Analysis of safety performances for parallel approach operations with PBN

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Overview

• Introduction
• Context and Approach
• State of the Art
• Modelling
• Experimental Set-up
• Analysis
• Conclusion
Introduction

- Improving parallel approach operations using PBN
  - To reinforce safety by reducing risk of loss of separation at interception
  - Conducted as part of SESAR 2020 (PJ01-03A)

- Safety performance at/around the interception
  - With PBN transition
  - Compared to conventional radar vectoring
  - Identify appropriate approach route structure

- Monte Carlo simulations addressing normal and non-normal operations
Context and Approach

- Safety risk determination at/around intercept
- Normal case
  - Supported by the Loss of Separation (LoS) safety metric
- Non-normal case (blunder)
  - Supported by the Collision safety metric
State of the art

- 1960s: FAA + MITRE start investigating Blunder Events
  - Along final approach, only

- Deployment of safety mitigation measures
  - Non-Transgression Zone
  - Precision Runway Monitoring
  - Special training on breakout maneuvers

- NO risk assessment in Intercept area
  → Procedure design requires 1,000 ft vertical / 3 NM lateral separation
  → No modelling of blunder during intercept

- 2011: FAA starts to investigate Established-on-RNP (EoR) concept
  - Aircraft considered established already prior intercept of final approach
  - Allows to reduce separation on intercept
    (separation only applies for non-established aircraft)
Modelling

- Integration of 2 parts into a common model
  - Normal Case + Non-Normal Case (blunder)
- Based on a fast-time, agent-based Monte-Carlo simulation environment
Modelling – Normal Operation

• Normal Operation = Aircraft intercept final approach course, possibly with loss of separation
• Idea: determine probability for loss of separation between an aircraft (X) and a sequence of encountering aircraft on parallel track (A, B, C)
• Macroscopic view
• Sequence of steps in a simulation of a single approach event:

1. Generate nominal flight paths
2. Apply navigation accuracy functions (e.g. RNP / ANP)
3. Cross-Correlation for each pair of adjacent aircraft

Source: Thiel C. und H. Fricke, Collision risk on final approach – a radar data based evaluation method to assess safety, ICRAT 2010
Modelling – Blunder

- Blunder = Aircraft diverges from own approach path towards adjacent approach path (Not a result of navigation tolerances)
- Worst-Case Blunder = Blunder that does not react on ATC corrective commands
- NEW:
  - Blunder on intercept (missed intercept)
- Idea: Simulate encounter of two aircraft, track minimum distance (slant range) between both
  → Counting Metric: Number of test criterion violations (e.g. 500 ft slant range)

- Microscopic View
  - Radar update
  - Radar resolution
  - Detection + Reaction Time
  - Navigation Tolerances
  - …
Experimental set-up

Set-up determined to:

- show if PBN transition improve safety
- identify the most beneficial approach route structure

Fixed parameters:

- RNP value: 0.22Nm
- Interception angle: 30°
- LoS threshold: 850ft/2.9Nm
- Collision threshold: 500ft

Variable parameters:

- 0.56Nm ≤ Rwy Spacing ≤ 3Nm
- 0Nm ≤ FAP-IF Offset ≤ 4Nm
- 10-1 ≤ Blunder rate ≤ 10-5
- Vectoring distribution: Narrow or wide
Sensitivity Analysis – Normal Case (NC) (1/3)

- Safety criteria
  - Loss of Separation (LoS): 850ft vertical /2.9Nm Horizontal
  - LoS Probability <10^-5 per approach

- Comparing PBN transition with vectoring
Sensitivity Analysis - NC (2/3)

- LoS probability when varying FAP-IF Offset

  Probability always lower with PBN
  Probability increases with the FAP-IF Offset
  Shape of the curve similar for all runway spacing up to 2.5Nm

- LoS probability when varying runway spacing

  Probability always lower with PBN
  Gradual reduction until 2.5Nm
  Sharp decrease after 2.5Nm
Sensitivity Analysis - NC (3/3)

- Conclusion for the normal case

Safety improvement with PBN
18 to 21 % reduction compared to wide vectoring
6 to 9 % reduction compared to narrow vectoring

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Sensitivity Analysis-
Non-normal Case – NNC (1/4)

• Safety criteria
  • Collision
  • Test Criteria Violation (TCV): 500ft
  • TCV Probability < 5x10-8 per approach

• Comparing PBN transition with vectoring

• Current blunder limitation:
  • no vertical blunder
  • no ATC recovery
  • same blunder rate between PBN and Vectoring
Sensitivity Analysis - NNC (2/4)

- Collision rate probability when varying the runway spacing

  ![Collision rate versus runway spacing graph](image)

  Collision rate peak for 2.35Nm runway spacing

  Lower collision risk with PBN for runway spacing larger than 2.5Nm

- Collision rate probability when varying FAP-IF Offset

  ![Collision risk versus FAP-IF Offset graph](image)

  Collision rate sensitive to IF location

  For such geometry do not locate IF with an offset between 0 and 1Nm
• Collision Rate peak for 2.35Nm runway spacing

For each runway spacing there is an IF location to avoid for this geometry.

IF0 location to be avoided for this geometry.

For each runway spacing there is an IF location to avoid.
• Lower collision risk with PBN for runway spacing larger than 2.5Nm

PBN

Smaller trajectory dispersion with PBN

Presence of the NTZ

Recovery for blunders penetrating NTZ

Vectoring
Conclusion

• For normal operation during interception
  • Better performance with PBN
  • Net safety improvement
  • Better performance with small FAP-IF offset (e.g. IF0)

• For non-normal operation during interception
  • More sensitive to IF location for PBN
  • Careful IF location requested for good result
  • Better performance for FAP-IF Offset greater than 1Nm

• CRM facilitates ‘a priori’ demonstration of the safety performance

• The most appropriate approach route structure for interception can be determined

• Further work is needed for the refinement of the blunder