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Experiences in Flight Inspecting GBAS

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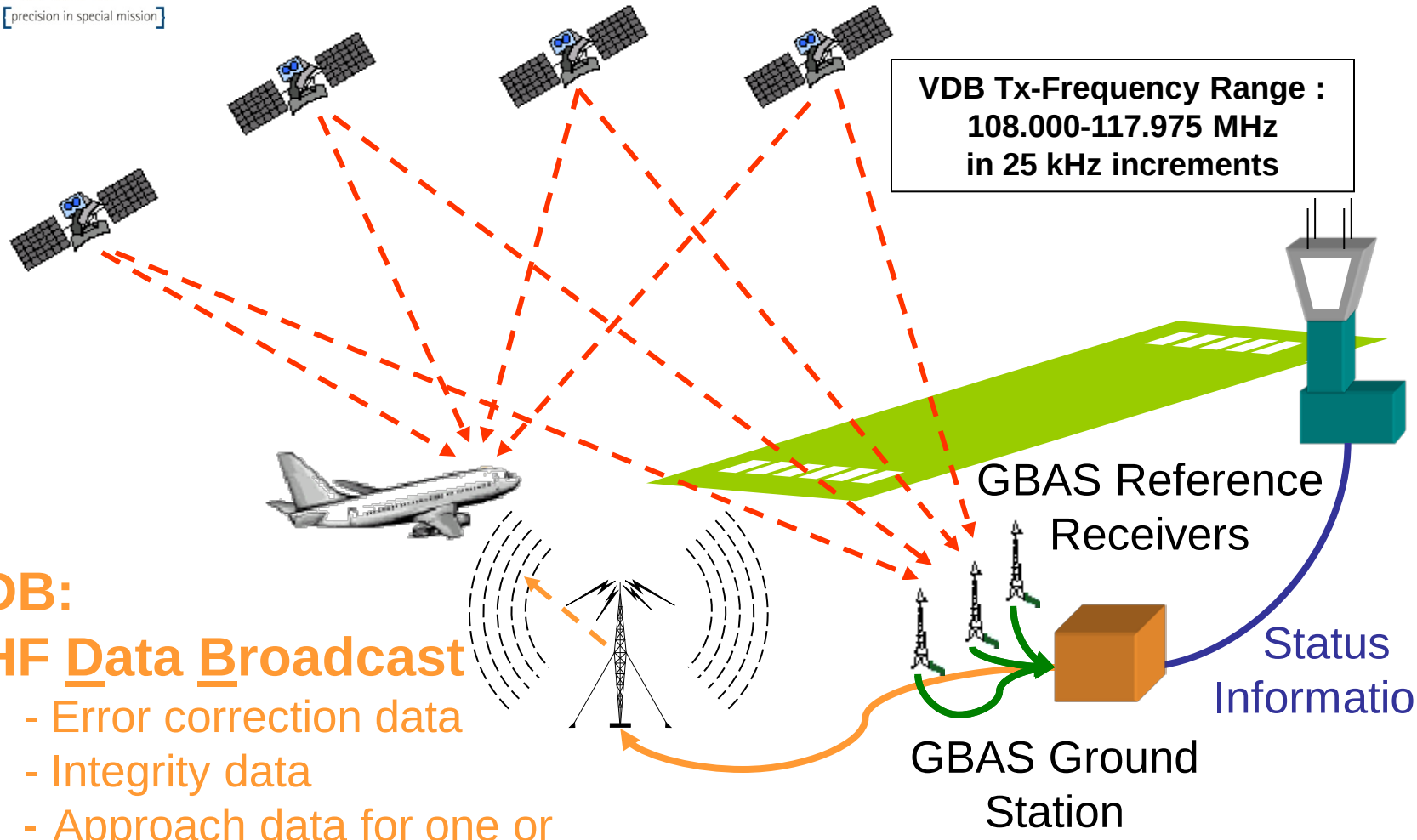
Flight Inspection of GBAS

Overview

- Basics
- Requirements
- Equipment
- Flight Inspection
- Summary

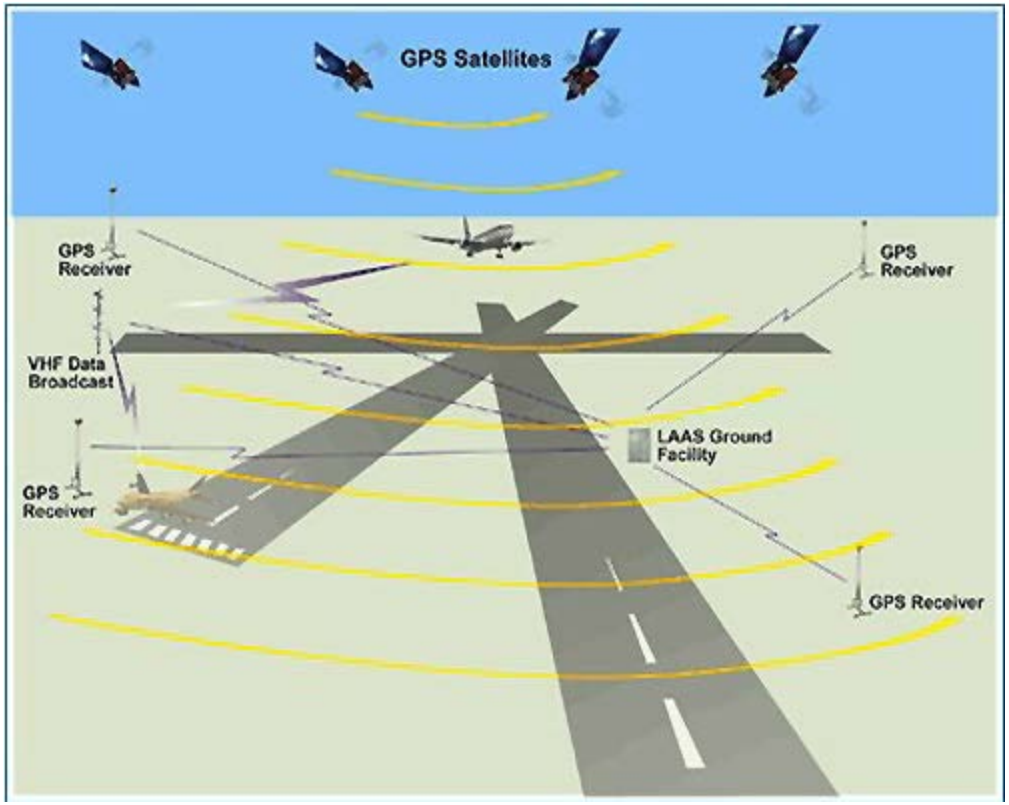
Ground Based Augmentation System



VDB:
VHF Data Broadcast

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

Ground Based Augmentation System



– One GBAS Ground station may support several runways and approaches

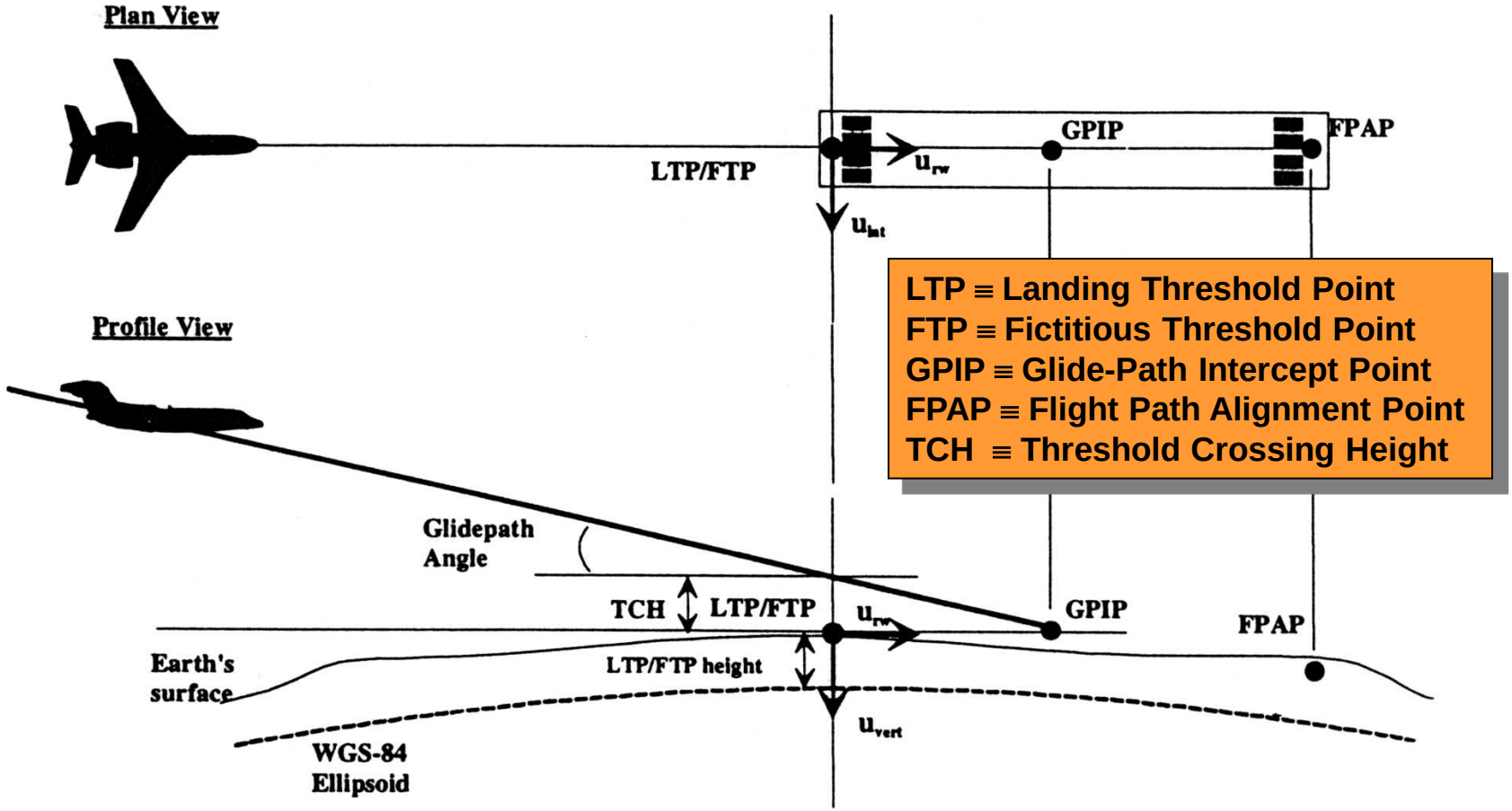
– „ILS Lookalike“ Deviations are provided to the pilot:

GLS Distance
GLS Lateral Deviation
GLS Vertical Deviation

VHF Data Broadcast (VDB) Messages

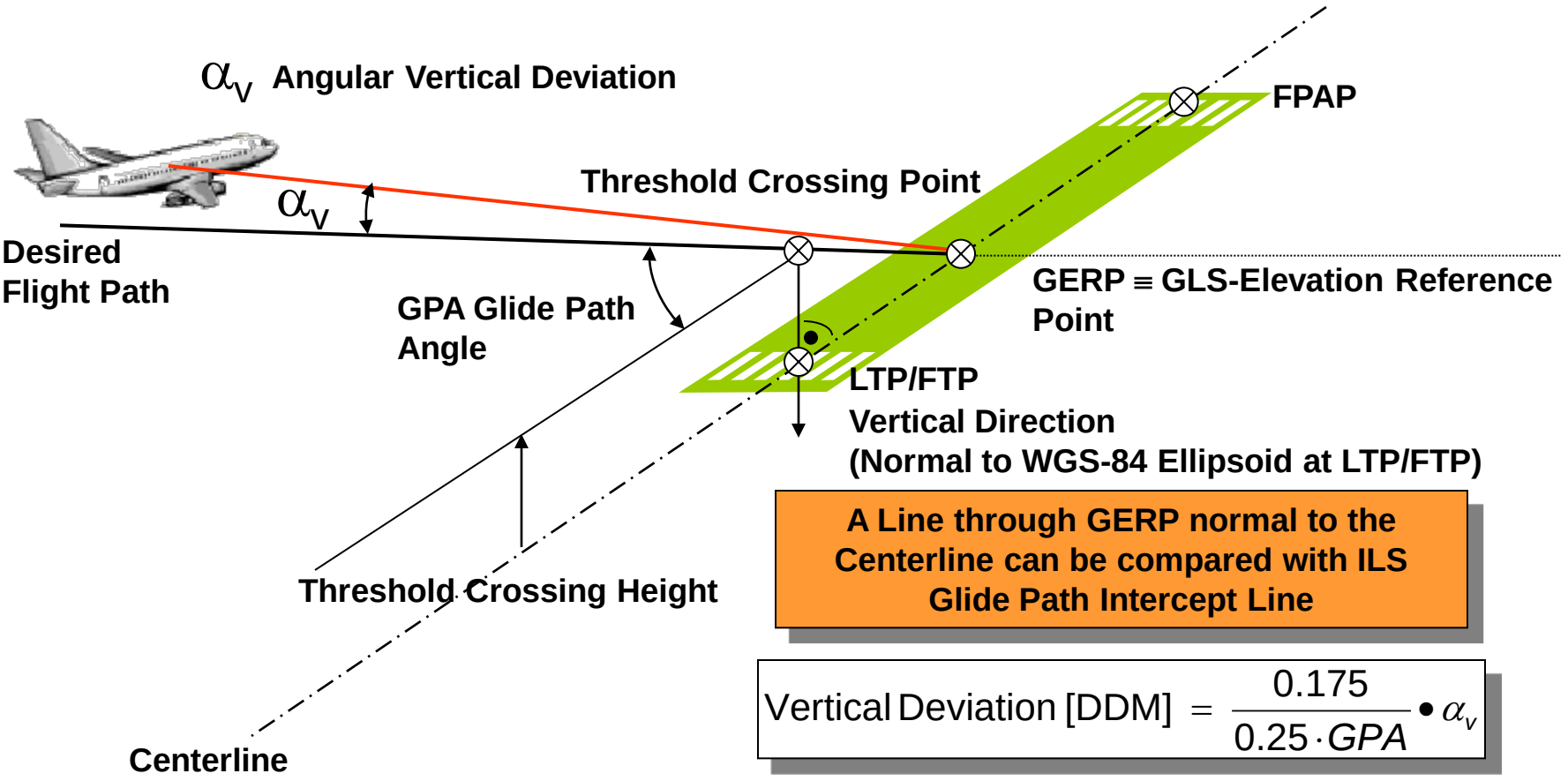
- **Type 1:** Differential Error Correction Data
- **Type 2:** Differential Reference Point Data
- (Integrity Data)
- **Type 3:** Reserved for GBRS **G**round **B**ased **R**anging **S**ource (Airport Pseudolites)
- **Type 4:** FAS **F**inal **A**pproach **S**egment Construction Data for one or more Runways/Approaches
- **Type 5:** Ranging Source Availability (optional)
- **Type 6:** Reserved for Carrier Corrections
- **Type 7**: Reserved for Military
- **Type 8:** Reserved for Test

Final Approach Segment Diagram



LTP ≡ Landing Threshold Point
FTP ≡ Fictitious Threshold Point
GPIP ≡ Glide-Path Intercept Point
FPAP ≡ Flight Path Alignment Point
TCH ≡ Threshold Crossing Height

GLS (GNSS Landing System) Vertical Deviation



A Line through GERP normal to the Centerline can be compared with ILS Glide Path Intercept Line

$$\text{Vertical Deviation [DDM]} = \frac{0.175}{0.25 \cdot GPA} \bullet \alpha_v$$

GLS (GNSS Landing System) Lateral Deviation

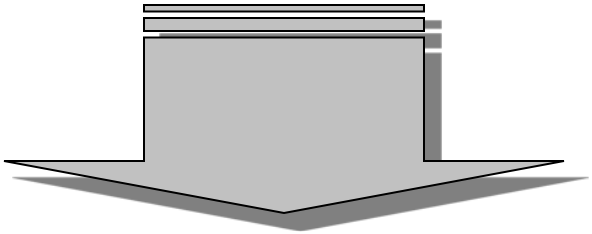
GARP can be compared with the ILS-LLZ Antenna

$$\text{Lateral Deviation [DDM]} = \frac{0.155}{\arctan\left(\frac{CourseWidth}{D_G}\right)} \bullet \alpha_{Lat}$$

Comparison GLS – ILS

GNSS Landing System ← → Instrument Landing System

GLS	ILS
GLS Azimuth Reference Point	Localizer Antenna Position
GLS Elevation Reference Point	Glide path intercept Line
Deviation calculated in DDM	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

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

What should be inspected on ground

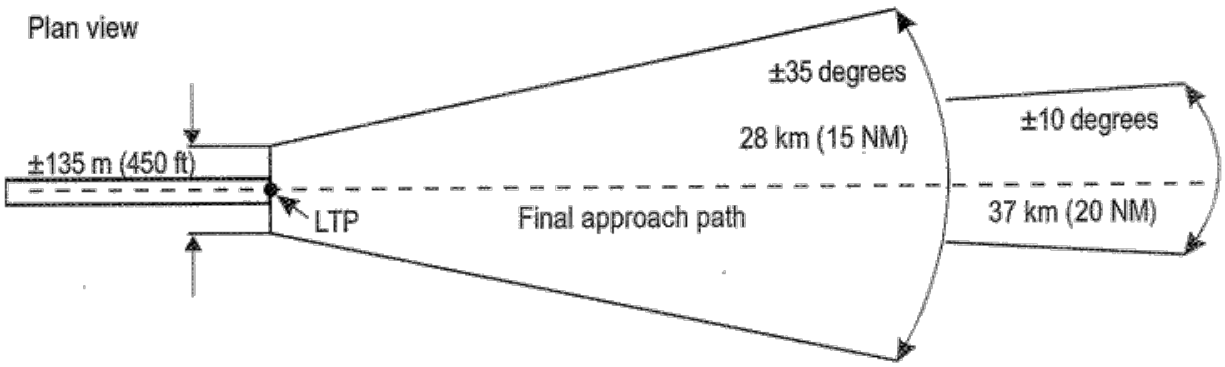
- Data Contents
  - FAS
    Horizontal Tolerance: 0,4m horizontal, uncertainty 0,05m
    Vertical Tolerance: 0,2m vertical, uncertainty 0,05m
  - Integrity Data
  - Differential Correction Data
- Runway surface coverage
  (> -99 dBW/m² < -35 dbW/m² @ 3,7m / 12ft above runway)
- Availability of Satellites 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 ±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)

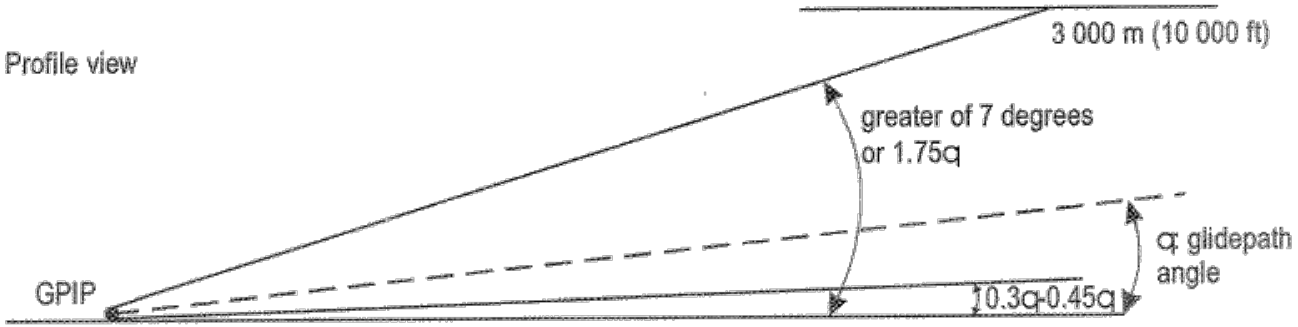
Coverage Area

The minimum operational VDB coverage area has to be:



No Data Continuity Alerts shall be allowed in this area

-35 dBW/m²> Field Strength > -99 dBW/m²



Procedures

20 NM Arc around LTP/FTP @ 0.3 –0.45 Theta (~ 2000ft HAT) ±10°

15 NM Arc around LTP/FTP @ 0.3 –0.45 Theta (~ 1500ft HAT) ±35°

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/m²

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

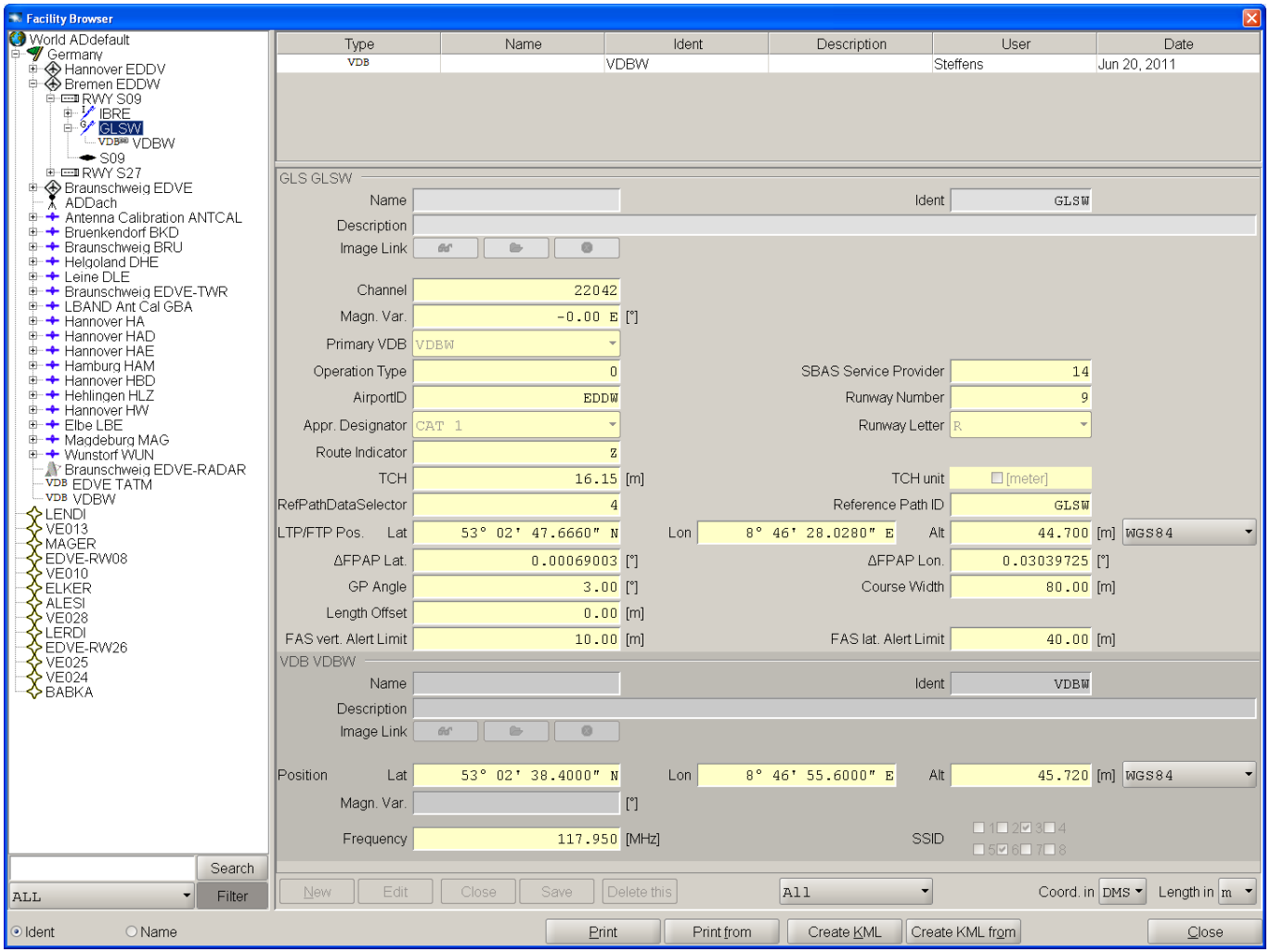
AFIS Provides:
- GLS Lateral Deviation
- GLS Vertical Deviation
- GLS Distance

➔ Use of Autopilot for GLS!

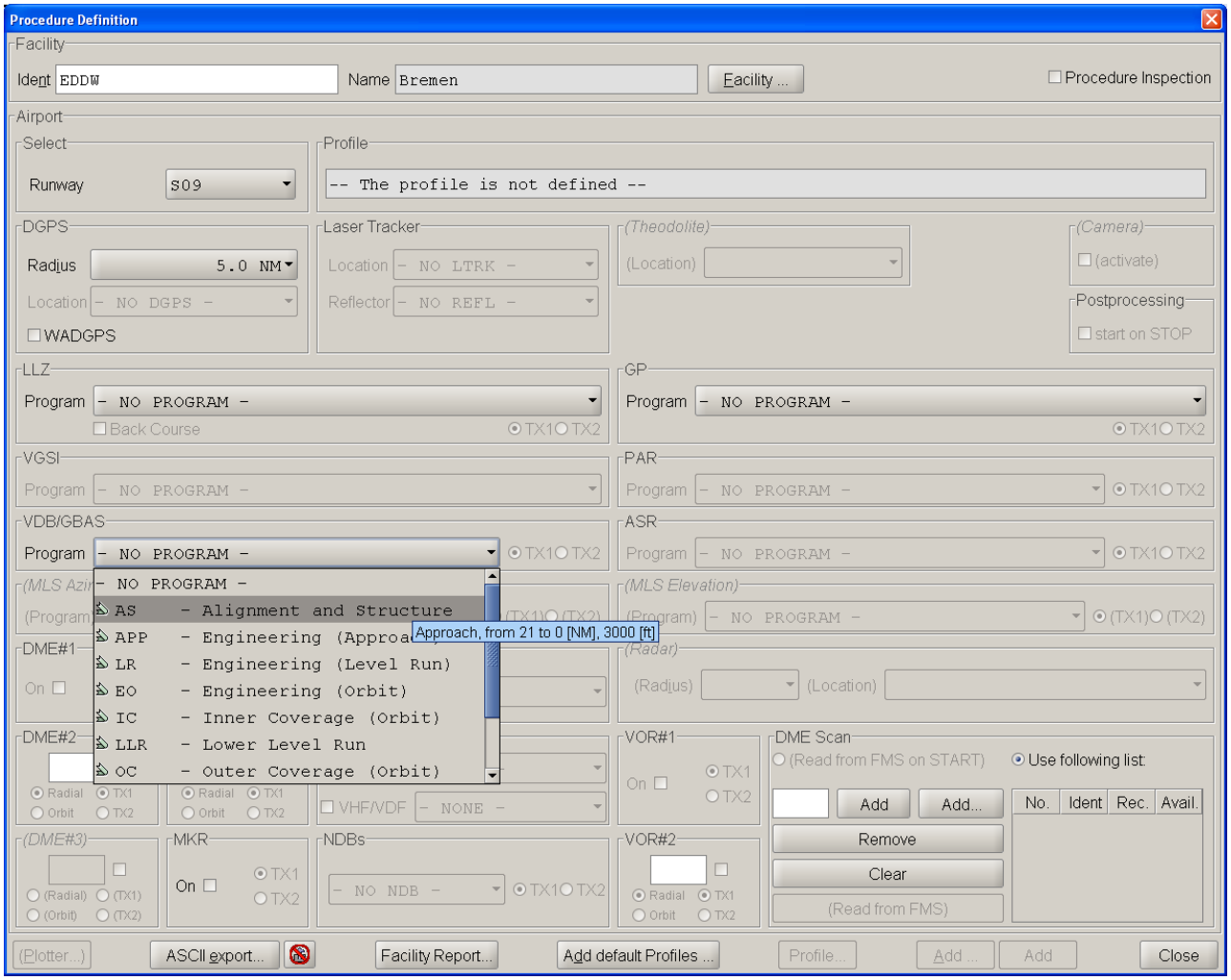
GBAS Software

- 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 avionic 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

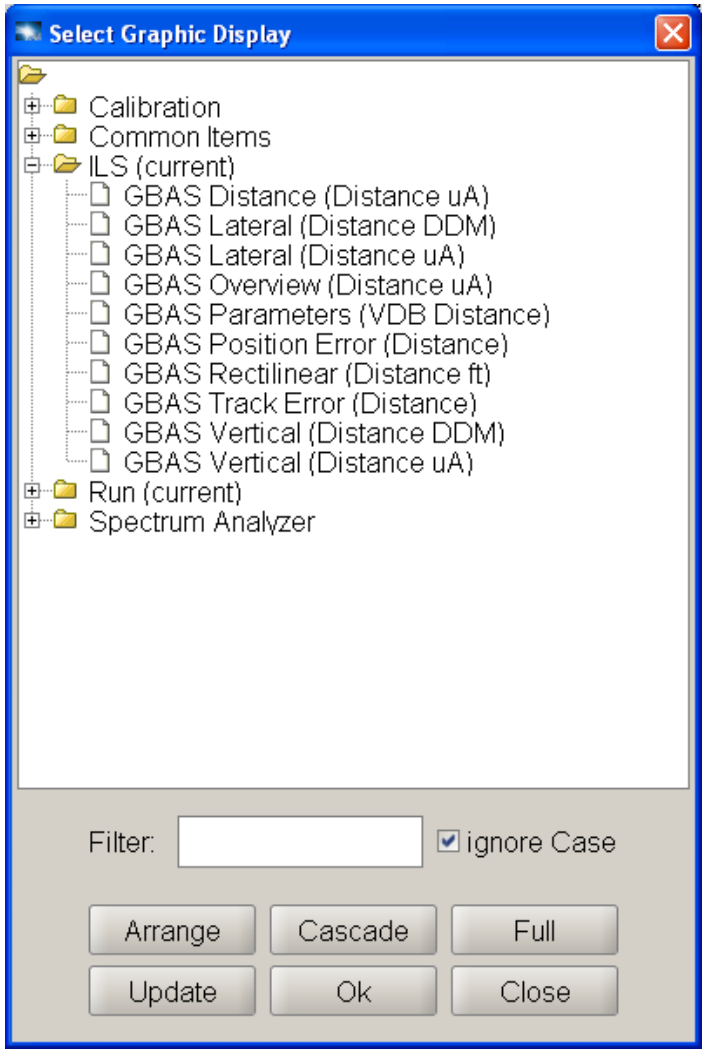
Software - Database



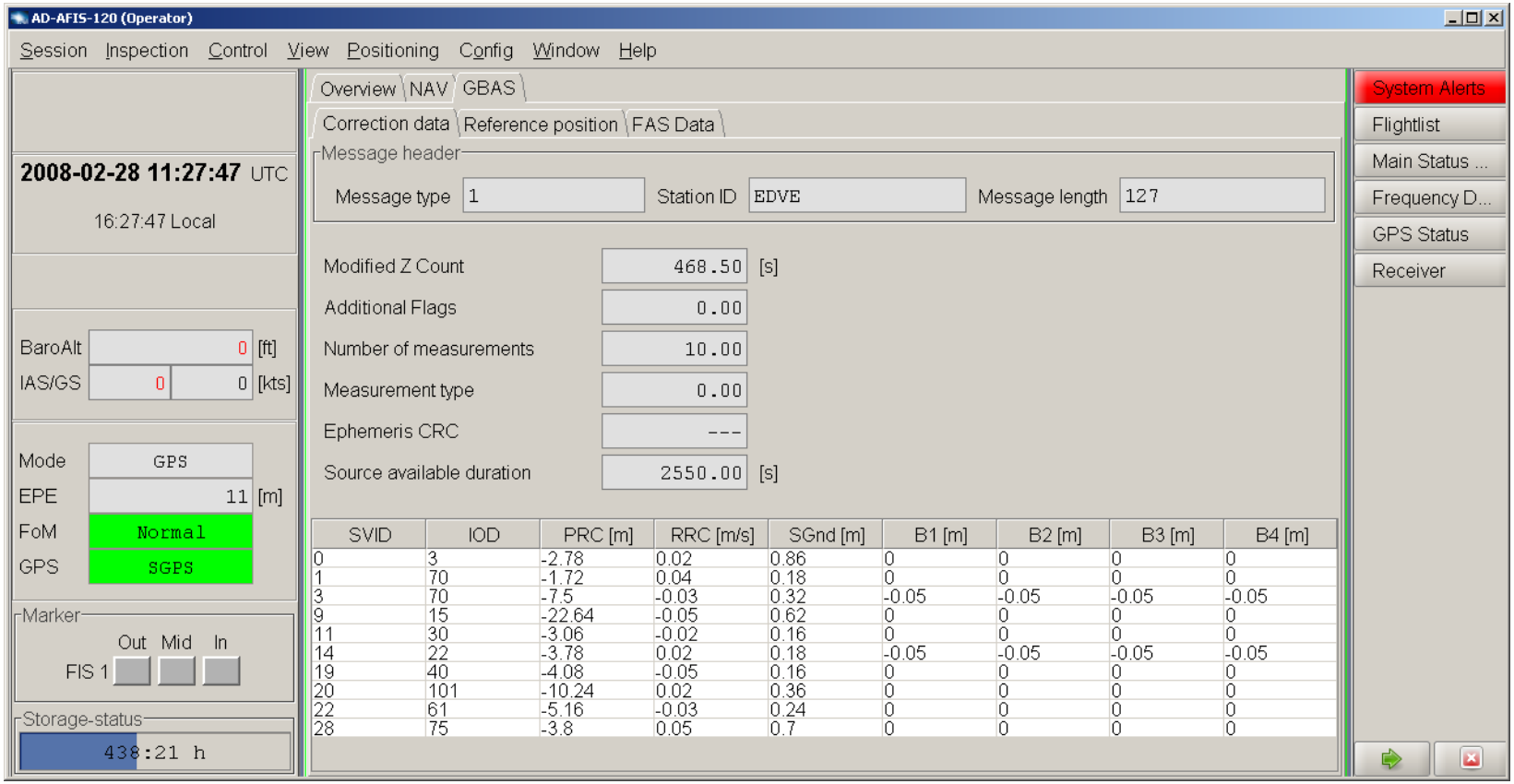
Software – Procedure Definition



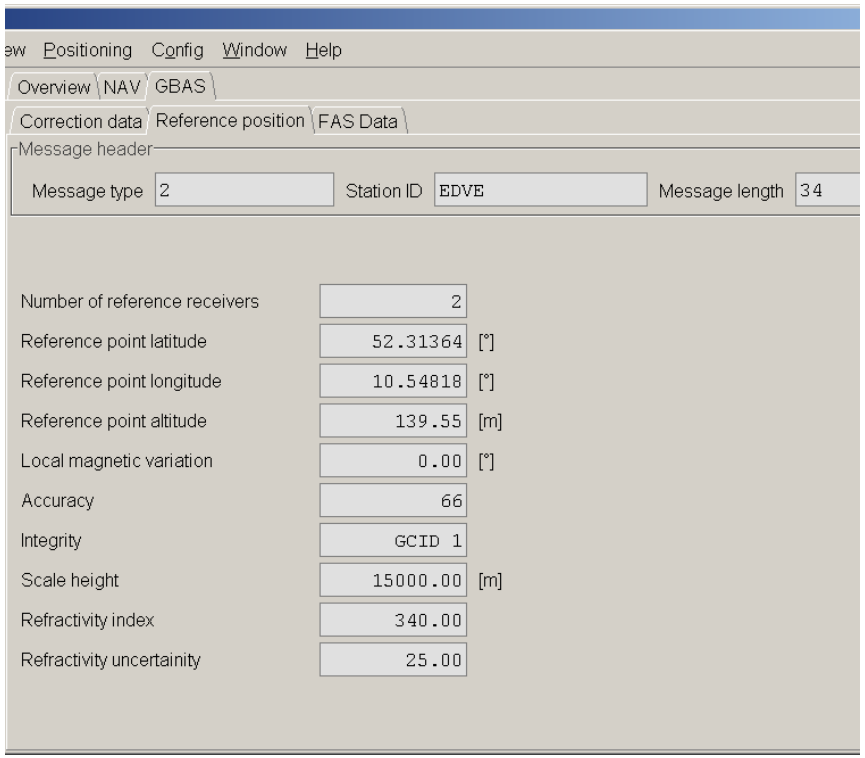
Software – Graphic Selection

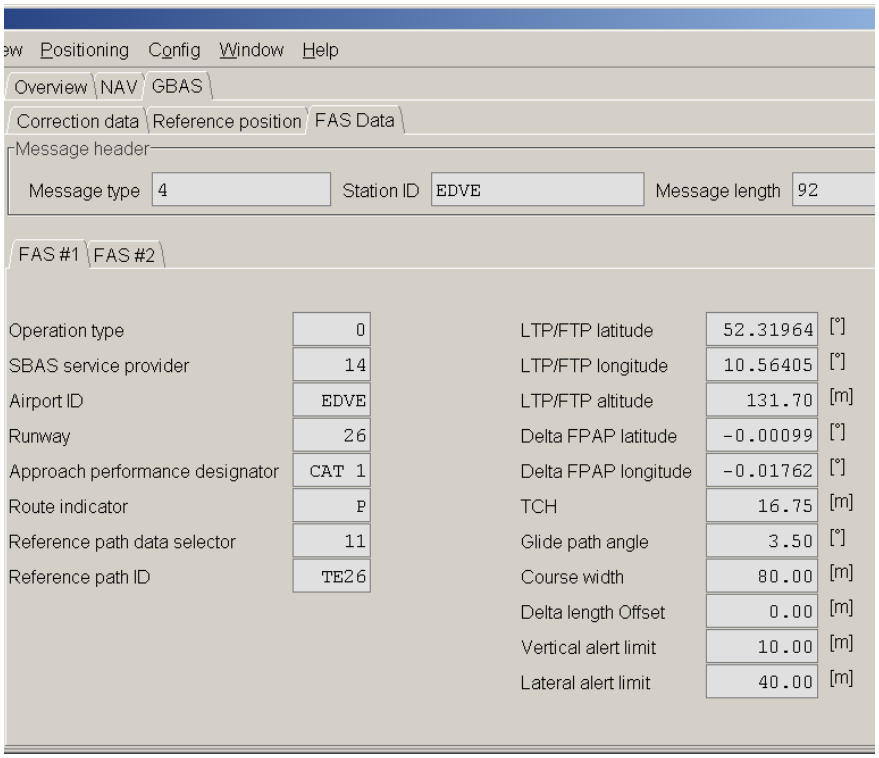


Software – FAS Data

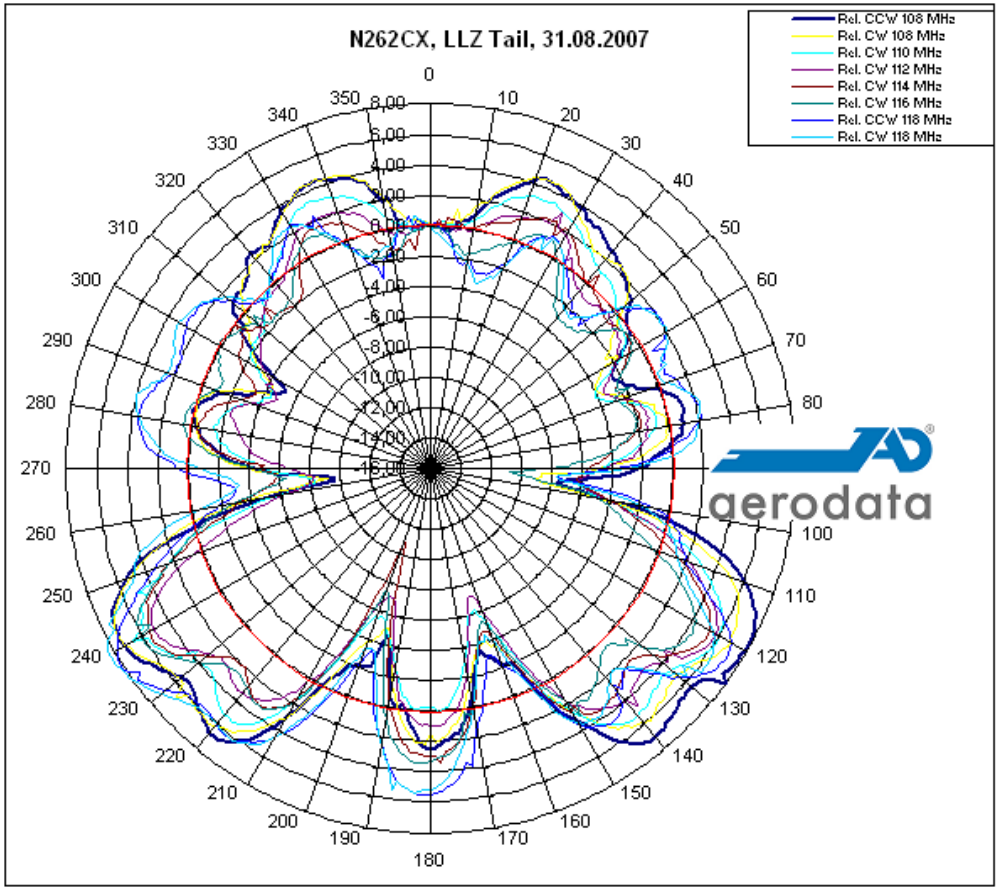


Software – FAS Data





Software – Antenna Pattern Correction



Flight Inspection Equipment

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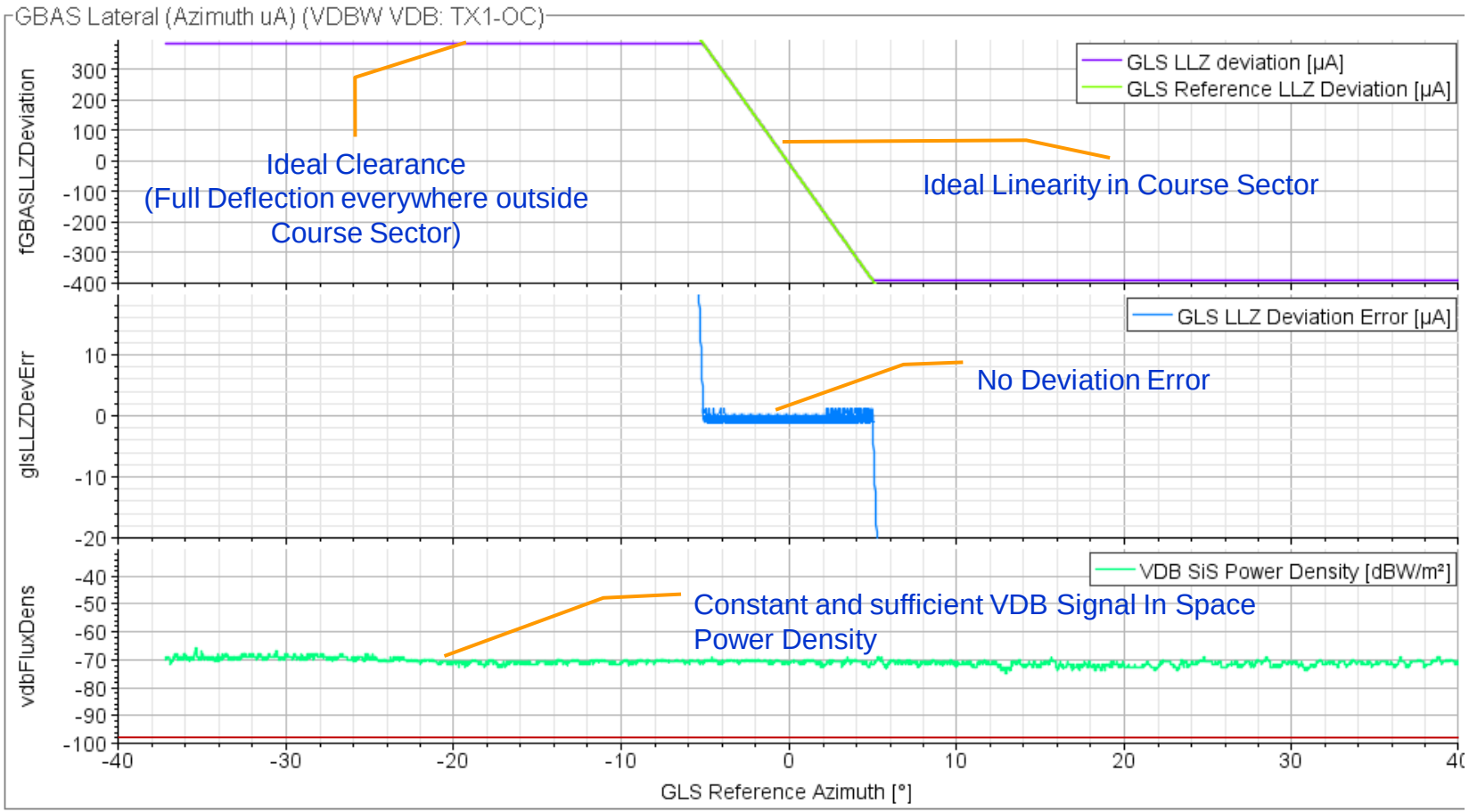
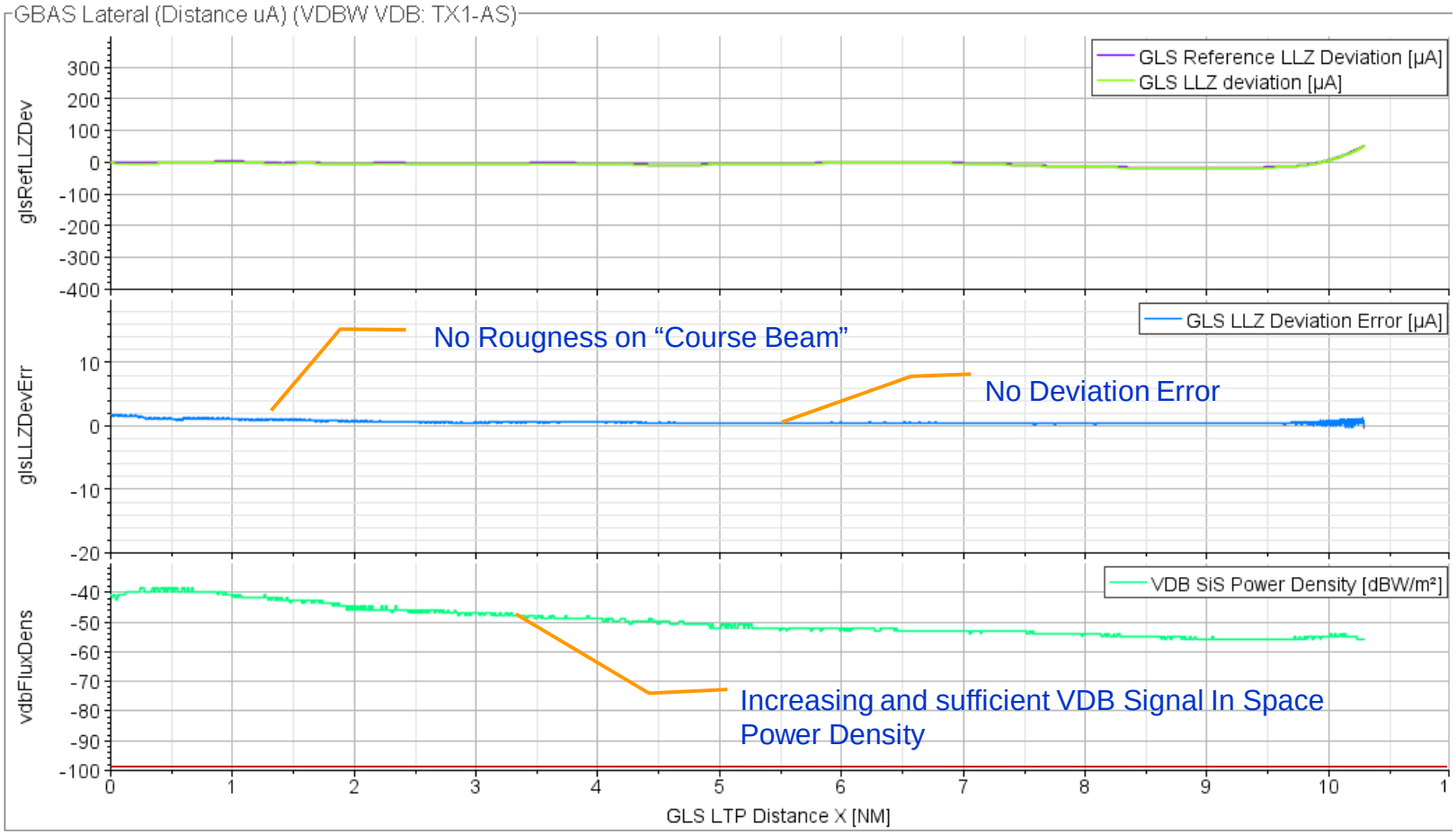
Hardware

in A/C

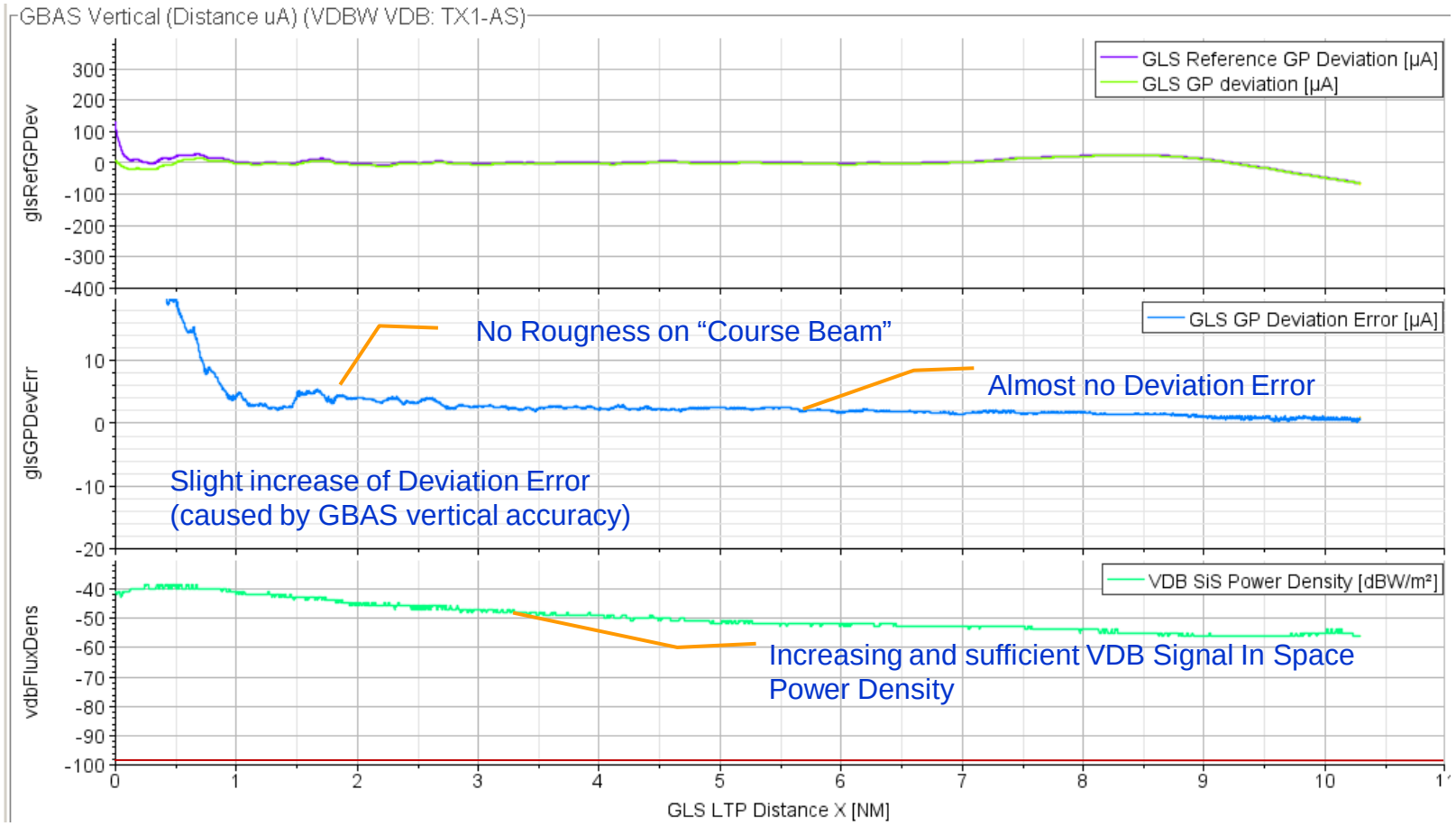
GBAS Coverage Arc



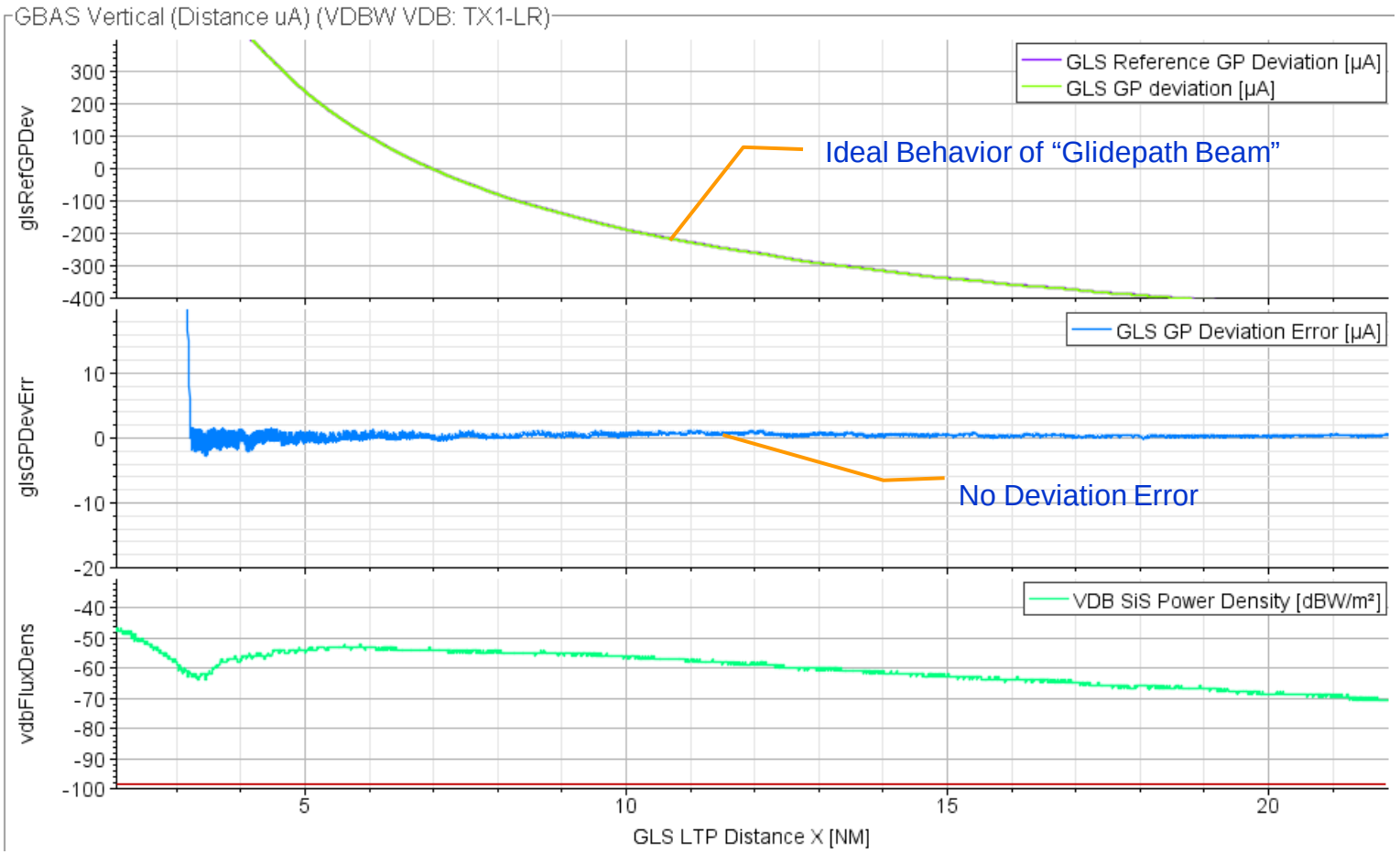
GBAS Approach (lateral)



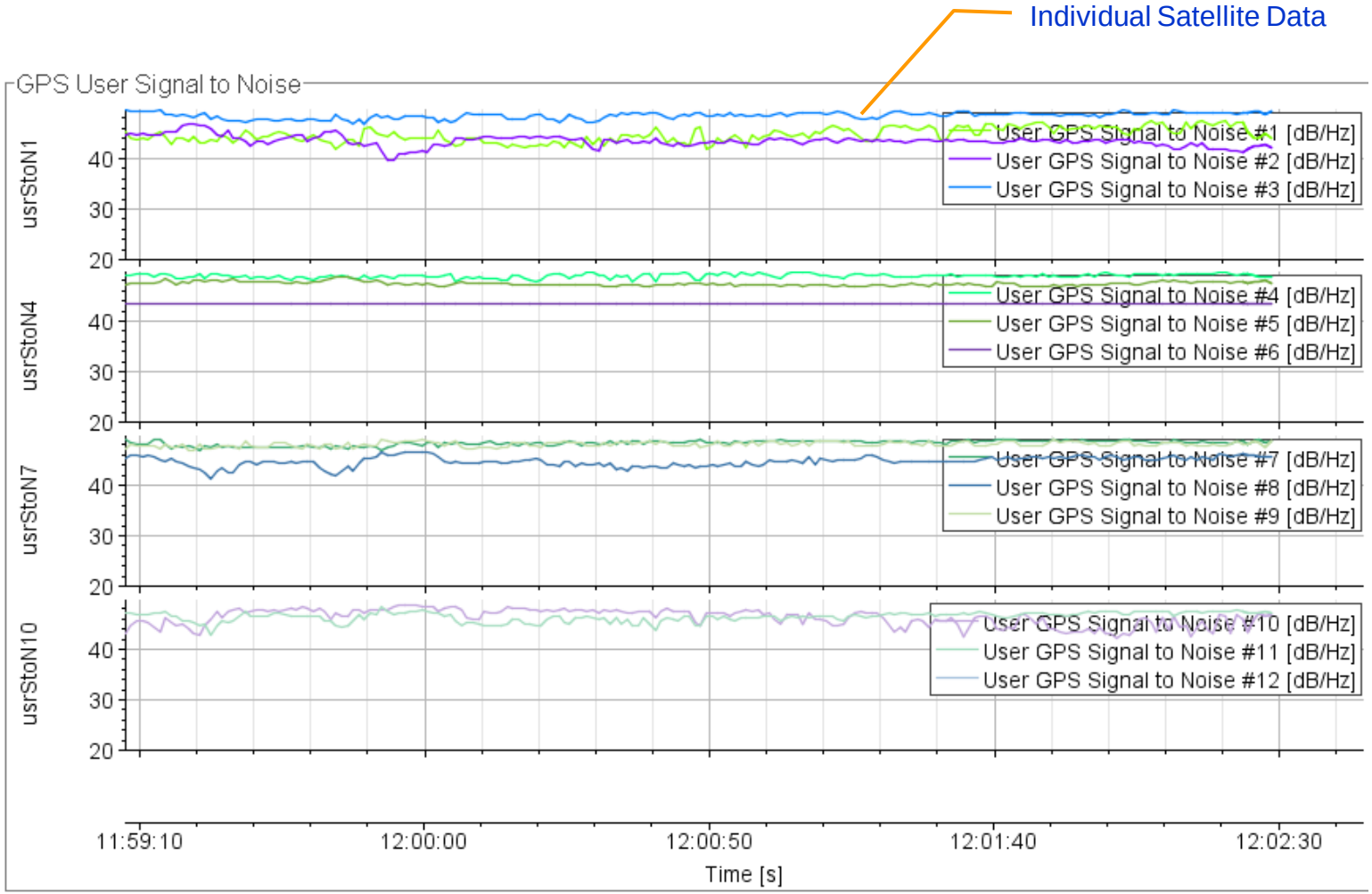
GBAS Approach (vertical)



GBAS Level Run



GBAS GPS Signal Analysis



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

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.

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

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Thank you for your attention!