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
Performance Based Navigation
RNAV and RNP

**NEXT GEN Components: RNAV/RNP**
Moving to Performance-Based Navigation

- **Conventional Routes**: Today’s airways connect ground-based navigation aids
- **RNAV**: Area Navigation (RNAV) routes follow defined “waypoints”
- **RNP**: Required Navigation Performance (RNP) routes within specified “containment area”

- >90% air carrier fleet
- >30% air carrier fleet

*Source: Federal Aviation Administration*
Noise Complaints at BOS: One Dot per Address

Each dot represents an address that registered at least one complaint during period

**Departures**

**Arrivals**

**Complaint Data:** August 2015–July 2016

**Track Data:** ASDE-X from 12 days of operation, 2015-2016
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
Outreach (Partial List)

• Community
  – Community Meetings
  – Massport Community Advisory Committee
  – Public Officials
  – ASCENT

• FAA
  – ATO Air Traffic (HQ, TRACON, Tower, Center, Region)
  – AJV Flight Procedures
  – AFS Flight Standards
  – AEE Environment and Energy

• Airlines
  – Technical Pilot Group
  – A4A
## Massport/FAA MOU Process Timeline

(Preliminary/Subject to Change)

### Block 1
- MCAC/Public Meeting
  - Feb 2017
- Briefed MCAC Aviation Subcommittee
  - May 2017
- Briefed MCAC Aviation Subcommittee
  - Sep 2017
- MIT Technical Feasibility/Noise Analysis
  - Oct 2017
- MCAC/Public Meeting Block 1 and update on Block 2
  - Nov 2017
- MCAC Block 1 Final Recommendations
  - Dec 2017
- MPA Block 1 Recommendation to FAA
  - Jan/Feb 2018
- FAA internal review (safety, efficiency, NEPA)
  - Ongoing
- FAA Implementation Process
  - Ongoing

### Block 2
- MCAC/Public Meeting
  - Feb. 2017
- Briefed MCAC Aviation Subcommittee
  - May 2017
- Briefed MCAC Aviation Subcommittee
  - Sept 2017
- Technical Review (procedure and noise analysis)
  - Jun 2017- Ongoing
- Brief MCAC (Full and Aviation Subcommittee)
  - Mar 2018- Ongoing
- MIT Technical Feasibility/Noise Analysis to FAA and Massport
  - TBD
- MCAC/Public Meeting on Block 2
  - May 2018
- MCAC Block 2 Final Recommendations
  - TBD
- MPA Recommendation to FAA
  - TBD
- FAA internal review (safety, efficiency, NEPA)
  - TBD
- FAA implementation (may include extensive NEPA process)
  - TBD
Block 1

- **Departure Mods**
  - 33L and 27
    - Reduced speed departures (1-D1)
      - 220 Knots (clean) to 10,000’
      - NADP-1 to 6,000’
  - 15R
    - RNAV waypoint relocation (1-D2)
  - 22L/R
    - RNAV waypoint relocation
      - Climb to intercept course (1-D3a)
      - Climb to altitude then direct (1-D3b)
    - Heading-based departure (1-D3c)
- **Arrival Mods**
  - 33L Low-noise overwater approach procedures
    - Overwater RNAV Instrument Approach Procedure with RNP Overlay which as closely as possible flies the jetBlue RNAV Visual track (1-A1a)
    - Public distribution mechanism for the jetBlue RNAV Visual procedure (1-A1b)
Block 1: Reduced Speed Departures (1-D1)
Impact of Climb Speed
Matching Airframe to Engine Noise Level Minimizes Total

Boeing 737-800 Departure L_{MAX} Contours (Generated in ANOPP)

Exploring flight test validation opportunities
Standard departure procedures vary by airline.

**Baseline:** Typical profile includes thrust reduction at 1,000’ AGL followed by an acceleration to 250 kt climb speed and flap retraction.

**Recommended procedure:**

a. Thrust reduction at 1,000’ AGL followed by an acceleration to **220 kt** climb speed or minimum safe airspeed in clean configuration, whichever is greater until a TBD altitude (i.e. 6,000’ or 10,000’).

b. NADP-1 extended to 6,000’
737-800: Delayed Acceleration Climb
220 knots

<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>

**Population Exposure**

<table>
<thead>
<tr>
<th></th>
<th>60dB</th>
<th>65dB</th>
<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Departure</td>
<td>231,600</td>
<td>94,100</td>
<td>30,200</td>
</tr>
<tr>
<td>Delayed Acceleration</td>
<td>177,718</td>
<td>61,888</td>
<td>25,855</td>
</tr>
<tr>
<td>Reduction</td>
<td>53,882</td>
<td>32,212</td>
<td>4,345</td>
</tr>
</tbody>
</table>

Flights and LAMAX Noise Contours (dB)
777-300: Delayed Acceleration Climb
240 knots

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>B777-300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
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</tr>
<tr>
<td>Notes</td>
<td>Runway 33L: Maintain Standard Climb Thrust &amp; 240 KIAS to 10,000’</td>
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</table>

Population Exposure

<table>
<thead>
<tr>
<th></th>
<th>60dB</th>
<th>65dB</th>
<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Departure</td>
<td>442,860</td>
<td>243,891</td>
<td>98,958</td>
</tr>
<tr>
<td>Delayed Acceleration</td>
<td>426,540</td>
<td>229,450</td>
<td>89,236</td>
</tr>
<tr>
<td>Reduction</td>
<td>16,320</td>
<td>14,441</td>
<td>9,722</td>
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</tbody>
</table>
E-170: Delayed Acceleration Climb
220 knots

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>E-170</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>
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Population Exposure

<table>
<thead>
<tr>
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<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Departure</td>
<td>146,595</td>
<td>47,371</td>
<td>6,988</td>
</tr>
<tr>
<td>Delayed Acceleration</td>
<td>96,993</td>
<td>30,839</td>
<td>5,844</td>
</tr>
<tr>
<td>Reduction</td>
<td>49,602</td>
<td>16,532</td>
<td>1,144</td>
</tr>
</tbody>
</table>
Is NADP An Alternative?

- Airlines expressed concern about nonstandard slow-speed climbs
- Noise Abatement Departure Procedures (NADP) already established as standardized procedure
- Identified NADP-1 (extended to 6,000 ft) as a potential alternative to clean-configuration climb at 220 knots

Figure: Joint Aviation Authority
NADP-1 to 6000 ft vs. 220 Knots to 10,000 ft: B737-800 Noise Exposure

### Populations Exposure (L_{MAX})

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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Baseline Departure</td>
<td>231,600</td>
<td>94,100</td>
<td>30,200</td>
</tr>
<tr>
<td>NADP1 to 6000 ft</td>
<td>179,420</td>
<td>56,578</td>
<td>25,354</td>
</tr>
<tr>
<td>Difference</td>
<td>52,180</td>
<td>37,522</td>
<td>4,846</td>
</tr>
</tbody>
</table>

Noise Model: ANOPP

### 220 KIAS to 10,000 ft

<table>
<thead>
<tr>
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<th>70dB</th>
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<td>177,718</td>
<td>61,888</td>
<td>25,855</td>
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<tr>
<td>Difference</td>
<td>53,882</td>
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<td>4,345</td>
</tr>
</tbody>
</table>

Noise Model: ANOPP
Runway 27 Departures: 2010-2015
**Delayed Acceleration Climb – 220 knots**

**Notes**
- Runway 27: Maintain Standard Climb Thrust & 220 KIAS to 10,000’

**Aircraft**
- B737-800

**Metric**
- $L_{A,\text{MAX}}$

**Noise Model**
- ANOPP

**Population Exposure**

<table>
<thead>
<tr>
<th></th>
<th>60dB</th>
<th>65dB</th>
<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Departure</td>
<td>200,576</td>
<td>102,274</td>
<td>37,078</td>
</tr>
<tr>
<td>Delayed Acceleration</td>
<td>187,400</td>
<td>76,261</td>
<td>21,066</td>
</tr>
<tr>
<td>Difference</td>
<td>13,177</td>
<td>26,014</td>
<td>16,011</td>
</tr>
</tbody>
</table>

**Preliminary**
Fuel Burn and Time Impact

• Reduced speed climb profiles have an impact on fuel burn and flight time
• Magnitude varies by speed and aircraft type
• Example impact for reduced-speed climb to 10,000ft:

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Clean Climb Speed</th>
<th>Fuel Burn Increase</th>
<th>Time Increase</th>
<th>Fuel Burn Increase</th>
<th>Time Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>B737-800</td>
<td>220 KIAS</td>
<td>46 lbs 6.8 gallons</td>
<td>30 seconds</td>
<td>104 lbs 15.3 gallons</td>
<td>40 seconds</td>
</tr>
<tr>
<td>E170</td>
<td>220 KIAS</td>
<td>9 lbs 1.3 gallons</td>
<td>22 seconds</td>
<td>68 lbs 10.0 gallons</td>
<td>54 seconds</td>
</tr>
<tr>
<td>B777-300</td>
<td>240 KIAS</td>
<td>71 lbs 10.4 gallons</td>
<td>12 seconds</td>
<td>317 lbs 46.6 gallons</td>
<td>36 seconds</td>
</tr>
</tbody>
</table>
Potential Throughput Impacts

Two throughput concerns:
1. Impact of runway release rate due to reduced acceleration after takeoff
2. Impact of aircraft with minimum safe speed above 220 knots

Possible mitigations:
1. Relax speed constraint on leading aircraft
2. Vector-based divergent headings
3. Add departure release buffer for faster trailing aircraft

Modeled to check for potential separation issues using 2015/2016 ASDE-X radar data
- Small Impact:
  1. Less that 4 minutes of total delay over 2 years
  2. 54 of 27,713 flights would have required average delay of 2.5 seconds
Block 1: Runway 15R RNAV Waypoint Relocation (1-D2)
Runway 15R Departures: 2010-2015

2010

Flight Track Density Plot
January 1, 2010 to December 31, 2010
Runway 15R Jet Departures
(11,532 Flight Tracks)

- Airport Runway
- Routes
- Municipal Boundary
- Water

Flight Track Density
Low  Medium  High

2015

Flight Track Density Plot
January 1, 2015 to December 31, 2015
Runway 15R Jet Departures
(8,384 Flight Tracks)

- Airport Runway
- Routes
- Municipal Boundary
- Water

Flight Track Density
Low  Medium  High
Summary: Relocate initial waypoint on RNAV SID from FOXXX to BRRRO in order to provide noise relief at Hull.

Benefits Mechanism:
- Reduced noise at Hull due to waypoint relocation.

Population Exposure

<table>
<thead>
<tr>
<th></th>
<th>60dB</th>
<th>65dB</th>
<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline RNAV SID</td>
<td>5,372</td>
<td>299</td>
<td>116</td>
</tr>
<tr>
<td>Modified Procedure</td>
<td>4,058</td>
<td>288</td>
<td>116</td>
</tr>
<tr>
<td>Reduction</td>
<td>1,314</td>
<td>11</td>
<td>0</td>
</tr>
</tbody>
</table>

Potential Operational Constraints:
- None anticipated.
Block 1: Runway 22L/R RNAV SID Modification
Runway 22R Departures: 2010-2015

2010

2015

Flight Track Density Plot
January 1, 2010 to December 31, 2010
Runway 22R Jet Departures (All Arrival Tracks)

Flight Track Density
Low  Medium  High

Flight Track Density Plot
January 1, 2015 to December 31, 2015
Runway 22R Jet Departures (All Arrival Tracks)

Flight Track Density
Low  Medium  High
Potential waiver requirements for minimum leg length between WPONE and WPTWO
### Option A - Climb to Intercept Course (1-D3a): Noise Impact

<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>AEDT</td>
</tr>
<tr>
<td>Notes</td>
<td>Vertical departure profile derived from median or historical radar data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Population Exposure (L_{\text{MAX}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>60dB</td>
</tr>
<tr>
<td>Baseline RNAV SID</td>
</tr>
<tr>
<td>Modified Procedure</td>
</tr>
<tr>
<td>Reduction</td>
</tr>
</tbody>
</table>
### Option B - Climb to Altitude Then Direct (1-D3b): Definition

**Preliminary Procedure Geometry**

- **Localizer Rwy27**: 273°
- **ATC Sector Boundary**: 1.5 NM
- **Early Turn (e.g. light B757)**
- **Latest Turn (500’/NM)**
- **Typical Narrow-Body Turn**

### Potential waiver requirements for turn arc radius to WPTWO

<table>
<thead>
<tr>
<th>Waypoint</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPTWO</td>
<td>42°19'24.04&quot; N</td>
<td>070°54'21.64&quot; W</td>
</tr>
</tbody>
</table>
### Option B - Climb to Altitude Then Direct (1-D3b): Noise Impact

#### Aircraft
- B737-800

#### Metric
- $L_{A,\text{MAX}}$

#### Noise Model
- AEDT

#### Notes
- Vertical departure profile derived from median or historical radar data.

<table>
<thead>
<tr>
<th>Metrics</th>
<th>60dB</th>
<th>65dB</th>
<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline RNAV SID</td>
<td>17,630</td>
<td>4,541</td>
<td>549</td>
</tr>
<tr>
<td>Modified Procedure</td>
<td>16,250</td>
<td>4,511</td>
<td>537</td>
</tr>
<tr>
<td>Reduction</td>
<td>1,380</td>
<td>30</td>
<td>12</td>
</tr>
</tbody>
</table>
Option C: Heading-based departure (1-D3c)

Definition

- **Concept**: During periods where runway 27 not in use for arrivals, issue takeoff clearance with heading (followed by vectors or direct-to on course)
Option C - Heading-based departure (1-D3c): Noise Impact

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>B737-800</th>
</tr>
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<tbody>
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<td>AEDT</td>
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<td>Notes</td>
<td>Vertical departure profile derived from median or historical radar data</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Population Exposure ($L_{\text{MAX}}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60dB</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Baseline RNAV SID</td>
</tr>
<tr>
<td>Modified Procedure</td>
</tr>
<tr>
<td>Reduction</td>
</tr>
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</table>
Block 1: RNAV Approach
Runway 33L with RNP Overlay
33L Low-Noise Overwater Approach Procedures

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**Track Data:**
- 241 days ranging from April 2015 to March 2016
- 4052 total jetBlue arrivals in period
- Night time arrivals shown in green (11pm-5am), 837 total night arrivals

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**No Criteria Compliance Constraints**

**No Current Mechanism for Public Distribution**

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**VFR Weather Minimums**

- Ceiling 3000' - VIS 5

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**WEATHER MINIMUMS**

1. On initial contact with ATC request RNAV Visual Rwy 33L.
2. In FMS database select, GPS33L.
3. Advise ATC, "Airport or Preceding Traffic in sight" ASAP.
4. Adhere to all ATC restrictions and clearances.
33L RNAV Visual vs. RNAV GPS (Draft)

Community Request to generate RNAV procedure as close as possible to jetBlue “RNAV Visual”
## Precision vs. Non-precision Procedures

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Minimum Final Level Segment Length</th>
<th>Maximum Final Approach Intercept Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNAV (Precision)</td>
<td>Distance where Glidepath Angle intercepts Intermediate Segment minimum altitude</td>
<td>15° at Final Approach Fix</td>
</tr>
<tr>
<td>LP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNAV/VNAV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNAV (Non-precision)</td>
<td>Distance where Visual Descent Angle intercepts Intermediate Segment minimum altitude</td>
<td>30° at Final Approach Fix</td>
</tr>
<tr>
<td>LP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNAV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNP</td>
<td>Final Rollout at farthest of: • 500’ altitude • 15 or 50 seconds before Decision Altitude (depending on RNP level)</td>
<td>Radius to Fix Turn from Final Approach Fix to Rollout Point</td>
</tr>
</tbody>
</table>

![Diagram showing Precision and Non-precision (30°) final approach](image)
### Overwater RNAV Instrument Approach Procedure with RNP Overlay (1-A1b) – Noise Exposure

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>B737-800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
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<tr>
<td>Noise Model</td>
<td>AEDT</td>
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<tr>
<td>Notes</td>
<td>3 degree continuous glide slope</td>
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</table>

<table>
<thead>
<tr>
<th>Population Exposure ($L_{MAX}$)</th>
<th>60dB</th>
<th>65dB</th>
<th>70dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline RNAV SID</td>
<td>2,386</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>Modified Procedure</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reduction</td>
<td>2,386</td>
<td>240</td>
<td>0</td>
</tr>
</tbody>
</table>
Block 1

• Departure Mods
  – 33L and 27
    • Reduced speed departures (1-D1)
      – 220 Knots (clean) to 10,000’
      – NADP-1 to 6,000’
  – 15R
    • RNAV waypoint relocation (1-D2)
  – 22L/R
    • RNAV waypoint relocation
      – Climb to intercept course (1-D3a)
      – Climb to altitude then direct (1-D3b)
    • Heading-based departure (1-D3c)

• Arrival Mods
  – 33L Low-noise overwater approach procedures
    • Overwater RNAV Instrument Approach Procedure with RNP Overlay which as closely as possible flies the jetBlue RNAV Visual track (1-A1a)
    • Public distribution mechanism for the jetBlue RNAV Visual procedure (1-A1b)