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Interoperability Trials with SBAS and GBAS Equipment

Presented by France, Germany, Russia and EUROCONTROL
Prepared by Andreas Lipp

Summary

Interoperability issues for GBAS and SBAS, addressed from a regulatory standpoint in SARPS and MOPS, need to be verified in practice. In a joint effort between European states and EUROCONTROL, initial tests are taking place to assess potential issues. This Information Paper outlines objectives and status of these trials. The first results are encouraging and will be complemented with further trials and more detailed evaluation.

1 Background

With both SBAS and GBAS systems and equipment maturing and entering the certification phase, interoperability issues, addressed from a regulatory standpoint in SARPS and MOPS, need to be verified in practice. In a joint effort between European states and EUROCONTROL, initial tests are taking place to assess potential issues. This Information paper outlines objectives and status of these trials.

2 Need for Interoperability Trials

In principle, equipment interoperability is guaranteed by the development and validation of the ICAO SARPS and complemented by industry standards, such as RTCA and EUROCAE MOPS, ICD's and ARINC standards. However, the technical complexity of satellite-based systems is such that different interpretations of standards cannot be excluded. These should be detected and clarified as quickly as possible. Additionally, MOPS are regional documents and may not be applied identically by all certification entities.
In consequence, EUROCONTROL has reviewed public information about existing approach-capable GBAS and SBAS equipment and existing interoperability trial experience and has complemented this by suitable experiments.

These experiments, conducted in close cooperation with German, French and Russian authorities also serve to broaden the experience base for satellite-based systems. Notably for GBAS, flight test experience in Europe is limited, since most activities had in the past concentrated on S-CAT systems.

3 Interoperability Test Matrix

For interoperability aspects, three different areas need consideration:

1) SBAS avionics systems interoperability with different SBAS service providers
2) GBAS ground and avionics systems interoperability
3) Comparability between GBAS and SBAS approaches using identical FAS data elements (which includes comparison of VDB-uplinked and onboard database approaches)

In order to be able to perform trials in areas 2) and 3), only airports with GBAS installations could be considered and for financial reasons, trials had to take place in Europe. Therefore area 1) was limited at the outset to trials with EGNOS and with available SBAS (EGNOS) capable airborne equipment.

A full SBAS test matrix was therefore not developed, but it was noted that several states had extensively reported in GNSSP and NSP on past interoperability trials, notably between the US and Europe and regarding the use of SBAS equipment outside the service area of specific service providers.

For area 2), the existence of several real-time and post-processing experimental systems was acknowledged, but also work toward airborne systems certification using prototypes from Honeywell and Thales ATM. Furthermore Russia has reported the certification of a ground station by NPPF-Spektr and ASA, the FAA and Honeywell are working towards certification of a

Honeywell system. On the airborne side, Boeing has reported the certification of Rockwell-Collins GBAS avionics and Airbus reports progress, also using a Rockwell-Collins system.
The following matrix tries to show the reported status, with experimental systems summarized for clarity.

	Airborne equipment			
Ground Equipment	Rockwell-Collins GLU 925 (Airbus)	Rockwell-Collins GLU 925 (Boeing)	NPPF-Spektr avionics (prototype)	Experimental receivers
Honeywell SLS-3000 (beta-LAAS)		FAA, ASA and Boeing		FAA and continuously (static) by DFS
Honeywell SLS-3000 Beta LAAS Plus (provably safe prototype)	Planned for 2007 in Bremen and Malaga (OPTIMAL)	FAA with GNLU 930 in Memphis Sept. 06 and planned for 2007 in Bremen and Malaga		Planned for 2007 in Malaga and Bremen
Honeywell SLS-4000 (production)	planned for 2008/9 in Bremen and 2008 in Sydney	Planned for 2008/9 in Bremen and 2008 in Sydney		Planned for 2008/9 by DFS in Bremen
Thales AS615 (prototype)	Airbus flights	Continuous (static) monitoring by DSNA/DTI		continuously (static) by DSNA/DTI
NPPF-Spektr LCCS-A-2000 (production)			Internally by NPPF-Spektr	Internally by NPPF-Spektr
Experimental Ground Stations	Post-processed by TUBS in 2006 (PEGASUS)	Boeing, FAA, and Ohio University (with GNLU 930)		Diverse experiments worldwide

<u>Table 1:</u> Overview of publicly available information on GBAS interoperability testing

In the frame of the constraints identified above, EUROCONTROL has planned to complement the available tests by additional activities. These are added in the updated table 2 below in bold. Some of the activities are duplicates, but have not yet been performed in Europe or were needed to verify the experiment setup and equipment. In each case they were performed in close cooperation with the local service providers.

Bold: EUROCONTROL supported trials	**Airborne equipment**			
Ground Equipment	Rockwell-Collins GLU 925 (Airbus)	Rockwell-Collins GLU 925 (Boeing)	NPPF-Spektr avionics (prototype)	Experimental receivers
Honeywell SLS-3000 (beta-LAAS)	**Flight FRA 08/06**	FAA, ASA and Boeing, **Flights FRA 01/06 and 04/05**	**Planned for 2007**	FAA and continuously (static) by DFS, **FRA 04/05, 01/06**
Honeywell SLS-3000 Beta LAAS Plus (Provably safe prototype)	Planned for 2007 in Bremen and Malaga (OPTIMAL)	FAA with GNLU 930 in Memphis Sept. 06 and planned for 2007 in Bremen and Malage	**Planned for 2007**	Planned for 2007 in Bremen and Malaga
Honeywell SLS-4000 (production)	planned for 2008/9 in Bremen and 2008 in Sydney	Planned for 2008/9 in Bremen and 2008 in Sydney	Tbd	Planned for 2008/9 by DFS in Bremen
Thales AS615 (prototype)	Airbus flights, **Flights TOU 09/06**	Continuous (static) monitoring by DSNA/DTI, **Flights TOU 09/06**	**Planned for 2007**	continuously (static) by DSNA/DTI **Flights TOU 09/06**
NPPF-Spektr LCCS-A-2000 (production)	**Planned for Brauschweig 11/06**	**Planned for Brauschweig 11/06**	Internally by NPPF-Spektr	Internally by NPPF-Spektr **Planned for Brauschweig 11/06**,
Experimental Ground Stations	Post-processed by TUBS in 2006 (PEGASUS)	Boeing, FAA, and Ohio University (with GNLU 930) **FRA 04/05 and 01/06**	**Tbd**	Diverse experiments worldwide

Table 2: Table 1 with EUROCONTROL trials added

For area 3) Amendment 81 to Annex 10 allows the use of FAS information stored in the onboard database for GRAS APV-1 approaches, as well as its transmission over the GBAS VDB datalink. Other GBAS approach FAS data may be stored onboard for flight planning purposes as well. In addition the FAA has indicated that WAAS may be able to provide APV services to 200ft decision height, further blurring the distinction between performances of SBAS and currently standardized GBAS services. Analyzing the differences in pilot indication for SBAS and GBAS approaches using the same FAS path is thus one of the test objectives.

4 Trials Status

After initial static and dynamic ground tests for equipment verification in May 2005 on the Frankfurt/Main International Airport, the experiment campaign has started in January 2006 with a series of 50 approaches to the regional airport of Egelsbach, within coverage of the DFS-operated GBAS ground station in Frankfurt. Airspace restrictions and traffic have required dynamic maneuvers, testing equipment limits and VDB coverage models could be verified, as well as improvements in the aircraft installation identified. Ground station limitations, due to its upgrade path from an S-CAT prototype, were identified, but did not pose issues for the aircraft performance. A second campaign dedicated to identifying possible effects of aircraft orientation on SBAS approaches also showed no significant effects.
The improvements for the aircraft installation have been validated in a flight test campaign in Toulouse in September 2006, where another 48 approaches were performed, this time providing a direct comparison between ILS, GBAS and SBAS guidance.

The receiver and data recording setup was relatively complex, with redundancy and dissimilar receivers used as far as possible.

On the ground side, raw data from the GBAS station was collected, as well as data for GPS carrier-phase based truth reference systems, using three different receiver types. SBAS and GBAS VDB data were collected as well.

In the aircraft the two versions of the GLS-925 were installed using separate GPS and VDB-Antennas with a dedicated VDB-receiver and experimental GPS/SBAS receiver for each, sharing the respective antennas. For some tests a third GPS/SBAS receiver and a Garmin GNS-480 receiver with EGNOS-adapted software were also installed. INS, ILS, air data and other sensors were recorded together with all outputs of the GNSS, MMR and VDB receivers. Figure 1 shows the Dornier Do128-6 research aircraft used in the trials.

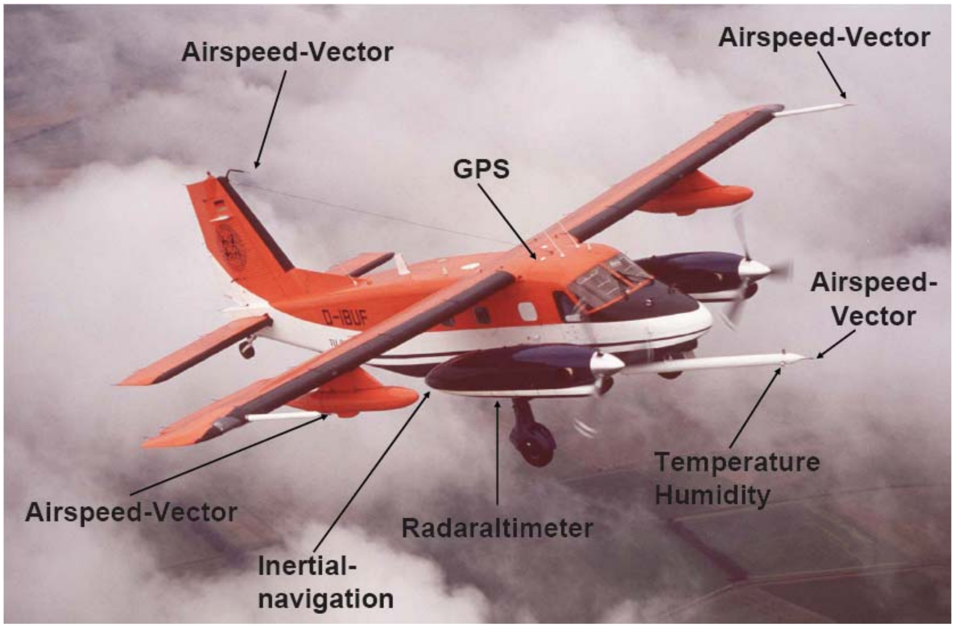


Figure 1: Aircraft used in the EUROCONTROL trials

Although data evaluation is still in a very early stage and results have not yet been corrected for certain data acquisition errors, the following figures show the good coherence between the guidance of the different systems.

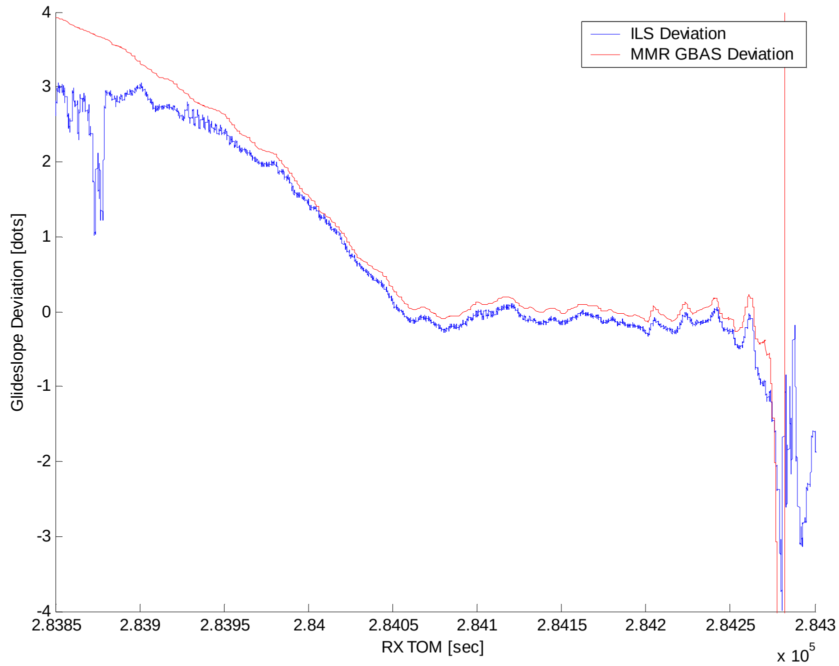


Figure 2: Vertical angular deviation over time for GBAS and ILS during one approach

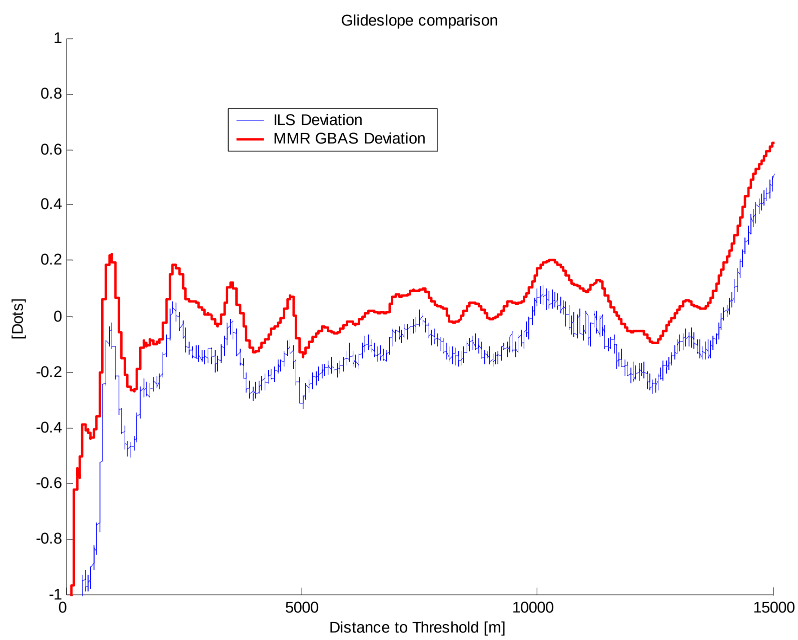
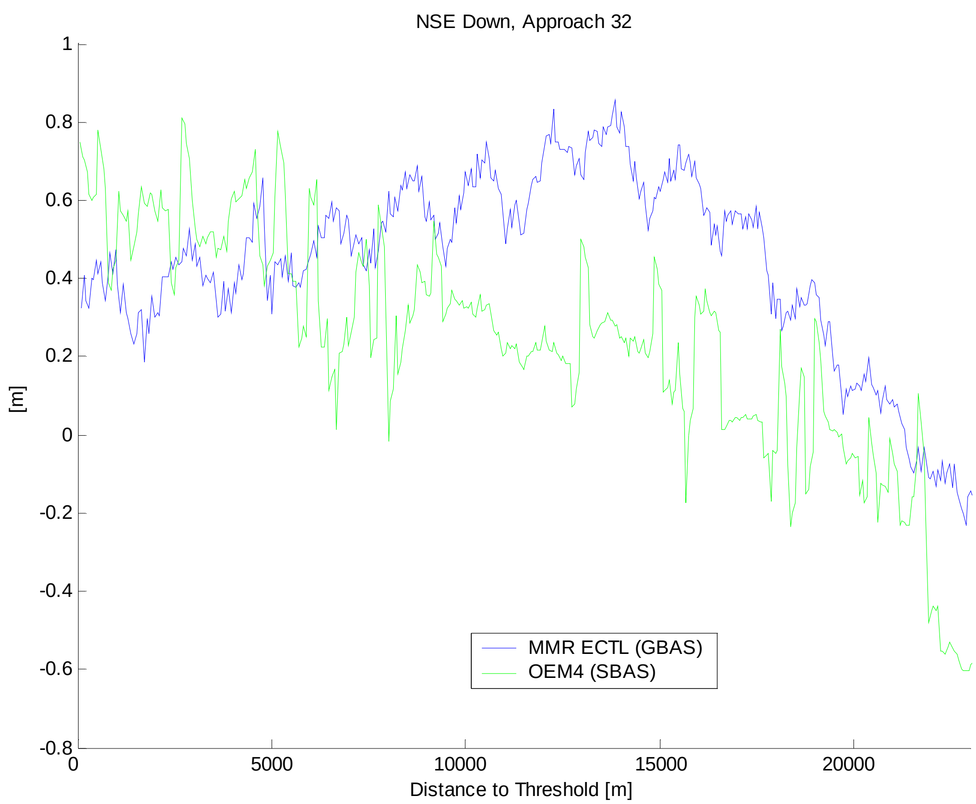


Figure 3: Extract of the information of Figure 2

The approach presented was flown using the experimental GBAS indications, with the safety pilot monitoring the certified ILS system. Clearly visible are the differences in the early capture phase, where ILS display is limited to +/- 3 dots, the good cohesion during capture and the approach and the sharp drop to negative deviations when initiating the go-around at approximately 20ft. After passing the glidepath antenna, ILS glidepath deviations become erratic, while the GBAS deviation output stops after having passed the Vertical Guidance Availability Region (VGAR). Also visible is the increase in guidance sensitivity in the last phase of the approach, leading to increased FTE through overcorrection in this manually flown approach. Lever arm corrections have not yet been performed, thus the slight offset between the graphs. RXTOM indicated GPS-Timescale as estimated by the airborne receiver. Figure 3 shows this in more detail as function of distance to Threshold.

Figure 4 shows the vertical Navigation System Error for GBAS and SBAS for the same approach. Both receivers were connected to the same antenna and the OEM 4 raw SBAS data were post-processed using the PEGASUS tool in accordance with DO-229c, acknowledging the test-mode status of the EGNOS system. The GBAS graph shows oscillations resulting from the manually flown approach and incomplete lever arm corrections with respect to the reference trajectory system. Both SBAS and GBAS errors are well within the CAT I requirements and always were below the protection levels.



<u>Figure 4:</u> Vertical NSE of GBAS and SBAS guidance for the example approach

5 Outlook

As of the writing of this paper, preparations for a temporary installation of the NPPF-Spektr GBAS ground station at Braunschweig research airport are being finalized for a campaign to be conducted in November/December 2006 with an identical aircraft installation and similar objectives as for the previous trials.

The reports of the measurement campaigns in spring 2006 are under final review and are planned to be published in December 2006. The data gathered in the campaigns of fall 2006 is being analyzed and results will be published in early 2007. Further campaigns as indicated in the Summary table are foreseen for 2007 and 2008 to complete the analyses.

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