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EGPWS challenges for RNP-AR approach design

18 October 2021

Presented by Stefan Brandt

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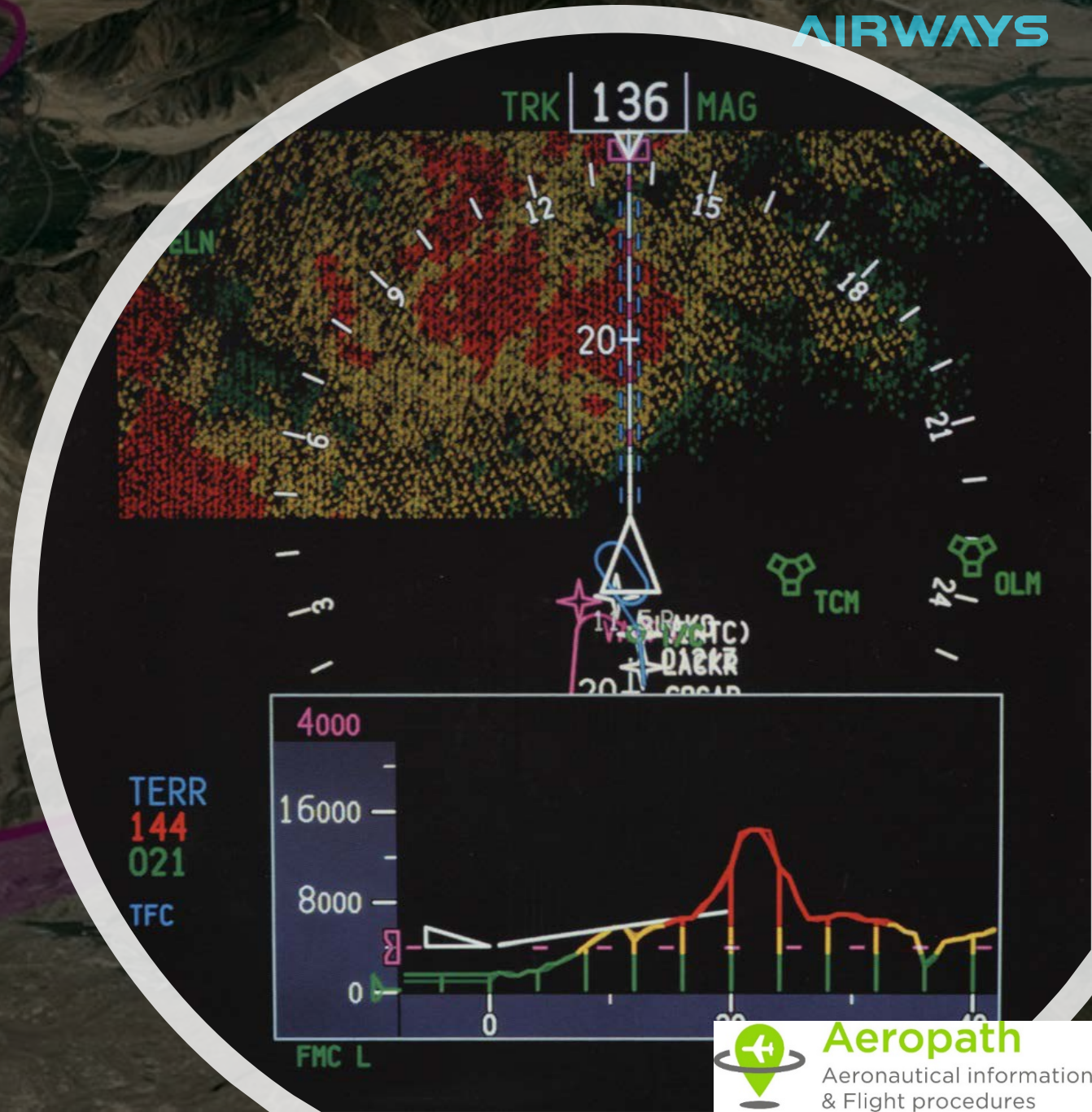
Introduction – EGPWS and RNP-AR design



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Agenda

- Nadi RNP-AR RWY 20 Approach Design (v1)
- Flight Validation
- Simulator Validation
- Airline Validations
- EGPWS
- Next steps/collaboration
- Approach Changes (v2)
- Questions/Experience from other countries

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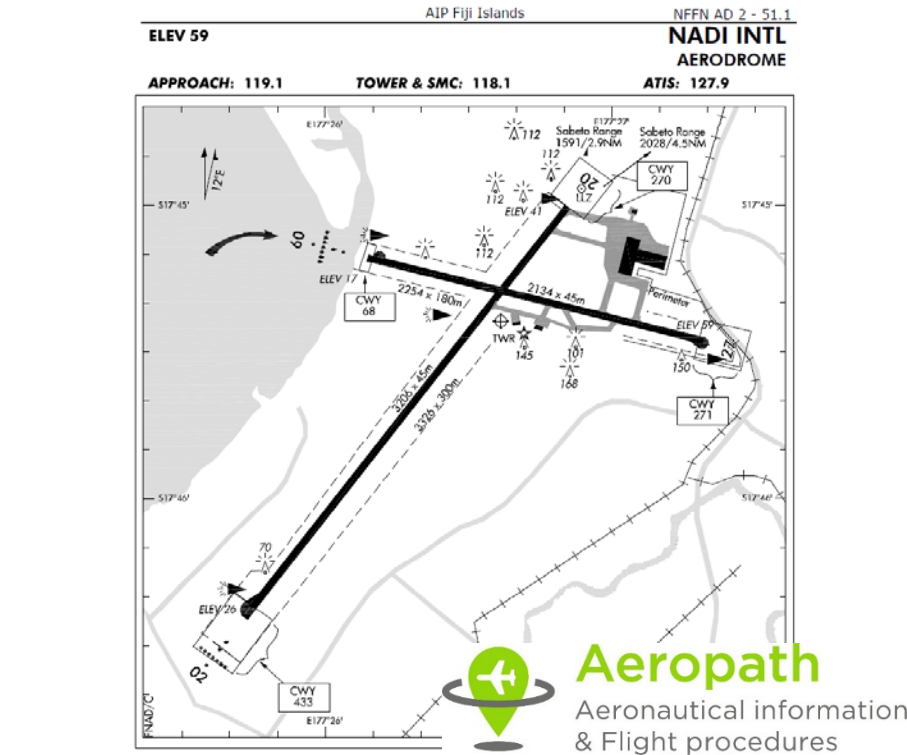
Background

- Nadi International Airport, Fiji
  - No instrument approach for RWY 20
  - Straight in approach RWY 20 doesn't work due terrain
  - Visual circling is discouraged by airlines
  - Aircraft land on RWY 02 with tailwind
  - When tailwind is too strong = diversion $$



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Terrain Challenges – Nadi International

COURTESY PRIVATEFLY

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Terrain Challenges – Nadi International

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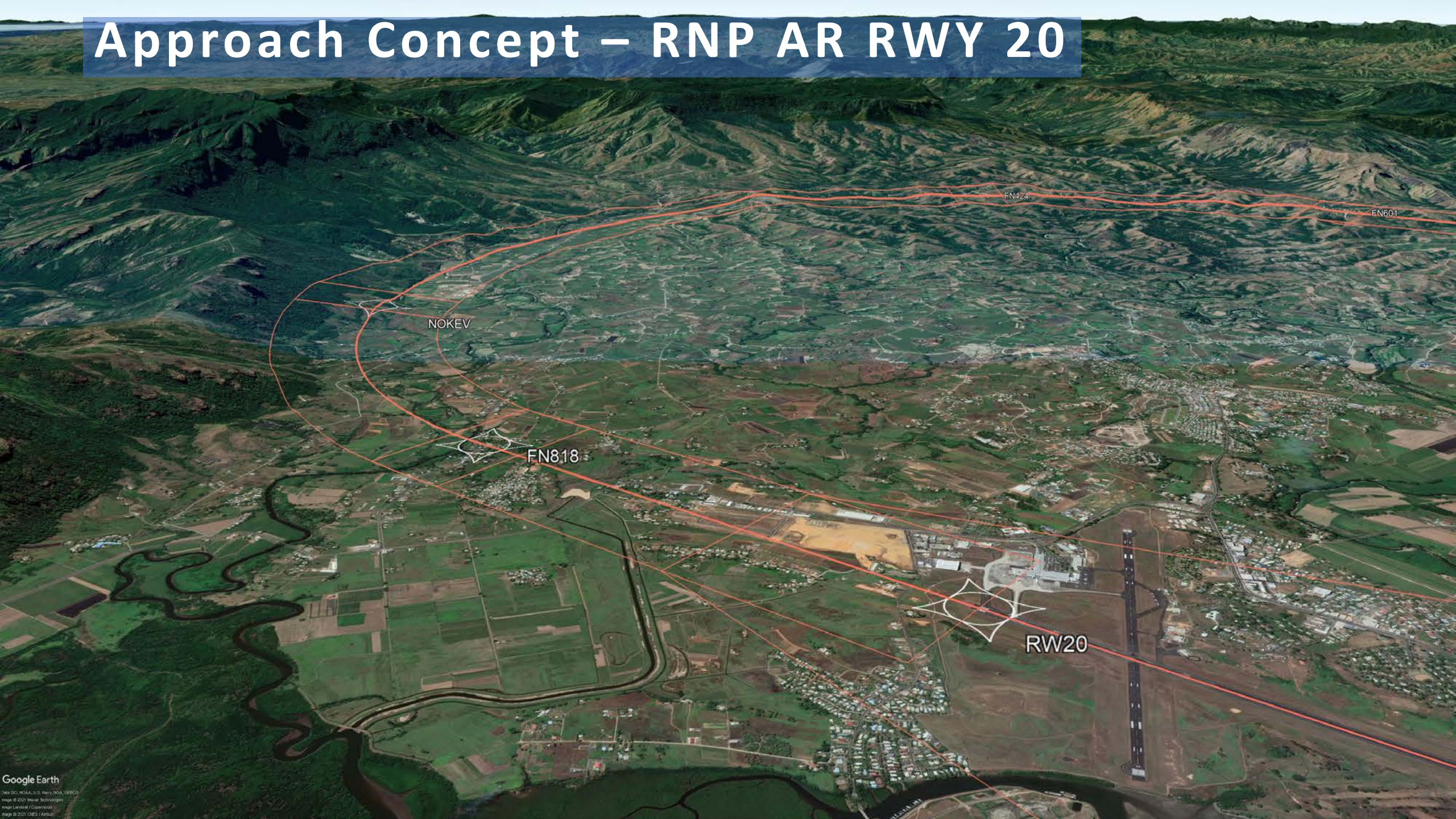
Approach Concept – RNP AR RWY 20




[−][Top][2D Wireframe]
TEDUM
KALTA
LAREB
MOTKI
170kts IAS
180kts TAS (1500ft, ISA +20)
G/S 230kts (50kts tailwind)
20° AOB
Min radius of turn 3915m
Radius used 3950m
MAX IAS 170 kt
210kts IAS
227kts TAS (3000ft, ISA +20)
G/S 277kts (50kts tailwind)
20° AOB
Min radius of turn 5697m
Radius used 5800m
210kts IAS
231kts TAS (4000ft, ISA +20)
G/S 291kts (60kts tailwind)
20° AOB
Min radius of turn 6265m
Radius used 6400m
MAX IAS 210 kt
N
W
TOP
E
S
WCS
Type a command
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Flight Validation

- Ref. Doc 9906 Vol 5
- Flight Inspection Aircraft Piper Cheyenne 400LS Turboprop
- First run – Partial flap setting, gear down
  - EGPWS Caution ‘Terrain Ahead’ 1nm before FAF while pointing towards terrain
- Second run – Full flap, gear down
  - No EGPWS alerts
- Approach satisfactory

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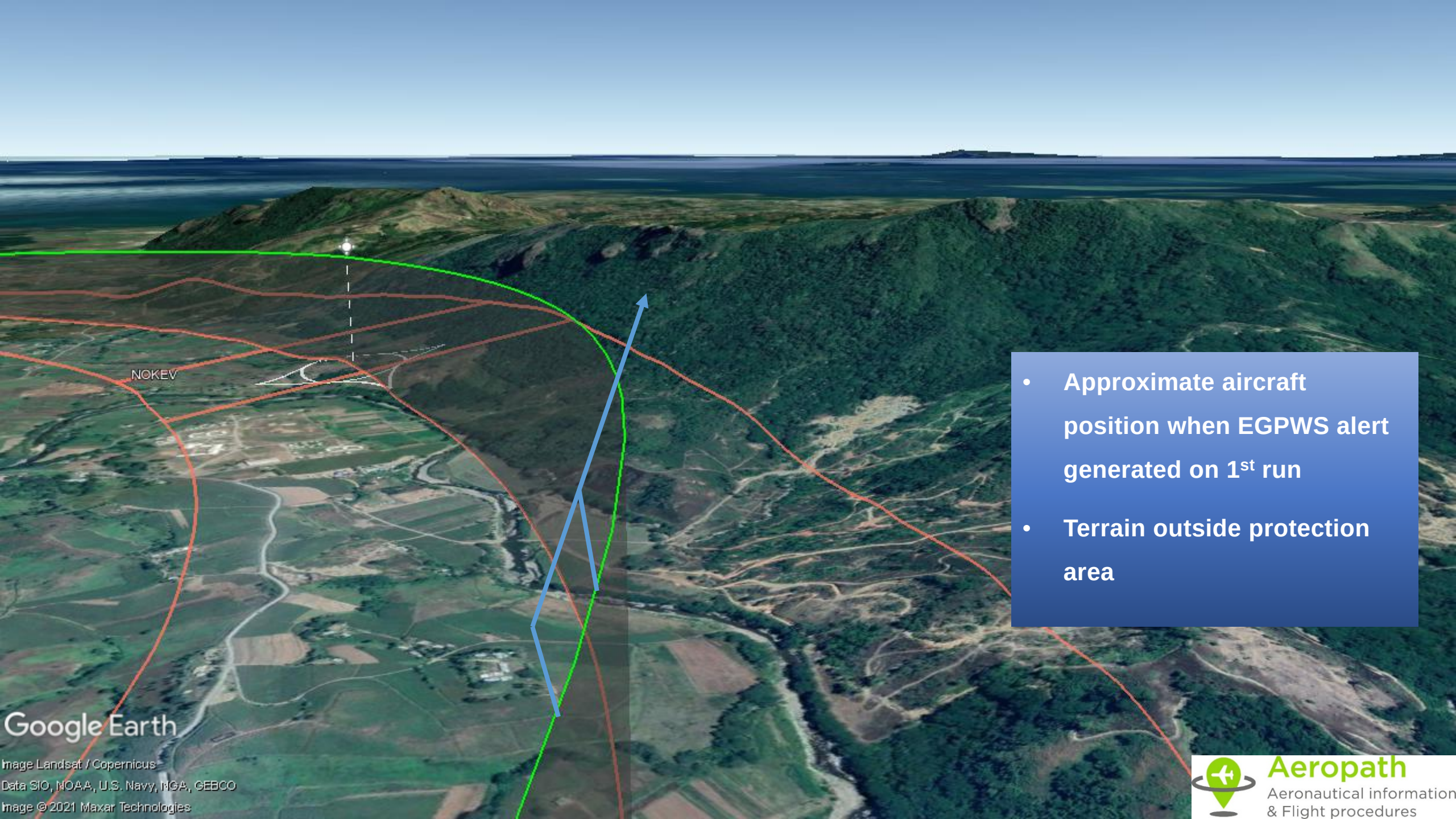

- **Approximate aircraft position when EGPWS alert generated on 1st run**
- **Terrain outside protection area**

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Flight Validation – ICAO Doc 9906

- ICAO Doc 9906 Vol 5 gives some guidance on EGPWS alerts
- Can be generated when flying over irregular or steep rising terrain
- EGPWS checks to be flown in proper configuration for phase of flight
- If repeated alerts received, flight crew to document location, speed, aircraft config.
- Designers can consider speed reduction, altitude constraints or moving waypoints

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Simulator Validation – B787

- **Coded procedure, flyability, handling check, human factors etc in accordance with ICAO Doc 9906 Vol 5**
- **Aircraft type for check representative of actual types likely to fly**
- **B787 ZFT simulator used, based on airline requirements**

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Simulator Validation – B787

- <u>Tech Crew Briefing</u>
- **Initially to be flown under normal conditions, speeds, configurations, weather etc**
- **Progressively more adverse weather conditions and higher speeds (within design spec) to ‘stress test’ procedure**
- **Special attention to EGPWS system**

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Simulator Validation – B787

- Initial runs using normal approach speeds, calm winds – No terrain alerts
- More adverse winds (tailwind on base while aircraft pointing towards terrain) to stress test procedure – No terrain alerts
- Flight at maximum speeds (170kts at FAF) – No terrain alerts
- Satisfactory procedure
- Side note: Received terrain warning only when flown outside design spec (fast on final approach)

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Approach Signoff

- Successful flight validation
  - Terrain caution noted but subsequent satisfactory run
- Successful simulator validation in B787
- Procedure certified
- Publishing!

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Airline Simulator Validation

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- Data sent to database houses for coding
- Airlines begin internal validation process prior to effective date
- Simulator runs completed on each fleet type by various airlines
- Procedure coded into FMS
- Tested under varying conditions, tailwinds, aircraft speeds

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Airline Simulator Validation

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Airline 1

Aircraft Type	Comments
B777	EGPWS terrain alerts experienced on approach
B787	Approach satisfactory
A320/321 NEO	Approach satisfactory
A320/321 CEO	EGPWS terrain alerts experienced on approach

Airline 2

Aircraft Type	Comments
B777	EGPWS terrain alerts experienced on approach
B787	Approach satisfactory
B737-800	EGPWS terrain alerts experienced on approach
A320 CEO	EGPWS terrain alerts experienced on approach

Airline 3

Aircraft Type	Comments
B777	EGPWS terrain alerts experienced on approach
B737-800	EGPWS terrain alerts experienced on approach

Airline 4

Aircraft Type	Comments
B787	Approach satisfactory
A320 CEO	EGPWS terrain alerts experienced on approach

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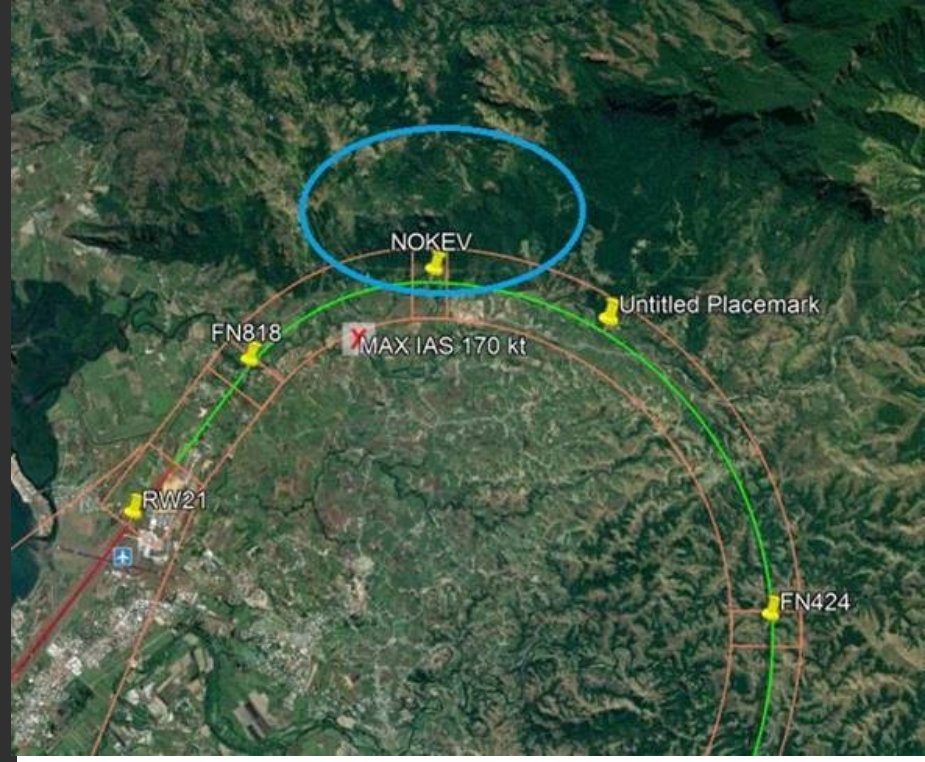
Airline Simulator Validation

- Common threads from simulator testing
- Aircraft types
  - B787, A320 NEO good
  - B777, B737-800, A320 CEO terrain alerts
- Location of alerts
  - Same as first flight validation run, approaching final approach fix pointing towards terrain

- Airlines report configuring aircraft early during testing, speed back to final approach but terrain still generating alerts.



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Airline Simulator Validation

- **1st Lesson**
- **Consider the aircraft type used when conducting simulator validation. Perhaps the most modern aircraft type in the fleet isn't the best choice…!**
- **Aircraft like B787 take programmed RF turns into account for the EGPWS system alerting, older aircraft do not**

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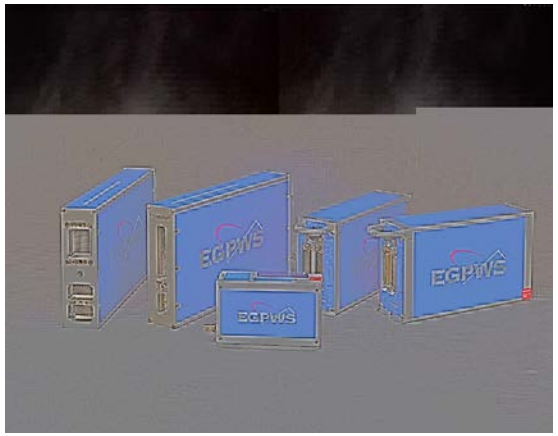
EGPWS

- Enhanced Ground Proximity Warning System
- Operates in two ways
  - 1st using radar altimeter to measure closure rate with terrain directly below
  - 2nd using GPS position and onboard database to predict aircraft position relative to terrain



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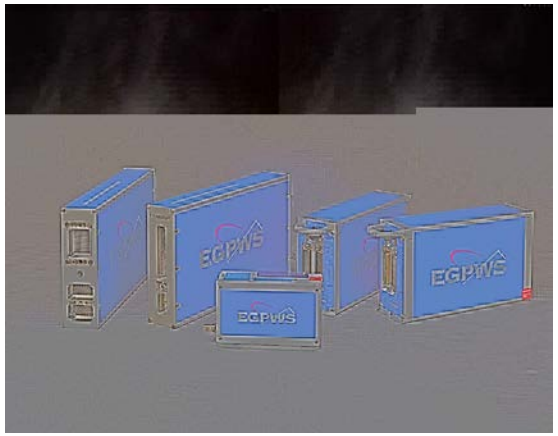
EGPWS

Basic Functions:

- **Mode 1 – Excessive Descent Rate**
- **Mode 2 – Excessive Closure to Terrain**
- **Mode 3 – Altitude Loss After Takeoff**
- **Mode 4 – Unsafe Terrain Clearance**
- **Mode 5 – Excessive Deviation Below Glideslope**
- **Mode 6 – Advisory Callouts**
- **Mode 7 – Windshear Alerting**

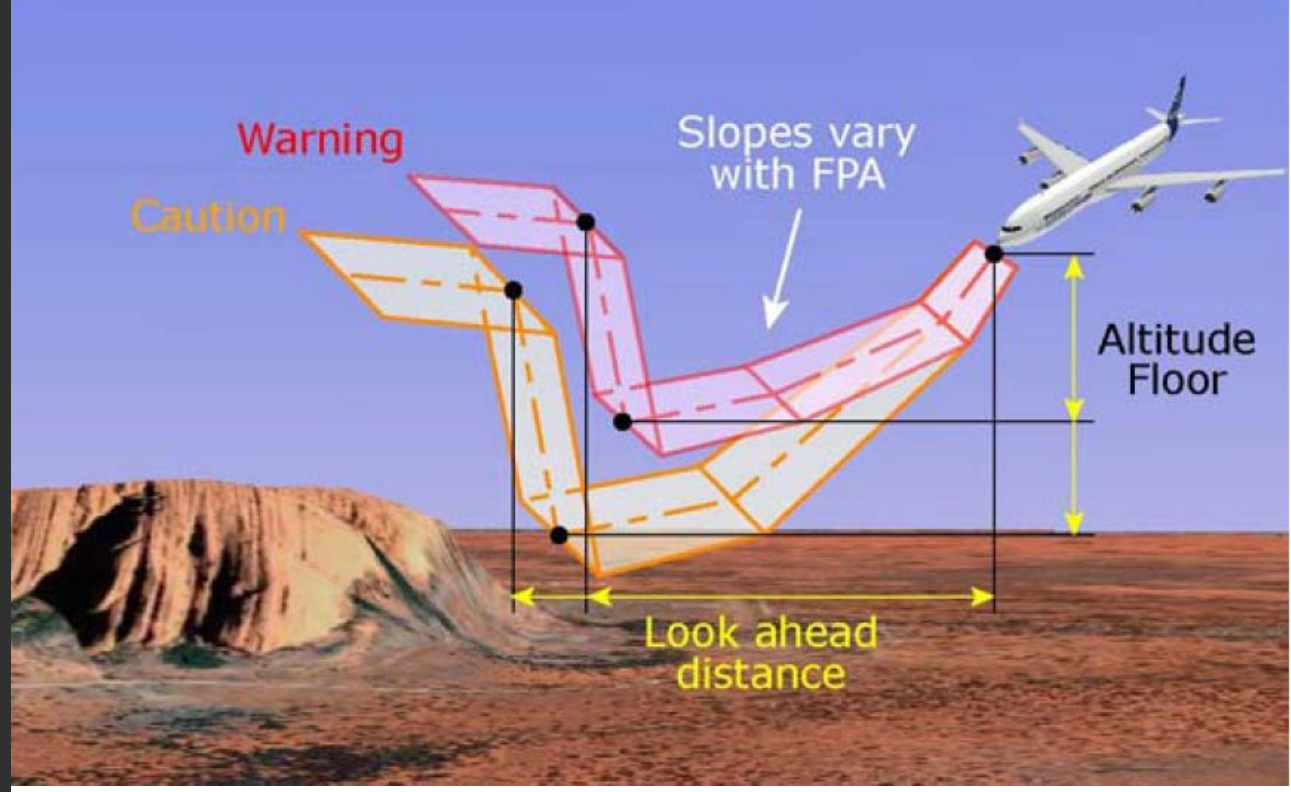
Enhanced Functions:

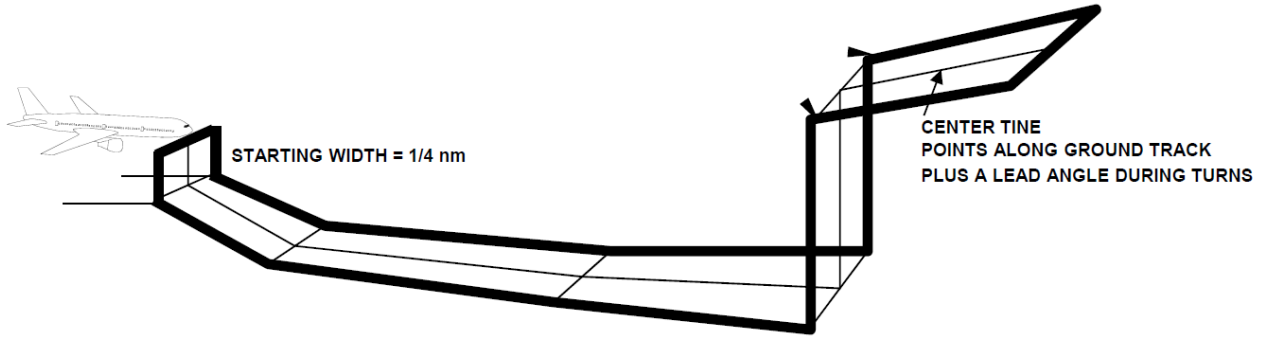
- **Terrain Clearance Floor**
- **Terrain Look-ahead Alerting**
- **Predictive Windshear**



EGPWS

- How does it work?
  - ‘Ribbons’ project ahead of aircraft
  - Project down, forward then up
  - Starting width ¼ mile and 3° either side
  - Slope varies with FPA
  - Points along A/C ground track
  - Lead angle inside turns
- Caution time to impact approx. 60 sec
- Warning time to impact approx. 30 sec
- Envelope size varies, based on pilot handling
  - Ground speed - IAS, tail/head winds
  - Configuration – Flaps
  - Distance to RWY





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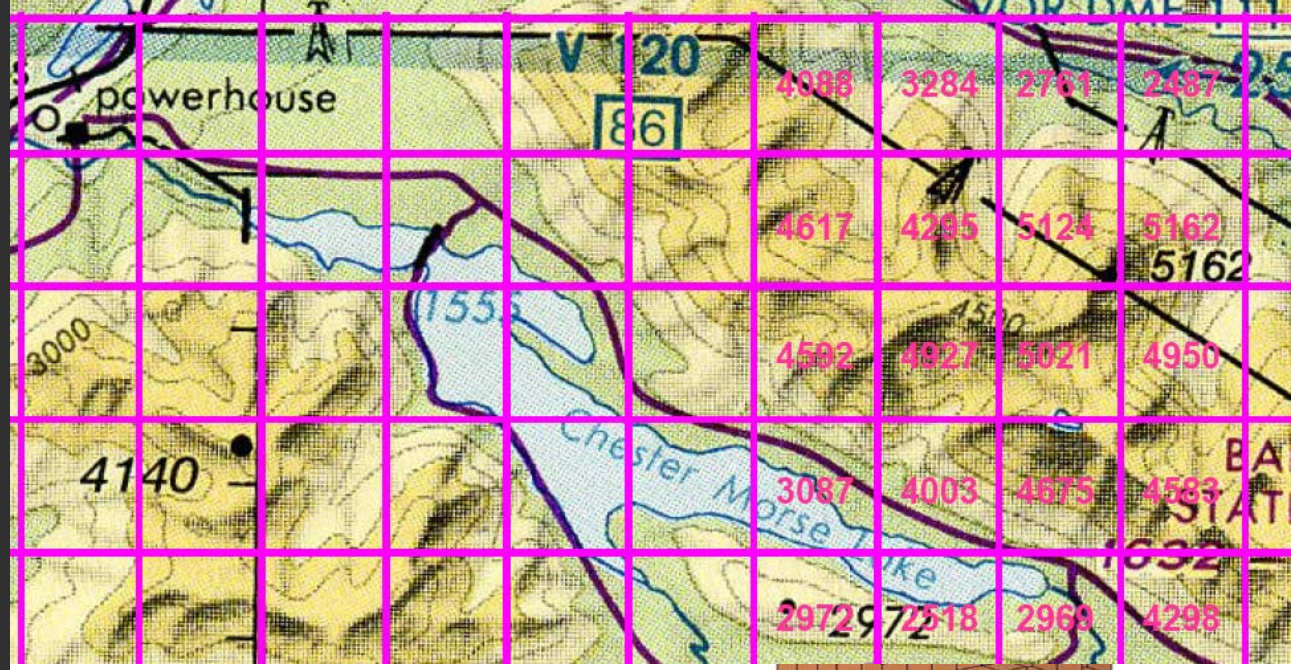
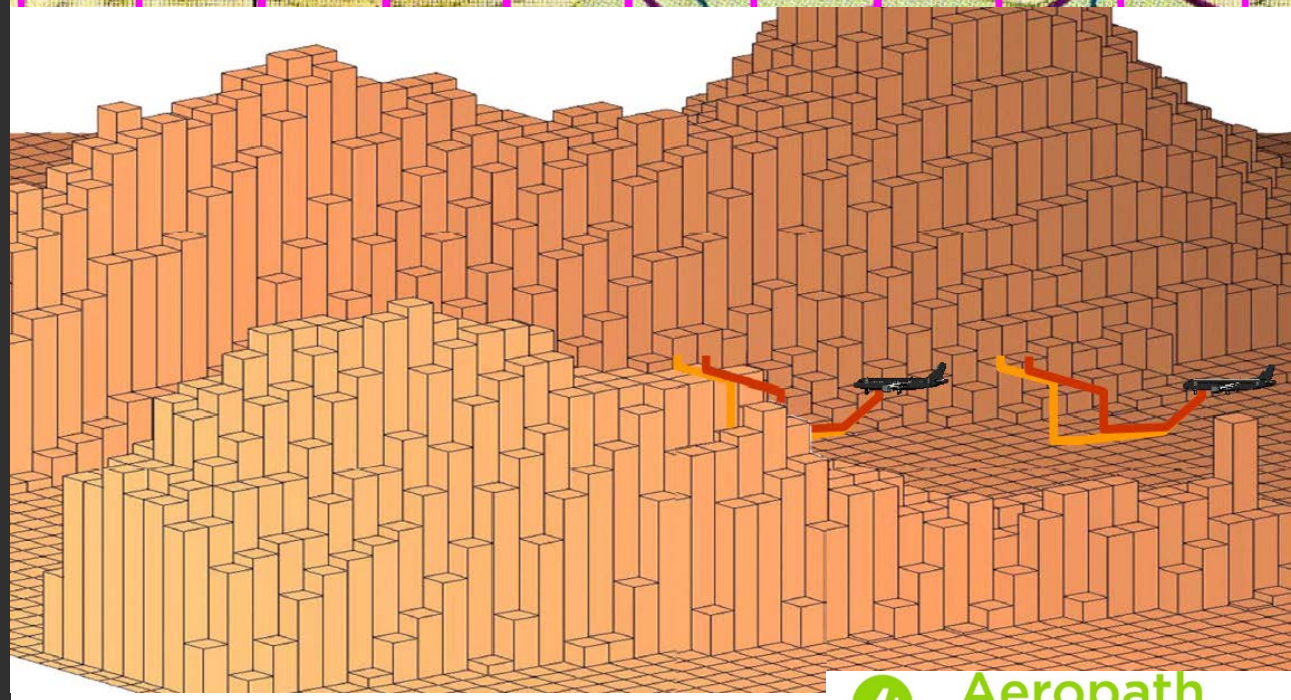
EGPWS - Database

- Internal database contains worldwide terrain data of varying resolution
- Land area divided into grid
- Each cell has a constant altitude defined by maximum altitude within that area
- Normal resolution 30 x 30 arc seconds
- Can be increased to 15 x 15 arc seconds (mountainous area airport)





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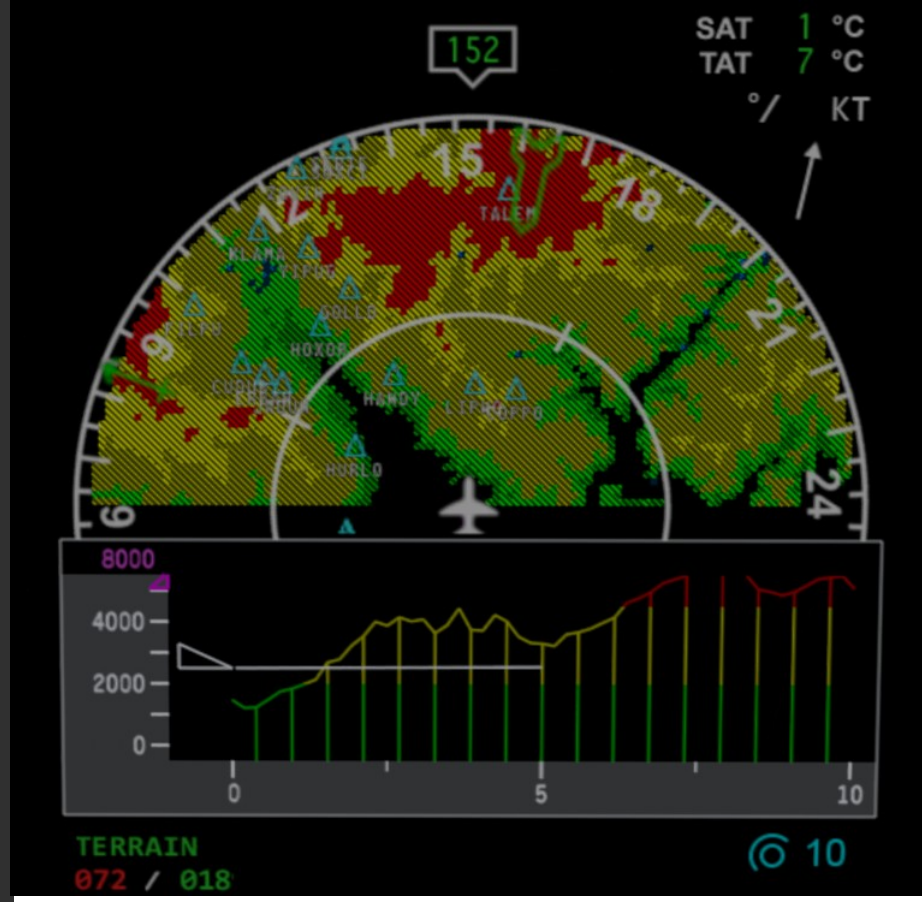
EGPWS – Envelope Modulation

- Nuisance alerts can be generated during normal operations
- Works by desensitizing various modes of operation at well identified locations
- Handled by FMS manufacturer and settings are stored in the database
- New approach procedures for places with not much jet traffic more likely to experience nuisance alerts



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Next Steps - Collaboration

- Airlines contact FMS manufacturer for support
- Problem – Different aircraft types within fleet sometimes have different FMS providers
- Checking of sim database vs aircraft database (can be different)
- Improved accuracy of terrain data requested from FMS manufacturer (designated mountainous area airport)
- Some airlines found Nadi not included in Envelope Modulated Database

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Further Testing

- New EGPWS database for testing delivered to airlines with higher terrain resolution
- Several airlines retested procedure in simulator and received terrain alerts
- Live flight flown in A321 NEO in VMC, terrain alerts generated
- No choice but to redesign…
- Interesting finding; one airline noted terrain alerts varied with temperature in sim (effective VPA)

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Approach Changes (v2)

- Requirement for greater clearance from terrain to the north
- Final approach speed further restricted (160 kts)
- Tighter turn radius, 25 degrees AOB
- FROP moved closer to RWY (1.3nm, 500ft)
- Bonus = Increased RNP value to 0.3 due to flight path further away from terrain

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NOKEV
FN424
FN818
FN601
RW20
Google Earth
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NIREV (FAF)
FN581
FN812
Google Earth
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1500m / 0.8NM
Google Earth
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Data LDEO-Columbia, NSF, NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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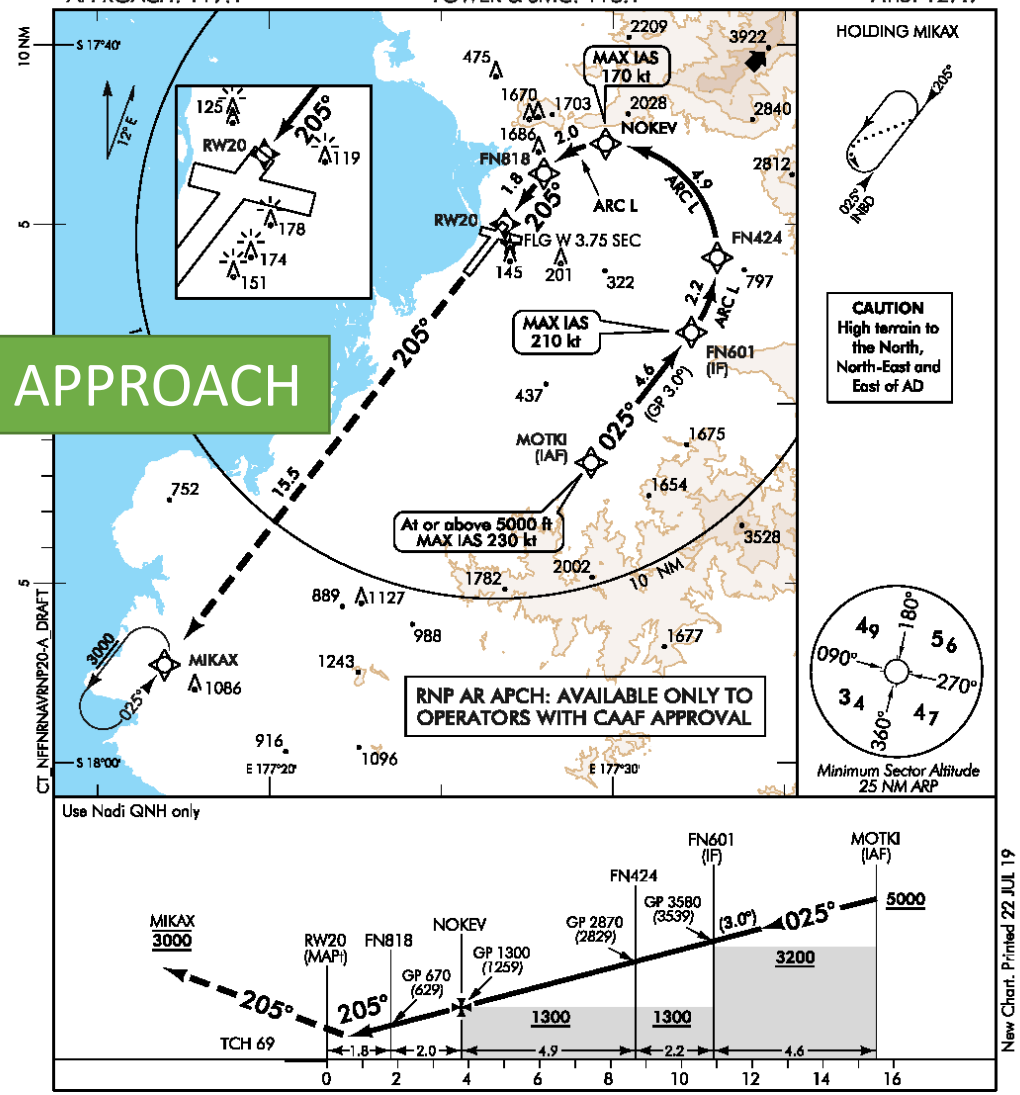
OLD APPROACH

ELEV 59
RWY 20 THR ELEV 41
CAT B,C,D

NADI INTL

RNP RWY 20 (AR)

APPROACH: 119.1 TOWER & SMC: 118.1 ATIS: 127.9



New Chart. Printed 22 JUL 19

MISSED APCH: Track 205° to MIKAX hold 3000

Category	A	B	C	D
RNP 0.16	NA	320(279) – 1600	330(289) – 2000	340(299) – 2000

1. Procedure NA when AD temperature is below 5°C or above 47°C
2. RF required
3. RNP 0.16 intial and intermediate segment, RNP 1.0 missed APCH segment

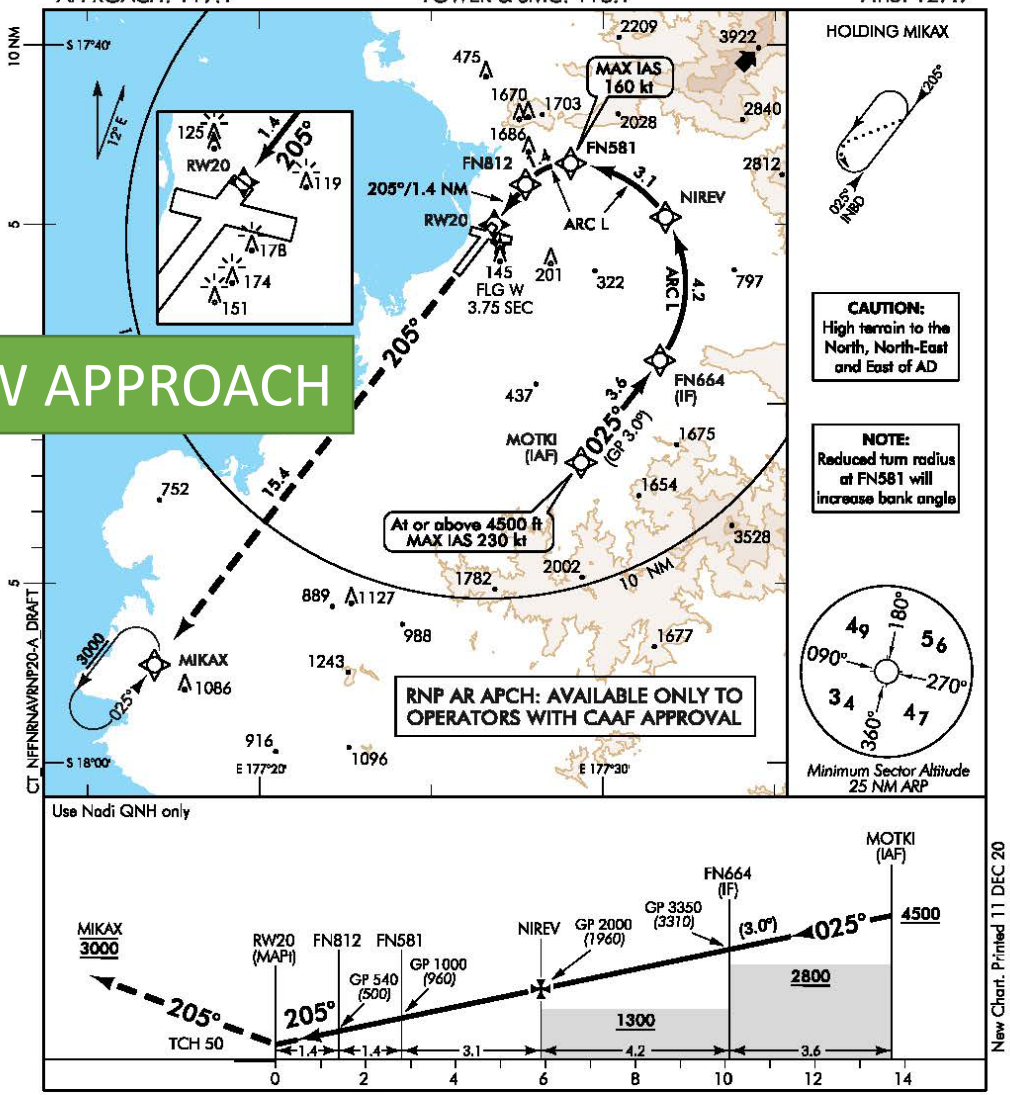
NEW APPROACH

ELEV 59
RWY 20 THR ELEV 40
CAT B,C,D

NADI INTL

RNAV (RNP) RWY 20

APPROACH: 119.1 TOWER & SMC: 118.1 ATIS: 127.9



New Chart. Printed 11 DEC 20

MISSED APCH: Track 205° to MIKAX hold 3000

Category	A	B	C	D
RNP 0.30	NA	320(280) – 1600	330(290) – 2000	340(300) – 2000

1. Procedure NA when AD temperature is below 10°C or above 46°C
2. RF required
3. RNP 0.30 between MOTKI and RW20, RNP 1.0 missed APCH segment

Approach Changes (v2) – Sim/Flight Testing

- Data sent to airlines to obtain test database
- Further sim testing carried out
- Positive results reported across different aircraft types/airlines including previous types which had terrain alerts
- Successful ‘live’ flight in VMC by B787
- Approach published, awaiting airlines to complete fleet validation

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Approach Changes (v2) – Sim/Flight Testing

- **2nd Lesson**
- **Send approach data to airlines early to enable simulator testing to prove concepts, perhaps before flight validation**
- **Ideally have different airlines test procedure in multiple aircraft types**

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What can we do as Procedure Designers?

- Design away from terrain as much as possible
  - Tight turn radius, AOB, speed reduction
  - Possibly steeper GPA
  - Roll out on finals as late as possible
- Avoid designing over rapidly rising terrain/ridges
- Envelope modulation/terrain data tweaks can help
- Be prepared for iterations after testing

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