

# Risk Mitigation in the Ground Mission Segment using the Galileo System Test Bed



10 Years IGS – 4 March 2004, Bern

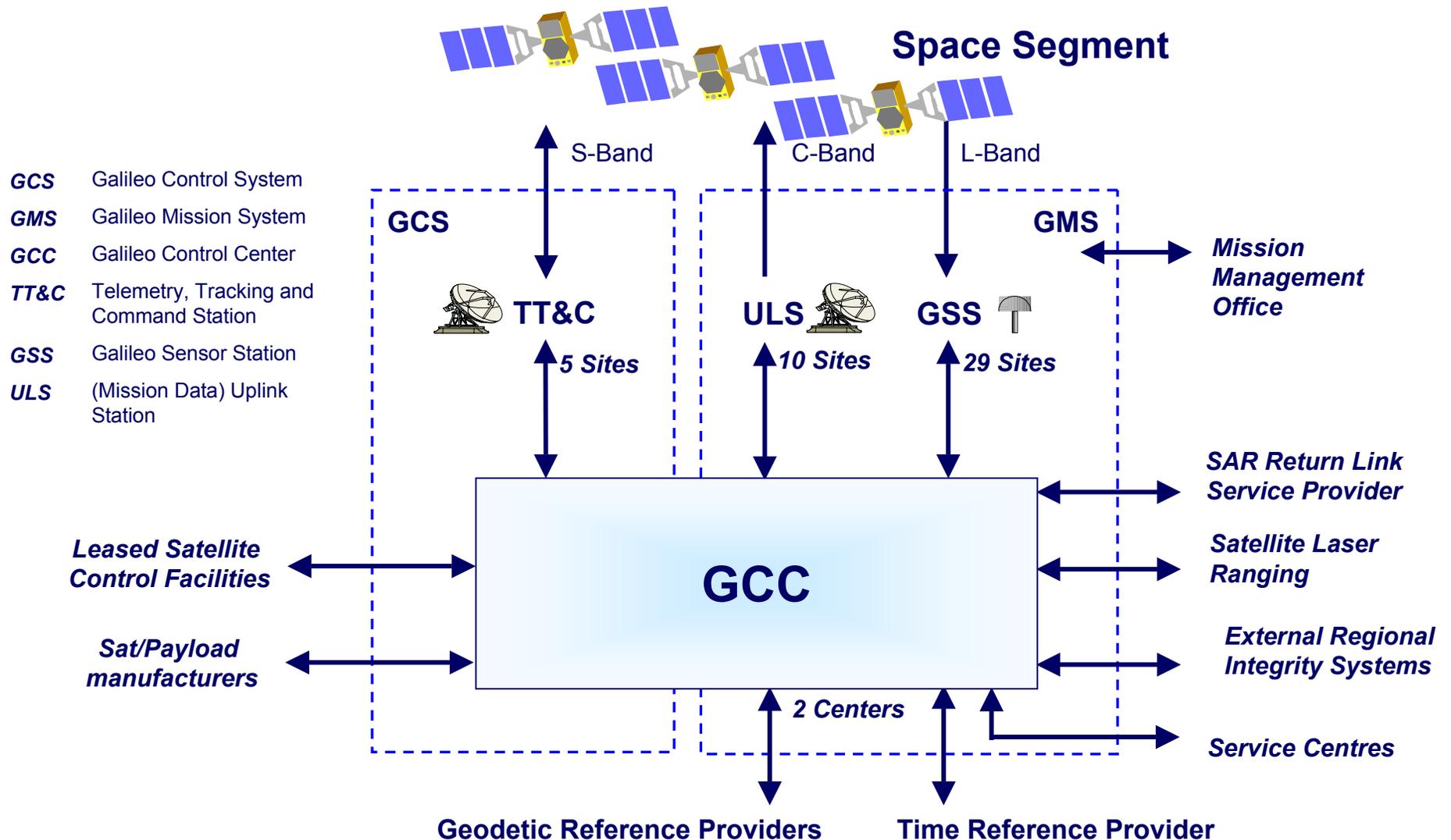
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# Service Performance

<b>GALILEO Global Services</b>	<b>Open Service</b>	<b>Commercial Services</b>	<b>Safety of Life Services</b>
<b>Coverage</b>	Global	Global	Global
<b>Positioning Accuracy</b>	15 m H - 35 m V (single frequency) 4 m H - 8 m V (dual frequency)		4 m H - 8 m V (dual frequency)
<b>Timing Accuracy</b>	30 nsec		30 nsec
<b>Availability</b>	99.5%	99.5%	99.5%
<b>Integrity</b>	None		Required
<b>Alert Limit</b>			12 m H - 20 m V
<b>Time to Alert</b>			6 seconds
<b>Integrity Risk</b>			$3.5 \times 10^{-7}$ / 150 seconds
<b>Continuity Risk</b>			$1.0 \times 10^{-5}$ / 15 seconds
<b>Access Control</b>	Free Open Access	Controlled Access of Ranging Code and Nav Data Message	Controlled Access of Nav Data Message
<b>Certification and Service Guarantees</b>	None	Guarantee of Service Possible	Build for Certification and Guarantee of Service

# Ground Segment Concept



# G/S Main Components

The Galileo Ground Segment comprises the **Ground Control Segment (GCS)** and the **Ground Mission Segment (GMS)** and includes:

- Global network of Galileo Sensor Stations (GSS)
- Global network of Up-link Stations (ULS) for real-time mission data up-link in C-Band
- Global network of Telemetry, Telecommand and Ranging Stations (TT&C) for control of the satellites in S-Band
- Interconnecting high performance communication network and
- 2 geographically redundant Galileo Control Centres (GCC) for all the centralised processing, monitoring & control.

# Risk Mitigation



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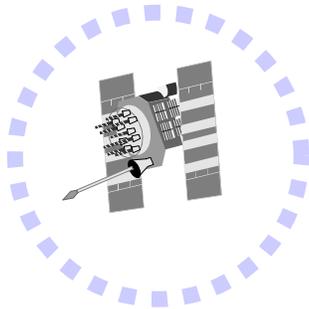


# Ground Mission Segment Risks Analysis

- Consolidation of Navigation performance and associated processing algorithms
- Consolidation of Integrity performance regarding the establishment of SISA and SISMA confidence levels, and the associated characterisation of Feared Events
- Consolidation of GSS Receiver Output Quality (i.e. multipath, interference and receiver noise) for the different Galileo Signal In Space frequencies
- Tuning of performances taking into account space segment characteristics (e.g. On-board clocks, MEO environment, Inter Frequency Bias, etc)

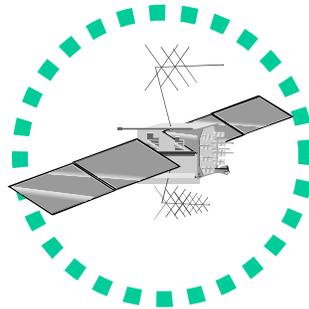
# Risk Mitigation: Incremental development logic

2004



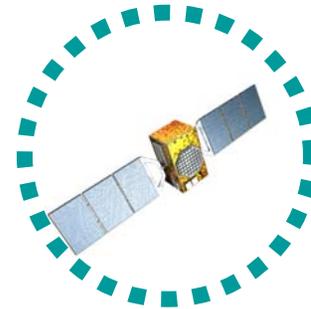
GPS and GLONASS  
Constellations

2005

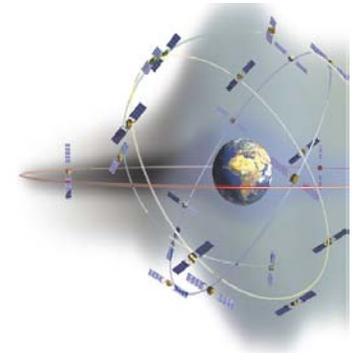


Galileo  
Exp. SV (\*1)

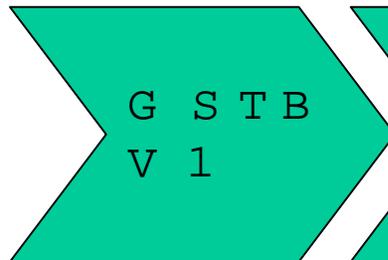
2007



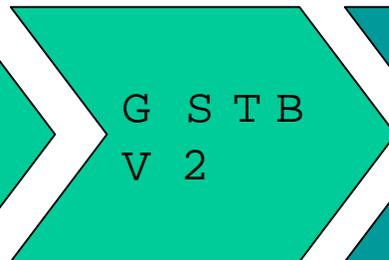
Galileo In Orbit  
Validation  
Const. (\*4)



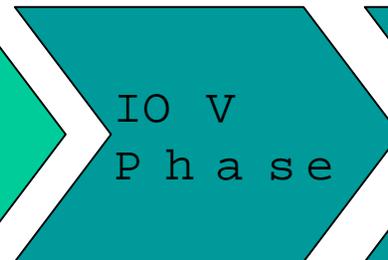
Galileo Full  
Operation  
Const. (30)



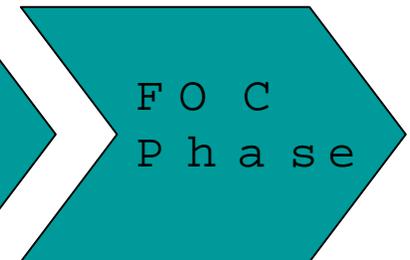
**Step 1**



**Step 2**



**Step 3**



**Step 4**

# **GSTB-V1**



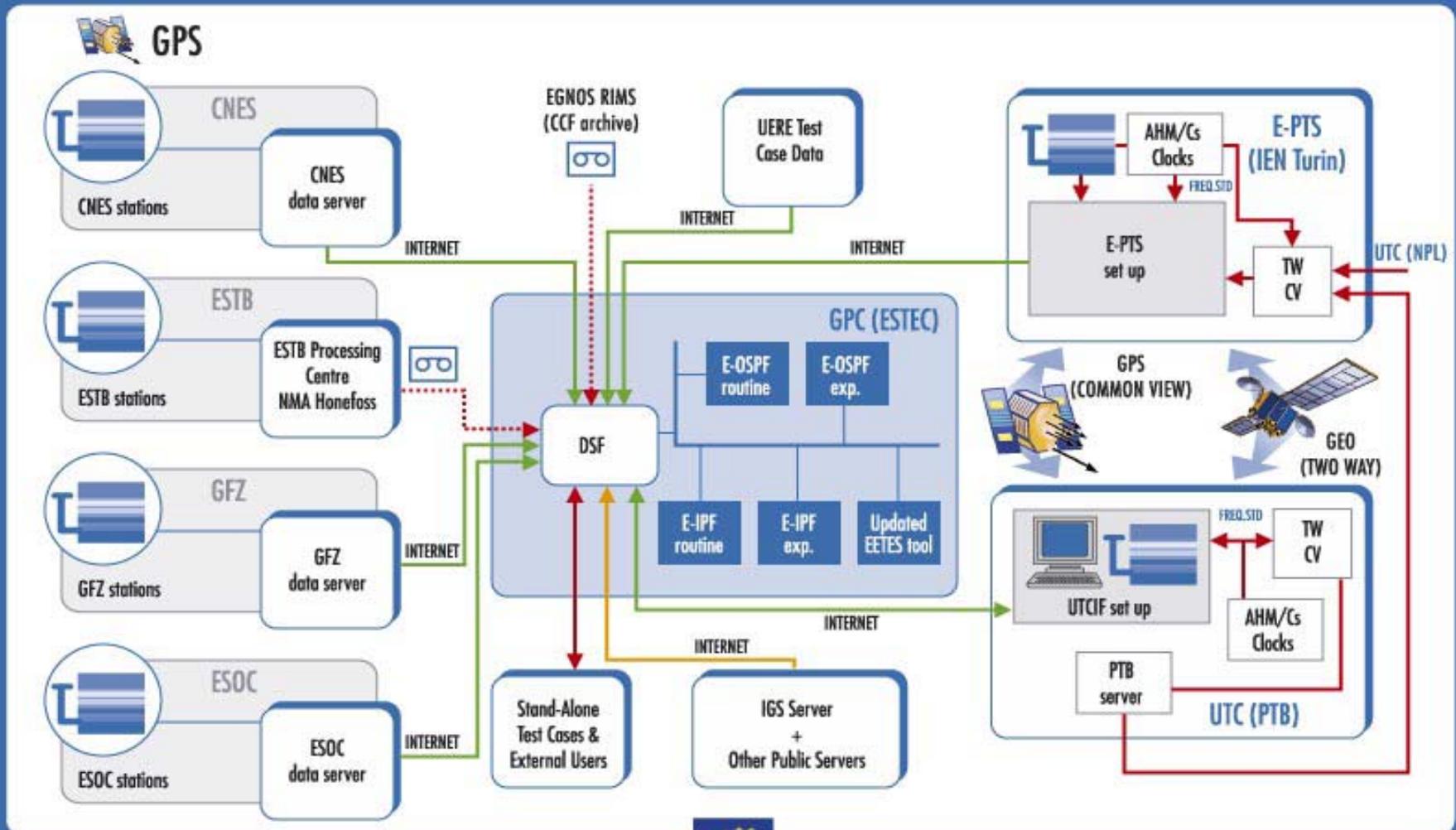
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# Galileo System Test Bed V1 Objectives

- GSTB V1 reduces the risk on the Galileo ground segment development through early experimentation with the Orbit Determination & Time Synchronisation and Integrity algorithms.
- Processing Facilities pre-developments are conducted based on realistic measurements from the GPS system
- Collaboration with the International GPS Service community and UTC Time Community established

# GSTB-V1 Architecture



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# GSTB-V1 Sensor Stations Network



# **GSTB-V1**

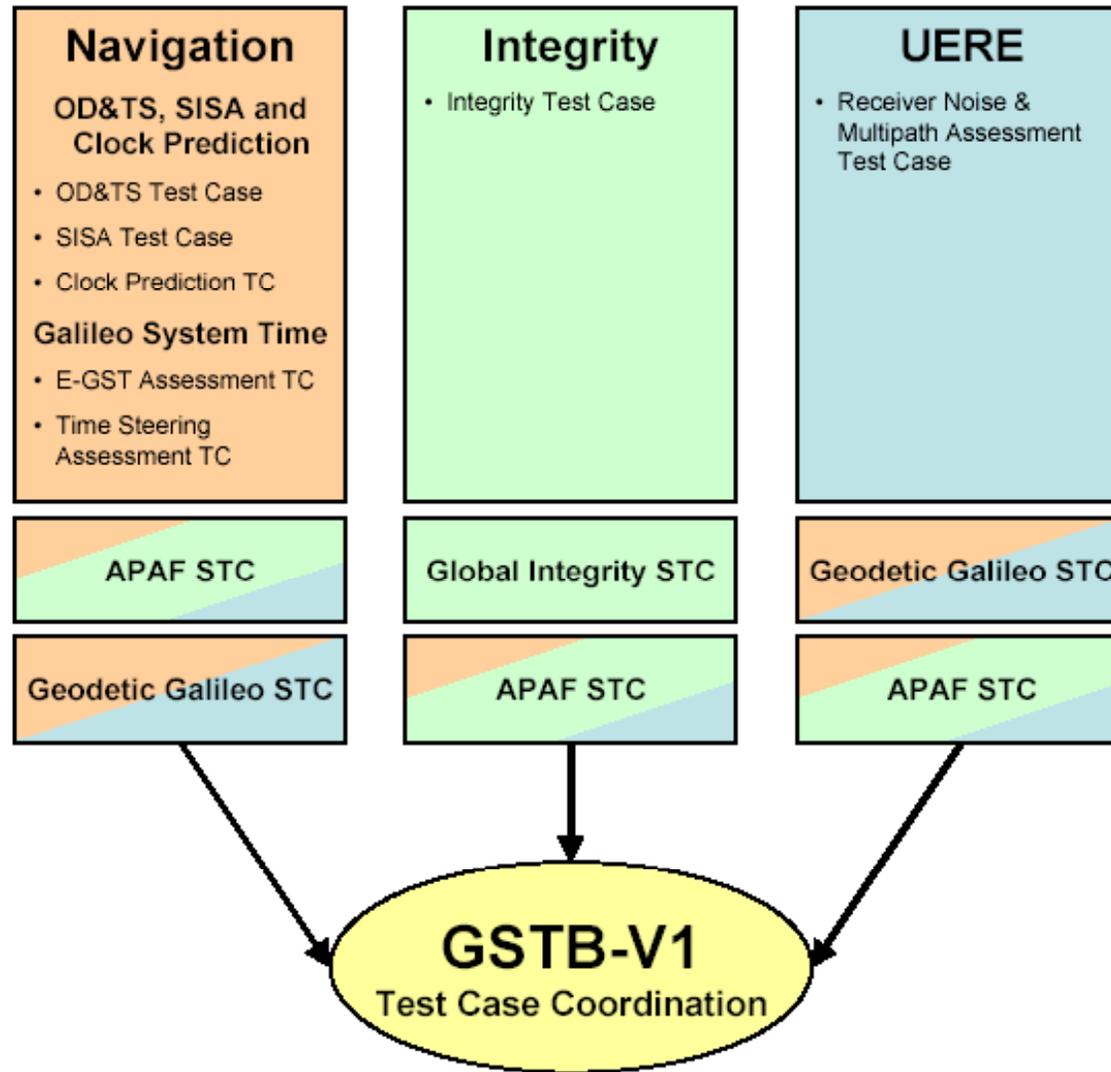
# **Experimentation**



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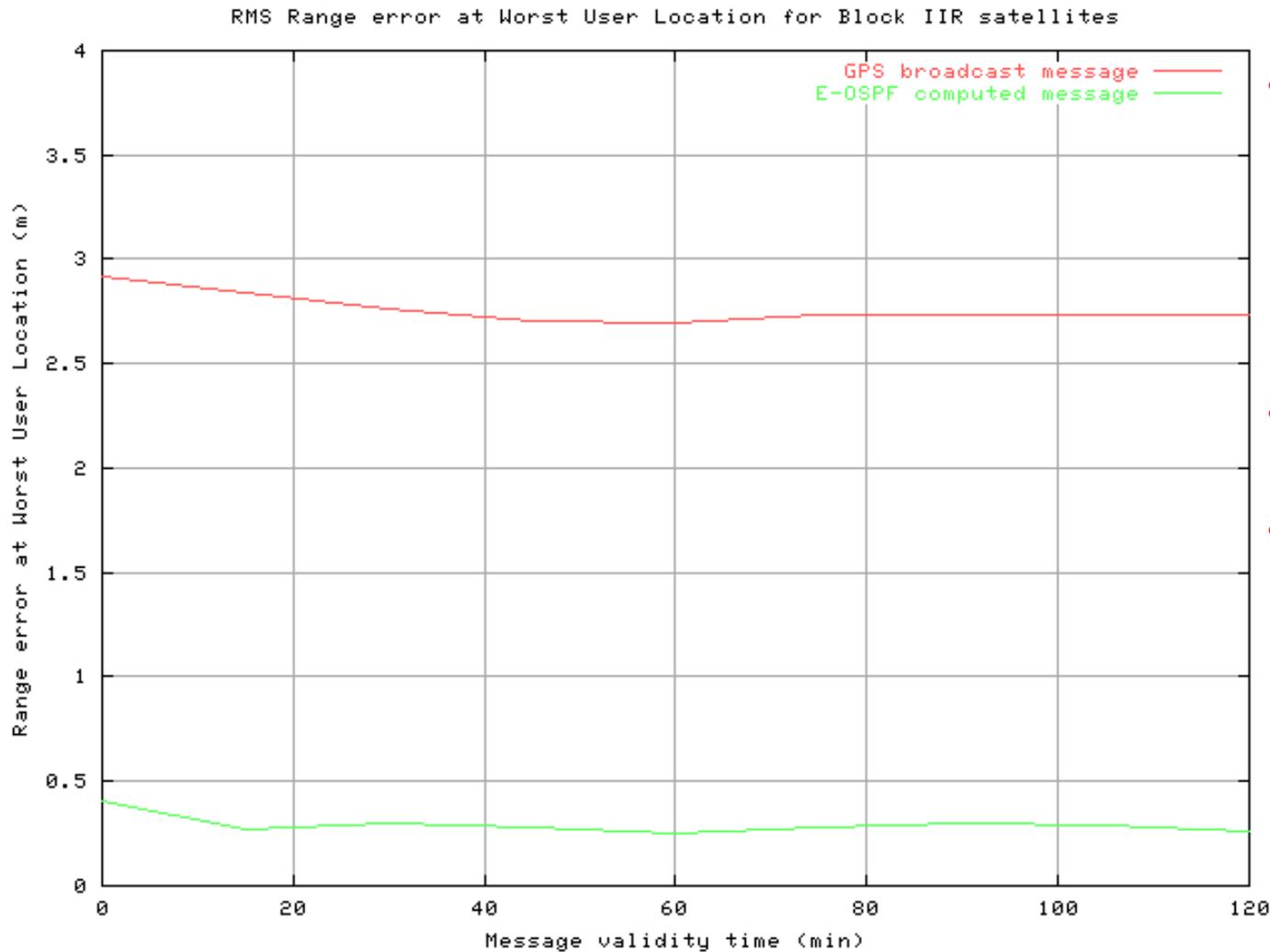
# Areas of Experimentation



# ODTS & SISA Performance Targets

	GMS REQUIREMENTS	E-OSPF Experimentation Target	Test Constraints
Predicted Clocks	GMSREQ-6483 65 cm	1.5 – 2ns (6 h prediction time, 67% percentile)	GPS Block IIR clocks
Predicted Orbits	Ranging Accuracy (67% percentile)	20 cm (6 h prediction time, 67% percentile)	
Restituted Clocks	GMSREQ-10746 0,3 ns (67% percentile)	Target: 0,3ns (67% percentile) not yet met [ $\sim 0.5$ ns]	GPS Block IIR clocks
Restituted Orbits	GMSREQ-10746 10 cm (67% percentile)	Target: 5cm (67% percentile) not yet met [10cm]	
SISA	GMSREQ-10765 85 cm	Target to be defined through experimentation	6 months a-priori ODTS statistics required

# RMS range error at WUL for Block IIR satellites



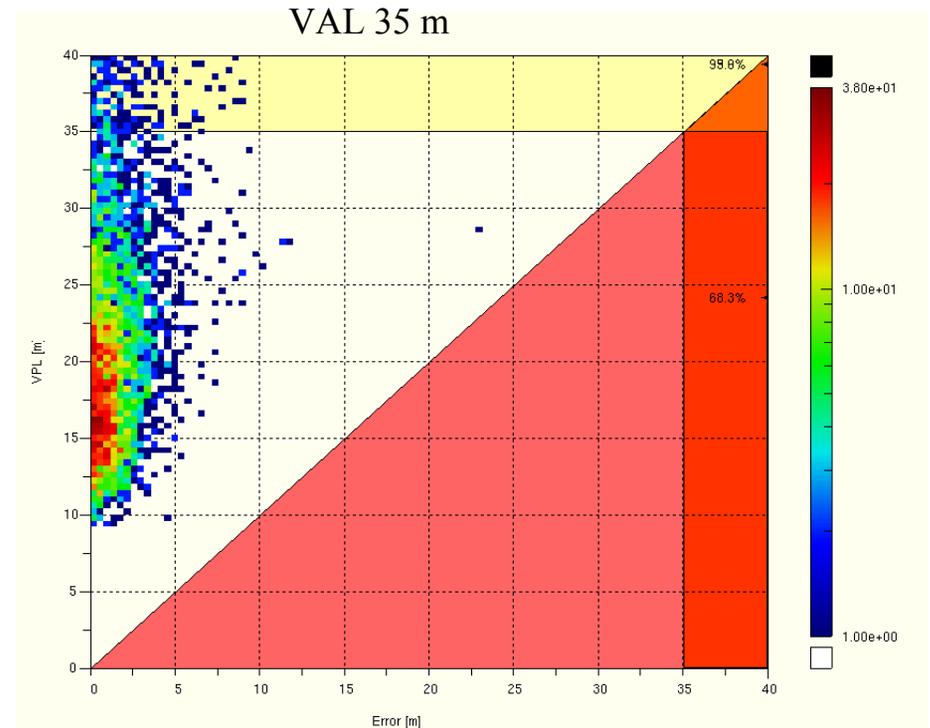
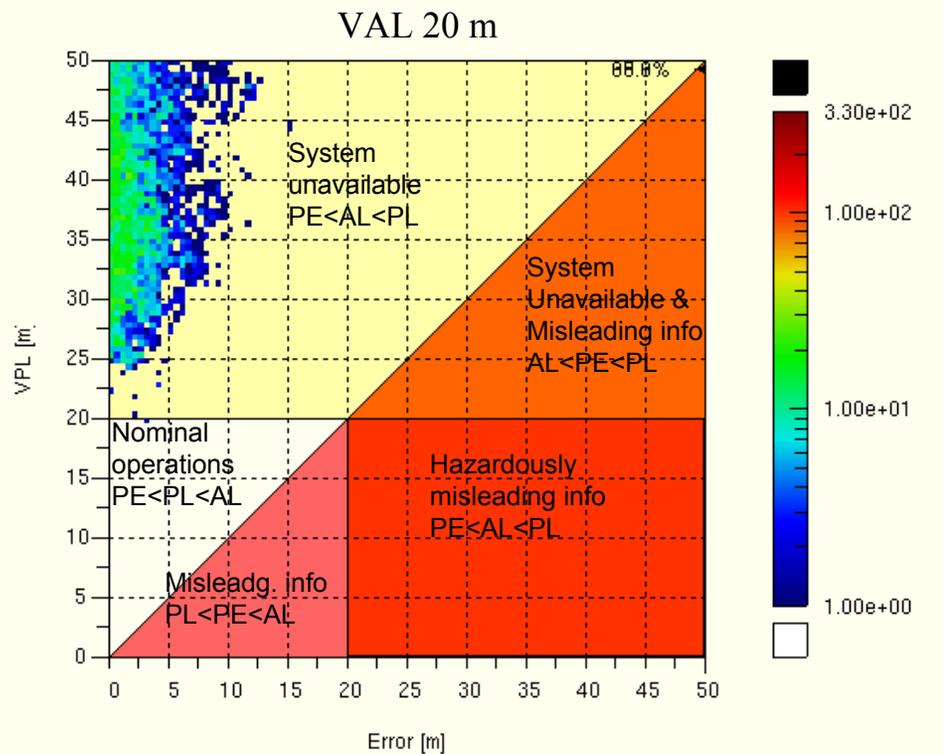
- Comparison of the Broadcasted GPS navigation msg with the E-OSPF generated one
- Validity Time (2 hrs)
- Galileo Reqt: 65 cm

# Integrity Performance Targets

	GMS REQUIREMENTS	E-IPF Performance Target at ERR	Test constrains
Broadcast SISMA	<p>GMSREQ-10638</p> <p>Nominal Broadcast SISMA lower than 70 cm.</p> <p>Assuming</p> <ul style="list-style-type: none"> <li>• Synchro. Noise: 0.7 nsec (rms)</li> <li>• Preprocessing range noise: 0.15 m (rms)</li> </ul>	<ul style="list-style-type: none"> <li>• Synchronisation noise Target: 2 nsec not yet met [~ 2.8 ns]</li> <li>• Pre-processing Range noise Target: 1 m currently met [0.7 m]</li> </ul>	<p>SISMA value characterised as a function of synchronisation and ranging noise (DoC unchanged)</p>

- GMSREQ SISMA value not yet consolidated
- Synchronisation Error is at the moment the major issue to be addressed in SISMA performance

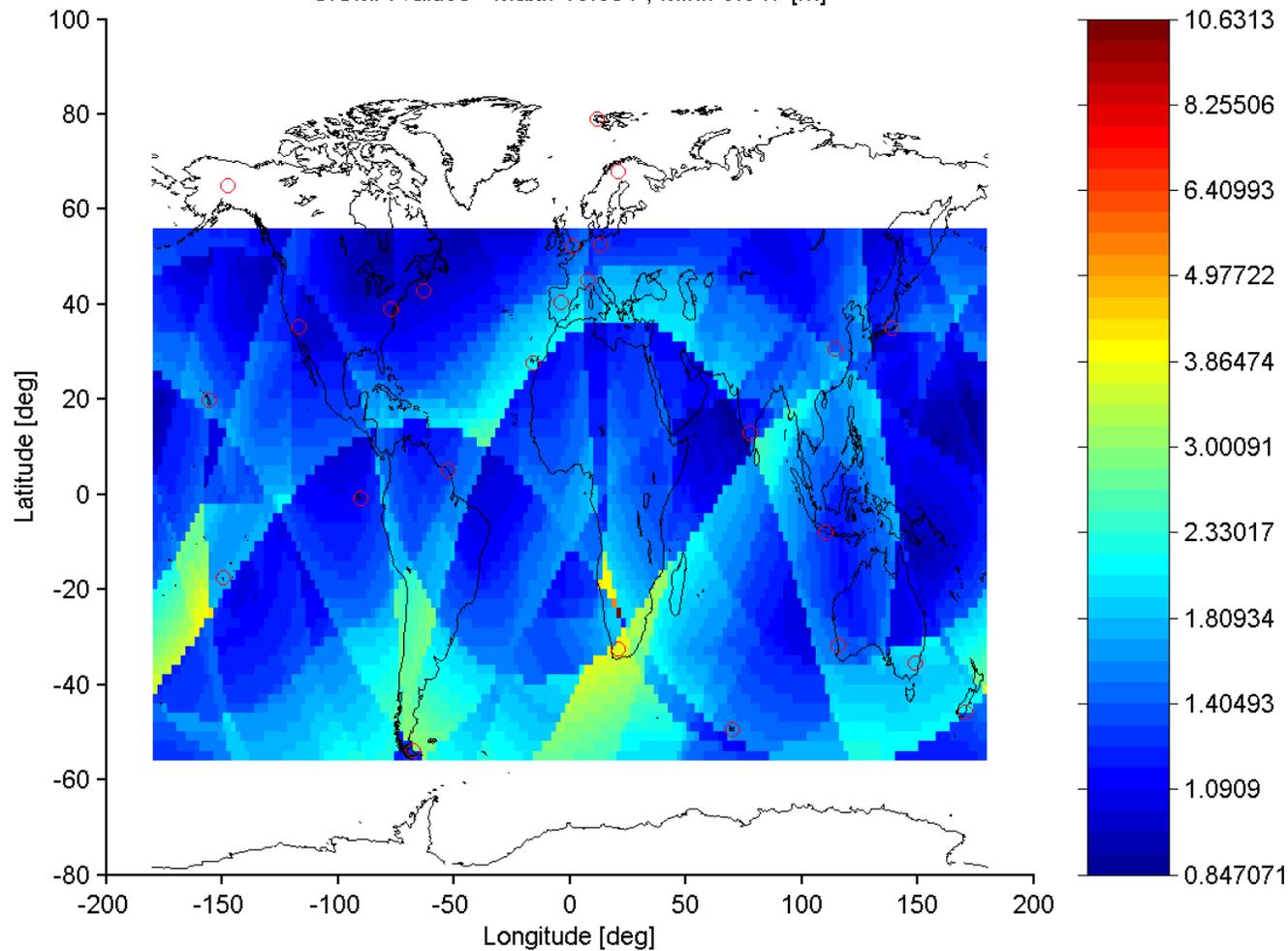
# GPS Integrity Availability



- GPS Integrity using Broadcast Navigation Message is NOT available
- Higher availability of GPS integrity using GSTB-V1 generated Navigation Message
- 1 day observations from 30 Stations
- Estimation of the position error based on 360 sec samples

# GPS\* SISMA map

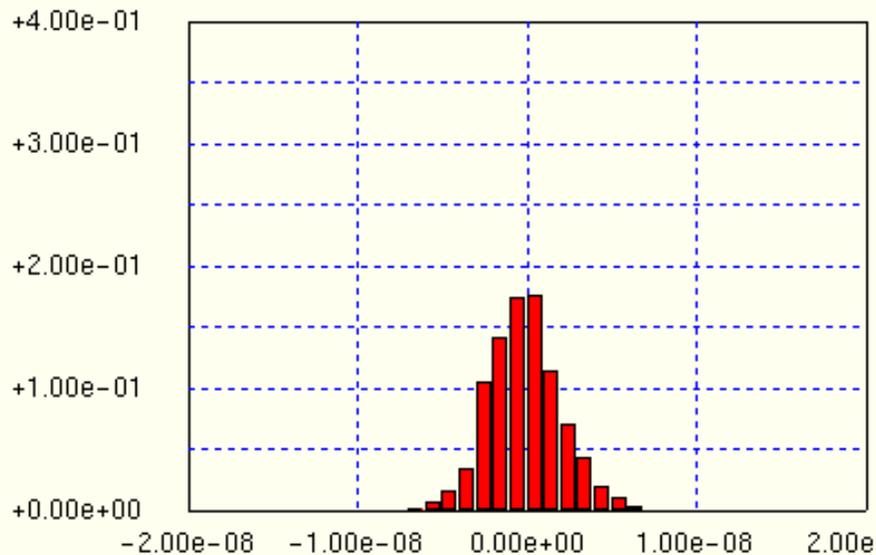
SISMA values - Max.: 10.631 ; Min.: 0.847 [m]



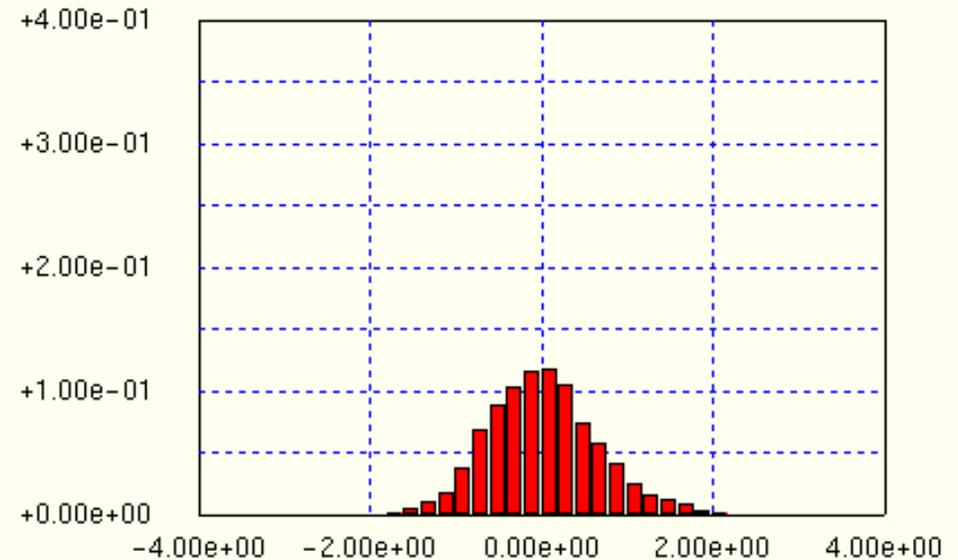
- Logarithmic scale Number stations: 26
- The SISMA is always above 84cm

# GPS\* Synchronization and Preprocessing Range Errors

## Synchronization Error



## Range Error



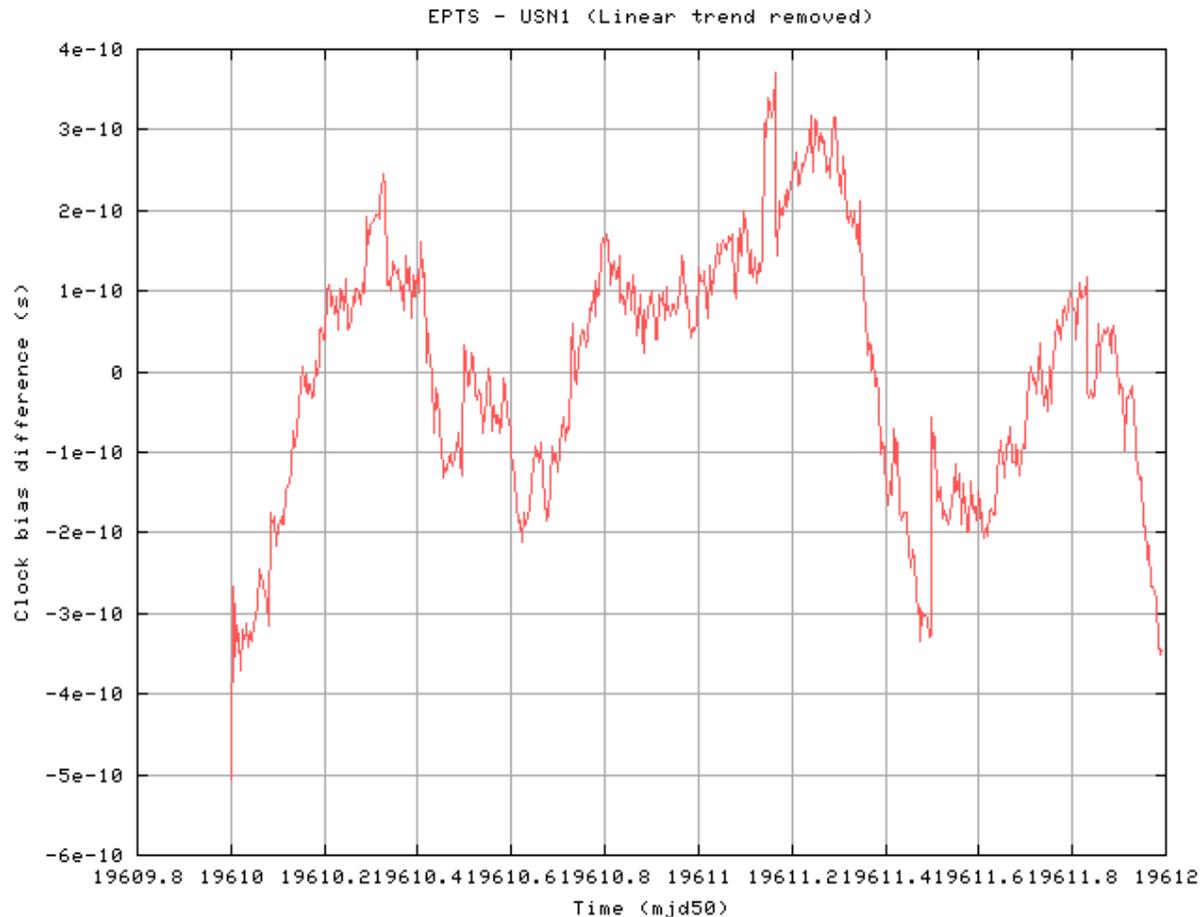
- The Synchronization Error (bounding standard deviation) is 2.8 nsec. [Exp. Target = 2nsec not yet met]
- The Range Error is 0.7 m. [Exp Target = 1m]

# Timing Performance Targets

	GMS REQUIREMENTS	E-PTS Performance Target at ERR	Test duration constrains
Prediction of the E-GST vs TAI/UTC offset	GMSREQ-6340 $ E-GST - UTC  < 50$ ns with an uncertainty of 28 ns (95%)	$ E-GST - UTC  < 1$ $\mu$ s with an uncertainty of 100 ns (95%)	2 months (due to BIPM data availability)
Stability of E-GST vs TAI/UTC	GMSREQ-6342 $5.5 * 10^{-14}$ over 1 day	$< 5 * 10^{-14}$ over 1 day	2 months (stability value to be provided accordingly)
Clock Stability Measurements	GMSREQ-1377 GMSREQ-6407 AHM and Cs Clocks specification	Adev @1s, up to 1 day AHM and Cs Clocks specification verification	10 days of data acquisition

- GSTB-V1 E-PTS E-GST vs TAI/UTC Requirements less stringent due to reuse of infrastructure and no TSP [  $1\mu$ s offset and 33 ns uncertainty] (extrapolation to 50 ns offset and 28 ns uncertainty by analysis)

# Comparison of E-PTS clock with USN1



- The constant offset and drift have been removed
- The spike is due to rejected carrier phase measurements in pre-processing. The measurement include the error in the snapshot estimation of the ODTS process (around 0.2 nsec), i.e. the EPTS clock is almost the same as USN1.

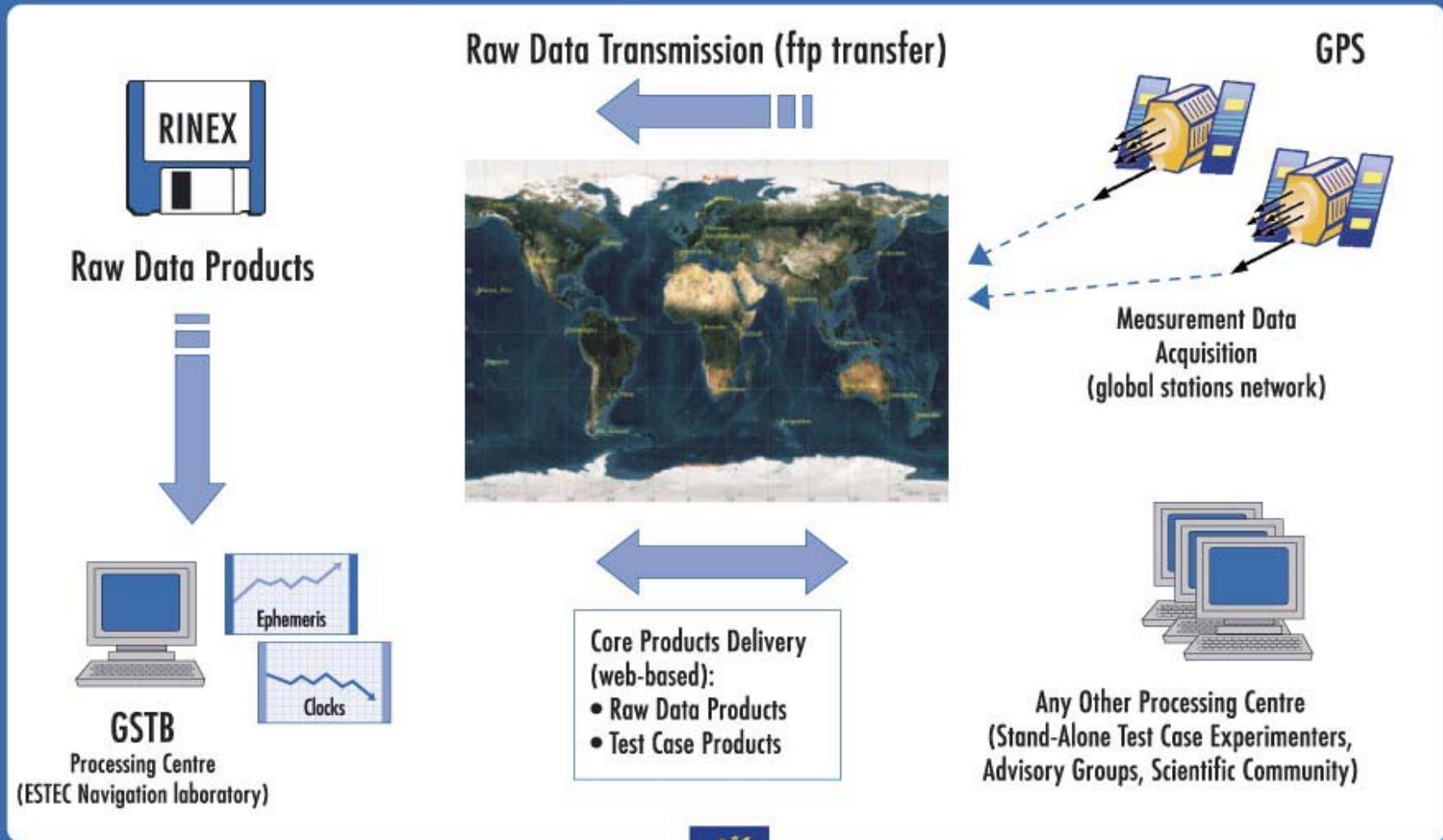
# **GSTB-V1 Core Products Access**



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# GSTB-V1 Open System



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# Availability of Data

- FTP/Web-based access:  
<http://www.gstb-v1.esa.int/>
- Physical Media DLT/DVD/DDS
- Core Products Format:
  - Standard Format (RINEX, SP3, etc) and
  - XML (XSLT and XSD on the web)
- Access to Core Products will be granted as soon as validation is completed (target: 16 March 2004)

# **GSTB-V2**



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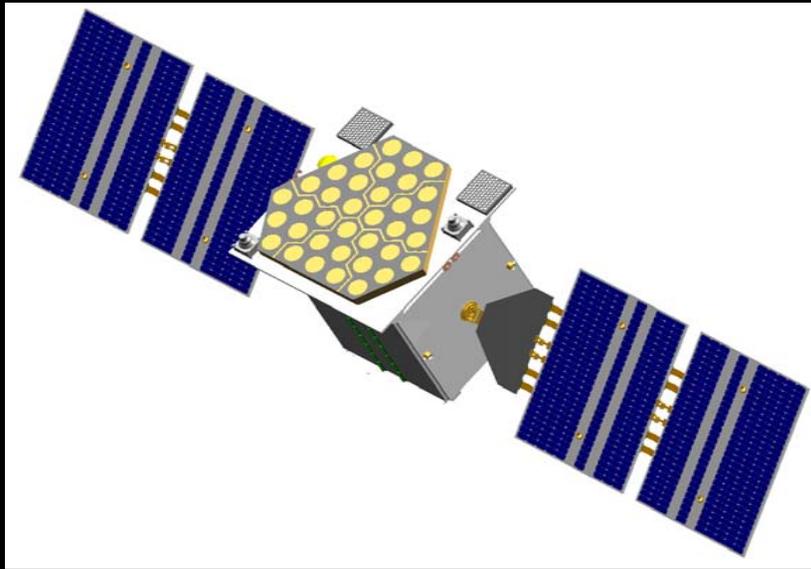


# Galileo System Test Bed V2 Objectives

- Secure Galileo Frequencies
- Test Payload technology in-orbit
- Provide experimental Signal-in-Space
- Characterize MEO radiation environment
- Schedule highly critical (launch date 17 October 2005)
- Risk Mitigation approach
  - GSTB-V2/A Surrey Satellite Technology Ltd
  - GSTB-V2/B Galileo Industries SA



**GSTB-V2 / A**



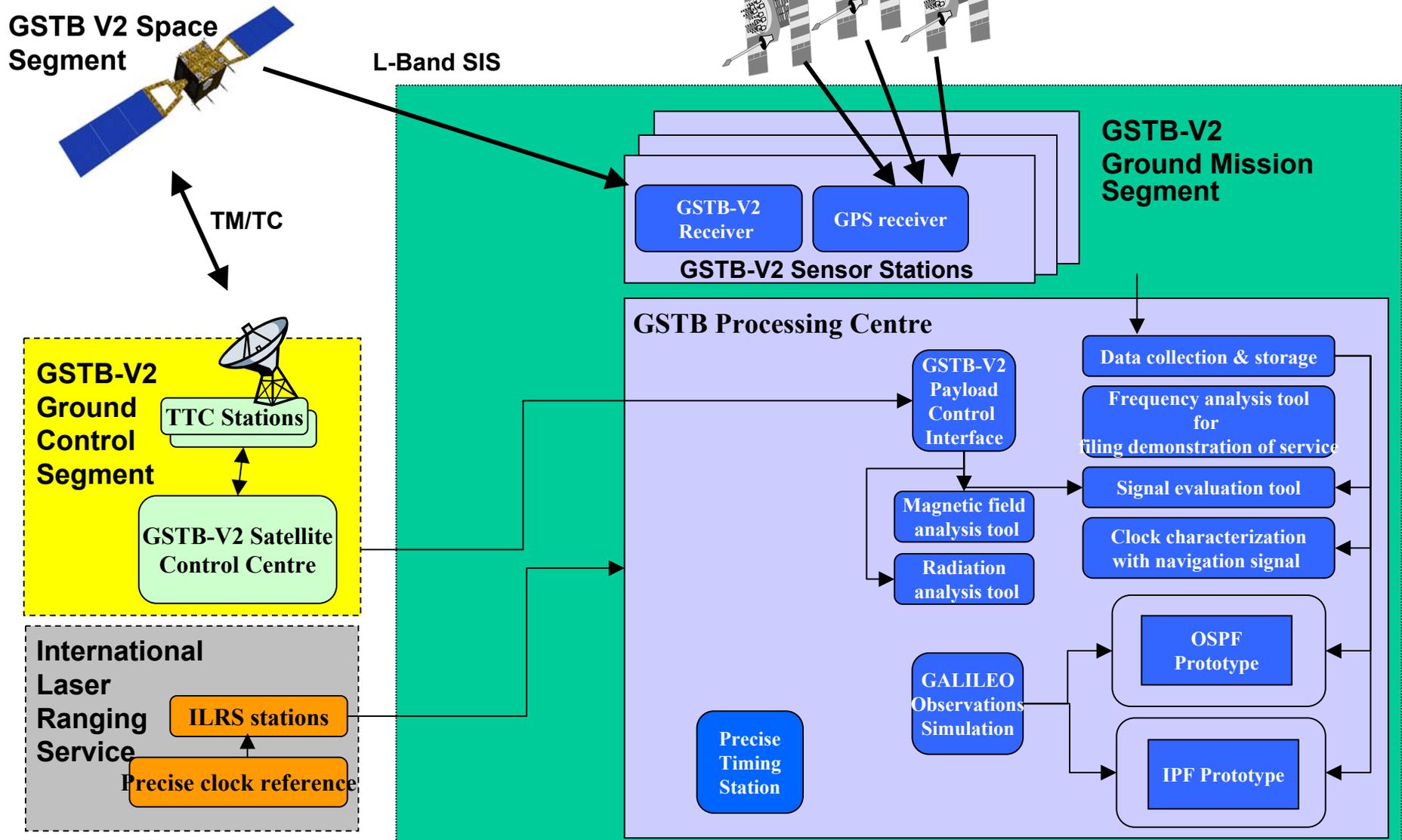
**GSTB-V2 / B**



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# GSTB-V2 Architecture



# Collaboration with IGS



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# Collaboration with IGS

- **GSTB-V1 would not exist without IGS:**
  - IGS Stations usage
  - Reference Truth for Experimentation
- **Collaboration with IGS needs to be continued:**
  - **GSTB-V1 Experimentation Results need to be shared with the scientific community (“friendly competition”)**
  - **independent assessment of critical design parameters such as CoP, CoM, BDGD, etc**
  - **Establishment of RINEX format for Galileo is a priority**
  - **Support in the consolidation of Galileo Navigation Message Content**
  - **Integration of Galileo into IGS processing, starting with GSTB V2**