Procedure Design Concepts for Logan Airport Community Noise Reduction

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Technical support from MIT ICAT students, HMMH, and Massport
RNAV Track Concentration

2010

Flight Track Density Plot
January 1, 2010 to December 31, 2010
Runway 33L, Jet Departures
(25,046 Flight Tracks)

2015

Flight Track Density Plot
January 1, 2015 to December 31, 2015
Runway 33L, Jet Departures
(25,055 Flight Tracks)
Noise Complaints and RNAV Track Concentration
Alternative Metrics to Capture RNAV Concentration Impacts

- RNAV concentration issue outside of Annual Average DNL 65dB contour
- Analysis performed by this research team at BOS, MSP, CLT, and LHR indicates that Peak Day 50 $N_{60}$ represents the noise threshold for complaints
BOS $N_{60}$ Count Thresholds

- **50 $N_{60}$ on a peak day** appears to capture complaint threshold in dispersion analysis.

### 33L Departures Peak Day $N_{60}$

<table>
<thead>
<tr>
<th>Peak Day $N_{60}$</th>
<th>Complaints Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td>25x</td>
<td>90.0%</td>
</tr>
<tr>
<td>50x</td>
<td>83.8%</td>
</tr>
<tr>
<td>100x</td>
<td>59.9%</td>
</tr>
</tbody>
</table>

### 4L/R Arrivals Peak Day $N_{60}$

<table>
<thead>
<tr>
<th>Peak Day $N_{60}$</th>
<th>Complaints Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td>25x</td>
<td>91.3%</td>
</tr>
<tr>
<td>50x</td>
<td>81.3%</td>
</tr>
<tr>
<td>100x</td>
<td>70.6%</td>
</tr>
</tbody>
</table>

### 27 Departures Peak Day $N_{60}$

<table>
<thead>
<tr>
<th>Peak Day $N_{60}$</th>
<th>Complaints Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td>25x</td>
<td>94.6%</td>
</tr>
<tr>
<td>50x</td>
<td>90.2%</td>
</tr>
<tr>
<td>100x</td>
<td>76.8%</td>
</tr>
</tbody>
</table>

*2017 Data*
LHR N\textsubscript{60} Count Thresholds

- 50 N\textsubscript{60} on a peak day appears to capture complaint threshold in dispersion analysis

<table>
<thead>
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<th>Complaints Captured</th>
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<tbody>
<tr>
<td>25x</td>
<td>92.1%</td>
</tr>
<tr>
<td>50x</td>
<td>85.5%</td>
</tr>
<tr>
<td>100x</td>
<td>66.2%</td>
</tr>
</tbody>
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<table>
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<tbody>
<tr>
<td>25x</td>
<td>89.6%</td>
</tr>
<tr>
<td>50x</td>
<td>80.9%</td>
</tr>
<tr>
<td>100x</td>
<td>75.6%</td>
</tr>
</tbody>
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</tr>
<tr>
<td>50x</td>
<td>70.1%</td>
</tr>
<tr>
<td>100x</td>
<td>56.5%</td>
</tr>
</tbody>
</table>

2017 Data
Massport/FAA MOU
MIT Technical Approach

• Collect Data and Evaluate Baseline Conditions
  – Pre and Post RNAV
  – Community Input (Meetings and MCAC)

• Identify Candidate Procedure Modifications
  • Block 1
    – Clear noise benefit, no equity issues, limited operational/technical barriers
  • Block 2
    – More complex due to potential operational/technical barriers or equity issues

• Model Noise Impact
  – Standard and Supplemental Metrics

• Evaluate Implementation Barriers
  – Aircraft Performance
  – Navigation and Flight Management (FMS)
  – Flight Crew Workload
  – Safety
  – Procedure Design
  – Air Traffic Control Workload

• Recommend Procedural Modifications to Massport and FAA
• Repeat for Block 2
Noise Modeling Framework
Developed under FAA ASCENT COE Project 23 [https://ascent.aero/project/analytical-approach-for-quantifying-noise-from-advanced-operational-procedures/]

Performance Model Inputs:
- Operating/mission parameters
- Aircraft sizing/performance parameters
- Engine sizing/performance parameters

Aircraft Type

TASOPT

BADA4 Existing Aircraft Data

Performance Model Outputs:
- Aircraft/engine performance & geometry

Procedure Definition:
- Lateral Path
- Speeds
- Configuration

Flight Procedure Generator

Flight Procedure:
- Thrust, velocity, position, gear/flap settings per time

Noise Model Control Inputs:
- Propagation Settings
- Observer Locations

ANOPP/AEDT

Output to Grid Rotation and Superposition

Single-Event Noise Grids
Initial Outreach (Partial List)

- Community
  - Community Meetings
  - Massport Community Advisory Committee
  - Public Officials
  - ASCENT (FAA Center of Excellence)
- FAA
  - ATO Air Traffic (HQ, TRACON, Tower, Center, Region)
  - AJV Flight Procedures
  - AFS Flight Standards
  - AEE Environment and Energy
- Airlines
  - Technical Pilot Group
  - A4A
- Manufacturers
  - Boeing
Performance Based Navigation Implementation Process

Purpose: To vet procedures with industry and facilities including airlines, ATC, and FAA

Following FAA 7100.41 working group, procedures will be reviewed by flight standards

Lessons learned:

- Stakeholders may have flyability concerns despite a procedure design being within TERPS criteria
  - RNP SIDS are being further analyzed for situations where RNAV SIDS do not meet the desired objectives
- Designing RNAV and RNP procedures that are similar enough to be used simultaneously relieves ATC of workload burdens and allows for slight additional noise benefits in the RNP procedure
Block 1 Examples:

Clear noise benefit, no equity issues, limited operational/technical barriers
Block 1: Runway 33L
RNAV Approach and RNP Approach
33L RNAV and RNP Approach

- RNAV design criteria not able to fully meet noise objectives, so RNP designed to fully meet noise objectives.
- RNAV and RNP designed similarly enough and with same feeder fix to allow for simultaneous use by ATC.

![Map showing RNAV and RNP approaches with feeder fix marked.](image)
1-A1a 33L RNP Approach FAA 7100.41 Group Final
Status: Procedure design supported by FAA 7100.41 Group

Implement an overwater RNP approach procedure to Runway 33L that follows the ground track of the jetBlue RNAV Visual procedure as closely as possible.

1-A1b: RNAV Visual procedures are distributed through the Lead Carrier who developed the procedure.
Implement an overwater RNAV approach procedure to Runway 33L that follows the ground track of the jetBlue RNAV Visual procedure as closely as possible.
Block 1: Reduced Speed Departures (1-D1)
Runway 33L Departures: 2010-2015

2010

2015
Runway 27 Departures: 2010-2015
**Baseline**: Typical profile includes thrust reduction at 1,000’ AGL followed by an acceleration to **250 kt climb speed & flap retraction**

**Reduced Speed Departure**: thrust reduction at 1,000’ AGL followed by an acceleration to **220 kt climb speed or minimum clean airspeed to 10,000 ft**
Impact of Climb Speed
Matching Airframe to Engine Noise Level Minimizes Total

Boeing 737-800 Departure LAMAX Contours with Variations in Climb Speed

Status = Pending
- Working with FAA/NASA to Validate Modeling Assumptions
- FAA Established National Implementation Group

Aerodynamic noise sensitive to “Wing Cleanliness” coefficient in ANOPP
Currently resolving with NASA & exploring clean airframe flight test validation opportunities
1-D1 Reduced Speed Departures

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>B737-800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>$L_{A,\text{MAX}}$</td>
</tr>
<tr>
<td>Noise Model</td>
<td>ANOPP</td>
</tr>
<tr>
<td>Notes</td>
<td>Runway 33L: Maintain Standard Climb Thrust &amp; 220 KIAS to 10,000’</td>
</tr>
</tbody>
</table>

**737-800: Delayed Acceleration Climb**

220 knots

### B737-800

**Population Exposure ($L_{A,\text{MAX}}$)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>187,106</td>
</tr>
<tr>
<td>Reduced Speed Departure</td>
<td>162,558</td>
</tr>
<tr>
<td>Baseline – Alternate</td>
<td>24,548</td>
</tr>
</tbody>
</table>

Analysis assumes higher airframe noise assumption
Working with FAA/NASA to Validate Modeling Assumptions
1-D1 Reduced Speed Departures

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B737-800
Population Exposure ($L_{A,\text{MAX}}$)

<table>
<thead>
<tr>
<th></th>
<th>60dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>178,973</td>
</tr>
<tr>
<td>Reduced Speed Departure</td>
<td>169,397</td>
</tr>
<tr>
<td>Baseline – Alternate</td>
<td>9,576</td>
</tr>
</tbody>
</table>

Analysis assumes higher airframe noise assumption
Working with FAA/NASA to Validate Modeling Assumptions

737-800: Delayed Acceleration Climb
220 knots

Flight Tracks & LAMAX Noise Contours (dB)
- 1 nm Spacing Marker
- Baseline Flight Track
- Baseline B738 Contours
- Alternate Flight Track
- 220 knots B738 Contours
Block 2 Examples:

*More complex due to potential operational/technical barriers or equity issues*
Block 2: Runway 33L and 27 Departures – Re-Introduce Dispersion
Runway 33L Departures: 2010-2015

Using Open SIDs or Flexible SIDs to Re-introduce Dispersion

2010

2015
Dispersion Concepts

Ease of Implementation:

- Altitude-Based 3000ft
- Altitude-Based 4000ft
- Controller-Based
- Divergent Headings
- RNAV Waypoint Relocation

Preliminary examples to evaluate methodology only. Should not be considered representative case.
Need for Community Decision Process for Procedures with Noise Redistribution

- Procedure Proposal
  - Single Track
  - Multiple Tracks

Evaluation and Visualization of Noise Redistribution
- Single Event Metrics
- Integrated Metrics

Examples for illustration

Implementation Decision Process?
- Community
- Operational Stakeholders

Implementation

Developing Methods to Communicate the Results of Procedure Changes
33L Departures Altitude-Based Dispersion at 3000ft
Change in \(N_{60}\) Compared to 2017

Preliminary example to evaluate methodology only. Should not be considered representative case.

Analysis based on peak day operations; only includes 33L departures

Population Exposure

\[
\begin{array}{|c|c|}
\hline
\text{\(N_{60}\)} & 50x \\
\hline
\text{Baseline} & 336,643 \\
\text{Dispersion} & 342,387 \\
\text{Baseline - Dispersion} & -5,744 \\
\hline
\end{array}
\]

Change In \(N_{60}\)

\[
\begin{array}{|c|c|}
\hline
\text{Change} & \text{Population} \\
\hline
+200x & 0 \\
+100x & 3,870 \\
+50x & 22,300 \\
-50x & 51,577 \\
-100x & 31,561 \\
-200x & 0 \\
\hline
\end{array}
\]

Baseline - Dispersion

Analysis updated Dec 4 2018 to correct for discretization differences

\(N_{60}\) Thresholds:
60dB \(L_{A,max}\) Day, 50dB \(L_{A,max}\) Night
33L Departures Altitude-Based Dispersion at 3000ft
Change in $N_{60}$ Compared to 2017
33L Departures Divergent Headings Dispersion Change in $N_{60}$ Compared to 2017

Preliminary example to evaluate methodology only. Should not be considered representative case.

Analysis based on peak day operations; only includes 33L departures.

Population Exposure

| $N_{60}$ | 50x |
| Baseline 2017 | 336,643 |
| Dispersion | 334,305 |
| Baseline - Dispersion | 2,338 |

Analysis updated Dec 4 2018 to correct for discretization differences.

Change in $N_{60}$

| Change | Population |
| +200x | 0 |
| +100x | 13,651 |
| +50x | 47,885 |
| -50x | 62,772 |
| -100x | 31,545 |
| -200x | 0 |

$N_{60}$ Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

2.7 nmi
27 Departures RNAV Waypoint Relocation
Change in N_{60} Compared to 2017

Preliminary example to evaluate methodology only. Should not be considered representative case.

Population Exposure

<table>
<thead>
<tr>
<th>N_{60}</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 2017</td>
<td>407,357</td>
</tr>
<tr>
<td>Dispersion</td>
<td>388,449</td>
</tr>
<tr>
<td>Baseline - Dispersion</td>
<td>18,908</td>
</tr>
</tbody>
</table>

Analysis updated Dec 4 2018 to correct for discretization differences

Change In N_{60} | Population
--- | ---
+200x | 0
+100x | 5,105
+50x | 30,578
-50x | 49,067
-100x | 20,423
-200x | 4,415

N_{60} Thresholds:
60dB L_{A,max} Day, 50dB L_{A,max} Night

Analysis based on peak day operations; only includes 27 departures
Block 2: Runway 4 Arrivals
Delayed Deceleration Approaches
Runway 4R Arrivals: 2010-2015
Delayed Deceleration Approaches (DDAs)

- In conventional approaches, aircraft decelerate early in the approach.
- DDAs provide potential for fuel burn & noise reduction.
- In DDAs, initial flap speed velocity held as long as possible during approach to lower drag and thrust requirements.
  - Lower thrust levels reduce engine noise.
  - Higher velocities increase airframe noise.

Standard Approach vs DDA
4000 ft Level Off, B738 (Boeing/Guo Flaps Method)

Preliminary example to evaluate methodology only. Should not be considered representative case.
Block 2: Runway 4R RNP Approach
Initial Examples of 4R RNP Approaches

- Initial examples of possible approaches to 4R with flexibility of RNP technology
- RNP technology allows approach to be kept over water near final approach

Preliminary example to evaluate methodology only. Should not be considered representative case.
4R Arrival RNP – Maximum Overwater

B737-800 60dB $L_{A,\text{max}}$ Noise Exposure

- **Flight Tracks & $L_{A,\text{max}}$ Noise Contours (dB)**
  - 1 nm Spacing Marker
  - Baseline Flight Track
  - Baseline AEDT B738 Contours
  - Alternate Flight Track
  - Alternate AEDT B738 Contours
  - Population Benefited
  - Population No Change
  - Population Disbenefited

**B737-800 Population Exposure ($L_{A,\text{MAX}}$)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight In</td>
<td>32,144</td>
</tr>
<tr>
<td>RNP</td>
<td>20,754</td>
</tr>
<tr>
<td>Difference (Straight In – RNP)</td>
<td>11,390</td>
</tr>
</tbody>
</table>

Different routes for 4R arrivals still under analysis

Preliminary example to evaluate methodology only. Should not be considered representative case.
Mechanisms for Community Input Procedures with Noise Redistribution

Procedure Proposal
- Single Track
- Multiple Tracks

Evaluation and Visualization of Noise Redistribution
- Single Event Metrics
- Integrated Metrics

Implementation
- Decision Process?
  - Community
  - Operational Stakeholders

Examples for illustration
RNAV and RNP Design Space

Start Here

Finish Here

9.1 nmi

RNP only
Need for Community Decision Process for Procedures with Noise Redistribution

- Community Input
- Operational Stakeholder Input
- Procedure Proposal
  - Single Track
  - Multiple Tracks
- Evaluation and Visualization of Noise Redistribution
  - Single Event Metrics
  - Integrated Metrics
- Implementation Decision Process?
  - Community
  - Operational Stakeholders
- Implementation

Examples for illustration
Discussion