Making the Case for GBAS

Experimental Aircraft Approaches in Germany

TU Braunschweig IFF Research airplane

Several satellite-based augmentation systems for improving GNSS accuracy and integrity to assist aircraft approach and landings are well under way around the world. Their ground-based counterparts (GBAS) are also being developed. As this article reveals, Braunschweig, Germany, is becoming one of the focal points for GBAS activities in Europe.

ULF BESTMANN
PER M. SCHACHTEBECK
THOMAS FEUERLE
PETER HECKER
TECHNICAL UNIVERSITY OF BRAUNSCHWEIG,
INSTITUTE OF FLIGHT GUIDANCE

Aircraft landing procedures based on satellite navigation systems are being used in the United States with the aid of the Federal Aviation Administration's Wide Area Augmentation System (WAAS). These procedures offer the opportunity to land in APV-I (approach procedure with vertical guidance, Level 1) conditions.

However, performing landings in adverse weather still requires — at least for the moment — the assistance of an instrument landing system (ILS). Ground-based augmentation systems (GBAS, or local area augmentation systems — LAAS — as they are called in the United States) are expected to play an active role in the safe landing of aircraft in low-visibility conditions. Certification of GBAS Category I (CAT I) procedures seems to be only a matter of time.

The Research Airport in Braunschweig, Germany, plans to participate in related investigations with a certification of CAT II/III systems ultimately in mind. Consequently, the German national aeronautical research agency (DLR) has started an acquisition process

for such a system. This acquisition effort is supported by the Institute of Flight Guidance (IFF) of the Technical University of Braunschweig, which owns a research aircraft, a Dornier Do128-6 with a wide range of navigational and atmospheric sensors.

This article describes some of the initial development work in support of Braunschweig's GBAS initiative.

Getting Ready

The first preparatory test trials were performed in the autumn of 2005 without GBAS-capable equipment. Four stationary reference receivers collected GPS data while a number of ILS approaches were flown. During postprocessing, we calculated deviations of the airborne receivers' positions from a previously self-constructed (i.e., not released by the air navigation service provider), desired flight path based on waypoints. This desired flight path and the processing after the flights were done with EUROCONTROL's PEGASUS software and our own postprocessing software (see Figure 1).

These software tools produced GBAS-like outputs (e.g., DGPS position, protection levels, and guidance information). The carrier phase–based reference track was generated using a commercial software. The results of the comparison of the GBAS guidance with those of the ILS were promising, with horizontal errors of less than two meters and vertical errors less than four meters at the CAT
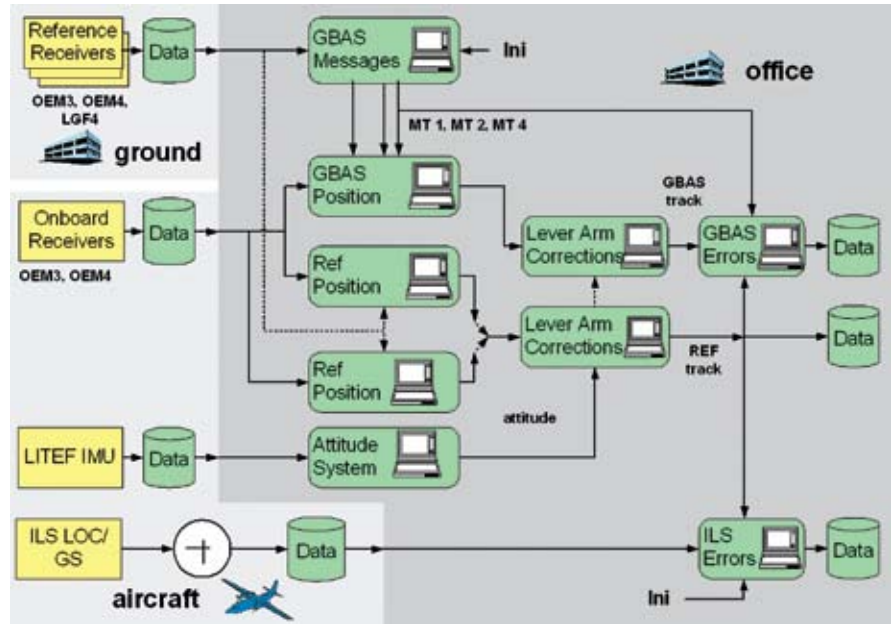

FIGURE 1 Postprocessing procedure

I decision height. Below this threshold a significant vertical offset between ILS and GBAS guidance appeared.

We believe this offset can be corrected by introducing additional parameters to the deviation calculation as shown in Equation 1. With the parameters DGERP and dGERP set to appropriate values for the geometry of the ILS installed at the Braunschweig Research Airport, vertical deviations even below the CAT I decision height until the flare maneuver can match ILS performance.

$$r_{GERP}^{ECEF} = r_{LTP}^{ECEF} + \left(\frac{TCH}{\tan(GPA)} + D_{GERP} \right) u_{rw}$$
$$+ d_{GERP}\, u_{lat}$$

From the pilot's point of view — and ignoring aspects of integrity and continuity for the time being — CAT II/III approaches down to the corresponding decision heights are possible.

Egelsbach Trials

In January 2006 the IFF conducted GBAS flight trials in the vicinity of Frankfurt/Main, Germany, at the Egelsbach Airport under contract with EUROCONTROL, which loaned a multimode receiver (MMR) for the test. With the assistance of the Deutsche Flugsicherung GmbH (DFS), Germany's air navigation service provider,

the Frankfurt GBAS ground station transmitted the required GBAS message types.

From the final approach segment (FAS) data blocks in those Frankfurt airport messages, the desired flight paths for the nearby — and less frequented — airport of Egelsbach can also be calculated, thereby showing the advantage of providing service to local airfields. At the time of writing, flight tests at the GBAS ground station in Toulouse are being performed and evaluated with a second MMR on board of the same type owned by the IFF.

All campaigns have been performed with MMRs and multiple high-end GPS receivers using different antennas in conjunction with inertial navigation systems (INS). With this setup, the trajectories of the various antennas can be transformed into one guidance reference point and directly compared.

For the two campaigns under contract with EUROCONTROL, an own-reference station has been established at the corresponding airports (Egelsbach/Toulouse) for carrier-phase positioning in addition to the commercial GBAS ground station under investigation (Frankfurt/Main and Toulouse, respectively). With this setup a wide range of settings can be compared.

ApproachtoBraunschweig
Research Airport

IFF designed an experimental cockpit display for the flights. As illustrated in Figure 2, the display incorporates a combined glideslope (GS) and course direction indicator (CDI) instrument as well as a horizontal and vertical view of the flight path. Pilots have used these instruments to perform the experimental approaches. Figure 2 also shows the experimental GBAS approaches inbound to Egelsbach (courtesy of DFS GmbH).

Results

Figure 3 shows a histogram of the deviations between the track provided by the MMR and a reference track calculated by commercial off-the-shelf real-time kinematic (RTK) software using data from the first day of the Egelsbach Airport flight trials. The plot indicates that the navigation system error (NSE) was lower than one meter most of the time, but some approaches had deviations of about two meters and even some larger outliers. Further investigation revealed that these larger deviations did not stem from errors in the GBAS trajectory but rather were due to substantially incorrect or unsolved carrier phase integer ambiguities.

The onboard equipment provides three kinds of protection levels for positioning accuracy: horizontal (HPL), vertical (VPL) and lateral (LPL). Figure 4 shows the NSE together with the corresponding protection levels of a typical approach against the distance to threshold. The figure data clearly shows that, during the entire approach phase, the NSE remains well inside the protection levels. Overall, at the Egelsbach airport trials the approaches all easily met required performance as the respective alert limits transmitted by the GBAS ground station are at least 10 meters.

An important aspect of the flight trials was to demonstrate performance of the GBAS philosophy on a so-called "remote airport," where the GBAS ground station is located at a different place. At Egelsbach the ground station is located at Frankfurt Airport with an approximate distance of 12 kilometers between the GBAS ground station and the landing runway threshold.

A problem with the remote operation of GBAS ground stations is the coverage of the VHF data broadcast (VDB) signal. Due to shadowing problems, no reli-

able VDB reception existed at Egelsbach airport after passing the decision height of 200 feet, which corresponds to CAT I operations.

The flight trials have demonstrated that, even during highly dynamic maneuvers, the desired flight path can be followed without difficulty. Further investigations will be made regarding the VDB coverage of the GBAS ground station as well as the influence of the aircraft thereupon.
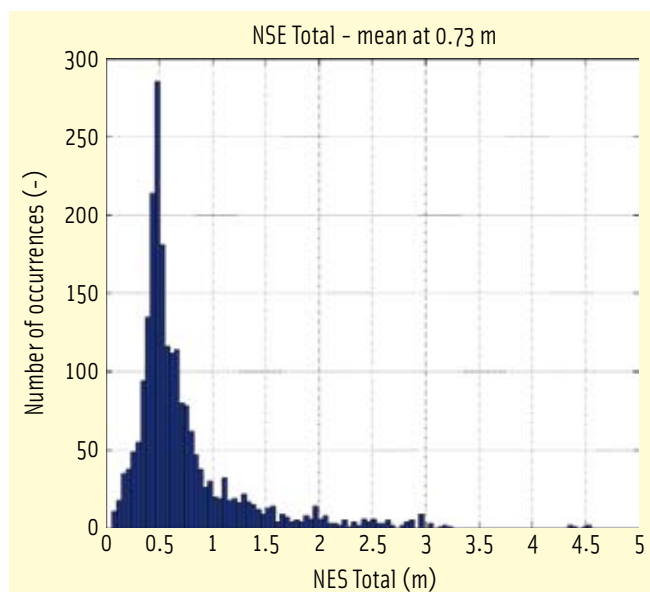
Acknowledgements

FIGURE 2 Flight Display

FIGURE 3 Navigation System Errors, Jan. 23, 2006, flight trials

End of a day of flight tests at Egelsbach.

for their work during data analysis, to DFS for the procedures, Andreas Lipp for his assistance, and messWERK GmbH for the visualization.

Manufacturers

For the flight tests described in this article, OEM-3 and OEM-4 GPS receivers from **NovAtel, Inc.**, Calgary, Alberta, Canada, were used on the aircraft for navigation and as ground reference receivers, using various NovAtel antennas with a passive splitter. The multimode receivers used were GLU-925-330s produced by **Rockwell Collins**, Cedar Rapids, Iowa, USA — one in a Boeing and one in an Airbus configuration. The carrier phase–based reference track was generated using Trimble Total Control software from **Trimble**, Sunnyvale, California USA.

Additional Resources

[1] "Preparation for GBAS at Braunschweig Research Airport – First Flight Test Results," P. Hecker, P. Schachtebeck, T. Feuerle, U. Bestmann, C. Butzmuehlen, ION NTM 2006 Monterey, California, USA

[2] Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment, RTCA DO 253A, RTCA, November 2001, Appendix C

[3] "GBAS Flight Testing and Performance Assessment," P. Hecker, P. Schachtebeck, T. Feuerle, U. Bestmann, CERGAL 2006

FIGURE 4 Protection Levels and NSE for Approach #13, Jan. 23, 2006

Authors

Dipl. Ing. Ulf Bestmann has been employed as research engineer at the Technical University of Braunschweig, Institute of Flight Guidance since 2003. He works in the areas of applied satellite and inertial navigation, real-time measurement systems, and visualization. In 2005 he established the company messWERK GmbH together with three colleagues.

Dipl. Ing. Per Schachtebeck is a research engineer of the Institute of Flight Guidance of the TU Braunschweig, where he received his diploma. His main responsibilities are in the field of satellite navigation, especially ground-based augmentation systems.

Dipl. Ing. Thomas Feuerle is employed at the Institute of Flight Guidance of the Technical University of Braunschweig as a scientist and pilot for the research aircraft and has participated in several flight trials. Besides the flight activities he works in the field of system integration into the aircraft and development of software components for the on-board real-time data acquisition and processing system.

Prof. Dr. Ing. Peter Hecker is the director of the Institute of Flight Guidance of the Technical University of Braunschweig since April 2005. He manages research activities in the areas of air/ground cooperative air traffic management, airborne measurement technologies and services, satellite navigation, human factors in aviation, and safety in air transport systems. **IG**
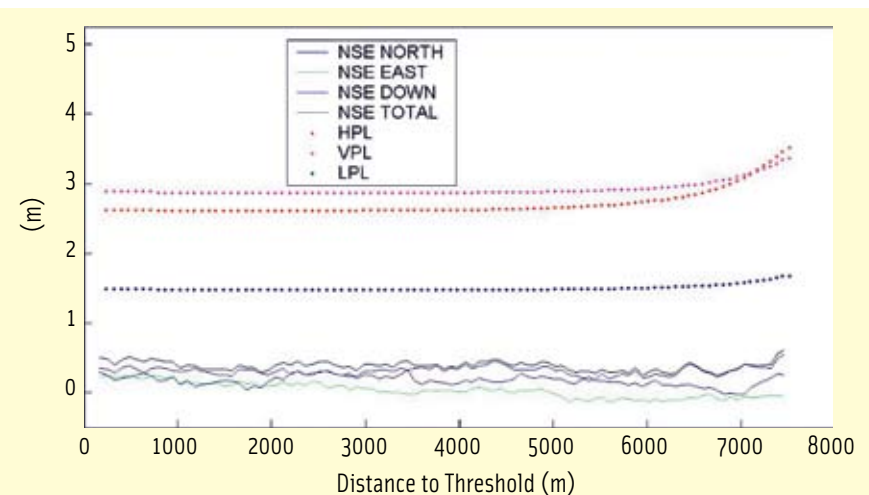
The Technical University of Braunschweig, Institute of Flight Guidance, will take part in the Focus GNSS presentations at the CeBIT conference March 15-21, 2007, in Hannover, Germany <http://www.cebit.de/>.