Required Navigation Performance
Design Equipment Performance and
System Capabilities

Honeywell RNP AR Consultancy Dept
Kimberly Ten Pas Bell
• 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 Verse 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

Circle-to-Land
- No straight in approach to RWY 30
- Minimums: 2216’ / 3

RNAV RNP Rwy 30
- RF legs used through final and missed approach
- Minimums: 323’ / 1
Agenda

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Benefits of RF Legs for RNP AR

STEP 1: Apply para 2-2
Segment Terminating Fix:
- Tangent Points
- 2 RNP
- 2 RNP

STEP 2: Locate Turn Center
Segment Initial Fix
- a=R
- b=R+(2xRNP)
- c=R-(2xRNP)
- R

STEP 3
- Evaluation
- Both Segments

STEP 4
- Succeeding Segment Evaluation
- Preceding Segment Evaluation
- Fly-By Turns
- Radius to Fix (RF) Segments

STEP 5
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.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Indicated Airspeed (Knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial &amp; Intermediate (IAF to FAF)</td>
<td>Cat A</td>
</tr>
<tr>
<td>Initial</td>
<td>150</td>
</tr>
<tr>
<td>Final</td>
<td>90</td>
</tr>
<tr>
<td>Missed Approach (FAF to Max HP)</td>
<td>110</td>
</tr>
</tbody>
</table>

*Airspeed restrictions may be used to reduce turn radius.
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Honeywell Proprietary
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%

EPU containment radius

EPU < 1 X RNP for continued operation
Lateral Containment Monitoring

- 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

- If EPU >= 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 (½ x RNP)
  - max lateral deviation for RNP 0.3 lines of minima remains 2 dots (1 x RNP)
- Missed approach required when lateral deviation limit exceeded

RNP < 0.3 lines of minima
Max lateral deviation = CDI – 1 dots (½ x RNP)

RNP 0.3 lines of minima
Max lateral deviation = CDI – 2 dots (1 x RNP)
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 EPUs will likely be experienced.
- If SBAS is ON EPU values of 0.00 are normal.
Vertical Containment

• 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

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

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

<table>
<thead>
<tr>
<th>FIX</th>
<th>SEQ</th>
<th>USE</th>
<th>PATH</th>
<th>TURN</th>
<th>FO/FB</th>
<th>RNP</th>
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<tbody>
<tr>
<td>SDONO</td>
<td>010</td>
<td>IAF</td>
<td>IF</td>
<td>FB</td>
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<td>K</td>
<td>FB</td>
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<tr>
<td>HOPUL</td>
<td>040</td>
<td>TF</td>
<td>FB</td>
<td>1.0</td>
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<td></td>
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<tr>
<td>YOCUL</td>
<td>050</td>
<td>RF</td>
<td>L</td>
<td>FB</td>
<td>1.0</td>
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<tr>
<td>WASAK</td>
<td>060</td>
<td>RF</td>
<td>L</td>
<td>FB</td>
<td>0.3</td>
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IF – FAF: FMS uses the highest final approach RNP value from the lines of minima = 0.3

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td>RNP 0.17 DA*</td>
<td>728-1</td>
<td>277 (300-1)</td>
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</tr>
<tr>
<td>RNP 0.30 DA**</td>
<td>855-1½</td>
<td>408 (400-1½)</td>
<td></td>
<td></td>
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<tr>
<td>RNP 0.30 DA</td>
<td>1320-3</td>
<td>869 (900-3)</td>
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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

<table>
<thead>
<tr>
<th>FIX</th>
<th>SEQ</th>
<th>USE</th>
<th>PATH</th>
<th>TURN</th>
<th>FO/FB</th>
<th>RNP</th>
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<tr>
<td>EUYSO</td>
<td>040</td>
<td>DF</td>
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<td>TRM</td>
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<td>TF</td>
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<tr>
<td>TRM</td>
<td>060</td>
<td>HM</td>
<td>R</td>
<td></td>
<td>FO</td>
<td>2.0</td>
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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](image-url)
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IRU Drift Characteristics w/o GPS Updating

• 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

<table>
<thead>
<tr>
<th>Initial RNP</th>
<th>Minutes</th>
<th>Seconds</th>
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<tbody>
<tr>
<td>0.000</td>
<td>2</td>
<td>42.0</td>
</tr>
<tr>
<td>0.010</td>
<td>2</td>
<td>24.0</td>
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<tr>
<td>0.020</td>
<td>2</td>
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<tr>
<td>0.030</td>
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<td>0.040</td>
<td>1</td>
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<td>13.5</td>
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<td>9.0</td>
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<tr>
<td>0.280</td>
<td>0</td>
<td>4.5</td>
</tr>
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</table>
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.