





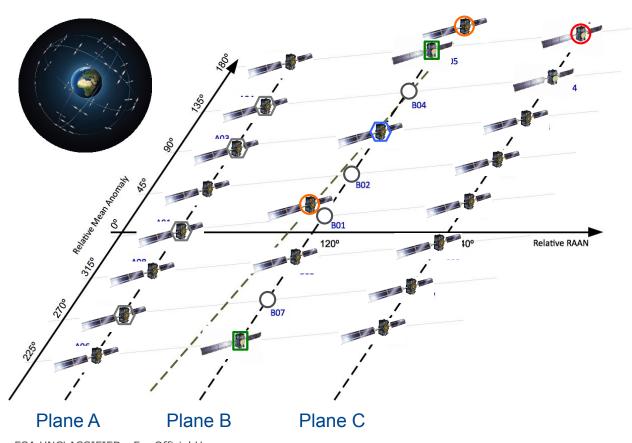
Technical Developments of the Galileo Architecture in a competitive GNSS world

Edrich Yau – European Space Agency Hd Galileo System Engineering Unit F.Gonzalez, J.Hahn

EUREF Amsterdam 2018

Galileo constellation Status





Navigation Payload (14 Operational)

22 satellites in orbit

4 under commissioning





1 spare



1 unavailable

Search and Rescue Payload (15 Operational)



2 out of 22 satellites with no SAR Transponder (by design)



4 under commissioning

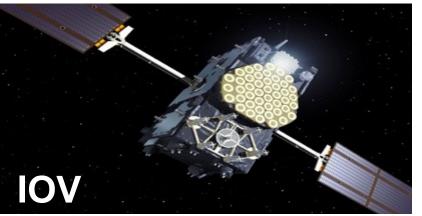


1 spare



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Constellation Satellites

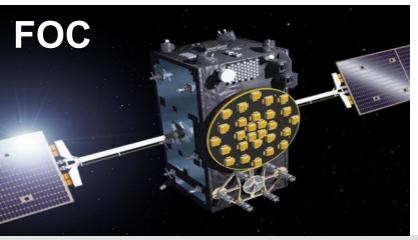


S/C Prime Contractor Astrium GmbH (now Airbus Defence & Space)

4 satellites - 4 In-Orbit

Mass at Launch
Power Consumption
Dimensions
Orbit Injection
Attitude Profile

700kg 1420W 2.7 x 1.6 x 14.5 m Direct into MEO orbit Yaw Steered



S/C Prime Contractor OHB Systems GmbH P/L Prime Contractor SSTL Ltd WO1/2: 22 satellites – 18 In-Orbit

Mass at Launch
Power Consumption
Dimensions
Orbit Injection
Attitude Profile

733kg 1900 W 2.5 x 1.1 x 14.7 m Direct into MEO orbit Yaw Steered







Ground Segment Status



Current GCS Operations

- ★ GCSv2.1.2 deployed at GCC-D and -I
- Spacecraft control automation
- ★ 26 satellite capability
- ★ TTCF-6 (Papeete) operational
- ★ Inter-GCC synchronisation

★ Current GMS Operations

- ★ GMSv2.1.1 deployed at GCC-D and -I
- ★ Dual GSS Chains deployed on all sites
- PTF upgrade deployed at GCC-D
- ★ 6 additional ULS Chains
- Inter-GCC synchronisation

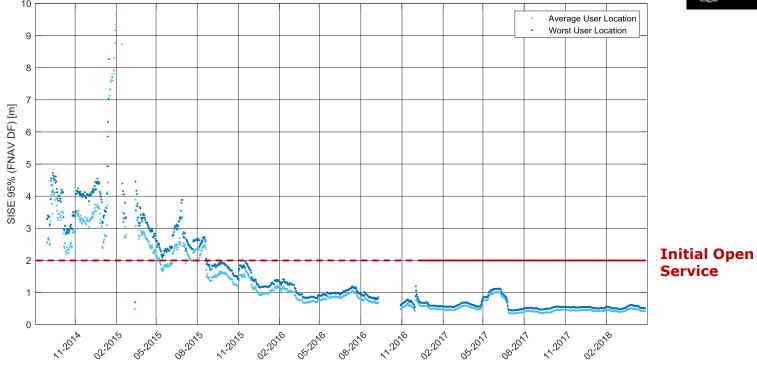




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As-observed Ranging Performance





- Decreasing Ranging Error trend due to increasing number of Satellites and G/S improvements
- Ranging accuracy (95%) 0.41m all satellites, 0.50m worst satellite in April 2018

























Galileo and GPS Scoreboards







Source: GPS Programme Update, UN ICG-12, December 2017

Source: ESA, TGVF

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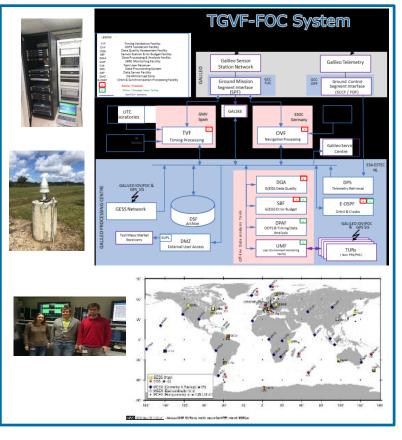








Galileo Time and Geodetic Validation Facility @ES



<u>Near real-time</u> Performance Monitoring/Service Notification plus KPI computation at ESA level for Galileo Initial Services

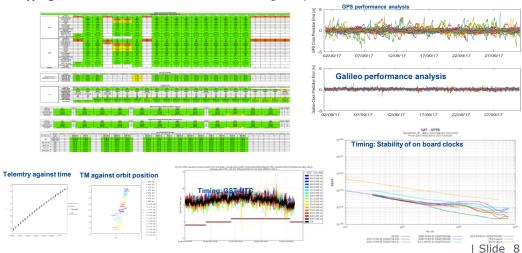
Support to <u>System Performance/Satellite Troubleshooting and investigation in general</u>

TM Monitoring at ESA level for Space Seg. trend analysis and Radiation Monitoring

Other activities such as **In Orbit Test support (orbit/clock characterisation)**

Independent System performance verification and validation

Prototyping such as OD&TS for Launch3 satellites and single frequency for GSAT0104







































Residual Statistics (satellite)





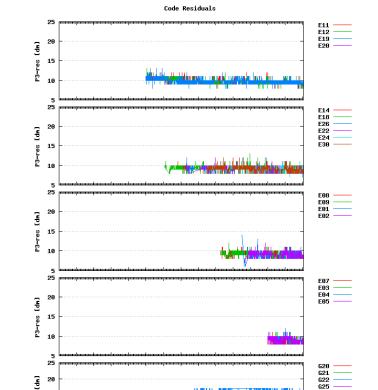












• GAL P3-RMS: ~9-12 dm

GPS P3-RMS: ~12-16 dm

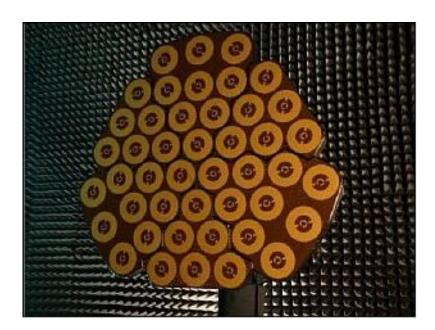
OVF measurements show that Code Residuals of Galileo are less

Satellite Metadata



Two antenna types

GSAT01xx - EADS CASA



GSAT02xx - Thales Alenia





























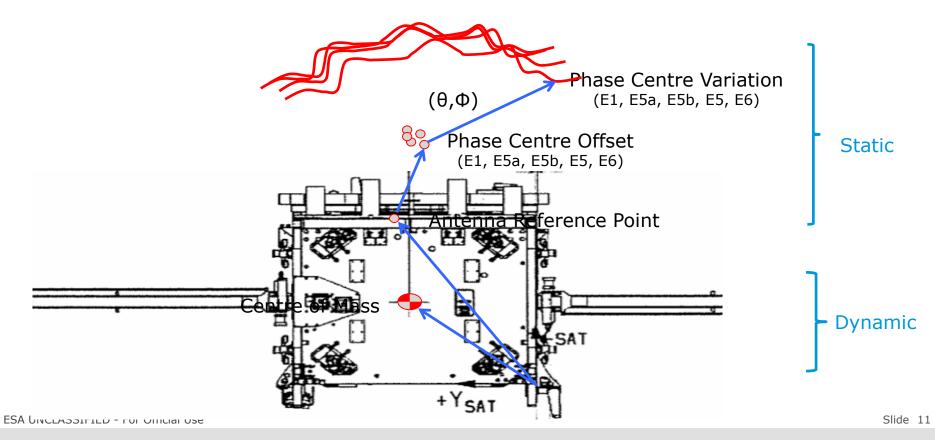






Galileo Antenna Metadata





Galileo Metadata



Calibrated Metadata for Galileo antenna phase center corrections

- Antenna Phase Centre Offset (PCO), Variation (PCV) and Reference Point (ARP)
- Satellite Centre of Mass (CoM) and Attitude (user direction)

Benefit

- Tie GNSS phase measurements consistently to the spacecraft CoM
- Especially relevant for GNSS-based realization of terrestrial scale, independent of SLR/VLBI
- Galileo is the first GNSS disclosing the full range of metadata for each antenna and carrier frequency
- Radial antenna offsets for other GNSS become accessible without the need to adopt any external scale

Status

- Galileo GSAT101-104 (IOV) released on Dec-2016
- Galileo GSAT201-214 (FOC) released on Oct-2017
- Galileo GSAT215-222 (FOC) planned for 2018

Location

• https://www.gsc-europa.eu/support-to-developers/galileo-satellitemetadatahttps://ilrs.cddis.eosdis.nasa.gov/missions/satellite_missions/current_missions/ga01_com.html

























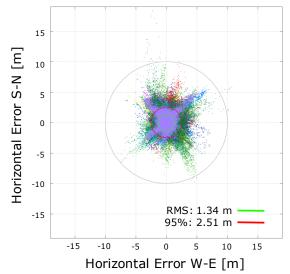




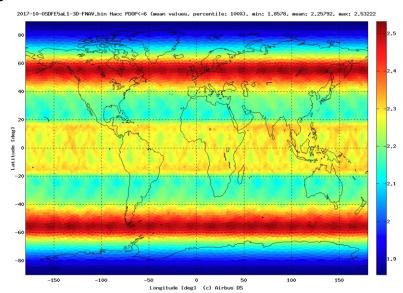
Positioning Performance & Availability



- 14 satellites usable
- 86% Availability of H Accuracy <10 m
- 72% Availability of Global PDOP <=6



Dual Frequency Horizontal Accuracy measured by global Receiver Network (10 – 13 Dec. 2017)



Global Dual Frequency Horizontal Accuracy (when PDOP <= 6)

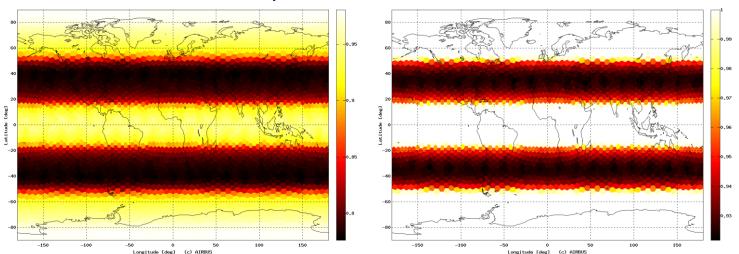
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Positioning Performance & Availability



- ★ 4 more satellites operational in Q3 2018
- \star Satellites in operational constellation: 14 \rightarrow 18
- \star Availability of H Accuracy < 10 m 86% \rightarrow 96% (Average User Location)
- ★ Global PDOP <=6 availability 73% → 95% (Average User Location)
 </p>



Availability of Horizontal Position Accuracy < 10 m for 14 satellites (left) and 18 satellites (right)

























Additional Satellites (16 SVs)

- FOC-M8 (**L10 Ariane-5 25/07/18**)
 - ★ **FM19** in OHB Bremen
 - ★ **FM20** in OHB Bremen
 - ★ **FM21** in OHB Bremen
 - ★ **FM22** in OHB Bremen
- Batch-3 Satellites (12 SVs)
 - ★ Signature and kick off of Batch-3 baseline contract with OHB (8 satellites)
 - ★ Procurement of 4 additional Batch-3 satellites (options) initiated
 - ★ Launch end 2020 onwards

































First mass-market dual frequency GNSS receiver







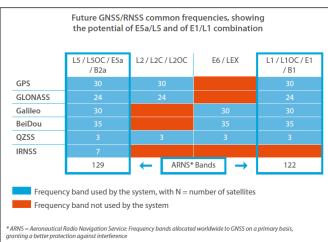
- World's first mass-market, dual frequency GNSS receiver device for smartphones
- Usage of E1/L1 and E5/L5 frequencies benefit from better accuracy, ionosphere error cancellation, improved code tracking pseudorange estimates and faster transition from code tracking to phase tracking
 - Provides lane-level accuracy with minimal power consumption and footprint enabling high-precision LBS applications, including lane-level vehicle navigation and mobile augmented reality (AR)

14 operational Galileo satellites (E1/E5)



+ 12 operational GPS Block IIF satellites (L1/L5)





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System Build 1.5.1 (2018)



SB1.5.1 will bring major benefits to Service provision:

- Improvement of business continuity
- > 2 fully redundant systems at control center level
- ➤ Introduction of GSC & real time dissemination support for High Accuracy
- > SAR RLM capability
- Operability improvements and robustness (Redundancy, TTCF6, ULSs, GSSs, combined PTF Rx)
- ➤ SB1.5.1 is the core infrastructure to support **Enhanced Services**

High Accuracy Service



- System and concept is under elaboration
- Commission Implementing Decision (EU) 2018/321 of 2 mar 2018
 - Better than two decimetre level of performance
 - Free of charge
 - Complementary to fee paying systems which provide better than decimetre level performance
 - Initial signals supply phase between 2018 and 2020' and '— Full service supply phase from 2020'
- Will be provided on E6 b/c
- Has a capacity of 448b/s per satellite
- Allows for global distribution from connected Galileo Satellites

System Build 2.0 / 2.1 (2020 onwards)



- Open Service Full Operational Capability (mass market)
- OS Navigation Message Authentication
- SAR Full Operational Capability
- Commercial Service (High Accuracy)
- PRS Signal- in- Space Evolution
- PRS Point of Contact Platform to interface Member States
- Cyber Security Monitoring

= "

Conclusions

esa

- **→ 22 satellites in orbit**
 - Proven Accuracy of Positioning and Timing
 - Galileo has entered the Single Frequency mass-market
 - Galileo is the de facto standard for Dual Frequency applications
- → **Ground Segment deployment continues in 2018** to support stable and continuous availability of Galileo SIS to users
- → Launch 10 in 25/07/2018
- → Procurement of additional 3rd Batch of 8+4 satellites initiated (38 satellites in total)
- → Galileo is available and contributes! Lets use it!

























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