

# Experiences in Flight Inspecting GBAS

Thorsten Heinke  
Aerodata AG

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

Equipment

Flight Inspec.

Summary

# Flight Inspection of GBAS

## Overview

- Basics
- Requirements
- Equipment
- Flight Inspection
- Summary

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

Equipment

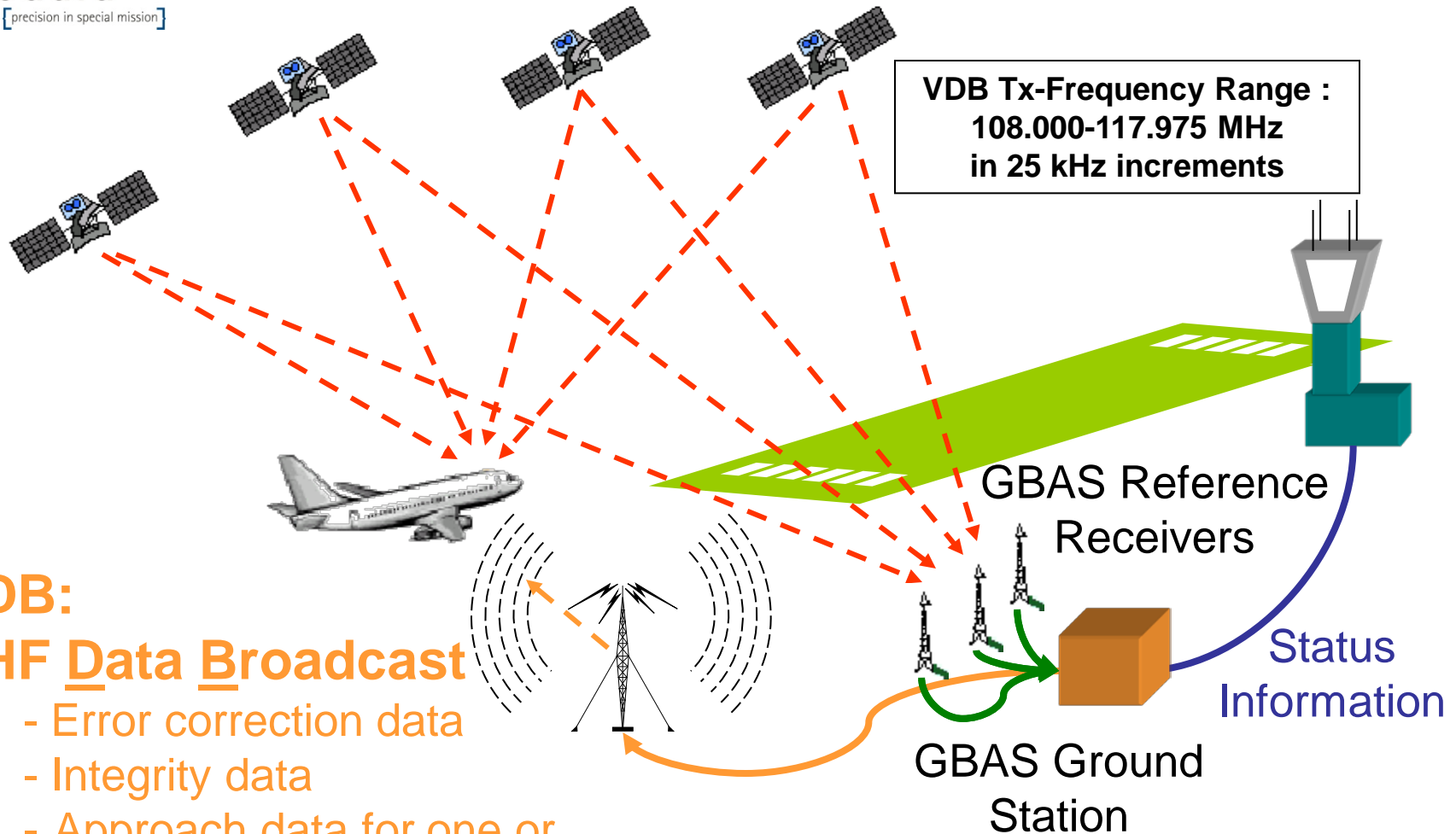
Flight Inspec.

Summary

# Ground Based Augmentation System

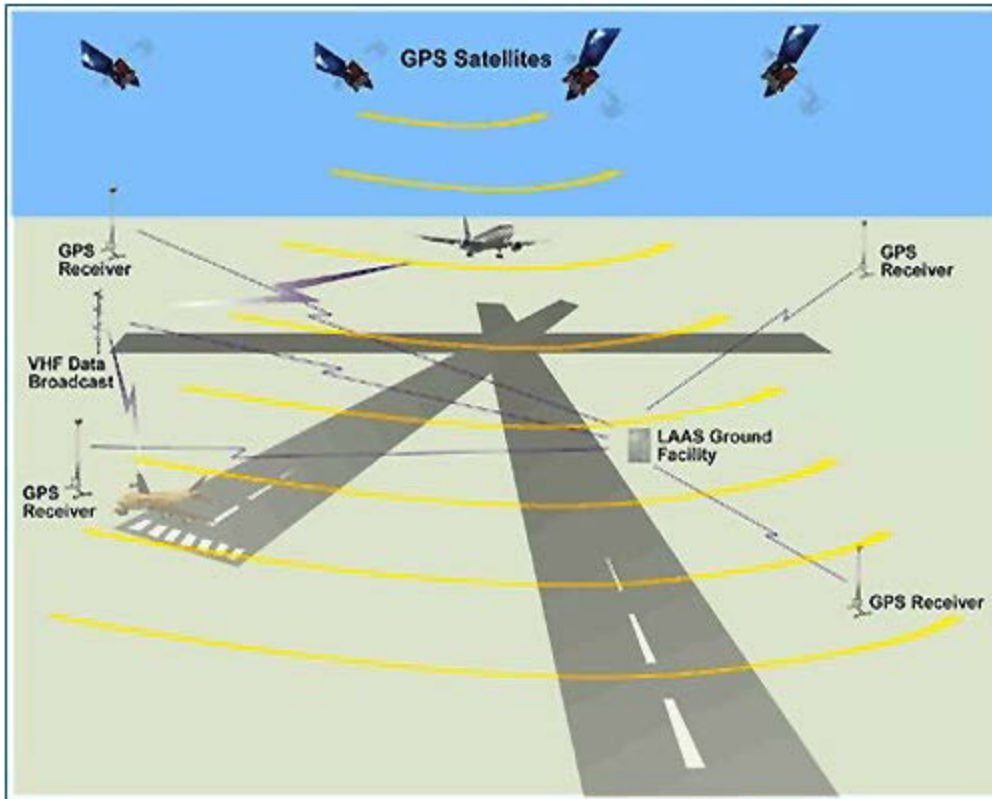
**VDB:**  
**VHF Data Broadcast**

- Error correction data
- Integrity data
- Approach data for one or more Runways/Approaches



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# Ground Based Augmentation System



- One GBAS Ground station may support several runways and approaches
- „ILS Lookalike“ Deviations are provided to the pilot:



GLS Distance  
GLS Lateral Deviation  
GLS Vertical Deviation

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

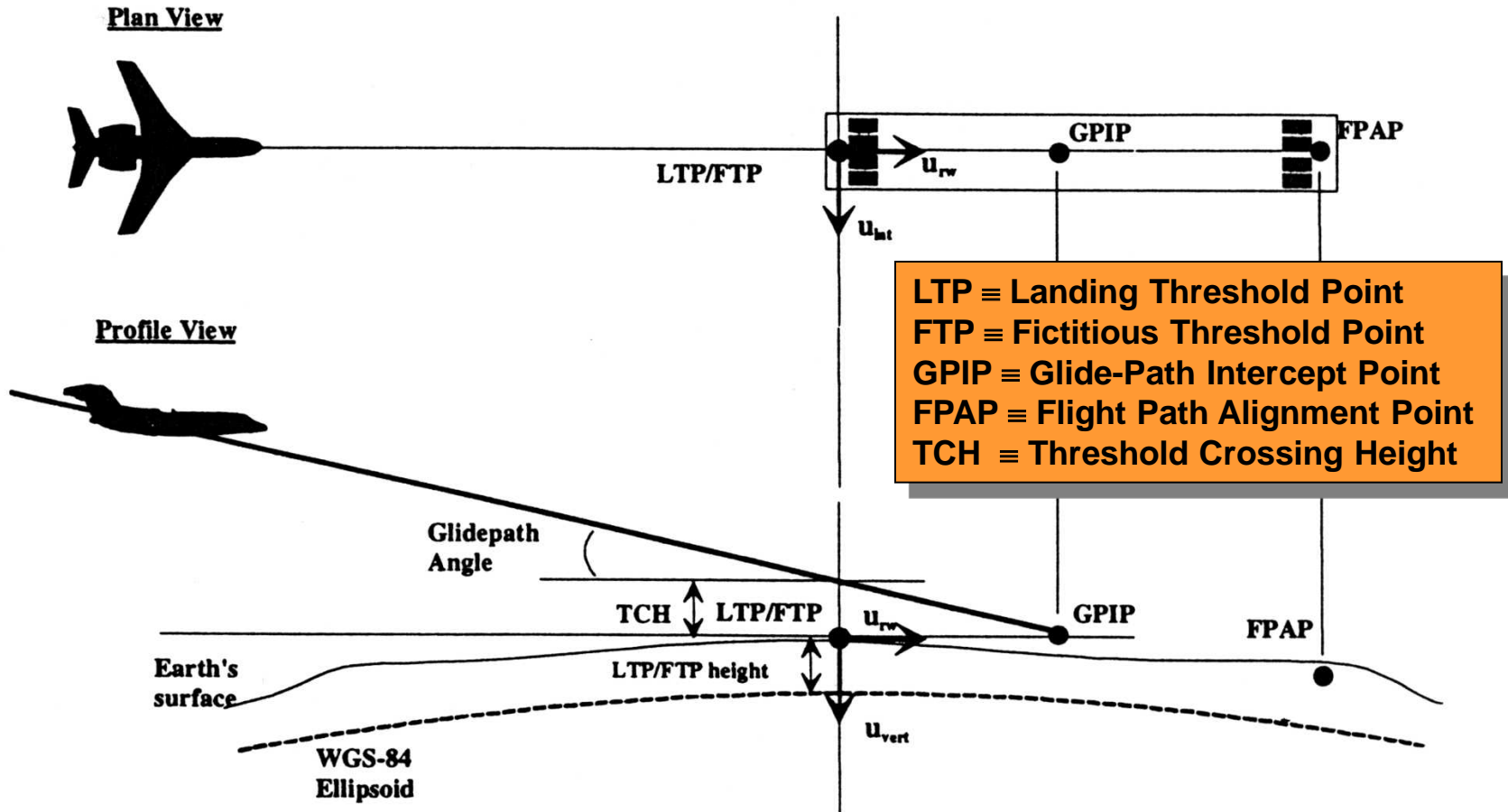
# VHF Data Broadcast (VDB) Messages



- **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

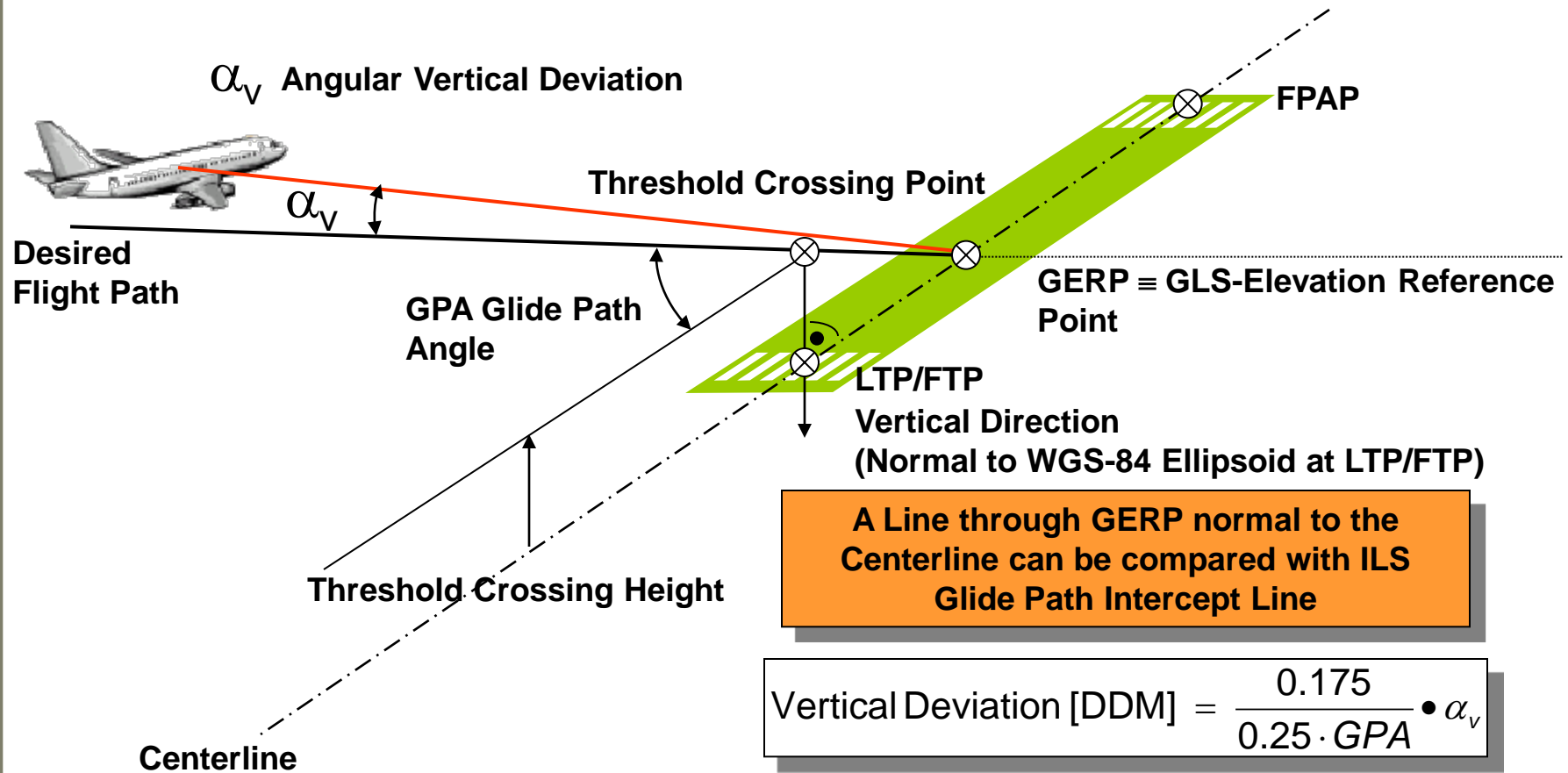
ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# Final Approach Segment Diagram

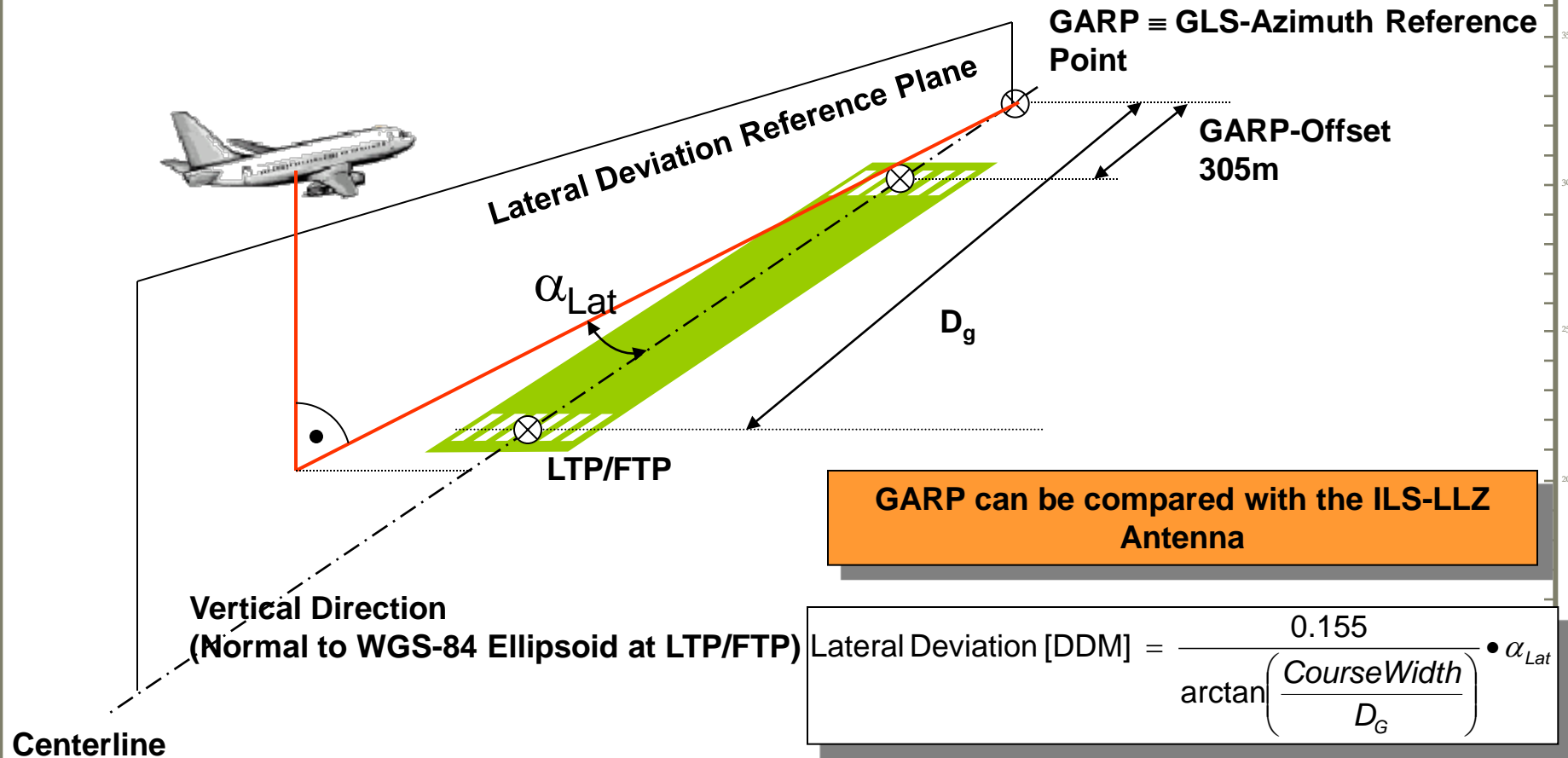


ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# GLS (GNSS Landing System) Vertical Deviation



# GLS (GNSS Landing System) Lateral Deviation



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

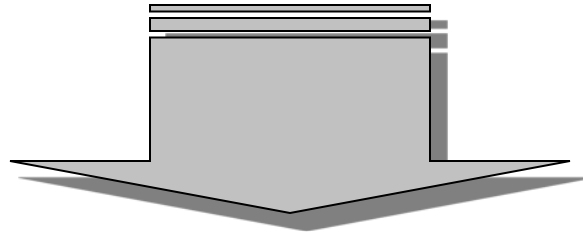


# Comparison GLS – ILS

**GNSS Landing System ← → Instrument Landing System**

GLS Azimuth Reference Point  
GLS Elevation Reference Point  
Deviation calculated in DDM

Localizer Antenna Position  
Glide path intercept Line  
Deviation measured in DDM



GLS is similar to ILS

# 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

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

## 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

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

## 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  
( $> -99 \text{ dBW/m}^2 < -35 \text{ dBW/m}^2$  @ 3,7m / 12ft above runway)
- Availability of Satellites at Ground Station
- Multipath at Ground Station
- Interference at Ground Station

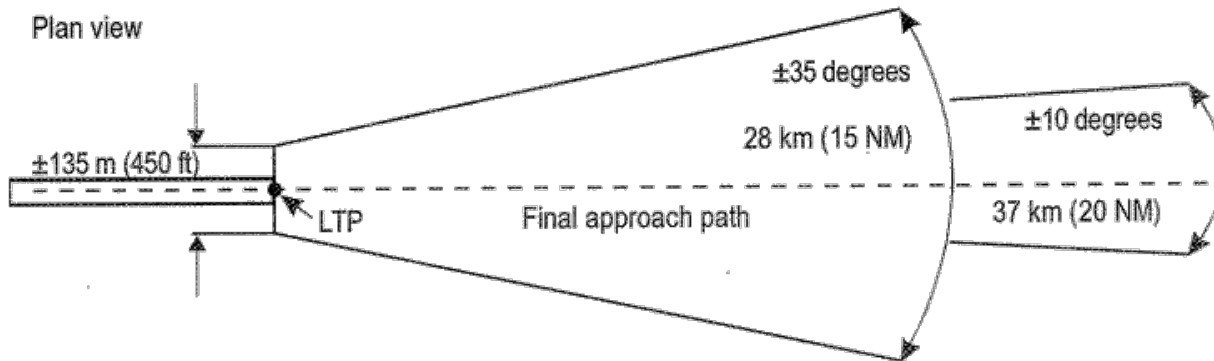
## What should be flight inspected

- Coverage of VDB Ground Station
- Frequency Spectrum of VDB Frequency  $\pm 100$  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)

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

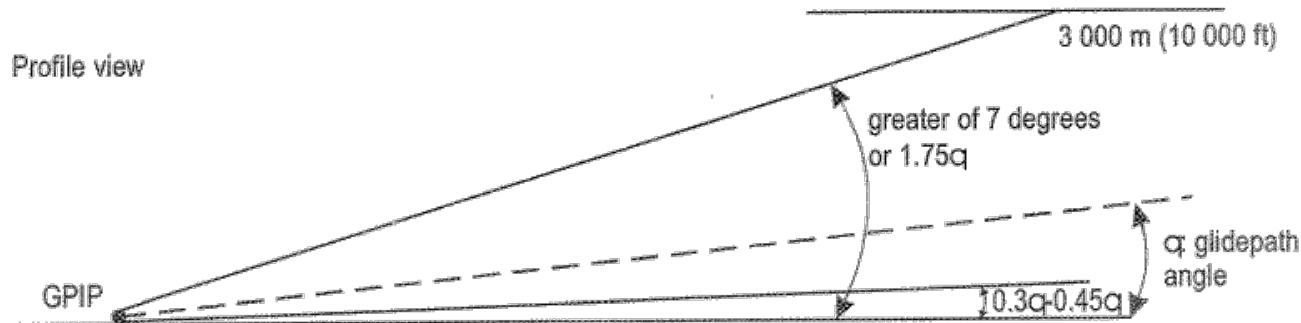
# Coverage Area

The minimum operational VDB coverage area has to be:



No Data  
Continuity  
Alerts shall  
be allowed  
in this area

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



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# Procedures

**20 NM Arc around LTP/FTP @ 0.3 –0.45 Theta (~ 2000ft HAT)  $\pm 10^\circ$**

**15 NM Arc around LTP/FTP @ 0.3 –0.45 Theta (~ 1500ft HAT)  $\pm 35^\circ$**

**Level Run from 20 NM to 13 NM or less at ~ 10000ft HAT**

**Level Run from 21 NM to 2.5 NM or less at ~ 2000ft HAT**

Field Strength > -99 dBw/m<sup>2</sup>

Main Purpose:

Coverage of VDB – Ground Station, Satellite availability, DOP

# GBAS Guidance in for Pilots

## Problem:

The Primary Aircraft Avionic (in Flight Inspection Aircraft) does NOT support GBAS (GNLU) installation!

How to provide Guidance to the pilots?



## Solution:

The AFIS provides GBAS(GLS) Deviations via the AFIS Flight Guidance Interface on EFIS

AFIS Provides:

- GLS Lateral Deviation
  - GLS Vertical Deviation
  - GLS Distance
- ➔ Use of Autopilot for GLS!

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK



- Measurement Programs for Coverage Arcs, Level Runs and Approaches
- Evaluation of GLS Deviations
- GLS Flight Guidance in cockpit provided through AFIS to provide GBAS Guidance to pilots (GBAS receiver can not be integrated to current avionics of flight inspection aircraft)
- Graphical and numerical analysis of VDB Signal in Space Power Density
- GPS L1 and L2 Spectrum Analyzer Measurement Program
- VDB Spectrum Analyzer Measurement Program

# Software - Database

**Facility Browser**

World ADDefault  
Germany  
Hannover EDDV  
Bremen EDDW  
RWY S09  
IBRE  
GLSW  
VDBW  
S09  
RWY S27  
Braunschweig EDVE  
ADDach  
Antenna Calibration ANTICAL  
Bruenckendorf BKD  
Braunschweig BRU  
Helgoland DHE  
Leine DLE  
Braunschweig EDVE-TWR  
LBAND Ant Cal GBA  
Hannover HA  
Hannover HAD  
Hannover HAE  
Hamburg HAM  
Hannover HBD  
Hehlingen HLZ  
Hannover HW  
Elbe LBE  
Magdeburg MAG  
Wunstorf WUN  
Braunschweig EDVE-RADAR  
VDB EDVE TATM  
VDB VDBW  
LENDI  
VE013  
MAGER  
EDVE-RW08  
VE010  
ELKER  
ALESI  
VE028  
LERDI  
EDVE-RW26  
VE025  
VE024  
BABKA

Type	Name	Ident	Description	User	Date
VDB		VDBW		Steffens	Jun 20, 2011

GLS GLSW

Name: Ident: GLSW

Description: Image Link: [Icons]

Channel: 22042  
Magn. Var.: -0.00 E [°]  
Primary VDB: VDBW  
Operation Type: 0  
AirportID: EDDW  
Appr. Designator: CAT 1  
Route Indicator: Z  
TCH: 16.15 [m]  
RefPathDataSelector: 4  
LTP/FTP Pos. Lat: 53° 02' 47.6660" N Lon: 8° 46' 28.0280" E Alt: 44.700 [m] WGS84  
ΔFPAP Lat: 0.00069003 [°]  
GP Angle: 3.00 [°]  
Length Offset: 0.00 [m]  
FAS vert. Alert Limit: 10.00 [m]  
SBAS Service Provider: 14  
Runway Number: 9  
Runway Letter: R  
TCH unit: [ ] [meter]  
Reference Path ID: GLSW  
ΔFPAP Lon: 0.03039725 [°]  
Course Width: 80.00 [m]  
FAS lat. Alert Limit: 40.00 [m]

VDB VDBW

Name: Ident: VDBW

Description: Image Link: [Icons]

Position Lat: 53° 02' 38.4000" N Lon: 8° 46' 55.6000" E Alt: 45.720 [m] WGS84  
Magn. Var.: [°]  
Frequency: 117.950 [MHz]  
SSID: [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] 6 [ ] 7 [ ] 8

ALL Search Filter

New Edit Close Save Delete this All Coord. in DMS Length in m

Print Print from Create KML Create KML from Close

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

Equipment

Flight Inspec.

Summary

# Software – Procedure Definition

**Procedure Definition**

Facility  
Ident: EDDW Name: Bremen Facility ... ☐ Procedure Inspection

Airport  
Select  
Runway: S09  
Profile: -- The profile is not defined --

DGPS  
Radius: 5.0 NM  
Location: NO DGPS  
☐ WADGPS

Laser Tracker  
Location: NO LTRK  
Reflector: NO REFL

(Theodolite)  
(Location):  
(Camera)  
☐ (activate)  
Postprocessing  
☐ start on STOP

LLZ  
Program: NO PROGRAM  
☐ Back Course TX1 TX2

GP  
Program: NO PROGRAM TX1 TX2

VGSI  
Program: NO PROGRAM TX1 TX2

PAR  
Program: NO PROGRAM TX1 TX2

VDB/GBAS  
Program: NO PROGRAM TX1 TX2

ASR  
Program: NO PROGRAM TX1 TX2

(MLS Azim)  
(Program): AS - Alignment and Structure  
APP - Engineering (Approach)  
LR - Engineering (Level Run)  
EO - Engineering (Orbit)  
IC - Inner Coverage (Orbit)  
LLR - Lower Level Run  
OC - Outer Coverage (Orbit)

(MLS Elevation)  
(Program):  
(Radius):  
(Location):

DME#1  
On ☐  
Radial TX1  
Orbit TX2

DME#2  
On ☐  
Radial TX1  
Orbit TX2

DME#3  
On ☐  
Radial TX1  
Orbit TX2

VHF/VDF: NONE

NDBs  
On ☐  
TX1 TX2  
NO NDB TX1 TX2

VOR#1  
On ☐  
TX1 TX2

VOR#2  
On ☐  
TX1 TX2

DME Scan  
☐ (Read from FMS on START) ☒ Use following list  
Add Add... No. Ident Rec. Avail.  
Remove  
Clear  
(Read from FMS)

(Plotter...) ASCII export... Facility Report... Add default Profiles ... Profile... Add ... Add ... Close

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

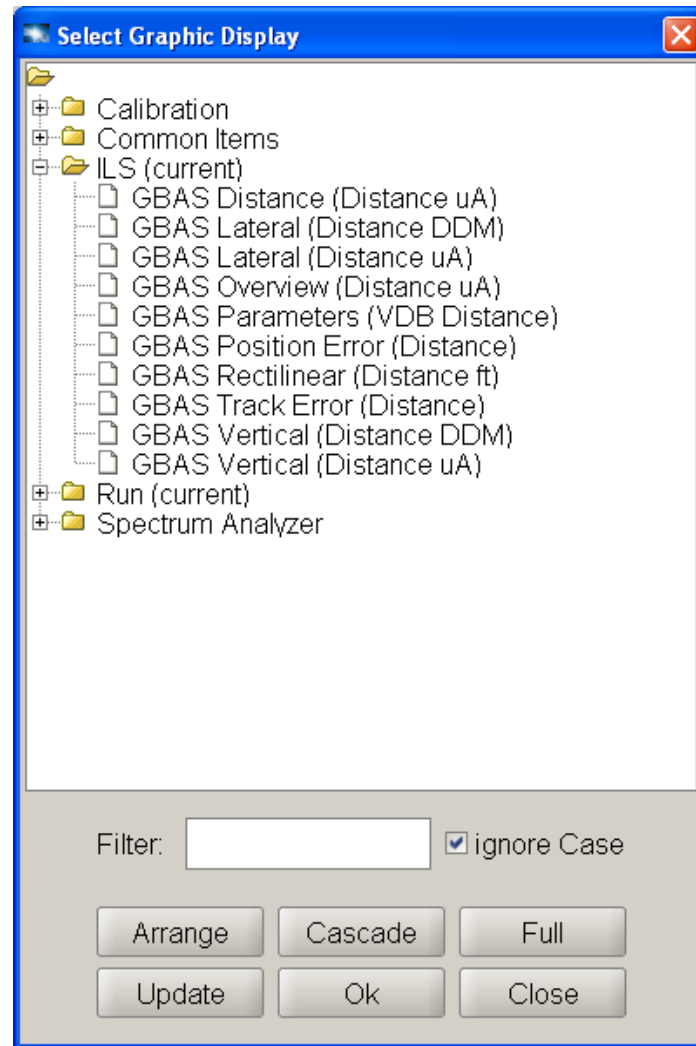
Requirements

Equipment

Flight Inspec.

Summary

# Software – Graphic Selection



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# Software – FAS Data

**AD-AFIS-120 (Operator)**

Session Inspection Control View Positioning Config Window Help

Overview NAV GBAS

Correction data Reference position FAS Data

Message header

Message type  Station ID  Message length

Modified Z Count  [s]

Additional Flags

Number of measurements

Measurement type

Ephemeris CRC

Source available duration  [s]

	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	0
1	70	-1.72	0.04	0.18	0	0	0	0	0
3	70	-7.5	-0.03	0.32	-0.05	-0.05	-0.05	-0.05	-0.05
9	15	-22.64	-0.05	0.62	0	0	0	0	0
11	30	-3.06	-0.02	0.16	0	0	0	0	0
14	22	-3.78	0.02	0.18	-0.05	-0.05	-0.05	-0.05	-0.05
19	40	-4.08	-0.05	0.16	0	0	0	0	0
20	101	-10.24	0.02	0.36	0	0	0	0	0
22	61	-5.16	-0.03	0.24	0	0	0	0	0
28	75	-3.8	0.05	0.7	0	0	0	0	0

2008-02-28 11:27:47 UTC  
16:27:47 Local

BaroAlt  [ft]  
IAS/GS  [kts]

Mode   
EPE  [m]  
FoM   
GPS

Marker  
Out Mid In  
FIS 1

Storage-status

System Alerts  
Flightlist  
Main Status ...  
Frequency D...  
GPS Status  
Receiver

# Software – FAS Data

ew Positioning Config Window Help

Overview NAV GBAS

Correction data Reference position FAS Data

Message header

Message type 2 Station ID EDVE Message length 34

Number of reference receivers	2
Reference point latitude	52.31364 [°]
Reference point longitude	10.54818 [°]
Reference point altitude	139.55 [m]
Local magnetic variation	0.00 [°]
Accuracy	66
Integrity	GCID 1
Scale height	15000.00 [m]
Refractivity index	340.00
Refractivity uncertainty	25.00

ew Positioning Config Window Help

Overview NAV GBAS

Correction data Reference position FAS Data

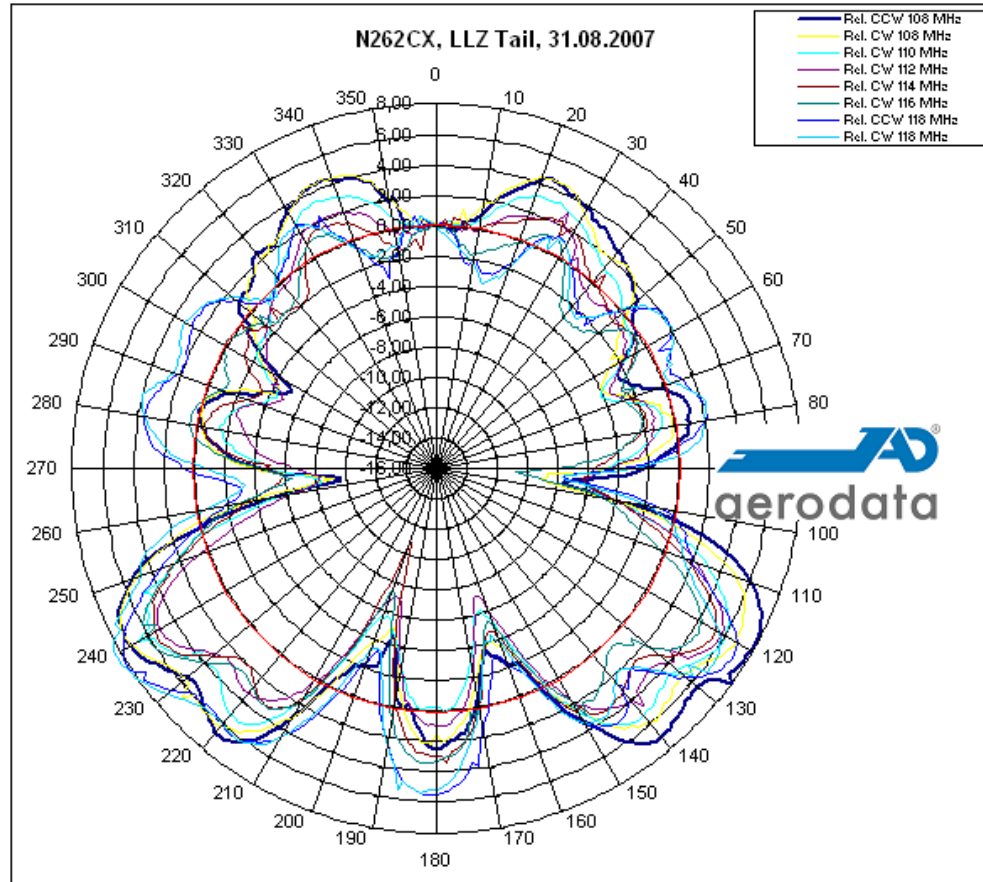
Message header

Message type 4 Station ID EDVE Message length 92

FAS #1 FAS #2

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

# Software – Antenna Pattern Correction



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

Equipment

Flight Inspec.

Summary

# Flight Inspection Equipment





# Hardware

**in A/C**



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

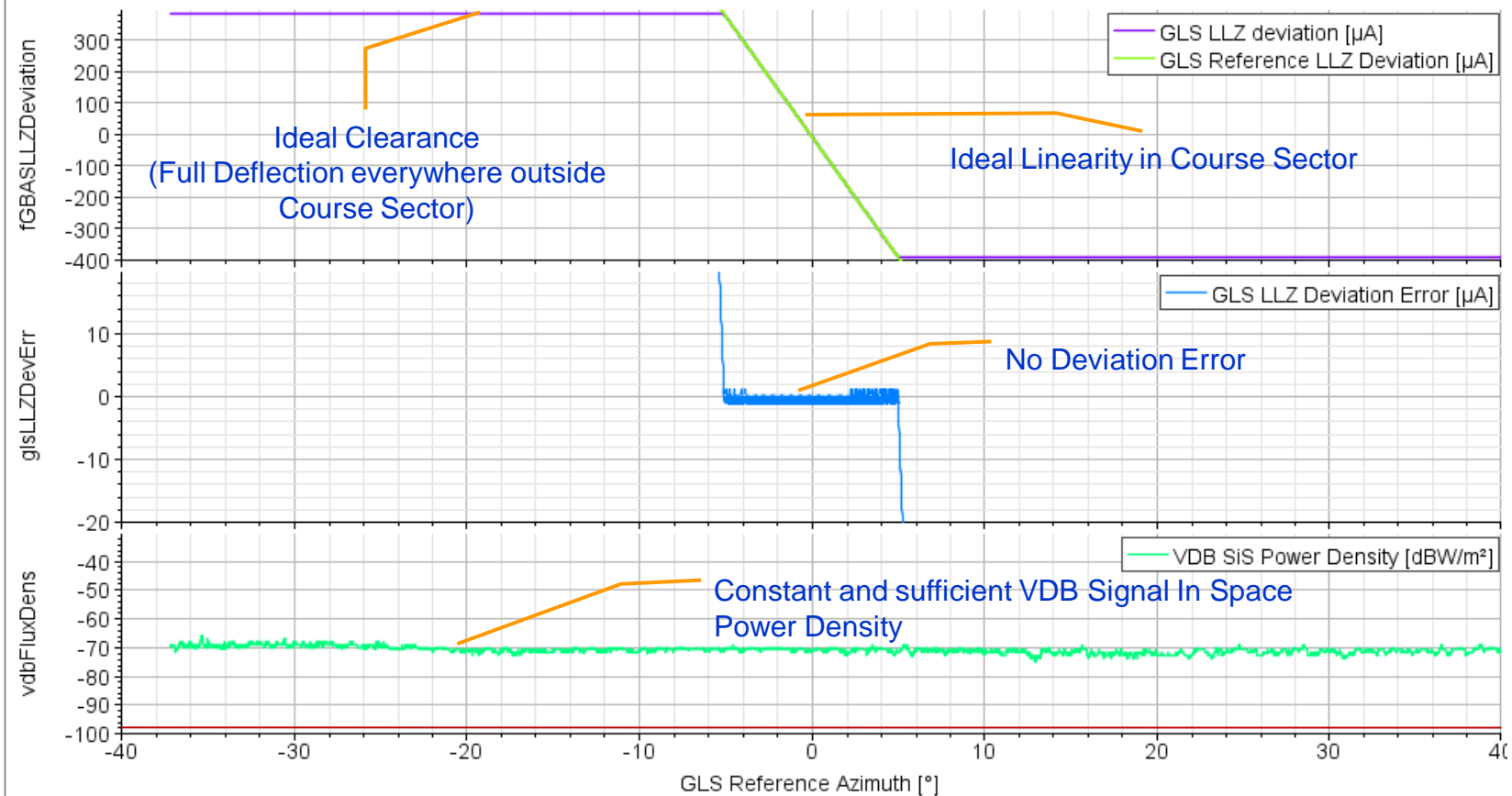
Equipment

Flight Inspec.

Summary

# GBAS Coverage Arc

GBAS Lateral (Azimuth uA) (VDBW VDB: TX1-OC)



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

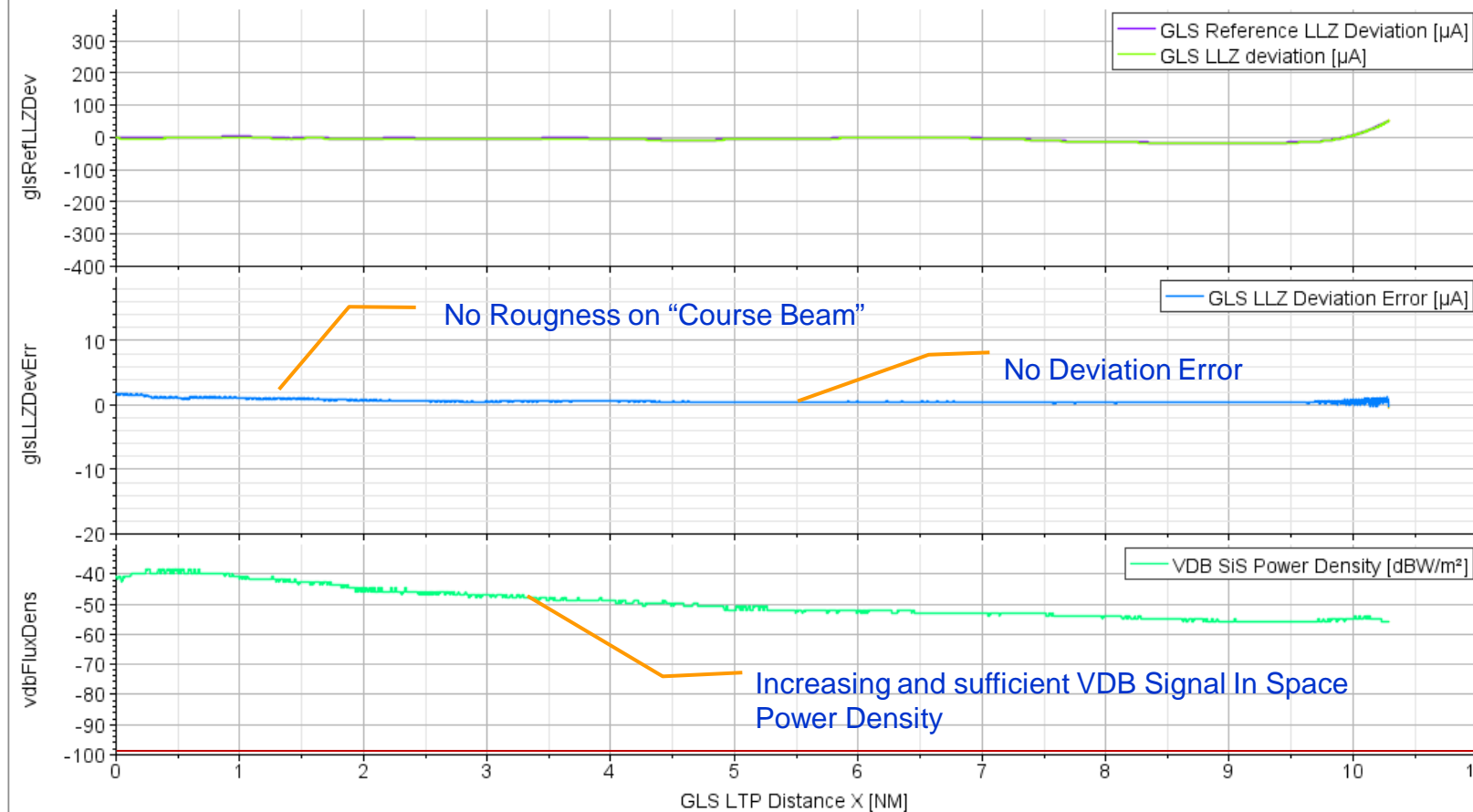
Equipment

Flight Inspec.

Summary

# GBAS Approach (lateral)

GBAS Lateral (Distance uA) (VDBW VDB: TX1-AS)



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

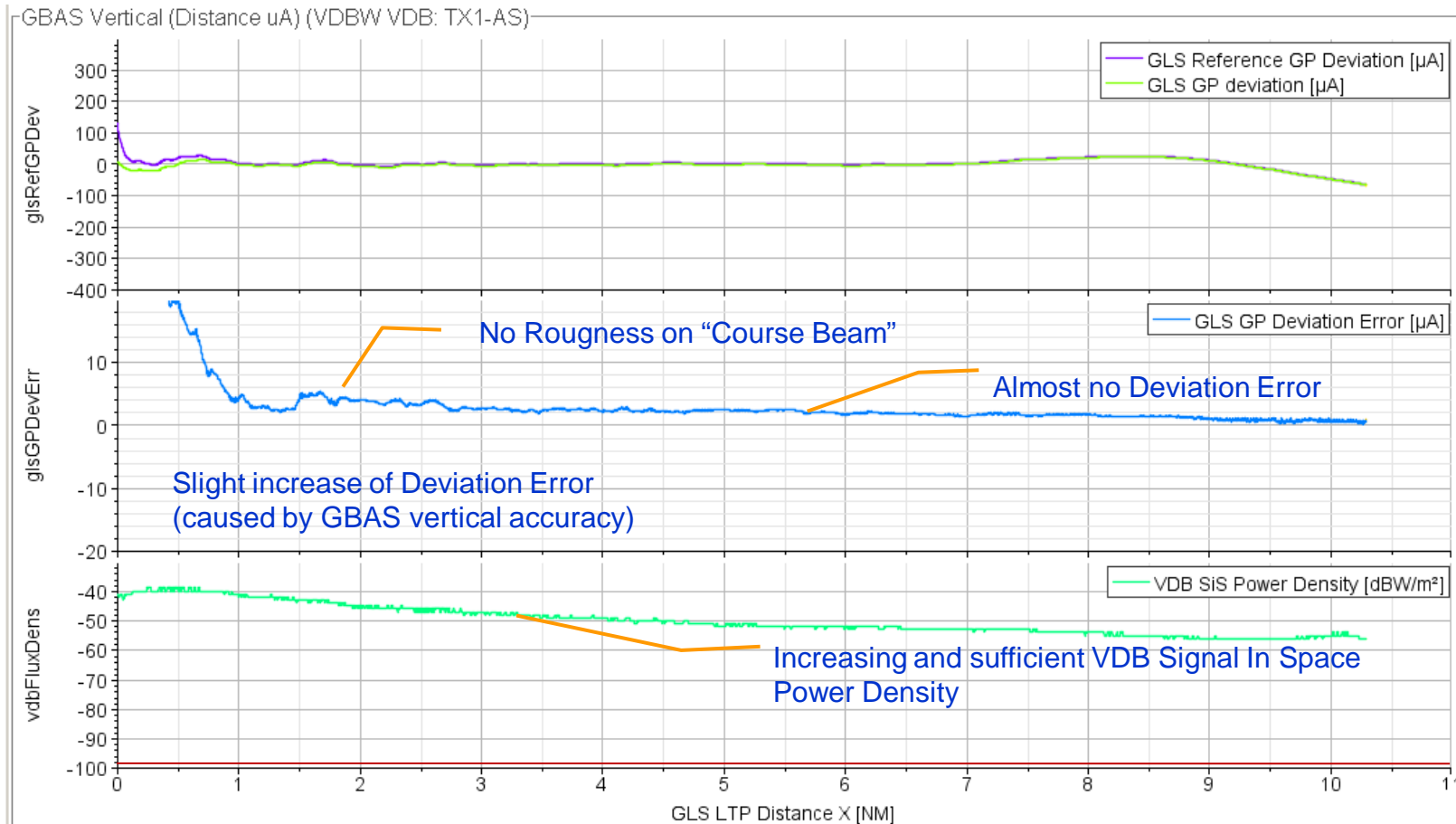
Requirements

Equipment

Flight Inspec.

Summary

# GBAS Approach (vertical)



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

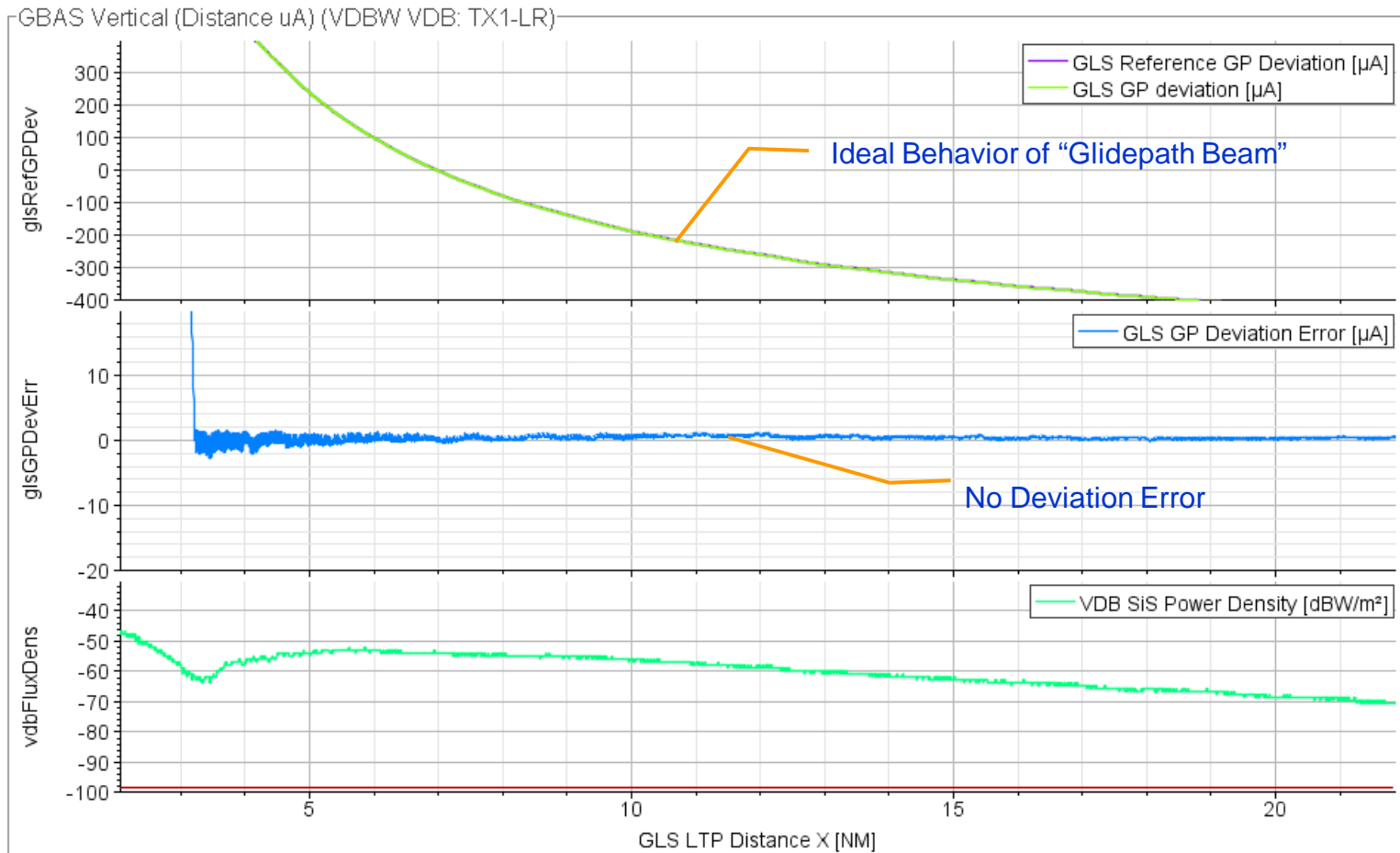
Requirements

Equipment

Flight Inspec.

Summary

# GBAS Level Run



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

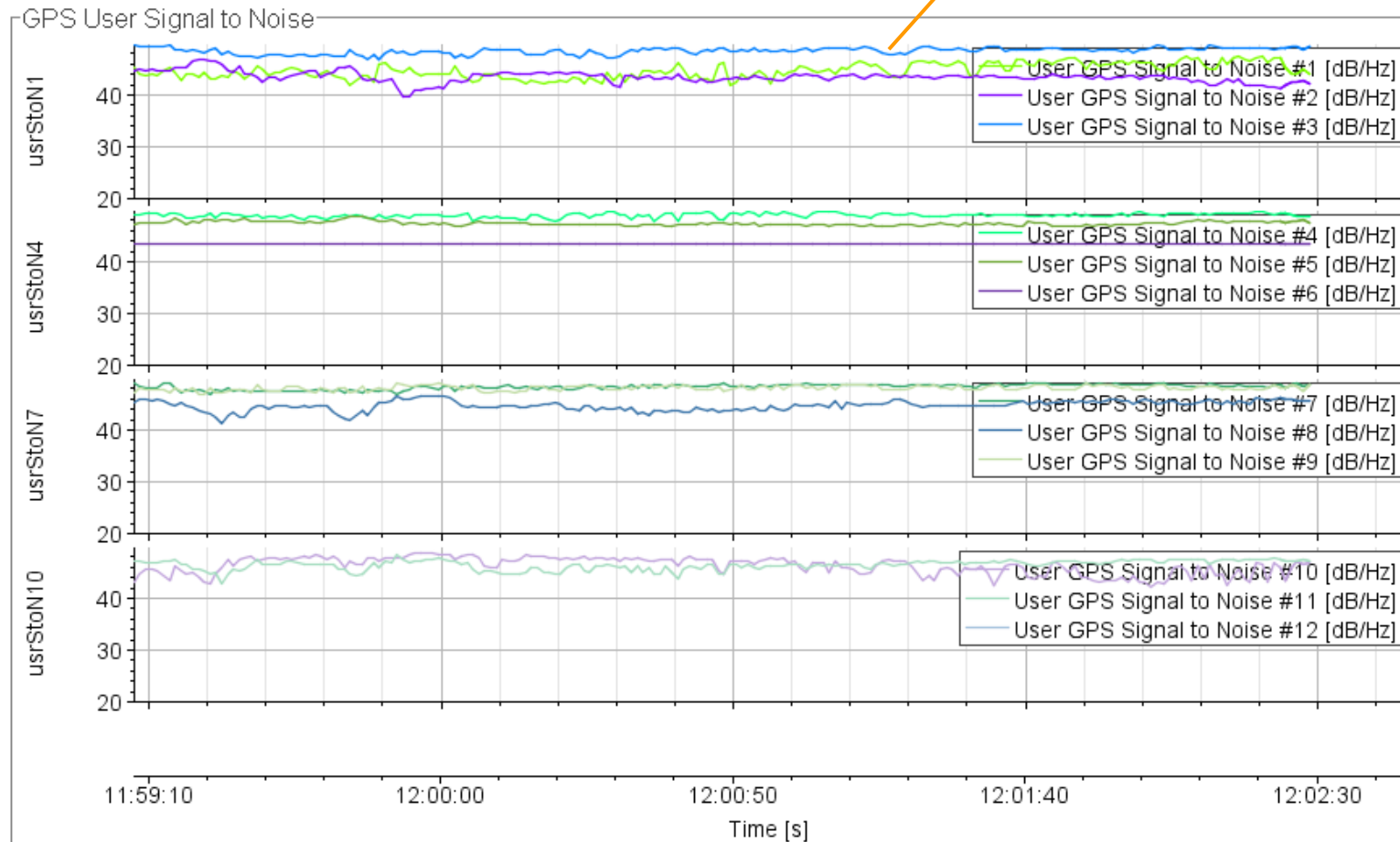
Equipment

Flight Inspec.

Summary

# GBAS GPS Signal Analysis

Individual Satellite Data



ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

Overview

Basics

Requirements

Equipment

Flight Inspec.

Summary

# Summary

In order to measure field strength accurate (+/- 3dB):

- VDB AGC Characteristics of receiver (GNLU) needs to be proper calibrated (polynomial correction curve)
- Aerodata therefore has developed GNLU calibration procedure.
- Cable Losses need to be compensated
- Antenna Characteristics of VDB Antenna needs to be compensated:
  - Azimuth compensation
  - Frequency Compensation



**Ground tests have demonstrated AFIS measures VDB Signal Strength with an absolute accuracy better than +/- 3dB!!!**

# Summary

In order to measure position Errors and Deviation Errors:

- GNLU shows different Time behavior for:
  - Position Output
  - GLS LLZ Deviation Output
  - GLS GP Deviation Output



**These Time Delays need to be compensated for accurate measurements**



# Summary

- Typical Flight Inspection Aircraft are not primary GNLU equipped;
- Retrofit solution for a GNLU installation in e.g. Beech King Air cockpit is not available

## How to fly the GLS Approach, especially if it is no overlay to ILS?



Solution: AFIS Flight Guidance Interface to aircraft EFIS allows the pilots to fly GLS Approaches using the AFIS GNLU.

Only this feature allows to :

- Evaluate the fly ability of GLS approaches with „regular“ Flight Inspection Aircraft
- Fly GLS approaches with autopilot

# GBAS Requirements

## Aircraft:

- Capability to fly GBAS Approach (e.g. provided by AFIS flight guidance)
- Capability to use autopilot for flying GBAS approach
- VDB and GPS antenna for GBAS (GNLU)

## Flight Inspection System:

- GBAS receiver (GNLU) with AGC output (non – standard version)
- Provide Cockpit Flight Guidance to fly GBAS procedures (Arcs, Level runs, Approaches)
- High accurate Reference Position with proven integrity (e.g. PDGPS)
- Compensation of Antenna Lever arms on flight inspection aircraft
- Compensation of Antenna Pattern characteristic for accurate field strength measurements
- Proper Time Synchronization of data (synchronization by timestamp!)
- Spectrum Analyzer interface

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# GBAS Benefits

## For Airlines:

- Nearly ideal Guidance Signal provided to pilots
- Fuel savings, noise abatement and reduced emissions (flexible flight paths)
- Higher precision guidance
- Minimal pilot training (similar to ILS)

## For Airports:

- Improved airport capacity (simultaneous operations to parallel runways, simultaneous )
- No Protection Areas (as required for ILS)
- Improved airport access, even where ILS cannot be installed for terrain or economic reasons.

## For Air Navigation Service Providers:

- Reduced cost and lower ongoing maintenance (one GBAS covers all runways at an airport)
- Flexibility to add or change final approach procedures without changing system configuration
- Continued operations during routine flight inspection or airport works.

ICAO Seminar 2011, 21. – 23. Nov., Sao Jose dos Campos THK

# GBAS Disadvantages

## Fully dependant on GPS:

- GPS Interference or jamming could disable entire system  
(Complete airport / all runways simultaneously!)  
Example: A simple 1 Watt handheld GPS Jammer can blast GPS Signals in a 100 kilometer radius



## Intentional Jamming:

- GPS Jammer like this can simply be bought via Internet

## Unintentional Interference:

- A defective microwave oven on board of a sailboat jammed GPS on an entire airport in the US.
- A wireless network router from University jammed GPS at an airport in Spain

- Costly Precision Approach Lighting system is required for every runway



**Thank you for your attention!**