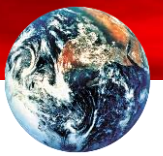


Earth
Space
&
Future

Von der Erde ins All.
Und zurück.

Intelligente Lösungen für
Industrie und Wissenschaft.

From Earth to Space.
And back.

Intelligent solutions for
industry and science.

Kayser-Threde GmbH

Space Technology & Applications

Science & Earth Observation

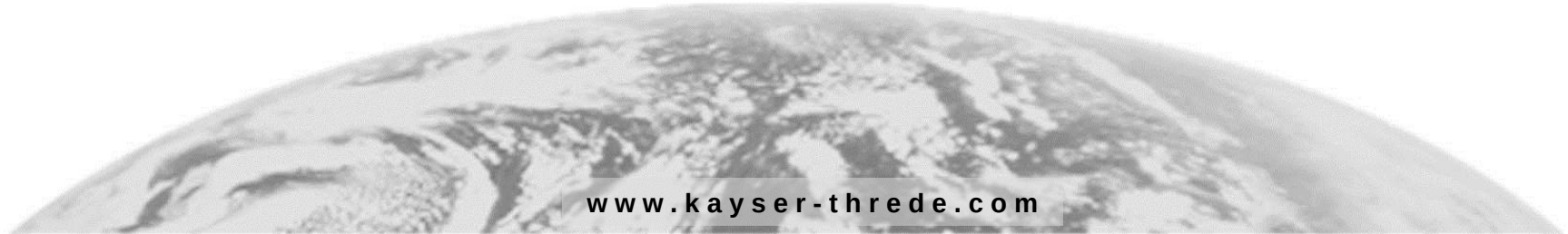
Process Control Systems

Automotive

Galileo Programme Status

Dr. Stefan Bedrich

4th ITSF, 14-16 November 2006, Prague

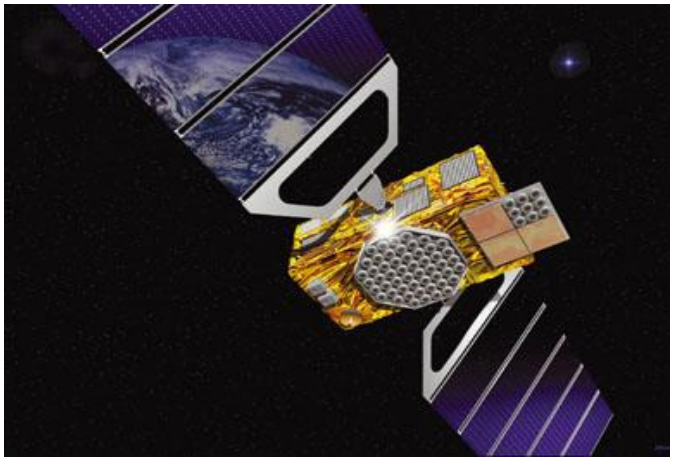


KAYSER-THREDE

Presentation Overview

- Galileo System Architecture, Signals, Services
- Commercialisation („Concessionaire“)
- Galileo vs. GPS
- The „time“ of Galileo, features, applications
- Summary and outlook

Some slides: courtesy ESA and/or EU (GJU)



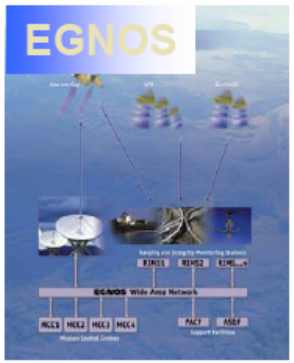
Galileo Architecture

GALILEO JOINT UNDERTAKING

Global
MEO
Constellation &
Ground Control

Regional
Components

Local
Components



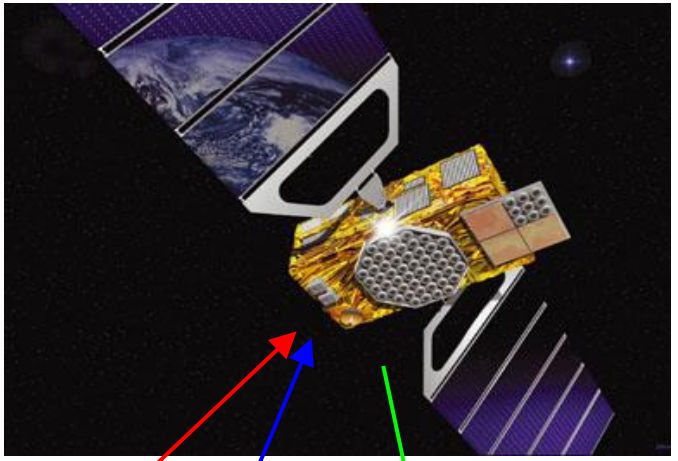
SAR

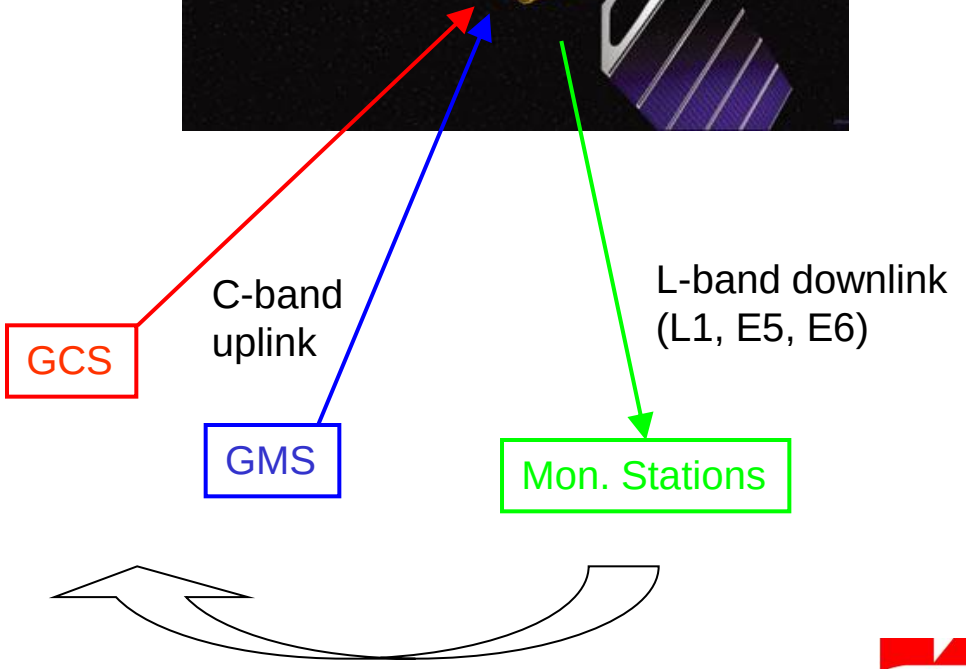
User
Segment

Service
Centres

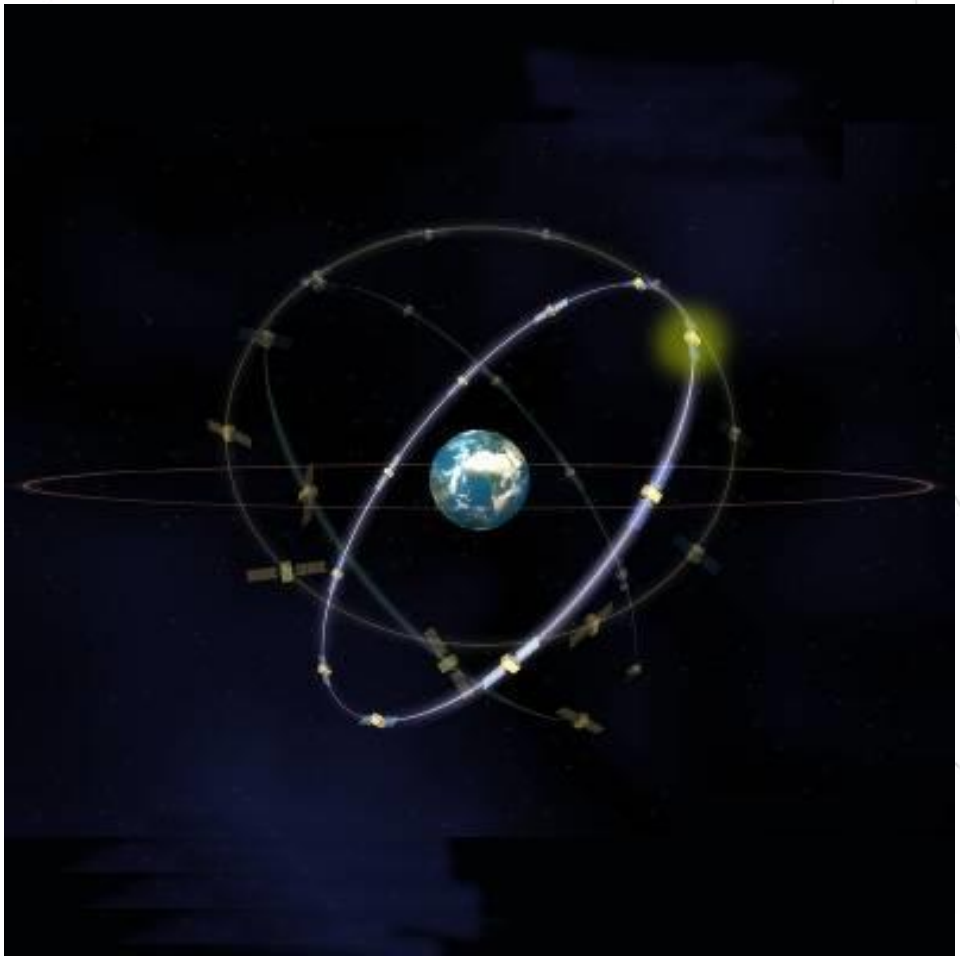
Galileo Closed-Loop System Architecture

1. Ground Control Segment (GCS) will control spacecraft (orbits, relative spacing, health status, …)
2. Ground Mission Segment (GMS) will control payload, i.e. navigation signals (power levels, coding, encryption, …)
3. World-wide network of signal monitoring stations (> 40) will monitor constellation and navigation signals
4. Data are fed back by terrestrial links in real-time to GMS and GCS
5. Mission control and data uplink centres: Oberpfaffenhofen/D, Fucino/I





Galileo Constellation



- 30 satellites in three Medium Earth Orbit MEO planes at 23,200 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

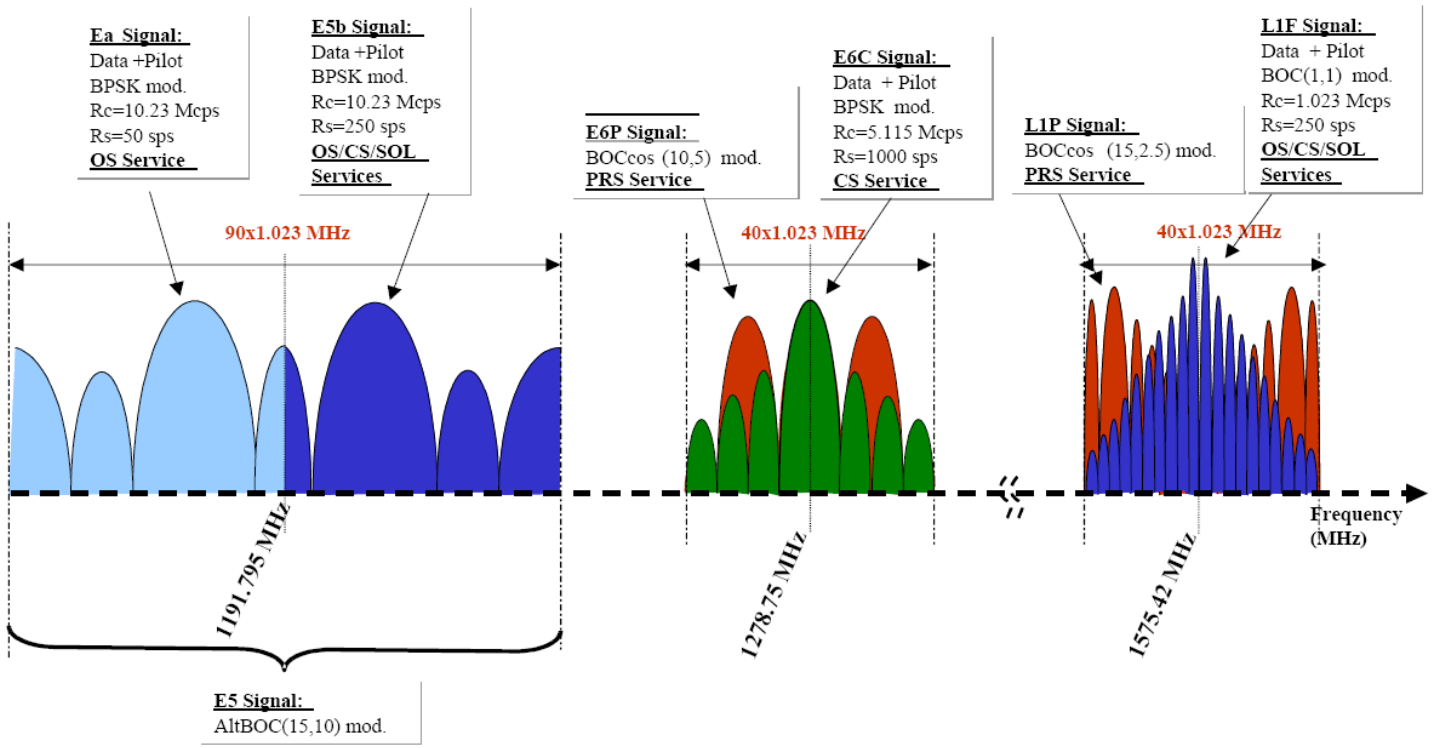
Galileo - Five Services

EU Transport Council Decision- December 2004

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

Galileo Signals

1. Span over three bands in L-band (bandwidth 40 to 90 MHz each)
2. There are modulated data signals and pure carrier pilot signals (I & Q)
3. The 4 (5) navigation services are spread over the bands (user will have to combine different carriers when using certain services in full)
4. 10 different signals in total



Galileo Specification

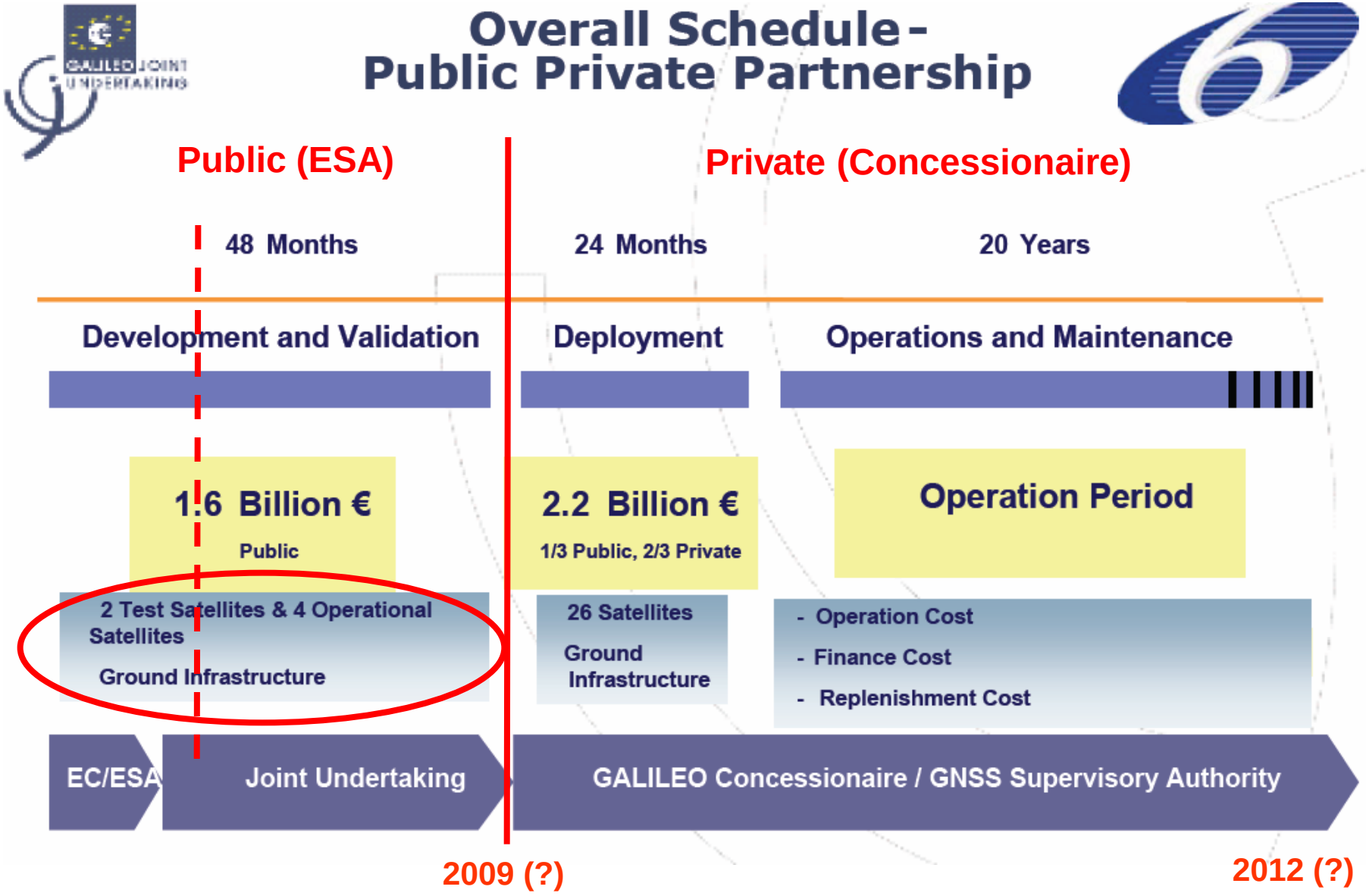
Service Guarantee

Certified Service

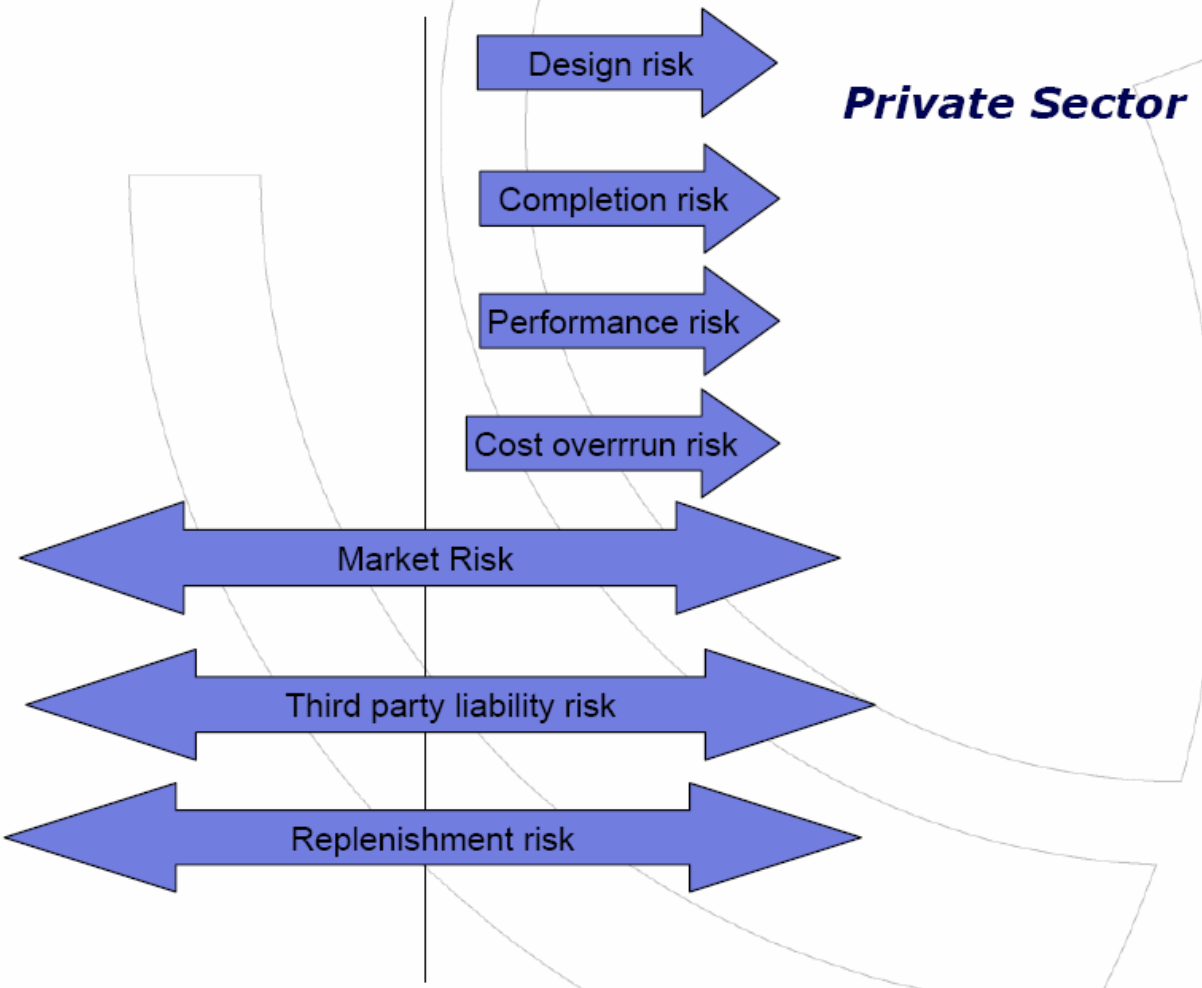
Signal Encryption

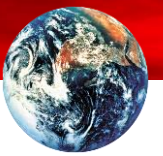
Galileo Global Services	Open Service	Commercial Service	Safety of Life Service	Public Regulated Service
Coverage	Global	Global	Global	Global
Positioning Accuracy	15m or 24m H – 35m V (single frequency) 4m H – 8m V (dual frequency)		4m H – 8m V (dual frequency)	15m or 24m H – 35m V (single frequency) 6.5m H – 12m V (dual frequency)
Timing Accuracy	30 nsec	30 nsec	30 nsec	30 nsec
Integrity: Alert Limit Time to Alert Integrity Risk	None	None	12m H – 20m V 6 sec 2.0×10^{-7} / 150 sec	20m H – 35m V 10 sec 2.0×10^{-7} / 150 sec
Continuity Risk			0.8×10^{-5} / 15 sec	0.8×10^{-5} / 15 sec
Service Availability	99.5%	99.5%	99.5%	99.5%
Access Control	Free Open Access	Controlled Access of Ranging Codes and Navigation Data Message	Free Open Access with Authentication	Controlled Access of Ranging Codes and Navigation Data Message
Certification and Service Guarantees	None	Guarantee of Service possible	Build for Certification and Guarantee of Service	Build for Certification and Guarantee of Service

Overall Schedule - Public Private Partnership



Main risk allocation in the concession approach





Galileo Application Overview

Safety of Life

- Aviation
- Rail
- Maritime
- Inland waterways
- Ambulance
- Police / Fire
- Search and Rescue
- Personal Protection
- Traffic surveillance
- Dangerous goods trans.
- ADAS

Mass Market

- Personal communication and navigation
- Cars / motorcycles
- Trucks & buses
- Light Commercial Vehicles
- Personal outdoor recreation
- Others…

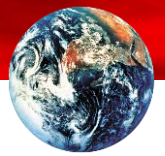
Professional

- Oil and Gas
- Mining
- Timing
- Environment
- Fleet Management
- Asset Management
- Geodesy
- Meteorological forecasting
- Land Survey / GIS
- Precision survey
- Precision Agriculture
- Fisheries / EEZ
- Vehicle control and robotics
- Construction / Civil Engineering
- Space

Integrity (**error-free**), Standards, Regulation, Continuity, Availability, Accuracy

Low costs, Low power cons., Small size, Friendly use, Best perf. accordingly

High precision, High accuracy, High reliability

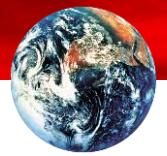


Technical and Commercial Features of Galileo (compared to GPS)

- Service guarantee
- Built-in integrity
- Better performance and stability

and

- Galileo System Time (GST) will be accessible physically on ground (not only through satellites)

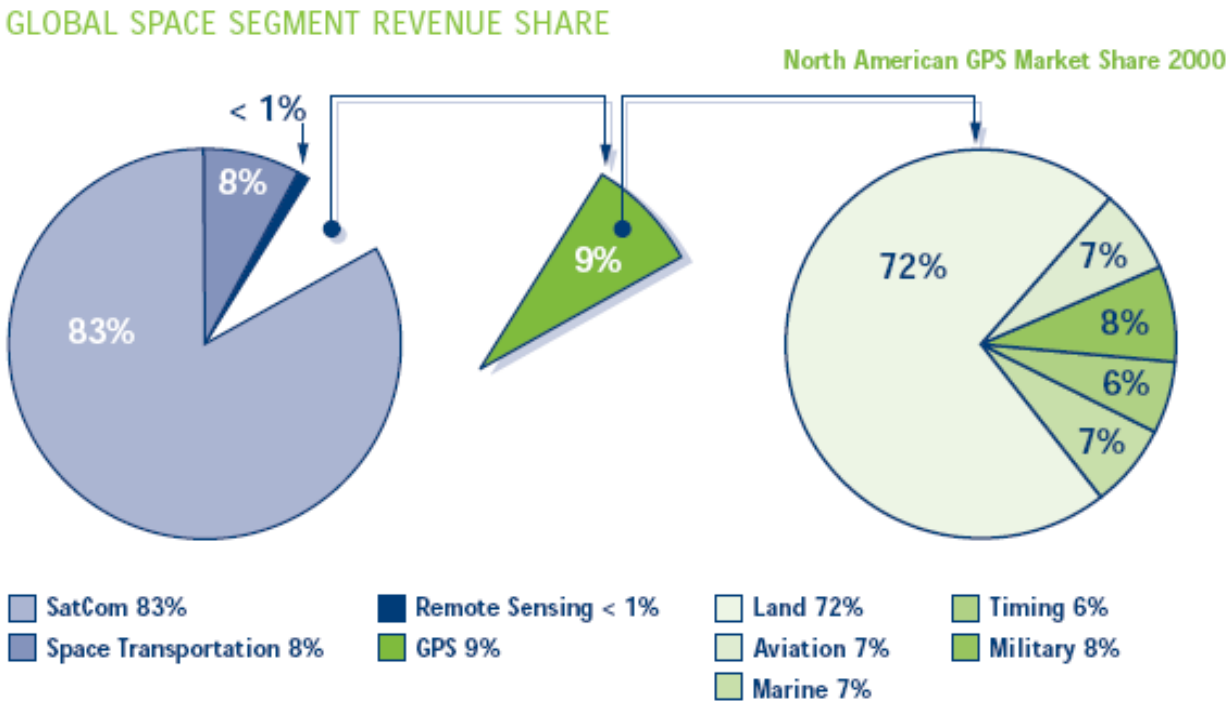


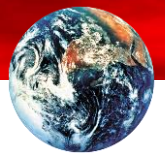
Technical and Commercial Features of Galileo (cont'd)

- Galileo's special features will allow to solve the time & sync demands of new applications:
  - The time link between the source (= Galileo System Time) and the target (= user application) can be closed unambiguously (terrestrial path)
  - This closure is a necessary prerequisite for development of certified time & sync services
  - Certified services can provide the added value of legal authentication, full traceability and, therefore, liability of the time information

Market Potential of Space-Based Time & Sync Applications

- Time & sync applications based on GNSS combinations (GPS + Galileo) are estimated to have a market potential of several hundred millions of Euro/year





The Precise Timing Facility (PTF) – the heartbeat of Galileo

Main functions:

1) Will generate Galileo System Time (GST)

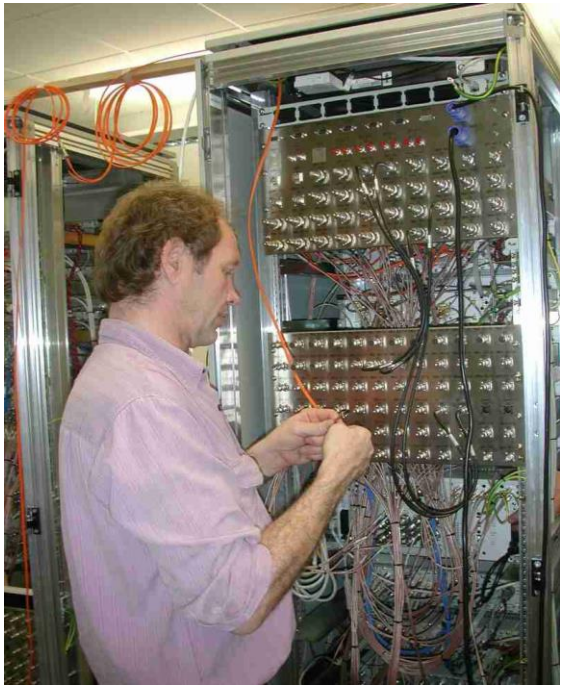
2) Will steer GST towards International Atomic Time (TAI)

3) Will compute the GST-GPS System Time Offset (GGTO)

Precise Timing Facility (located in Galileo Ground Control Centre)

H-Maser atomic clock

Equipment for clock stability determination



Switch matrix for time generation and distribution

PTF 1) Generate Galileo System Time (GST)

The highly accurate time reference (‘heartbeat’) of the whole Galileo system.

- Needs both short and long term stability

GST stability specification: 100 ps @ day

- In other words: GST will be accurate to about 100 trillionth of a second.
- Or think of it in this way: GST will lose 1 s in about 25 million years !

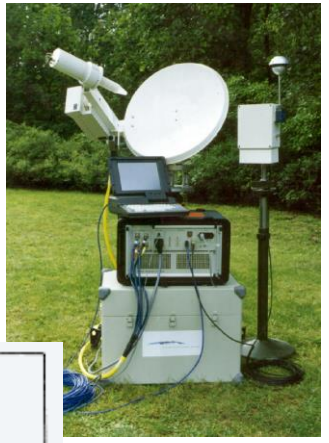
Clock measurement

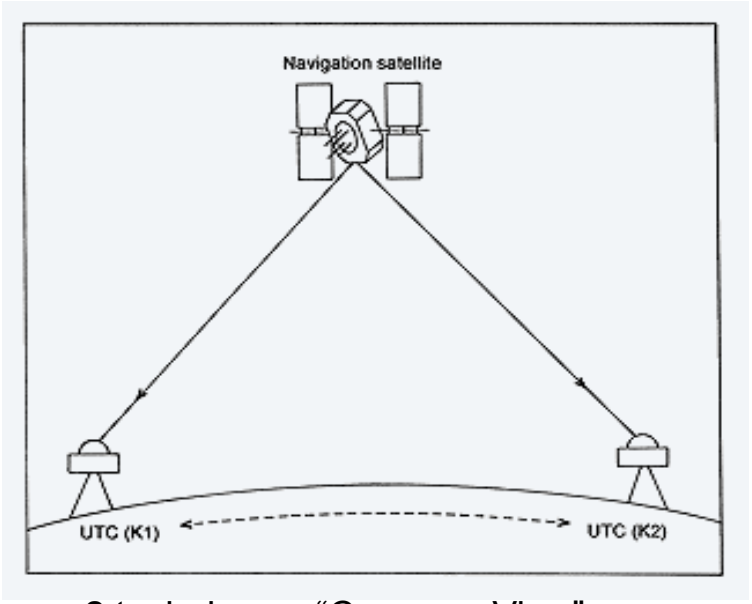
Caesium atomic clock

PTF 2) Compare GST to major world time scales

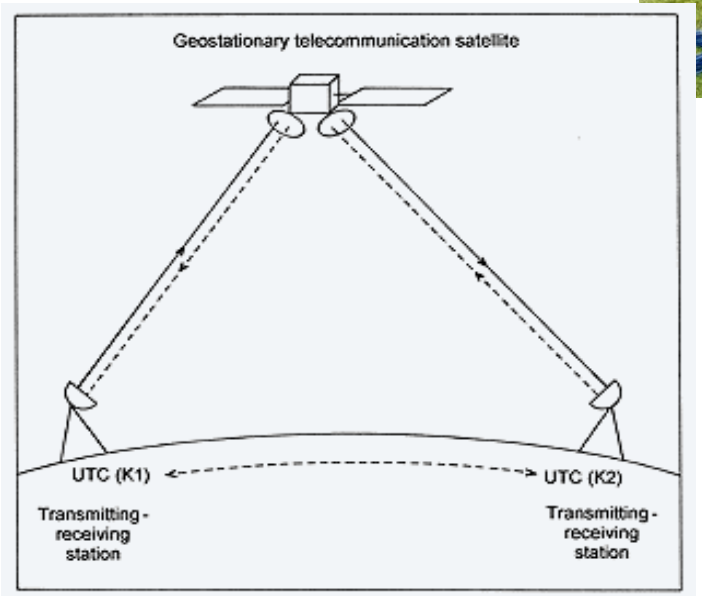
Comparison of Galileo System Time to:

- GPS System Time (USNO, Washington)
- European Timing Labs: UTC(k) laboratories

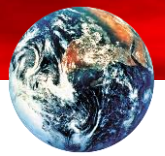




2 techniques: “Common-View”



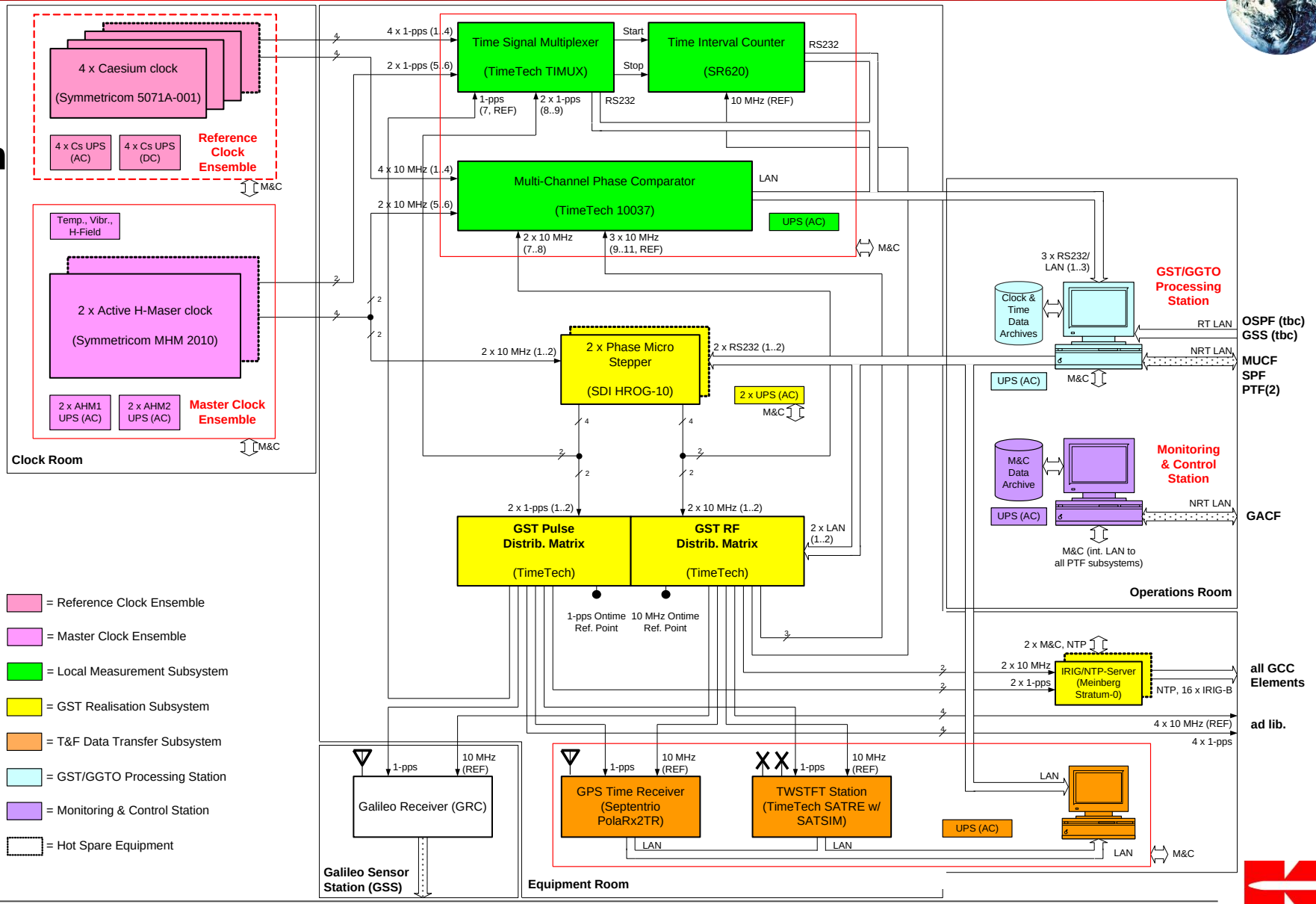
TWSTFT: Two Way Satellite Time & Frequency Transfer

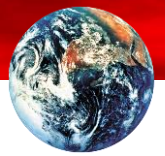


PTF 3) Compute the GST-GPS System Time Offset (GGTO)

- Computed using time transfer techniques (Common-View and TWSTFT)
- Vital for compatibility of GPS and Galileo
- GGTO allows the user to utilize a combination of both GPS and Galileo signals for navigation and synchronization, i.e. a GPS-Galileo combination, not GPS and then Galileo
- GGTO will be broadcasted by both the GPS and Galileo satellites

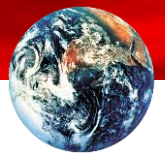
PTF Block Diagram





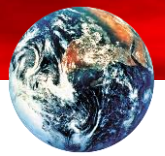
PTF Schedule

- PTF Preliminary Design Review (PDR) just completed
- PTF detailed design phase (CDR) will be completed by mid 2007
- PTF subsystem procurement and integration during second half of 2007
- PTF installation at the new Galileo Control Centre (GCC) in Oberpfaffenhofen during first half of 2008
- PTF calibration and start of operations by end of 2008



Summary

- Galileo will provide five services through three signals
- Galileo will be operated and marketed by commercial organization
- Service guarantee, built-in integrity, better accuracy will allow implementation of certified services with fully traceable liability
- Demanding time & sync applications may be prime customers for such certified services
- Precise Timing Facility (PTF) could act as source of new quality time signals



Thank you very much for your attention.

Galileo Info: www.esa.int/esaNA/galileo.html

Kayser-Threde Info: www.kayser-threde.com