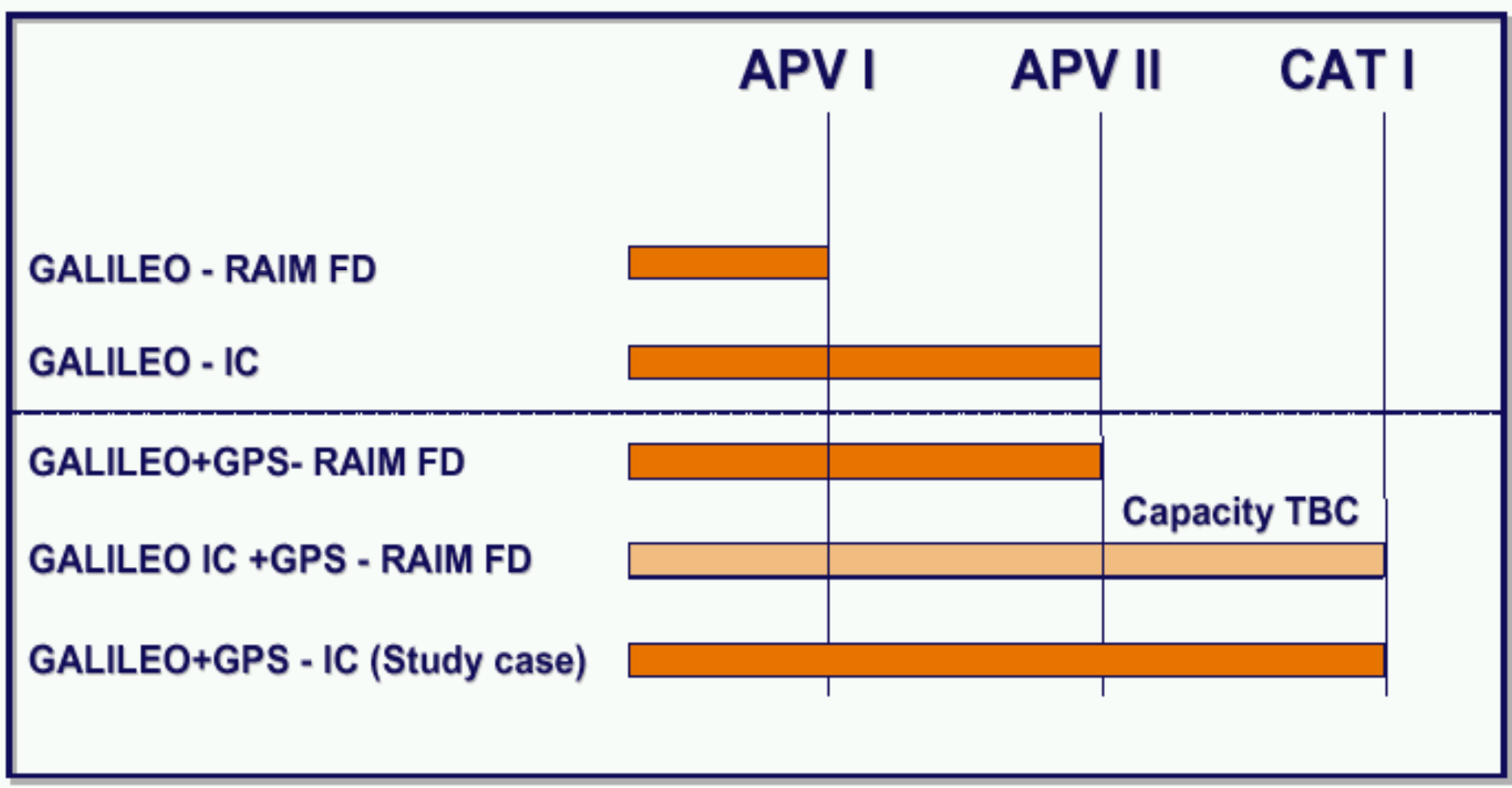
The integrity function is **available** when the **protection level** is computable and is less than the **alarm limit.**

Accuracy is the position error at 95% confidence level.

Availability of accuracy= 99,8 %

The probability that the accuracy requirement is met at any point in time.

Simulation of combined GPS/Galileo And RAIM Failure Detection with IC



Hypothesis: Masking angle <5degrees; GPS 24 satellites; Galileo 27 satellites

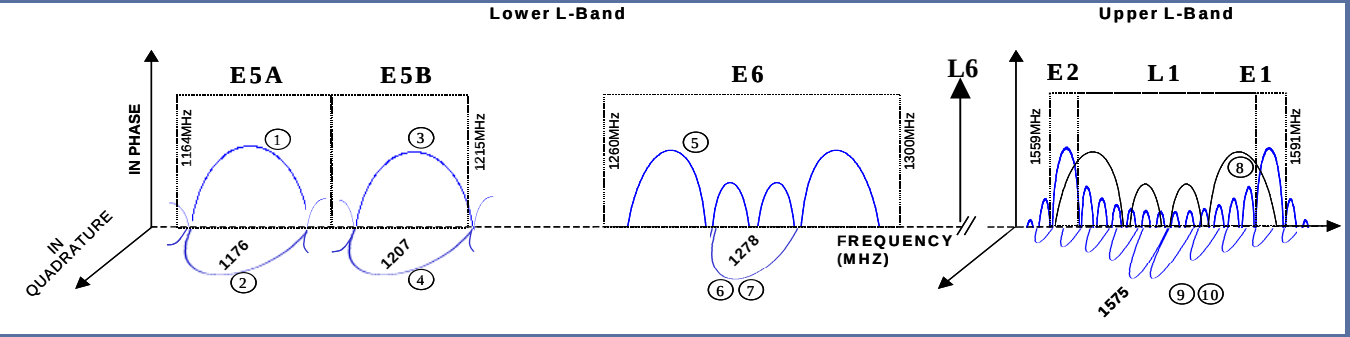
Simulation of combined GPS/Galileo And SBAS systems*

			APV I 50m	APV II 20m	CAT I 10m	Area
GPS stand alone	1 - GPS/SBAS. L1	IC				SBAS area
	2 - GPS/SBAS L5	IC				SBAS area
	3 - GPS/SBAS L1-L5	IC				SBAS area
GALILEO	4 - GALILEO L1-E5	IC				World-wide
Combinaison	5 - GALILEO L1-E5 + GPS L1-L5	RAIM FD				World-wide
	6 - GALILEO L1-E5 + GPS L1-L5(1)	IC				World-wide
	7 - GALILEO + GPS/SBAS dual freq.	IC				SBAS area
	8 - GALILEO + GPS/SBAS single freq.	IC				SBAS area

*Preliminary results

GALILEO Signal – Services Allocation

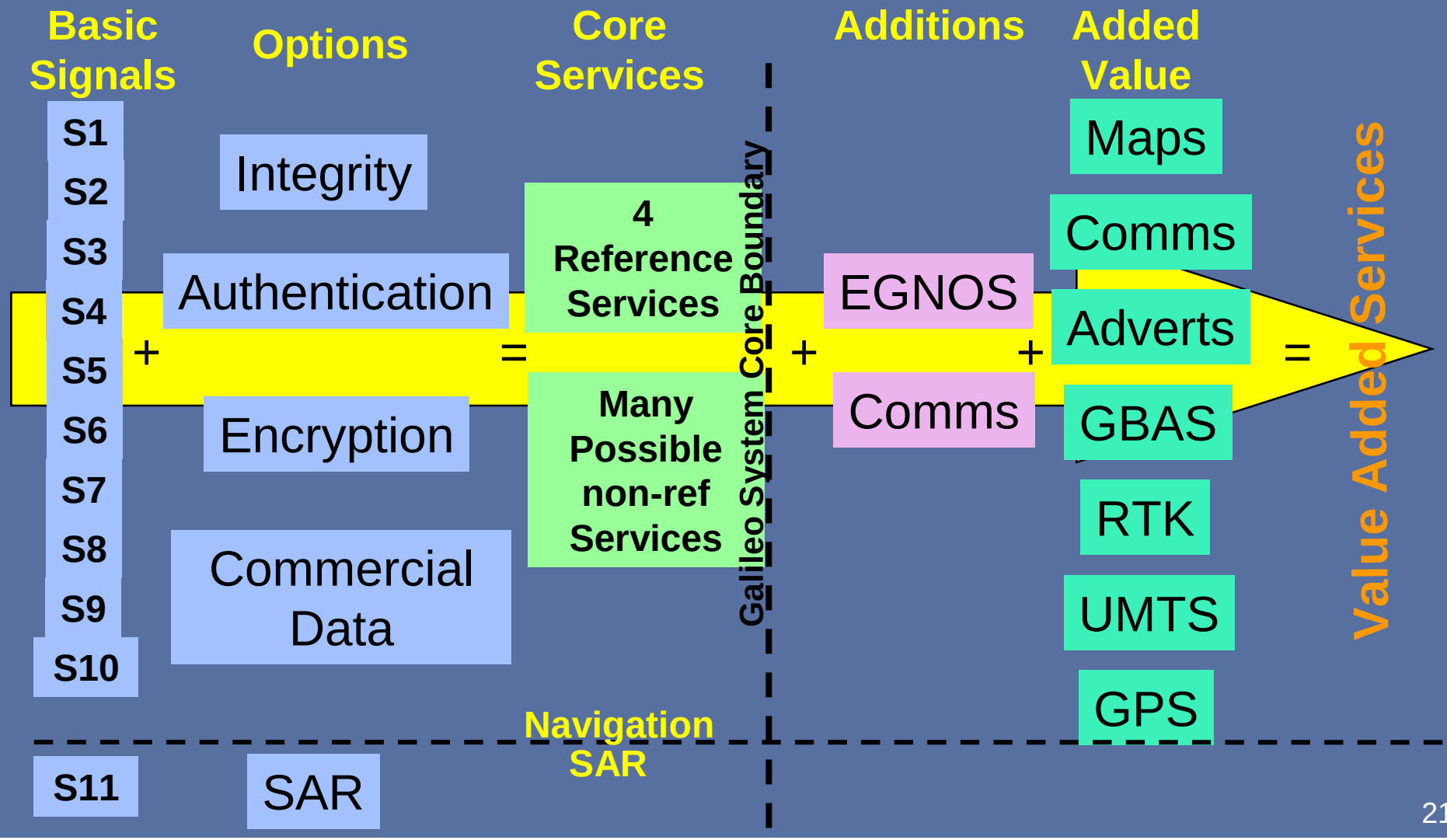
- The following signal / service allocation is foreseen:



Navigation Service	Signal Allocation	
Open Services	E5A, E5B, L1	(Id's: 1,2,3,4,9,10)
Commercial Services	E6	(Id's: 6,7)
Safety-Of-Life Services	E5A, E5B, L1	(Id's: 1,2,3,4,9,10)
Public Regulated Services	E6, L1	(Id's: 5,8)

- The SAR broadcast is transmitted in the 406 MHz and in the L6 (1544MHz) bands

Galileo core services and augmentations:



The Architecture of the GALILEO System

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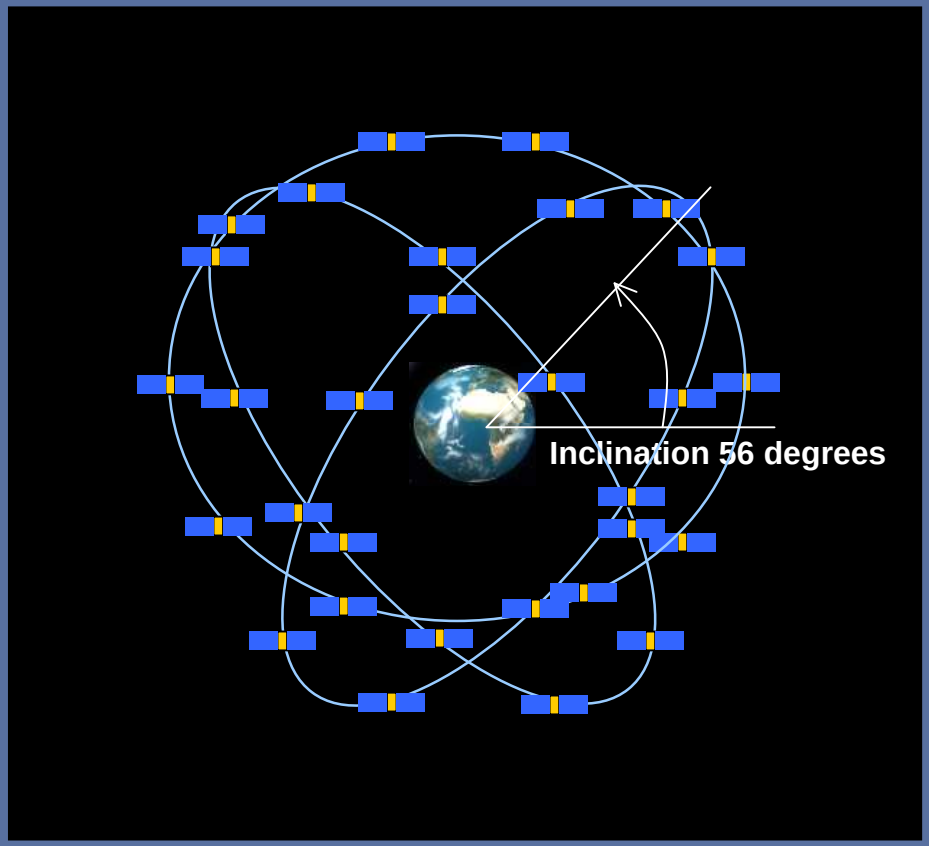
GALILEO Space Segment

The GALILEO Space Segment

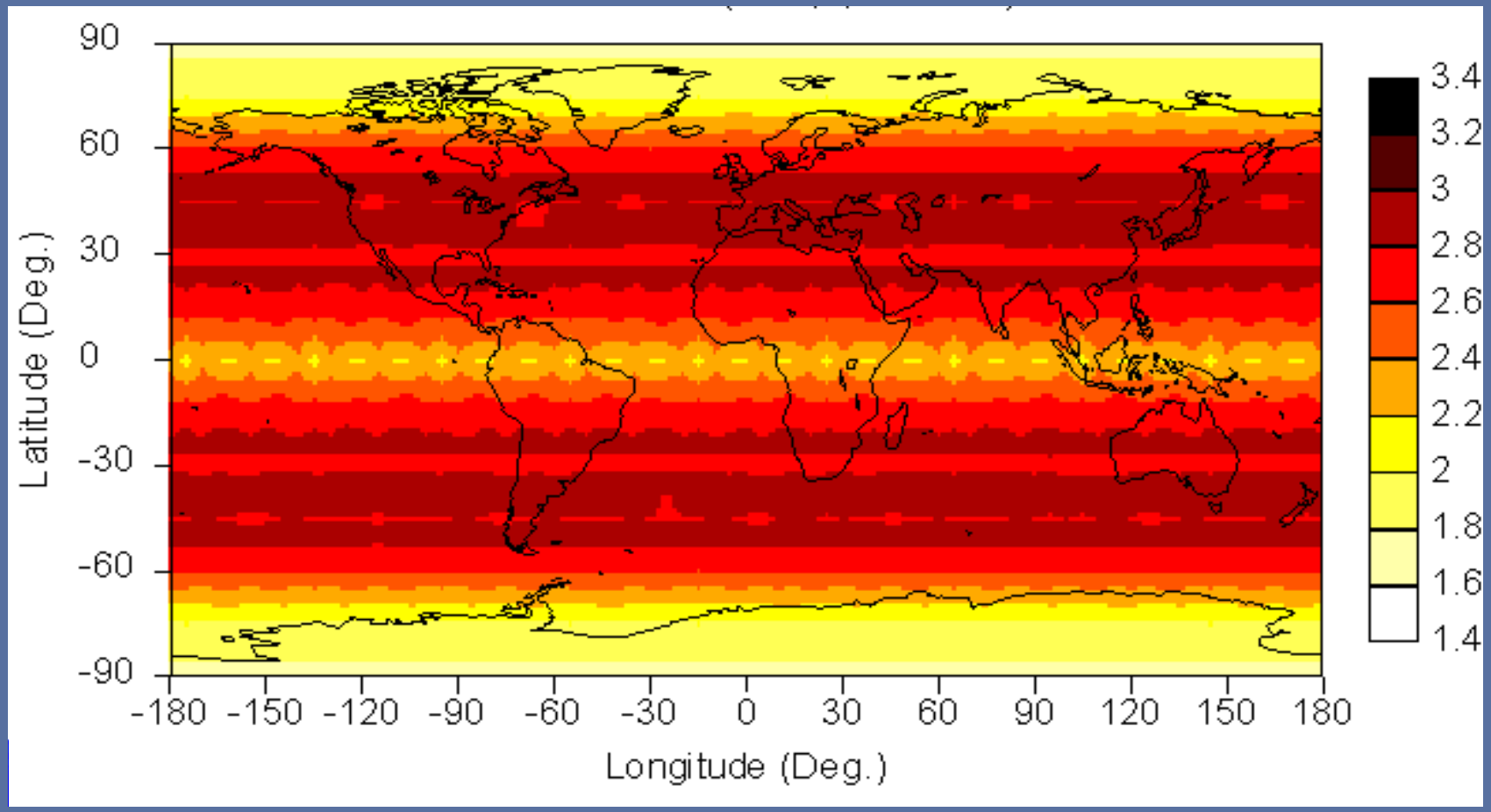
- Objective for the constellation design is to provide global services with respect to the navigation signal, the integrity signal and SAR services
- Constellation shall be very robust even when a satellite fails, in order to maintain service guarantees
- Constellation shall be as good for the professional areas (e.g. aviation) as for the civil mass markets; this influences the optimization with respect to the visibility
- Optimization of the constellation has been carried out with respect to affordability

The GALILEO Satellite Constellation



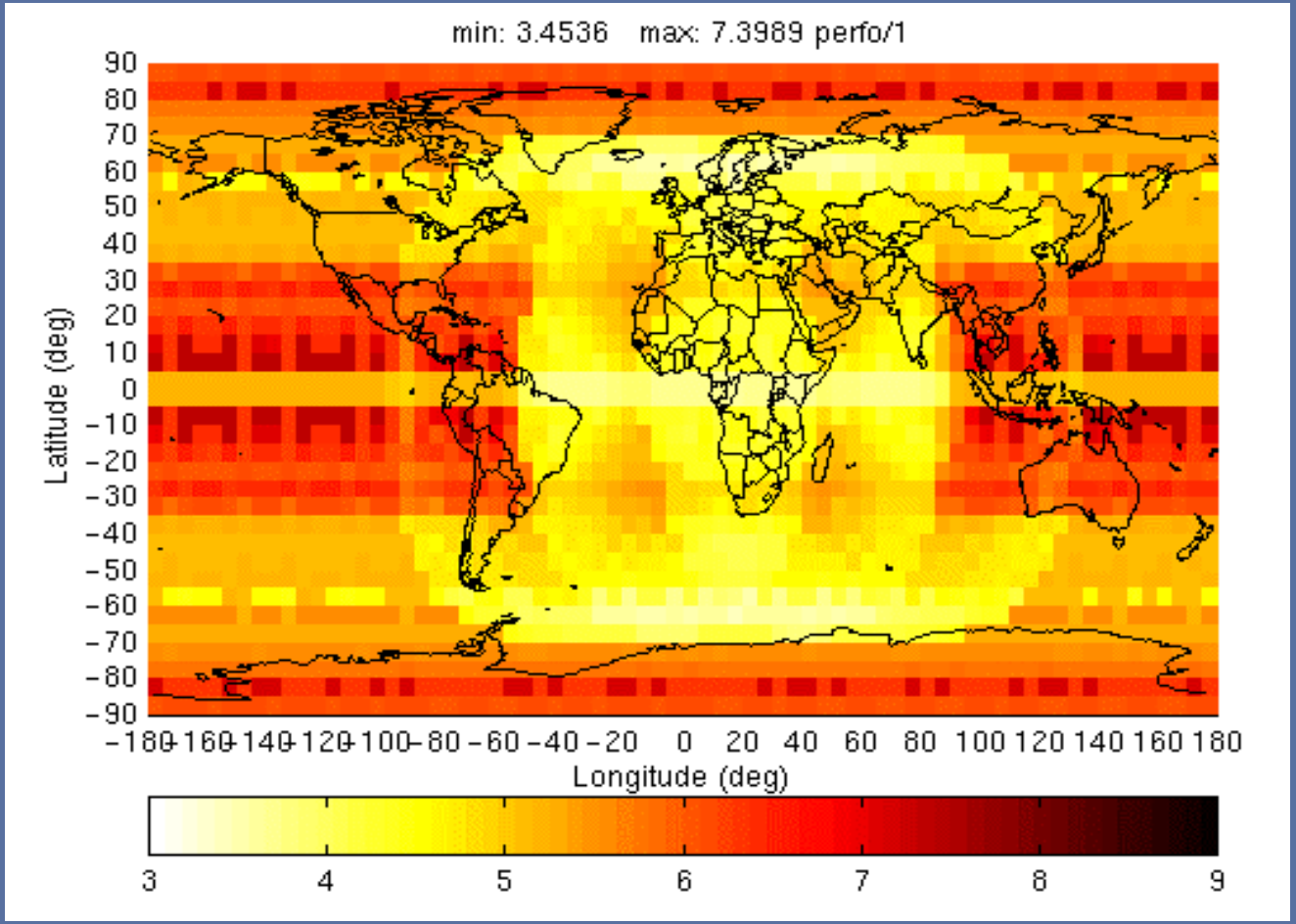
- 30 satellites in three Medium Earth Orbit MEO planes at 23616 km altitude
- 1 satellite per orbital plane is a spare
- Inclination of orbital planes 56 degrees
- One revolution 14 hours 4 min
- Ground track repeat 10 days

GALILEO Horizontal Accuracy



GEO Augmentation Over Europe

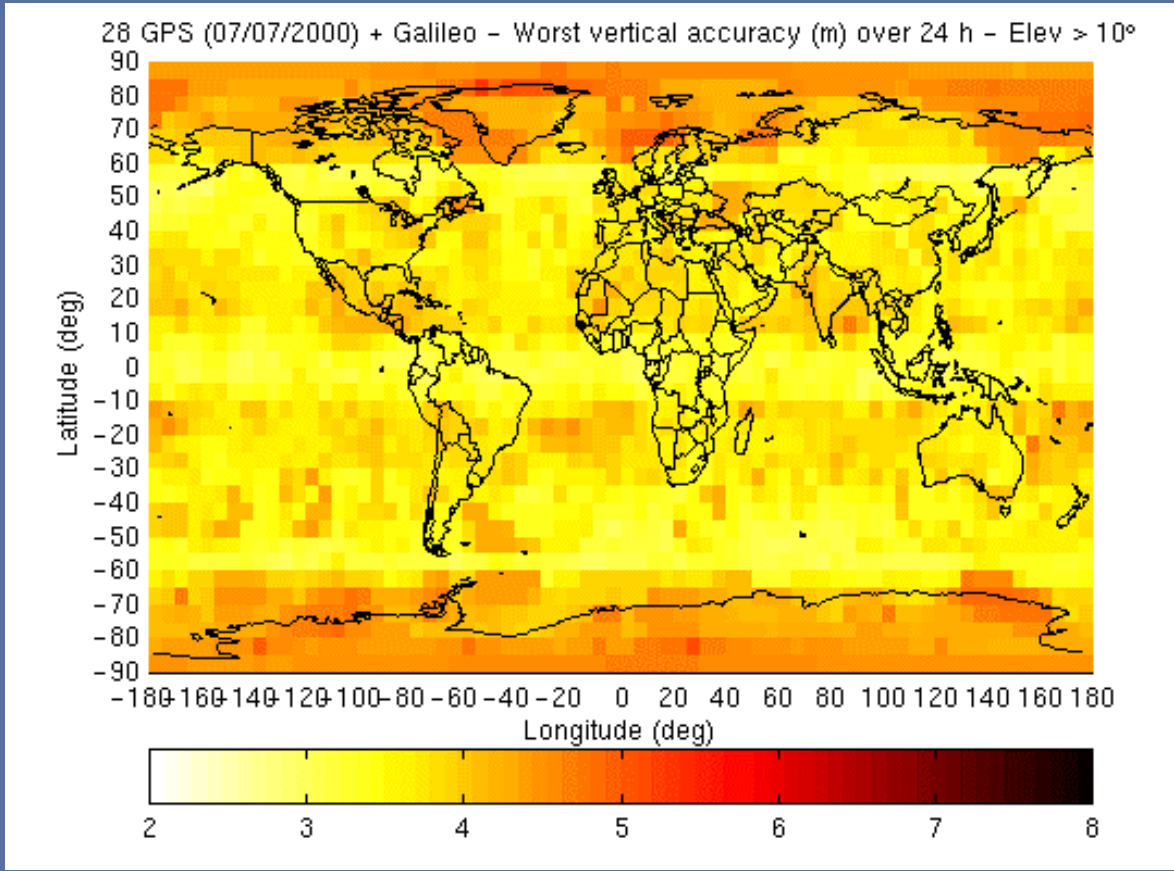
- Typical of GALILEO augmented with EGNOS



- Vertical Accuracy improved from 7.5 m to 5.5 m

GALILEO & GPS

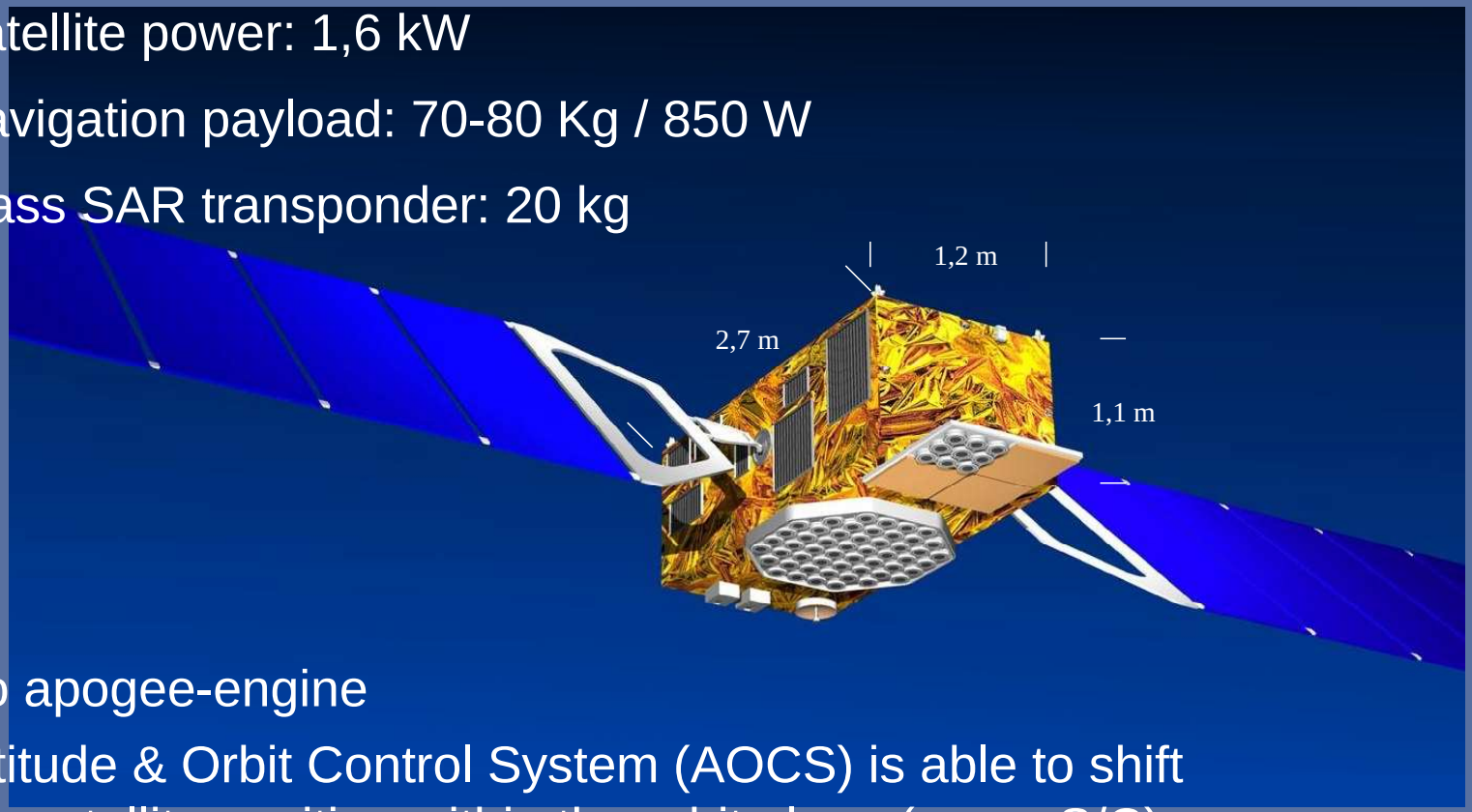
- GPS constellation assumed as that of 7 July 2000 (28 satellites)
- GPS UERE = GALILEO UERE assuming GPS modernized



- Vertical Accuracy improved from 7.5 m to 4.5 meters worldwide.
- Visibility under high masking angle conditions highly improved.

The GALILEO Satellite

- Satellite mass: 680 kg
- Satellite power: 1,6 kW
- Navigation payload: 70-80 Kg / 850 W
- Mass SAR transponder: 20 kg



- No apogee-engine
- Attitude & Orbit Control System (AOCS) is able to shift the satellite position within the orbit plane (spare S/C)

The Architecture of the GALILEO System

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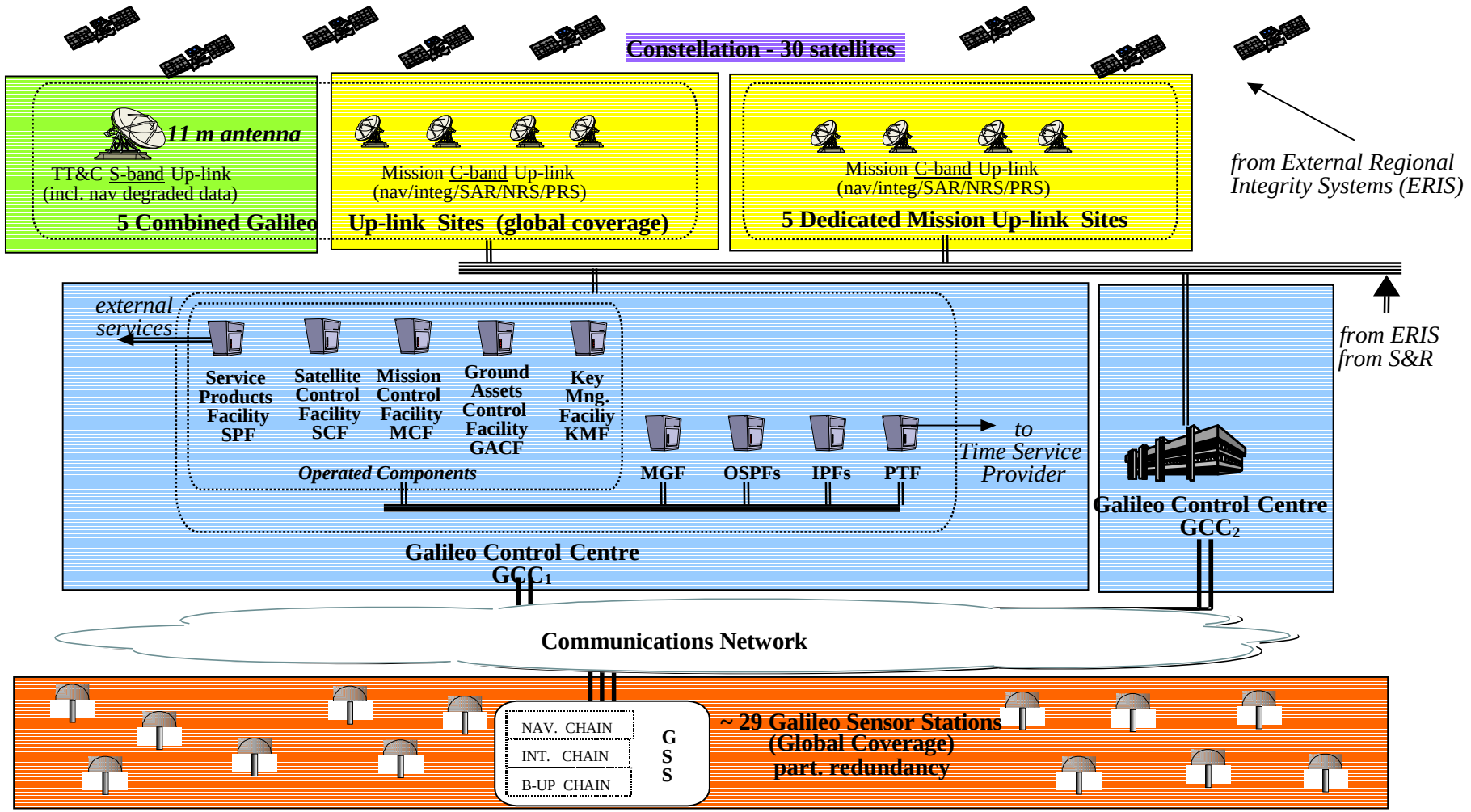
GALILEO Ground Segment

GALILEO Ground Segment

- 2 redundant GALILEO Control Centers
- 5 S-Band TT&C Stations (One 11m S-Band antenna per station)
- 9 C-Band Mission Up-link Stations (Four 3.2m C-band antennae per station)
- 30 Sensor Stations for OD&TS and Integrity purposes (each station contains a double receiving chain, one for navigation, one for integrity)
- Processing facilities (OSPF; IPF; TPF;..)

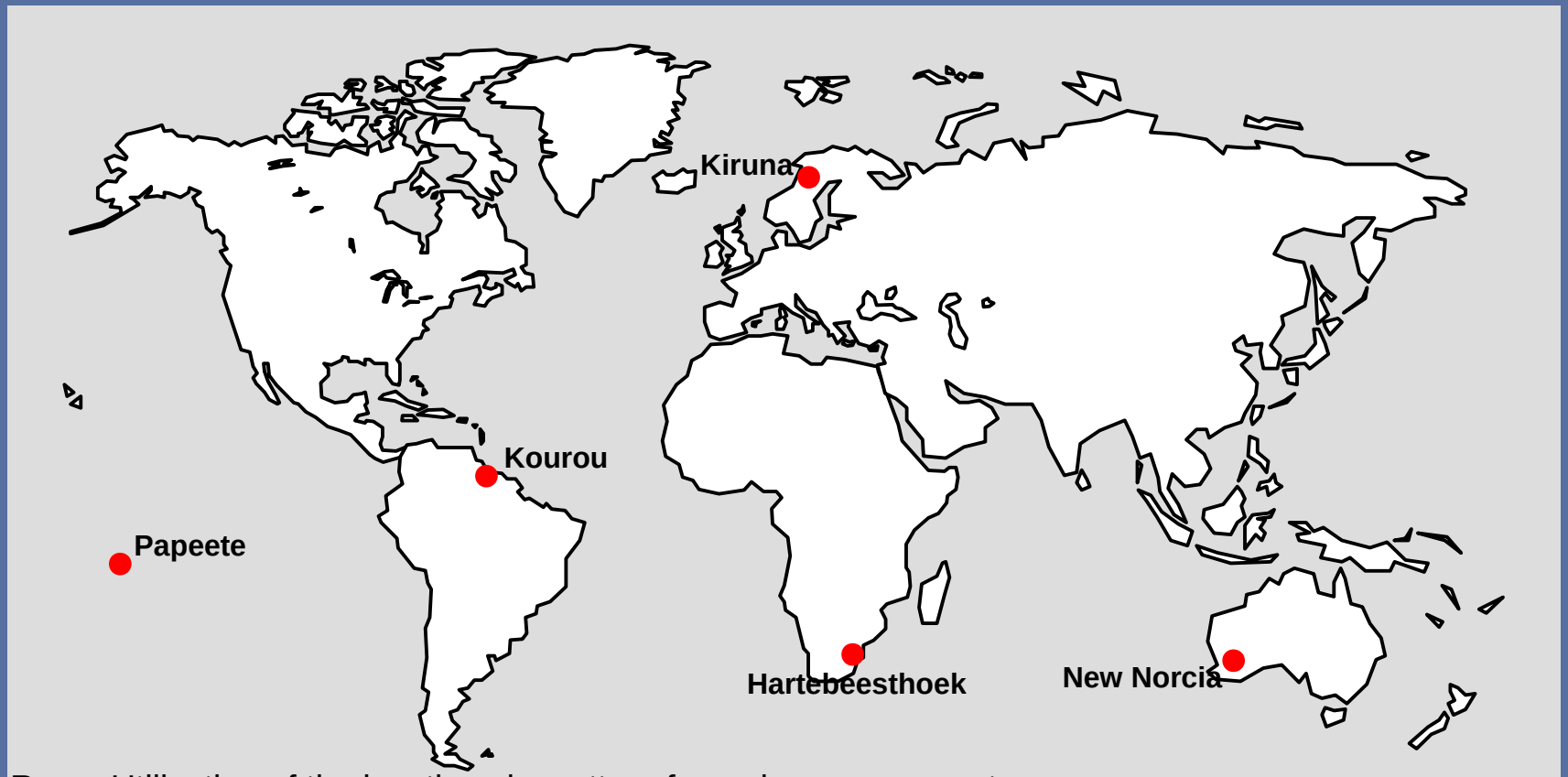
Overall architecture : physical view



The GALILEO Locations

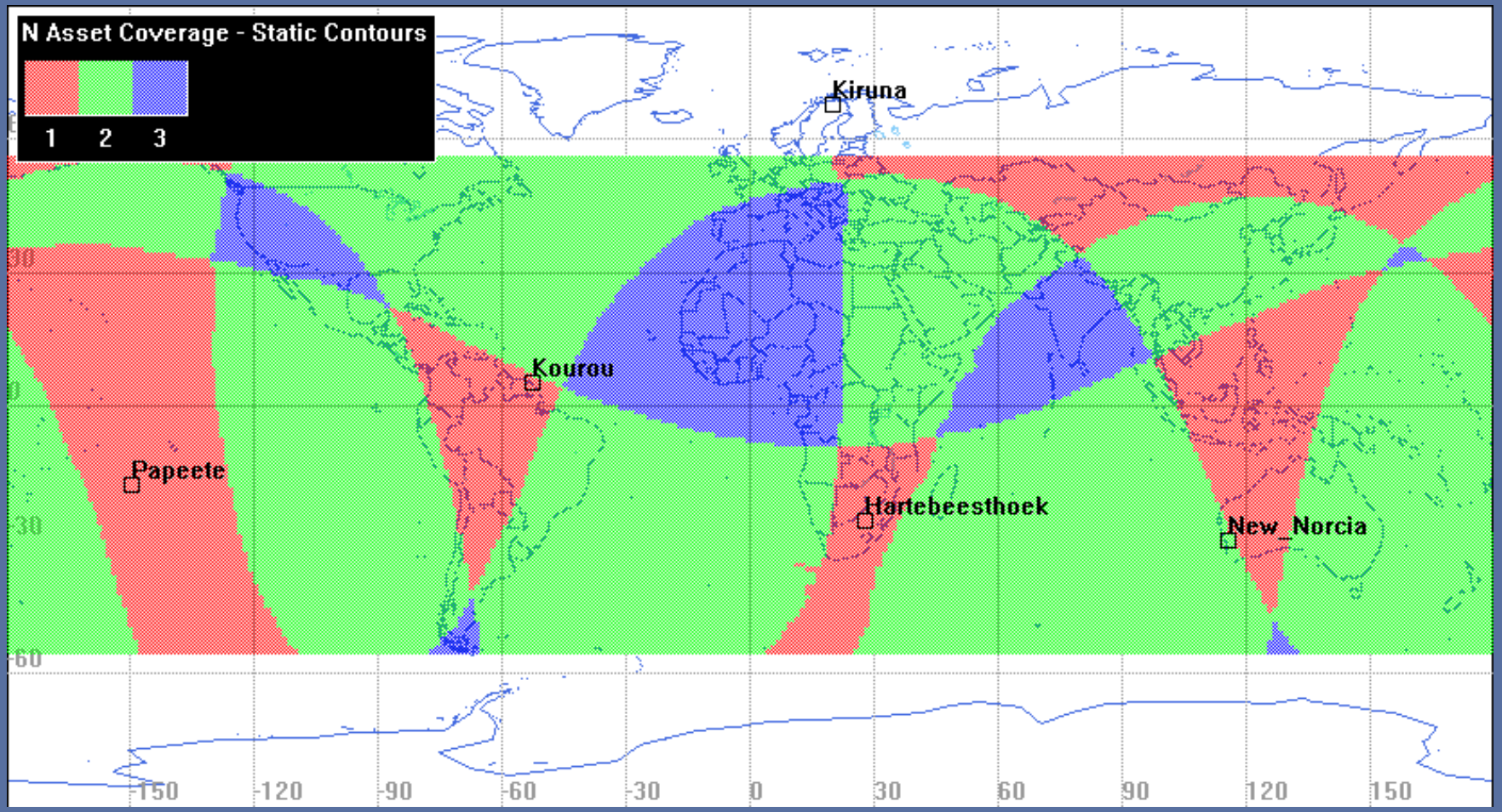
- The locations of the GALILEO ground segment elements are chosen with respect to system security
- Depending on the criticality and vulnerability of the element, the locations are selected as follows:
  - Control centers on European mainland
  - Uplink stations worldwide on European ground
  - Sensor stations worldwide on European ground and in countries with bilateral agreements
- The protection level of the ground stations will be at least the same as for civil aviation infrastructures

Proposed GALILEO TT&C Stations

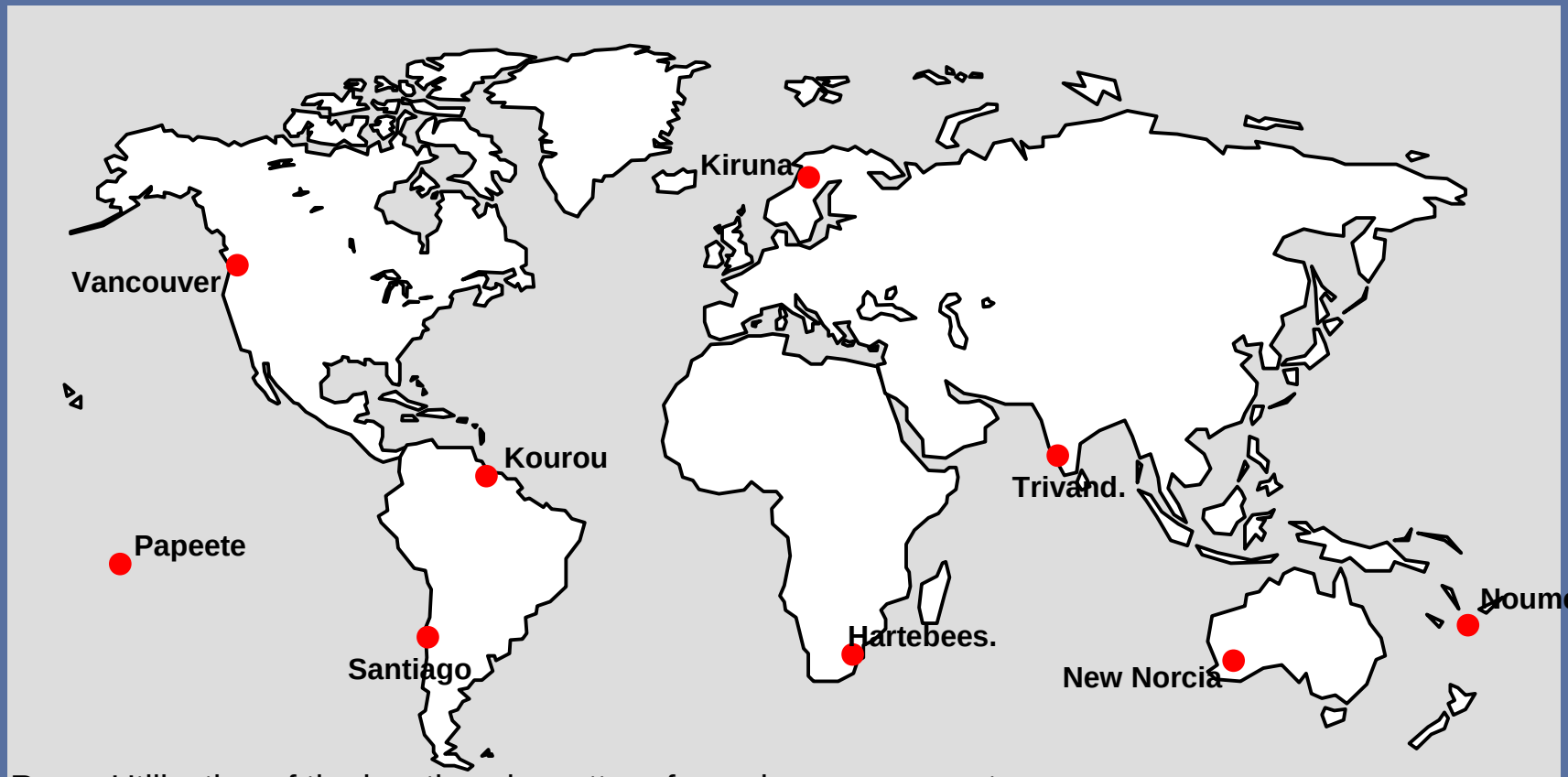


Rem.: Utilization of the locations is matter of ongoing assessment

Location of GALILEO TT&C Stations



Proposed GALILEO Up-Link Stations



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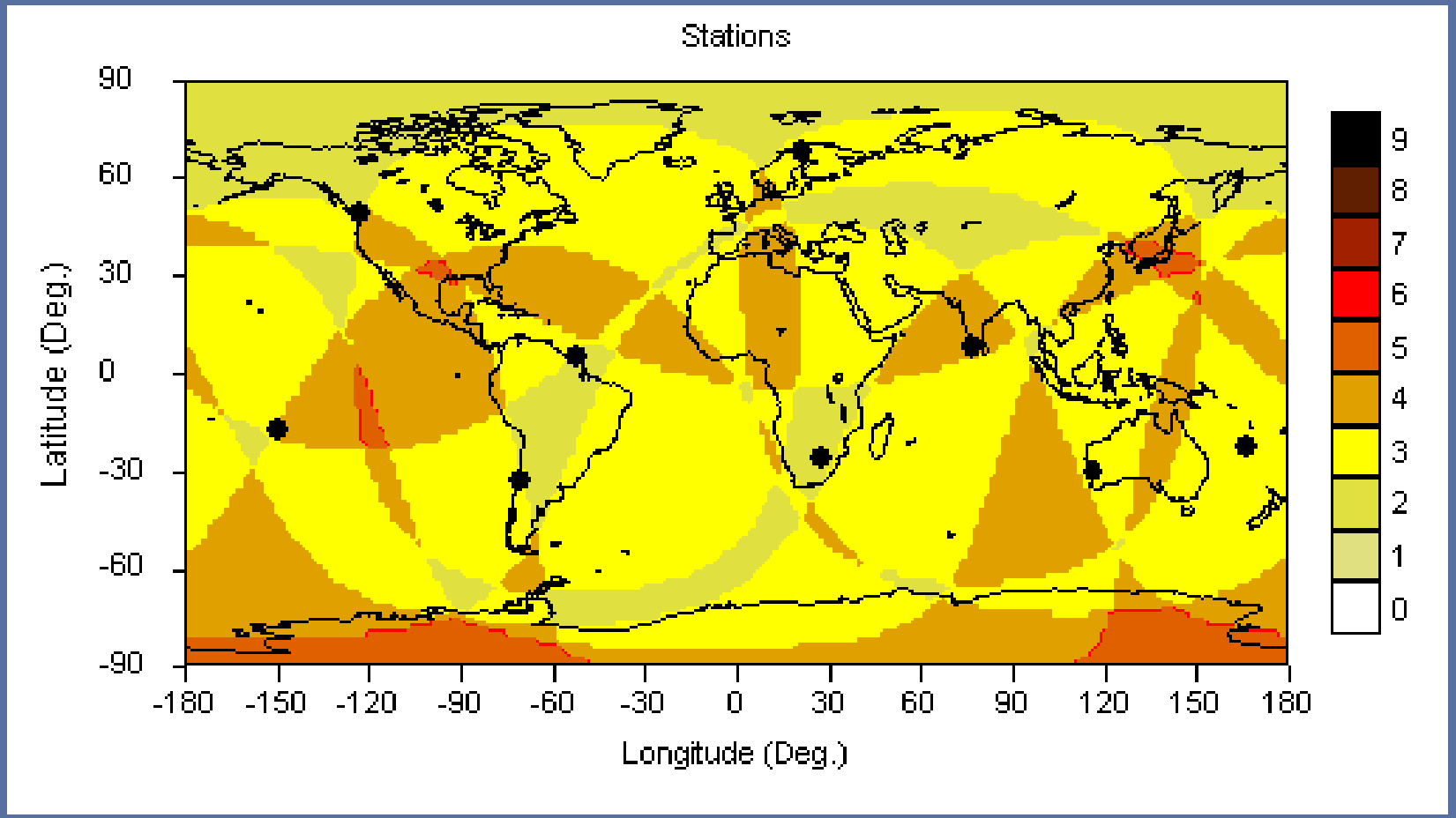
Coverage of Up-link Stations



Proposed GALILEO Sensor Stations

Rem.: Utilization of the locations is matter of ongoing assessment

Information and Communication

The GALILEO Communication

Web:

http://europa.eu.int/comm/dgs/energy_transport/galileo
http://www.esa.int/navigation

E-Mail:

Contact: tren-galileo@cec.eu.int