RNP AR and Air Traffic Management

Expanding the Utility of RNP AR

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RNP AR User’s Forum
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Talking points

- RNP AR not just for approach anymore
- RNP AR for procedural traffic separation
- Normal and Non-normal safety case
- Time-based vs. geometric mitigations
What are RNP AR Users Reporting?

- Safe, Stable and Efficient Instrument Approaches
- Access to Terrain Challenged Airports
- High level of Tracking performance (accuracy) and Navigation dependability documented
- Operating Savings credited to improved operating minima, track miles reduction
- Noise reductions for Communities due to track design and vertical path management (VNAV)
- Lower emissions associated with elimination of level segments of flight
### Which Airlines, Where, and What Value?

Airlines around the world are recognizing the Value of RNP

<table>
<thead>
<tr>
<th>Airlines Flying RNP Procedures</th>
<th>RNP Level</th>
<th>Value Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alaska Airlines</strong> 737</td>
<td>0.11</td>
<td>• “Palm Springs…27 avoided diverts in three months, 1,890 miles saved”</td>
</tr>
<tr>
<td><strong>WestJet</strong> 737</td>
<td>0.10</td>
<td>• “Two RNP procedures, one airport, $2.5 - $3.5 M annual savings…embarking on 90 procedures for 24 destinations”</td>
</tr>
</tbody>
</table>
| **Qantas** 737                 | 0.10      | • ZQN 3,200’ lower approach, 4,000’ lower departure  
                                   • Brisbane 18 miles saved, impacts fuel burn, noise, arrival rate, and emissions  
                                   • Eight domestic airports including Sydney |
| **Continental** 737            | 0.15      | • “RNP will sustain or boost capacity”  
                                   • “Plans for Houston, Newark, Guam, and several sites in South and Central America” |
| **Austrian** 737               | 0.15      | • “Innsbruck minimums reduced by 1,300 feet…reduced diversions, lower fuel burn, improved service reliability” |
| **Air China** 757              | 0.30      | • “China plans to certify 50 more RNP procedures in a five year period” |
Effect on Typical Noise Contours On Approach

Notional reduction in noise footprint for a flight operated with an RNP-based constant descent profile (green) vs. baseline parallel approach (red)

B747-400

B777
Results will vary with implementation: Expected 25-50% reductions per procedure
Challenge: to get these procedures in a busy, mixed traffic environment

**B747-400**
- 1700 lb. fuel
- 2,438 kg CO₂

**B777**
- 983 lb. fuel
- 1,407 kg CO₂
Expanding the Application of RNP to Air Traffic Management

- Parallel Approaches - Simultaneous RNP/RNP and RNP/ILS
- Terminal Airspace
  - Deconflicted STARS/SIDS for improved vertical profiles
- EnRoute Airspace (Radar airspace)
- Oceanic Airspace (Non-radar airspace)

Why?

- Similar efficiency mechanisms as single approaches, but potential gains in all phases of flight
  - Fewer Track Miles
  - Better Vertical Profiles
  - Less Environmental Impact
What's Missing?

- Accommodating RNP Routes in Air Traffic Procedures
  - Route design sensitive to other procedures and airspace
  - Airspace shape that can accommodate efficient departures and arrivals
  - Controller Decision support tools

- Safety Assessment inclusive of aircraft RNP AR performance
  - Crediting RNP AR Route Procedural Separation by design
    - Effect of normal performance and tracking accuracy
    - Understanding interactions and collision risk amongst multiple procedures
Monte Carlo Analysis of Potential System Interactions

Proving "When operating normally, participating traffic is safe"

Aircraft Systems Performance Data

System Behavior Characterization
What's Missing?

- Accommodating RNP Routes in Air Traffic Procedures
  - Route design sensitive to other procedures and airspace
  - Airspace shape that can accommodate efficient departures and arrivals
  - Controller Decision support tools

- Safety Assessment inclusive of aircraft RNP AR performance
  - Crediting RNP AR Route Procedural Separation by design
    - Effect of normal performance and tracking accuracy
    - Understanding interactions and collision risk amongst multiple procedures
  - Understanding ATC operational implications of AR procedures
    - Effect of integrity and frequency/likelihood of non-normal events
    - Risk Mitigation strategies for an RNP AR environment
RNP AR: Not just Improved Accuracy

RNAV GPS
- Database Management
- Lateral Accuracy
  - 95% 1NM, 0.3NM Final
- RAIM Alerting

RNP AR
- Validated Database Integrity
- Guaranteed Lateral Accuracy
  - 95% defined by RNP Value (as low as 0.1NM)
  - AFM demonstrated value which addresses operations
- RF availability
- Vertical Guidance
  - Stabilized Approach
  - Defined in Database (VEB, Baro)
- Integrity (Containment)
  - 99.999% defined by 2X RNP Value
- Alerting
- Required multi-sensor
- Redundant FMS Hardware
- Additional Crew Training and Procedures to Qualified Standards
### Historical Collision Avoidance Events: Traditional Parallel Approaches (ASRS data through 2006)

#### Parallel Operation Incidents by Phase of Flight

<table>
<thead>
<tr>
<th>Phase of Flight</th>
<th>Controller / Flight Crew</th>
<th>Terminal Arrival</th>
<th>Approach Transition</th>
<th>Course Acquisition</th>
<th>Glideslope</th>
<th>Land</th>
<th>Missed Approach</th>
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<tr>
<td>Approach</td>
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<td>ACN296830</td>
<td>ACN298184 (ACN298405)</td>
<td>ACN300720</td>
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<td>ACN439350</td>
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<td>ACN298350</td>
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<td>ACN641665</td>
<td>ACN333204 (ACN34035)</td>
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<td>Course</td>
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**Parallel Operation Incidents by Phase of Flight**

**ACN** stands for **Air Carrier Operations Normalization**.
Most Incidents Arise From Events In Early Phases of Approach

Controller Intervention Providing Collision Protection

Separation Failed Due To
- Set-up
- Procedures
- Communication

Parallel Operation Incidents by Phase of Flight
RNP AR Implementation Could Mitigate These Issues

Controller Intervention Providing Collision Protection

Parallel Operation Incidents by Phase of Flight

Controller / Flight Crew

Approach Transition

Course Acquisition

Glideslope

ACN298747
(ACN297250)

ACN341723
ACN425585

ACN332409

ACN334035

ACN334122

ACN641665

ACN511454

ACN564764

ACN439350

ACN432693

ACN426070

ACN432098

ACN298184

ACN297602

ACN297200

ACN298350

ACN300720

ACN305060

ACN294860

ACN294839

Land

Missed Approach

Terminal Arrival
An Example: Protecting a Time Envelope with Curved Parallel Approaches

- Note that the region between the purple lines denotes the *only* ownship offsets that can lead to an NMAC
- Less than ¼ nm long

Models can help define designs that have at least a minimum specified time before track-keeping performance becomes critical.
An Example: Protecting a Time Envelope with Curved Parallel Approaches

- **NMAC possible in this region only**
- **CPA distance**
- **500 ft plane**
- **Distance & Time**
- **NMAC in less than 90 sec possible in colored region only**

Protecting *Time* to Critical Events Enables Flexibility with Curved Approaches

- **Time to CPA**
- **Time to CPA less than 90 sec in this region only**

A Example: Protecting a Time Envelope with Curved Parallel Approaches

- **Protecting Time to Critical Events Enables Flexibility with Curved Approaches**

- **Distance & Time**
- **NMAC in less than 90 sec possible in colored region only**
In the Works and in the Near Future: Ops Guidance & Standards, FMC Function

**Using what we have today**
- ATM "Handbook" procedures
- RNP-AR based Separation Standards

**Near-term Future Improvements**
- Controller RNP-AR based decision aids
- Vertical RNP equivalent
  - Vertical Error Budget useful, but notion of containment would improve operational viability of true trajectory deconfliction
- Time RNP equivalent
  - RTA useful for 4D, but notion of containment would improve operational viability of true trajectory deconfliction
Summary

- RNP AR can be used as a useful construct for ATM today
- Benefits for ATM to be had in all phases of flight
- New Operations will require new procedures and standards
  - RNP AR affords procedural separation
  - Using Time for Mitigating Separation Risk by Design
    - Protecting linear airspace boundaries (as has been practiced over the last 50 yrs) won't work with curved lateral segments and optimized vertical profiles in climbs and descents
    - New concepts for traffic management, based around trajectories and complex airspace and paths require a new approach
    - Time-based protection strategy in procedure design provides safety mitigations with geometric and operational flexibility