INTEGRAIL

Final Presentation

ESTEC, Noordwijk
21 April 2004
Agenda

1. Project Overview, Specification, System Design (Kayser-Threde)
2. Field Test Preparation and Execution (Bombardier Transportation)
3. System Performance and Assessment (IfEN)
## Project Schedule

<table>
<thead>
<tr>
<th>Desc.</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kick-off</td>
<td>15.10 ▲</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Requirements Review</td>
<td>17.12 ▲</td>
<td></td>
<td></td>
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<tr>
<td>Progress Meeting 1</td>
<td>17.06 ▲</td>
<td></td>
<td></td>
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<tr>
<td>Acceptance Test Review</td>
<td></td>
<td>15.11 ▲</td>
<td></td>
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<tr>
<td>Progress Meeting 2</td>
<td></td>
<td></td>
<td>15.05 ▲</td>
</tr>
<tr>
<td>Live Demo (Linz)</td>
<td></td>
<td></td>
<td>16.06 ▲</td>
</tr>
<tr>
<td>Progress Meeting 3</td>
<td></td>
<td></td>
<td>17.11 ▲</td>
</tr>
<tr>
<td>Final Presentation</td>
<td></td>
<td></td>
<td>15.04 ▲</td>
</tr>
</tbody>
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- **Phase I (Design & Development)**: 13 Months
- **Phase II (Rail Tests & Performance Eval.)**: 17 Months

- Project partners: Kayser-Threde GmbH, Munich (Prime), Bombardier Transportation (Signal) Germany GmbH, Ulm, IfEN GmbH, Poing/Munich
- Project website: [integrail.kayser-threde.com](http://integrail.kayser-threde.com)
INTEGRAIL Motivation and Objectives

- The INTEGRAIL system shall allow **precise train positioning** including discrimination between parallel tracks and track change at switches.

- The INTEGRAIL mobile unit shall represent a **train-borne position sub-system** compatible to the train location and velocity determination functions as specified by the **European Train Control System (ETCS)**.

- The mobile unit shall consist of a **multi-sensor positioning system**, combining GPS and EGNOS (i.e. GNSS-1) data with other location/velocity sensor data within a **hybridized positioning solution**.

- The mobile unit shall **operate independently and autonomously**, i.e. without a permanent human operator, but **remote monitoring & control** from a **central facility** shall be possible.
INTEGRAIL Perspective: Integration into ERTMS/ETCS Train
Architecture of the ERTMS/ETCS Onboard System with the GNSS-Based Module
INTEGRAIL Prototype: System Specifications

- System performance according to ETCS requirements:
  - System positioning accuracy: < 5 m + 5% of distance travelled (95%, along-track), < 1 m (95%, cross-track).
  - System integrity: alarm limit < 20 m (terminals), < 50 m (busy lines), < 125 m (rural lines), TTA < 6 sec (target: < 1 sec), integrity risk < 3 x 10^-3
  - System availability/continuity: > 99,99999% (i.e. unavailability < 10^-7) for every 20 sec or 2 km travelled

- System qualification according to CENELEC standards (‘electronic systems on rolling stock’): thermal, EMC, vibration
System Overview: Mobile Unit

- CPU: Pentium 166 MHz
- OS: VxWorks
- GNSS-1 receiver
- Angular rate sensor
- Accelerometer
- GSM modem
- Flash disk (2 GB)
- Backup disk (10 GB)
- 4 units manufactured
Mobile Unit
Block Diagram
GPS/EGNOS Receiver ‘CMC Allstar’

- 10 channels GPS L1, 1 channel EGNOS (or 12 channels GPS L1)
- specified position accuracy: <3 m (with EGNOS, no SA)
- position update rate: 1 Hz
- integrated carrier phase output rate: 1 Hz
- communication: NMEA, CMC binary
- power: +5 V
- operating temp: -30 to +75°C
Heading Sensor 'KVH E-Core'

- Digital fibre-optic gyro
- resolution: 0.014 deg/sec
- scale factor: 0.00305 deg/sec/bit
- bias stability: 0.4 deg/sec p-p
- random walk: 0.08 deg/rt-hr
- digital output: 15 bits plus sign
- power: 12 V, 3 W
- operating temp: -40 to +75°C
Accelerometer, Crossbow CXL02LF1

- Three layer silicon vibrating structure
- Input range: +/- 2g
- Sensitivity: 1 V/g
- Non-linearity: 2%
- Alignment error: +/- 2°
- Power: +5 V
- Operating temp: -40 to +85°C
Structure of Sensor Fusion S/W Algorithm

- Pre-Processing
- Navigation Filter
- Evaluation of Solutions (Track Identification)

Sensor Fusion

- GNSS PVT
- Distance (Odo/Acc)
- Direction (ARS)

Location Data (Hybridized Navigation Solution)

Route Data Base

Route Data Base
Navigation Solution Computation

- Input: GNSS, Odometer/Accelerometer, Angular Rate Sensor
- Transform GNSS data to internal track-oriented coordinates
- Take into account data history, topology (route data base) and consistency
- Calculate distance and direction of movement from odometer/accelerometer
- Extrapolate last “Navigation Solution”, compute candidate solutions
- Check solutions for integrity
- Check solutions with data from angular rate sensor
- Output: “Hybridized Navigation Solution”
Communication Architecture

Central Server

LAN

Internet

User PC

User PC

EGNOS

GPS

Position and status via GSM

Mobile Unit
Central Server with Interactive GUI for Remote Control

Visualization

Archiving

Communication
System Test Overview

a) Acceptance tests (project phase I):
   - Functional/performance tests on component, subsystem and system level
   - Environmental tests

b) Application demonstration tests (project phase II):
   - Laboratory tests with signal simulator (GNSS-1 sensor performance under varying reception conditions)
   - Car tests (functional/performance tests on system level, communication test)
   - “In-the-field” tests on train (test of system, components, communication; performance tests performed on two different track networks for ten months)
1. Lab Tests with GNSS Signal Simulator (Example):
Horizontal Position Accuracy Run 03: EGNOS + Terrain

Mean Pos
Residual = 2.52 m
2. Car Tests for System Functional Verification
3. Application Tests on Railway Tracks

As rail test tracks, LogServ in Linz/Austria and SNCB in Belgium were selected. Main criteria for the selection:

- **Representative topography:** The landscape allowed a variety of satellite visibility conditions ranging from very good (in plain areas) to limited (in cities, forest or mountain areas).

- **Availability of position reference:** To validate the correct performance of the INTEGRAIL position solution, accurate reference position must be available at regular intervals.

- **Both rail operates are in favour of modern satellite-supported train positioning technology.**
Rail Application Test Schedule

LogServ, Austria

5. - 7.2. (first installation, no data)
25./26.2. (second installation, S/W update, no data)
26.2. - 9.4. (de-installation)
9./10.4. (first installation, reference data take)
10.4. - 22.5. (check, reference data take)
22.5. - 13.6. (check)
16.6. - 16.7. (check)
17.7. - 2.10. (de-installation)
4. - 6.11. (re-installation, reference data take)
11.7. (first installation, no data)
6.8. (check, S/W update, no data)
21.8. (check, S/W update)
22.8. - 29.9. (check)
29.9. - 28.11. (check)
28.11. - end 2003 (de-installation)

SNCB, Belgium

= MU1
= MU4
= data gaps
= data on CD-ROM