

International Flight Inspection Symposium

Oklahoma City, OK USA June 2008



Flight Inspecting GBAS

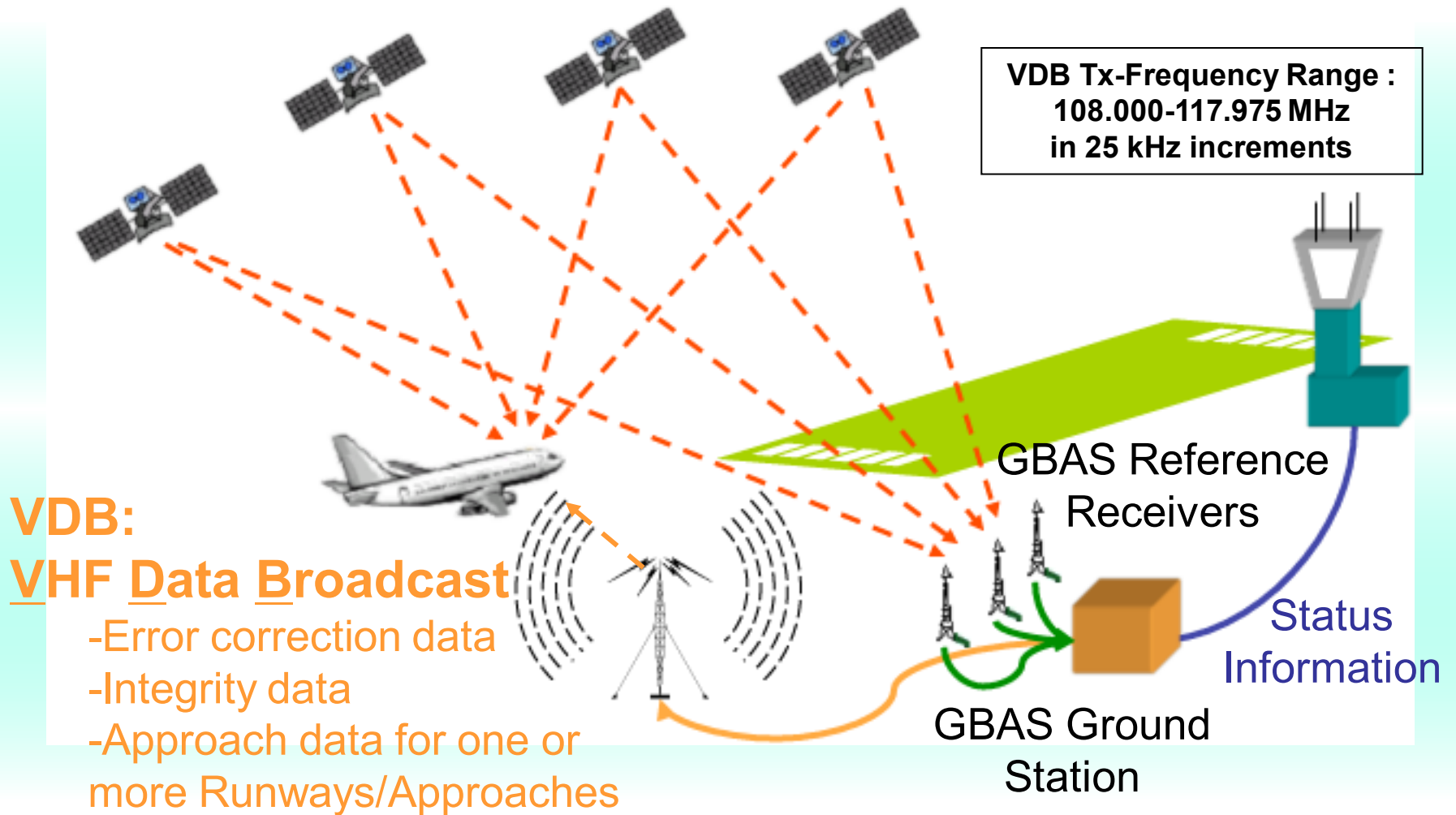
Thorsten Heinke
Aerodata AG
Thomas Feuerle
IFF TU Braunschweig

Flight Inspecting GBAS

Overview

- Basics
- Requirements
- Equipment
- Flight Testing
- Conclusion


Basics



Basics

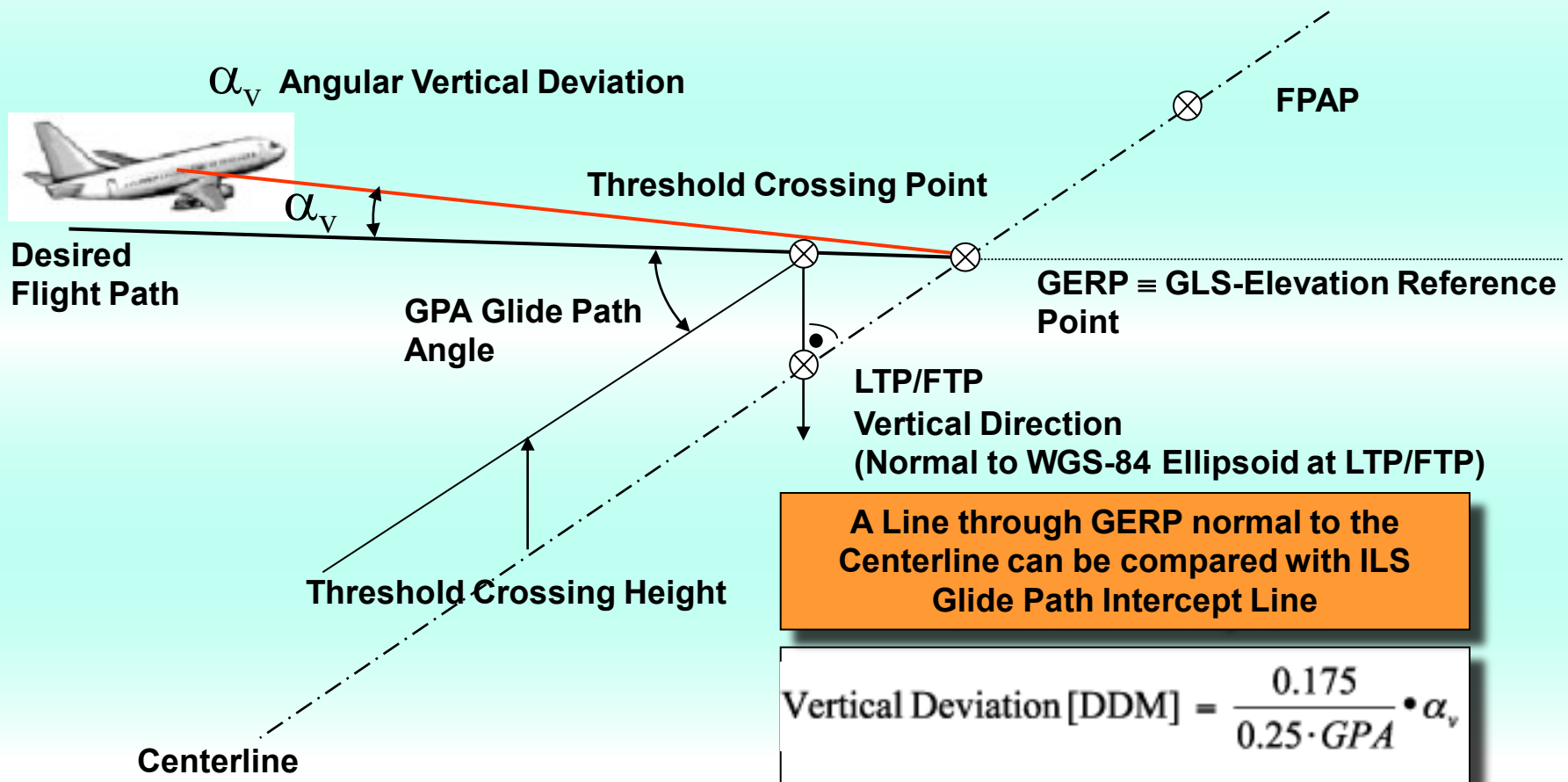
VHF Data Bradcast (VDB) Messages



- **Type 1:** Differential Error Correction Data
 - **Type 2:** Differential Reference Point Data
(Integrity Data)
 - **Type 3:** Reserved for GBRS Ground Based Ranging Source
(Airport Pseudolites)
- 
- **Type 4:** FAS Final Approach Segment Construction Data for
one or more Runways/Approaches
 - **Type 5:** Ranging Source Availability (optional)
 - **Type 6:** Reserved for Carrier Corrections
 - **Type 7:** Reserved for Military
 - **Type 8:** Reserved for Test

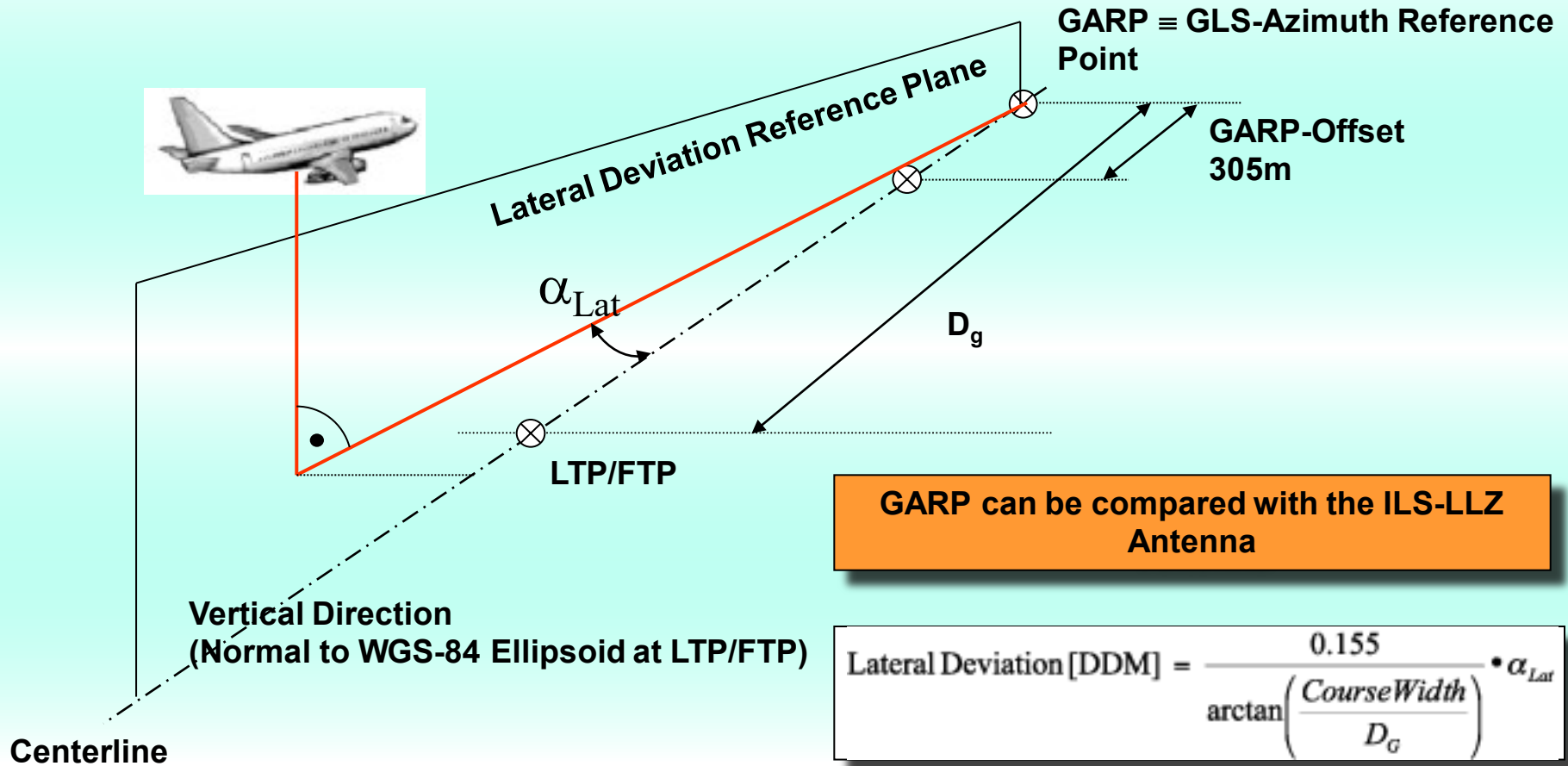
Basics

GLS (GNSS Landing System) Vertical Deviation



Basics

GLS (GNSS Landing System) Lateral Deviation



Requirements

What influences the Performance/Precision of GBAS?

- **Signal of GBAS – Ground Station**
 - Coverage
 - Interference
 - Incorrect FAS-Data
- **Availability of Satellites at the Ground Station**
 - Satellite Masking
 - Multipath
 - Interference
- **Availability of Satellites at the Aircraft**
 - Satellite Masking
 - Multipath
 - Interference
- **Satellite Constellation**
 - DOP

Requirements

When is Flight Inspection required?

- Prior to commissioning on each runway served and for each approach
- Whenever interference is reported or suspected and ground testing cannot confirm elimination of the source of interference
- As a result of a procedure modification or the introduction of a new procedure
- Whenever changes occur to the GBAS configuration such as the location of the GBAS ground subsystem antenna phase-centre, the location of the data link transmit antenna, or the system database
- Whenever site changes such as new obstructions or major construction occur that have the potential to impact GNSS signal reception and data broadcast transmission
- After certain maintenance activities

Requirements

What should be inspected on ground

- Data Contents
 - FAS
 - Horizontal Tolerance: 0,4m horizontal, uncertainty 0,05m
 - Vertical Tolerance: 0,2m vertical, uncertainty 0,05m
 - Integrity Data
 - Differential Correction Data
- Runway surface coverage
($> -99 \text{ dBW/m}^2 < -35 \text{ dBW/m}^2 @ 3,7\text{m} / 12\text{ft}$ above runway)
- Availability of Satellites at Ground Station
- Multipath at Ground Station
- Interference at Ground Station

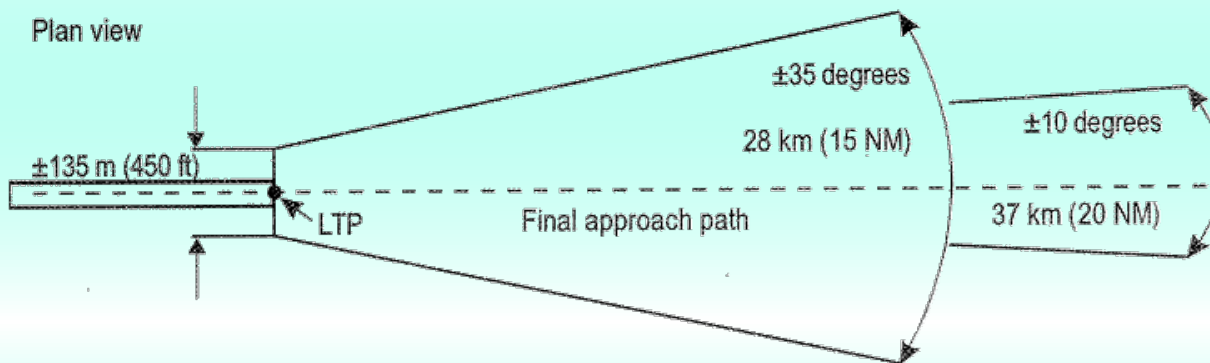
Requirements

What should be flight inspected

- Coverage of VDB Ground Station
- Frequency Spectrum of VDB Frequency ± 100 kHz either side in case of suspected interference
- Frequency Spectrum of GPS Frequency (1559-1595 MHz) when GPS Parameters indicate possible RF interference
- Satellite Availability at aircraft (PRN#)
- Satellite Constellation (VDOP, HDOP, EPE)

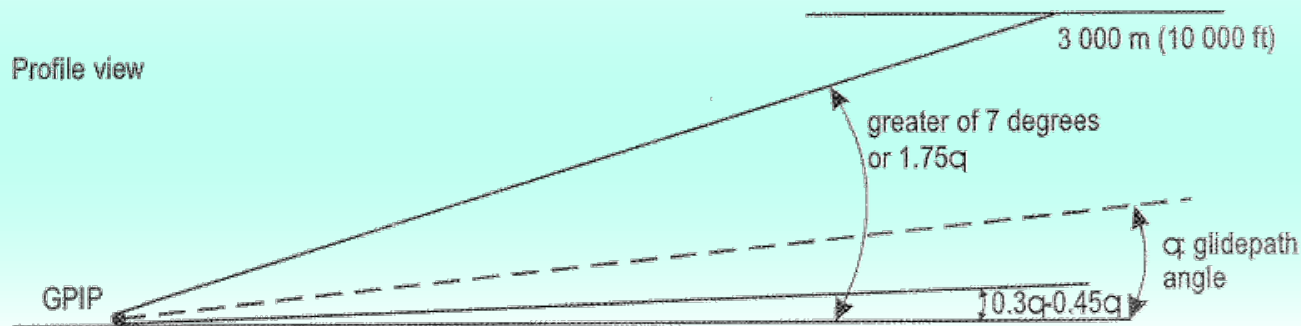
Coverage Area

The minimum operational VDB coverage area has to be:



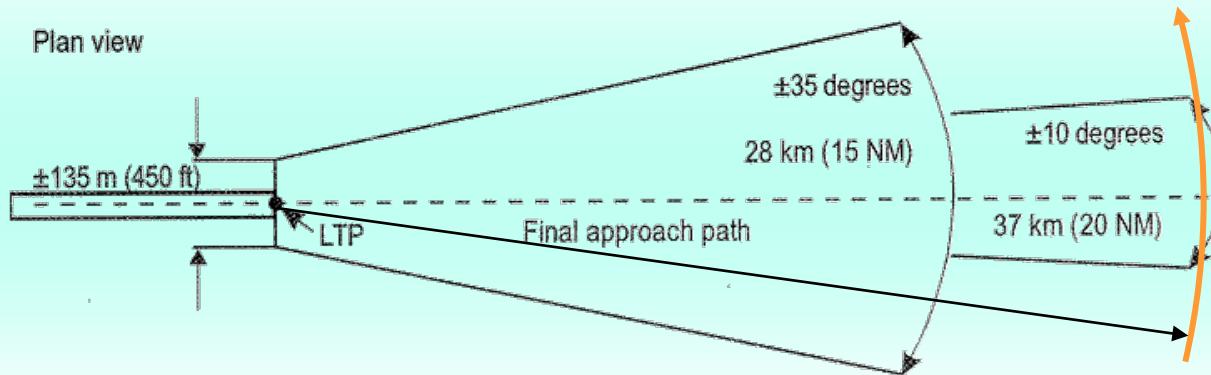
No Data
Continuity
Alerts shall
be allowed
in this area

$-35 \text{ dBW/m}^2 > \text{Field Strength} > -99 \text{ dBW/m}^2$

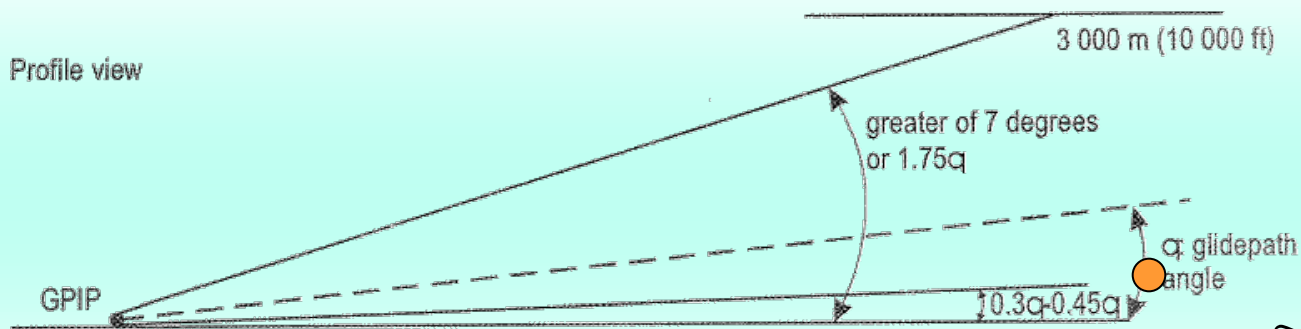


Procedures

20 NM Arc around LTP/FTP @ 0.3 – 0.45 Theta



Field Strength > -99 dBw/m²

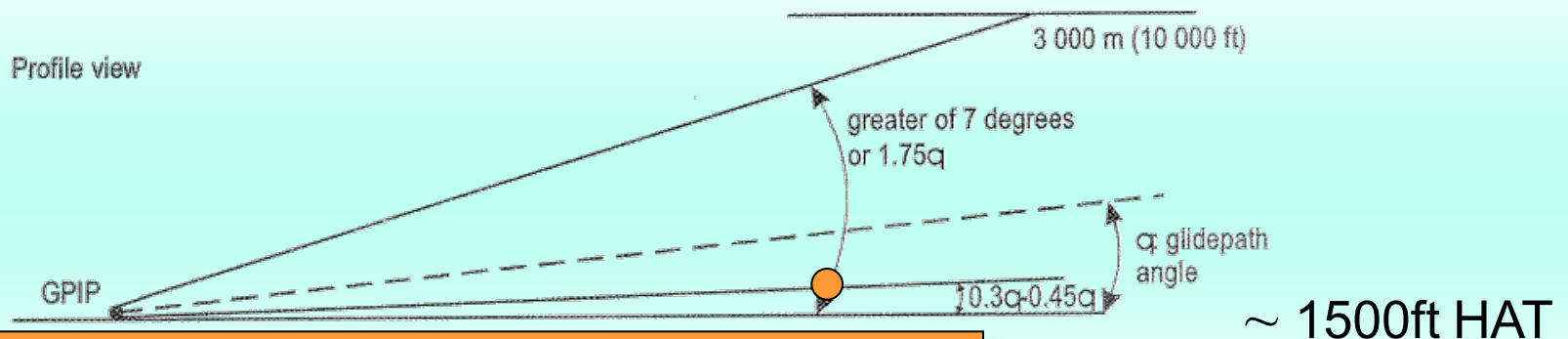
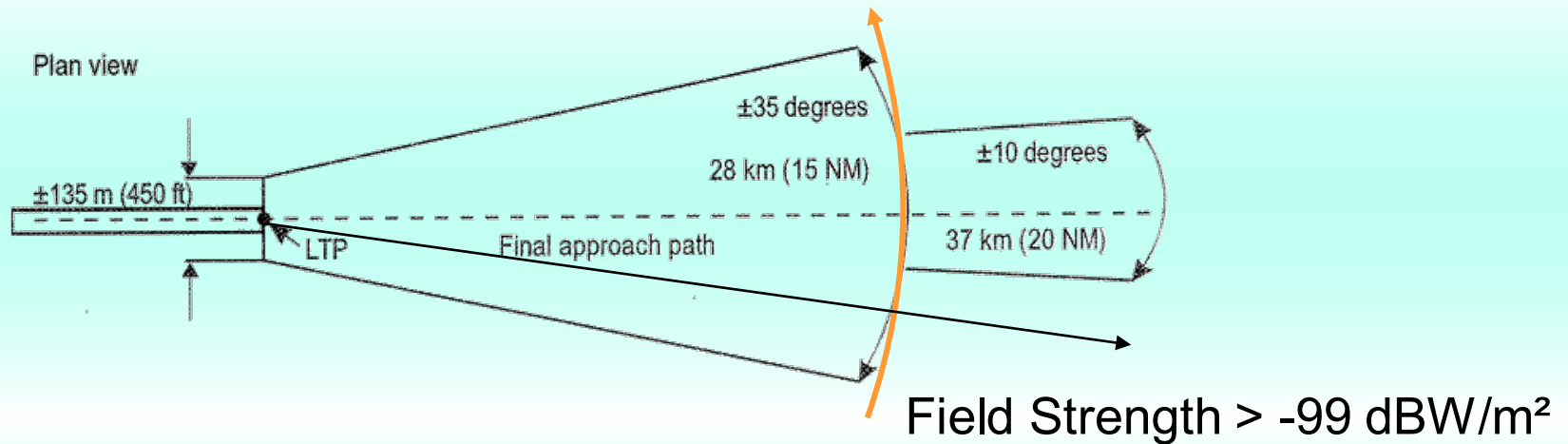


~ 2000ft HAT

Main Purpose:
Coverage of VDB – Ground Station, Satellite availability, DOP

Procedures

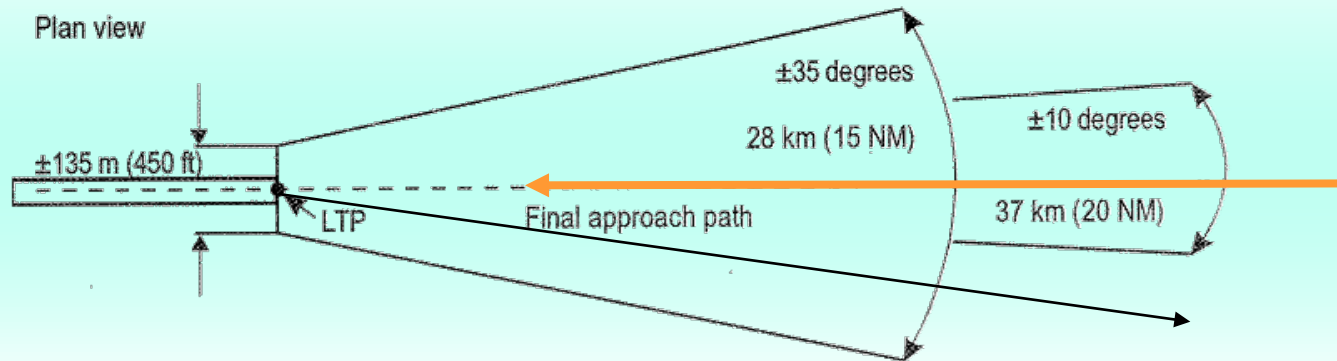
15 NM Arc around LTP/FTP @ 0.3 – 0.45 Theta



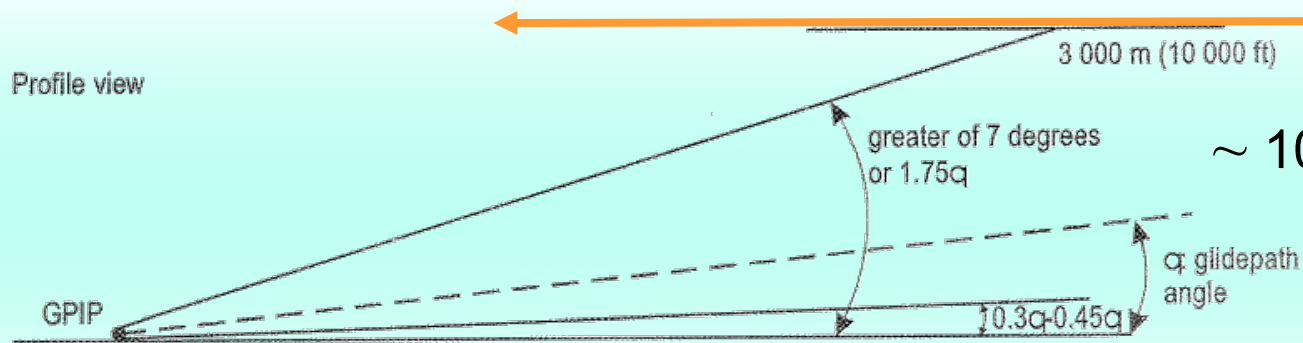
Main Purpose:
 Coverage of VDB – Ground Station, Satellite availability, DOP

Procedures

Level Run from 20NM to 13NM or less



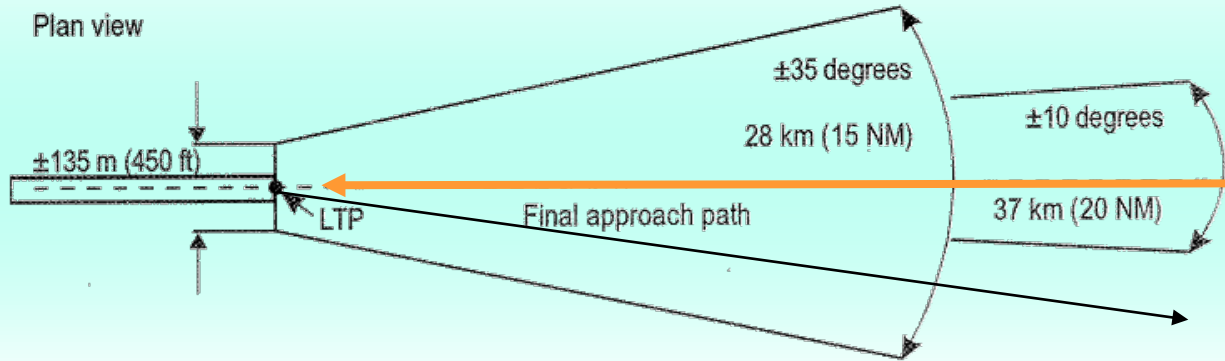
Field Strength > -99 dBW/m²



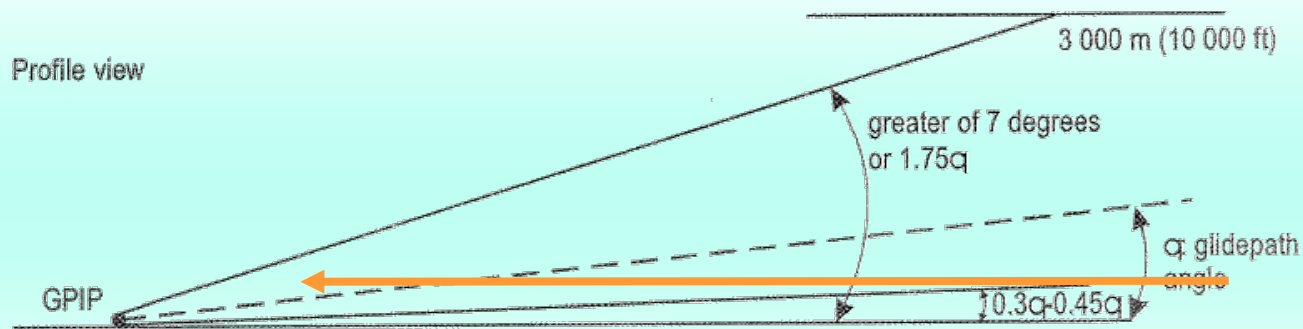
Main Purpose:
Coverage of VDB – Ground Station, Satellite availability, DOP

Procedures

Level Run from 21NM to 2,5 NM or less



Field Strength > -99 dBW/m²



~ 2.000ft HAT

Main Purpose:
Coverage of VDB – Ground Station, Satellite availability, DOP

Equipment

Aircraft premises

- GBAS Indication in Cockpit
 - Through primary avionic
 - Through FIS on separate Cockpit display
 - Through FIS on primary EFIS
- Additional NAV antenna

Equipment

Aircraft



IFIS 2008, OKC

Flight Inspecting GBAS

Equipment

FIS Premises

- GBAS receiver
- Polar Antenna diagrams for Azimuth and Frequency dependencies
- GBAS Data display graphical and numerical
- Measurement procedure for Coverage and Approach
- Cockpit interface for GBAS Flight Inspection Guidance
- Spectrum analyzer measurement program for VDB and GPS interference
- Autopilot coupling for even more accurate flying

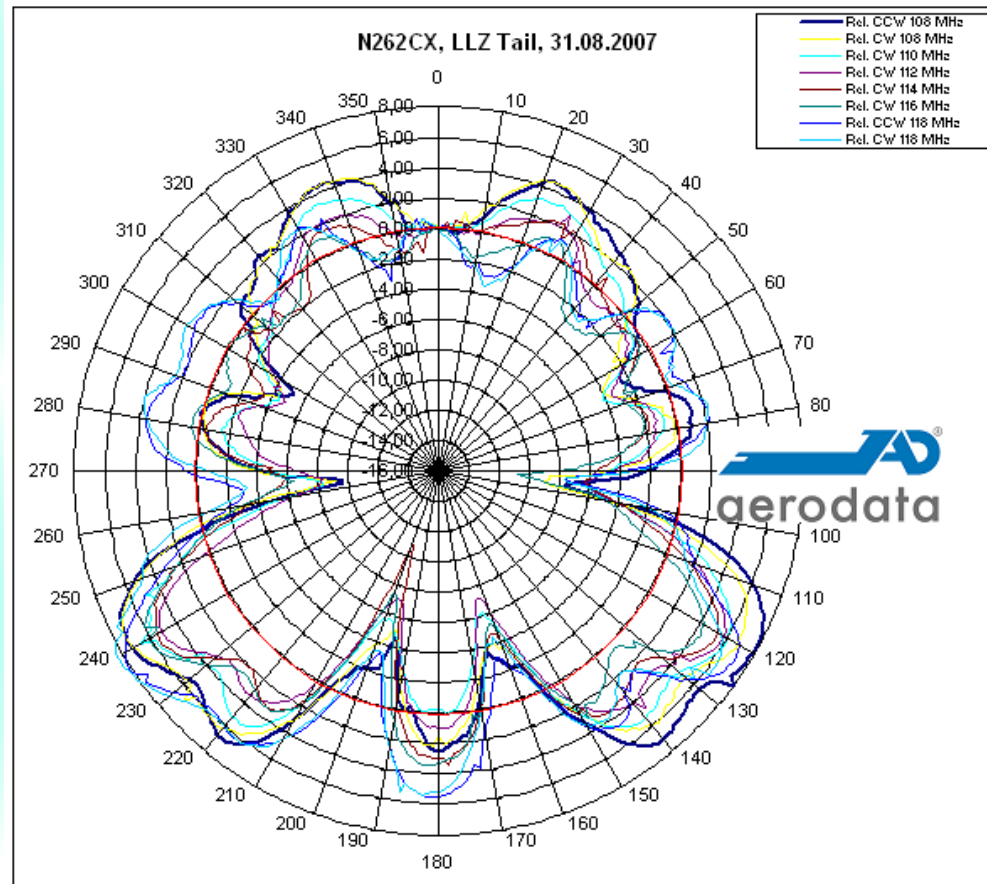
Equipment

FIS



Equipment

FIS



Equipment

FIS

The screenshot displays the AD-AFIS-120 (Operator) software interface. The main window shows a message header with the following details:

- Message type: 1
- Station ID: EDVE
- Message length: 127

Key parameters and values are shown in the center:

- Modified Z Count: 468.50 [s]
- Additional Flags: 0.00
- Number of measurements: 10.00
- Measurement type: 0.00
- Ephemeris CRC: ---
- Source available duration: 2550.00 [s]

A table of correction data is displayed at the bottom, with columns for SVID, IOD, PRC [m], RRC [m/s], SGnd [m], B1 [m], B2 [m], B3 [m], and B4 [m].

SVID	IOD	PRC [m]	RRC [m/s]	SGnd [m]	B1 [m]	B2 [m]	B3 [m]	B4 [m]
0	3	-2.78	0.02	0.86	0	0	0	0
1	70	-1.72	0.04	0.18	0	0	0	0
3	70	-7.5	-0.03	0.32	-0.05	-0.05	-0.05	-0.05
9	15	-22.64	-0.05	0.62	0	0	0	0
11	30	-3.06	-0.02	0.16	0	0	0	0
14	22	-3.78	0.02	0.18	-0.05	-0.05	-0.05	-0.05
19	40	-4.08	-0.05	0.16	0	0	0	0
20	101	-10.24	0.02	0.36	0	0	0	0
22	61	-5.16	-0.03	0.24	0	0	0	0
28	75	-3.8	0.05	0.7	0	0	0	0

On the left side, the interface shows the date and time: 2008-02-28 11:27:47 UTC (16:27:47 Local). It also displays various status indicators like BaroAlt, IAS/GS, Mode (GPS), EPE (11 [m]), FoM (Normal), and GPS (SGPS). A 'Marker' section shows 'FIS 1' with 'Out', 'Mid', and 'In' buttons. The 'Storage-status' section shows 438:21 h.

Equipment

FIS

aw Positioning Config Window Help

Overview | NAV | GBAS |

Correction data | Reference position | FAS Data |

Message header

Message type Station ID Message length

Number of reference receivers	<input type="text" value="2"/>
Reference point latitude	<input type="text" value="52.31364"/> [°]
Reference point longitude	<input type="text" value="10.54818"/> [°]
Reference point altitude	<input type="text" value="139.55"/> [m]
Local magnetic variation	<input type="text" value="0.00"/> [°]
Accuracy	<input type="text" value="66"/>
Integrity	<input type="text" value="GCID 1"/>
Scale height	<input type="text" value="15000.00"/> [m]
Refractivity index	<input type="text" value="340.00"/>
Refractivity uncertainty	<input type="text" value="25.00"/>

aw Positioning Config Window Help

Overview | NAV | GBAS |

Correction data | Reference position | FAS Data |

Message header

Message type Station ID Message length

FAS #1 | FAS #2 |

Operation type	<input type="text" value="0"/>	LTP/FTP latitude	<input type="text" value="52.31964"/> [°]
SBAS service provider	<input type="text" value="14"/>	LTP/FTP longitude	<input type="text" value="10.56405"/> [°]
Airport ID	<input type="text" value="EDVE"/>	LTP/FTP altitude	<input type="text" value="131.70"/> [m]
Runway	<input type="text" value="26"/>	Delta FPAP latitude	<input type="text" value="-0.00099"/> [°]
Approach performance designator	<input type="text" value="CAT 1"/>	Delta FPAP longitude	<input type="text" value="-0.01762"/> [°]
Route indicator	<input type="text" value="P"/>	TCH	<input type="text" value="16.75"/> [m]
Reference path data selector	<input type="text" value="11"/>	Glide path angle	<input type="text" value="3.50"/> [°]
Reference path ID	<input type="text" value="TE26"/>	Course width	<input type="text" value="80.00"/> [m]
		Delta length Offset	<input type="text" value="0.00"/> [m]
		Vertical alert limit	<input type="text" value="10.00"/> [m]
		Lateral alert limit	<input type="text" value="40.00"/> [m]

Flight Testing

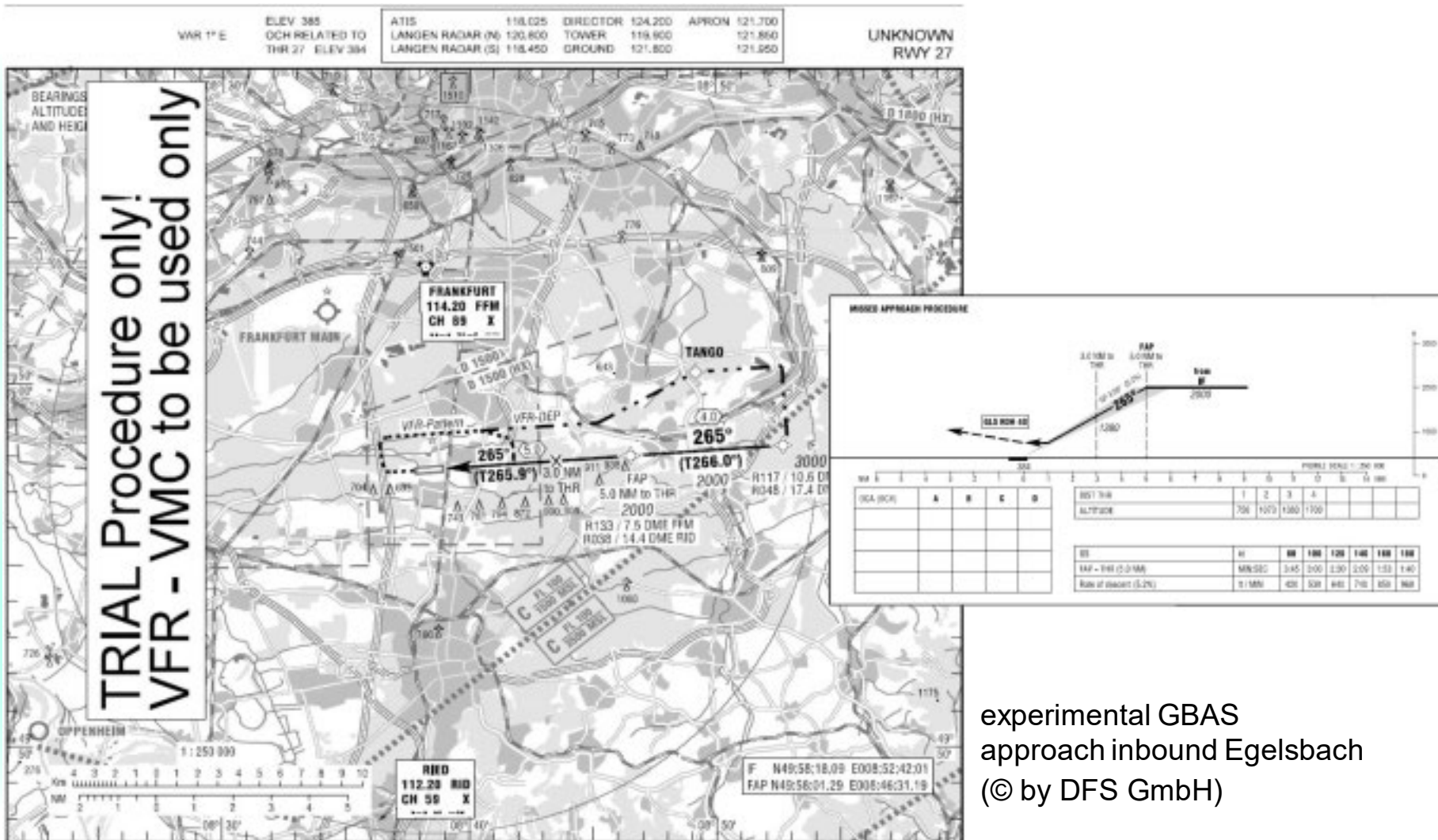
Scenario

- design GBAS approaches to Egelsbach (airport 12 km from Frankfurt)
- use Honeywell prototype GBAS ground station (SLS-3000) at Frankfurt airport
- do 50 GBAS approaches to Egelsbach (remote airport)
- with an experimental aircraft DO 128-6 from TU Braunschweig
- equipped with the GBAS MMR GLU-925
- connected to the experimental cockpit on the co-pilot side
- use Thales ATM GBAS ground station at Toulouse Blagnac

Motivation for DFS, STNA/DTI and EUROCONTROL

- check new GBAS procedure design tool
- test FAS data file generation & FAS data chain for the SLS-3000
- gain experience with MMR installation onboard the DO 128-6
- gain experience with VDB field strength measurements
- check & improve EUROCONTROL PEGASUS tool

Flight Testing



experimental GBAS
approach inbound Egelsbach
(© by DFS GmbH)

Flight Testing

Egelsbach

1st day:

- 31 approaches
- distance flown between 2 NM and 7 NM from Threshold
- procedure: after low approach right turn out to intercept “back beam”
- 3 approaches with a northern traffic pattern due to other traffic

2nd day:

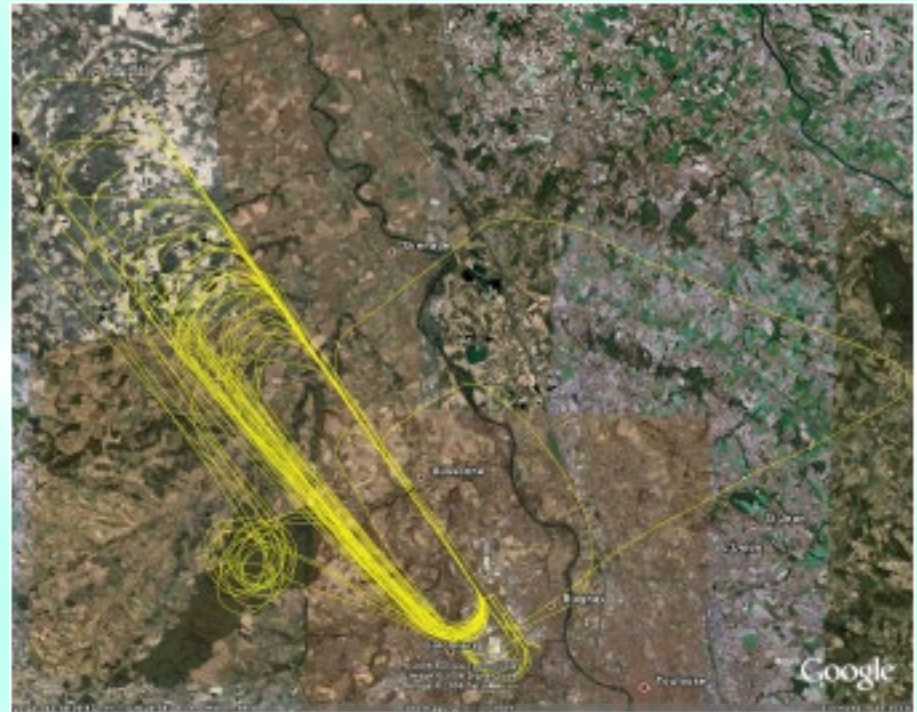
- 20 approaches
- distance flown between 3 NM and 12 NM from Threshold
- procedure: after low approach northern traffic pattern



Flight Testing

Toulouse

- 48 approaches
- 3 consecutive days (September 2006)
- approach started at 3.000 ft

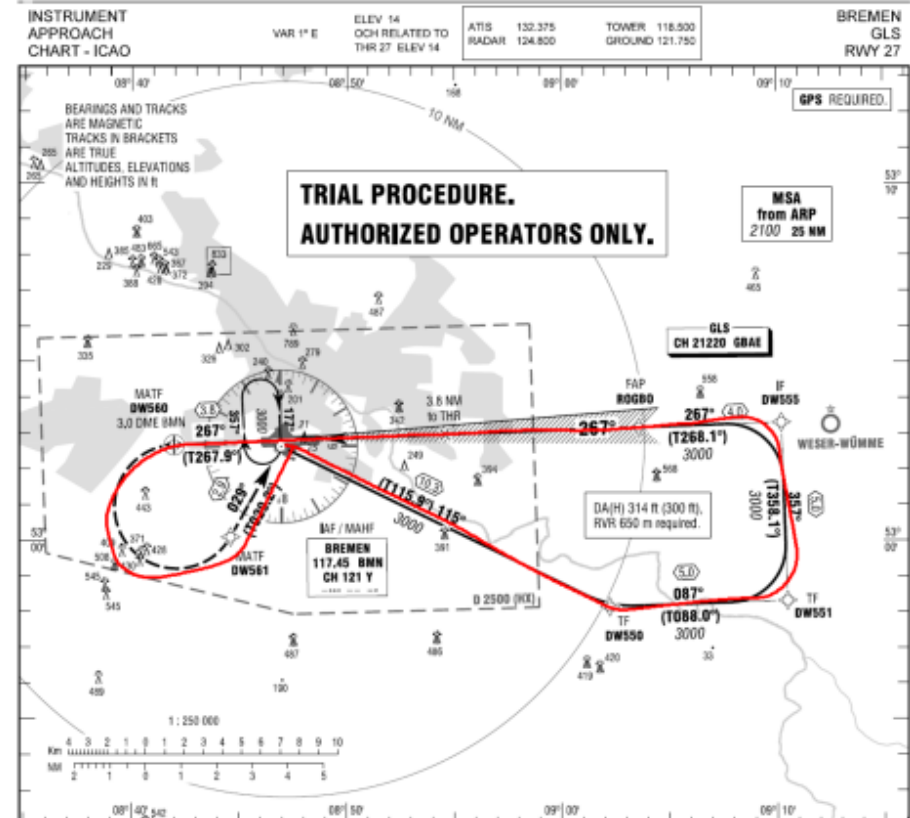
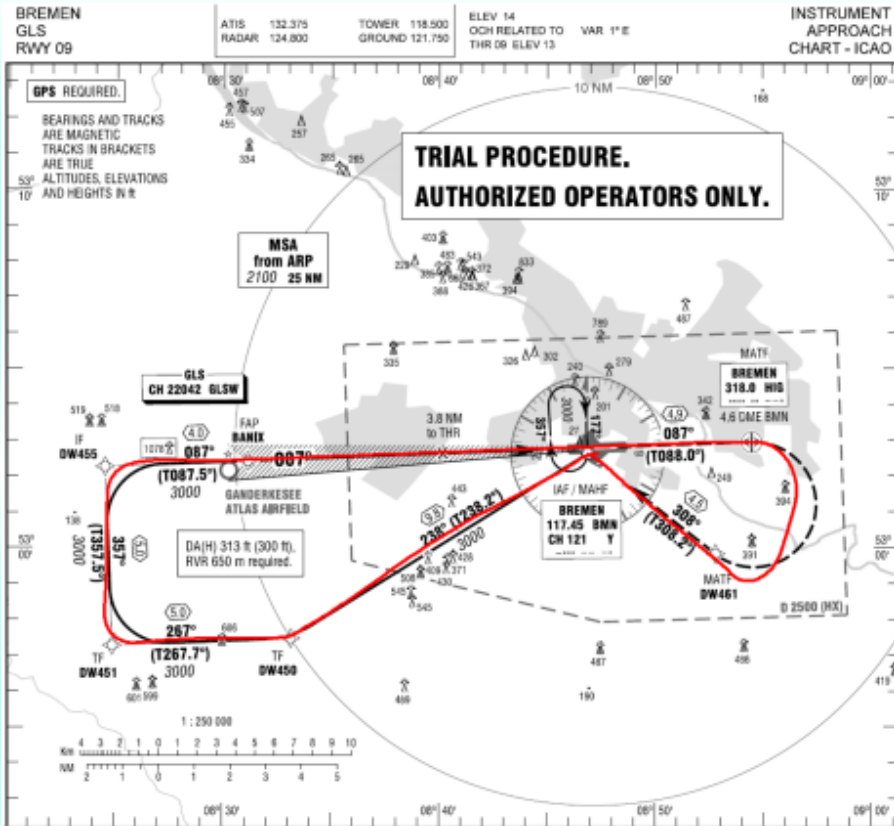


Flight Testing

Bremen

- Initial Flight Check of Bremen GBAS installation
- Funded by DFS GmbH
- Program according to ICAO Doc 8071 Vol. II
- Program flown twice on different days
- Intention
 - Check of VDB coverage area
 - Check of data contents
 - Check of interference issues

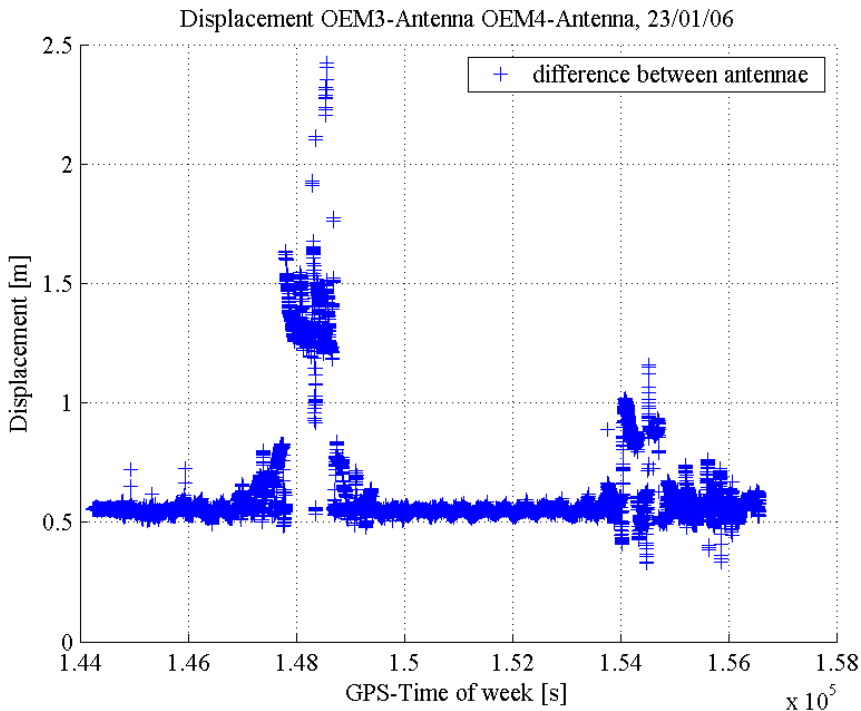
Flight Testing



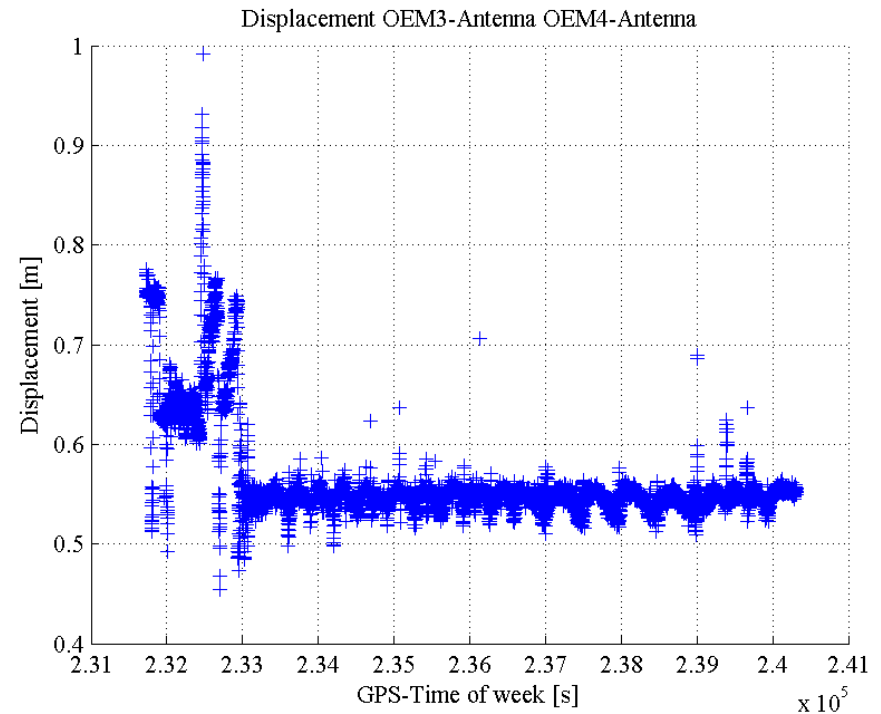
Approach charts and flight track of Bremen approaches

Flight Testing Results

Difference of OEM3-Reference track and OEM4-Reference track (i.e. on-board OEM3 on one antenna, on-board OEM4 on another antenna; difference of both antennas: 0.569 m; on ground both receivers used same Antenna)

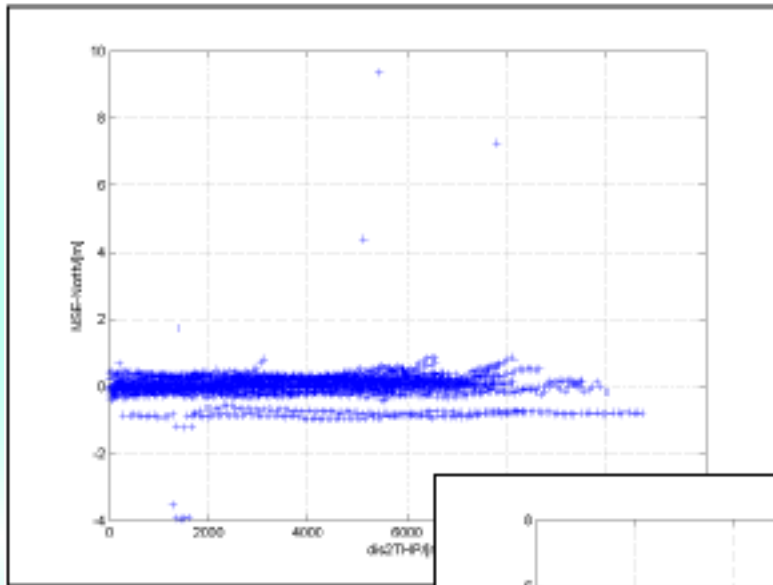


Day 1 (23/01/2006)

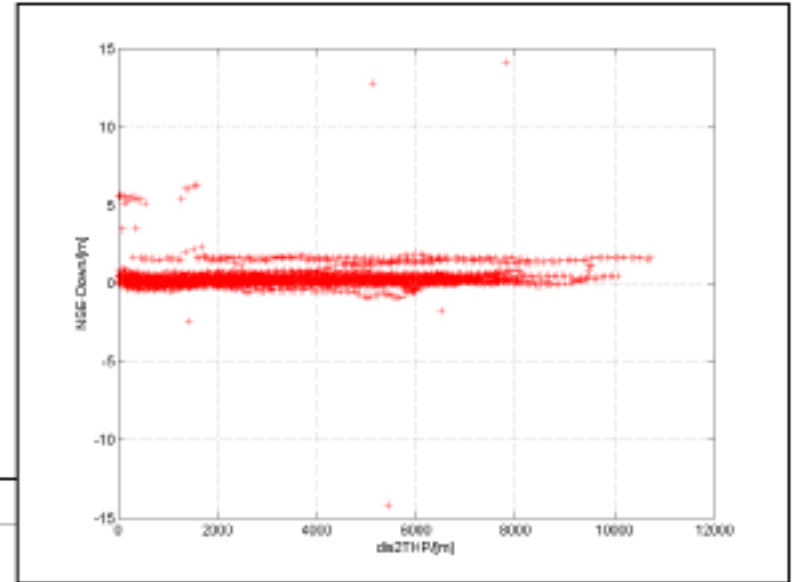


Day 2 (24/01/2006)

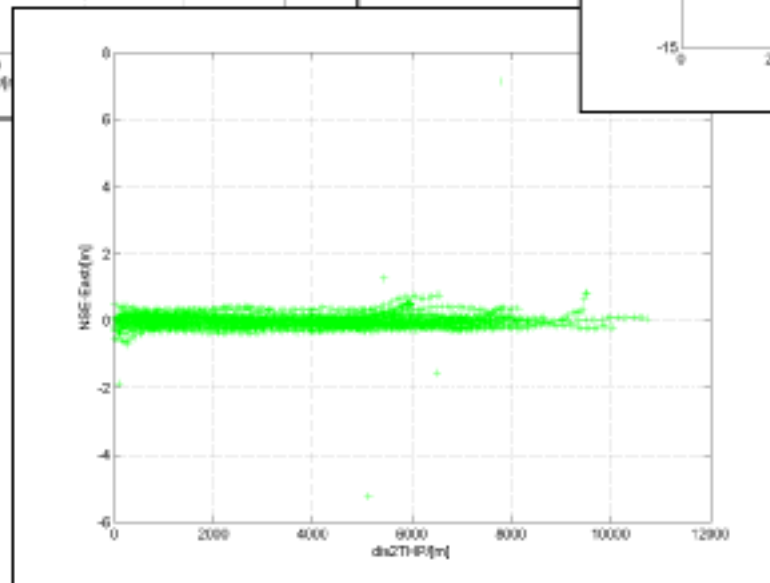
Flight Testing Results



NSE North
(cross track,
Egelsbach)



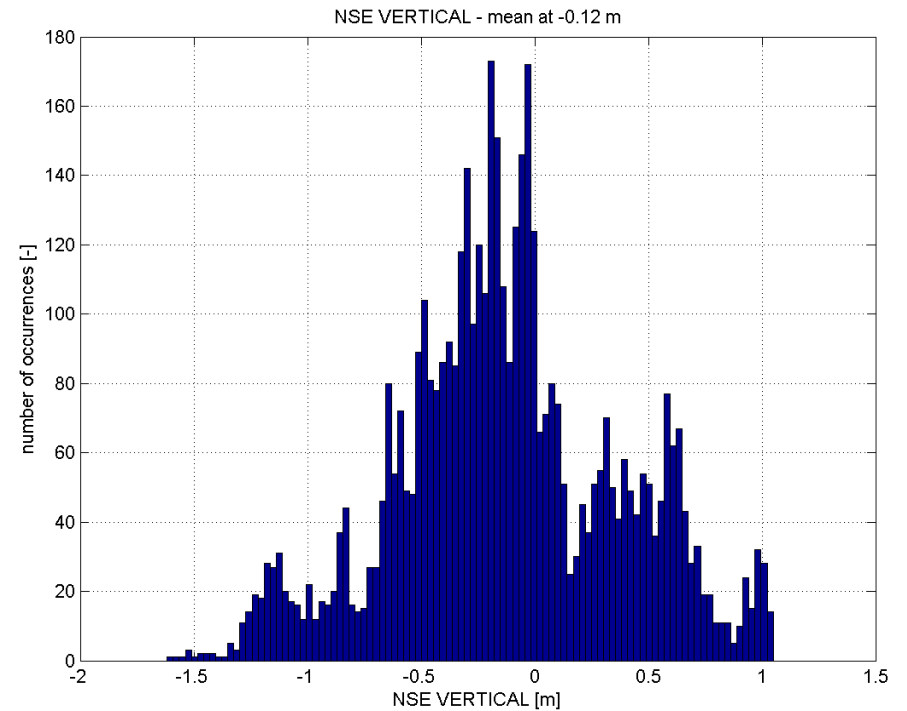
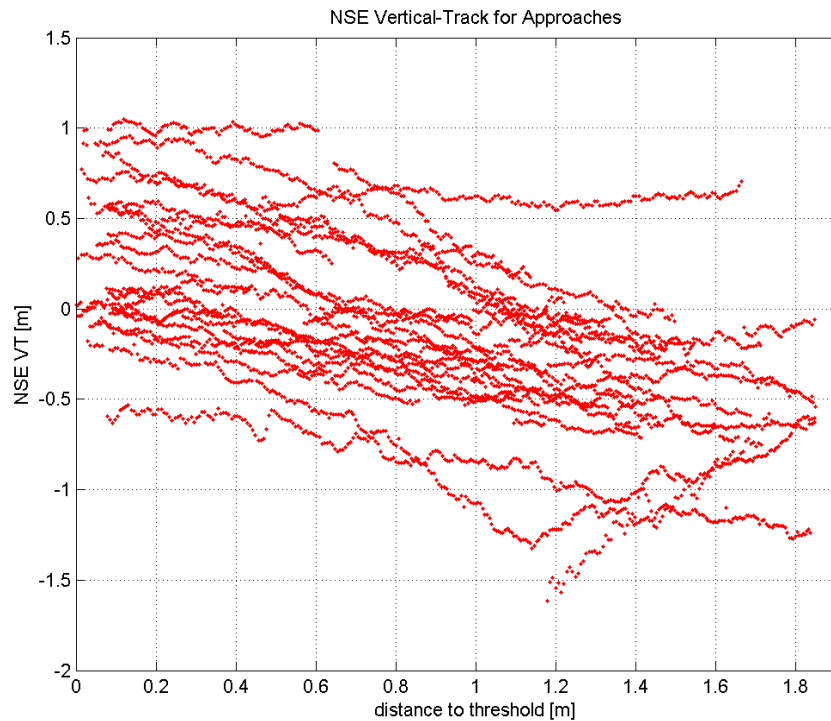
NSE Down
(vertical,
Egelsbach)



NSE East
(along track,
Egelsbach)

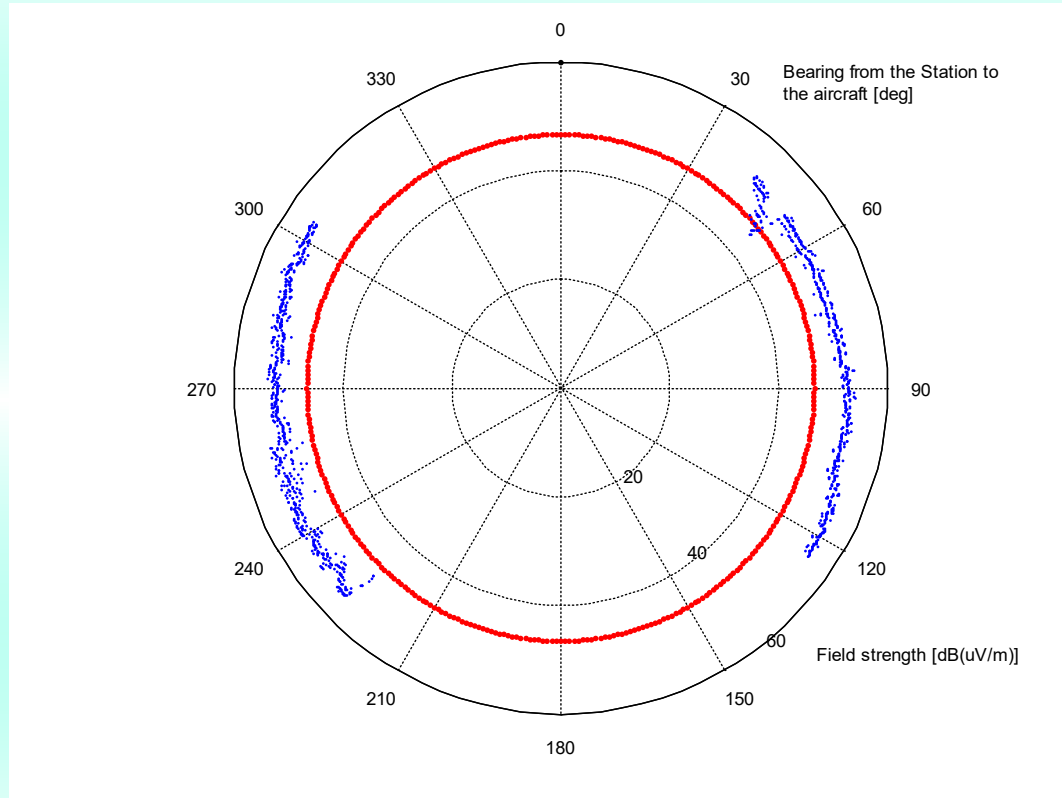
Flight Testing Results

NSE Vertical Track, Toulouse



Flight Testing Results

Bremen, Field Strength Coverage, 15NM



Conclusion

- **GBAS is a good alternative to perform ILS look-a-like approaches**
- **For Flight Inspecting GBAS below mentioned equipment is found necessary:**
 - **GBAS Receiver**
 - **GBAS Flight Guidance in the Cockpit by Primary Equipment or from Flight Inspection System**
 - **Suitable spectrum analyzer for GPS and VDB**
 - **Calibrated VDB antenna system**

Thank you for your attention!