New French DGPS maritime service powered by EDAS

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² CEREMA, FR

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Outline

• Alberding GmbH and CEREMA
• Background
• Modernised French DGPS service
• Initial performance results
• Conclusions and service operator feedback
Alberding GmbH

• German GNSS software and hardware development company

• Founded in 1994

• Based in Wildau (near Berlin)

• 14 employees (12 engineers)

• Independent from GNSS receiver manufacturers
Adaptable **software, sensors, systems** and **services** for automated applications of precise (mm-cm) satellite-based positioning, monitoring and data transmission.
Beacon.net + Beacon Site Control

Alberding Beacon.net

- Central data processing
- Scalable, modular DGNSS software
- GNSS data input, VRS and EGNOS-VRS processing, integrity monitoring (PBM, FFM), data transmission (RTCM, AIS #17, VDES, Ntrip)
- Combination of DGNSS/RTK and waterway information
- R-Mode support

Alberding Beacon Site Control

- Decentralised processing – local backup
- EGNOS-VRS correction generation
- Pre-Broadcast Integrity Monitoring
- Correction selection for transmission
DGPS service in France - stakeholders

- **Central administration**
  French Maritime Authorities (DAM) manage policy and budget at the national level
  The AtoN office of the DAM maritime safety department is responsible for the DGPS stations

- **8 decentralised administrations**
  (DIRM & DM) manage the operation and maintenance of the AtoNs

- **CEREMA** (public administrative institution)
  navigation and positioning systems division supports DAM by providing scientific and technical expertise
Legacy French DGPS network

- 7 beacon DGPS stations
- No redundancy at the stations
- No Pre-Broadcast Monitoring
- Central control station at Belle-île (Far Field Monitoring)
- Old low rate WAN
- No changes since the 90’s
- Obsolete equipment
- Availability decreasing
Role of CEREMA in the project

- CEREMA was requested by DAM to
  - Analyse the legacy DGPS system
  - Propose a cost effective solution to modernise the service
  - Conduct a Proof of Concept on that solution including a prototype, tests and result analysis at laboratory scale & field scale
  - Specify requirements for the modernisation of the service
  - Support AtoN operators to deploy the modernised service

- Test campaigns and preliminary studies
  - Successful test campaigns in 2016-2018
  - Cost-Benefit Analyses conducted by CEREMA and GSA

  Centralised EGNOS-based architecture selected
EGNOS benefits

- Free of charge service
- Redundancy of signal sources (SiS and EDAS)
- EGNOS-based VRS:
  corrections generated remotely for locations
  with no physical reference stations
  (centralised architecture)
- Reduction of onsite infrastructure
- Quality of corrections not affected by local issues
  that could impact the beacon site (e.g. multipath,
  interference)
- Transparent for end users and compatible with
  deployed user equipment
Modernised French DGPS network

- Official commissioning of the first French IALA beacon station transmitting EGNOS-based VRS corrections: 1 March 2019 (Olonne)
- 3 more stations equipped in 2019
- All 6 stations will be commissioned by the end of 2020

<table>
<thead>
<tr>
<th>EGNOS-VRS</th>
<th>PBM Station (Monitoring)</th>
<th>FFM Station (Rover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IALA HEAU</td>
<td>PBM HEAU</td>
<td>FFM BELL 1</td>
</tr>
<tr>
<td>Héauville</td>
<td>0 km</td>
<td>Belle Île</td>
</tr>
<tr>
<td>IALA PNDB</td>
<td>PBM PNDB</td>
<td>FFM BELL 2</td>
</tr>
<tr>
<td>Pont de Buis</td>
<td>0 km</td>
<td>Belle Île</td>
</tr>
<tr>
<td>IALA SABL</td>
<td>PBM SABL</td>
<td>FFM BELL 3</td>
</tr>
<tr>
<td>Olonne</td>
<td>0 km</td>
<td>Belle Île</td>
</tr>
<tr>
<td>IALA PORQ</td>
<td>PBM PORQ</td>
<td>FFM TOUL</td>
</tr>
<tr>
<td>Porquerolles</td>
<td>0 km</td>
<td>Toulon</td>
</tr>
</tbody>
</table>

IALA Beacon  
Far Field Monitor  
Central Server

IALA Beacon  
Far Field Monitor  
Central Server
Modernised facilities

- Modernised DGPS rack at transmission site
- Modernised transmitting antenna IALA Beacon BEAR
New system architecture

Central Server
Cerema

Beacon.net

- EDAS
- SISNet client
- TCP/IP client

IALA Beacon HEAU
- MSK modulator
- GNSS receiver
- Local backup
- RTCA -> RTCM & Integrity checks

IALA Beacon PNDB
IALA Beacon SABL
IALA Beacon PORQ

MF antenna

DGNSS corrections

GNSS raw data + EGNOS messages

FFM: Trimble SPS 356

PBM: Hemisphere R110
Central data processing

Central Server (Linux)

Alberding Beacon.net sw

Web Interface
- Configuration
- Visualisation
- Alarming

Data input, plausibility check

EGNOS-VRS correction generation
RTCA → RTCM

DGNSS corrections for EGNOS PRNs 123 & 136

Pre-Broadcast Monitoring

Data formatting, switched output

EGNOS-PRNs 123 & 136

Far Field Monitoring

DGNSS corrections for EGNOS PRNs 123 & 136 with integrity information

Operating staff

EDAS SISNeT

GNSS Rx

RTCA data

GNSS raw data + EGNOS SIS RTCA data

Operating staff

EGNOS Backup

IALA Beacon

Far Field Monitor station

NMEA

RTCM MT 9/3

MF 100 bps

About  Background  New System  Performance Results  Conclusions

Tamás Horváth  New French DGPS maritime service powered by EDAS  25 Sept 2019  13/22
Redundant setup

- **RTCA source:** EDAS SISNeT with EGNOS SiS backup
  software takes any available RTCA input

- **EGNOS-VRS corrections generated for PRNs 123 & 136**
  software automatically selects one of them for output based on availability, health status and user-defined priority

- **Pre-broadcast integrity monitoring with 2 monitoring stations**
  software automatically selects monitoring station based on availability (not used in the current French setup)

- **EGNOS SiS based local backup at the IALA beacon**
  EGNOS-VRS corrections generated and checked locally if no connection to data centre (not used in the current French setup)
## Maritime performance requirements

<table>
<thead>
<tr>
<th></th>
<th>Accuracy (95%)</th>
<th>Time to Alarm</th>
<th>Continuity (15 min)</th>
<th>Availability</th>
<th>Update Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour entrances, harbour approaches and coastal waters</td>
<td>≤ 10 m</td>
<td>&lt; 10 s</td>
<td>≥ 99.97%</td>
<td>&gt; 99.8%</td>
<td>≤ 2 s</td>
</tr>
</tbody>
</table>

IMO Resolution A.1046 (27)
# Initial performance results


<table>
<thead>
<tr>
<th></th>
<th>HEAU</th>
<th>PNDB</th>
<th>SABL</th>
<th>PORQ</th>
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<tbody>
<tr>
<td><strong>Availability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before integrity check</td>
<td>99.97%</td>
<td>99.97%</td>
<td>99.97%</td>
<td>99.97%</td>
</tr>
<tr>
<td>of healthy corrections</td>
<td>98.56%</td>
<td>99.89%</td>
<td>99.92%</td>
<td>99.93%</td>
</tr>
<tr>
<td><strong>Accuracy (mean)</strong></td>
<td>0.85 m</td>
<td>0.88 m</td>
<td>0.45 m</td>
<td>0.57 m</td>
</tr>
<tr>
<td><strong>Accuracy (95%)</strong></td>
<td>1.51 m</td>
<td>1.40 m</td>
<td>0.98 m</td>
<td>1.08 m</td>
</tr>
<tr>
<td><strong>Continuity before integrity check</strong></td>
<td>98.37%</td>
<td>98.37%</td>
<td>98.38%</td>
<td>98.39%</td>
</tr>
<tr>
<td>of healthy corrections</td>
<td>97.57%</td>
<td>97.19%</td>
<td>98.08%</td>
<td>98.06%</td>
</tr>
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<table>
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<th>Requirement IMO Res. A. 1046</th>
<th></th>
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<tbody>
<tr>
<td>Availability</td>
<td>&gt; 99.8%</td>
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<td></td>
<td></td>
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</table>

Availability and continuity: service level, measured at the central server with 1 s temporal resolution

Accuracy: system level, measured at the FFM station
Remarks to performance results

- **HEAU-VRS availability affected by**
  - 28 h communications outage to IALA Beacon station HEAU on 1-2 July.
    - add local backup at the transmission sites
    - use redundant communication lines
    - use redundant PBM with 2 monitoring stations

- **Accuracy performance affected by**
  - Biased FFM station coordinates. New coordinates introduced on 18 July causing a position error reduction of ~ 0.5 m.
    - determine station coordinates with cm accuracy

- **Continuity performance affected by**
  - Monitoring station data gaps
    - Many short (< 1 min) data gaps in the correction output due to overloaded server computer
    - add more computing power to central server
  - Several ‘unhealthy’ integrity events
    - increase position error PBM threshold to 10 m
    - use high quality GNSS equipment and ensure clear sky view at the monitoring stations

- **Integrity events in the pseudorange domain**
  - Very few events (0.06% of all epochs)
  - Individual low elev. satellites excluded due to high PRC residuals
Radiobeacon skywave interference

Field Strength

Signal to Noise Ratio

Word Error Rate

Data Age

Position Quality

FFM HEAU BELL (274 km)
FFM PNDB BELL (127 km)
RTCM Type 1 → Type 9/3

Type 9 messages are useful for slow data links that are susceptible to interference

- **Word Error Rate**
  - Graph showing word error rate over time

- **Data Age**
  - Graph showing data age over time

- **Position Quality**
  - Graph showing position quality over time
Conclusions and recommendations

- The legacy French DGPS system is currently being replaced by a new centralised EGNOS/EDAS-based DGPS service

- **Significant cost savings** of the EGNOS/EDAS-based solution with respect to a traditional DGPS setup (at least 50%)

- Very good initial operational performance results indicate
  - Significantly increased service availability compared to the old system. **Availability performance meets the IMO requirements.**
  - **Accuracy performance** fulfils expectations and clearly **meets the IMO requirements.**
  - Continuity performance is affected by overloaded server computer, monitoring station outages and not optimal integrity settings.

  → **made recommendations to improve continuity performance**
  - Integrity performance proved the high quality of EGNOS-based VRS corrections
EGNOS correction transmission via IALA beacons is still a rather new concept and not too many off the shelve products exist.

Requirements need to be carefully specified in that case.

Cost savings can be made if working with smaller companies instead of the big equipment manufacturers. Consequently, we need to work with hardware companies that are sometimes not DGNSS specialists.

During the testing and early operations phase we experienced some interruptions in our service both due to software and hardware failures that had to be improved with the providers.

A local backup at the transmission sites would be very interesting to complement the EGNOS-based centralised approach. It is not clear yet if this backup should also be EGNOS-based or traditional DGPS.

Remote control & monitoring of all on site equipment is very important.
Thank you for your attention!

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Reserve slides
## French PBM integrity settings

<table>
<thead>
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<th>Integrity parameter</th>
<th>PBM threshold</th>
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<tbody>
<tr>
<td>Max PRC</td>
<td>60 m</td>
</tr>
<tr>
<td>Max RRC</td>
<td>0.6 m/s</td>
</tr>
<tr>
<td>Max PRC Residual</td>
<td>10 m</td>
</tr>
<tr>
<td>Max RRC Residual</td>
<td>0.5 m/s</td>
</tr>
<tr>
<td>Max (Horizontal) Position Error</td>
<td>5 m</td>
</tr>
<tr>
<td>Max PRC Residual Delay</td>
<td>5 s</td>
</tr>
<tr>
<td>Max RRC Residual Delay</td>
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