Precise Time Facility (PTF) for Galileo IOV

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PTF = Galileo‘s Time Reference on Ground

- Core task of PTF: navigation timekeeping
  - critical function for fulfilling the navigation mission
  - needed for accurate satellite orbit determination / satellite clock synchronisation

⇒ realized by Master Clock (= Active H-Maser, AHM), steered to local Caesium clock ensemble; output is Galileo System Time (GST)

⇒ GST is steered to TAI (UTC) by applying frequency corrections (~1/day) determined by external Galileo Time Service Provider (GTSP)

- Galileo System Time (GST) specification:
  - Precision of GST - UTC Offset ("GST uncertainty"): < 28 ns, 2σ (95% confidence level)
  - Accuracy of GST - UTC Offset ("GST limits"): < 50 ns, 2σ (95% of any yearly interval)
  - GST Frequency Offset (normalized to UTC): < 5.5 E-14 (over 1 day)
  - GST Autonomy: accumulation of less than 28 ns (2σ) uncertainty over 10 days (95% confidence level)
GST Stability Specification

![Graph showing GST stability over time with different markers for 1 hour, 1 day, and 1 month.](image)

- **CS**
- **S-PHM**
- **S-RAFS**
- **G-H-MASER**

Markers indicate:
- 1.5 E-13
- 2.0 E-14
- 5.0 E-15
- 2.0 E-15 Steered H-maser
PTF Core Function: GST Generation

[Diagram showing the components and connections of the Precise Time Facility (PTF) for Galileo IOV, including

- Clocks subsystem
- Local measurement subsystem
- GST realization subsystem
- GST processing subsystem

Key components:
- Multiplexer
- Time interval counter
- Phase micro stepper
- Pulse distribution amplifier
- RF distribution amplifier
- 1pps
- Cs
- AHM
- 10MHz
- GST 1pps
- GST 10 MHz

Connections:
- Galileo (GSS) Receiver
- TWSTFT Modem
- Ensemble time algorithm
- GST steering algorithm
- GST to UTC correction
- Clock, Ensemble
- Steering correction

Business Unit: Space Technology]
PTF Second Function: GST/GPS Time Offset (GGTO) Determination

- GPS time receiver at PTF
  - Raw GST - GPST data
  - GPS data processing function
  - Pre-processed GST-GPST

- TWSTFT modem at PTF
  - Results of TWSTFT between PTF and USNO
  - TWSTFT data processing function
  - Raw GST-GPST data (link with USNO)

- GGTO prediction function
  - Computed GGTO parameter and quality characteristics

- GGTO verification function
  - Verified GGTO parameter
  - GGTO quality flag

- Galileo Control Center
  - UTC(USNO) - GPS Time (data from USNO)
  - Computed GGTO parameter and quality characteristics from USNO/GPS side
PTF Block Diagram

- **PTF Block Diagram**
  - **Clock Room**
    - 4 x Cs UPS
    - 2 x Active H-Maser clock (ON EFOS-C)
    - 2 x AHM UPS
- **Clock Measurement Subsystem**
  - Multi-Channel Phase Comparator
  - 2 x Active H-Maser clock
- **Monitoring & Control Subsystem**
  - Time Interval Counter (SR620)
- **Time Signal Multiplexer**
  - 4 x 10 MHz Buffer
- **Switch Matrix**
  - 2 x 10 MHz Buffer (1..2)
- **GPS Time Receiver**
- **TwSTFT Equipment**
- **Equipment Room**
- **Operations Room**

**System Synchronization**
- 4 x 10 MHz (1..4)
- 2 x 1-pps (1..4)
- 2 x 10 MHz (5..6)
- 2 x 1-pps (5..6)
- 2 x 1-pps (9..10)
- 10 MHz (7)
- 10 MHz (8)
- 10 MHz (11..12)
- 1-pps 10 MHz
- 1-pps Ontime
- 10 MHz

**Equipment**
- **Galileo Sensor Station (GSS)**
- **Operations Room**
- **Site LAN**
- **LAN**
- **10 MHz**
- **1-pps**

**Data Archiving**
- **2 x RS232/LAN (1..2)**
- **2 x GPIB/LAN (1..2)**
- **OSPF**
- **SPF**
- **GACF**
- **GCF**
- **MSF**
- **PTF(2)**

**TCO**
- **Galileo System Clocks Data**
- **USNO's GPS/GST Time Offset**
- **GPS Time Receiver**
- **TwSTFT Equipment**

**Reliability**
- **4 x Cs UPS**
- **2 x AHM UPS**

**Environmental Monitoring**
- **Temp., Hum., H-Field**

**Network**
- **Site LAN**
- **GACF Site LAN**
- **Site LAN**

**Time Reference**
- **GPS Time Receiver**
- **TwSTFT Equipment**

**Clock Synchronization**
- **2 x 1-pps (1..2)**
- **2 x 10 MHz (11..12)**
- **10 MHz (8)**

**Data Transmission**
- **2 x RS232/LAN (1..2)**
- **2 x GPIB/LAN (1..2)**
- **OSPF**
- **SPF**
- **GACF**

**Processing**
- **GST/GGTO Processing Subsystem**
- **Galileo Realisation Subsystem**
- **Redundancy Equipm. (Hot Spares)**
- **T&F Data Transfer Subsystem**

**Operations**
- **Galileo Sensor Station (GSS)**
- **Operations Room**
- **Site LAN**
- **LAN**
- **10 MHz**
- **1-pps**

**Networks**
- **Site LAN**
- **GACF Site LAN**
- **Site LAN**
- **OSPF**
- **SPF**
- **GACF**

**Stabilization**
- **1-pps 10 MHz**

**Monitoring**
- **Monitoring & Control Subsystem**
- **Equipment Room**
- **Operations Room**
- **Site LAN**
- **LAN**
- **10 MHz**
- **1-pps**
PTF Physical Implementation Steps

**In-Orbit Verification (IOV) after 2007 (~ 4 S/C in orbit, ~ 15 worldwide signal observation sites):**
- one core PTF shall be operational („Master PTF“)
- planned to be located at Galileo Ground Control Centre (GCC)
- hot redundant backup PTF („Slave PTF“) planned to be located in European UTC(k) laboratory

⇒ same autonomy and performance specification as in final configuration (FOC, see below)
⇒ relaxed requirements w.r.t. redundancy and UTC steering (GTSP prototype in place)
⇒ architecture shall allow immediate extension to FOC configuration

**Final Operational Capability (FOC) after 2010 (full constellation and ground segment deployed):**
- two GCC will be available, two fully redundant, identical (w.r.t. performance) and synchronized PTF's shall be operated (master/slave concept)
⇒ GTSP fully in place and performing to specification
PTF Operations at IOV

- GST short/mid-term performance in IOV will be comparable to FOC
- but weaker redundancy concept within each PTF (1 AHM master clock, 3 Caesium clocks, 1 Phase Stepper, each with one hot back-up)
- test procedures for steering of the Slave to the Master PTF and switching from the Master to the Slave PTF have still to be defined (will have major effect on S/C orbit determination process, i.e. OSPF activity)
New Concept of Scalable PTF

- Parallel independent H/W chains for each available master clock

- Decision on actual master clock taken on higher level (i.e. by OSPF process)
Summary and Conclusions

- PTF for Galileo IOV will be realized by competent European expert team
- Clear concept for GST to perform according to specification during IOV
- Clear concept to determine and predict GGTO
- Flexible architecture which allows immediate upgrade to FOC configuration

- Identified risk areas: redundancy; switching
- Solution: new concept of independent H/W chains for each master clock
  - less tense synchronization in H/W (only some tens of ns) required,
  - determination of all clock offsets in S/W possible,
  - additional performance check and master authority at OSPF (~ 1 ns level)