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Working Group WG 3

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Pilot project for the transmission of SBAS corrections via IALA beacons and AIS for Maritime and IWW – Main Outcomes

# Summary

This paper is aimed at presenting the operational benefits and recommendations identified in the SC24 pilot project [2] funded by the European GNSS Agency. The main objective of this project was to demonstrate the operational performance of the transmission of EGNOS corrections converted to Differential GPS corrections over the existing transmission infrastructure (AIS base stations/IALA beacons) in the Maritime and Inland Waterways domains, while providing a detailed cost benefit analysis of the solutions proposed.

## Purpose of the document

The purpose of the document is twofold:

* To present the main outcomes of the SC24 pilot project [2] and propose some updates to the IALA SBAS Guidelines [1].
* To present the recommendations derived from the project.

## Related documents

* IALA G1129 THE RETRANSMISSION OF SBAS CORRECTIONS USING MF-RADIO BEACON AND AIS

# Background

Following the publication of the IALA Guidelines for the use of SBAS [1] as well as the recommendations from the European Maritime Radionavigation Forum (EMRF), the European GNSS Agency decided to launch a pilot project to support the adoption of the solutions described in the IALA guidelines by the different maritime and inland waterways authorities.

During 6 months, 4 European scenarios representing a fair combination of both IALA beacons and AIS/VDES stations as well as maritime and IWW domains have been analysed.

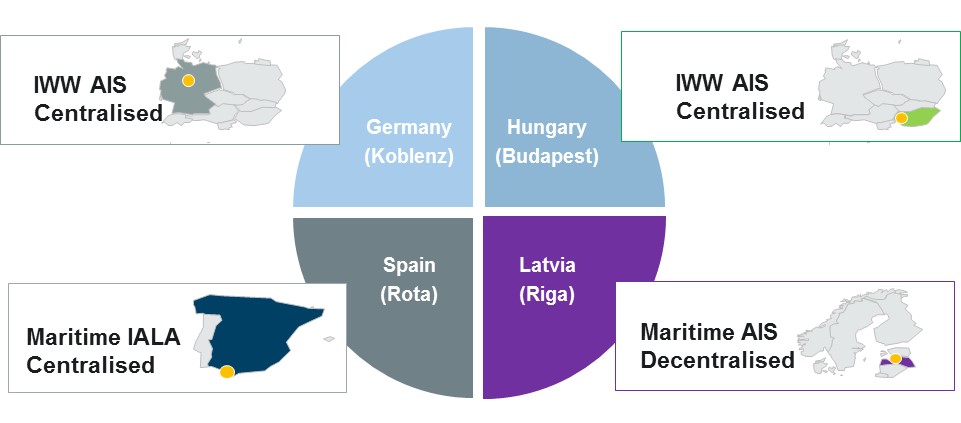


Figure 1: Pilot project locations and architectures/domains

# Discussion

## Pilot Project Performance

The following table summarizes the results obtained during pilot projects test campaign:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pilot Project** | **Availability** | **Continuity** | **Accuracy (95%, m)** | **Integrity** |
| **HU (RSOE, Budapest)** | **99.98 %** | **99.95 %[[3]](#footnote-3)** | **2.05 m** | Pseudorange domain: several high PRC residual error events affecting individual low-elevation satellites only  Position domain: 2 major events (both not-monitored) taking several minutes each and 7 short events (most of them not-monitored and a few no data) ranging from a few seconds to a few minutes |
| **DE (WSV, Koblenz)** | **99.99 %** | **98.95 %** | **1.11 m** | Pseudorange domain: several high PRC residual error events affecting individual low-elevation satellites only.  Position domain: Lots of short events (unmonitored). |
| **LV (MRCC, Riga)** | **99.83 %** | **98.98 %** | **3.60 m** | Pseudorange domain: No events.  Position domain: Some short events (unmonitored). |
| **ES (PdE, Rota)** | **99.97%** | **99.38%** | **0.65 m** | No integrity events detected. |

Table 1: Pilot projects overall performance results

Green cells indicate that the performance is compliant with IMO requirements, whereas red cells indicate the opposite.

Based on these results shown above, it is concluded that the **availability** of the EGNOS-based corrections is enough to meet the 99.8% availability requirement defined by IMO in the A.915 and A.1046 resolutions.

As it can be derived from the table, the most demanding performance parameter is the **service continuity**. The reason why there are red cells in the table above is mainly due to missing monitoring raw data to perform the Pre-Broadcast Monitoring (PBM) check. The missing raw data causes short continuity events that have an impact on the parameter calculation. In most of the cases, these raw data gaps/delays are due to the fact that pilot projects use conventional communication lines (i.e. not dedicated) to transmit data from the monitoring receiver to the central facility.

In addition, short EGNOS performance degradation events in October and November also contributed to lower the continuity value in the Budapest pilot project. These regional performance degradation events only affected the pilot in Budapest.

Regarding the **accuracy** results, it is to be noted that the position accuracy highly depends on the quality of the antenna and the GNSS receiver. In this sense, the results obtained for the Rota pilot project, where a high quality antenna and GPS receiver was used, illustrates the performance levels that could be obtained with an EGNOS-based solution (horizontal position error below 1 meter at the 95 percentile).

Finally, the results yield by the **integrity** monitoring module show that no single satellite correction has been discarded due to high PRC, RRC and only a few due to high corresponding residual values (affecting satellites at low elevations). This provides a quantitative measurement of the corrections quality. If the corrections are accurate, the differences between the geometric and the corrected pseudorange will be low and therefore good position accuracies will be obtained. At the position domain, only a few events with errors exceeding the horizontal position threshold have been detected in the Riga pilot project.

In summary, it can be stated that the pilot projects have performed really well mainly due to:

* the high availability of the EGNOS SiS (100% in the period of analysis when using combined SiS), and EDAS (only minor outages detected), and
* the high quality of the corrections generated.

## Cost Benefit Analysis

In close cooperation with the participating authorities, the consortium has developed a complete cost-benefit model that allows to quantify potential savings brought by EGNOS introduction in all the scenarios and to assess the optimal deployment strategy for maximising benefits of this transition. More specifically, for all the scenarios analysed the results have been the following:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Port Authority /State** | **Domain** | **Reference Scenario**  **Architecture** | **EGNOS Option Architecture** | **Total Savings** | **Savings percentage**  **(EGNOS Option vs**  **Reference Scenario)** |
| MRCC/Latvia | Maritime | AIS decentralised | AIS centralised | 0,19 Mln Eur | 52% |
| Puertos del Estado/Spain | Maritime | IALA decentralised | IALA centralised | 1,8 Mln Eur (Hybrid Centralised) | 28% |
| RSOE/Hungary | IWW | AIS centralised | AIS centralised | 0,80 Mln Eur | 19% |
| WSV/Germany | IWW | AIS centralised | AIS centralised | 0,36 Mln Eur | 5% |

Table 2: Phase 2 CBA results

The results demonstrate that in the four countries participating in the Working Groups, the EGNOS-based solution entitles relevant cost reduction in terms of: CAPEX, OPEX, and maintenance (fewer spares and effort to repair).

The reason for this cost reduction is that the infrastructure in centralised EGNOS-based solutions is lighter (i.e. it requires fewer components) when compared to a classical DGNSS approach.

## Operational Benefits for IALA SBAS Guidelines Update

The following operational benefits for the provision of EGNOS-based DGPS corrections have been identified in the project

* **Reduction of spares and maintenance effort**: The rationalization of the infrastructure in a centralised solution permits to rely on a more agile and lighter architecture, consisting on a smaller number of devices and tools, also for maintenance purposes. In return, this derives on a reduced number of man-days effort required to perform the maintenance activities.
* **Increased infrastructure robustness against RF interferences (jamming/spoofing):** In an EGNOS-based centralized architecture Reference Stations (RS) are virtualised and therefore, cannot be jammed or spoofed. Only Integrity Monitoring Stations (IMS) can suffer this attack, which can be minimized by adding redundant IMS. In traditional DGNSS systems, however, since normally both RS and IMS are co-located, they can be equally jammed/spoofed.
* **Increased infrastructure robustness against failures:** When EGNOS is used in combination with traditional DGNSS (hybrid solution), EGNOS introduces redundancy on the source of the corrections. Furthermore, EGNOS corrections can be obtained via a double source: SiS or EDAS. This implies that, when a source of corrections fails, the system can automatically switch to a different source to avoid service interruption. Thus, the system is more robust to potential malfunctions coming either from HW failures or SW failures.
* **Synergies between IALA and AIS systems:** A centralised EGNOS solution could increase synergies between IALA and AIS systems, since the central server could generate corrections for both systems in an efficient way thanks to the VRS concept. These synergies could in return decrease the costs of generating corrections to be broadcasted by both systems.
* **Enhanced integrity at system level:** EGNOS corrections contain **integrity alerts** either in the Integrity Information Message (MT6) or the Fast Corrections Messages (MT2 to MT5 and MT24). The application SW will map these integrity alerts into **DGNSS RTCM format** for transmission by either setting the DGNSS MT1/9 PRC field to binary 1000 0000 0000 0000 (which means this satellite cannot be used for the navigation solution) or even, when the alert condition affects all satellites, by setting the Station Health field to “not working”. On top of the EGNOS integrity check, the DGNSS system will continue providing alerts also at integrity monitoring level, as they currently do.

## Project Recommendations

This section contains the recommendations that have been derived from the project. Table 3 details the recommendations to be considered by National Competent Authorities when implementing an Aid to Navigation service based on EGNOS (centralised or hybrid architecture):

| ***ID*** | ***System***  ***(AIS/IALA)*** | ***Recommendation*** |
| --- | --- | --- |
| *1* | *Any* | *Ensure good communications between monitoring stations to server and between server to transmission sites (by setting up a) SLA with communications provider, b) redundancy of monitoring stations, or c) redundancy of communication lines* |
| *2* | *Any* | *Use infrastructure equipment of geodetic quality* |
| *3* | *Any* | *Ensure good locations for installed antennas (free of multipath effects)* |
| *4* | *Any* | *Ensure that old corrections are not buffered when a communications outage occurs* |
| *5* | *AIS* | *Verify that owned AIS Base Stations really support Message Type 17* |
| *6* | *AIS* | *Ensure correct definition of configuration parameters related to Message Type 17 broadcast.* |

Table 3: Project Recommendations for NCA consideration

On the other hand, and based on the issues faced during the pilot projects setup and the performance campaign, the following table contains a set of recommendations/topics to be considered for discussion at IALA level.

| ***ID*** | ***System***  ***(AIS/IALA)*** | ***Recommendation*** |
| --- | --- | --- |
| *6* | *AIS* | *Define guidelines to ensure correct definition of configuration parameters related to Message Type 17 broadcast.* |
| *7* | *VDES* | *Continue investigation of transmission of EGNOS-based corrections through VDES* |
| *8* | *AIS* | *Clarify how transponders should process corrections coming from multiple sources* |
| *9* | *AIS* | *Solve switching problems between stations that transponders face at the cross-borders* |

Table 4: Project Recommendations for IALA consideration

Details about these recommendations are provided in ANNEX 1

# References

1. IALA GUIDELINE G1129 THE RETRANSMISSION OF SBAS CORRECTIONS USING MF-RADIO BEACON AND AIS
2. Specific Contract GSA/OP/07/13/SC24 ‘Support to Maritime Service Providers for the transmission of EGNOS corrections via IALA beacons and AIS/VDES stations’

# Action requested of the Committee

The Committee is requested to:

1. Note the information provided in this paper.
2. Assess the convenience to update the existing IALA Guidelines G1129 [1] taking into account the operational benefits identified in this project.
3. To consider for information the general recommendations derived from the SC24 project [2].
4. – Project Recommendations
5. Project recommendations

This section details the list of recommendations derived from the project.

* 1. Recommendations to Competent National Authorities

In general terms, authorities should consider the following technical recommendations when implementing an Aid to Navigation service based on EGNOS (centralised or hybrid architecture):

* Ensure good **communications** lines both to transmit the corrections generated at the server as to get **raw data from the monitoring stations for PBM** (Id #1)
* Equipment (receiver and antenna) used for PBM and FFM should be of high quality (geodetic receiver and antenna). It is of special relevance that the antenna has multipath reduction capability (Id #2).
* **Location of the installed antenna for PBM** (away from possible local interference effects) is crucial to achieve a good system performance (Id #3).

Notwithstanding, particular recommendations for IALA, AIS and communications have been derived from the execution of the pilot projects and are presented below.

**Particular recommendations for IALA beacons**

When broadcasting **corrections through IALA beacons**, authorities should take into account the following recommendation:

* In case a communication outage between the central server and the transmitter site occurs, the system should be designed to avoid buffering and retransmitting the old corrections once the communication is resumed (Id #4).

Even though this issue has been identified when using a DGNSS radio-beacon, it can also be made extensible to AIS architectures.

**Particular recommendations for AIS Base stations**

When broadcasting **corrections through AIS**, authorities should take into account:

* Verification that the AIS Base Station can actually **broadcast Message 17.** When planning to use an AIS Base Station as a **FFM**, verification that it can actually **use Message 17 to compute its position** (Id #5).
* **Ensure the following parameters are properly defined** (Id #6)**:**
  + Number of slots per message
  + Msg17 slot interval
  + Separation between Msg17 start slots on AIS channels A and B

IALA Recommendation A-124 Appendix 16 provides general recommendations on AIS Message 17 slot settings. However, the actual implementation depends on local circumstances (e.g. location, traffic density, GNSS systems supported, whether AIS base station models in use support single slot reservation to meet 10 seconds TTA or not, etc.). Hence, these parameters should be defined on a case by case basis.

* In order to **minimise impact of transmission of Message Type 17 on other types of information**, the following approach should be followed (Id #6):
* As long as there is not an integrity event, other messages can use message 17 slots. However, a minimum update rate of the corrections shall be respected in order to ensure that corrections are provided for all visible satellites and in this way preserve positioning accuracy.
* A requirement shall be set to guarantee the capability of transmitting a message within the next 3 1/3 seconds upon an event as already stated in IALA Recommendation A-124 Appendix 16. Alternatively, other ways to meet the 10-second TTA requirement should be identified. This question should be revisited within IALA.

**Communication issues**

In EGNOS-based centralised solutions, reliable communication lines are required to ensure that no data gaps or network outages occur, compromising the availability and continuity figures. This problem is common with other architectures that have similar communications requirements, such as:

1. DGNSS beacons following the network approach
2. AIS base stations that receive corrections via the Internet generated by a DGNSS reference station.

These communication problems can be solved by setting Service Level Agreements (SLA) with the communication providers (Id #1).

However, for those cases where this is not possible (e.g. remote locations located in rural areas) or even when this is possible but to ensure enough redundancy, there are two alternative solutions (Id #1):

1. **Redundancy of monitoring stations**

With this solution a network of IM stations is distributed in the service area, which will be responsible of:

* Providing raw data to perform the Pre-Broadcast Integrity checks at the Central Server.
* Act as Far-Field monitors assessing also the quality of the correction data radio link.
* Inform service operators in case of problems detected with reference stations.

Furthermore, to ensure stations redundancy, it is possible to use public GNSS networks for this purpose (EUREF Permanent Network, SAPOS network in Germany, etc.) perhaps with a combination of authority-owned sensor stations. This should reduce the deployment and maintenance costs.

1. **Redundancy of data links**

Diversification of data links is also beneficial to ensure that if a data link fails, another link can be available.

Both solutions can be implemented separately or a fair combination of both can also be adopted.

* 1. Recommendations to IALA

**Related to AIS Base Stations**

During the pilot project setup, it was detected that for same AIS Base Stations, it was not possible to configure the reserved the slots to meet the 10-seconds TTA requirement (one single slot every 3 1/3 seconds), being therefore necessary to increase the MT17 update rate, with the corresponding impact on the channel loading.

AIS Base Stations manufacturers should provide clear instructions about the most suitable values of some of the configuration settings, including: nominal update rate, broadcasting time, separation of the slots, reserved slots, etc. This could perhaps be addressed through one of the already established working groups in IALA (Id #6).

On the other hand, based on feedback received from the project advisory board, it seems that there is no body at European or International level in charge of controlling the time slots used by AIS. This could be solved, perhaps through the creation of specific guidelines (Id #6).

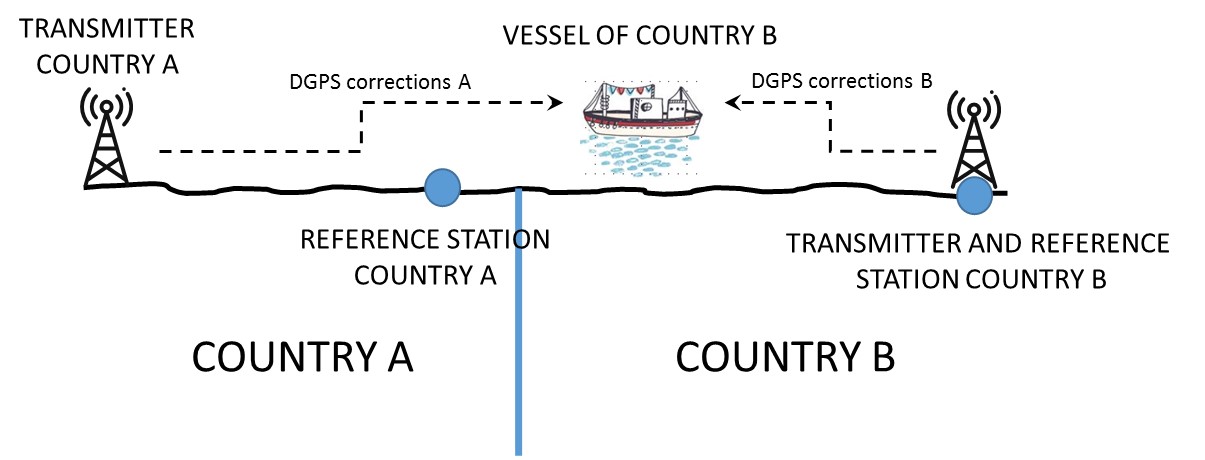
**Related to AIS transponders’ corrections data processing**

It is not clear how the transponder manages situations where there is an overlapping of corrections received from various AIS Base Stations. According to ITU-R Recommendation M.1371-5, where DGNSS corrections are received from multiple sources, the DGNSS corrections from the nearest DGNSS reference station should be used taking into account the Z count, and the health of the DGNSS reference station. However, as it has been noted in the project, not all transponders follow this recommendation and, instead, they apply different correction selection criteria. Perhaps it is also time to revisit the ITU-R Recommendation M.1371-5, since at the time of writing it centralised architectures were not being implemented. Instead, RS were always located at the point where corrections were broadcasted. Since centralised architectures have changed this paradigm, it is worth reviewing the recommendation taking into account the possibilities introduced by this architecture.

It is highly recommended that this information is made available in the transponder’s datasheet (Id #8).

**Related to cross-borders issues**

During the AB meetings it has been raised the point that users located in regions close to country borders may suffer reference station switching problems. At the country borders, mariners may use corrections broadcasted from a country different from their own as depicted in the following figure:



In the above figure, vessel B from country B will be using DGPS corrections A (originated in country A) despite being in country B waters. This is because the Reference Station of country A is closer than the one in country B.

The AB has suggested that a cooperation document (e.g. guidelines) dealing with country borders issues shall be considered in the short term to solve cross-border and overlapping of signal slots. There are some existing IALA recommendations addressing the topic, namely:

IALA Recommendation A-124 – on the AIS Service (Edition 2.1, 2012)

IALA Recommendation A-124 Appendix 14 – FATDMA Planning and Operation of an AIS Service (Edition 2, 2011)

* IALA Recommendation A-124 Appendix 16 – DGNSS Broadcasts from an AIS Service (Edition 2, 2011)

However, they should be revisited and updated if necessary to cover with situations such as the one depicted in the figure above.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Input papers should be assigned to a work task as listed in the Committee work plan which is available in input papers. Leave open if uncertain but consider how the paper is to be processed if not relevant to a work task [↑](#footnote-ref-2)
3. According to IALA Guideline 1112 [RD-38], the continuity of each individual reference station shall be **>99.95%** in case the DGNSS service consists of areas of overlapping coverage. Due to the relatively flat terrain of Hungary and the dense network of AIS Base Stations deployed along the Hungarian stretch of the river Danube, the VHF signal of multiple AIS Base Stations can be received at any location on the river, including the capital Budapest. Therefore the continuity minimum requirement of >99.95% has been applied in this pilot project. In all other pilot projects, the continuity minimum requirement is 99.97%, as recommended by IMO Resolution A.1046 and IMO Resolution A.915. [↑](#footnote-ref-3)