High Accuracy Performance Based Navigation Aircraft Approach Paths Combined with Precision Final based on GNSS

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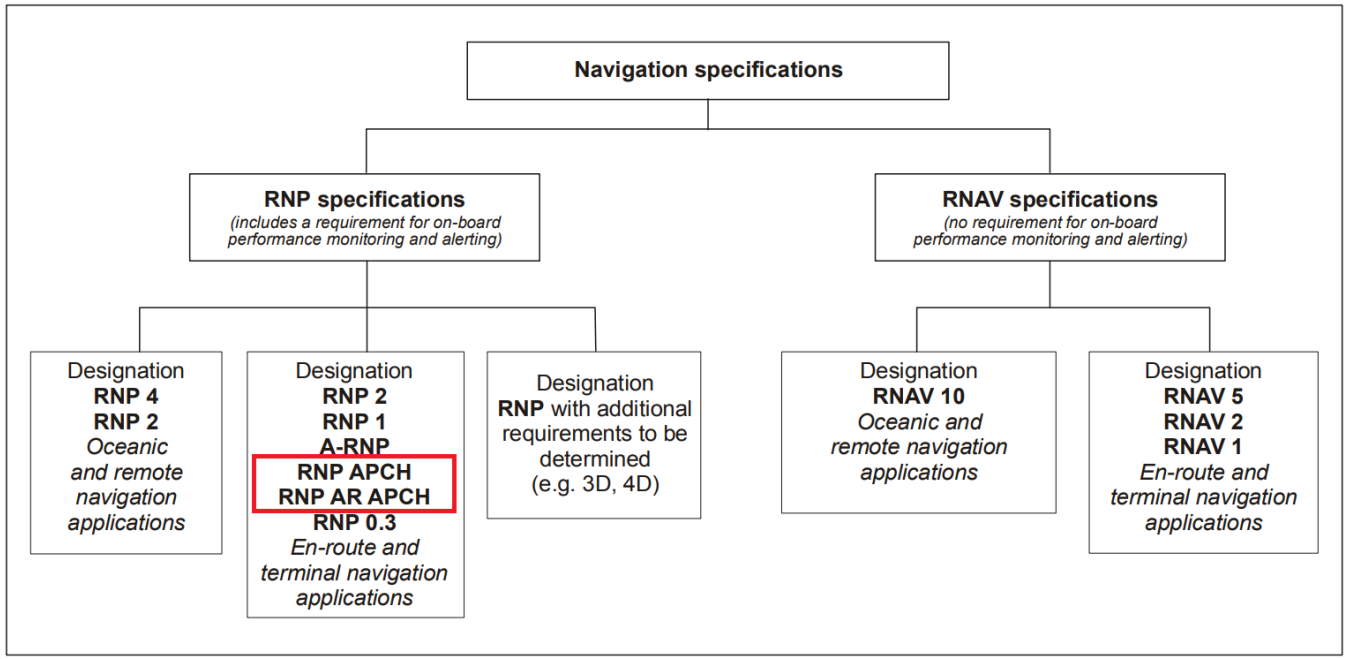
Overview

I. Introduction: RNP AR and LPV – what is that and why makes merging sense?
II. Introduction: Salzburg Airport
III. Procedure Design
   - ✓CAT I segment
   - ✓Intermediate Approach
   - ✓Obstacle Assessment
IV. Coding
V. Simulator Assessment
VI. Conclusion & Outlook

Performance-based Navigation (PBN)

- Reference: ICAO PBN manual (Document 9613)
- In short: Procedures are defined based on a required navigation performance, required functionalities of the navigation system, required air crew procedures and sensor requirements (= navigation specification)
- RNP APCH and RNP AR APCH are the two main specifications for approaches



RNP and RNP AR

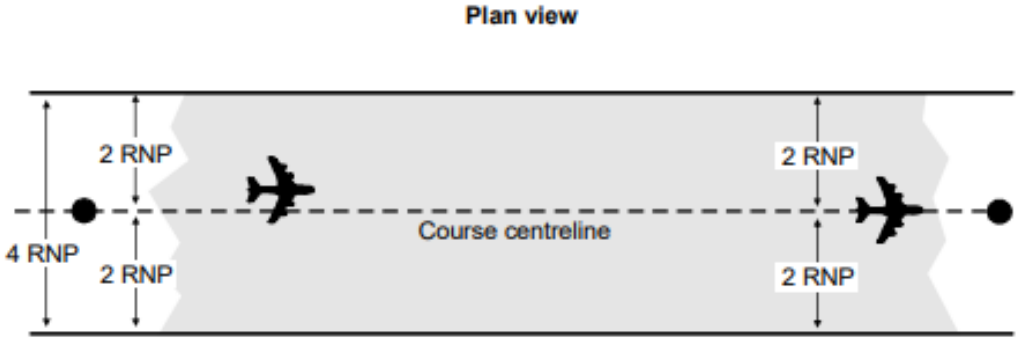
- RNP = *Required Navigation Performance*
- RNP X…X = accuracy value in NM; equals 95% total system error (TSE) [lateral navigation]

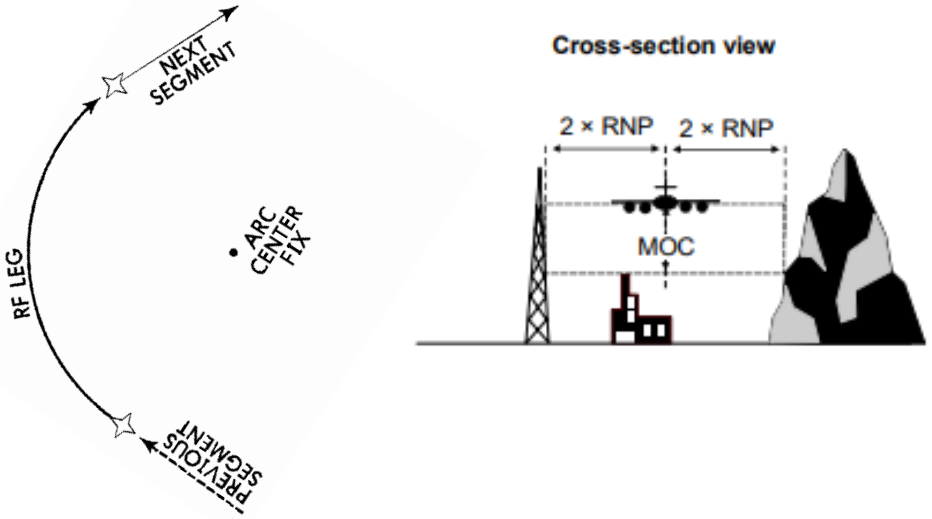
Higher accuracy means smaller protection areas and obstacle assessment surfaces!

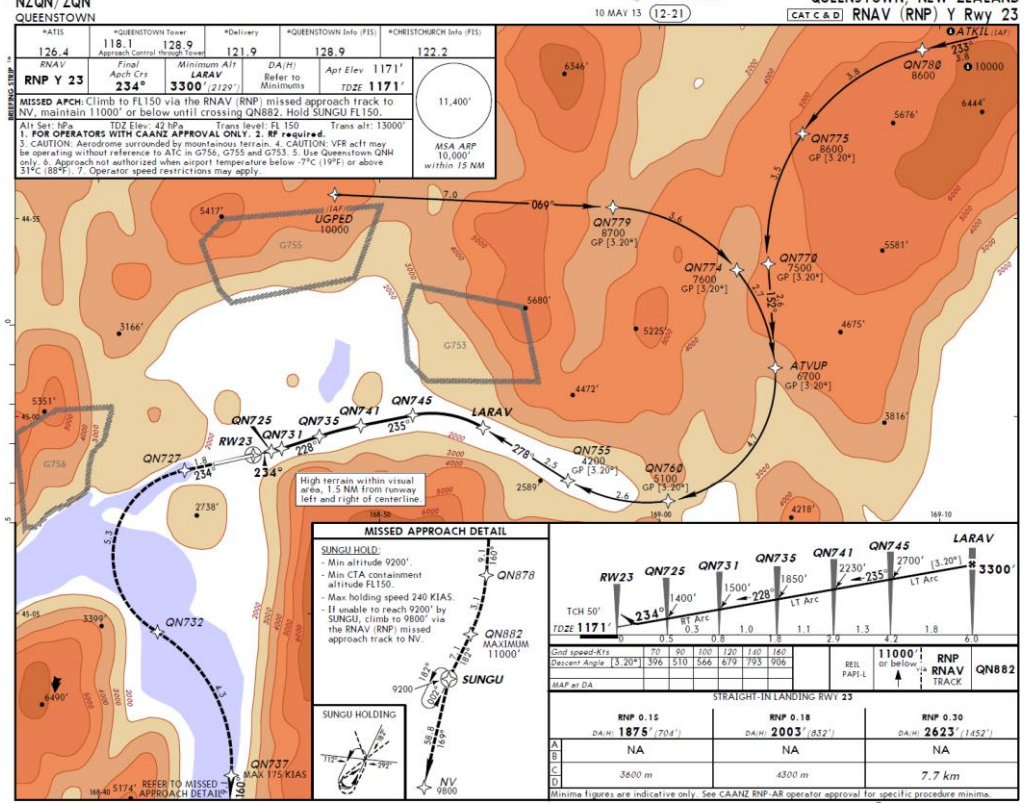
Part Chapter	*Navigation specification*	*Flight phase*							
		En-route oceanic/remote	*En-route continental*	*Arrival*	*Approach*				*DEP*
					Initial	*Intermediate*	*Final*	*Missed*[1]	
C, Ch.4	Advanced RNP (A-RNP)[4]	2[5]	2 or 1	1	1	1	0.3	1	1
C, Ch.5	RNP APCH[6]				1	1	0.3[7]	1	
C, Ch.6	RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	

- RNP AR allows extremely low accuracy values/high accuracies in ALL approach segments

RNP AR

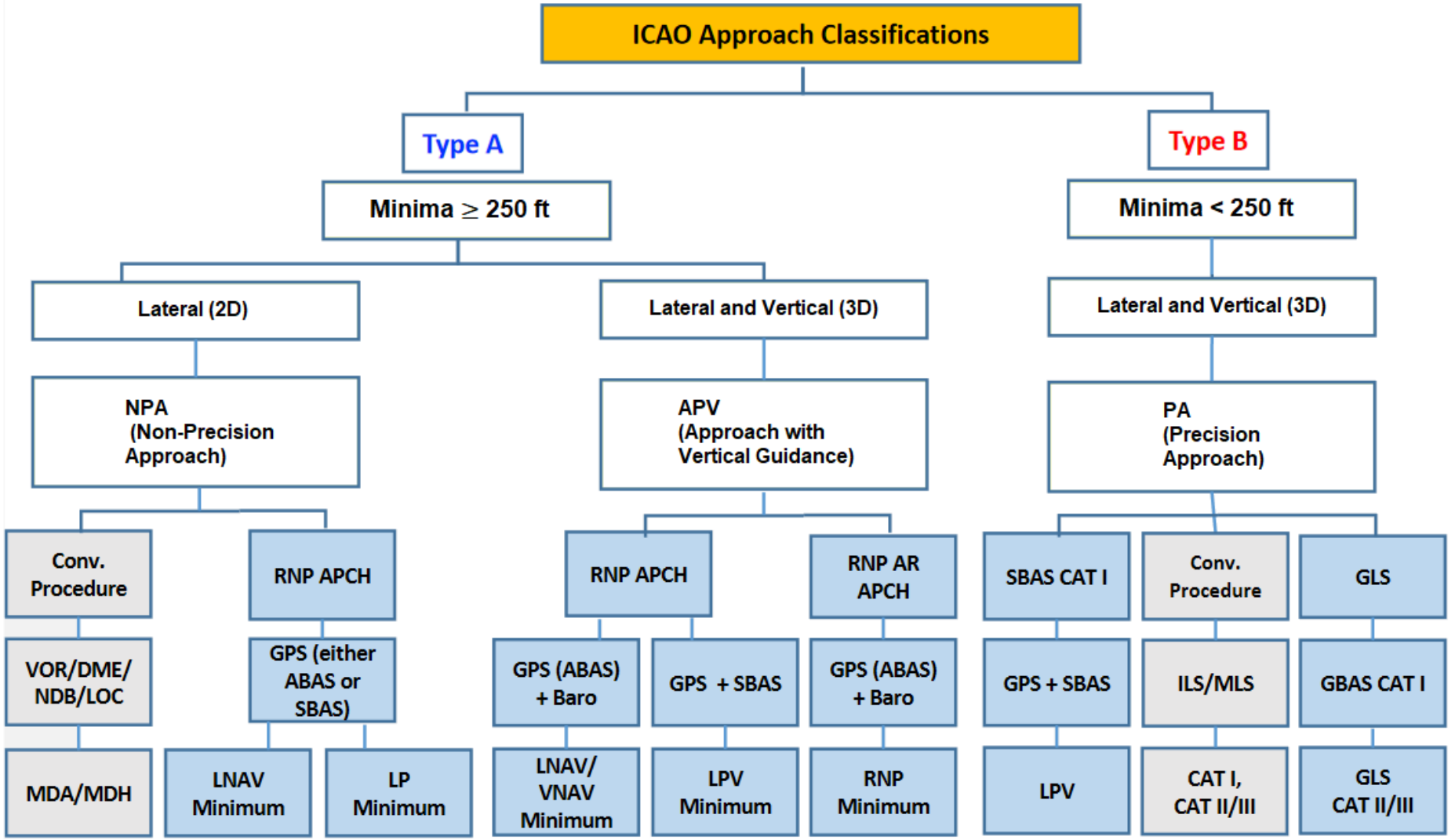




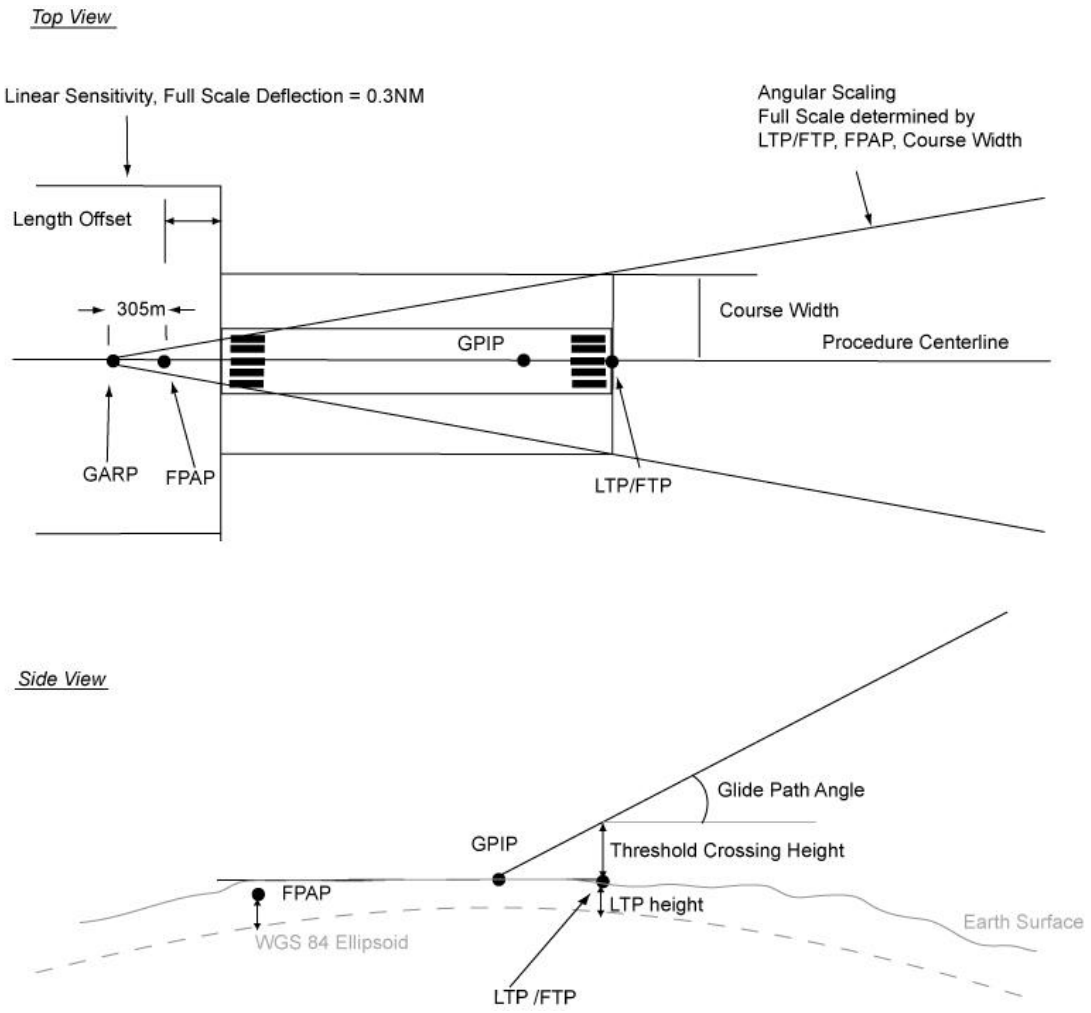


- RF legs till 500ft AGL
- RF in missed approach
- Reduced obstacle protection
- Special flight crew training required

Approach classification (Annex 6)



Localizer Performance with Vertical Guidance LPV



SBAS FAS Data Block Coding Table Wien-Schwechat RNAV (GNSS) RWY 34	
Input data	
Operation Type	0
SBAS Provider	1
Airport Identifier	LOWW
Runway	34
Runway Direction	0
Approach Performance Designator	0
Route Indicator	
Reference Path Data Selector	0
Reference Path Identifier	E34A
LTP/FTP Latitude	480519.0700N
LTP/FTP Longitude	0163528.8200E
LTP/FTP Ellipsoidal Height (metres)	222.7
FPAP Latitude	480713.5290N
Delta FPAP Latitude (seconds)	114.4590
FPAP Longitude	0163440.4200E
Delta FPAP Longitude (seconds)	-48.4000
Threshold Crossing Height	50.0
TCH Units Selector	0
Glidepath Angle (degrees)	3.00
Course Width (metres)	107.00
Length Offset (metres)	80
HAL (metres)	40.0
VAL (metres)	35.0
Output data	
Data Block	10 17 17 0F 0C 22 00 00 01 34 33 05 BC 2C A3 14 68 C7 1E 07 B3 1C 36 7E 03 E0 85 FE F4 01 2C 01 6C 0A C8 AF E6 DC 80 DC
Calculated CRC Value	E6DC80DC
Required Additional Data	
ICAO Code	LO
LTP/FTP Orthometric Height (metres)	178.7
FPAP Orthometric Height (metres)	178.7

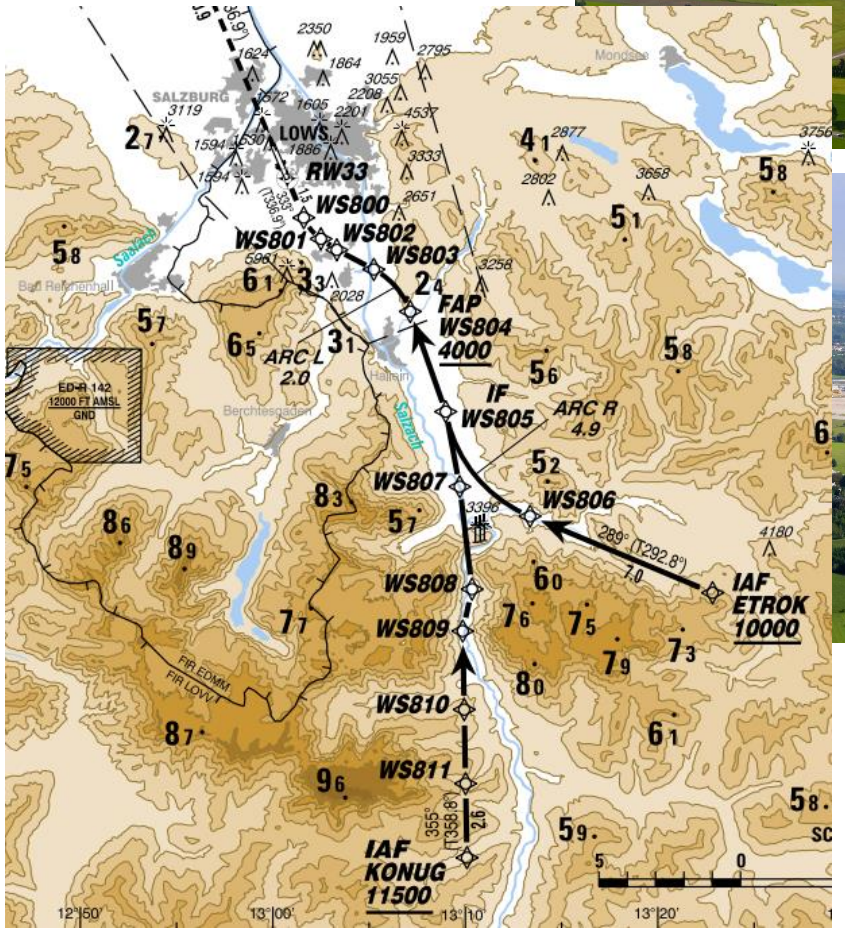
Our Aim: Combination of RNP AR and LPV

What we want: RNP AR approach with LPV segment, i.e. final approach based on LPV

- Lower Minimum
- Ground Referenced Guidance
- Longer Final Approach Segment

Salzburg Airport

- RWYs 15/33
- RWY15: ILS available, no spatial constraints
- RWY33: High terrain to the south and south-east of the field prevents IAPs except for RNP AR

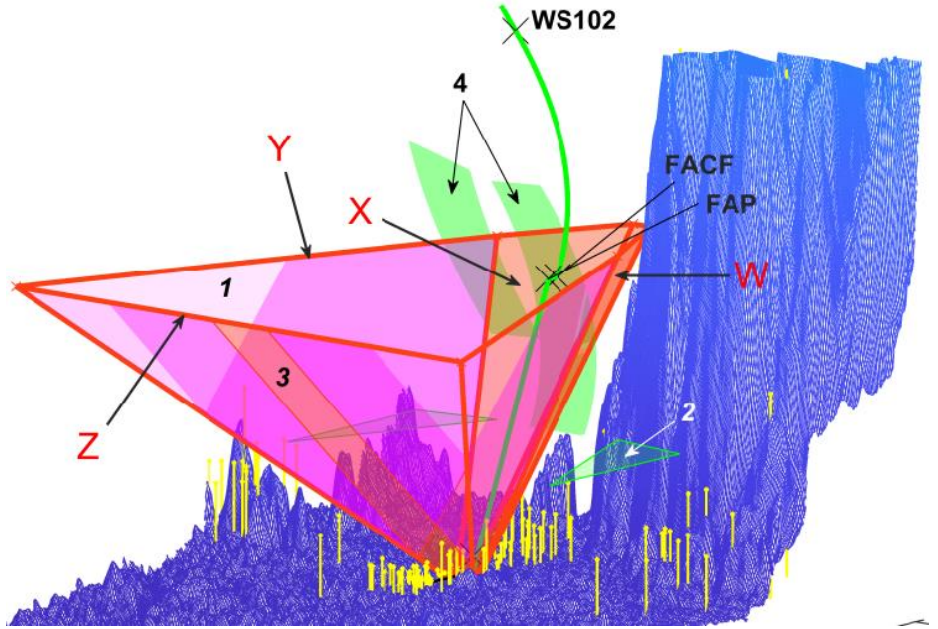


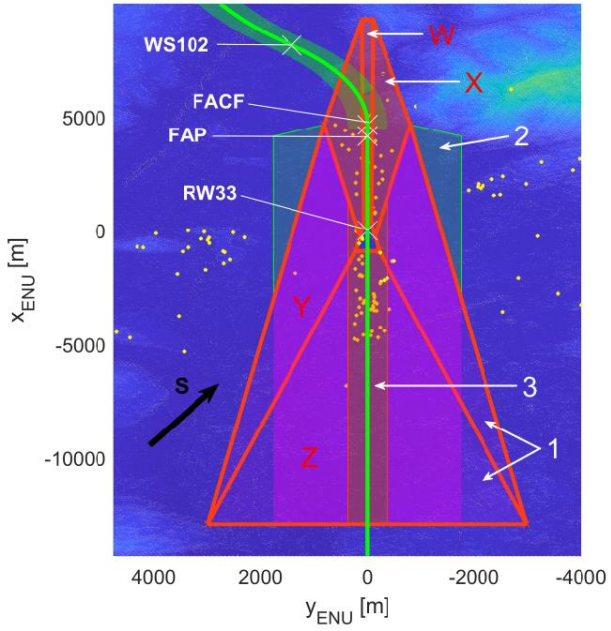
LPV segment (2)

- The resulting ILS CAT I OAS do not cut into the terrain but are very close to it

- The FAP must now be placed within the system
  - ✓ PANS-OPS: 3 NM minimum final approach length
  - ✓ Here: Shorter length advisable due to terrain -> We favor 2 NM -> FAP @2300 ft, ~2.2 NM from the THR
- 218 ft, -151 ft less than existing RNP Z (AR)

- Merge RNP AR Surfaces with APV Surfaces RNP 0.1





Simulator Assessment

Scenario briefing

- **A350-900** Level D FFS (FT72 LAT MUC)
- 5 Scenarios
  - ✓185000 t GW (20 t below MLW)

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Wind

The simulator did not always represent the desired values!

- Generally three layers
  - ✓ 3000 ft MSL upon entry to the second RF leg -> maximum tailwind (RNP AR specs)
  - ✓ 1000 ft above THR shortly before the FACF -> maximum crosswind (RNP AR specs)
  - ✓ SFC: maximum crosswind (A350 OM)

Scenario	Wind [°/ kt]	Temperature	End of Scenario	Remarks
#1	NIL	ISA	Go-Around	Baseline
#2	All levels: 055/35	ISA	Go-Around	Turbulence: 50% Intended Wind (differences): 3000 ft: 109/50 1000 ft: 063/35
#3	3000 ft: 109/50 1000 ft: 109/50 Surface: 055/25	ISA-32	Touch-and-Go	Turbulence: 50% Intended Wind (differences): 1000 ft: 063/35
#4	All levels: 109/50	ISA+15	Go-Around	Turbulence: 50% Intended Wind (differences): 1000 ft: 243/35 Surface: 250/35
#5	All levels: 109/50	ISA+25	Approach only	Turbulence: 50% Intended Wind (differences): 1000 ft: 243/35 Surface: 250/35

Aim: Making the achievement RNP 0.1 performance as hard as possible

On-board representation of the approach (1)

Approach was selectable as **RNP approach with LPV final (FMS)**…

- RNP values correctly stored for all segments, retrievable via the F-PLN page
- FAS DB correctly stored (i.e. identifier, channel number, course, GPA etc.)

… interpreted as **RNP AR** once intercepted, e.g.:

- RNP AR lateral/vertical deviation bricks available
- Green RNP AR identifier displayed to the lower right of the artificial horizon
- Leg RNP displayed on the ND (not in LOC & GA TRK mode)

On-board representation of the approach (2)

LS activated brought the LPV „diamonds“ to the PFD…

- RNP AR identifier switched to SLS
- LPV guidance was available and used after pressing the APPR button

On-board representation of the approach (3)

- The RNP AR lateral deviation bar disappeared in the LOC guidance mode
- The RNP AR vertical deviation disappeared upon intercepting the LPV glide path (G/S* guidance mode)
- The RNP AR lateral deviation bar came back upon initiating a go-around as required, even if LS was still active -> overlapped with the SLS diamonds

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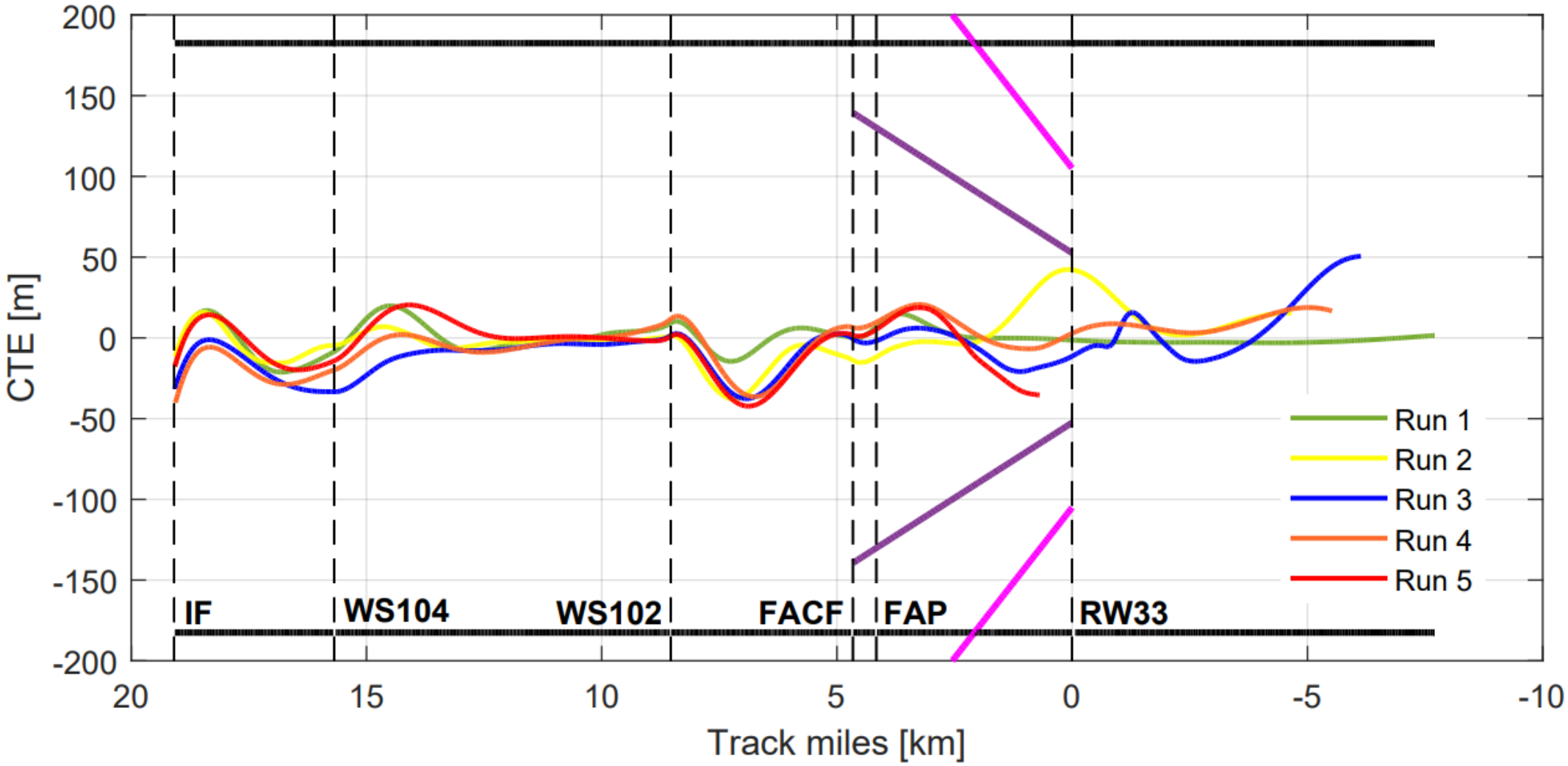
The witnessed behavior represented the best possible fulfillment of the combined requirements of the PBN manual for LPV & RNP AR as the RNP AR deviations were always available when they were required, as were the LPV deviations!

Cross-track Error Performance (XTE)

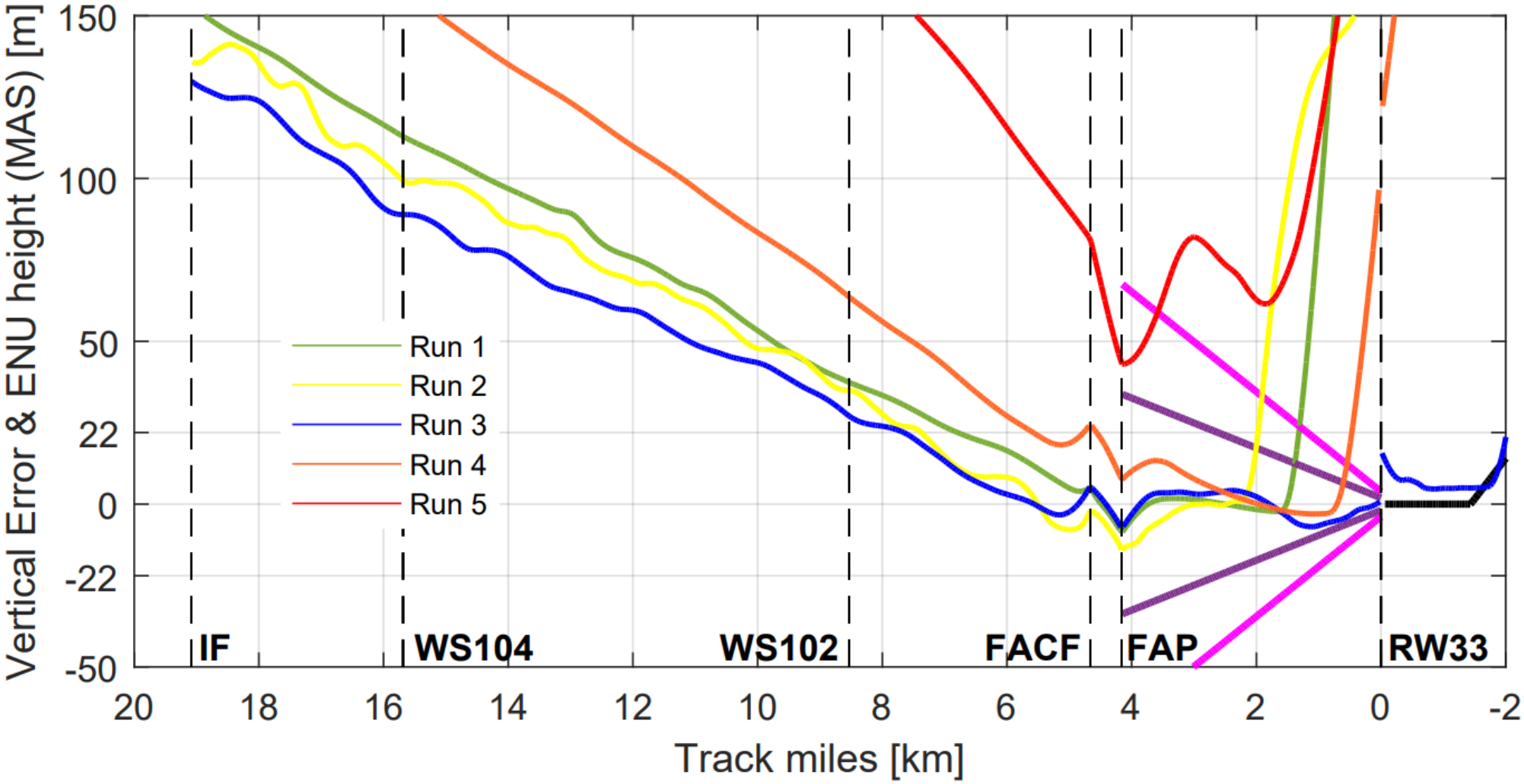
XTE remained **below 50 m** at all times
As expectable, stronger wind caused slightly larger XTEs



Vertical Error Performance (VE)

All coded minimum altitudes until the FACF were met

The vertical error was within the limits allowed by RNP AR and considered by Appendix D (PANS-OPS) for all BUT scenario 5



Assessment: Conclusions

- Vertical Path must be followed properly to achieve LS intercept at the FAP
- Since the way the segment is designed does not include any margin in case of off-nominal behavior, we recommend the upper temperature limit to be lowered slightly below ISA+25

- LPV can become available also in areas with tight spatial constraints that previously prevented it
- RNP AR performance on feeder segments allows significant reduction of protection areas
- Merging rules for RF legs to the final approach course can be adjusted to RNP AR performance

- Shorter final approach did not cause issues during the simulator trials -> might be an option for applications where the constraints are particularly tight, PANS-OPS minimum length requirement could be reviewed

End

Thank you for your attention!