European GNSS Programmes
Galileo and EGNOS

3rd Meeting of the International Committee on GNSS
Pasadena, California, USA
December 8 -12, 2008

Paul Verhoef
European Commission
Outline

- Galileo and EGNOS Description
- Galileo and EGNOS Services
- Compatibility and Interoperability
Galileo Description
Galileo – An Infrastructure

- 30 satellite Constellation
- 5 TT&C Stations
- 10 mission Uplink stations
- 3 Control Centres

Users & Service Providers

- 30 MEO satellites

30-40 Galileo Sensor Stations

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Galileo – Space Segment

Walker 27/3/1
3 in-orbit spares (1/plane)

Semi major axis 29600 km
Inclination 56 deg
Period: 14 hr 22 min
Ground track repeat about 10 days
Orbit Graveyard at MEO +300km
Galileo: Current Signals

- E5a-Q
- E5b-Q
- L5 Band

- E6a-Q
- BOC(15,10)
- E6b-I
- BPSK(5)
- L2 Band

- E6-
- BOC(10,5)
- 1278.75 MHz
- E6-
- BPSK(5)
- 1207.14 MHz

- L2 Band

- L1 Band
- L1, L1: CBOC(6,1,1/11)
- L1, BOC(15,2.5)
Galileo : System Time and Geodetic Reference Frame Standards

Galileo System Time:
» Steered to TAI (International Atomic Time)
» The difference between GST and TAI and between Universal Time Coordinated (UTC) and TAI broadcasted to the users via the SIS
» GPS-Galileo Time Offset broadcasted

Galileo Terrestrial Reference System (GTRS)
» Realisation (GTRF) within < 3 cm (2 sigma) wrt. ITRF (International Terrestrial Reference Frame)
<table>
<thead>
<tr>
<th>Galileo Service</th>
<th>Horizontal Accuracy (95%) (incl. system margins)</th>
<th>Vertical Acc. (95%) (incl. system margins)</th>
<th>Availability (WUL)</th>
<th>Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Service</td>
<td>4 m</td>
<td>8 m</td>
<td>&gt; 99.5%</td>
<td>NO</td>
</tr>
<tr>
<td>Safety of Life</td>
<td>4 m</td>
<td>8 m</td>
<td>&gt; 99.5%</td>
<td>YES – LPV200</td>
</tr>
<tr>
<td>Commercial Service</td>
<td>Detailed performance requirements under elaboration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public Regulated Service</td>
<td>4 m</td>
<td>8 m</td>
<td>&gt; 99.5%</td>
<td>YES</td>
</tr>
</tbody>
</table>
Galileo Implementation Plan

Full Operational Capability
27 (+3) Galileo Satellites
2013

In-Orbit Validation
4 satellites plus ground segment
2010

Galileo System Testbed v2
Initial Test Satellites
2005

Galileo System Testbed v1
Validate critical algorithms
2003

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GIOVE Mission Architecture
Galileo Test Satellites

- **Giove-A** still operating since Jan. 2006

- **Giove-B** launched on 27 April 2008
  - Works as expected
  - First maser atomic clock ever flown
  - MBOC (CBOC) signal première
Ground Segment Sites (IOV status)

- Cordoba GSS
- Troll GSS
- Alaska GSS
- Hawaii GSS
- Papeete ULS/GSS
- Easter Island GSS
- Washington GSS
- Kourou
- Svalbard ULS/GSS
- Kiruna TTC
- Tju GSS
- Fucino GSS
- Urumchi GSS
- Riyadh GSS
- Reunion ULS/GSS
- South Africa GSS
- Perth GSS
- New Caledonia ULS/GSS

Sensor Stations
- Up-Link stations
- TT&C stations
- Control Centres
# Galileo – IOV vs FOC

<table>
<thead>
<tr>
<th>Component</th>
<th>IOV Phase</th>
<th>FOC Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellites</td>
<td>4</td>
<td>27(+3)</td>
</tr>
<tr>
<td>Control Centres</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mission Uplinks</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>TT&amp;C</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Sensor Stations</td>
<td>20</td>
<td>30-40</td>
</tr>
</tbody>
</table>
GALILEO Re-Structuring in 2007

- PPP: private sector limitations
  - Was not ready to bear market and technical risks at early stage (IOV)
  - No (or expensive) money

- Implementation funding secured: 3.4 billion € (some 4.7 billion $)

- European Commission
  - Fully in charge
  - Owner
Updated Governance

Political oversight

Council and European Parliament

Programme oversight and Programme Management

European GNSS Programme Committee

European Commission

Execution

Independant advisors

European Space Agency

GNSS Supervisory Authority

IOV contracts

FOC contracts

delegation

assistance and delegation

Assistance tasks to EC

Tasks delegated by EC

Market preparation

Research

Accreditation

Others

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GALILEO FOC Procurement

- Contract notice: 1 July 2008
- EC procurement rules (subject to WTO agreements on government procurement)
- Infrastructure in 6 work-packages
- Enter the « Competitive Dialogue » phase
- Full Operational Capability in 2013
FOC Procurement: Selected Candidates

- **1. System Support**
  - ThalesAleniaSpace (IT)
  - Logica (NL)
- **2. Ground Mission System**
  - ThalesAleniaSpace (FR)
  - Logica (UK)
- **3. Ground Control System**
  - Astrium (UK)
  - G-Nav grouping represented by Lockheed Martin IS&S (UK)
- **4. Space segment**
  - Astrium (DE)
  - OHB System DE
- **5. Launch Services**
  - Arianespace (FR)
- **6. Operations**
  - Nav-up grouping represented by Inmarsat (UK)
  - DLR (DE) and Telespazio (IT)
Fucino (Italia) Control Centre

Building A: Administrative Area

Building B: Operational Area

Courtesy ESA
Kiruna Galileo Site Completed (Nov’07)

Svalbard Galileo Site Completed (May’08)

Courtesy ESA
Oberpfaffenhofen (Germany) Control Centre

Courtesy ESA
CSG- Kourou Galileo TTC/ULS/GSS

TTCF Building construction (Jul’08)  Site Technical Building finished (Jul’08)

Courtesy ESA
Troll GSS Site Completed (Apr’08) and ready for Site Acceptance (Feb’09)

Galileo Troll Site at Site Survey (Feb’08)

GSS Troll Artic Building finished (Mar’08)

Courtesy ESA
EGNOS Description
EGNOS Becoming Operational

EGNOS Satellite Footprints

EGNOS Service Area

AOR-E (15.5°W) ID 33
Artemis (21.3°E) ID 37
IOR (65.5°E) ID 44

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EGNOS System Architecture

- Users
- GPS & GLONASS
- 3 GEO Sats
- 6 NLES Navigation Land Earth Stations
- 34 RIMS Ranging & Integrity Monitoring Stations
- 2 Support Facilities
- 4 MCC Mission Control Centers

EWAN (EGNS Wide Area Network)
EGNOS Performance 01/2007-08/2008
The deployment of 7 additional RIMS in Southern Europe and Northern Africa, and 1 additional in Northern Europe will increase the coverage area.
EGNOS Timeline

EGNOS
Regional Infrastructure & Services

EGNOS Programme Phases

- Definition Phase
- IOP Phase
- Long Term Operations, Extensions and Replenishments

2002 2003 2004 2005 2006 2007 2008
EGNOS : 2008 Programme Status

- Assets transfer from the European Space Agency to the European Community
- EC will contract an operator
- Although already broadcasting excellent signals quality, enters formally into operations Spring 2009
- Certification by end 2009
- Service geographical service extension under study
- EC is finalising the procurement and lease of an EGNOS transponder to replace Artemis as of 2011
Galileo and EGNOS Services
## Galileo – 5 Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Access</td>
<td>Free to air; Mass market; Simple positioning</td>
</tr>
<tr>
<td>Commercial</td>
<td>Encrypted; High accuracy; Guaranteed service</td>
</tr>
<tr>
<td>Safety of Life</td>
<td>Open Service + Integrity and Authentication of signal</td>
</tr>
<tr>
<td>Public Regulated</td>
<td>Encrypted; Integrity; Continuous availability</td>
</tr>
<tr>
<td>Search and Rescue</td>
<td>Near real-time; Precise; Return link feasible</td>
</tr>
</tbody>
</table>
## Description of Galileo Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Receiver</th>
<th>Benefits</th>
<th>Target user groups</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Open Service</strong></td>
<td>OS</td>
<td>Single frequency</td>
<td>- Additional satellites for better multi-system coverage (e.g., deep urban)</td>
<td>Open</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Coding and modulation advances for increased sensitivity and multi-path mitigation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Pilot signal for fast acquisition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double frequency</td>
<td>- As above + increased accuracy with 2nd frequency</td>
<td></td>
</tr>
<tr>
<td><strong>Commercial Service</strong></td>
<td>CS</td>
<td>Double frequency</td>
<td>- Increased accuracy using additional frequencies and signals</td>
<td>Commercial basis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Additional features under investigation (e.g., data rate capacity)</td>
<td></td>
</tr>
<tr>
<td><strong>Safety of Life Service</strong></td>
<td>SoL</td>
<td>Single frequency (Level B)</td>
<td>- As OS +</td>
<td>Certified receivers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Integrity and authentication of signal</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Continuity and service guaranty</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double frequency (Level A and C)</td>
<td>- As above at higher performance levels suitable for stringent dynamic conditions</td>
<td>Certified receivers</td>
</tr>
<tr>
<td><strong>Public Regulated Service</strong></td>
<td>PRS</td>
<td>Dual frequency</td>
<td>- As OS +</td>
<td>Regulated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- High Continuity (in times of crisis)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Improved Robustness (vs jamming, spoofing)</td>
<td></td>
</tr>
<tr>
<td><strong>Search and rescue</strong></td>
<td>SAR</td>
<td>Single frequency</td>
<td>- Almost instantaneous reception of emergency calls</td>
<td>Certified &amp; registered beacons</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Exact positioning of emergency beacon</td>
<td></td>
</tr>
</tbody>
</table>
# EGNOS Services

<table>
<thead>
<tr>
<th>Transmission means</th>
<th>Open Service</th>
<th>Safety Of Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF signal (L1 frequency)</td>
<td>RF signal (L1 frequency)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>EGNOS MRD</th>
<th>EGNOS MRD</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Guarantee of Service</th>
<th>None</th>
<th>Guarantee of compliance to ICAO standards (certification)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Definition of the Service</th>
<th>SIS only (free-to-air)</th>
<th>SIS + Guarantee of compliance to ICAO standards (certification)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Typical user communities</th>
<th>Pedestrian, in-car navigation</th>
<th>Aviation, Maritime, railway, road (tolling), emergency services</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Added-Value Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground network</td>
</tr>
<tr>
<td>EGNOS MRD</td>
</tr>
<tr>
<td>Guarantee of compliance to SLA</td>
</tr>
<tr>
<td>EGNOS data + Guarantee of compliance to SLA</td>
</tr>
<tr>
<td>Pedestrian, in-car navigation, research (e.g. atmospheric, tectonics), high-precision GNSS</td>
</tr>
</tbody>
</table>
EGNOS Service Evolutions Under Study

- Coverage Evolution
  - Enlargement (Eastern Europe, MEDA)
  - Extensions (Africa, Middle East)
  - Regional extension module

- Potential Standard Evolution
  - New frequencies

- Potential Infrastructure Evolution
  - Augmentation of new GNSS

- Additional services
  - EGNOS Time Service
  - Critical Communication message (ALIVE concept)
Compatibility and Interoperability
ICG Providers Forum

Galileo complies with ICG Providers Forum’s definitions of Compatibility and Interoperability of Sep. 2007, Bangalore

» Bi-lateral and multi-lateral coordination meetings
EU Objectives in Bi-lateral and Multi-lateral Coordination with other GNSS (1/2)

- Ensure compatibility at a minimum: ability of space-based PNT services to be used separately or together without interfering with each individual service or signal, and without adversely affecting national security
  - Radio frequency compatibility (ITU provides a framework)
  - Spectral separation between PRS and other signals
EU Objectives in Bi-lateral and Multi-lateral Coordination with other GNSS (2/2)

- Achieve interoperability between Galileo open signals (OS, SoL and CS) and other space-based PNT signals when desired for the benefits of users
  » Focus on E1 CBOC, AltBOC E5b (+ E5a & E5b) and E6 BPSK(5) CS signals
Outstanding Issues on Interoperability

- Definition of interoperability?
  - **Technical**: same center frequency, same modulation, commonly agreed maximum power level, geodetic reference frames realization and system time reference
  - **Non-technical**: transparency and availability of open information on signals (e.g. SIS ICD), availability of open information on performance standards and actual performance

- ICG should work on the definition of consolidated “boundary conditions” to achieve interoperability
Planned GNSS Signals as of ICG Expert’s Meeting, July 2008

- E5a, E5, E5b, E6
- L5
- L5, L3/E5b, CDMA?
- L5, E5b, E6
- L5, E6
- L5
- E1/L1
- L1
- L1
- L1

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Conclusions

EGNOS is in its Operational Validation Phase
  - Initial Commercial Services starting in 2007
  - Open Service in 2008
  - Safety of Life Service in 2009

Galileo is in its Development Phase
  - Major EU initiative
  - GIOVE-A, GIOVE-B missions on-going
  - Initial 4 satellites around 2010
  - Full Operational Capability around 2013

International Coordination is an important feature:
  - Ensure compatibility at a minimum and achieve interoperability when desired