Enabling LPV for GLS Equipped Aircraft Using a SBAS to GBAS Converter

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ABSTRACT

We build a prototype system intended to bring together the advantages of both the ground based and satellite based augmentation systems (GBAS, SBAS). It combines an SBAS-capable global navigation satellite systems receiver with a database and a GBAS-compatible data link. The correction and integrity data received from the SBAS satellite are automatically translated into GBAS-compatible structures and sent to the airborne multi-mode receiver using the final approach segment data block. As commercial air transport aircraft are rarely equipped with SBAS capable receivers but are increasingly fitted with GBAS receivers our System adds the SBAS capability to a GBAS equipped aircraft. Here, we present data collected during airline trials in the summer of 2022.

I. INTRODUCTION

We built a prototype system intended to combine the advantages of both the ground based and the satellite based augmentation systems (GBAS, SBAS). The system includes an SBAS-capable global navigation satellite systems receiver with a database and a GBAS-compatible data link. The correction and integrity data received from the SBAS satellite are automatically translated into GBAS-compatible structures and sent to the airborne GBAS receiver using the final approach segment data block. In both GBAS and SBAS, instant integrity information is provided by estimating protection levels, a high probability bound for the computed position. This is then compared to the alert limit of the respective system. Since both systems are quite similar, and the SBAS signal can nowadays be decoded by even low cost receivers, one can receive the augmentation data from the SBAS, slightly modify it to fit into the GBAS data structure and broadcast this data to a GBAS equipped aircraft. Said aircraft could execute a RNP approach with the Localizer Performance and Vertical guidance (LPV) final approach segment which would otherwise not be available. This may come especially handy in places where no non-precision minima are published, such as the RNP-E approach into Innsbruck. Since there are slight differences between the two systems, we made sure that integrity for the safety-of-life approach service is ensured. We named the system GLASS (GLS Approaches using SbaS), built a prototype and tested it with real GBAS avionics hardware. We implemented the system in C++ on a 64 bit Linux PC and connected this PC to a Telerad VDB Transmitter. The necessary correction data was obtained from a Septentrio AsteRx3 GNSS receiver. The technical details such as proctection level mapping and integrity assurance are already described in detail in Dautermann et al. (2020) and are not repeated here.
A similar concept was initially proposed by Rife et al. (2006) or Shively et al. (2006) as the "bent pipe" concept of the wide area augmentation system but with the aim of providing category 1 approach service via a GLS data link. We make use of the GBAS approach service type A (GAST-A) that was originally intended for Australia's ground based regional augementation system GRAS Crosby et al. (2000). GRAS was thought to provide the ICAO approach with vertical guidance (APV) service which is the same provision as for the LPV final of any RNP approach.

We installed GLASS prototype stations at the airports of Kekyra and Thessaloniki in Greece. Both airports have RNP approaches to runways that are not equipped with any precision approach procedured. Dautermann et al. (2021) and Dautermann and Ludwig (2022) describe the initial validation experiments using DLR flight test aircraft.

II. AIRLINE TRIALS

During 2022 we asked airlines operating GLS equipped aircraft to evaluate the GLS guidance provided by GLASS during regular line operations. We received feed back from two 737 operators. The pilots were flying the regular RNP approach procedures to Kekyra's and Thessaloniki's runways 34. Both runways are not equipped with precision approaches. The appropriate GLS channel was tuned by the pilot, which caused GLS deviations to be displayed as ghost pointers in white behind the navigation performance scales of of the RNP guidance.

The pilots had thus the oportunity to evaluate the guidance provided by the GLASS system with respect to the LNAV/ Baro VNAV guidance of the RNP approach. Figure 1 shows the primary flight display (PFD) and Navigation Display (ND) of a 737 on approach to Thessaloniki on final approach track shortly before waypoint CEFEB. In the Multifunction Control and Display Unit (MCDU) on the lower right, we can see that the cross track total system error of the navigation system is 0.02 nautical miles (37.04m). The aircraft is 32ft below the calculated path. Even though the plane is low on the barometric vertical path, it

Table 1: List of Flights in the Airline Trials

Flight number	Date	OAT [°C]
FR5336	2022-08-01	32
FR5526	2022-08-01	28
X34468	2022-08-02	27
FR5336	2022-08-01	27
FR5526	2022-08-01	25
FR3094	2022-08-02	24
FR3564	2022-08-05	35
FR5336	2022-08-05	34
FR3094	2022-08-09	32
FR3094	2022-08-11	33

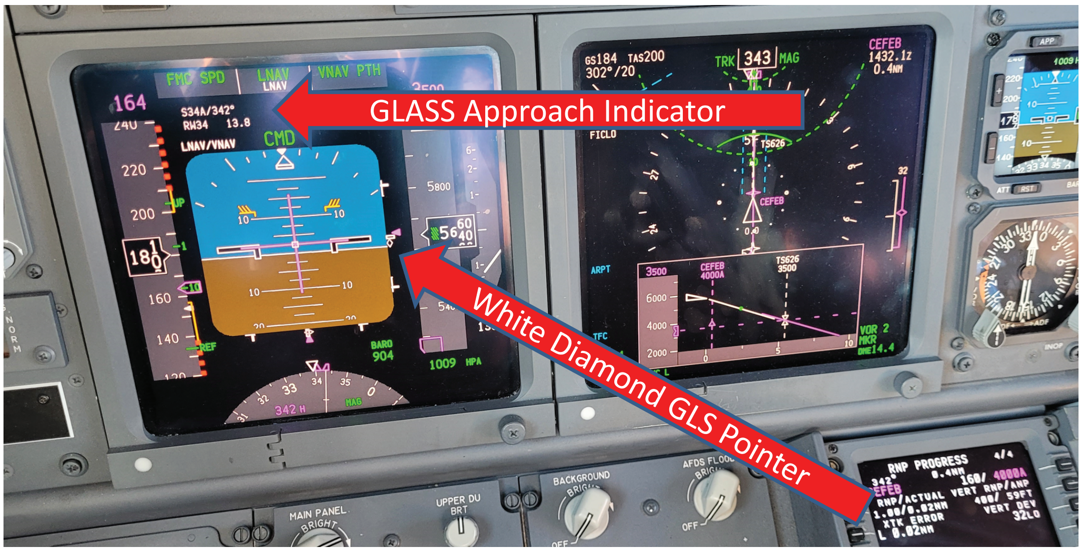

Figure 1: GLASS tune in "shadow" mode during the RNP approach

is still above the GLS computed glide path. Since all flights were conducted during the summer with temperatures well above the international standard atmosphere temperature of 15^oC this is expected as a warmer atmosphere is less dense and hence the altimeter overreads. The GLS guidance is reference to the WGS84 ellipsoid (see Malys and Slater (1994)) and independent of temperature variations. Table 1 shows a list of all shadow mode trials of 2022.

Figure 2 shows the results of the questionnaire provided to the pilots. In general the lateral track provided a good match between the RNP guidance and the GLS guidance. Vertically due to the warm weather, the GLS glide path was mostly below the barometrically calculated vertical guidance. Overall, the system performed as expected and predicted by our previous work. Naturally, with only ten flights, rare continuity and integrity events could not be observed.

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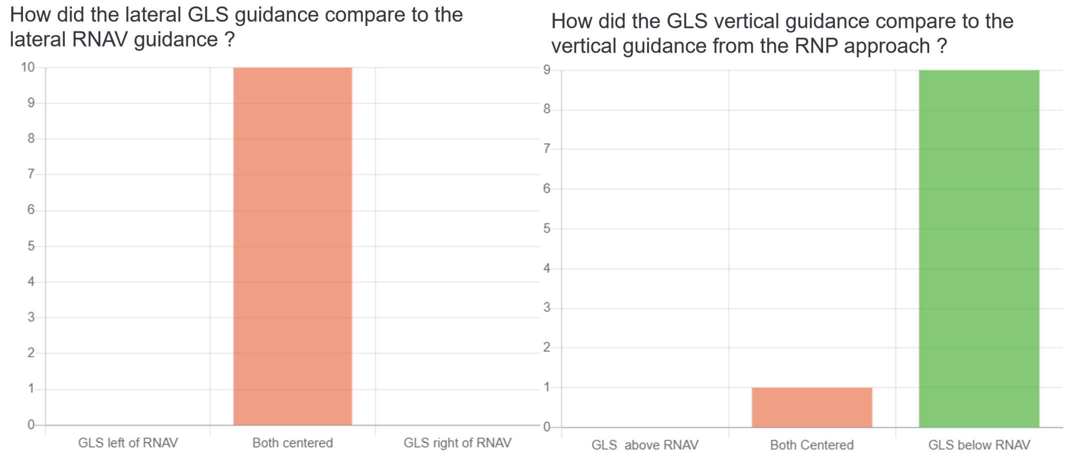

Figure 2: Results of the airline trials

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