



Required Navigation Performance Design Equipment Performance and System Capabilities

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Agenda

- Required Navigation Performance (RNP)
- Unique Equipage Features
 1. Display of RF legs
 2. On board Monitoring and Alerting
 - Lateral
 - Vertical
 3. RNP management
 4. Continuous LNAV After TO/GA
 5. Missed Approach navigation
 - IRU's
 - DME/DME

Required Navigation Performance (RNP)

Authorization Required



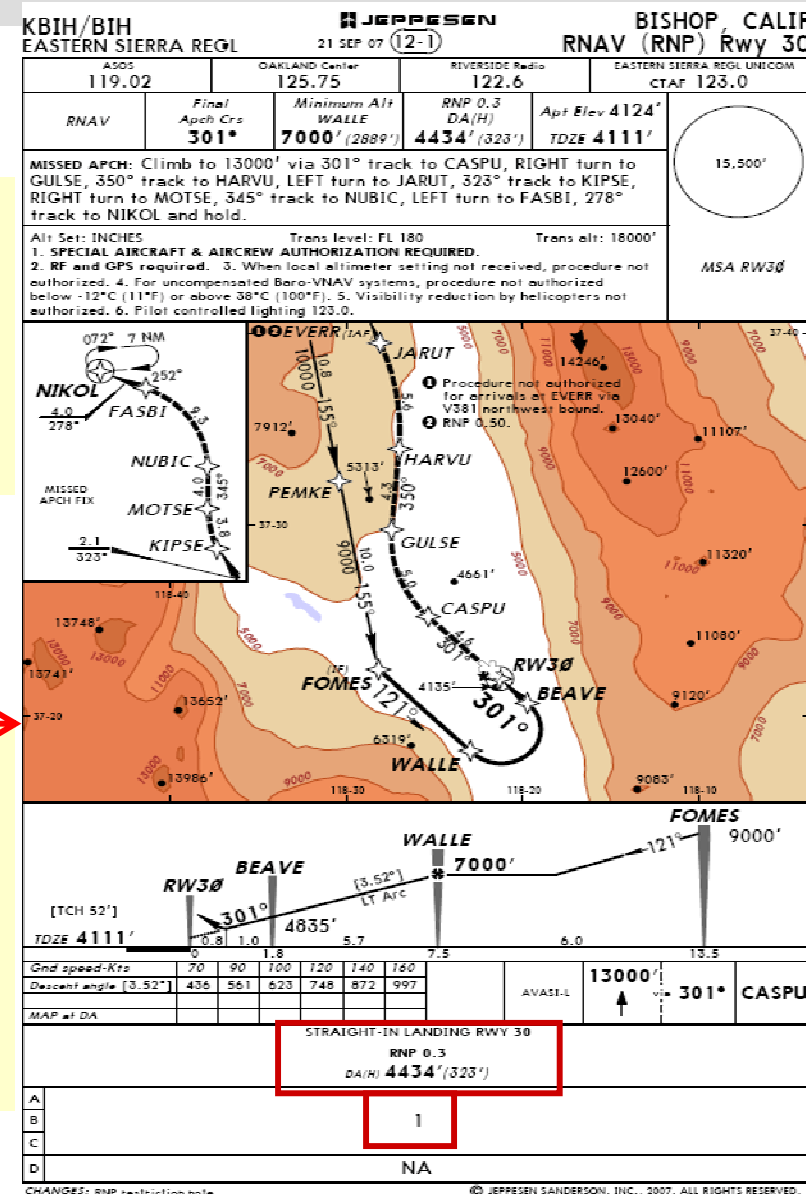
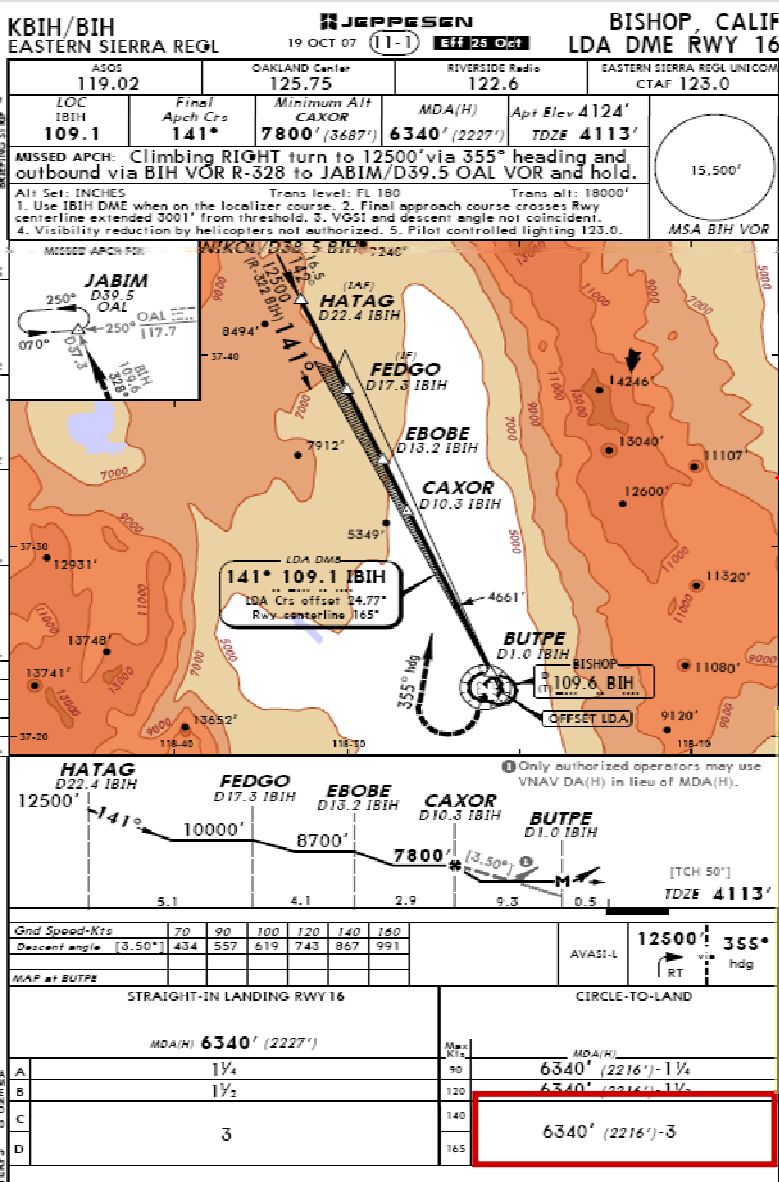
Key Elements of RNP AR

1. Curved flight paths (RF Legs)
2. Path conformance with high degree of accuracy and repeatability
3. Precise missed approach guidance

RNP Versus RNAV:
Onboard monitoring avionics keep
aircraft within a tightly specified
airspace corridor

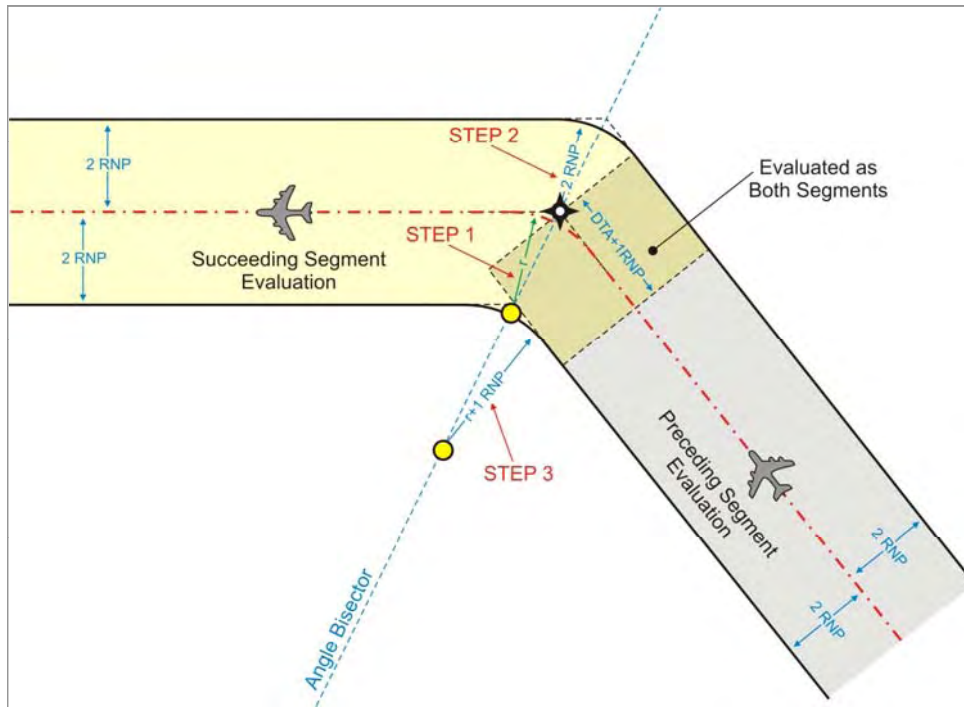
***Overview of 5 specific Aircraft
Design features to enable this
Performance Based Navigation
method of Flight operations***

A Classic Example – BIH RWY 30

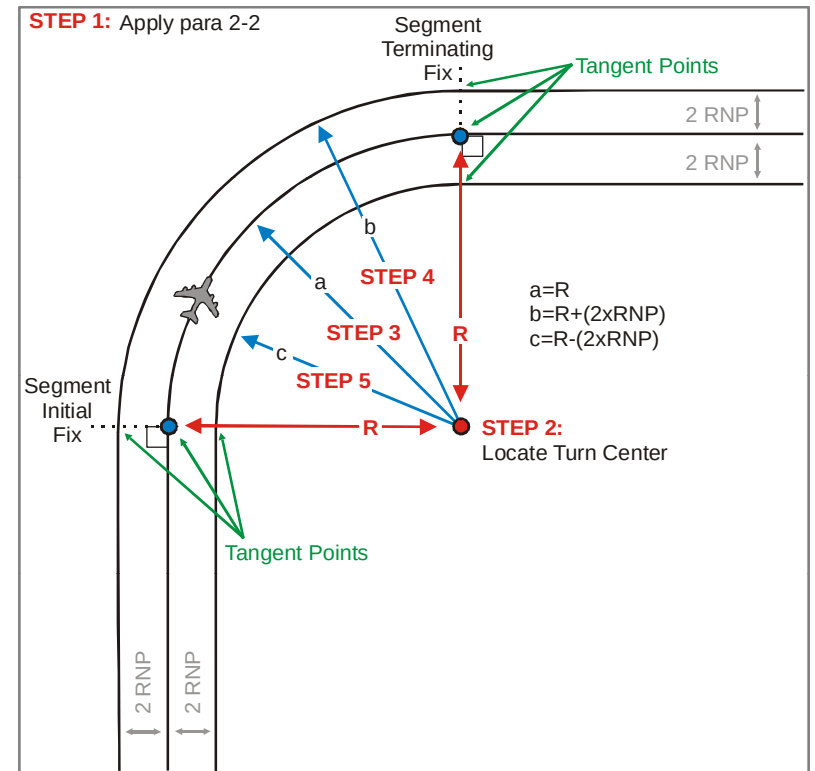


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Fly-By Turns



Radius to Fix (RF) Segments

Display of RF Legs

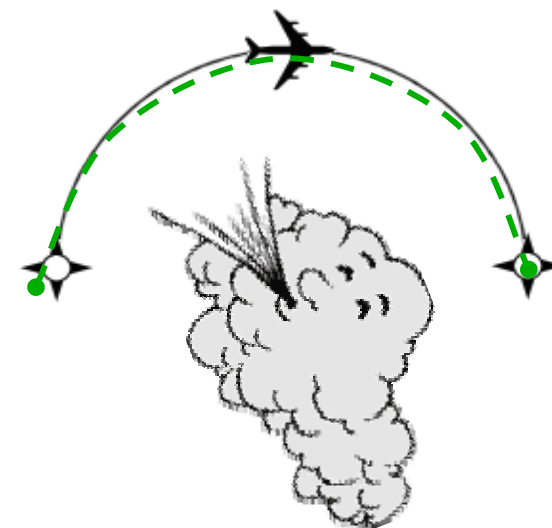
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Although RF legs have been a ARINC leg type for many years there are still many challenges encountered in displaying them. It requires both an FMS upgrade, but in legacy aircraft many times a display upgrade as well.

RF Legs & Containment

- An RF turn is a constant radius turn starting and ending on a waypoint
- **Containment in an RF turn requires flying at the appropriate speed for the aircraft category**
- Approach design limits required bank angles to
 - 25 Degrees above 400' AGL
 - 8 Degrees below 400' AGL
- Flight Guidance bank angle commands are limited with altitude
- Strong winds could cause containment deviation
- Pilot training covers RF legs including a Flight simulation.



Indicated Airspeed (Knots)					
Segment	Indicated Airspeed by Aircraft Category				
	Cat A	Cat B	Cat C	Cat D	Cat E
Initial & Intermediate (IAF to FAF)	150	150	240	250	250
Final (FAF to DA)	90	120	140	165	As Specified
Missed Approach (DA to MAHP)	110	150	240	265	As Specified
Airspeed Restriction*	As specified				

*Airspeed restrictions may be used to reduce turn radius.

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Position Estimation Error (PEE)

- Many Industry terms for PEE
 - Actual Navigation Performance (ANP)
 - Estimated Position Error (EPE)
 - Navigation Sensor Error (NSE)
 - **Estimated Position Uncertainty (EPU)**

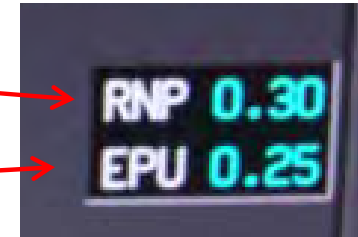


- The Estimated Position Uncertainty (EPU) is the 95% bound on Horizontal Position
 - Cross Track / Lateral and Along Track
- EPU is defined as the radius of a circle, centered on a reported position, such that the probability of the actual position being outside the circle is 5%

Lateral Containment Monitoring

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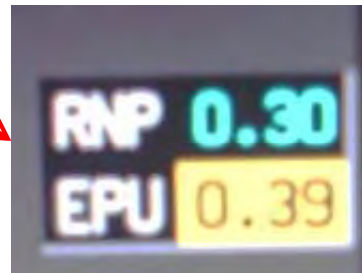
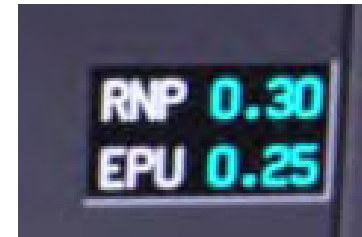
- The required RNP value is displayed
- The EPU value is displayed
- The FTE is displayed on the CDI
 - Full scale deflection (2 Dots) = 1 X RNP



Lateral Monitoring one OEM's implementation

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- If EPU $\geq$ RNP
 - The EPU will flash Amber for 5 seconds
 - Then changes to solid Amber with DEGRADE and MSG annunciation
 - The vertical deviation scale pointer will change to Amber
 - The CDI scale will change to Amber
- **CDI scaling tied dynamically to RNP values**



Maximum Lateral Deviation

- Maximum lateral deviation for low RNP approaches (lines of minima lower than RNP 0.3): 1 dot on CDI ($\frac{1}{2} \times \text{RNP}$)
 - max lateral deviation for RNP 0.3 lines of minima remains 2 dots ($1 \times \text{RNP}$)
- Missed approach required when lateral deviation limit exceeded

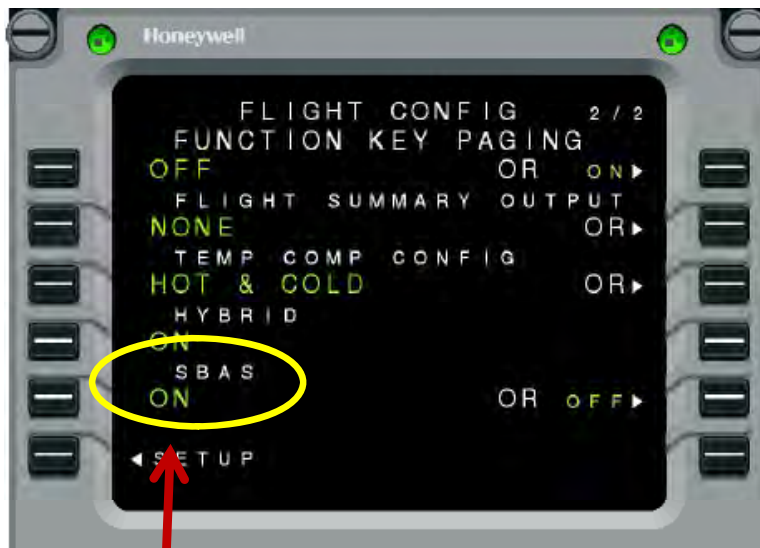


RNP < 0.3 lines of minima
Max lateral deviation = CDI – 1 dots ($\frac{1}{2} \times \text{RNP}$)

RNP 0.3 lines of minima
Max lateral deviation = CDI – 2 dots ($1 \times \text{RNP}$)

GPS Updating with SBAS

- With the Satellite Based Augmentation System (SBAS) function selected ON, FMS navigation source will display as GPS or GPS-D



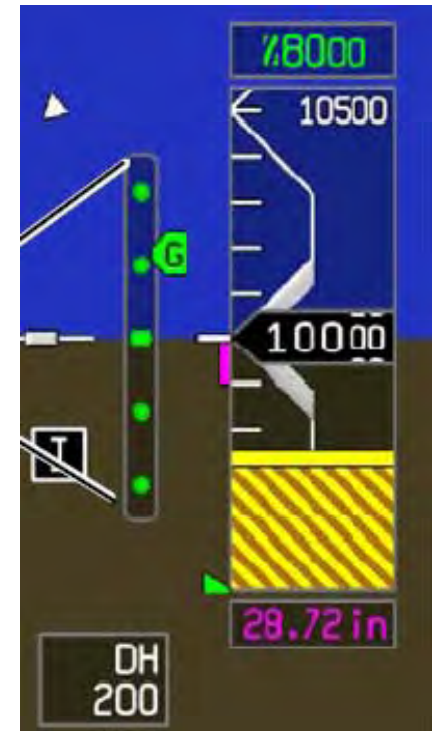
- With a SBAS signal, navigation source will be displayed as GPS-D (D = Differential)
- SBAS is not required to fly an RNP SAAAR approach
- With SBAS OFF higher EPU values will likely be experienced.
- If SBAS is ON EPU values of 0.00 are normal



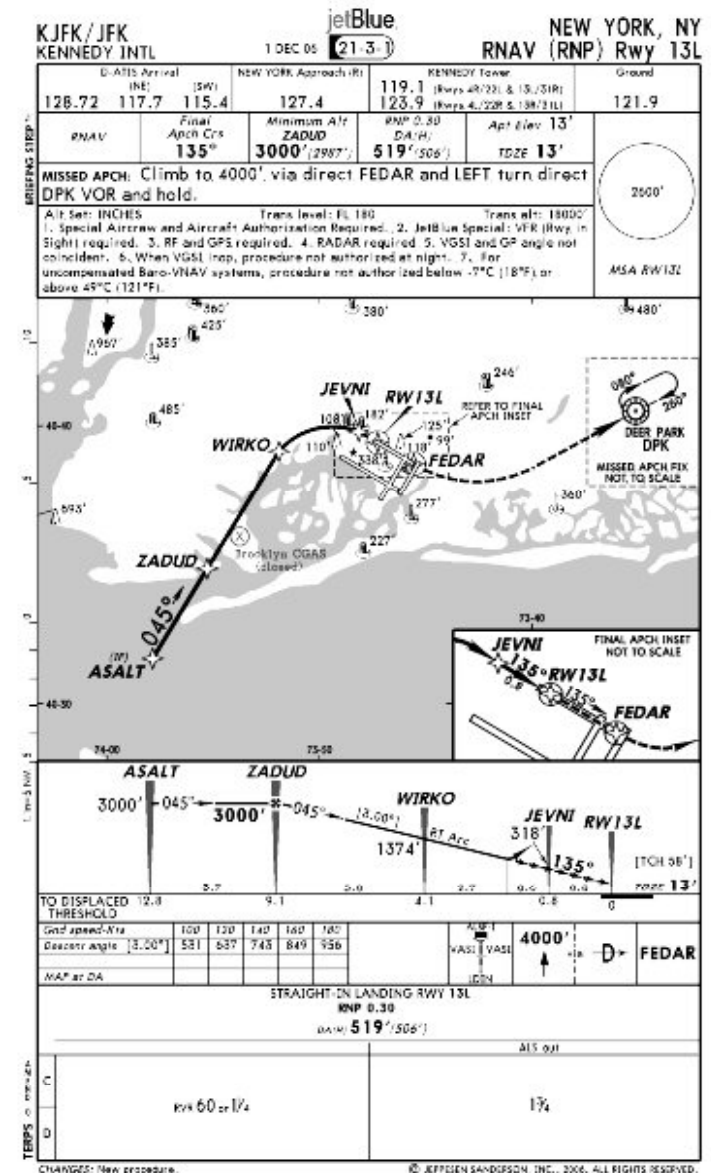
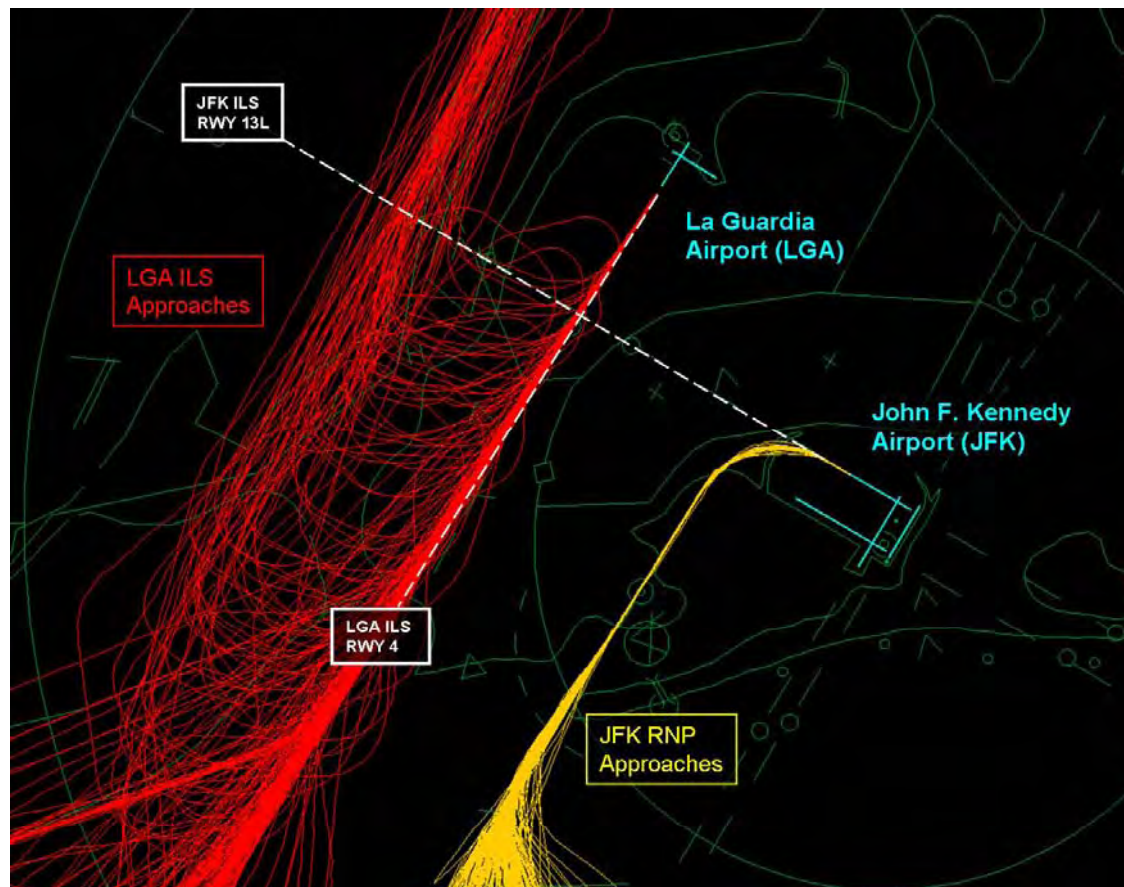
Vertical Containment

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- Altimeters Set & Cross-Checked at Transition Altitude (+/- 100')
- Operational Requirements from IAF to FAF
 - Altimeters Set using "Local" Altimeter Setting
 - Remote altimeter settings are not allowed
 - At a known point altimeters crosschecked within +/- 100'
- Final Approach Segment
 - ♦ A missed approach must be initiated when the vertical deviation exceeds +/- 75'
 - ♦ **One dot on the deviation scale is +/- 75'**
 - ♦ When the aircraft is in an excessive deviation condition, the vertical deviation scale and pointer turn amber and flash
- During approach
 - MAP VSD Displayed and monitored
 - Radar and EGPWS set up and monitored



Success of Lateral and Vertical monitoring



Success of Lateral and Vertical monitoring

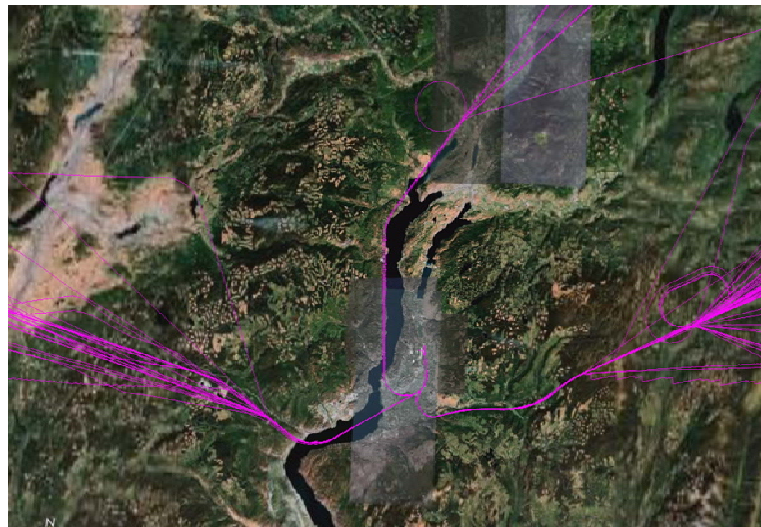


**WestJet Special RNP
Kelowna RWY 34
(.3nm) Boeing 737**



Tracks before RNP:

- 116 arriving flights



Tracks after RNP:

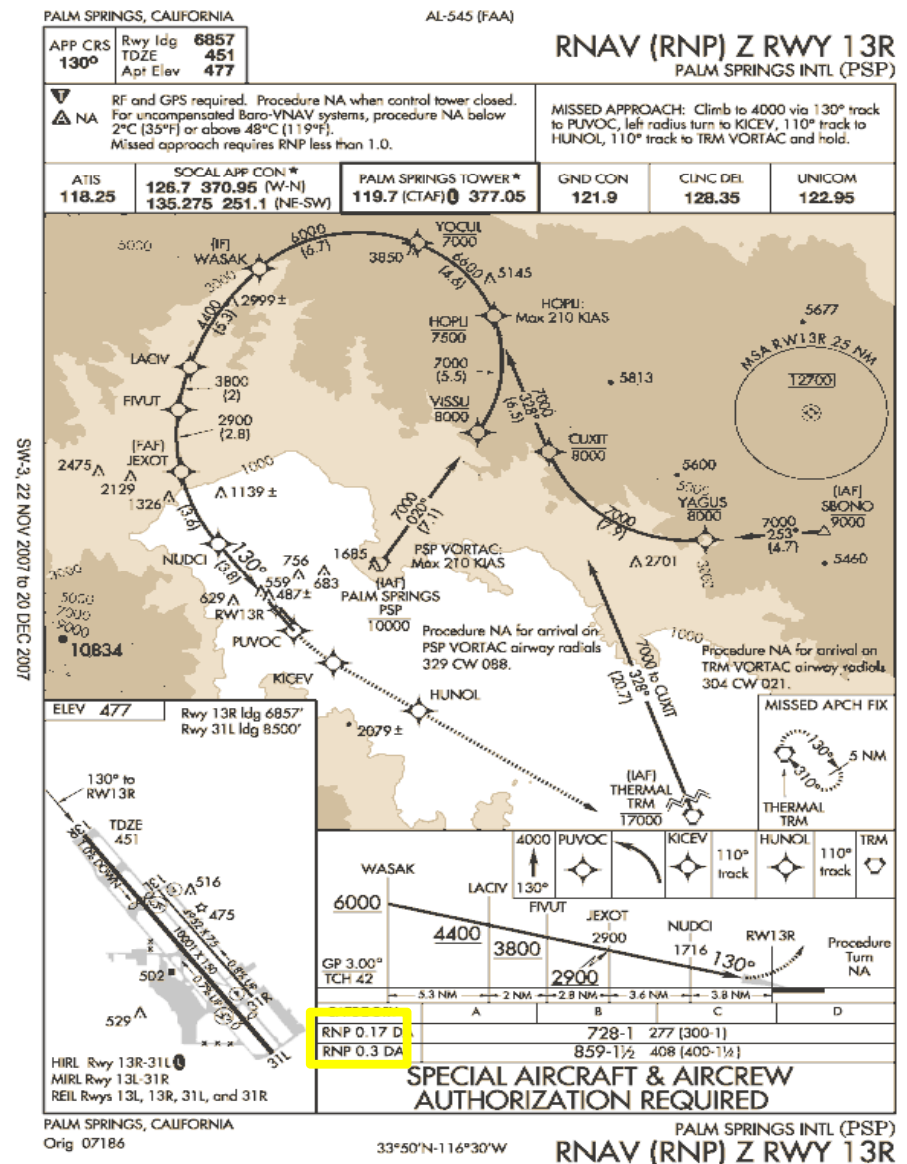
- 128 arriving flights
- Arrivals from west 31nm shorter
- Arrivals from east 41nm shorter
- 5% fuel savings

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RNP Management

- PSP RNAV RNP 13R approach as an example.
- The FMS system needs to be able to “read” or process the RNP values for the procedure.
- This procedure has multiple lines of minima, as well as a missed approach below 1.0.
- Approach plates do not have the leg segments defined. Only available on the detailed 8260-10's or similar procedure design details.



Low RNP Capability

- RNP SAAAR/AR procedures to lines of minima down to RNP 0.1
 - RNP values for published lines of minima are selectable in FMS



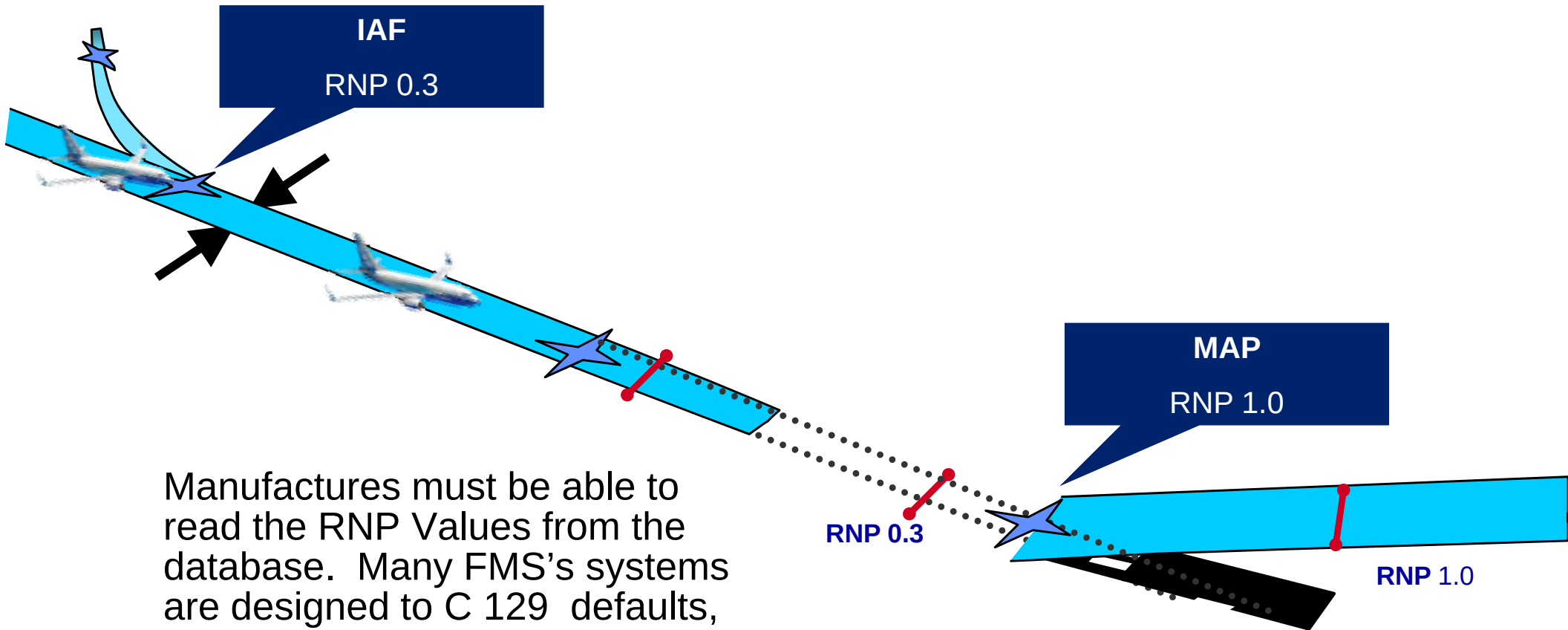
RNP value selected for loaded approach now displayed on ARRIVAL page. Defaults to lowest RNP value available for the approach.



FMS APPROACH MINIMA TYPE page displays up to 3 RNP values: lowest 2 RNP values along with highest RNP value are

displayed and selectable.

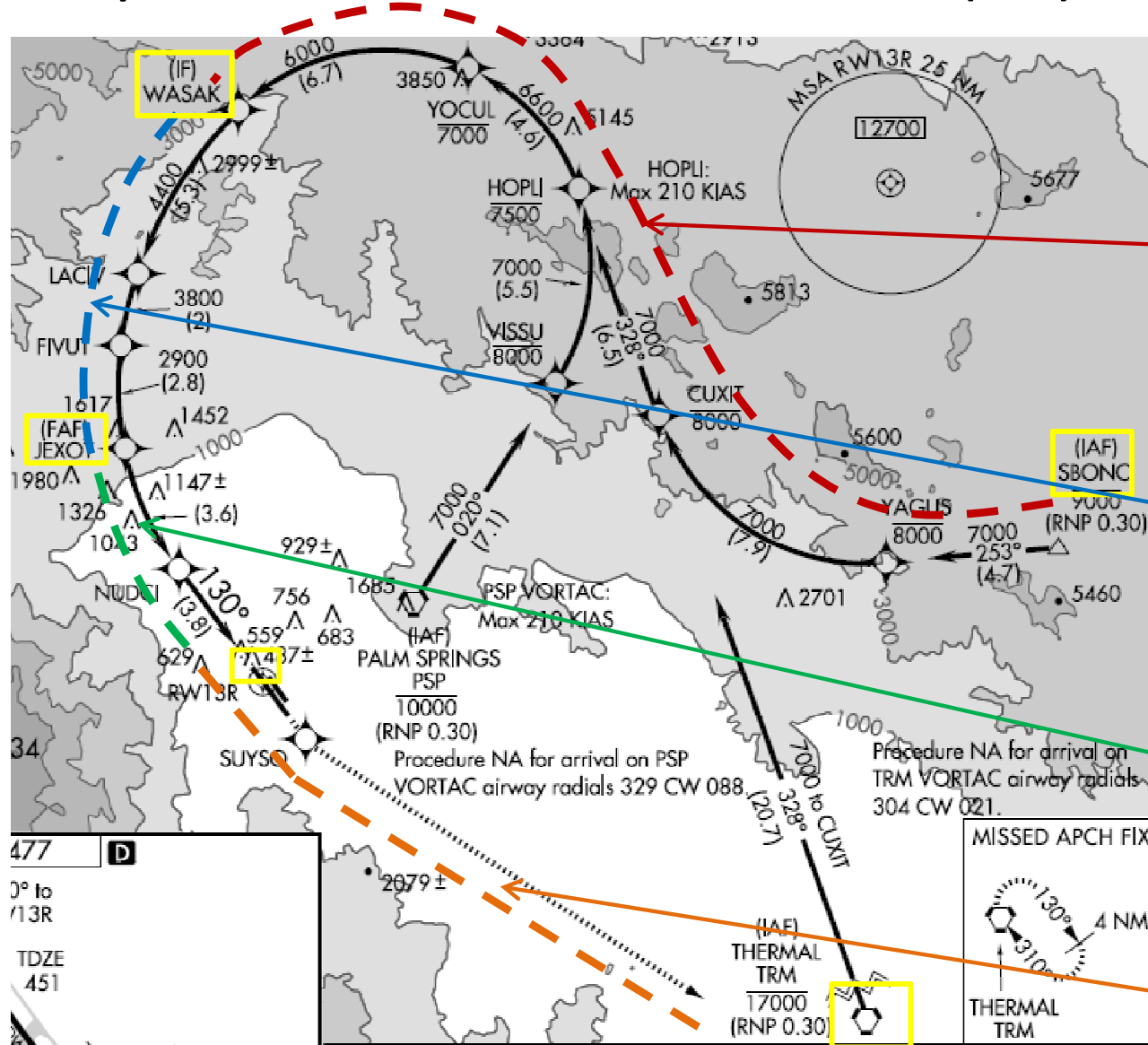
RNP Transitions



Manufacturers must be able to read the RNP Values from the database. Many FMS's systems are designed to C 129 defaults, in RNP AR the example of PSP standard defaults for the missed approach **will not be accurate.**

RNP Management - Use of Navigation Database RNP Values

Example of FMS Use of RNP Values: KPSP RNAV (RNP) Y 13R



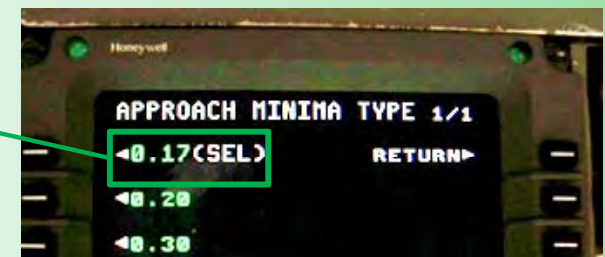
IAF – IF: FMS uses the lowest RNP value from legs in this segment = 0.3

FIX	SEQ	USE	PATH	TURN	FO/FB	RNP
SBONO	010	IAF	IF		FB	
YAGUS	020		TF		FB	1.0
CUXIT	030		RF	R	FB	1.0
HOPLI	040		TF		FB	1.0
YOCLL	050		RF	L	FB	1.0
WASAK	060		RF	L	FB	0.3

IF – FAF: FMS uses the highest final approach RNP value from the lines of minima = 0.3

CATEGORY	A	B	C	D
RNP 0.17 DA*		728-1	277 (300-1)	
RNP 0.30 DA**		859-1½	408 (400-1½)	
RNP 0.30 DA		1320-3	869 (900-3)	

FAF – MAP: FMS uses the RNP selected by pilot in the APPROACH MINIMA TYPE page = 0.17



MAP – Hold Fix: FMS uses the lowest RNP value from legs in this segment = 2.0

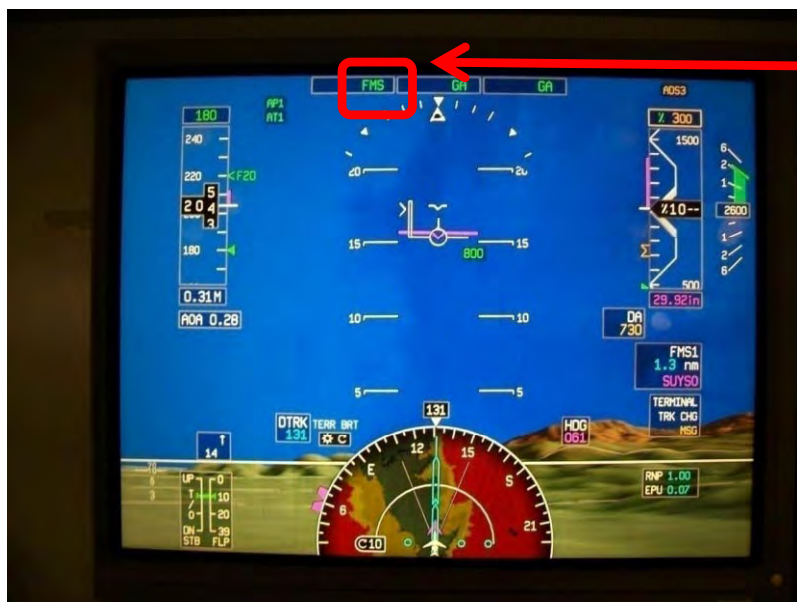
FIX	SEQ	USE	PATH	TURN	FO/FB	RNP
SUYSO	040		DF		FB	
TRM	050		TF		FO	
TRM	060		HM	R	FO	2.0

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Continuous LNAV After TO/GA

- **Continuous LNAV with use of TO/GA**
 - Software Certification D and E drop LNAV and revert to HDG mode when TO/GA was initiated.
- **No special missed approach/go around procedures required**



Lateral mode remains LNAV/FMS after TO/GA



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IRU Drift Characteristics w/o GPS Updating

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- For US procedures, Initiation of all RNP SAAAR approaches is based solely upon GPS updating
- Most common Back-up navigation in the event of GPS failures is IRU
- Radio NAVAID updating must be disabled (US requirement)
- **In a Honeywell design if GPS is not available the FMS will revert to IRS navigation mode**
- Each FMS manufacturer has **unique navigation** sensor selection methodologies.
- Assumed IRU drift characteristics are:
 - 8nm/hr for the first two minutes
 - 2nm/hr afterward



Initial RNP	Minutes	Seconds
0.000	2	42.0
0.010	2	24.0
0.020	2	6.0
0.030	1	57.0
0.040	1	52.5
0.050	1	48.0
0.060	1	43.5
0.070	1	39.0
0.080	1	34.5
0.090	1	30.0
0.100	1	25.5
0.110	1	21.0
0.120	1	16.5
0.130	1	12.0
0.140	1	7.5
0.150	1	3.0
0.160	0	58.5
0.170	0	54.0
0.180	0	49.5
0.190	0	45.0
0.200	0	40.5
0.210	0	36.0
0.220	0	31.5
0.230	0	27.0
0.240	0	22.5
0.250	0	18.0
0.260	0	13.5
0.270	0	9.0
0.280	0	4.5

DME/DME missed approach navigation

- Each FMS manufacturer has unique navigation sensor selection methodologies.
- One manufacturer did achieve an approval but, had to prove the navigation accuracy. Significant cost, and only one procedure approved.
- Currently, the US is leaning towards approving DME/DME navigation for missed approaches that are 1.0 nm. No aircraft approvals yet.
- Issue is that DME/DME characteristics are **unique** for each airport. While RNP AR operational approvals are “**blanket approvals**”. An operator is approved to fly all current and future procedures to a particular level.

Question: What is the anticipated plan for EASA future. Many aircraft do not have IRS nor an upgrade path.

Summary Aircraft unique capabilities

- This presentation in it's limited time highlighted several of the unique features that a manufacturer must obtain to achieve a certifiable aircraft for RNP AR operations.

Most common design changes:

1. Display and navigation for RF Legs
2. Monitoring and Alerting
3. RNP management/ database
4. For low RNP – LNAV engagement on TO/GA
5. Missed approach navigation

The guidance in both AC 90-101 and AMC 20-26 was written to grandfather many of the legacy aircraft. The items above represent some of the new features that manufactures are designing as we move forward in PBN.