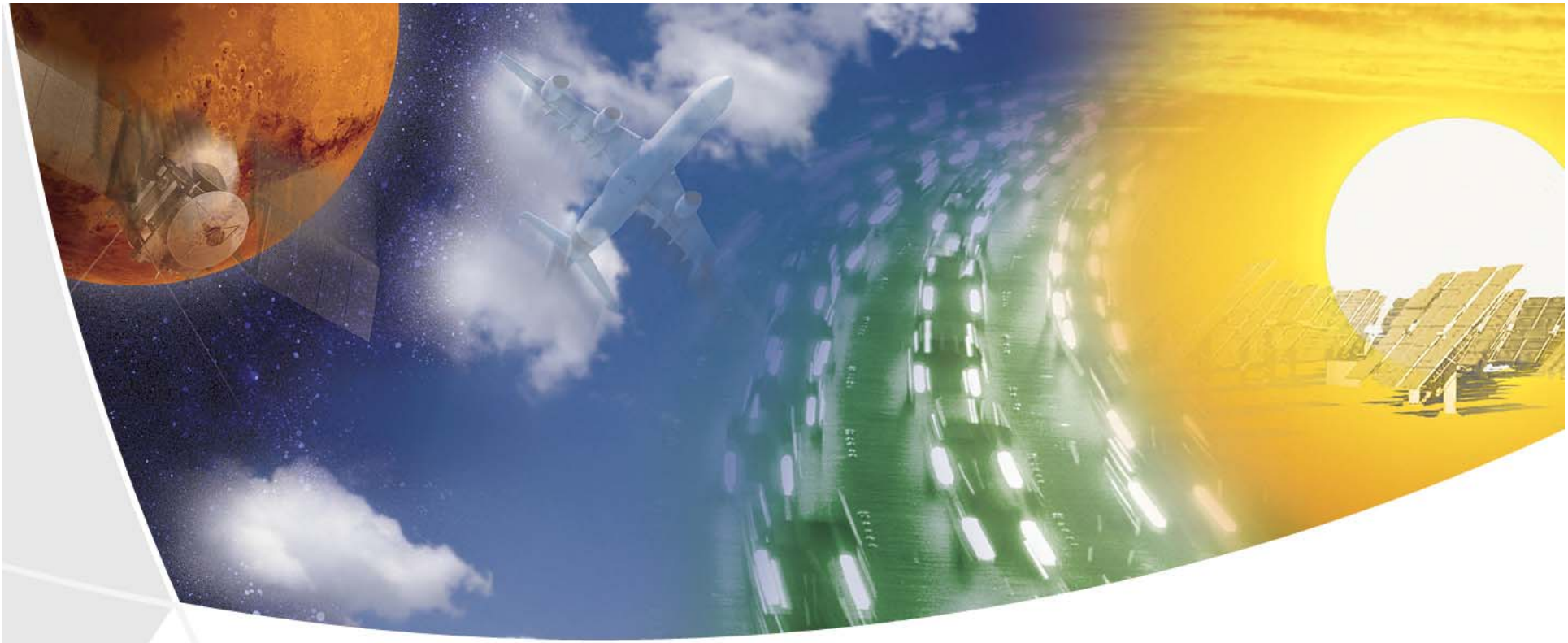


Galileo – Systemaufbau und Mehrwert

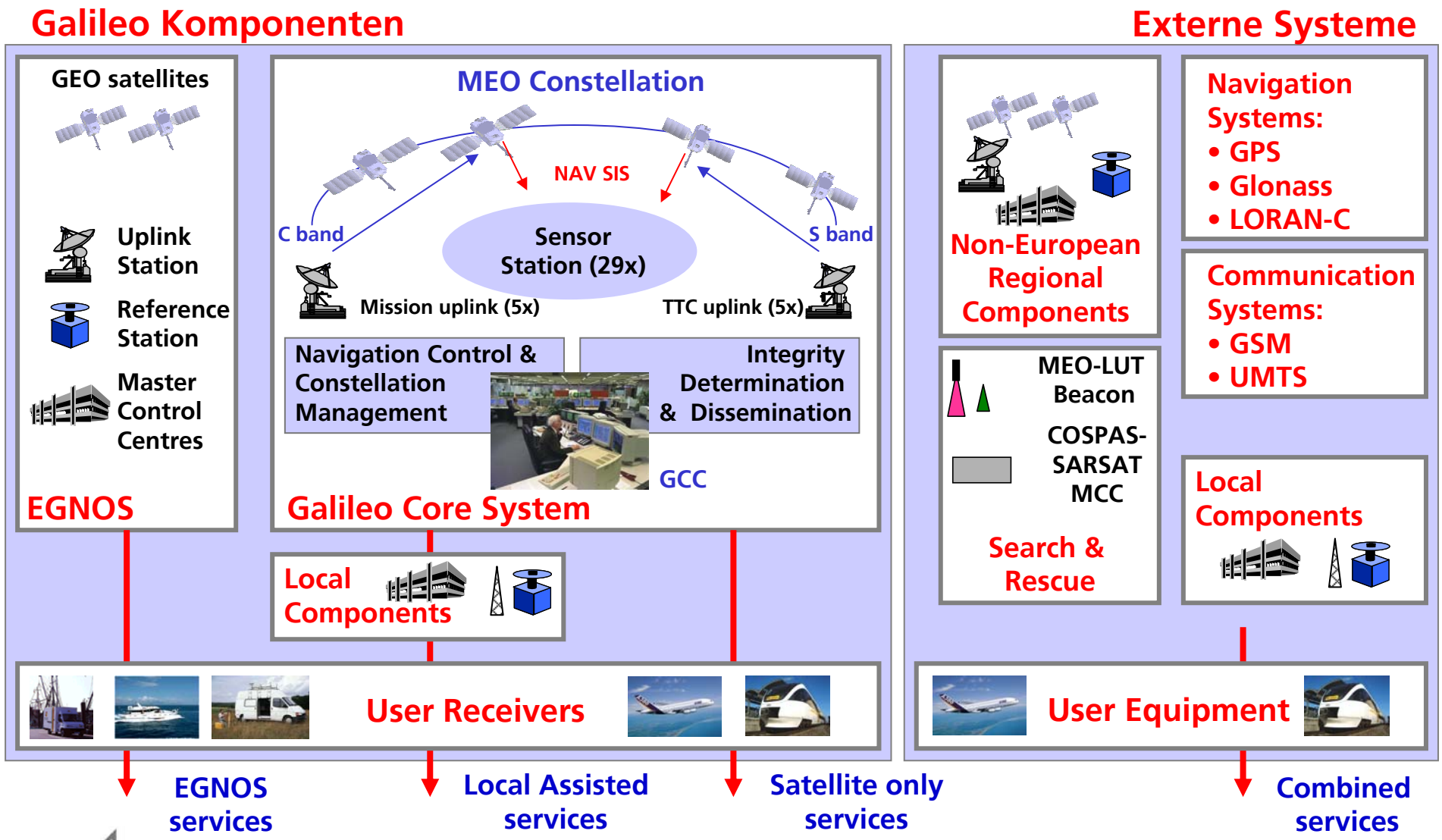
Dr. E. Engler

DLR - Institut für Kommunikation und Navigation

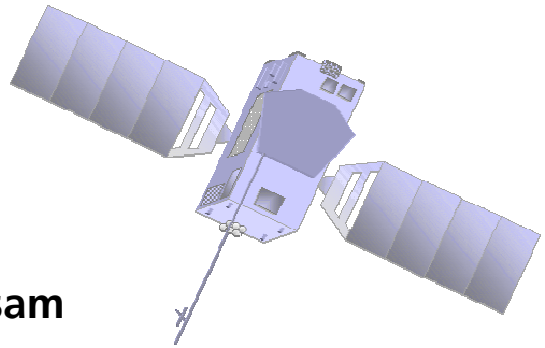
Topics

- Galileo – Systemaufbau
- Galileo Mehrwert
  - >> aus Satellitenverfügbarkeit
  - >> aus Signalverfügbarkeit
  - >> aus spezifischen Diensten
  - >> aus Interoperabilität
- Meilenstein: Galileo Testsatellit
- Galileo Verwertung

Galileo Systemaufbau



Technischer Mehrwert - Galileo

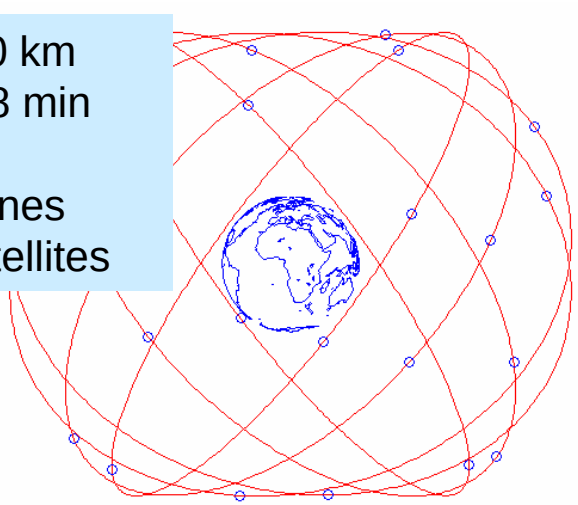


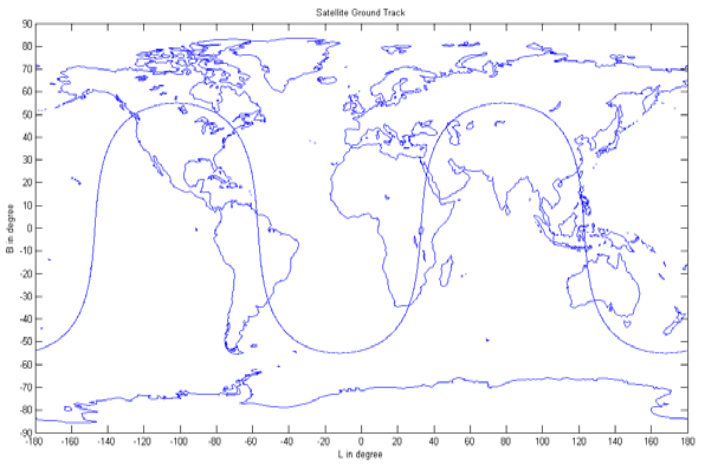
- **Unabhängigkeit:** GALILEO ist ein komplettes, eigenständiges GNSS.
- **Verfügbarkeit:** GALILEO ist global verfügbar. Bessere Konstellationsgeometrie.
- **Interoperabilität:** GALILEO + GPS können gemeinsam genutzt werden.
- **Performance:** Services kundenoptimiert, Mehrfrequenzempfang / Ranging Performance.
- **Verantwortlichkeit:** Eigenständige Überwachung der Services und ihrer Performance durch Real Time Integrity Network.

- ✓ Service Garantien werden gegeben
- ✓ Integritätsinformationen werden geliefert
- ✓ SoL Zertifizierung wird möglich
- ✓ Lokale Ergänzungen bereits im Design berücksichtigt
- ✓ Kompatibilität zu GPS unterstützt die Nutzung beider (Redundanz, Verfügbarkeit)

GPS

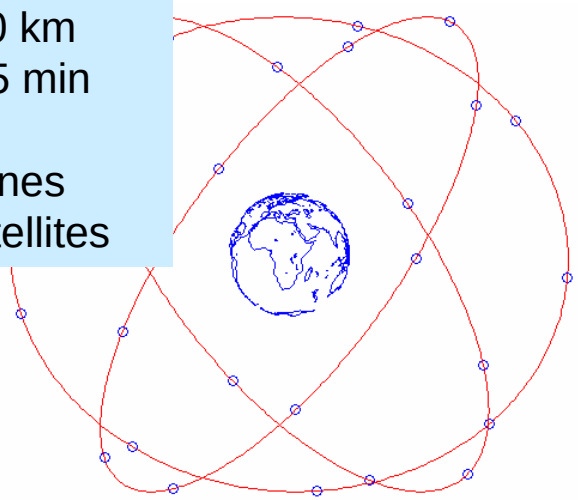
R = 26’600 km
T = 11h 58 min
i=55º,
6 orbit planes
24 (28) satellites

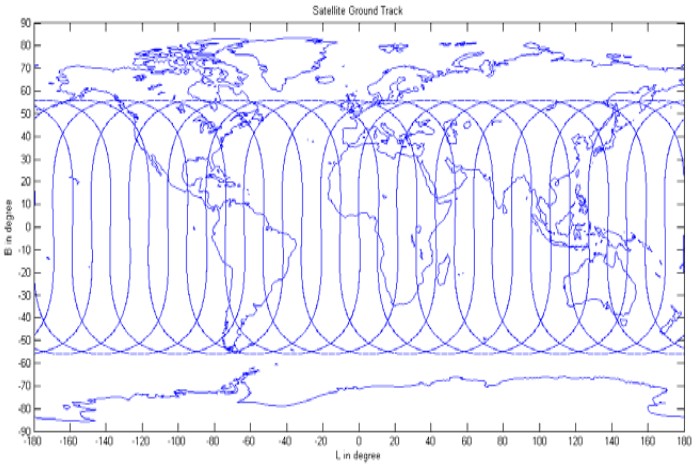




Galileo

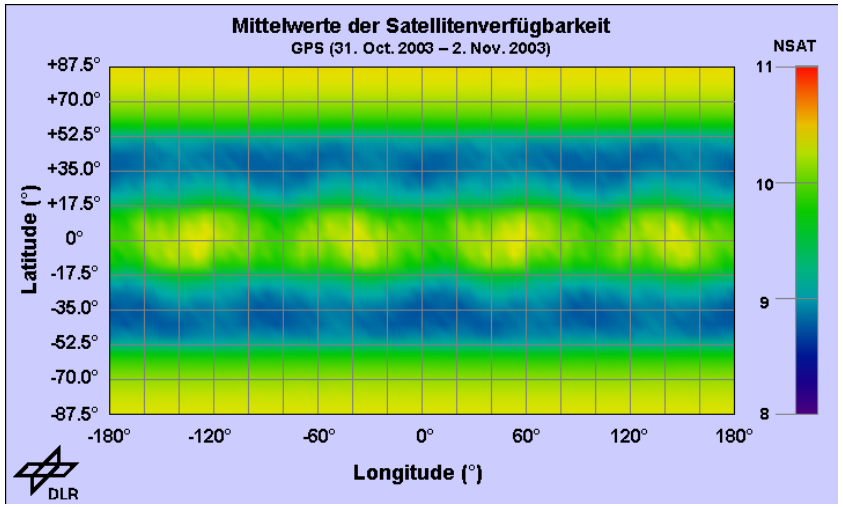
R = 29’600 km
T = 14h 05 min
i=56º,
3 orbit planes
27 (30) satellites

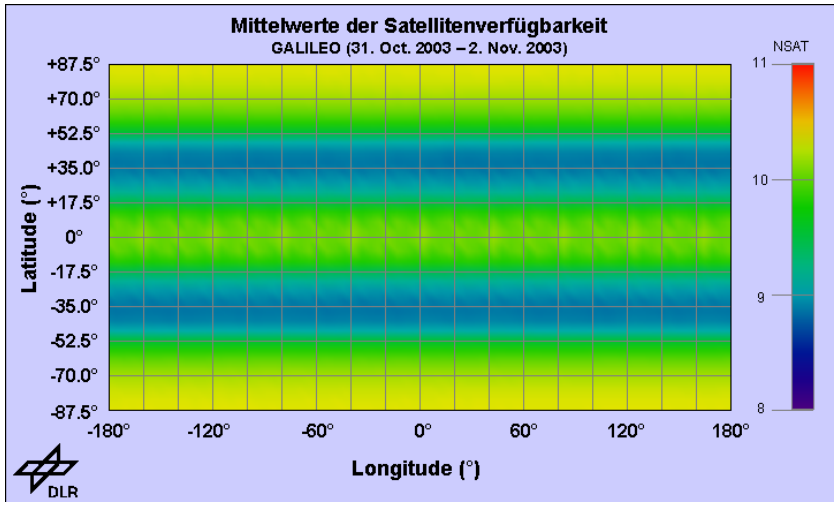


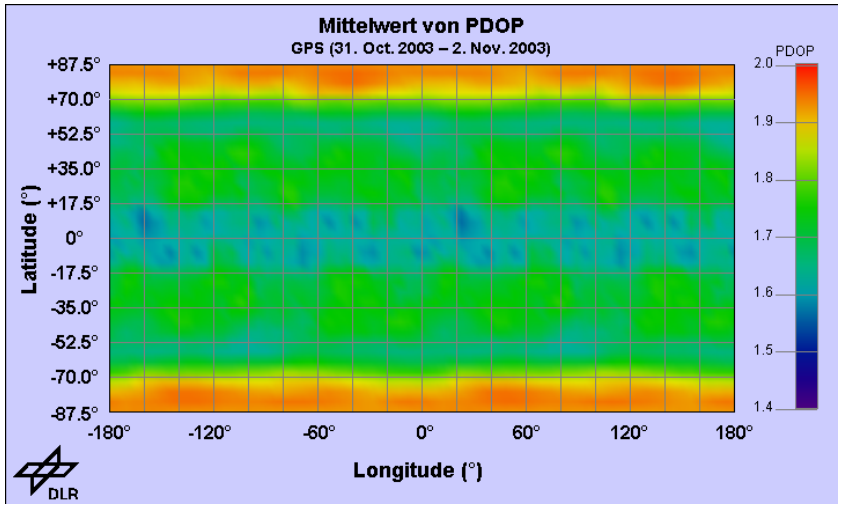


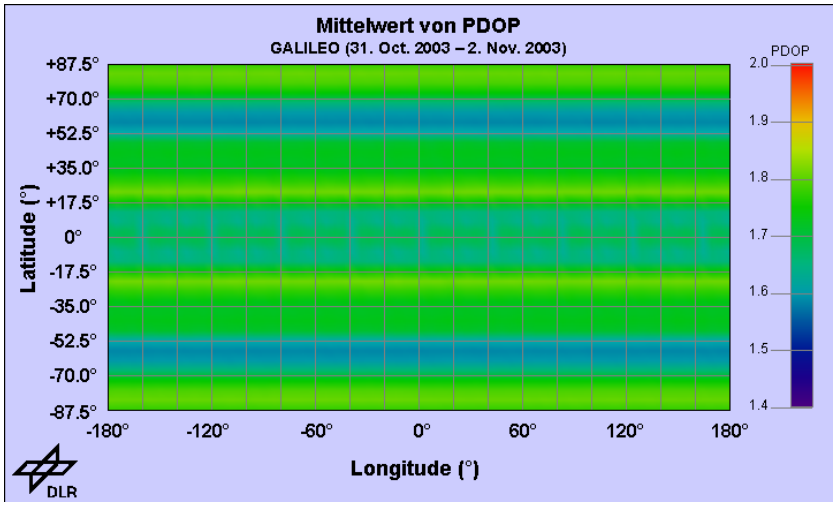
Source: Graf (DLR/TUM)

Galileo - Konstellation



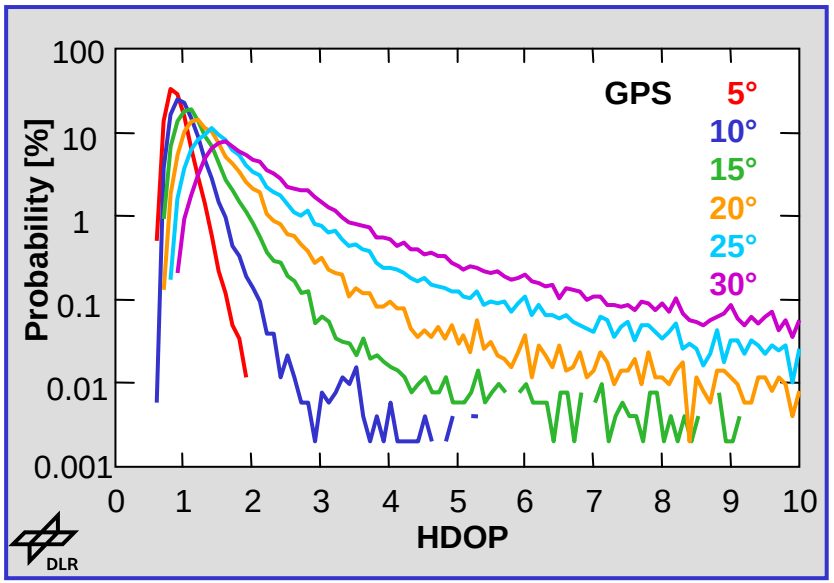


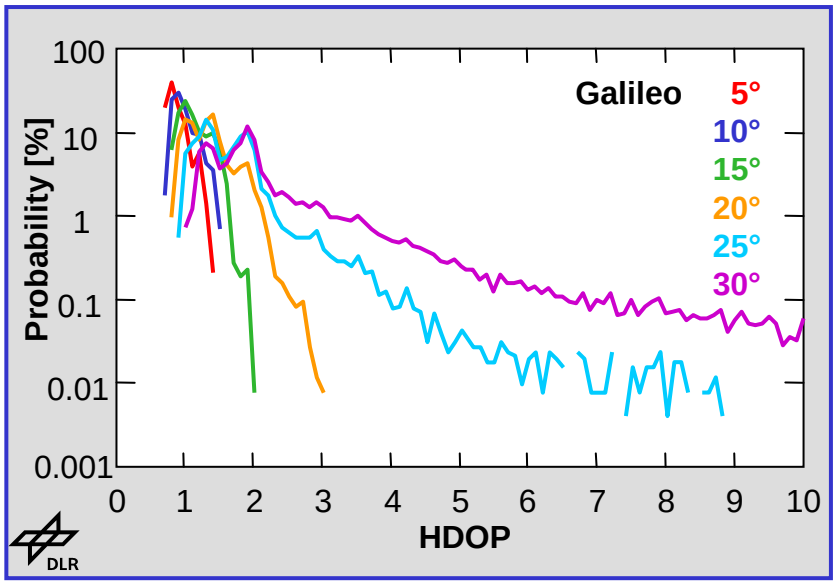




Source: NavSim (DLR)

Galileo – Positioniergenauigkeit (HDOP)





Prozentualer Anteil von Messpunkten mit weniger als 4 Satelliten

bei ele=20°	(GPS= 0.07%,	GAL= 0.00%)
bei ele=25°	(GPS= 1.88%,	GAL= 0.00%)
bei ele=30°	(GPS= 11.46%,	GAL= 1.95%)
bei ele=35°	(GPS= 35.76%,	GAL=19.93%)
bei ele=40°	(GPS= 65.59%,	GAL=57.21%)
bei ele=45°	(GPS= 84.17%,	GAL=83.87%)

Source: NavSim (DLR)

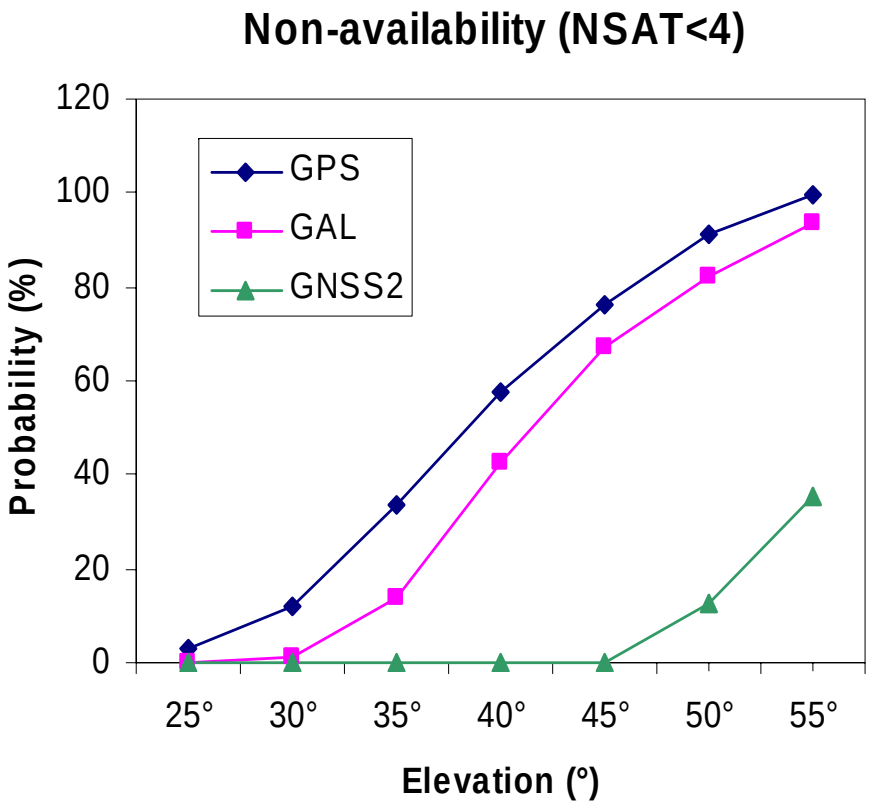
Mehrwert durch mehr GNSS Satelliten

Example: Munich

Abschattungen reduzieren die Anzahl real empfangener GNSS Signale.

Galileo Konstellation ermöglicht noch bei 25° Elevationsmaske die Positionierung.

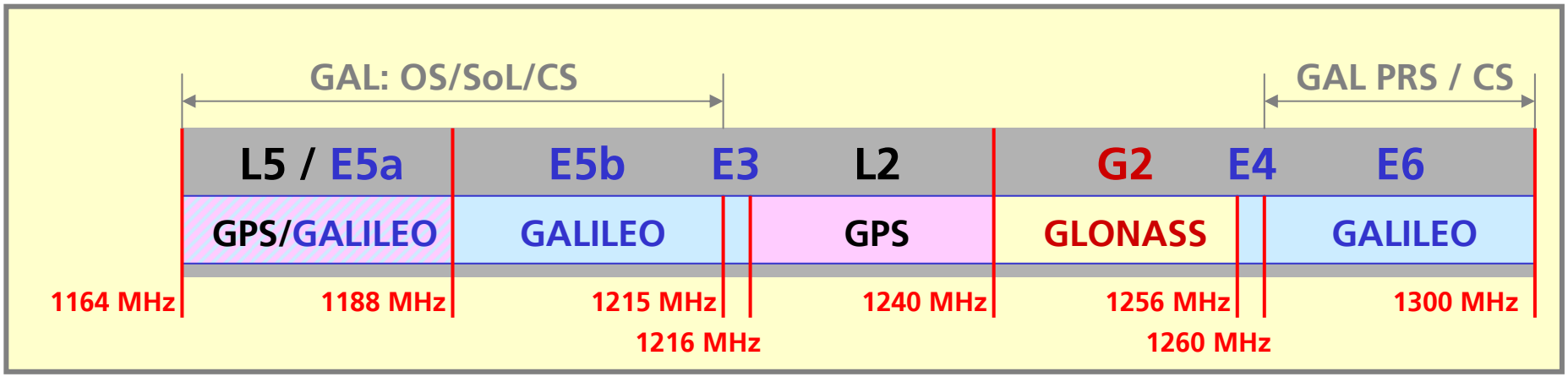
Die gemeinsame Nutzung von GPS und Galileo reduziert das Problem des nicht ausreichenden Signalempfangs auf Elevationsmasken über 40°.



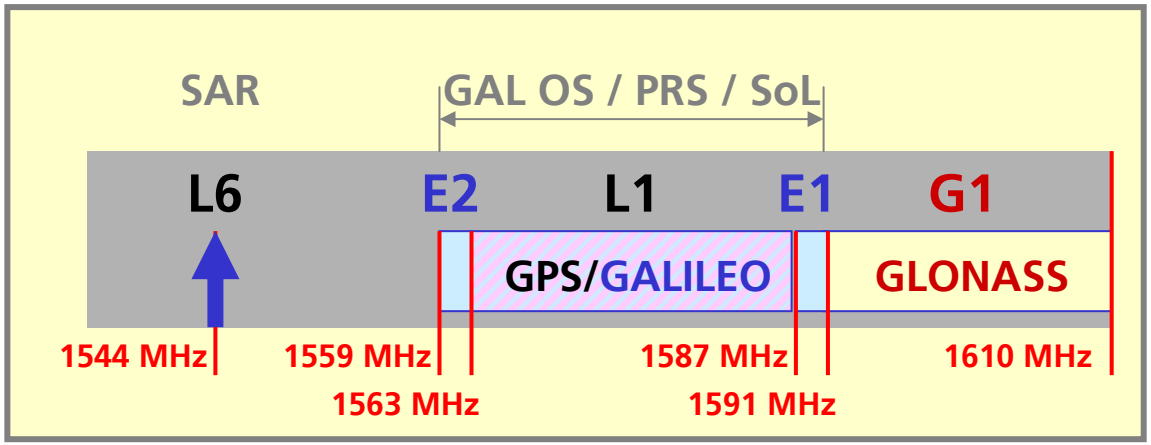
Source: NavSim (DLR)

GNSS Frequenzbänder

Lower L-band



Upper L-band

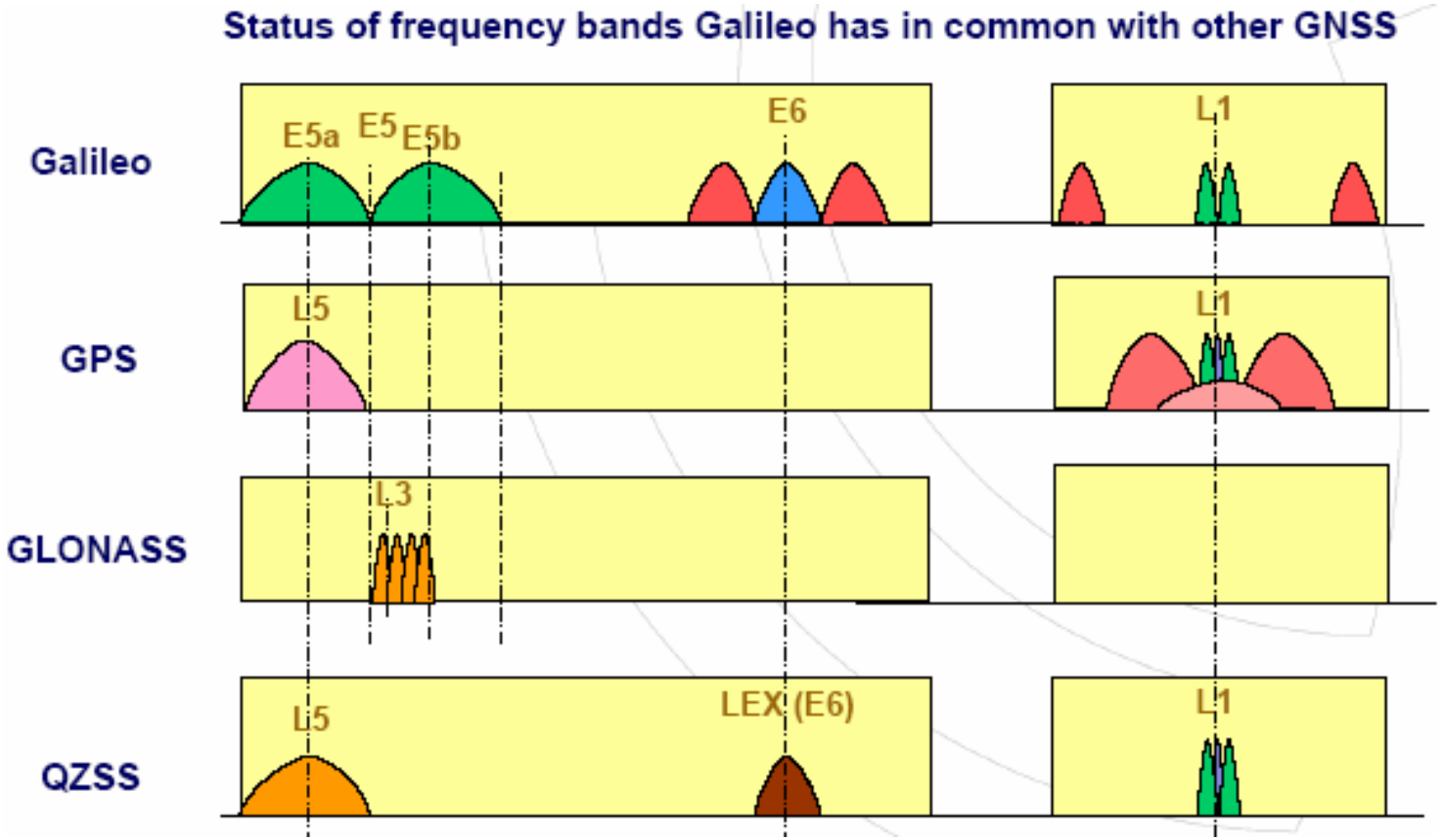


GPS : L1/L2 und L3
GPS 2: L1,L2 und L5

Galileo:
E5, E6, L1

QZSS: L1, L5, LEX(E6)

Interoperability



Source: Riuz / GJU

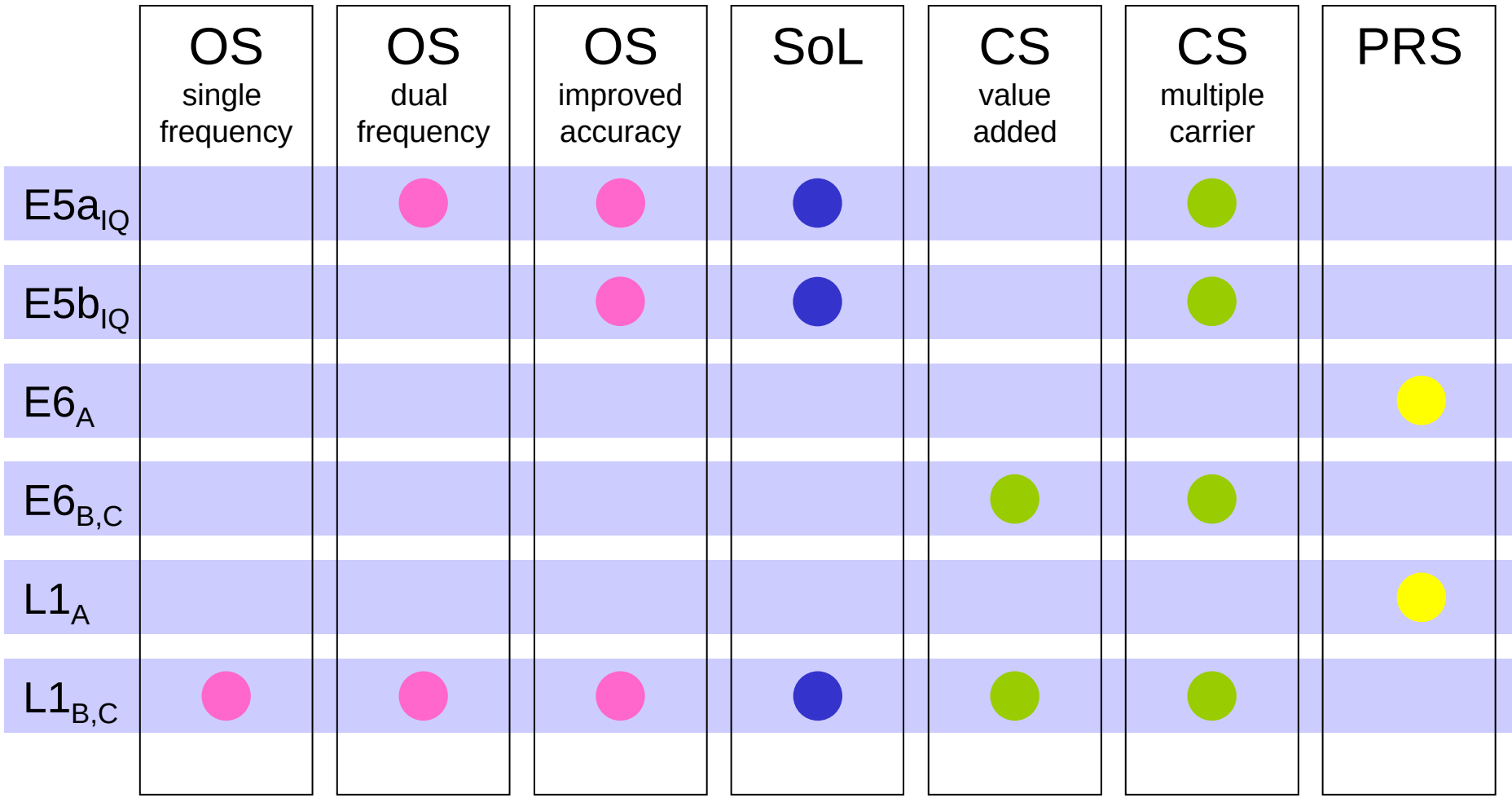
Galileo Signale

CASM: Coherent Adaptive Sub-Carrier Modulation
BOC: Binary Offset Coding

Band	Multiplex	Band-width [MHz]	Com-ponent	Modu-lation	Power [dbm]	1. Code	2. Code	Data Rate	Service
E5	AltBOC (15,10)	90 x 1.023	E5a/I	BPSK(10)	-128	10230	20	50	OS
			E5a/Q	BPSK(10)	-128	10230	100	pilot	OS
			E5b/I	BPSK(10)	-128	10230	4	250	SoL
			E5b/Q	BPSK(10)	-128	10230	100	pilot	SoL
E6	CASM	40 x 1.023	A	BOC(10,5)	-125	classified			
			B	BPSK(5)	-128	5115	1	1000	CS
			C	BPSK(5)	-128	5115	100	pilot	CS
L1	CASM	40 x 1.023	A	BOC(15,2.5)	-125	classified			
			B	BOC(1,1)	-128	4092	1	250	OS/SoL
			C	BOC(1,1)	-128	4092	25	pilot	OS/SoL

Status 9.05.2005, as far as known

Galileo Services



Open Service (OS)

- Kostenfrei
- Massenmarkt
- Interoperabilität mit anderen GNSS

Carriers		Single (L1)	Dual (L1+E5)
Ionospheric Corrections		Based on simple model	Based on dual processing
Coverage		Global	
Accuracy (95%)		H: 15 m V: 35 m	H: 4 m V: 8 m
Integrity	Alarm Limit	Not applicable	
	Time-To-Alarm		
	Integrity Risk		
Availability		99.8 %	
Timing Accuracy		30 ns (wrt UTC/TAI)	

Time to first fix (cold start):	200 s
Time ro precise fix (cold start):	100 s
Time to fix (warm start):	30 s
Time to fix (re-acquisition):	1 s

SoL - Service

- ICAO/IMO Regularien
- Servicegarantien
- Zertifizierbarkeit & Haftungsgarantien

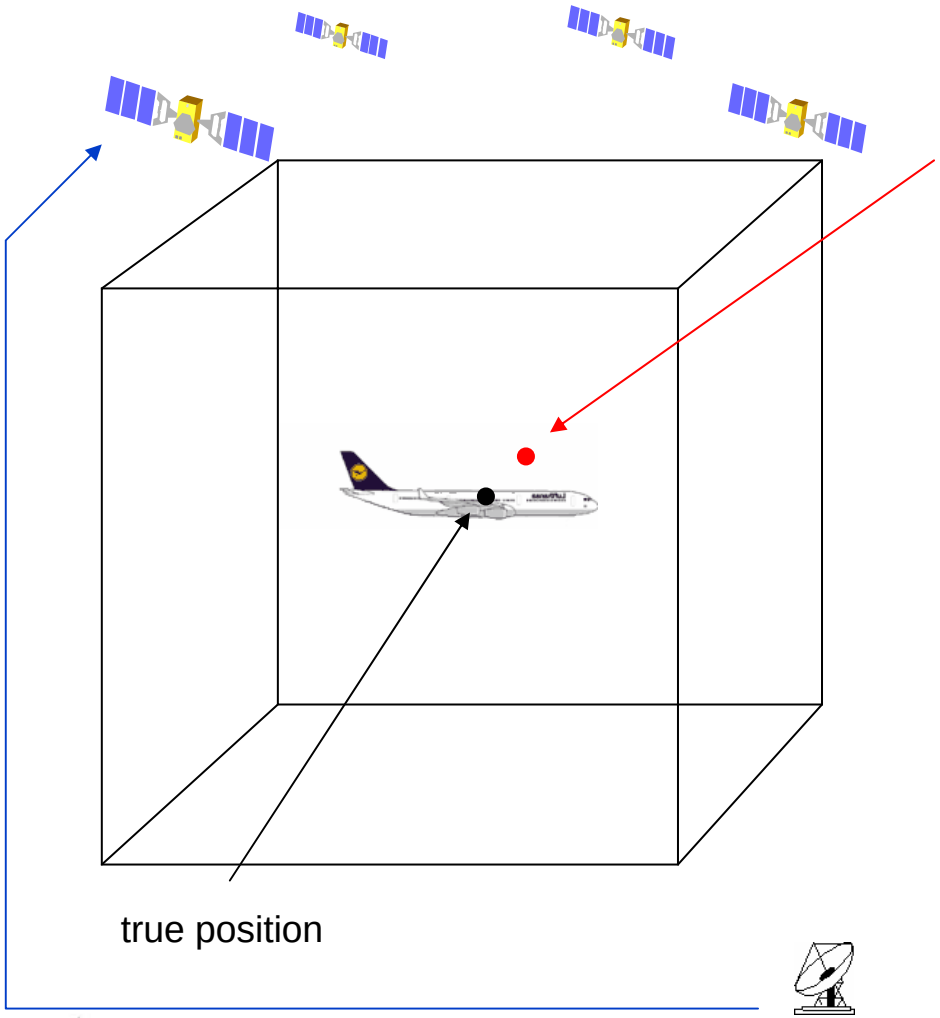
SoL =

OPEN SERVICE

+ Integrity

Carriers		Three Frequencies (L1 + E5a + E5b)	
Ionospheric Corrections		Based on dual processing	
Coverage		Global	
Time Critical Level		Y	N
Accuracy (95%)		H: 4 m V: 8 m	H: 220 m
Integrity	Alarm Limit	H: 12m / V: 20 m	H: 556 m
	Time-To-Alarm	6 sec	10 sec
	Integrity Risk	3.5e-7 / 150 s	1e-7 / h
Continuity Risk		1e-5 / 15 s	1e-4 to 1e-8 / h
Availability: Acc.		99.8 %	
Availability: Int.		99.5 %	

Safety of Life: Concept of Integrity



Permanently Computation of Positioning Error

- depends on satellite – receiver geometry
- determines by ranging performance

Permanently Assessment of Positioning Error

- estimation continuously
- comparison with fixed alarm levels

Service Operation: Provision of Alarms

Integrity risk means:
3D Error > 3D Alarm level
without informing the user

Public Regulated Service (PRS)

- means provision of robust and encrypted signals under EU Member States control
- will be used for applications devoted to European/national security, regulated or critical applications and activities of strategic importance
- The December `04 Transport Council:
  - has validated the PRS as one of the five Galileo services
  - has invited the Commission to develop a policy of PRS access

Carriers		Dual Frequencies (L1 + E6)
Ionospheric Corrections		Based on dual processing
Coverage		Global
Accuracy (95%)		H: 6.5 m V: 12.0 m
Integrity	Alarm Limit	H: 20 m / V: 35 m
	Time-To-Alarm	10 sec
	Integrity Risk	3.5e-7 / 150 s (tbc)
Continuity Risk		1e-5 / 15 s
Timing Accuracy		100 ns (wrt UTC/TAI)
Availability		99.8 %

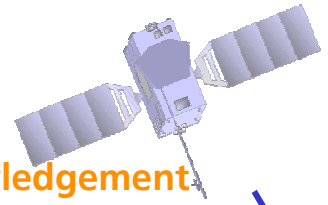
Commercial Service (CS)

- **The Galileo Operating Company will determine and guarantee the precise levels of performance.**

- **Commercial Service will include:**
  - **Dissemination of data (500 bps)**
  - **Broadcasting of additional 2 signals outside from OS frequency bands**
  - **High precision navigation (dm-level)**
  - **Pilot signal for integration in positioning applications and wireless communication networks**

Search and Rescue Service

- Signale von 150 Funkbaken durch Galileo Satellit gleichzeitig weiterleitbar
- Empfangsbestätigung: 6 Messages a 100 bit pro min
- Verfügbarkeit: 99.8 %
- Kommunikation von Funkbake zur SAR Bodenstation in weniger als 10 Minuten
- BER < 1e-5

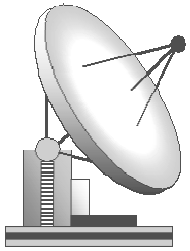


Acknowledgement message

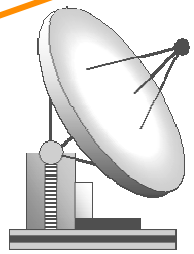
Navigation signal

Distress signal (L-band)

Distress signal (406 MHz)



Galileo Uplink (C-band)

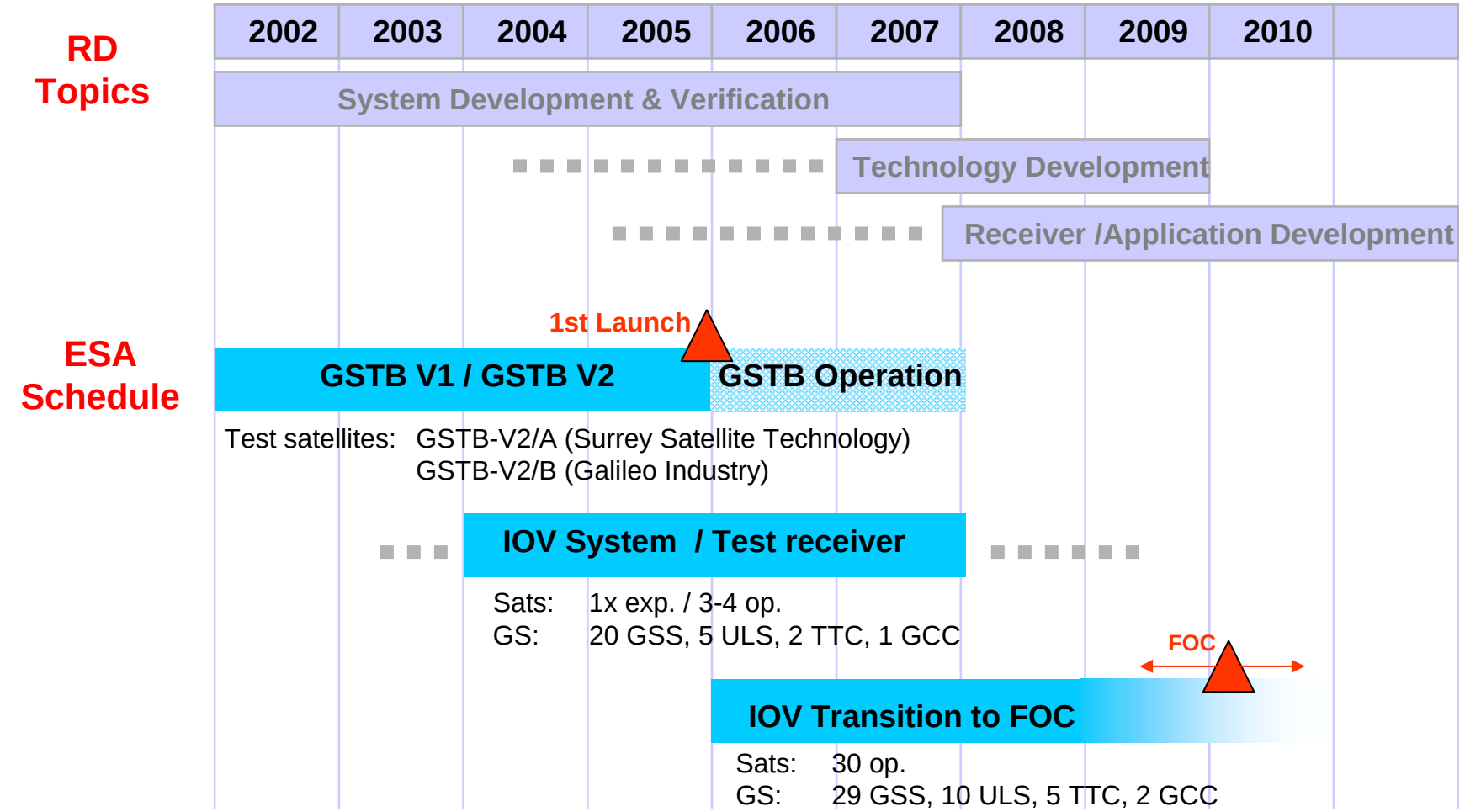


COSPAS SARSAT MEOLUT

Status of Interoperability

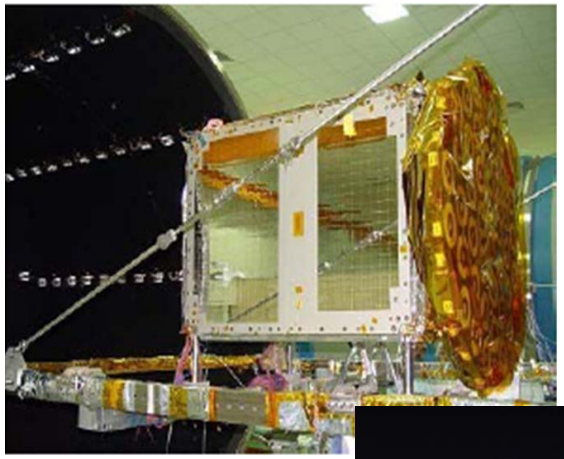
- **GPS and Galileo**
  - **Adoption a common L1 signal for Galileo and GPS III: BOC(1,1)**
  - **Interoperability of timing and geodesy standards**
  - **Broadcasting offset of system times GPS vs. Galileo**
- **Glonass and Galileo**
  - **Frequency sharing between Galileo E5b and Glonass L3 gives prospect of interoperability**
  - **Broadcasting offset of system times Glonass-K vs. galileo is envisaged**
- **QZSS and Galileo**
  - **Agreement that the same signal structure as Galileo E6 will be used to ensure compatibility and interoperability**

Galileo Implementierung



Galileo – Milestone

Start of the 1. Galileo IOV Experimentation Satellite



GIOVE -A

Preparations in Baikonur

Launch (28. Dec. 2005)

Source: ESA

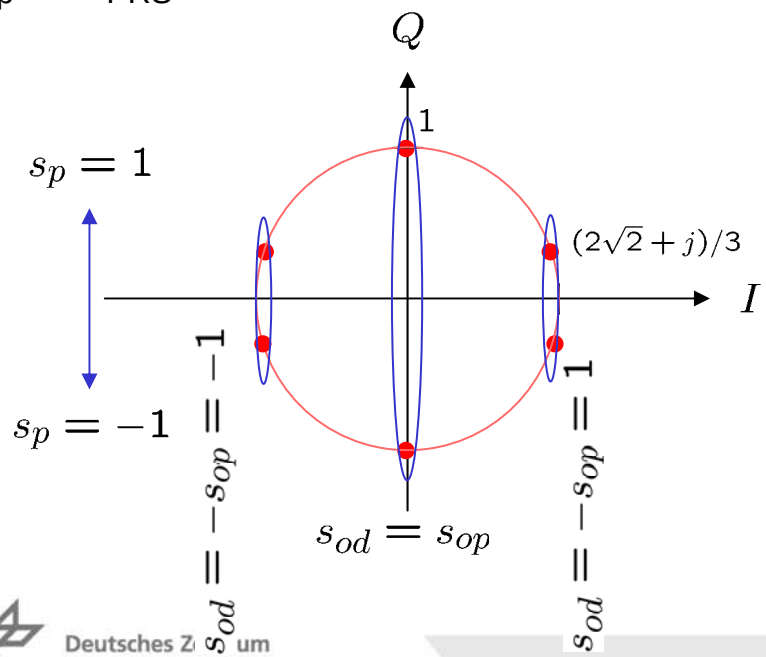
Galileo Signal Evaluation

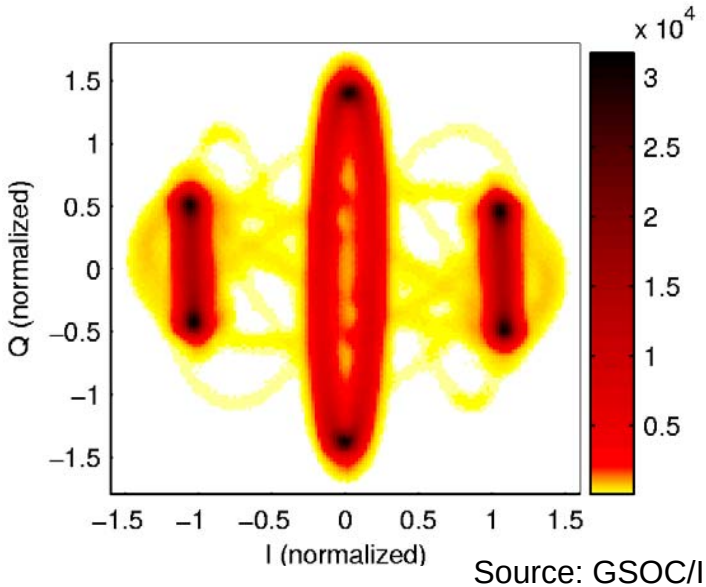
First Signals January 12th, 2006

- **Measurement campaign on January 14th, 2006 on the 30 m Telescope of the DLR in Weilheim**
- **L1-Signal**

od = OS,data
op = OS,pilot
p = PRS

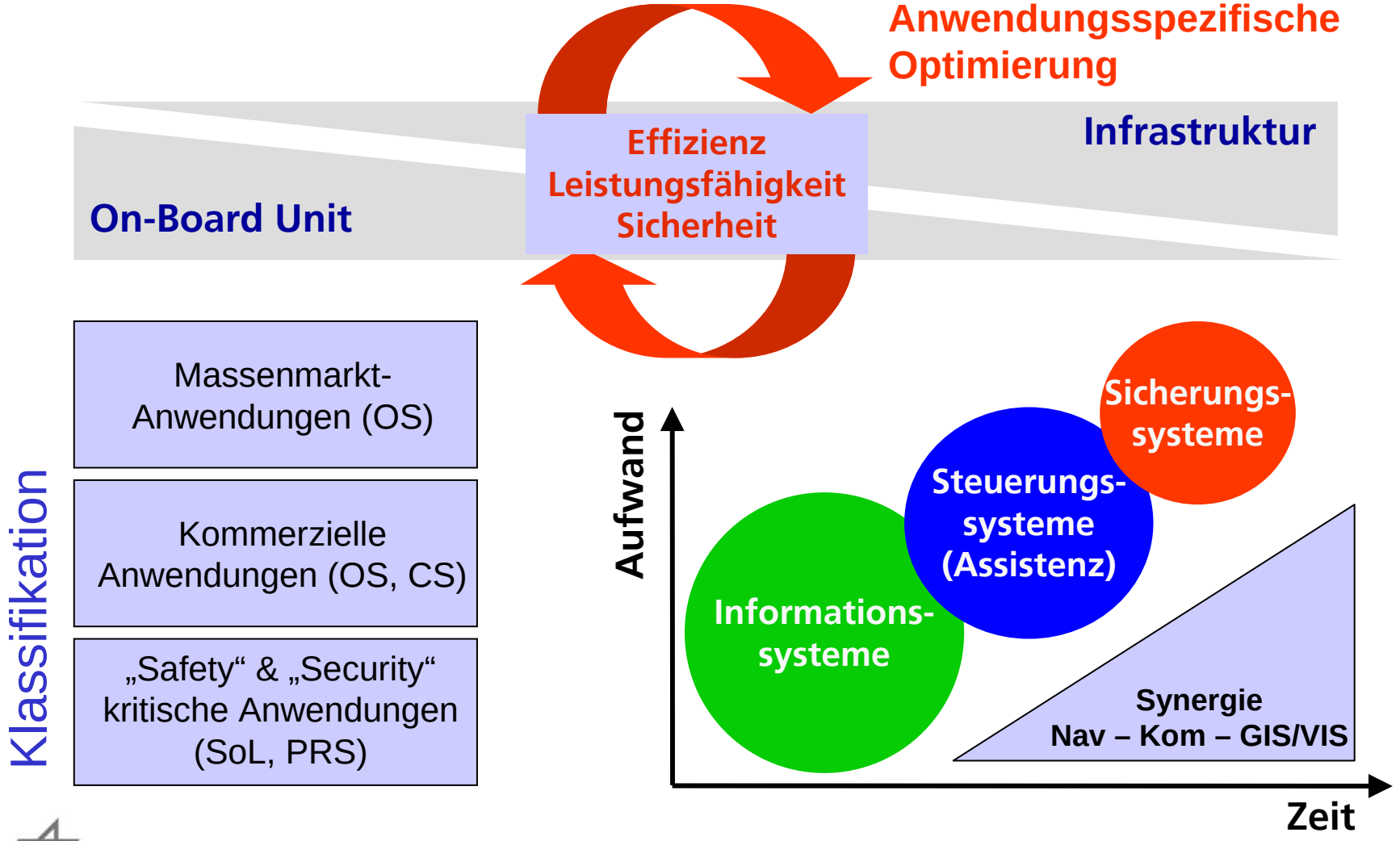
$$s_{L1}(t) = \frac{\sqrt{2}}{3}\left[s_{od}(t) - s_{op}(t)\right]\cos(\omega_{L1}t) + \frac{1}{3}\left[2s_p(t) + s_{od}(t)s_{op}(t)s_p(t)\right]\sin(\omega_{L1}t)$$





Source: GSOC/IKN (DLR)

Galileo basierte Anwendungen



Maritime R&D Strategy & Objectives

>> Galileo Integration
>> Multi-Sensor Navigation
>> Local Augmentation

Satellite Based Navigation

>> Stand alone
>> Information aided
>> Assisted
>> Controlled

Vessel Navigation Techniques

Vessel Communication Techniques

Innovative Solutions and Services for Efficient Vessel Guidance and Transport

Innovative Maritime Services

>> Information
>> Assistance
>> Remote control

>> Service optimised
>> Reliable
>> Assured

Mecklenburg /Vorpommern

- **Memorandum of Understanding (21.02.2006)**
  - **Der Freistaat Bayern, das Land Niedersachsen und das Land Mecklenburg-Vorpommern beabsichtigen, bei der Entwicklung, dem Aufbau und der Nutzung des europäischen Satellitennavigationssystems GALILEO zu kooperieren.**
  - **MV: Galileo Augmented Motion in Maritime Application (GAMMA)**

    Einrichtung und Betrieb einer Testumgebung für die Entwicklung maritimer Applikationen für Galileo und der Erprobung von prototypischen Anwendungen im Hafenbereich Rostock
- **MV – 1. Progressmeeting (30.03.2006)**
  - **Konsolidierung des Vorhabens Forschungshafen Rostock (Ministerien, FuE, KMU…)**
  - **Konzeptentwurf bis 27.04.2006 (Phase 1) unter Federführung DLR**
- **InnoMAG – Innovative Maritime Anwendung von Galileo (29.03.2006)**
  - **Nationale Arbeitskreisgründung unter Federführung Telematica**

Forschungshafen Rostock

Forschungshafen Rostock = Maritime Testumgebung

Quelle: http://www.rostock-port.de/

zur Verifikation von EGNOS/Galileo/GBAS unter realen Bedingungen

zur Validierung darauf aufbauender Dienste und Assistenzsysteme in den Bereichen Schiffsführung, Verkehrsmanagement und Transportlogistik

Danke für Ihre Aufmerksamkeit !