Challenges in Complex Procedure Design Validation

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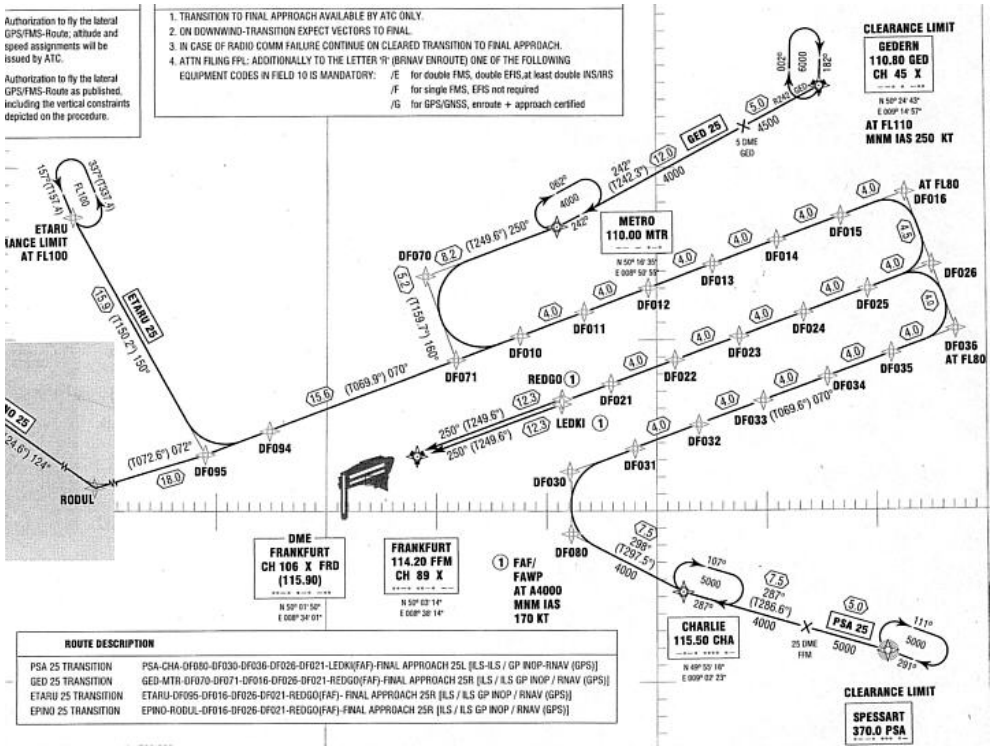
Procedure Validation

Any new or modified Instrument Flight Procedure
is required to be validated before publication.



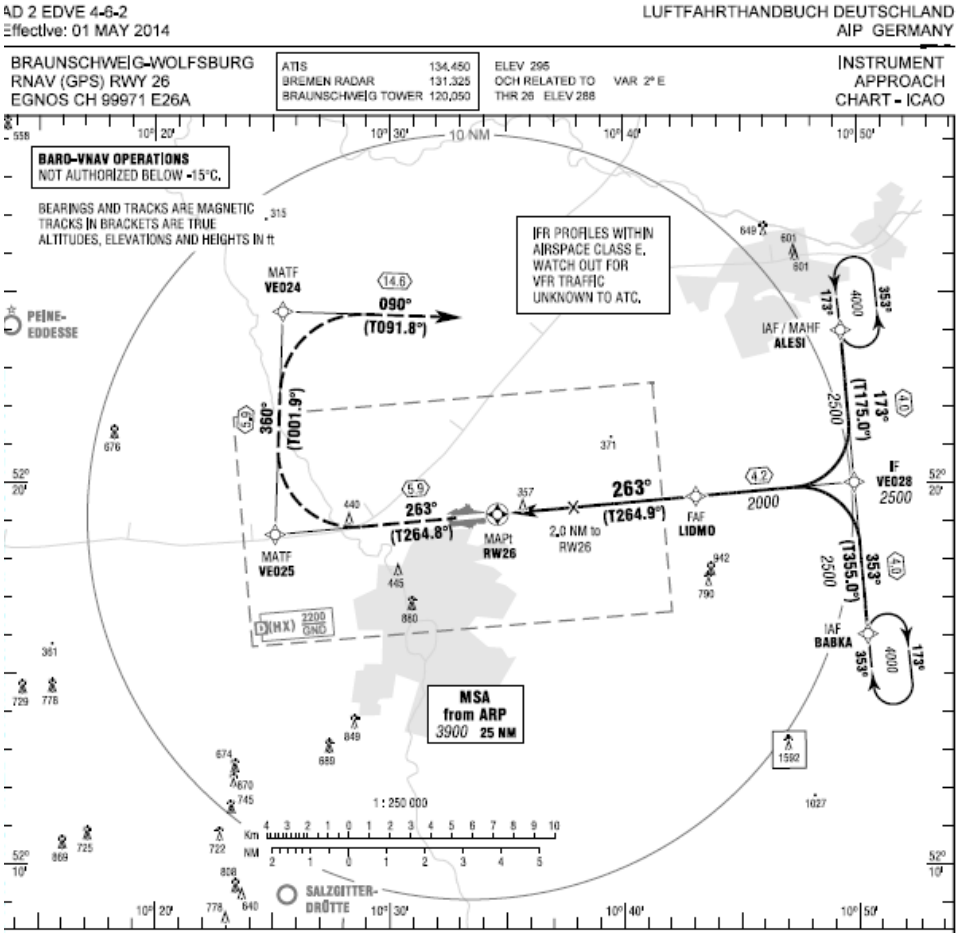
The purpose of procedure validation is:

To ensure a proper standard and safe operation

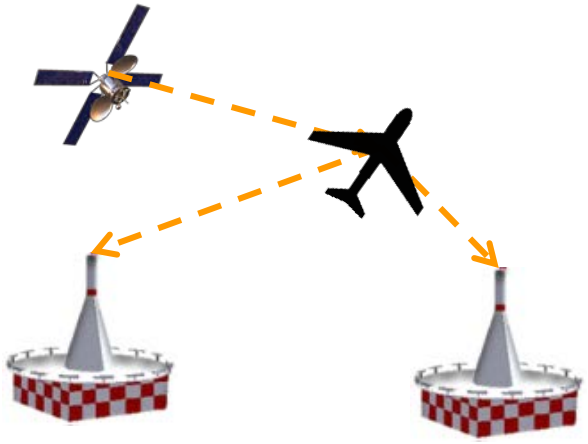
Subject of the Validation

Pre-Flight Validation:

- ✓ Data Correctness
  - Charts, FMS database
  - Waypoint
    - Coordinates,
    - Identifier,
    - fly-by / fly-over
  - Tracks and Distances
  - Final Approach Segment data
  - Suitable path transitions

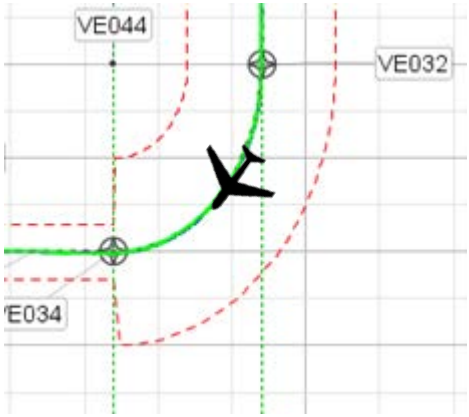


Subject of the Validation (continued)



In-Flight Validation

- ✓ Coverage of navigation signals:
  - GNSS
  - SBAS
  - DME/DME
  - Conventional Navaids (as applicable)
- ✓ RNP Containment
  - deviation from the track
    must not be more than +/- <RNP> NM, 95% of time
- ✓ Communication coverage
- ✓ Possible Interference of navigation signals
- ✓ Terrain and Obstacle clearance
- ✓ Flyability → “Overall Procedures Soundness”



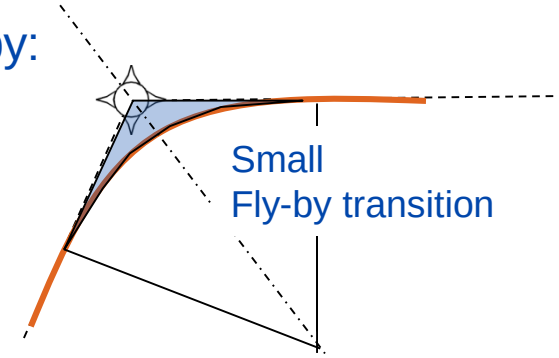
RNP Path Terminators

For precise definition of ground tracks RNP Procedures mainly use the following ARINC424 path terminators:

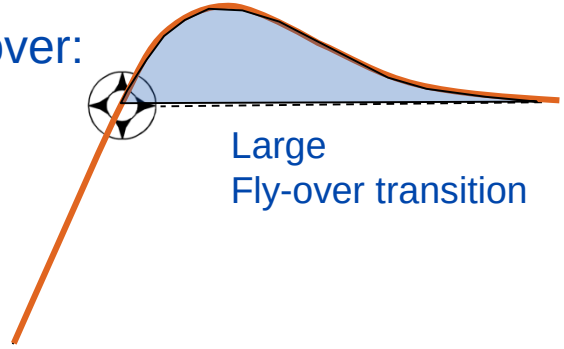
- ✓ Initial Fix (IF)
  - Starting point for a procedure

- ✓ Track To Fix (TF)
  - Great Circle Track between two fixes
  - Typically as Fly-by Waypoints for more precise path definition:

Fly-by:



Fly-over:



Correct Fly-By / Fly-over coding is important!

RF-leg

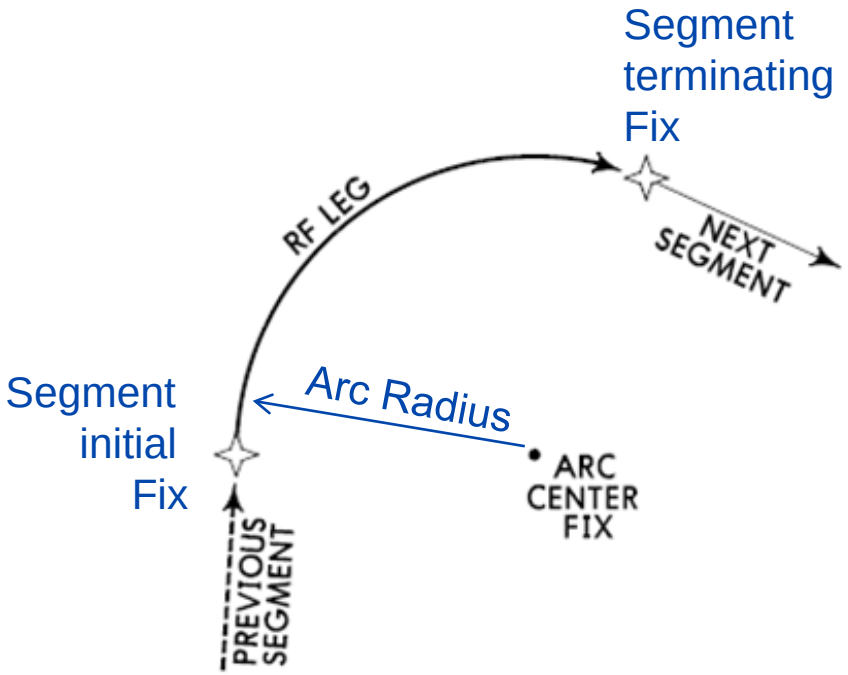
Much better path definition for turns by “Radius To Fix (RF)”

RF-legs are defined in ARINC424 by:

- ✓ Segment initial Fix
- ✓ Arc Center Fix
- ✓ Arc Radius
- ✓ Segment terminating Fix
- ✓ Turn direction (CW/CCW)

RF-legs shall be:

- ✓ Tangent to inbound track
- ✓ Tangent to outbound track

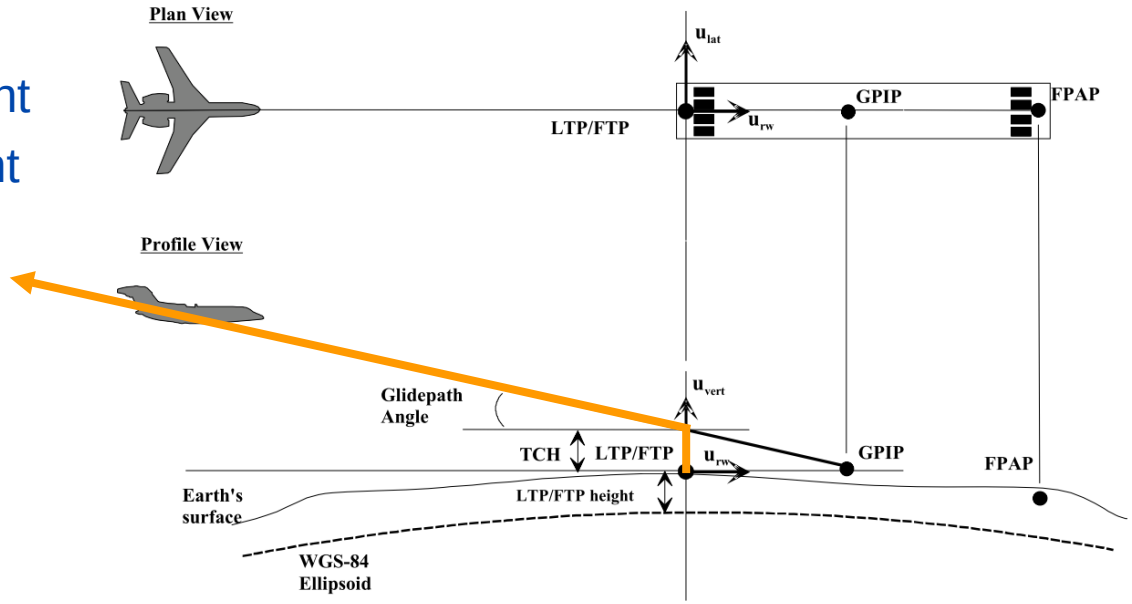


RF-legs are over specified!

Possible consistency issues may result…

Final Approach Segment (FAS)

- Approach path defined by:
  - LTP/FTP
  - Flight Path Alignment Point
  - Threshold Crossing Height
  - Glidepath angle
  - …
  - CRC checksum



- Approach path definition is backwards from LTP/FTP

Possible Inconsistency issues…

Automatic Checks

In order to standardize the Validation Process it is desirable:

Pre-Flight:

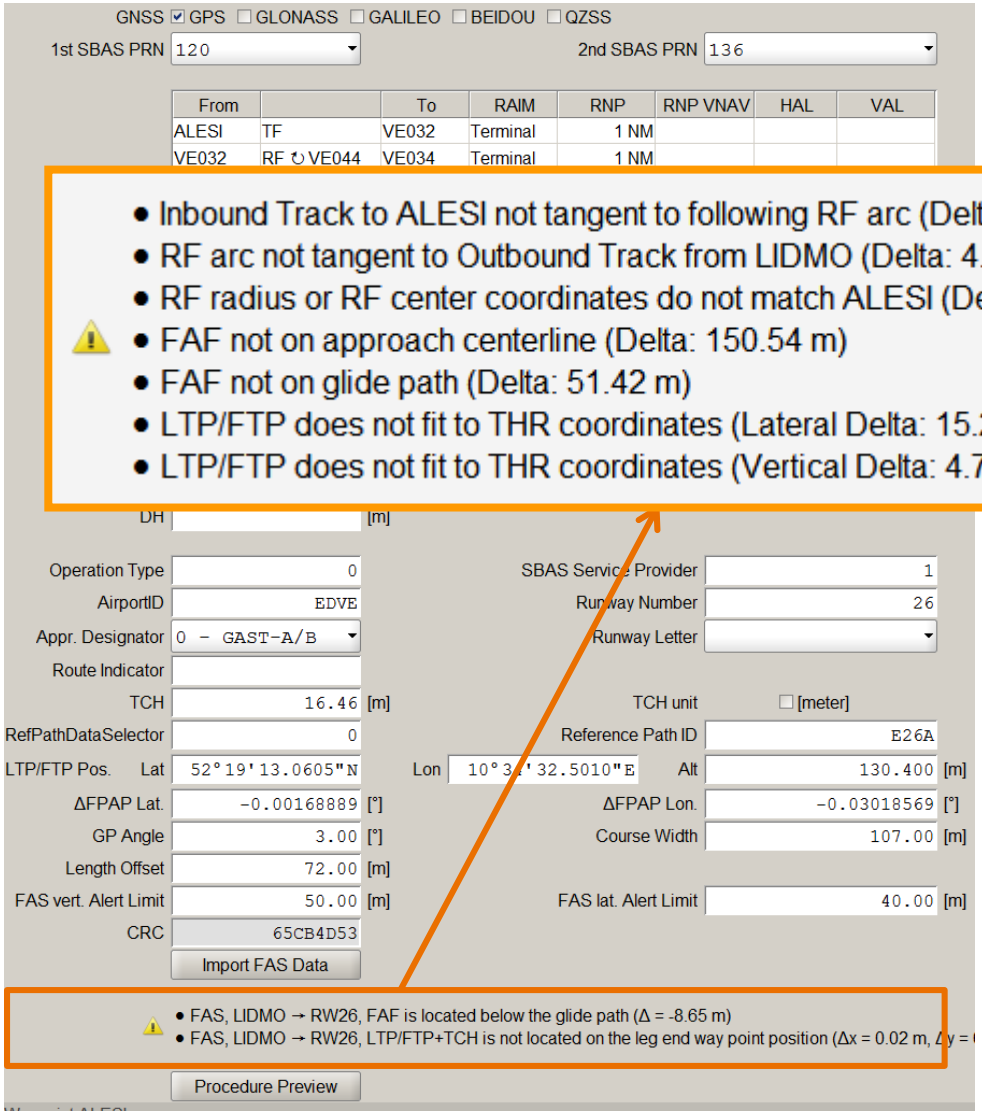
- ✓ Provide means to identify procedure design errors
- ✓ Perform consistency and plausibility checks
- ✓ Use automation to a high extent

In-Flight:

- ✓ Provide means to pre-define the numerous validation tasks → automation
- ✓ Safe the defined settings together with the procedure → standardization

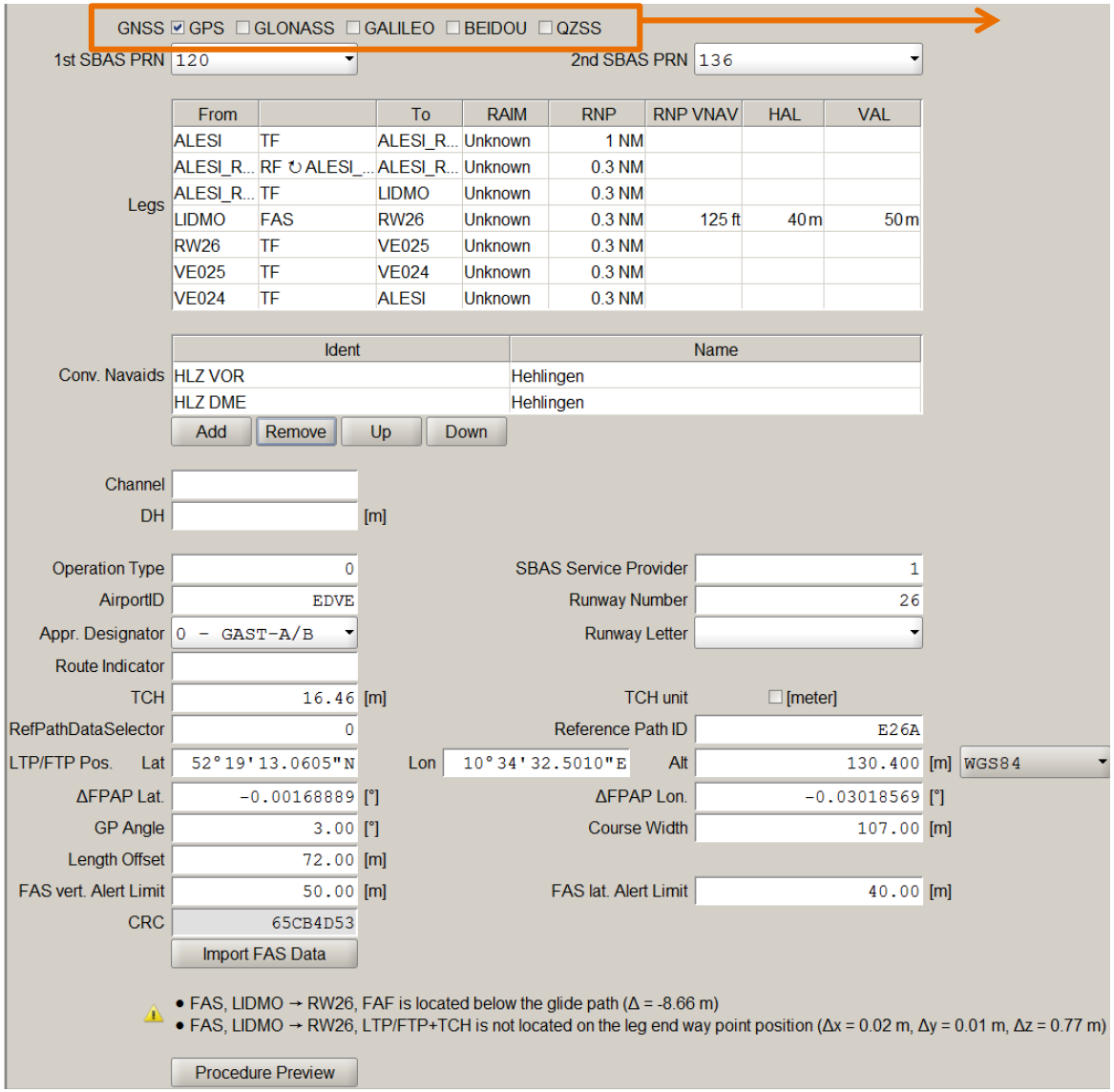
In the following such implementation in a flight inspection system is described…

Procedure Data Stored in AFIS Database



Automatic Consistency Checks for the Procedure

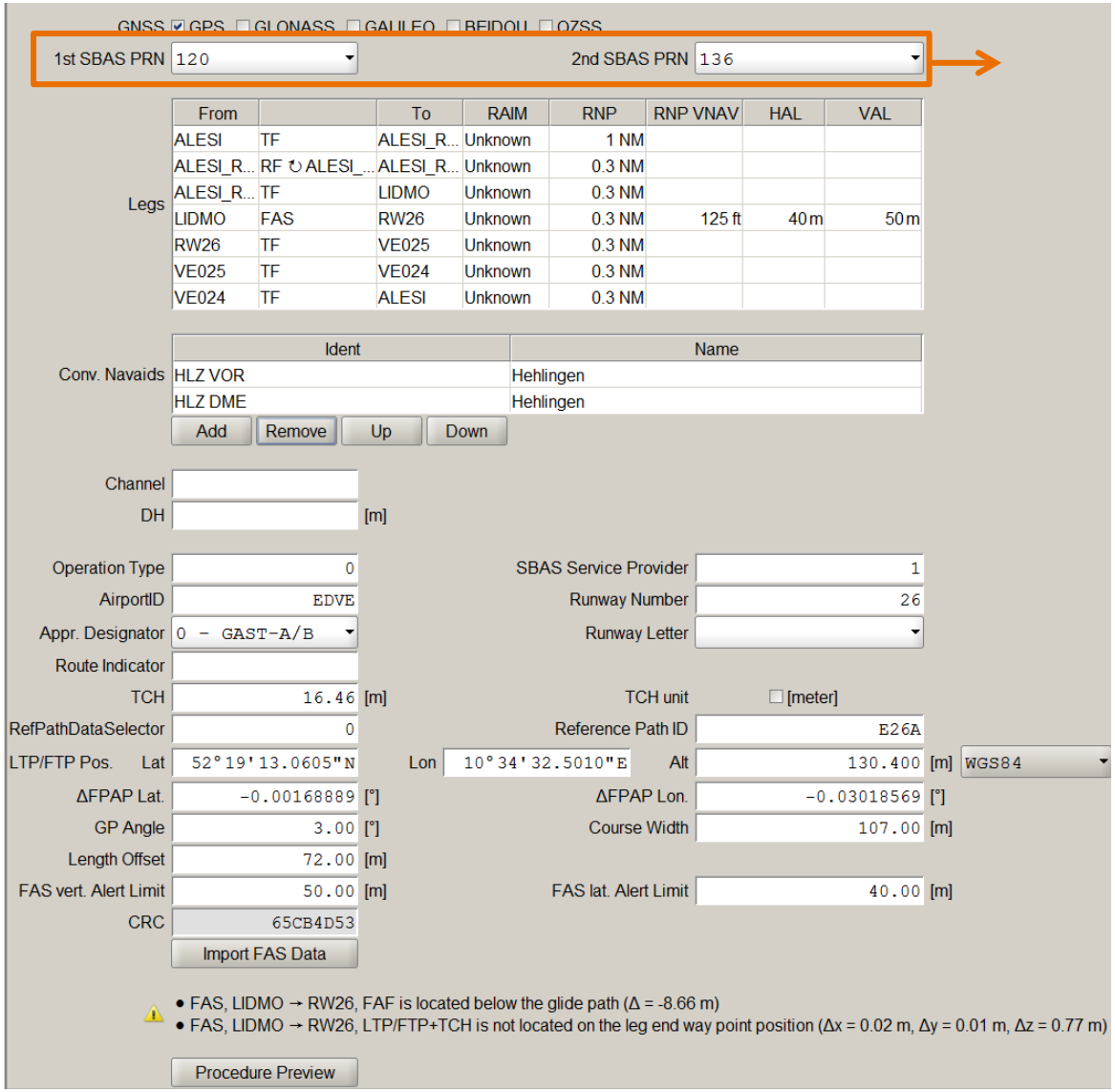
Procedure Settings in AFIS Database



Selection of GNSS Service:

- ✓ Defines which GNSS service is analyzed during the procedure validation
- ✓ Evaluated Data will be included in:
  - Graphics,
  - Report

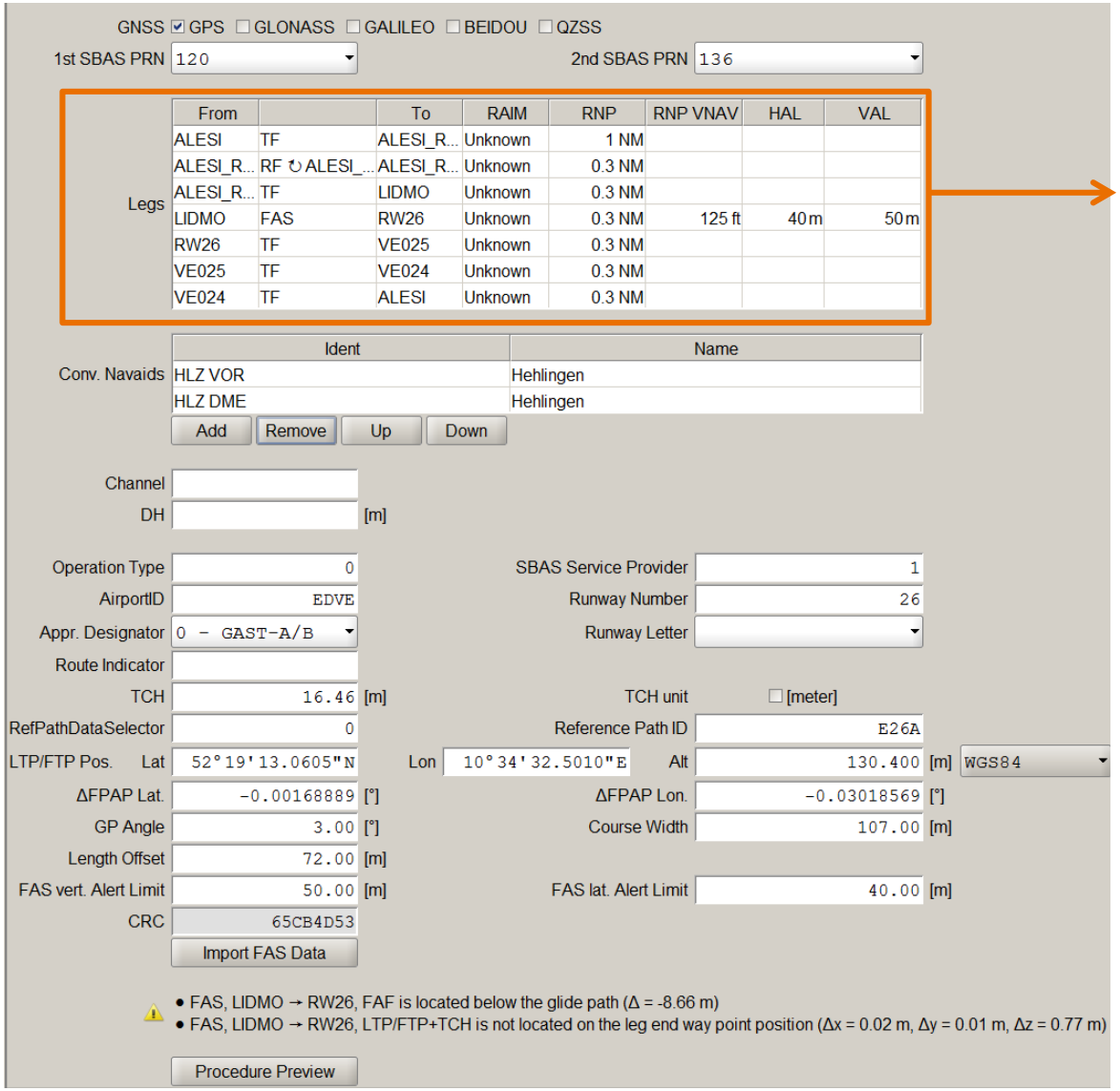
Procedure Data Stored in AFIS Database



Selection of SBAS:

- ✓ Defines primary and secondary SBAS satellite to be analyzed
- ✓ Automatic configuration of GNSS receiver
- ✓ SBAS evaluation data will be included in:
  - ✓ Graphics,
  - ✓ Report

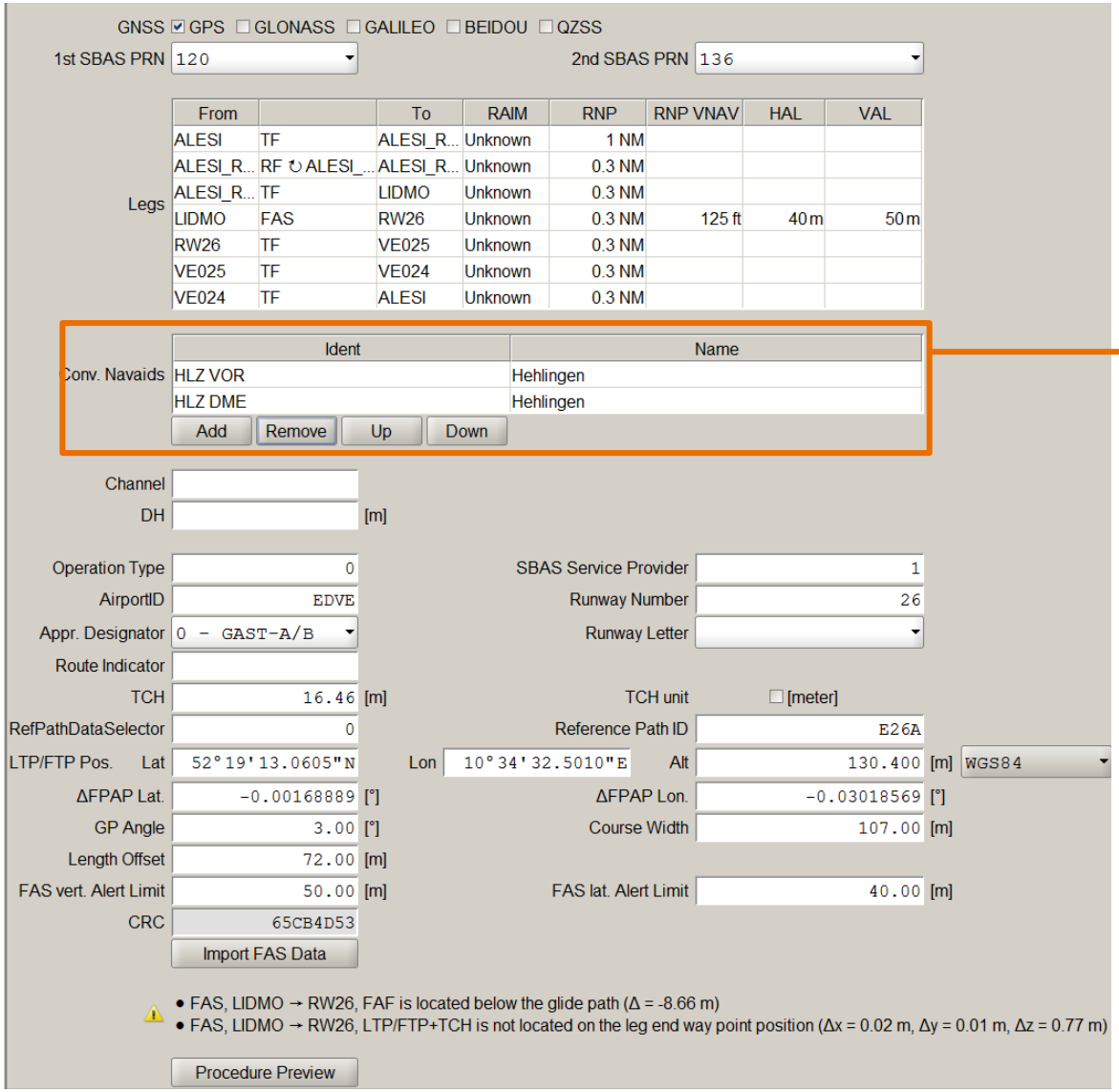
Procedure Data Stored in AFIS Database



For each procedure segment it can be defined:

- ✓ Method of RAIM check
- ✓ RNP / RNP VNAV
- ✓ HAL
- ✓ VAL

Procedure Data Stored in AFIS Database



Definition of Conventional Navaids to be checked

All available flight inspection receivers can be used simultaneously e.g.:

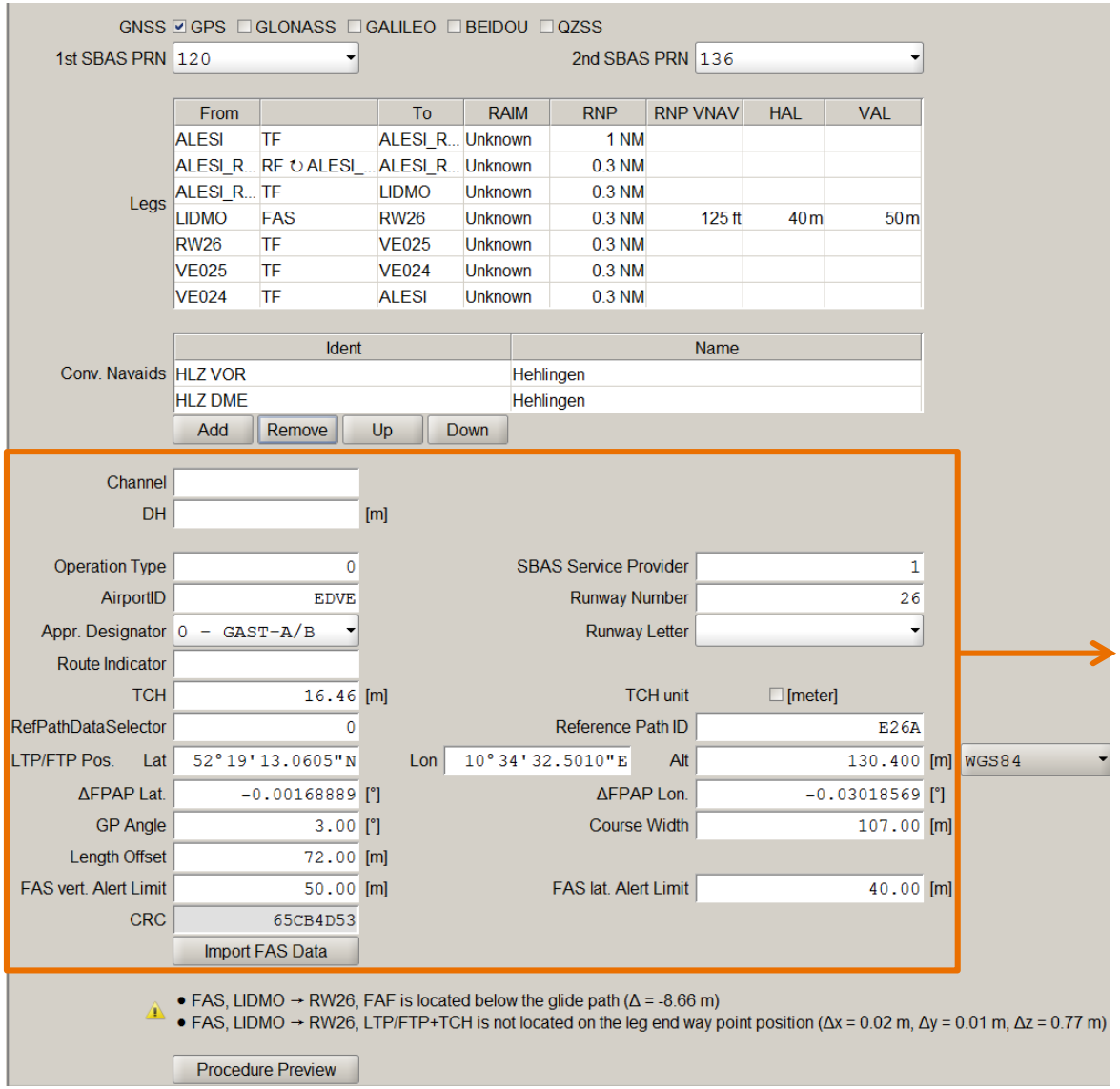
- ✓ 2x VOR
- ✓ 2x DME (or 8 Channel DME/DME)
- ✓ TACAN
- ✓ NDB

Procedure oriented analysis

Results for each selected Navaid are included in:

- ✓ Graphics,
- ✓ Reports

Procedure Data Stored in AFIS Database



FAS Datablock
(LPV approaches):

- ✓ FAS Data import (binary) or
- ✓ FAS Data manual input (not recommended)
- ✓ CRC Calculation / check

Procedure Data Stored in AFIS Database

GNSS ☑ GPS ☐ GLONASS ☐ GALILEO ☐ BEIDOU ☐ QZSS

1st SBAS PRN 120 2nd SBAS PRN 136

Legs

From		To	RAIM	RNP	RNP VNAV	HAL	VAL
ALESI	TF	ALESI_R...	Unknown	1 NM			
ALESI_R...	RF ↻ ALESI_...	ALESI_R...	Unknown	0.3 NM			
ALESI_R...	TF	LIDMO	Unknown	0.3 NM			
LIDMO	FAS	RW26	Unknown	0.3 NM	125 ft	40 m	50 m
RW26	TF	VE025	Unknown	0.3 NM			
VE025							
VE024							

Conv. Navaids HLZ VC

HLZ DM

Add

Channel

DH

Operation Type

AirportID

Appr. Designator 0 – C

Route Indicator

TCH

RefPathDataSelector

LTP/FTP Pos. Lat 52° 1

ΔFPAP Lat.

GP Angle 3.00 [°] Course Width 107.00 [m]

Length Offset 72.00 [m]

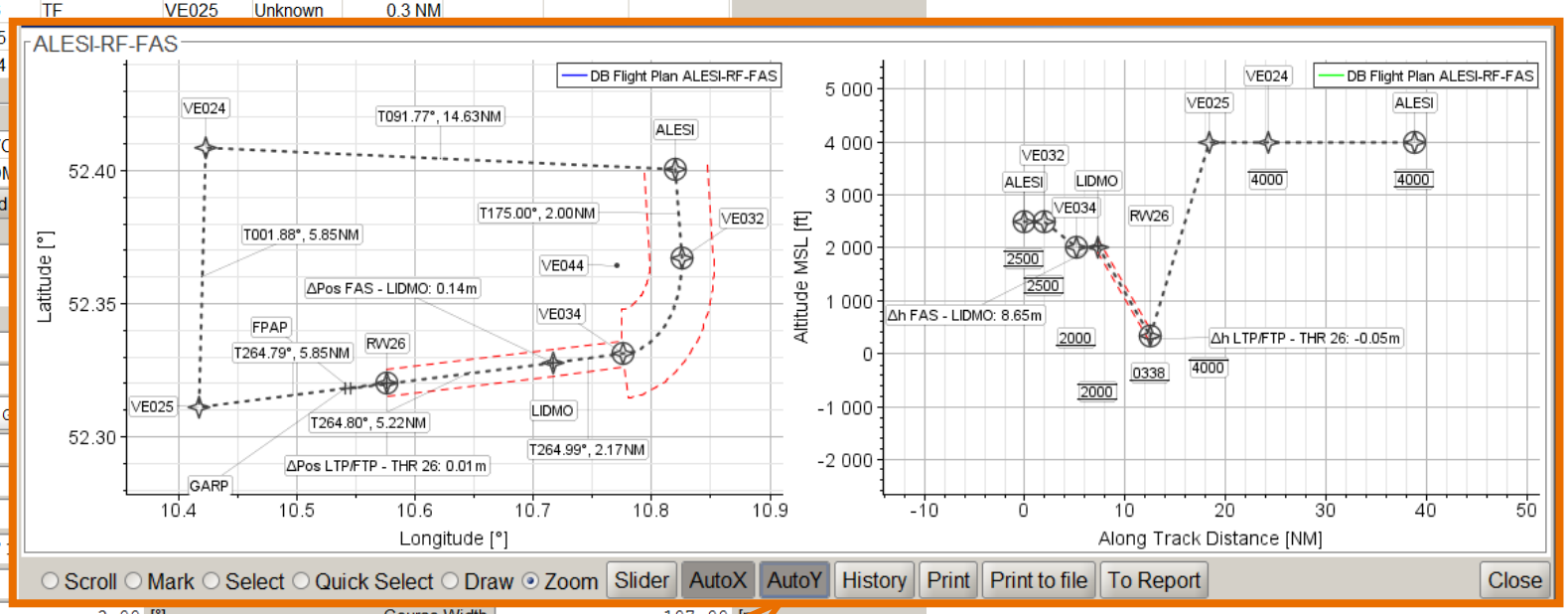
FAS vert. Alert Limit 50.00 [m] FAS lat. Alert Limit 40.00 [m]

CRC 65CB4D53

Import FAS Data

⚠ • FAS, LIDMO → RW26, FAF is located below the glide path (Δ = -8.66 m)
• FAS, LIDMO → RW26, LTP/FTP+TCH is not located on the leg end way point position (Δx = 0.02 m, Δy = 0.01 m, Δz = 0.77 m)

Procedure Preview



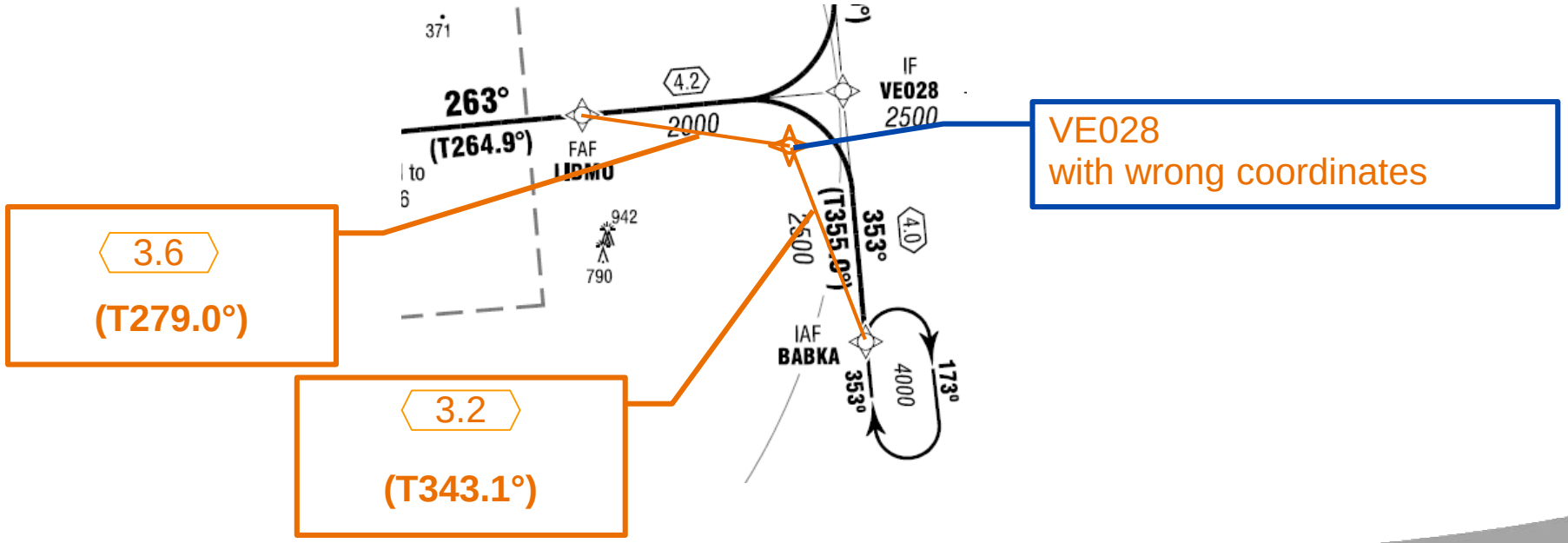
Procedure Preview

- ✓ Lateral
- ✓ Vertical

TF-leg issues in database

- ✓ Incorrect coordinates of waypoints:
- ✓ Results in:
  - Other Distances between waypoints
  - Other Tracks between waypoints

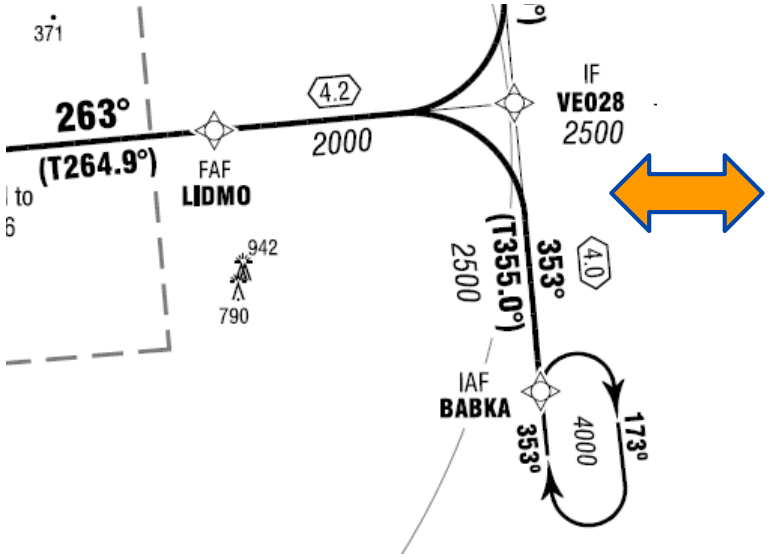
Example: Wrong coordinates of VE028:



TF-leg issues in database

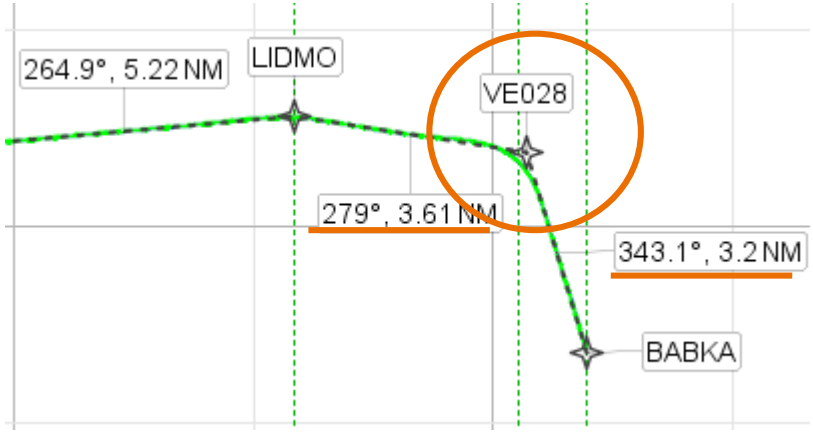
Visualization of TF-legs by AFIS:

- ✓ Calculation of Tracks
- ✓ Calculation of Distances



Original Procedure Chart

→ VE028 has wrong coordinates



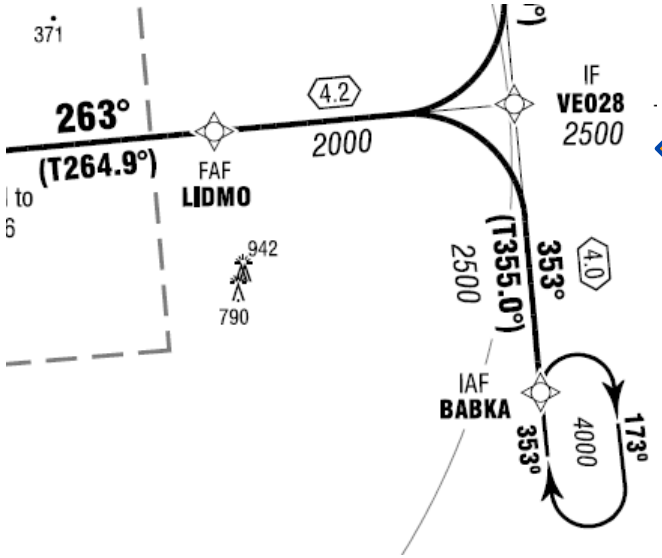
Visualization in AFIS

TF-leg issues in database

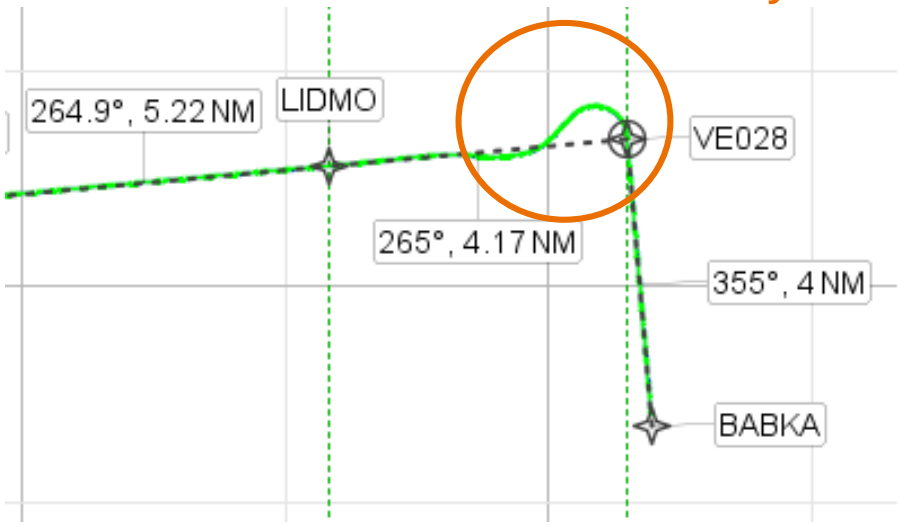
Visualization of Fly-by / Fly-over: by AFIS

- ✓ Use of different symbols
- ✓ Resulting flight track simulation
  - Simulation for different Aircraft Types available (e.g.: Airbus A300, Dornier 328, Dornier 128)

→ VE028 is defined as fly-over



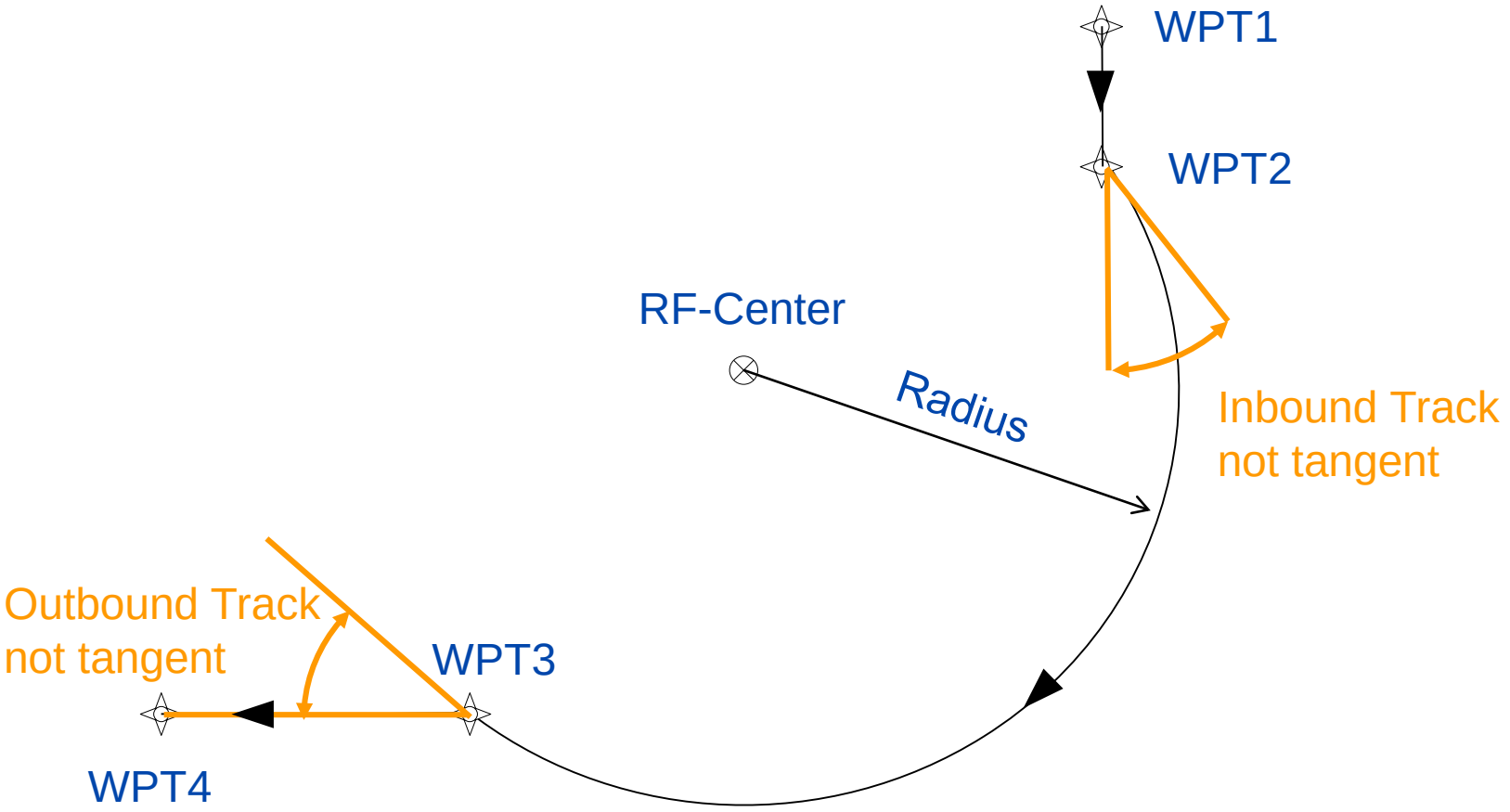
Original Procedure Chart



Visualization in AFIS

RF leg issues in Databases

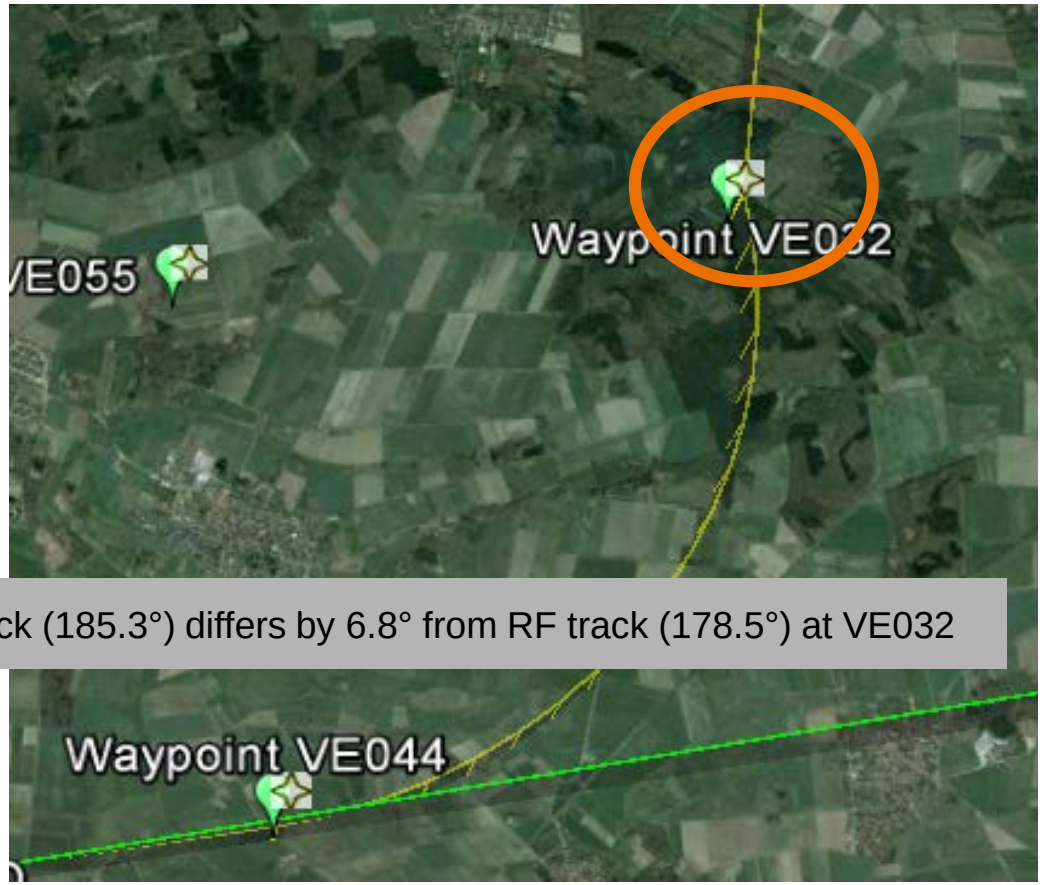
Inbound / outbound track not tangent to RF-leg:



RF leg issues in Databases

RF-track check by AFIS:

- ✓ Visualization
  - Google Earth
  - Graphics
- ✓ Alerts
  - Highlights even small differences
- ✓ Alert Example:



•RF VE032 → VE044: Inbound track (185.3°) differs by 6.8° from RF track (178.5°) at VE032

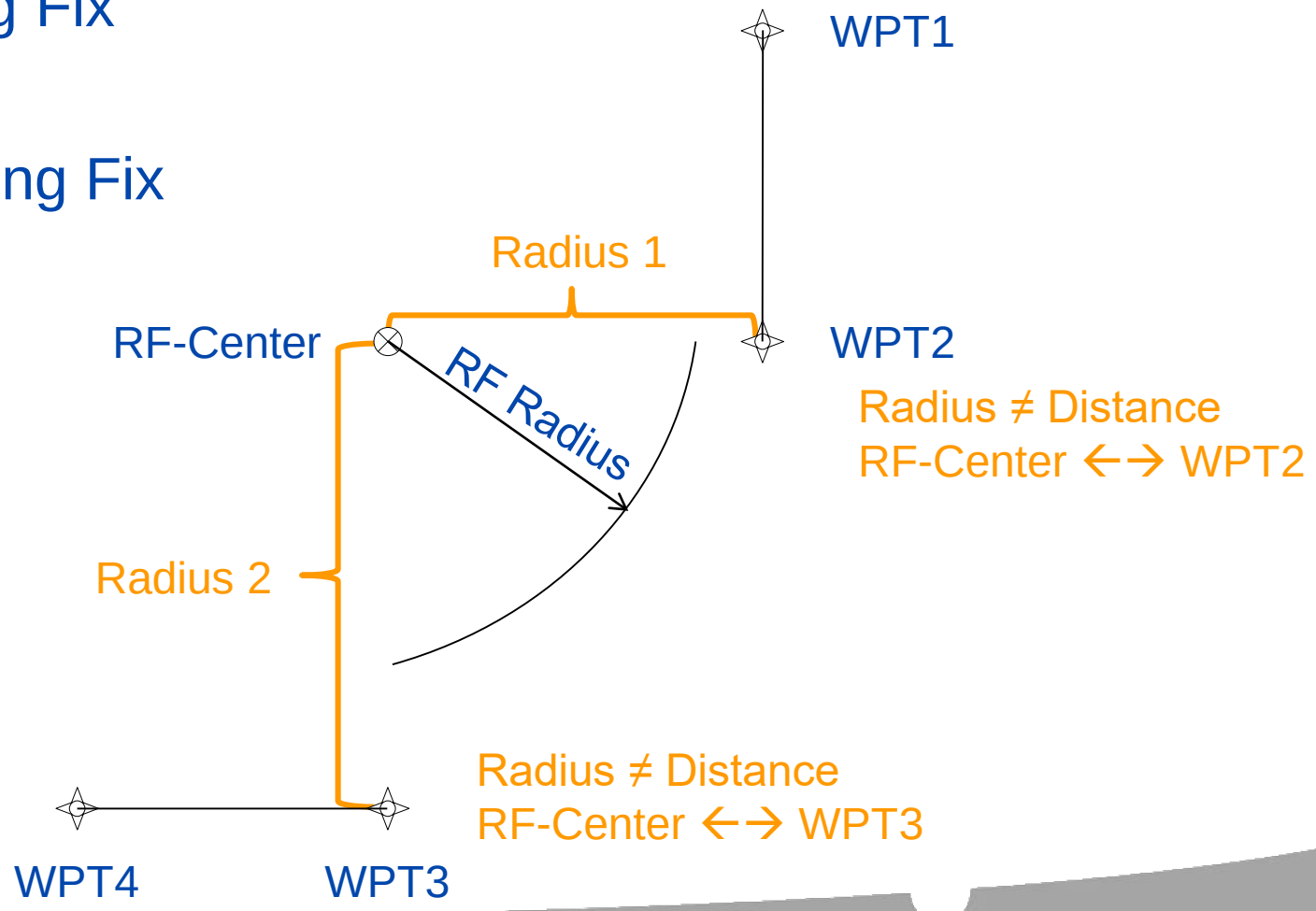
RF legs issues in Databases

Defined Radius / Center Fix does not fit to:

- Beginning Fix

and/or

- Terminating Fix



RF legs issues in Databases

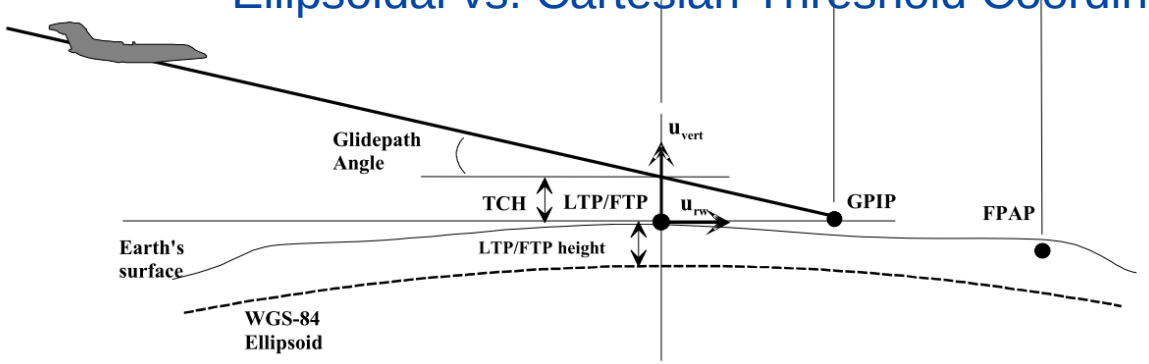
RF radius check by AFIS:

- ✓ Visualization
  - Google Earth
  - Graphics
- ✓ Alerts
  - Highlights even small differences
- ✓ Alert Example:

⚠ •RF VE032 → VE044: Radius is 55.7m smaller than distance Center → VE032
•RF VE032 → VE044: Radius is 48.9m smaller than distance Center → VE044

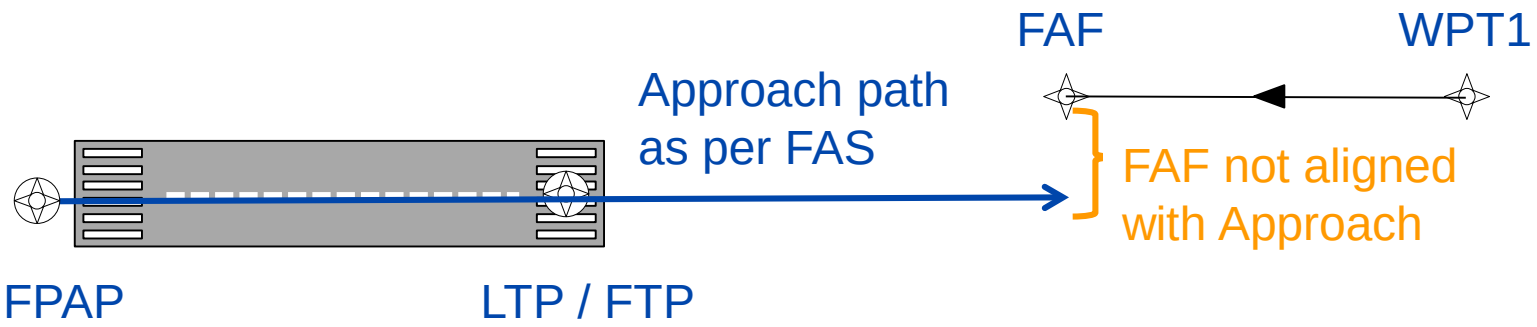
FAS Datablock Issues

- ✓ All FAS data referenced to LTP/FTP (WGS84)
  - Approach path is defined in Cartesian coordinate system
- ✓ Guidance transition at FAF → FAS:
  - Baro Altitude (Ellipsoid) → Vertical Deviation (Cartesian)
- ✓ Typical issues with FAS data:
  - Wrong LTP/FTP Height:
    - Wrong datum e.g. MSL or NAD83 vs. WGS84
  - FAF mixed up with FPAP
  - FPAP calculated with inverse approach course
  - Coordinate system issues (wrong calculations):
    - Ellipsoidal vs. Cartesian Threshold Coordinate System



FAF → FAS transition issues

- Waypoint sequence delivers the aircraft to forward to FAF
- The lateral approach path as per FAS is defined backwards from FPAP with reference to LTP/FTP
- The FAF might not be aligned with the lateral approach path as defined per FAS datablock:



FAF → FAS transition issues

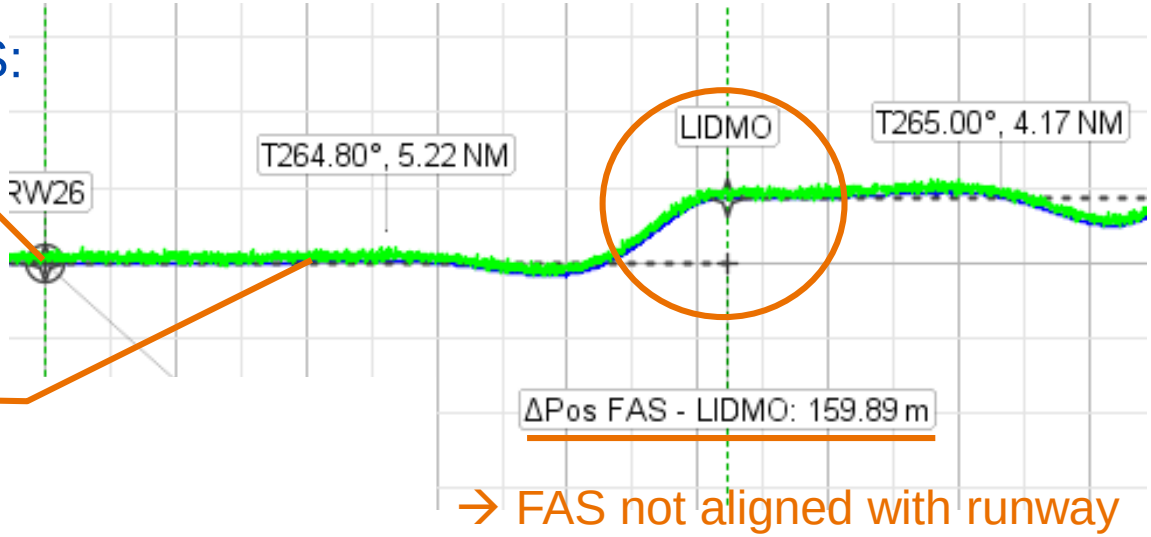
Visualization of incorrect FAS/FAF Alignment by AFIS

- ✓ Display of procedure in Threshold Coordinate System
- ✓ Easy detection of mis-aligned waypoints
- ✓ AFIS Alert:

Visualization in AFIS:

Procedure transformed into Threshold Coordinates (Threshold at origin)

X-axis represents runway alignment

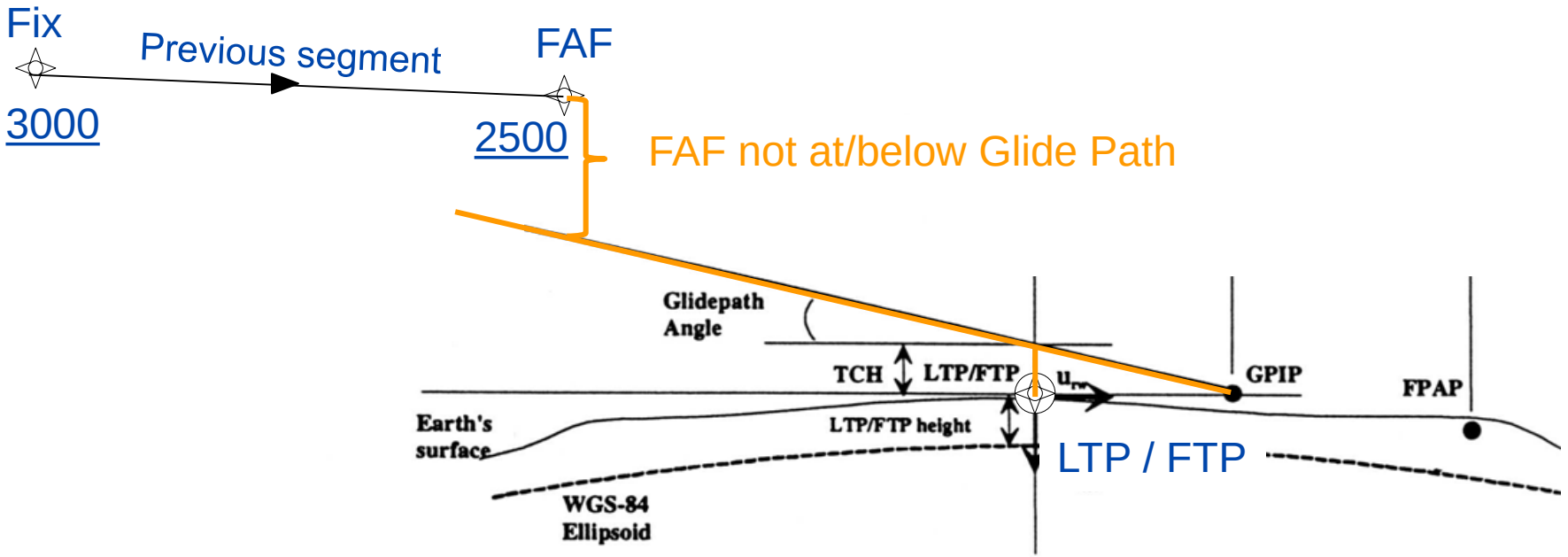


→ FAS not aligned with runway

⚠ •LIDMO → FAS: LIDMO not on FAS approach centerline. LIDMO is 159.9 m right

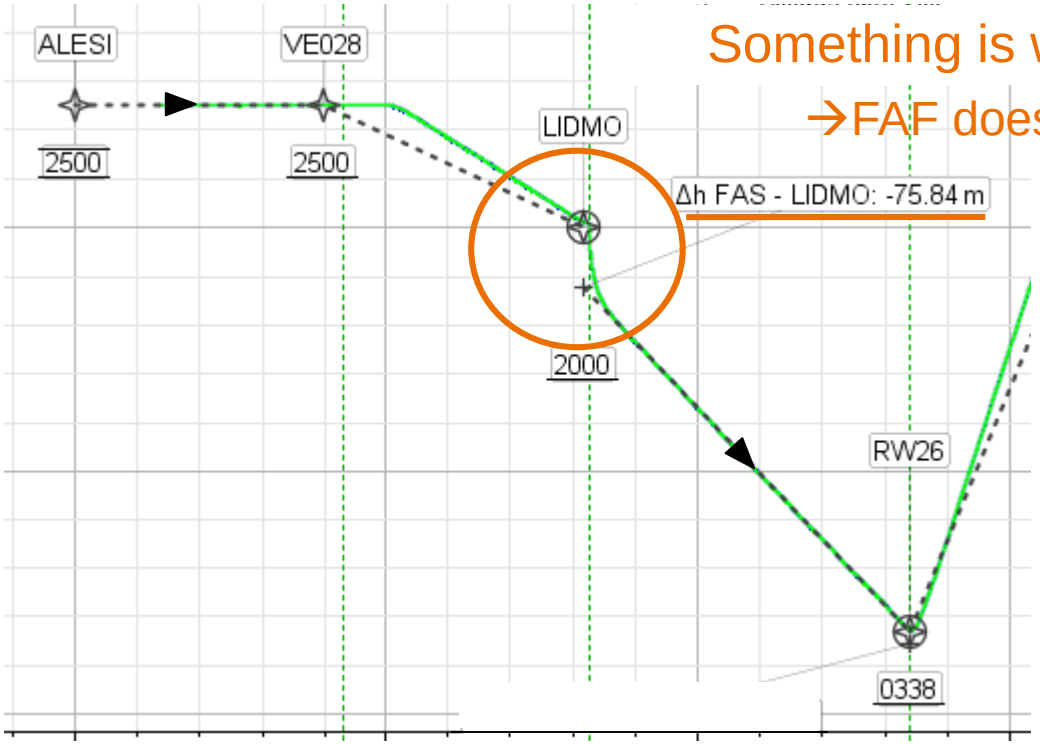
FAF → FAS transition issues

- The procedures delivers the aircraft to FAF (altitude)
- The vertical approach is defined backwards with reference to LTP/FTP
- The glidepath/TCH as defined by FAS datablock might not fit to the altitude at FAF waypoint:



Automatic AFIS Checks

Visualization of vertical conflict FAF←→FAS



Something is wrong here!

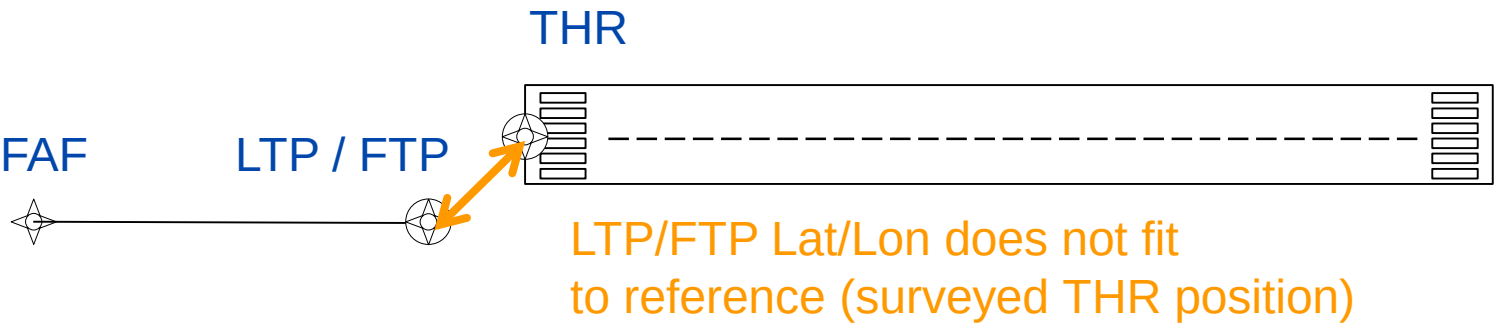
→FAF does not fit to FAS

- ✓ Altitude at FAF (LIDMO) is above Glideslope as defined by FAS
- ✓ No-go! Glideslope intercept from above!
- ✓ Alert by AFIS

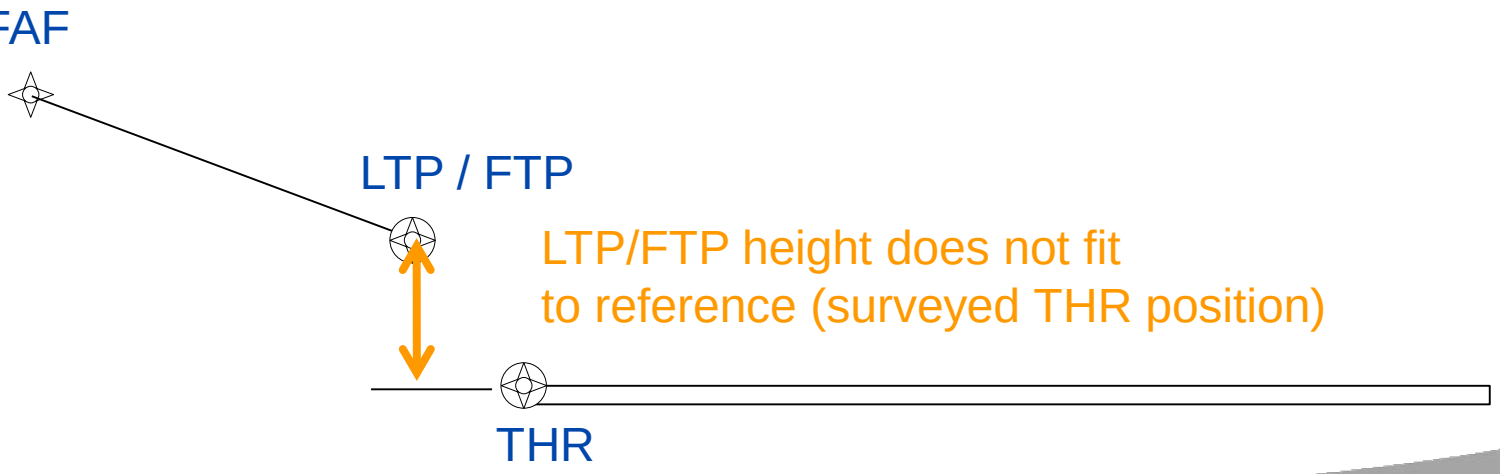
LTP/FTP issues

- Coordinates of LTP/FTP might not be accurate (e.g.: wrong datum used)

Lateral:



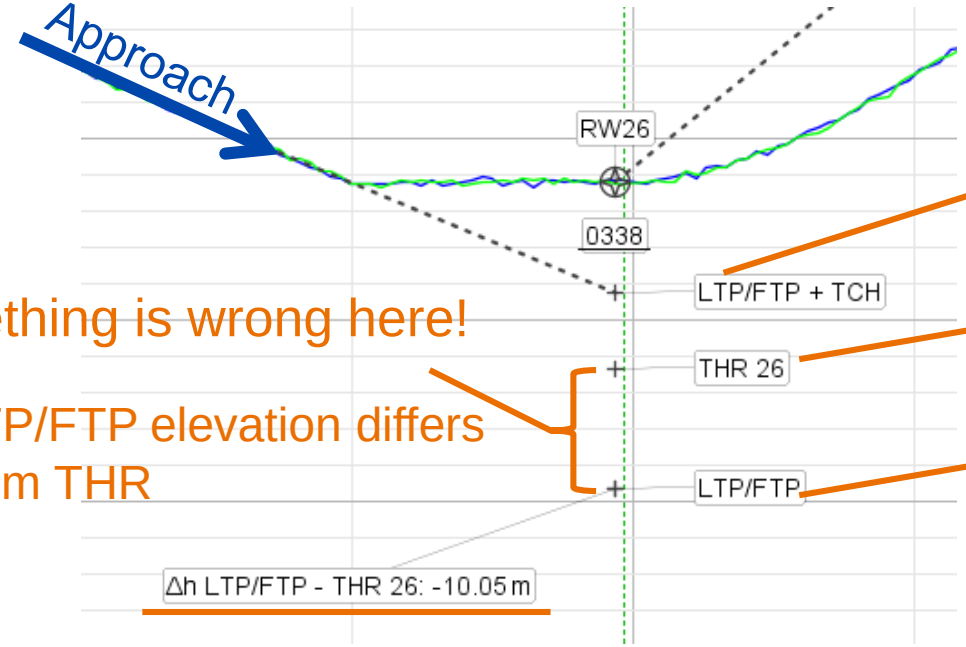
Vertical:



Automatic Pre Flight Checks

Vertical LTP/FTP checks

- ✓ Possible height difference:
  - THR (Reference: surveyed threshold for flight inspection)
  - LTP/FTP (FAS datablock)
- ✓ The AFIS provides visualization and Alert in case of differences:



Something is wrong here!

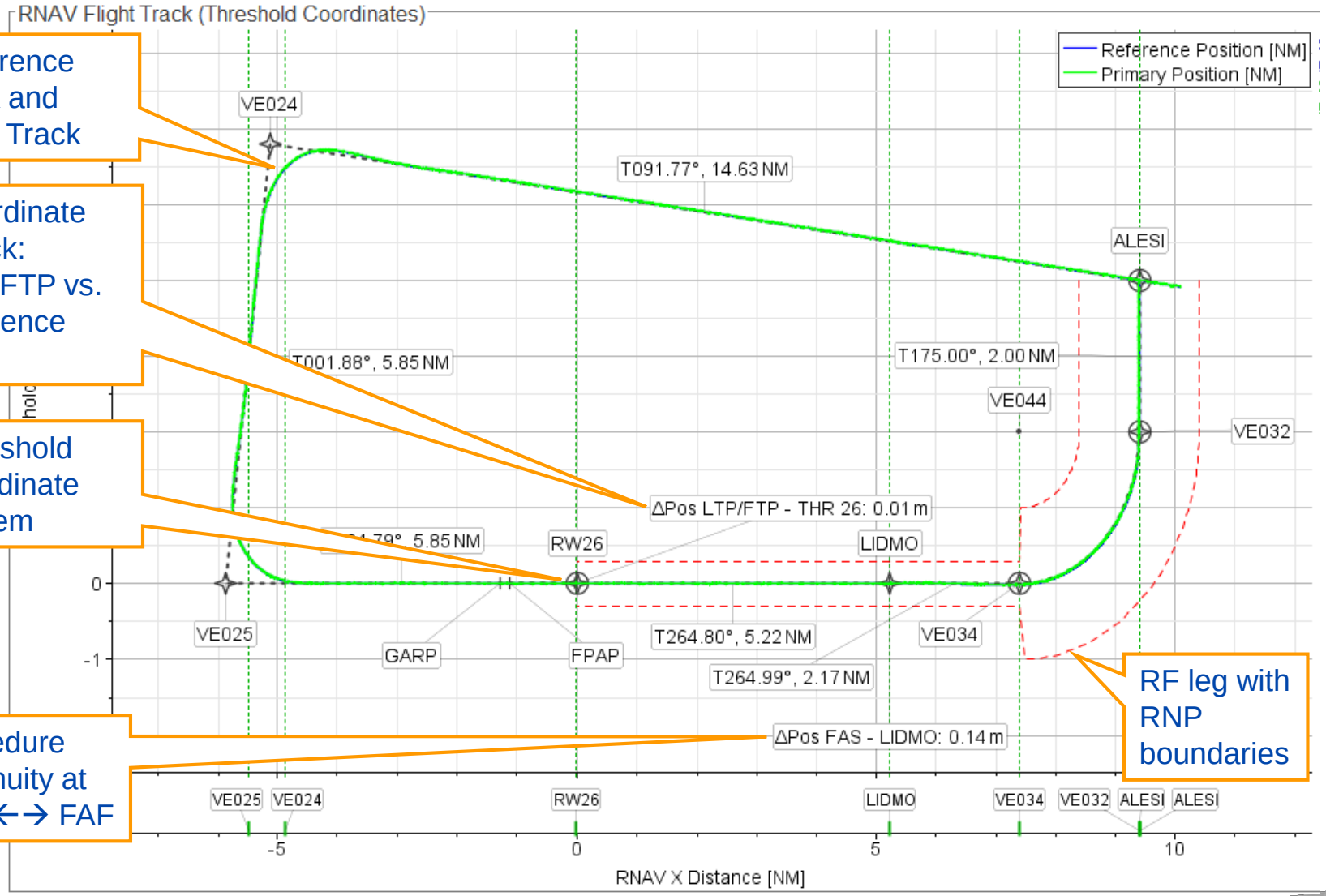
→ LTP/FTP elevation differs from THR

LPV Flight Path vertical aiming point

Threshold as per flight inspection survey

LTP/FTP as per FAS data block

Flight Track (Threshold Coordinate System)



Reference track and FMS Track

Coordinate check: LTP/FTP vs. reference THR

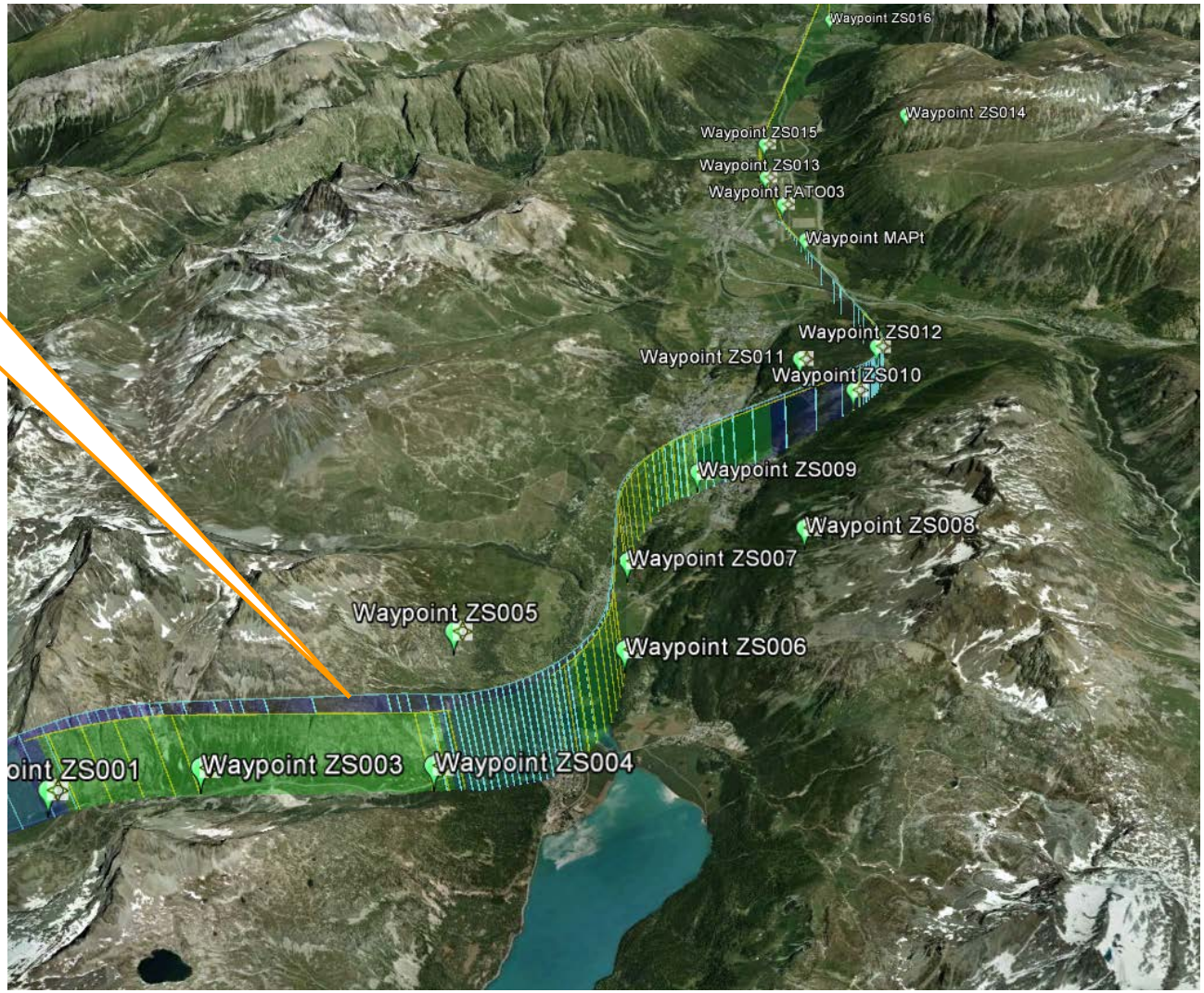
Threshold coordinate system

Procedure continuity at FAS ←→ FAF

RF leg with RNP boundaries

RNAV Graphics: Threshold Coordinate System.

Example of RNP 0.3 Helicopter approach procedure



In Flight Validation

In Flight the AFIS automatically performs:

Flight Track Evaluation:

- ✓ RNP containment (lateral/vertical)

GNSS/SBAS Evaluation:

- ✓ Coverage
- ✓ Protection Level (HPL/VPL)
- ✓ Interference

Conventional Navaid Evaluation

- ✓ Navaid Error
- ✓ Signal in Space

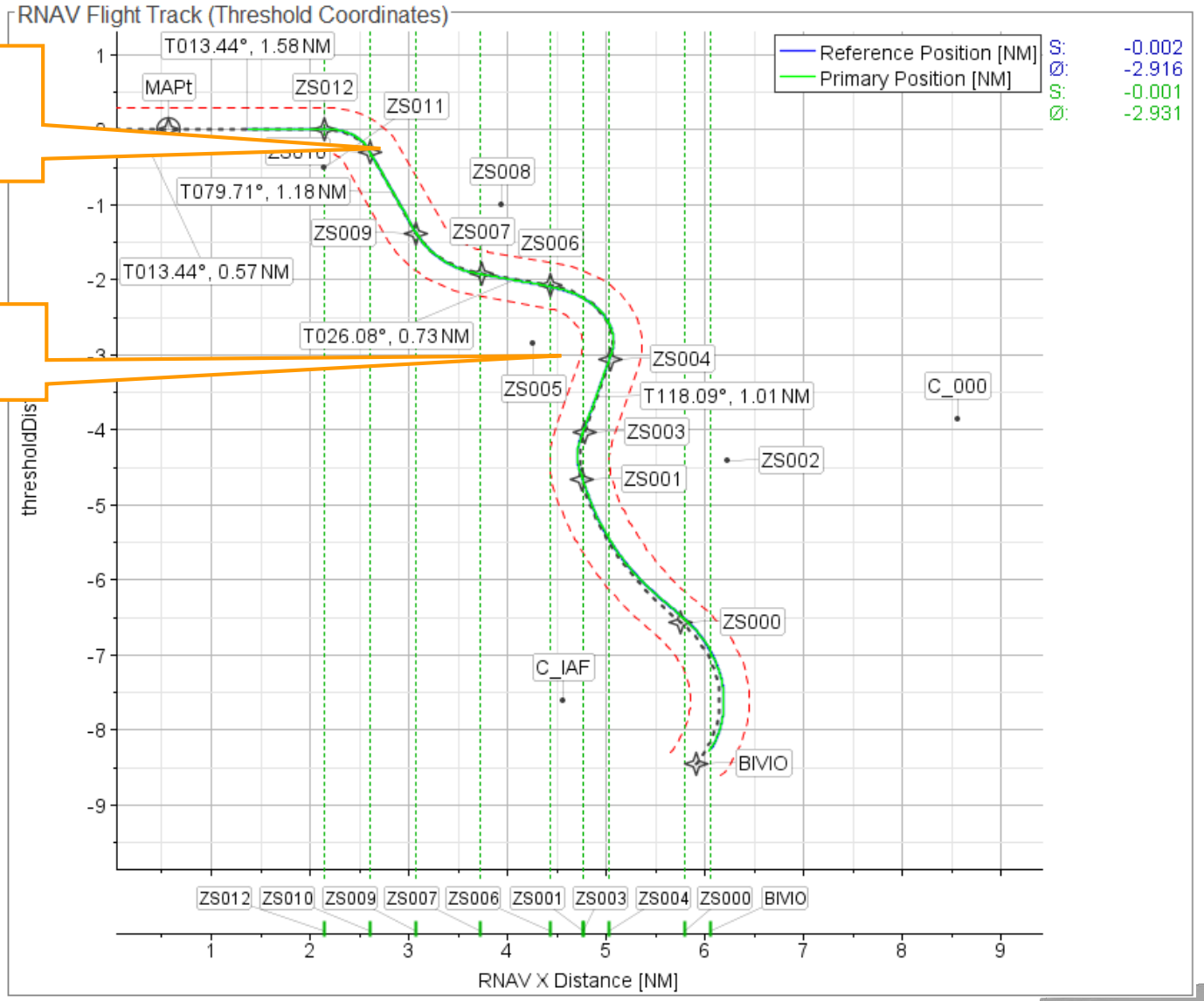
Procedure Report Compilation

- ✓ Numerous Graphics for each Procedure…

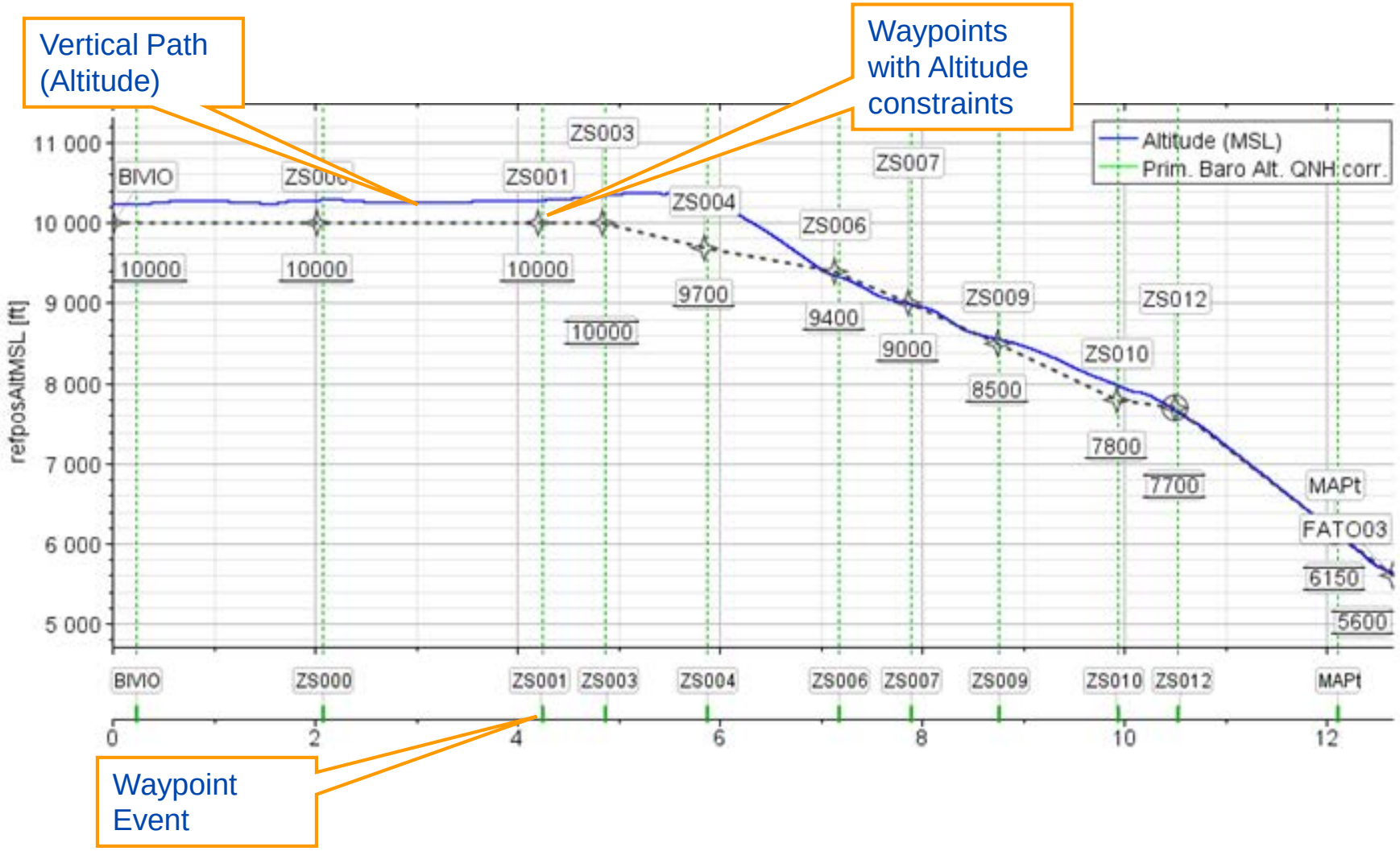
Flight Track Graphics

Reference track and FMS track

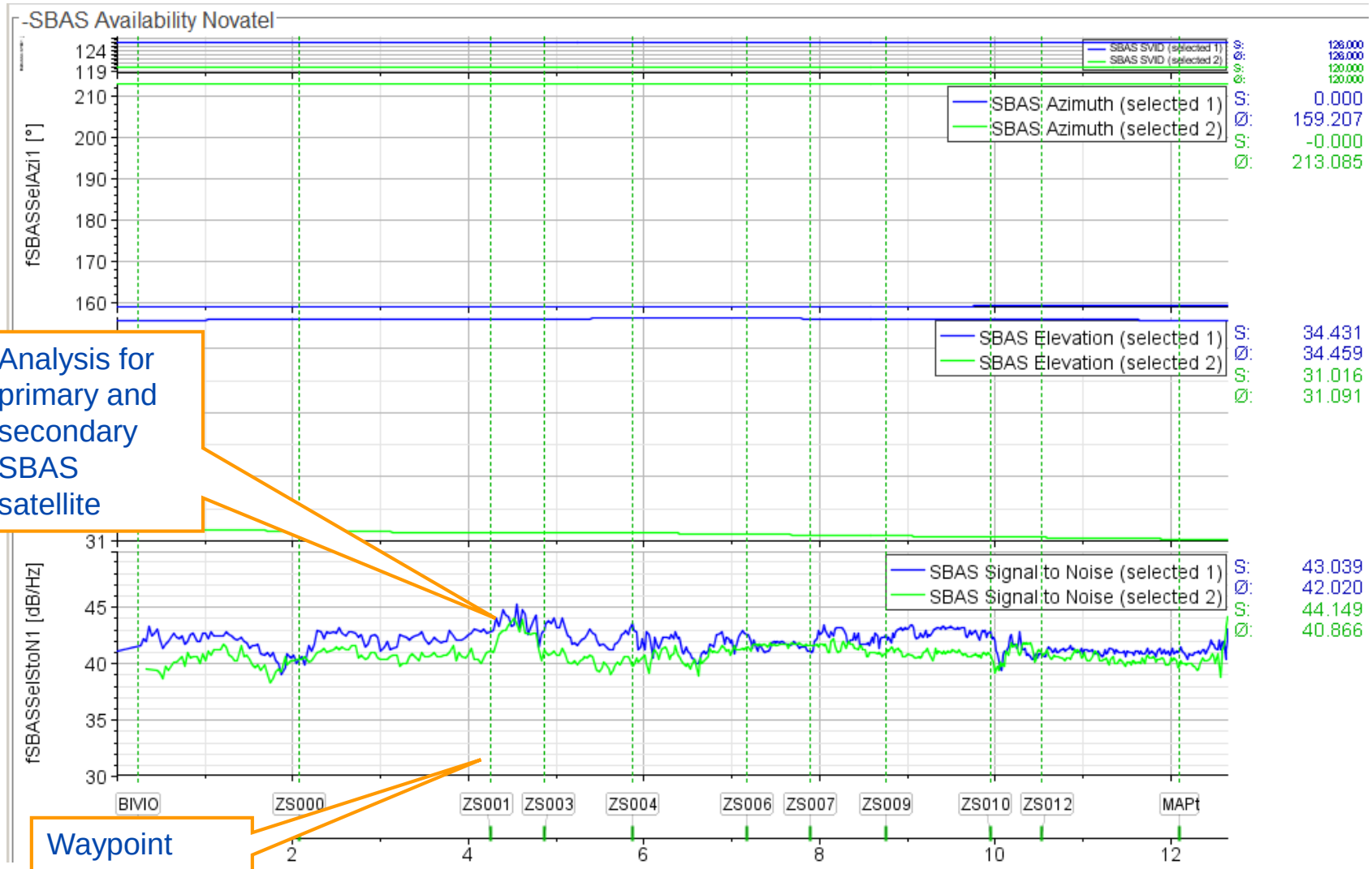
RNP 0.3 boundaries



Vertical Profile



SBAS Evaluation



Report Compilation

According to the procedure configuration in database the corresponding report will be compiled with e.g.

If GNSS evaluation selected:

Integrity: GNSS_GPS

	x DP	Max VDOP	Max HPL	Max VPL	Max HFOM	Max VFOM	Max ATK Error	Max XTD Error	Max XTD	Min # SV Used	Min C/N0	RAIM Fault Time
			[m]	[m]	[m]	[m]	[NM]	[NM]	[NM]		[dBHz]	[s]
1	1.0	1.8	97	175	9.4	17.5	0.004	0.001	0.056	8	42.6143	0.000
2	1.0	1.8	97	170	9.4	17.5	0.004	0.001	0.061	8	41.7805	0.000
		1.8	97	165	9.5	17.6	0.003	0.001	0.027	8	39.5882	0.000

If SBAS evaluation selected:

Integrity: GNSS_SBAS - Primary = 120, Secondary = 126

	Max HDOP	Max VDOP	Max HPL	Max VPL	Max HFOM	Max VFOM	Max ATK Error	Max XTD Error	Max XTD	Min # SV Used	Min C/N0	RAIM Fault Time
			[m]	[m]	[m]	[m]	[NM]	[NM]	[NM]		[dBHz]	[s]
1	1.0	1.8	5	10	1.1	2.0	0.004	0.001	0.056	8	42.6143	
2	1.0	1.8	5	10	1.1	1.9	0.004	0.001	0.061	8	41.7805	
3	1.0	1.8	5	10	1.0	1.9	0.003	0.001	0.027	8	39.5882	
4	1.0	1.8	5	10	1.0	1.9	0.003	0.001	0.013	8	42.8297	
5	1.0	1.8	5	9	1.0	1.9	0.003	0.002	0.023	8	40.4157	
6	1.0	1.8	5	9	1.0	1.9	0.003	0.001	0.015	8	41.5572	
7	1.0	1.8	5	9	1.0	1.9	0.003	0.001	0.012	8	40.0175	
8	1.0	1.8	5	9	1.0	1.9	0.002	0.001	0.006	8	41.6238	
9	1.0	1.8	5	9	1.0	1.9	0.003	0.002	0.016	8	40.2174	

Summary

- ✓ Validation of instrument flight procedures is a complex task.
- ✓ In order to ensure a constant quality of the validation output standardization and automation is required.
- ✓ The flight validation can be simplified and standardized by saving settings for evaluation together with the procedure in the AFIS database.
- ✓ Leg types like RF and FAS provide potential for inconsistencies and discontinuities.
- ✓ Many errors or inconsistencies can be detected by AFIS prior to flight by automatic checks, alerting and features for graphical visualization of the procedure and the relevant points.
- ✓ The AFIS as described in here can significantly contribute to a standardized validation output with constant quality, independent of individual operator's human performance.


We keep you on the best path!
Thank You!