Welcome to Frankfurt
Overview

- GBAS Ground Station
- SESAR, SESAR 15.3.6
- Frankfurt Airport GBAS sites
- GBAS CAT I (GAST C) Installation
- GBAS CAT III (GAST D) Installation
- GBAS Monitoring Site & Systems (IGM, GIMOS)
- GBAS Ground & Flight Testing, SIS Validation
Early DGPS Ground Station Experience of DFS

D910, Munich
1995

D920, Frankfurt
1998

SLS-3000, Frankfurt
2000

GBAS Bremen - DFS GBAS CAT I Pilot Project

03/2005 Project Kickoff
04/2007 Honeywell SLS-3000+ in Bremen
  Operational trials TuFly
11/2008 Red label SLS-4000 in Bremen
  Operational Trials Air Berlin
08/2009 new German regulator (National Supervisory Authority)
09/2009 FAA SLS-4000 System Design Approval (SDA)
11/2011 German SLS-4000 type approval
12/2011 EC Declaration of Verification 'Nav system airport Bremen'
01/2012 Final VDB frequency license
01/2012 GBAS safety assessment
02/2012 maintenance interface (NLS) approved
02/2012 DFS Technical Acceptance & Operational Acceptance
02/2012 public ICAO GBAS CAT I service without restrictions
  Full Operational Use by Air Berlin
07/2012 ATC interface in Bremen finalized (IDVS, ATC ISS)
1st GBAS CAT I for Regular Air Service in the World

Feb. 09, 2012: first GLS landing using fully certified GBAS ground system - Air Berlin Boeing 737-800 in Bremen

GBAS Principle & Architecture
GBAS - Differential GPS Principle

GBAS - System Overview

GBAS ground subsystem has 2 - 4 precisely surveyed GNSS reference antennas
GBAS Architecture - Ground Station Example

Frankfurt GBAS CAT I (GAST C) Station 5/2014

4x GPS reference antenna
RH circular pol. GPS L1, L2, L5 (1.4m mast)

SLS-4000 cabinet redundancy (dual-dual)
2x VDB Tx, 2x VDB Rx

1x VDB Tx antenna
116.425MHz, slot E,G (13.6m mast)
SESAR

Single European Sky ATM Research - Program by EC, ECTL

- **Goal**
  - Modernization of the European ATM system by coordinating and concentrating all relevant research and development efforts with a view to harmonizing implementation.

- **Phases**
  - definition phase (2005 - 2008)
  - development phase (2008 - 2013)
  - deployment phase (2014 - 2020)

- **Performance targets for 2020**
  - enable a threefold increase in capacity
  - improve safety by a factor of 10
  - reduce by 10% the environmental impact per flight
  - cut ATM costs by -50%
Frankfurt Airport - GBAS Sites

GBAS CAT I (GAST C) Site, Honeywell SLS-4000
- new ground station shelter (building 842)
- 4 GPS reference antenna sites (>100m)
- 1 VDB transmit antenna site (10m)

GBAS GAST D Site, Indra Navia Normarc 8100
- ground station shelter (ILS Marker 07R, building 844)
- 4 GPS reference antenna sites (50…200m)
- 1 remote VDB shelter & VDB transmit antenna site (250m)
- 1 GNSS Interference Monitoring System

Monitoring Site in 6.1 km distance from ground station
- building 101 is highest building in this part of the airport
- direct line of sight to old runway system
- green roof (grass, limited multipath)
- 6 GNSS antennas, 2 VDB antennas
- 2 IGM - Independent GBAS Monitor Systems
- Novatel base station from Honeywell (reference path)
**SESAR 15.3.6 Prototype Phase 2 Installation 2014**

Indra RRA#4

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**SESAR 15.3.6 Frankfurt GAST D Station 5/2013**

4x GPS RRA (1.2m mast)
Normarc 8100 GBAS ground station rack (no redundancy)
Normarc 8100 GBAS VDB rack (no redundancy)
1x VDB Tx antenna 116.55MHz, slot A.B.C (12.6m)

250m data cable
SESAR 15.3.6 Prototype Phase 2 Installation 2014

DFS Monitoring System - IGM

**Independent GBAS Monitor**
- 2 different GNSS receivers (SF GPS & DF SBAS)
- VDB ground station data link receiver
- Online GBAS CAT I + CAT III receiver simulation
- Certified GBAS CAT I MMR

in mobile (laptop) or stationary configuration (server) to support
- GNSS data recording (ICAO SARPs Att. D.11)
- GNSS performance assessment (ICAO SARPs Att. D.12)
- GBAS ground testing (ICAO Doc 8071 Vol. II, 4.2)

2005 IGM development started
2010 update of server & laptop HW & operating system
2011 GAST D update phase 1 (HETEREX)
  - handling of new GAST D message types
  - add online GAST D receiver simulation (algorithms TU BS)
2012 IGM testing Bremen (CAT I), Braunschweig (GAST D)
2013 IGM verifying Frankfurt SESAR 15.3.6 phase 1 GAST D GS
2014 GAST D GS update phase 2 (SESAR 15.3.6)
DFS Monitoring System - GIMOS

GNSS Interference Monitoring System
- programmable real time spectrum analyzer
- TSO C-129 certified GPS receiver
- embedded PC
to support mobile and stationary measurements of
- GNSS interference (GPS NPA, SBAS, GBAS)
- VDB interference (GBAS)
- VDB field strength (GBAS)

1998 GIMOS I development started (GNSS interference)
2000 GIMOS II second generation introduced
2006 GIMOS II VDB capabilities added
2011 GIMOS III development for VDB measurements started
  - new hardware (PC, spectrum analyzer)
  - update software capabilities
2012 GIMOS III testing Bremen (CAT I), Braunschweig (GAST D)
2013 GIMOS III validating Frankfurt SESAR 15.3.6 GAST D GS
2014 GIMOS IV add GNSS interference capabilities

VDB Measurements - VDB Transmitter Setup

VDB transmitter setup to support
- Lab measurements
  - improve setup for unwanted emission & adjacent channel measurements (ground testing, type approval)
  - develop frequency coordination criteria (SESAR 15.3.6)
- Testing of the DFS measurement systems (IGM, GIMOS)
- Site measurements
  - Munich 2010 – VDB site survey for GBAS CAT I (ground & flight measurements)
  - Frankfurt 2011 – VDB ground coverage for GBAS CAT II/III (GAST D, SESAR 15.3.6)
  - Zurich 2011 – support Skyguide in VDB site survey for GBAS CAT I (ground measurements)
  - Frankfurt 2013 – VDB site survey for GBAS CAT I and Prototype GBAS CAT III (GAST D)
GBAS Ground Testing

- GBAS ground testing divided into blocks
  - GNSS interference (GIMOS)
  - Survey of antenna phase center position (geodetic equipment)
  - RF measurements (Tektronix RSA 6114A)
  - VDB runway coverage & interference (IGM, GIMOS)
  - FAS data check on runway thresholds (IGM)
  - Performance evaluation & data content (IGM)

- Matrix in DFS maintenance directive to allow more flexible response to certain maintenance activities

GBAS Flight Testing - Flight Inspection Aircraft

GBAS CAT I flight inspection performed by FCS (Flight Calibration Services, Braunschweig)

- Certified flight inspection aircraft King Air 350
- Certified flight inspection system (FIS)
  - modified GBAS MMR integrated
  - MMR guidance signal can be switched to primary avionics incl. autopilot
  - FIS software is now GBAS capable
- Licensed crew (pilots, FI engineer)

- 02/08/2011 First GBAS flight inspection in Europe with certified aircraft, equipment and crew performed in Bremen
  - participation of BAF representative
- 30/09/2011 final flight inspection report

source: FCS
SESAR 15.3.6 - Site Survey Taxiway Coordinates

SESAR Phase 2 Ground Compatibility Testing
SESAR 15.3.6 - GBAS Ground & Flight Testing

GIMOS III onboard the aircraft (Dornier Do 128-6, TU Braunschweig)

VDB Ground Coverage Runway 25L/07R (GAST D)
### T18 - SIS Verification Phase 1 & Phase 2

- **Input:** Verification exercises prepared in T16 “System Validation Plan”
- **Output:** Documented verification of the GS - “15.3.6 D18 Implementation and SIS Verification Report Site 2 - V1.1 - 30.09.2013 (Phase 1).pdf”
- **Summary of the verification exercises performed in 2013 (1)**

<table>
<thead>
<tr>
<th>Exercises</th>
<th>Short Description</th>
<th>Example Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXE-15.03.06-VALP-SITE.0001</td>
<td>Siting measurements - reference antenna phase center position - distance of the GBAS reference point to approach threshold points ≤ 5km - reference antenna multipath analysis</td>
<td>Antenna 1 – CMC Analysis</td>
</tr>
<tr>
<td>EXE-15.03.06-VALP-SITE.0002</td>
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<td></td>
</tr>
<tr>
<td>EXE-15.03.06-VALP-SITE.0003</td>
<td></td>
<td></td>
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</tbody>
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**JULY 2014**

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### GAST D Ground Station Performance

- **Stanford Plot, 72h**
  - 100% availability, no MI, HMI

- **Ground Accuracy Designator Plot, 1 week**
  - GAD C4 in 100% of the time

**JULY 2014**