Galileo
IOV Results
1. Galileo IOV System Configuration and IOV Test Campaign Objectives - E. Breeuwer (ESA)

2. Quality of the broadcast Galileo navigation message
   a) Orbit and clock prediction, ionospheric and group delay parameters - A. Ballereau (ESA)
   b) UTC-Galileo System Time offset and GPS-Galileo Time Offset - F. Gonzalez (ESA)

3. Galileo UERE and Position accuracy results - G. Lopez-Risueno (ESA)

4. Performance extrapolation to FOC & Outlook towards Galileo Early Services - D. Blonski (ESA)
Galileo
IOV System
Configuration
And Test Campaign

Edward Breeuwer
ESA – Galileo Project
Deployment / Exploitation Plan

Development System Testbed
GIOVE A/B

In-Orbit Validation
4 satellites
initial ground infrastructure

Early Galileo Services
OS, SAR, PRS
and CS demonstrator

Hand-over
Exploitation Phase
FOC1 System

Full Operational Capability
30 operational satellites
and complete ground infrastructure

2005

… 2013

2014/15

End 2016

2020
Galileo IOV Configuration

4 Galileo IOV Satellites

L-band

S-band

C-band

GSS

GPS COTS Rx

Galileo Rx

GCC-I (GMS)

GSS PTF

11 Monitoring Stations +

GSS PTF

External Entities

(TVF, OVF, RLSP, GALSEE)

Test User

Receivers

L-band

S-band

C-band

GCC-D (GCS)

3 ULS

2 (+1) TTC

Galileo Rx

Galileo Rx

GPS COTS Rx

GPS COTS Rx

Galileo Rx

Galileo Rx

GPS COTS Rx

GPS COTS Rx
**IOV FM3/FM4 Satellites**

**SPACECRAFT Properties**

- **Mass at Launch (incl. Propellant):** ~700 kg
- **Power Consumption:** 1420 W
- **Dimensions:** 2.74 x 14.5 x 1.59 m
- **Lifetime:** 12 years
- **Orbit Injection:** Direct into MEO orbit
- **Attitude Profile:** Yaw Steered

**FM1/2 + FM3/4 differences**

- **SAR Transponder (not on FM 1/2)**
- **NSGU**

**EADS Astrium GmbH**
EADS Astrium Ltd
Thales Alenia Space – Italy

**Antennas**
- Uplink antenna (C band)
- Navigation antenna (L band, array)
- SAR Tx antenna (L band)
- SAR Rx antenna (406 MHz, array)
First two IOV Satellites (PFM/FM2) launched from Guiana Space Center on 21 October 2011
IOV-2 Launch 12th of October 2012
Galileo Control Centre (D)
IOV Main Objectives

1. Validation in fight of all space, ground and user components, including their interfaces, prior to full system deployment
2. Analysis of system performance with the view to refine the FOC system prior to full system deployment
3. Verification of the adequacy of the site requirements
4. Verification of Navigation Processing
5. User Equivalent Range Error budget characterization
6. Characterization of feared events
7. Verification of operational procedures
8. Deployment risk reduction
12 March 2013 – Galileo 1st Position Fix

95th Percentile: 5.9 [m]
50th Percentile: 3.1 [m]

12/03/2013 10:00 -11:00 UTC
Positive Feedbacks Around the World

Galileo fixes Europe’s position in history

12 Mar 2013 - Galileo. This first position fix of longitude, latitude and altitude took place at the Navigation Laboratory at ESA’s technical heart ESTEC, ...

NavSAS, Septentrio Report
Galileo IOV Positioning Results, Turin

13 Mar 2013 - Two European organizations announced successful positioning results yesterday (March 12, 2013) using signals from the four Galileo in-orbit ...

PLAN Group Tracks Galileo Satellites for Positioning in Canada

15 Mar 2013 - Within a day of their initial activation over central Europe on March 12, Galileo satellites were visible over North America. The PLAN Group of ...

Four Galileo Birds Sighted over Asia

27 Mar 2013 - Scientists in Hanoi, Vietnam, send word that on March 27 the four Galileo in-orbit validation satellites were visible at the same time in the sky over that Southeast Asian country ….

Real-time PPP with Galileo is now a reality!

25 Mar 2013 – Press Release indicates that the noise level of the position is better with Galileo alone than when GPS and GLONASS satellites are also used. This suggests a strong future for Fugro’s Galileo PPP solution.

GALILEO-only Position Fix from India

9 Sep 2013 - First successful Galileo-only 3-dimensional position solution obtained from Burdwan, India on 03 July, 2013.
IOV test campaign Facts and Figures

★ IOV Test Campaign started on 14th May up to 31st Oct 2013
★ More than 5 months of continuous navigation validation campaign conducted in Rome, Fucino and at ESTEC
★ 2 months of Search and Rescue validation campaign conducted in Toulouse, Maspalomas and ESTEC
★ 2 months of PRS access control campaign in Fucino, Rome and ESTEC
★ Test Activity conducted in Galileo GCCs, ESA, CNES and TASI Laboratories and facilities (both fixed and mobile)
★ Teams of up to 35 people for Industry and 25 for ESA continuously deployed
★ Tens of Terabites of data accumulated and processed during the campaign
★ Mobile Vans
  ★ Open Service 8500Km and 250 hrs
  ★ PRS 2000Km and 100 hrs
IOV Test campaign achievements

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>12 March</td>
<td>First Position Fix</td>
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<tr>
<td>16 April</td>
<td>First GST-UTC offset dissemination</td>
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<tr>
<td>22 April</td>
<td>First GGTO dissemination</td>
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<tr>
<td>27 May</td>
<td>First implementation of GTRF aligned to ITRF2008</td>
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<tr>
<td>25 June</td>
<td>First dissemination of Commercial Service data</td>
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<tr>
<td>9 July</td>
<td>First SAR localisations using Maspalomas MEOLUT</td>
</tr>
<tr>
<td>July</td>
<td>First PRS position fix by Member States (PPTI)</td>
</tr>
<tr>
<td>October</td>
<td>First dissemination of SAR Return Link</td>
</tr>
<tr>
<td>12 November</td>
<td>First aeronautical test (incl. PRS)</td>
</tr>
<tr>
<td>22 November</td>
<td>First Mobile PRS Access Control</td>
</tr>
</tbody>
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Time and Geodetic Validation Facility (TGVF)

- Independent reference for GMS orbit and clocks
- Off-line PVT computation at each GESS location

GPC ESTEC

Network of 16 Galileo Experimental Sensor Stations (GESS)
Generates orbit & clock reference based on IOCE tool processing GSS data
Collects and compares orbit and clock data directly retrieved from GMS through dedicated interface
Test User Receivers

- OS and PRS versions
- Collect data for UERE analysis and run PRS access control tests
- Fixed and Mobile set-ups (ESTEC and TAS-I/Rome).
First Galileo Aeronautical Trials

- 3 flights in November 2013 co-organized by ESA and NLR
- Done in Gilze-Rijen Air Force Base using the NLR Metro-2 aircraft.
Galileo Positioning works well

Dual Frequency Positioning Accuracy (PDOP <=5):

- Horizontal (95%) 8 m in average
- Vertical (95%) 9 m in average

GUSN 23rd August - 3rd September 2013, GDOP<10 [mean GDOP = 4.5]

95th Percentile:7.8[m]
drms: 4[m]
Galileo Timing works well

Timing Accuracy: 10 nsec in avg

- 67% availability with 4 IOV S/C
- 96% availability after 1st FOC launch (6 S/C)
Search And Rescue/Galileo

GALILEO Control Center

Search and Rescue Mission Control Center

GALILEO Up-Link

SAR MEOLUT

Acknowledgment

Alarm

Rescue Coordination Center
Galileo Search and Rescue works well

SAR Beacons
Localisation Accuracy:

- **Within 2 km** 
  (77% localisations)
- **Within 5 km** 
  (95% localisations)

Grey = 3 s/c
Black = 4 s/c
IOV Industry Team

★ WP1 SETA Industrial Team:
  ★ TASI as Prime Contractor
  ★ Astrium-D (now Airbus!) for Signal, Performance and External Interfaces
  ★ TCS for Security

★ WP6 Operations Industrial Team:
  ★ SpaceOpal as Prime Contractor
  ★ DLR Lead for Spacecraft Operations and GCS Ground Operations
  ★ Telespazio Lead for GMS Ground Operations and PLSU M&C
Galileo works very well!!

**Positioning**

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- drms: 4 m

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**Timing**

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**Search And Rescue**

SAR Beacons Localisation Accuracy:
- Within 2 km (77% localisations)
- Within 5 km (95% localisations)
Thank You

http://www.esa.int/Our_Activities/Galileo
http://www.gsc-europa.eu