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May 31, 2017

VIA ELECTRONIC MAIL
David Carlon, Chairman
Massport Community Advisory Committee
david.carlon@mac.com

Ralph Dormitzer, Subcommittee Chair
Aviation Subcommittee
Massport Community Advisory Committee
rdormitzer@gmail.com

RE: *RNAV Presentation Provided to the Aviation Subcommittee on May 5, 2017*

Dear Chairman Carlon and Subcommittee Chair Dormitzer:

The presentation provided by MIT (Massport and the FAA's lead technical consultant) at the May 5th Massport CAC Aviation Subcommittee meeting reflects the initial technical screening options under review in the RNAV study. This initial presentation was based on (1) the MOU between Massport and the FAA; (2) the community feedback from the Massport CAC meetings and (3) the feedback from Massport's and MIT's February 22nd public presentation and hearing. This presentation was used as visual tool to assist with the technical narrative provided at the public meeting on May 5th by the consultant team.

The analysis presented in the attached deck includes procedure design options that may be technically feasible but require further review - both technical review (including by the FAA and Airlines), as well as impact review for regional equity, including by the Massport CAC. The presentation also included ideas that were explored and rejected due to adverse noise impact or safety concerns.

The presentation includes a summary of procedure options assigned to Block 1 (expected to have higher probability of technical success and minimal or no noise shifting) and Block 2 (more technically challenging and/or presents noise equity concerns). There is an ongoing process to review both the Block 1 and Block 2 ideas. If Block 1 ideas are technically feasible, then they will be recommended to the Massport CAC, the FAA and Massport. Similarly, any ideas that may be considered in Block 2 must undergo further technical analysis related to safety/operational feasibility and additional impact analysis on shifting of noise. Following this analysis, any Block 2 options, including but not limited to those in the attached presentation, will be presented to the FAA, Massport and the Massport CAC for further discussion and consideration.

We look forward to continuing to work with the Massport CAC and the Aviation Subcommittee on this matter.

Very truly yours,

Elizabeth Dello Russo Becker
Director of Community Relations & Government Affairs

CC: (via electronic mail)
John Nucci, Massachusetts Port Authority
Flavio Leo, Massport
Anthony Gallagher, Massport

Attachment:
May 5th Massport CAC Aviation Subcommittee presentation by MIT

MIT International Center for Air Transportation

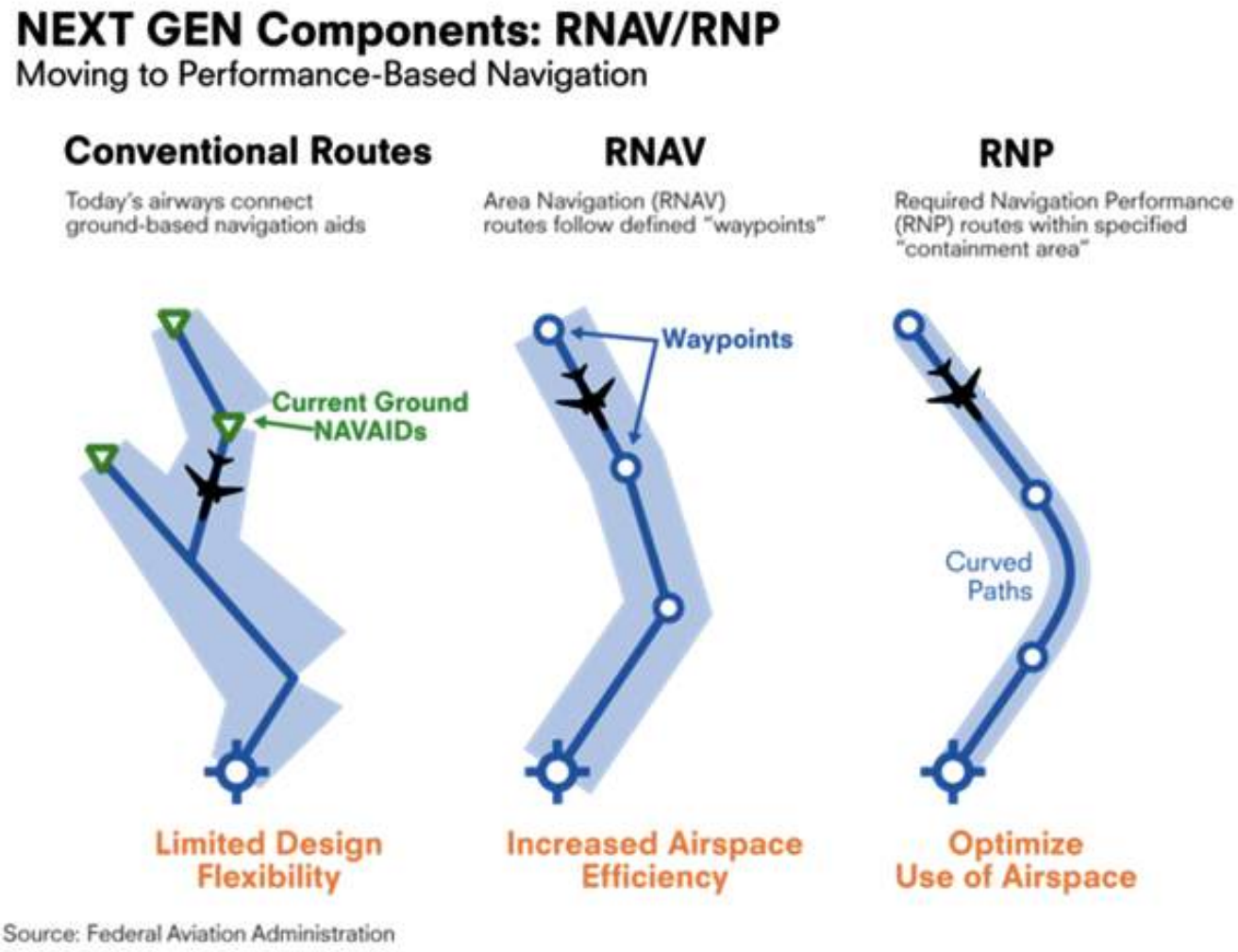
Procedure Design Concepts for Logan Airport Community Noise Reduction

R. John Hansman
rjhans@mit.edu

Technical support from MIT ICAT students, HMMH, and Massport

May 5, 2017
Logan Office Center
East Boston, MA

Performance-Based Navigation (PBN)



100% equipage

95% equipage

60%-70% equipage
Crew Training Requirements

RNAV Track Concentration

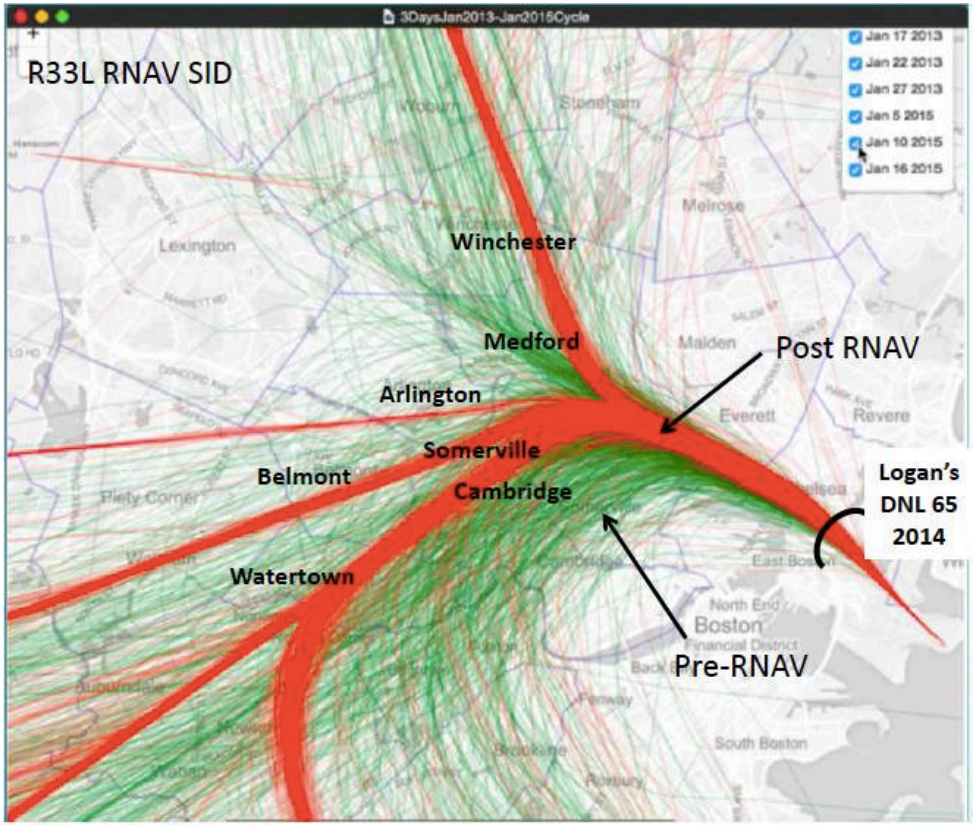
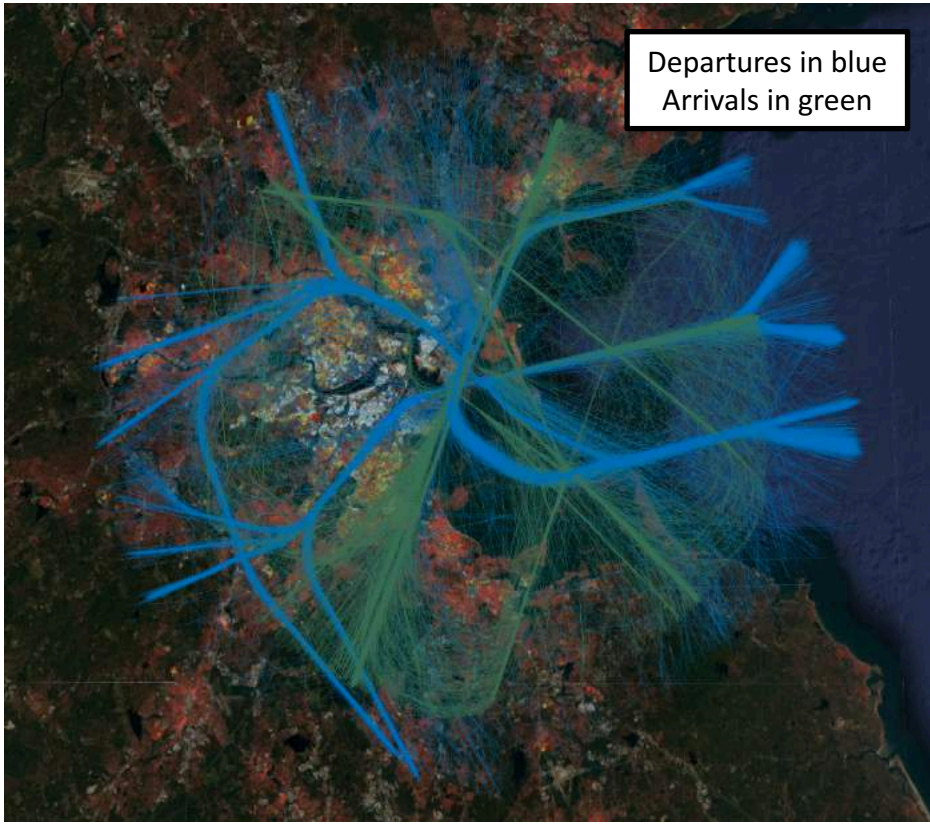


Image Source: Massport



Source: ASDE-X
8 days in 2015

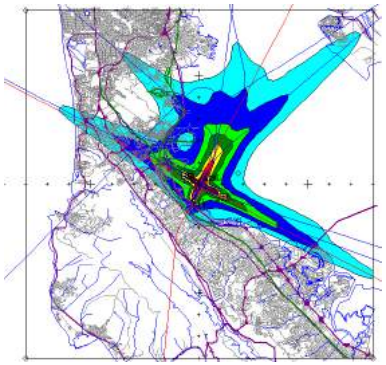
Technical Approach

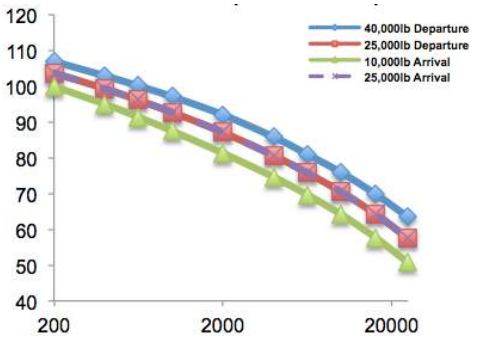
- Collect Data and Evaluate Baseline Conditions
  - Pre and Post RNAV
- Identify current procedures which appear to have community noise benefit
- Determine Technical and Operational Limitations
  - Aircraft Performance
  - Navigation and Flight Management (FMS)
  - Flight Crew Workload
  - Safety
  - Procedure Design
  - Air Traffic Control Workload
- Identify Candidate Procedure Modifications
  - Block 1/Block 2
- Model Noise Impact
  - Standard and Supplemental Metrics
- Evaluate Implementation Barriers
- Recommend Procedural Modifications to Massport and FAA
- Repeat for Block 2

Noise Modeling Background

Two Approaches to Noise Modeling

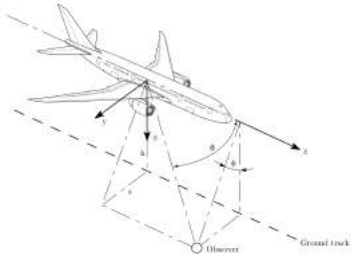
Aviation Environmental Design Tool (AEDT)

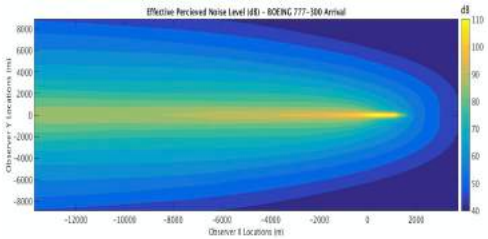




- Current industry standard model to evaluate aircraft noise impacts
- Noise-Power-Distance (NPD) based computations
  - Interpolation from flight test data
- Assumes engine noise dominates aerodynamic noise on approach
  - Effects of configuration and speed not captured
  - Simple directivity assumptions

Aircraft NOise Prediction Program (ANOPP v1)





- NASA-developed software incorporating physics-based methods
- Computes far-field engine and airframe noise at an observer grid given various flight profile and configuration metrics
  - Semi-empirical calculations require detailed engine/aircraft performance inputs
    - e.g., Engine mass flow, areas, and temperatures, airframe geometry, etc.
  - Input requirements for ANOPP v2 much more extensive

Aircraft Noise Model: Aircraft NOise Prediction Program (ANOPP)

ANOPP Inputs:

Flight Profile:

- Position Profile
- Velocity Profile
- Thrust Profile

Airframe Geometry:

- Wing area
- Wing span
- Tail area
- Tail span
- Configuration

Thrust Profile:

- Engine Geometry
- Engine Performance

ANOPP
Source Noise Calculations:

Airframe Noise

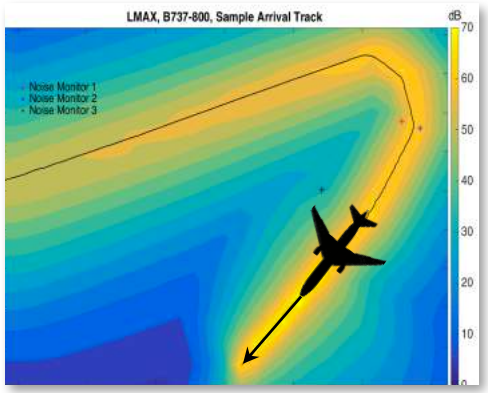
Turbofan Engine Noise

Fan Noise

Combustion Noise

Jet Noise

ANOPP Outputs:
Noise at All Observer Locations



Physics-Based Noise Analysis Framework

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

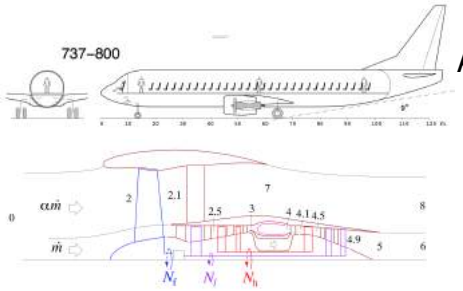
Aircraft Type

Procedure Definition:
Lateral Path
Speeds
Configuration

TASOPT

BADA4 Existing Aircraft Data

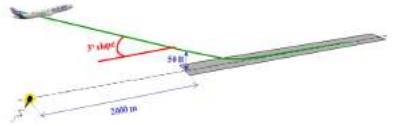
Performance Model Outputs:



Aircraft/engine performance & geometry

Flight Profile Generator

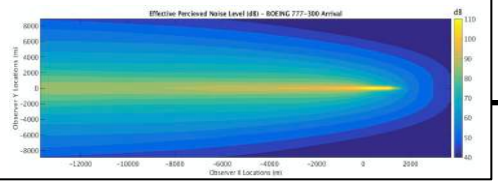
Flight Procedure:
Thrust, velocity, position, gear/flap settings per time



Noise Model Control Inputs:
Propagation Settings
Observer Locations

AEDT/ANOPP

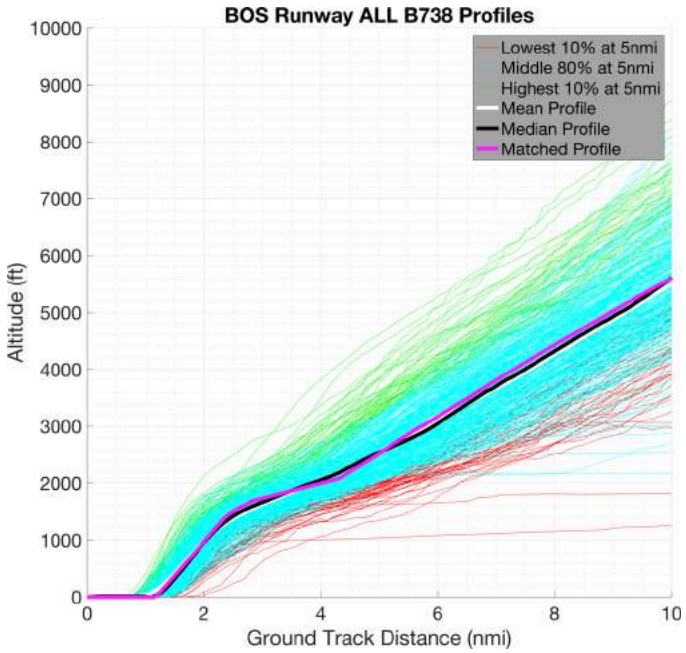
Single-Event Noise Grids



Output to Grid Rotation and Superposition

Radar Data Profile Matching

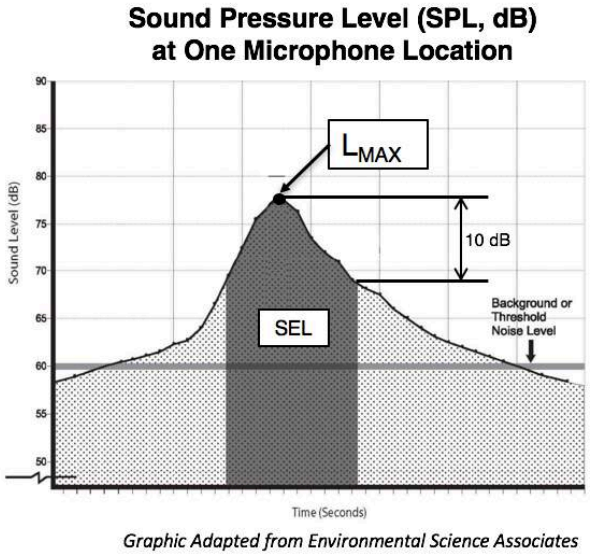
- Takeoff thrust and climb thrust set to match median radar-based initial climb rate
- Departure weight assumed to be 90% of MTOW, arrival weight assumed to be 75% of MTOW
  - Consistent with most AEDT procedures

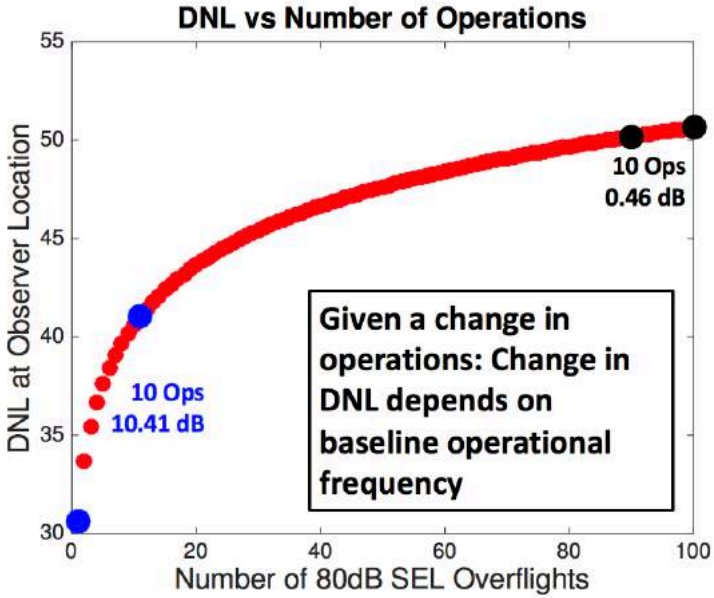


Attribute	Data Source
Drag	BADA 4
MTOW	TASOPT or BADA 4
Takeoff/landing roll	ASDE-X data matching
Max thrust	Published data
V2	TASOPT

Noise Metrics Used for Evaluation

- Single-Event Metrics
  - **L_{MAX}**
  - **SEL**
- Exposure-based metrics
  - **DNL**
  - **N_{ABOVE}**
- Population exposure
  - **L_{MAX}**
  - **N_{ABOVE}**
  - **DNL**



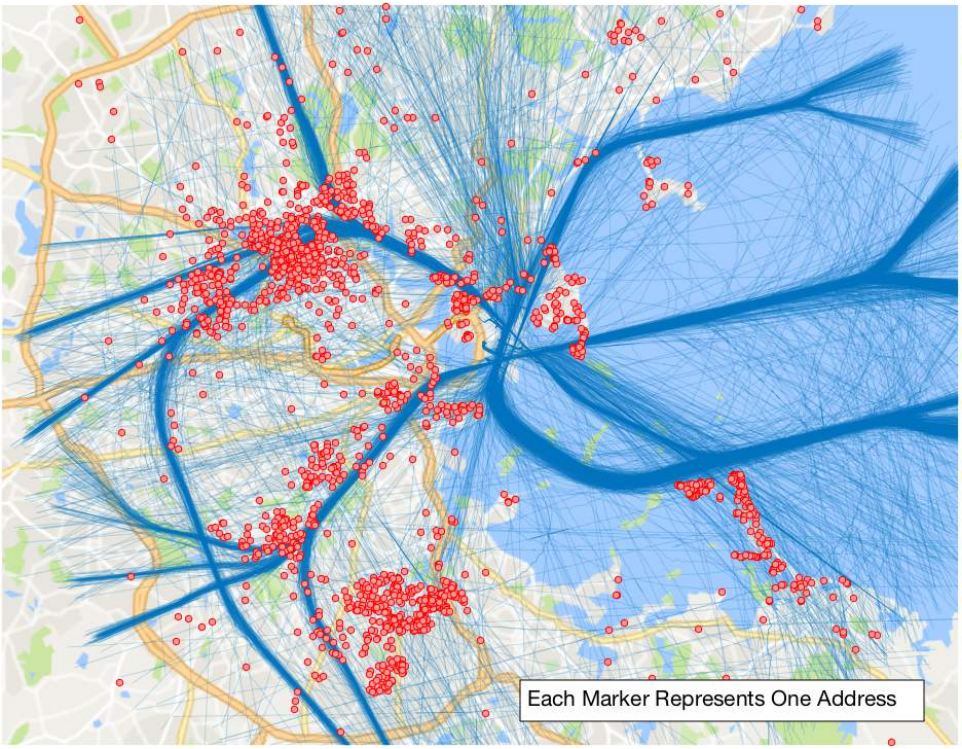


Boston Analysis

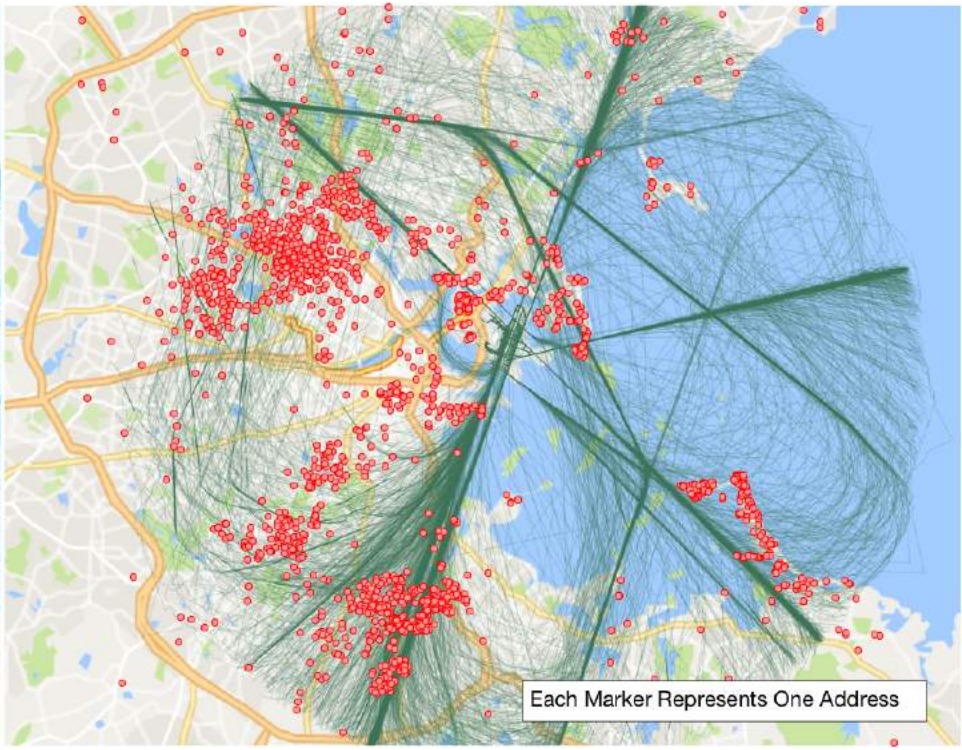
Noise Complaints at BOS: One Dot per Address

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

Potential Uses of PBN for Reducing Noise

Departure Procedure Modifications

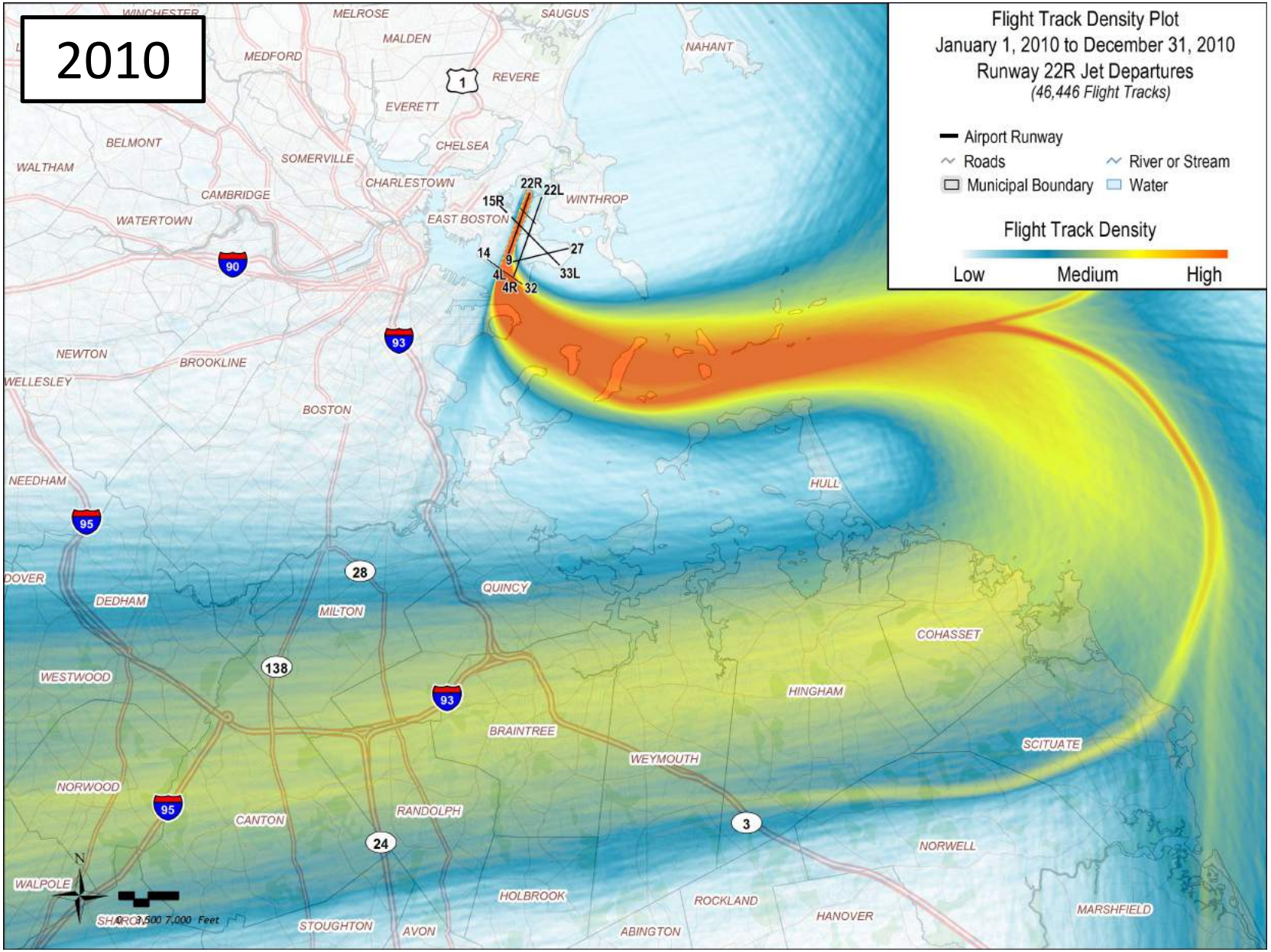
- Noise-preferential lateral paths
  - Early turns after takeoff
  - SID waypoint relocation
  - Overflight of high ambient noise areas
- Reduced procedural separation allowing overflight of areas with compatible land use
- Modified climbs
  - Reduced speed
  - Delayed thrust cutback
  - Thrust scheduling
- Dispersion of departure routes
  - Open-SID
  - Vectors/headings
- Other?

Arrival Procedure Modifications

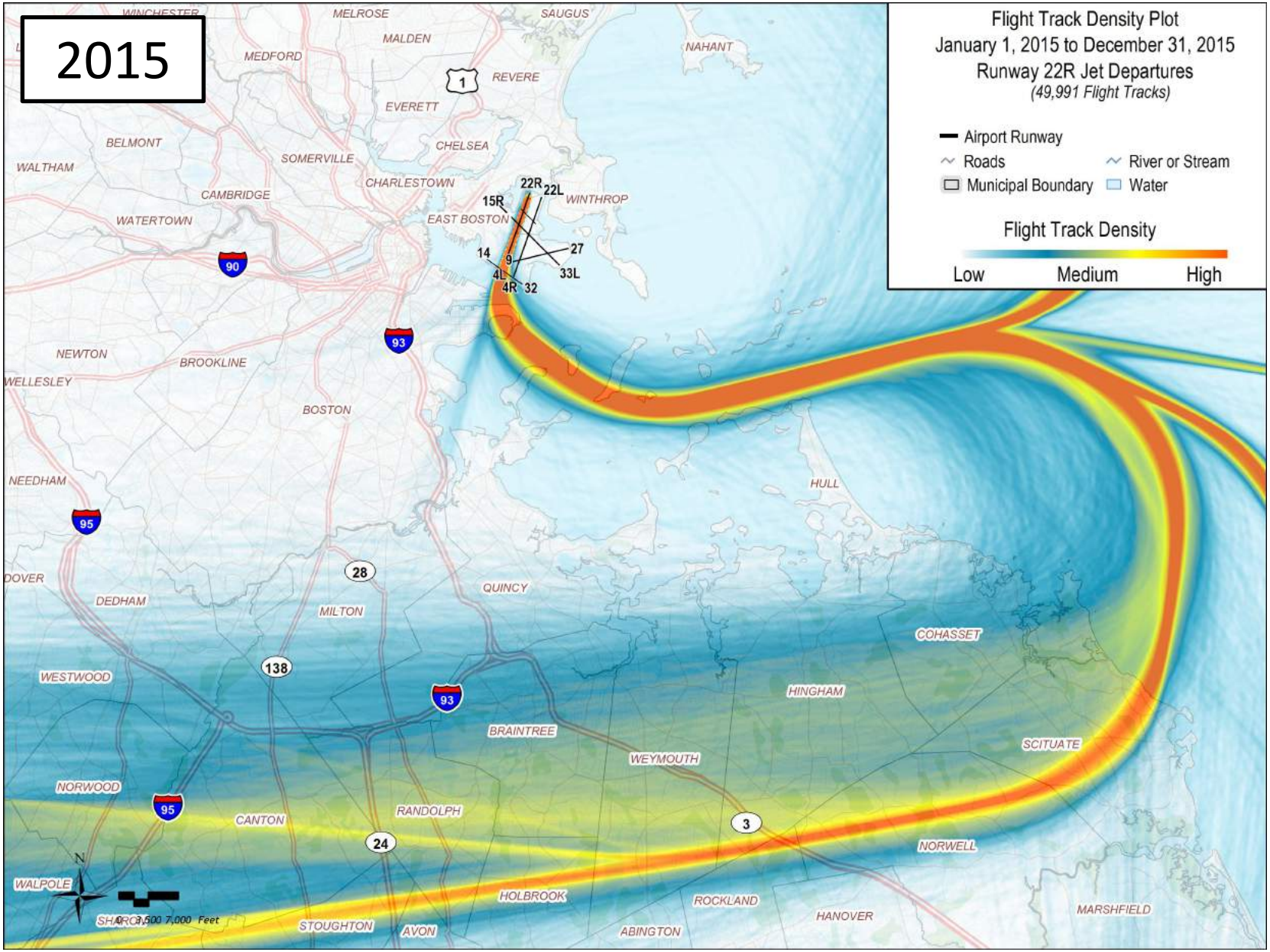
- Noise-preferential lateral paths
  - Overflight of areas with high ambient noise or low population (e.g. Expressway approach)
  - Late turn to final (e.g. Canarsie-like approach paths)
- Steep approaches
  - 1-segment steep approaches
  - 2-segment steep approaches
- Speed/configuration management
- Other?

Runway 22R and 15 Departures

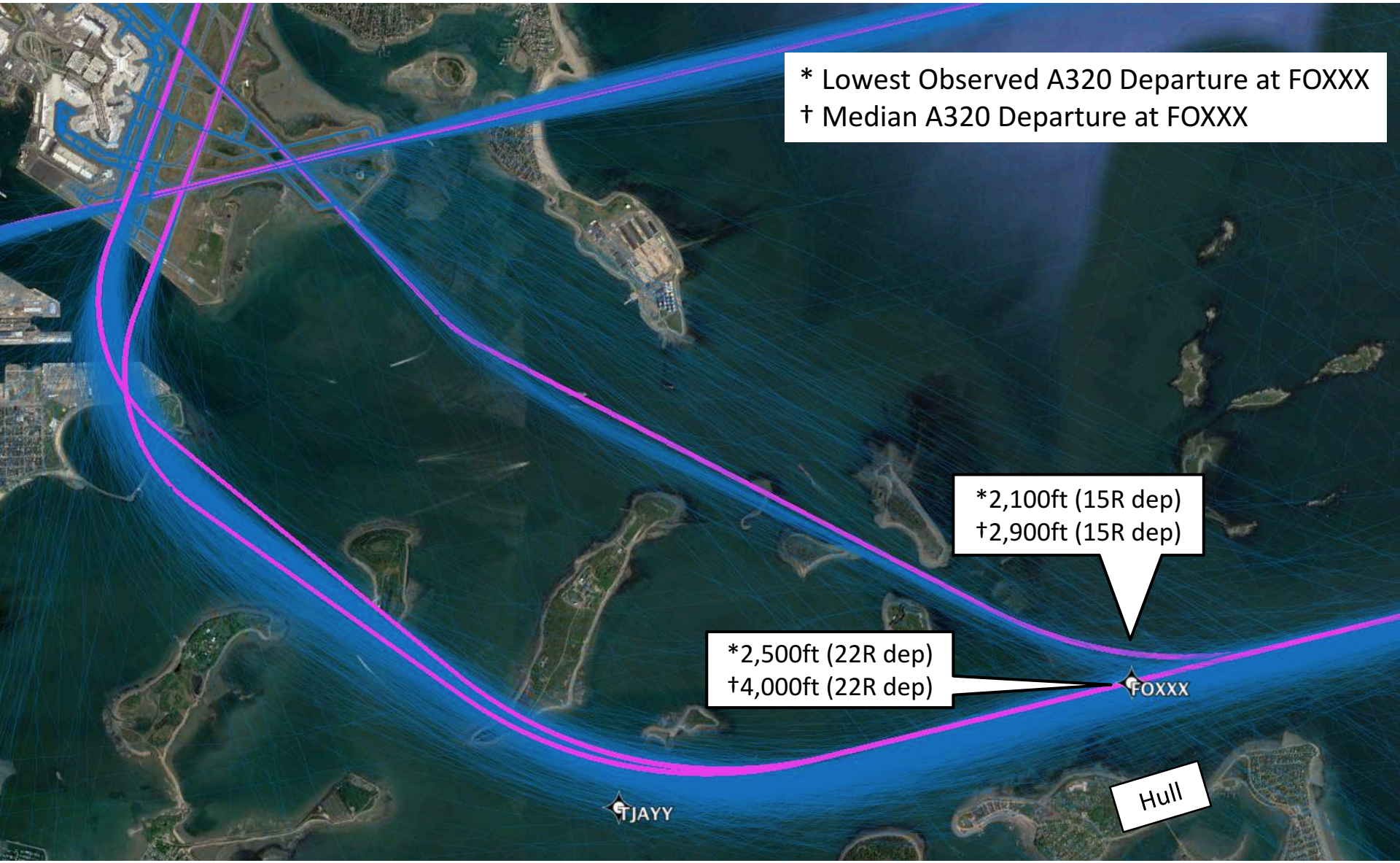
Runway 22R Departures: 2010-2015



Runway 22R Departures: 2010-2015

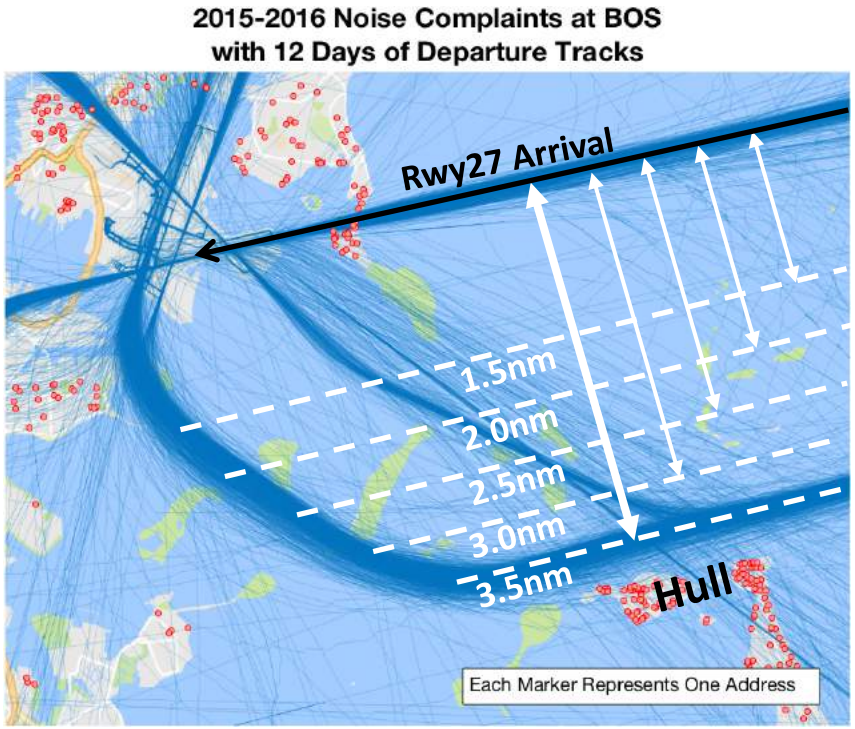


22R, 22L, and 15R Departure Tracks



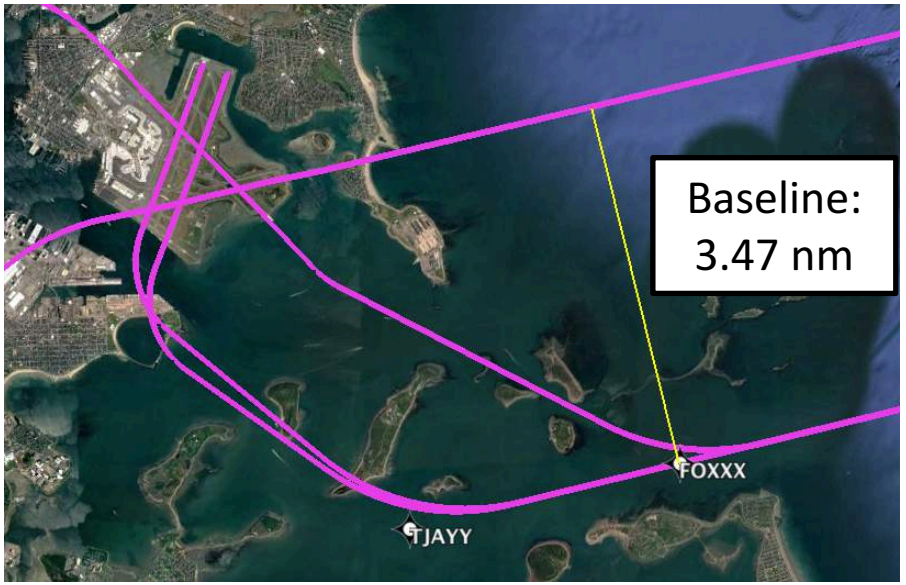
Runway 22R and 22L Departure Procedure Concepts

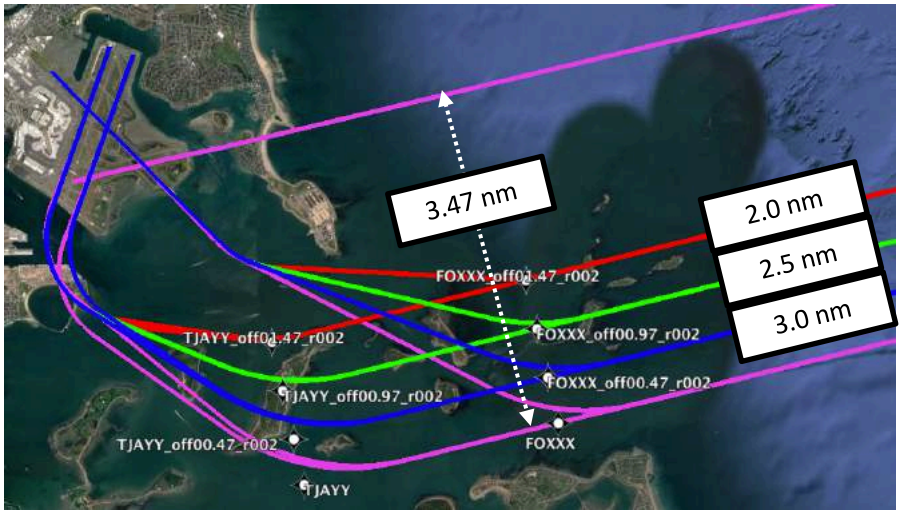
1. Reduced separation with Rwy 27 arrival flow
2. Early turn after takeoff to reduce noise at Castle Island and surrounding areas



22R/22L Departure Spacing with 27 Arrivals (Standard Turn)

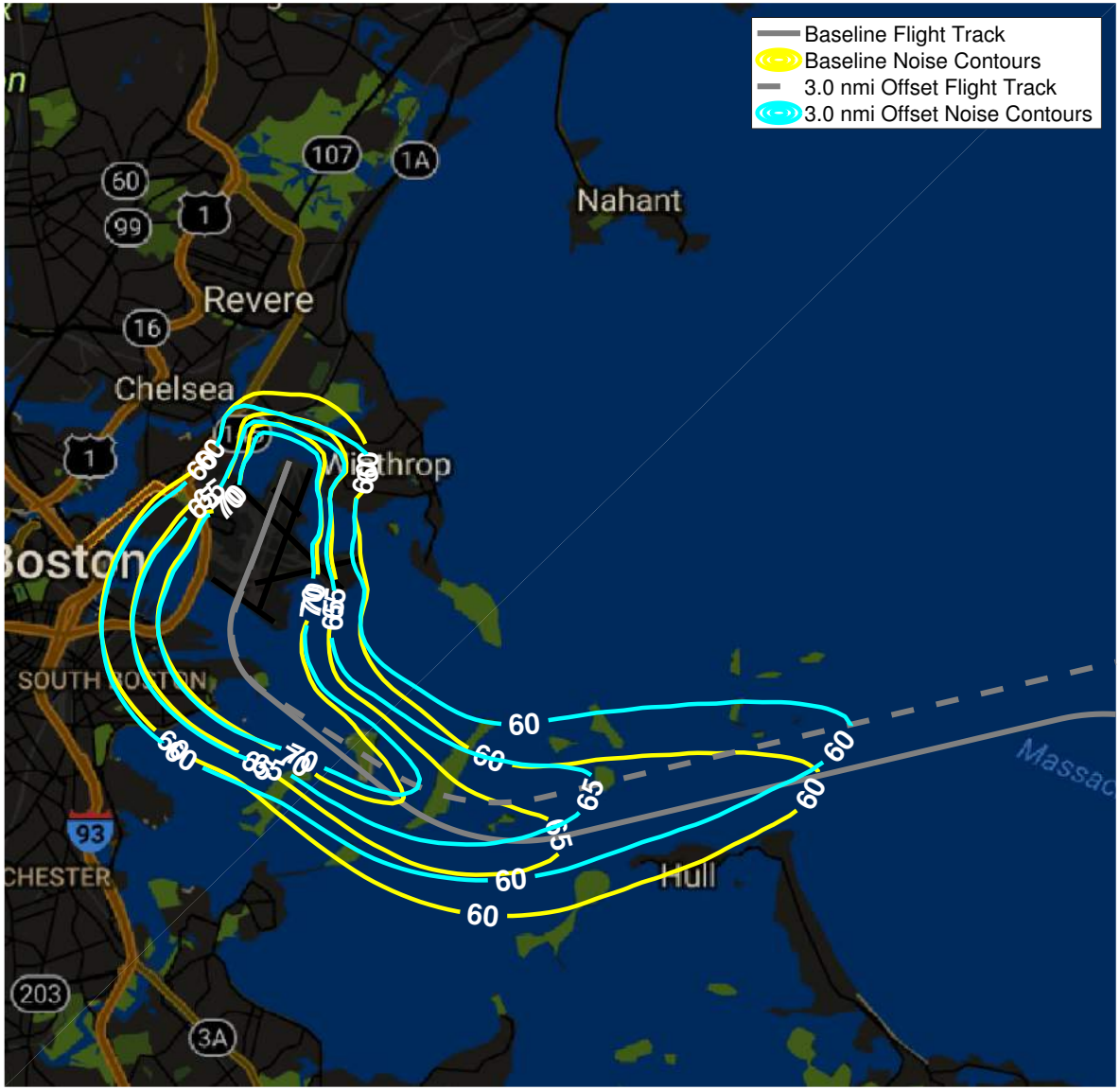
- Evaluating departures at several spacing levels
  - Baseline: 3.47nm
  - 3.0, 2.5, 2.0nm shown in figure
- Current RNAV turn location for Runway 22R departures:
  - Runway heading to intercept course 144 to TJAYY





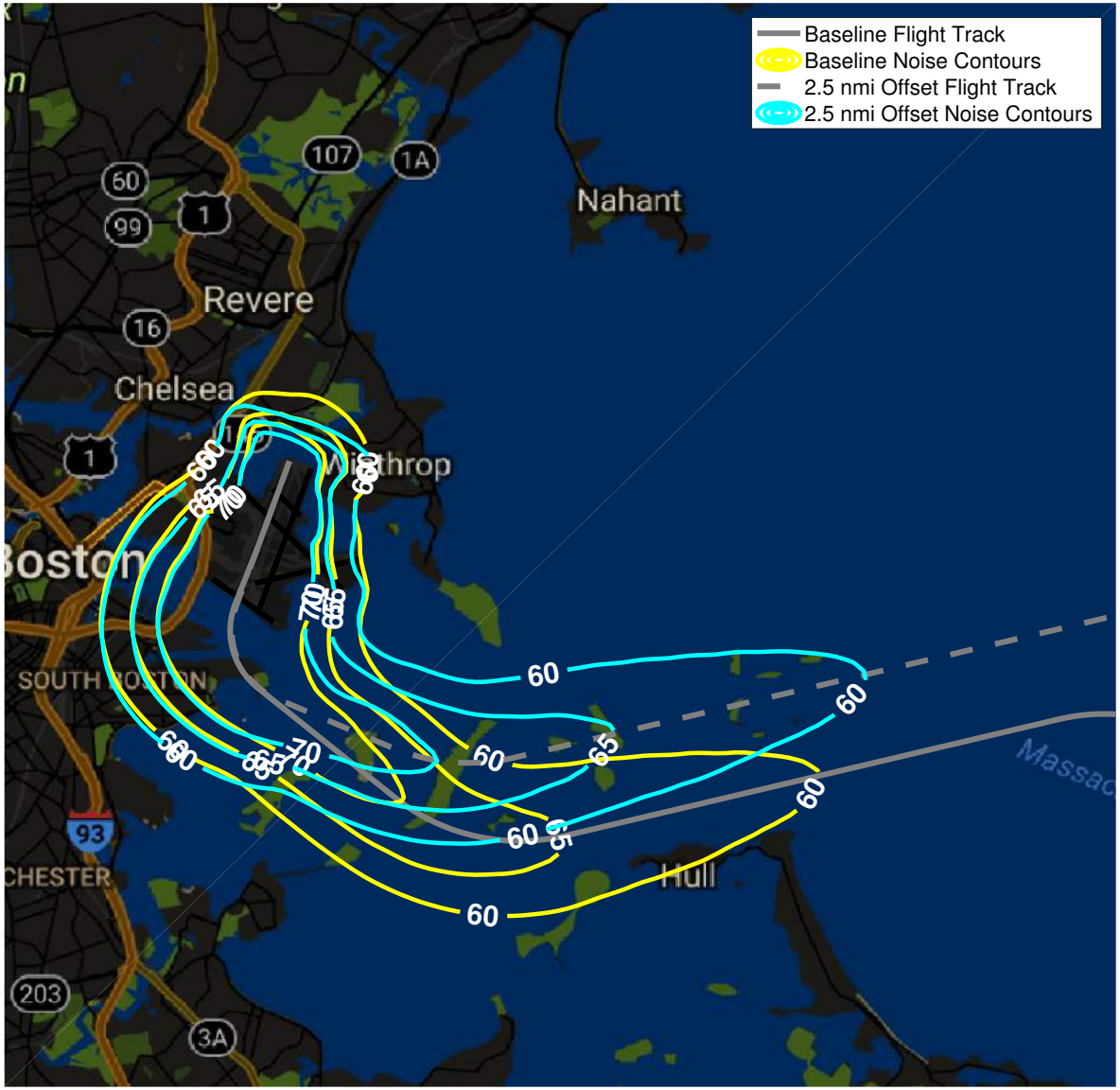
Noise Exposure: 22R/22L Departure with 3.0nm Offset from 27 Arrivals (Standard Turn)

- 22R/22L Departure 3.0nm Lateral Offset from 27 Arrivals
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT



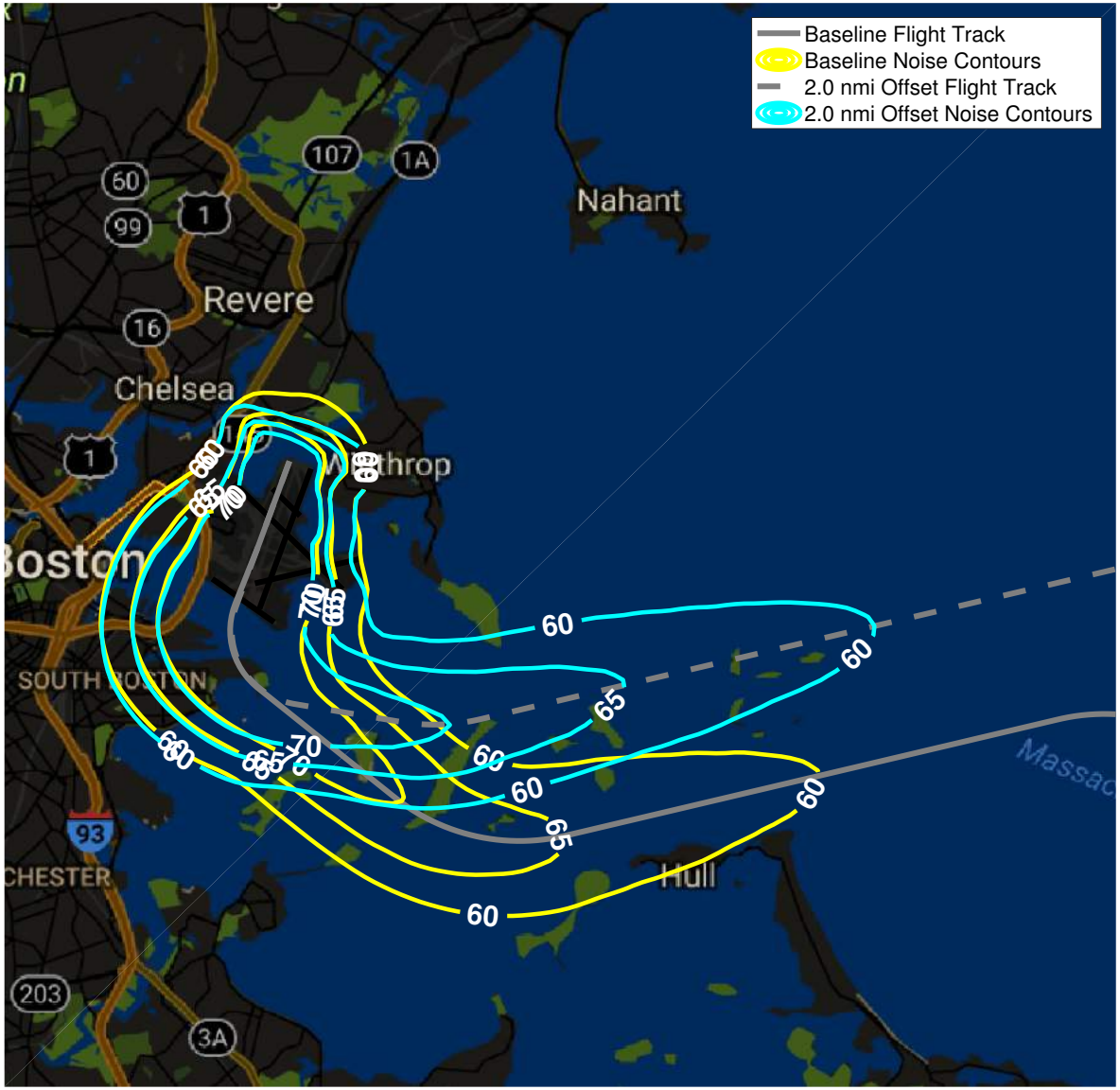
Noise Exposure: 22R/22L Departure with 2.5nm Offset from 27 Arrivals (Standard Turn)

- 22R/22L Departure 2.5nm Lateral Offset from 27 Arrivals
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT



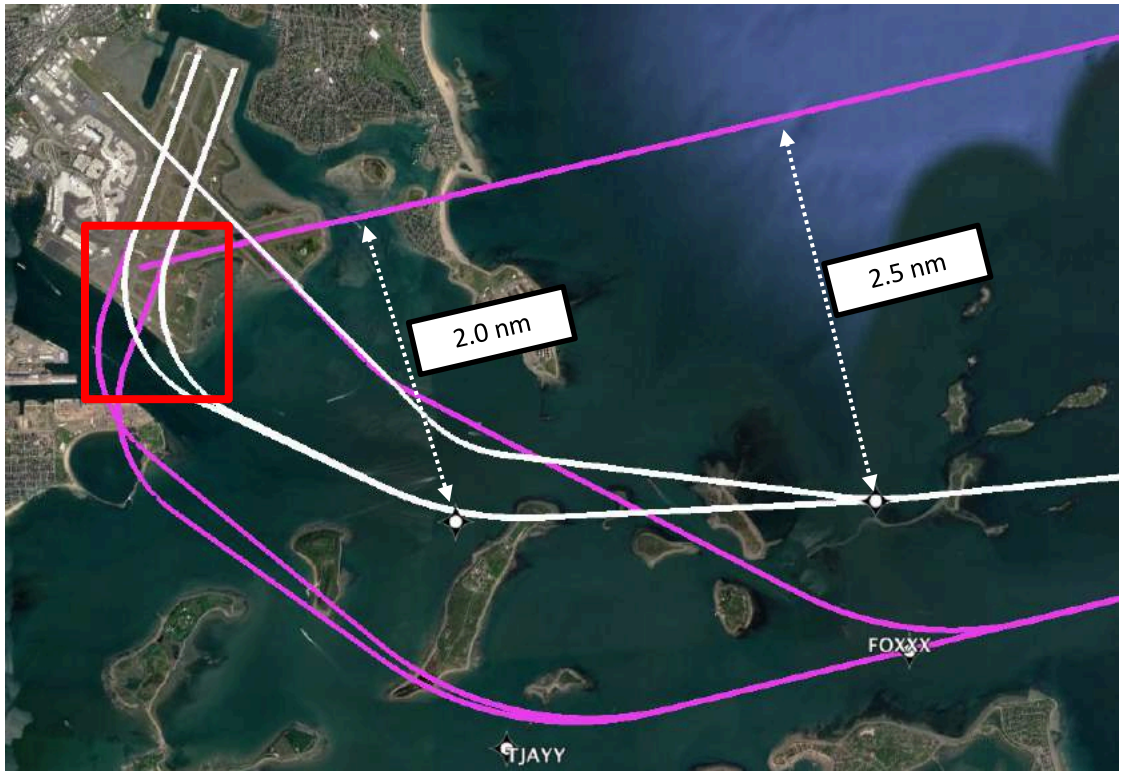
Noise Exposure: 22R/22L Departure with 2.0nm Offset from 27 Arrivals (Standard Turn)

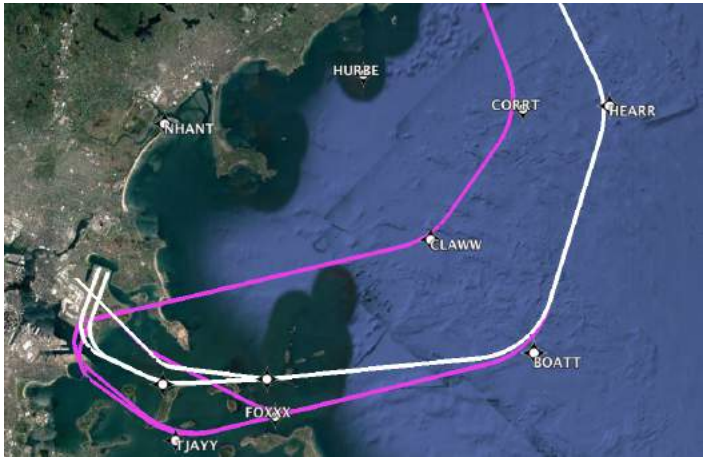
- 22R/22L Departure 2.0nm Lateral Offset from 27 Arrivals
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT



22R/22L Departure Spacing with 27 Arrivals (Early Turn) and 15R Departure Waypoint Relocation

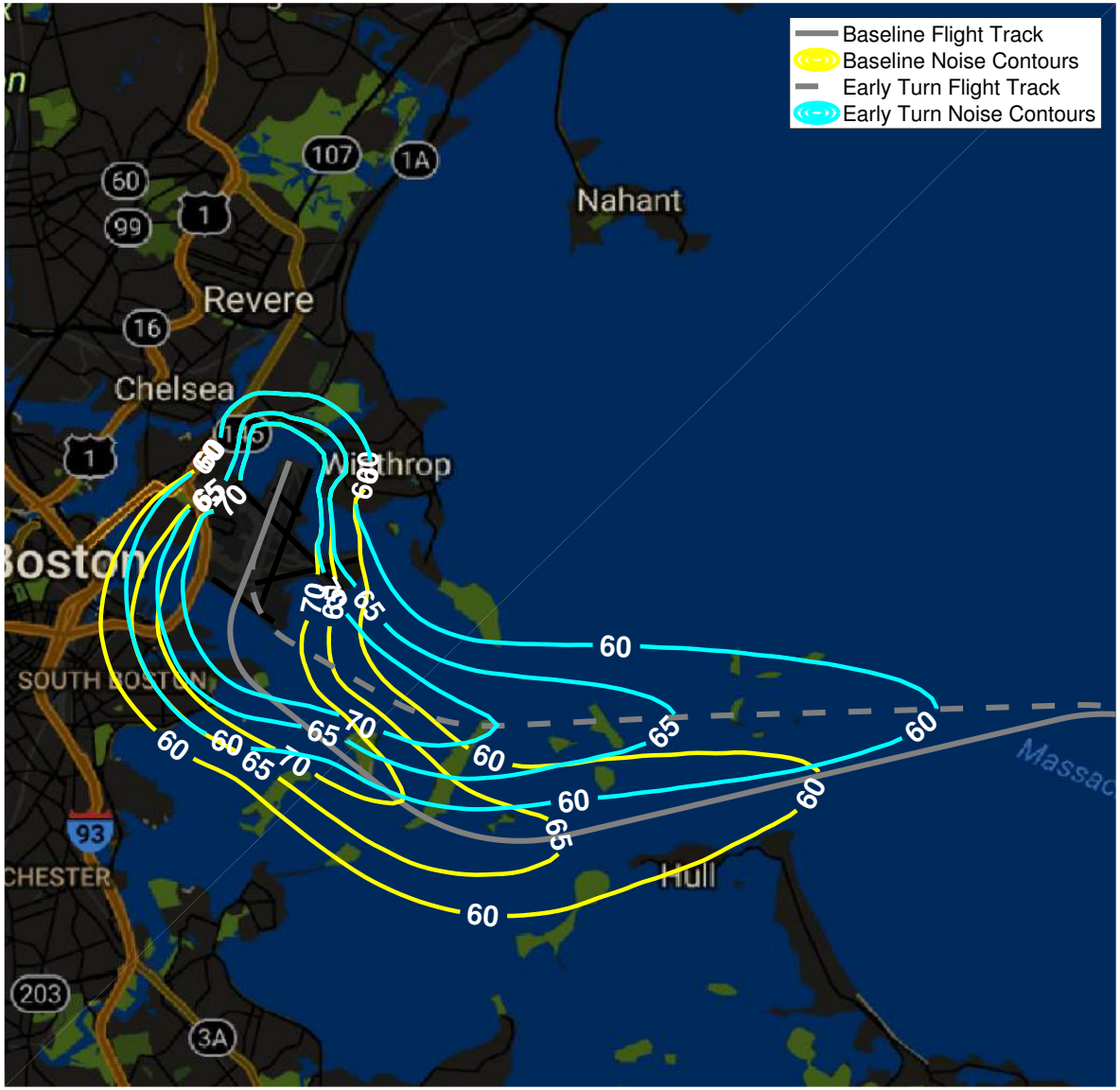
- 22R Early turn:
  - Initial turn at 500' AGL
  - Direct-to initial waypoint located on target departure corridor
- Runway 15R Departure Fix:
  - Current procedure uses same departure fix as 22R departures (FOXXX)
  - Potential benefit from changing departures to use fix offset from Hull





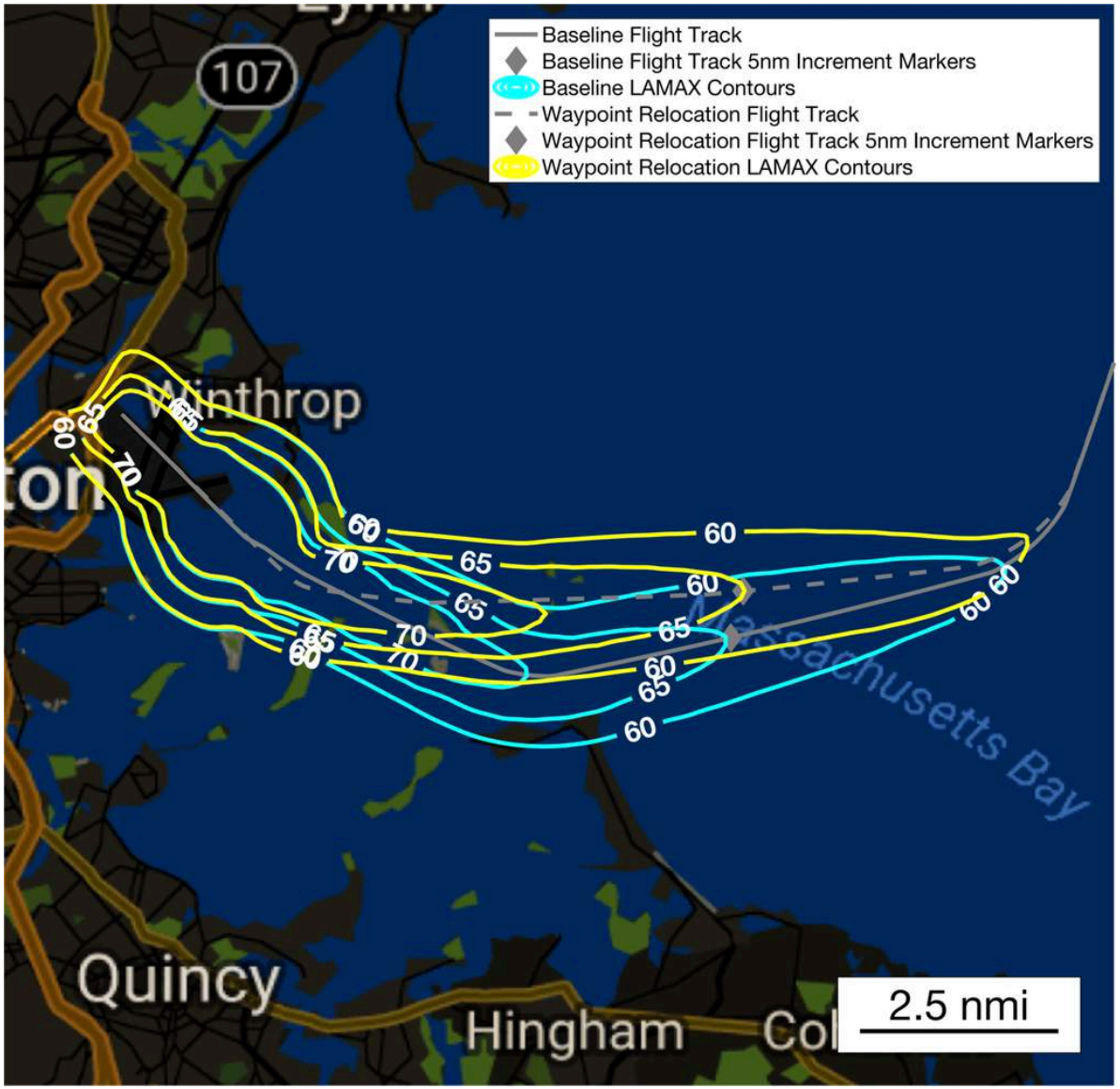
Noise Exposure: 22R/22L Early Turn

- 22R/22L Early Turn and Waypoint Relocation
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT



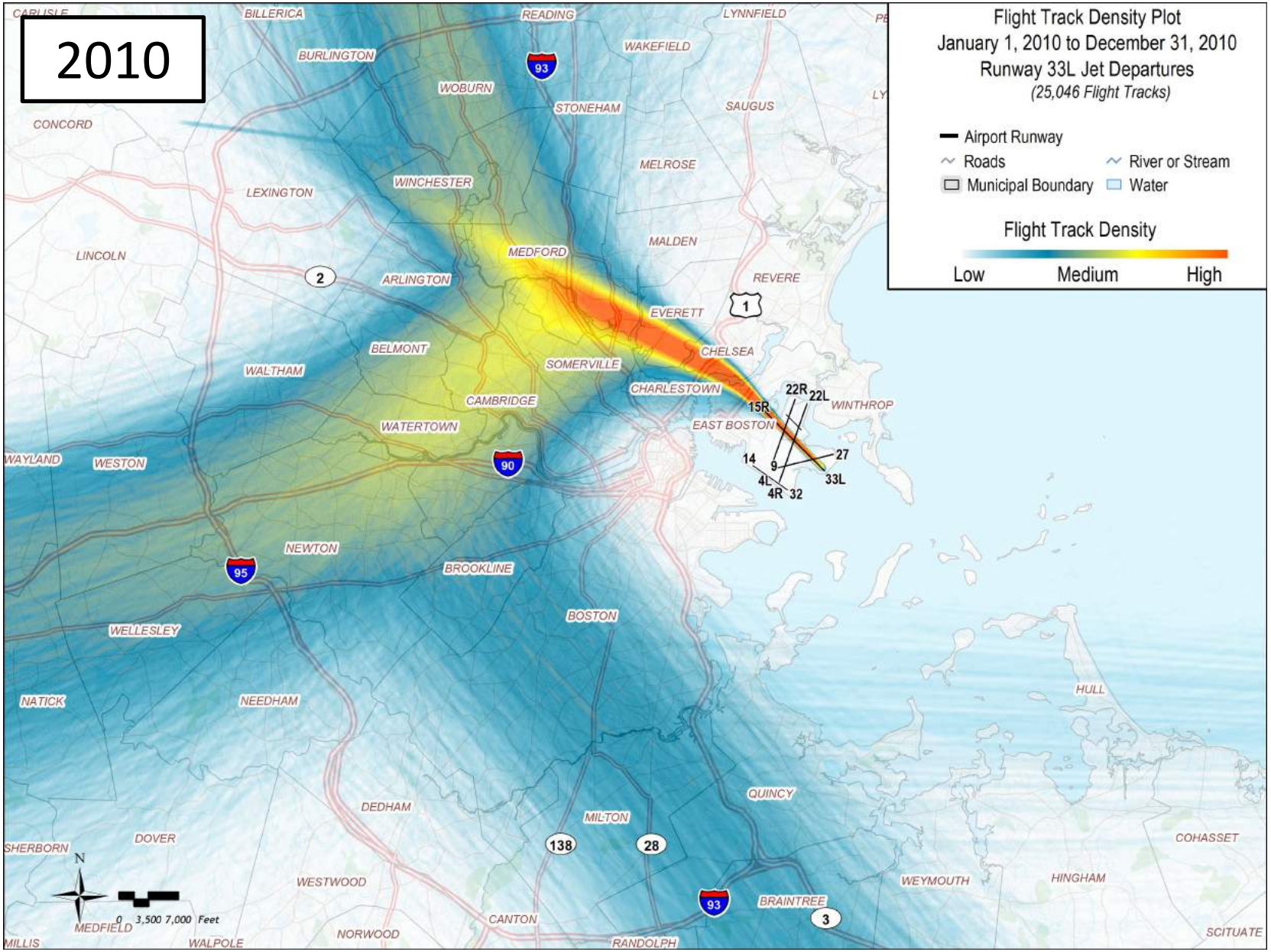
15 Waypoint Relocation

- 15R Departure Waypoint Relocation
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT

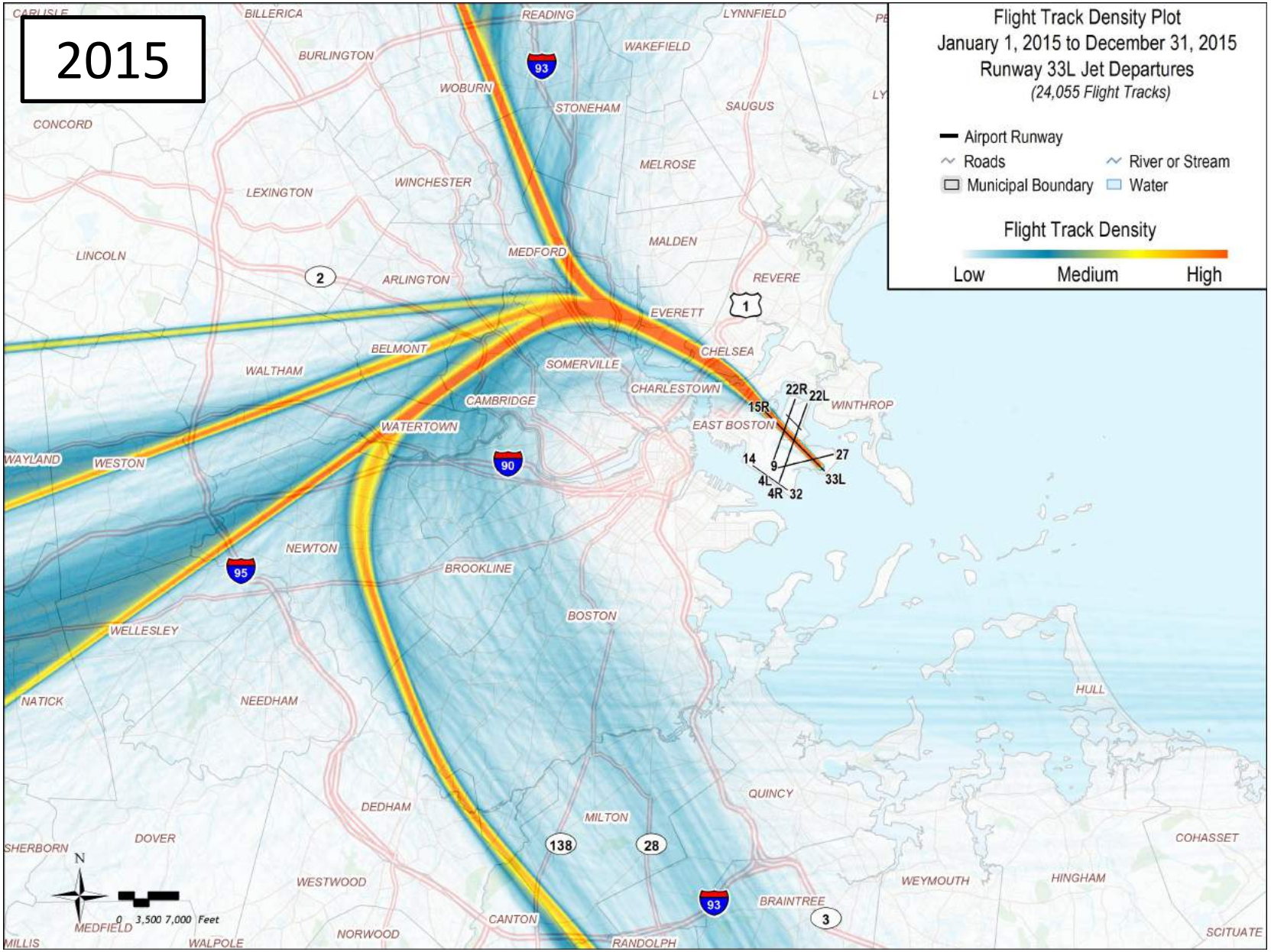


Runway 33L Departures

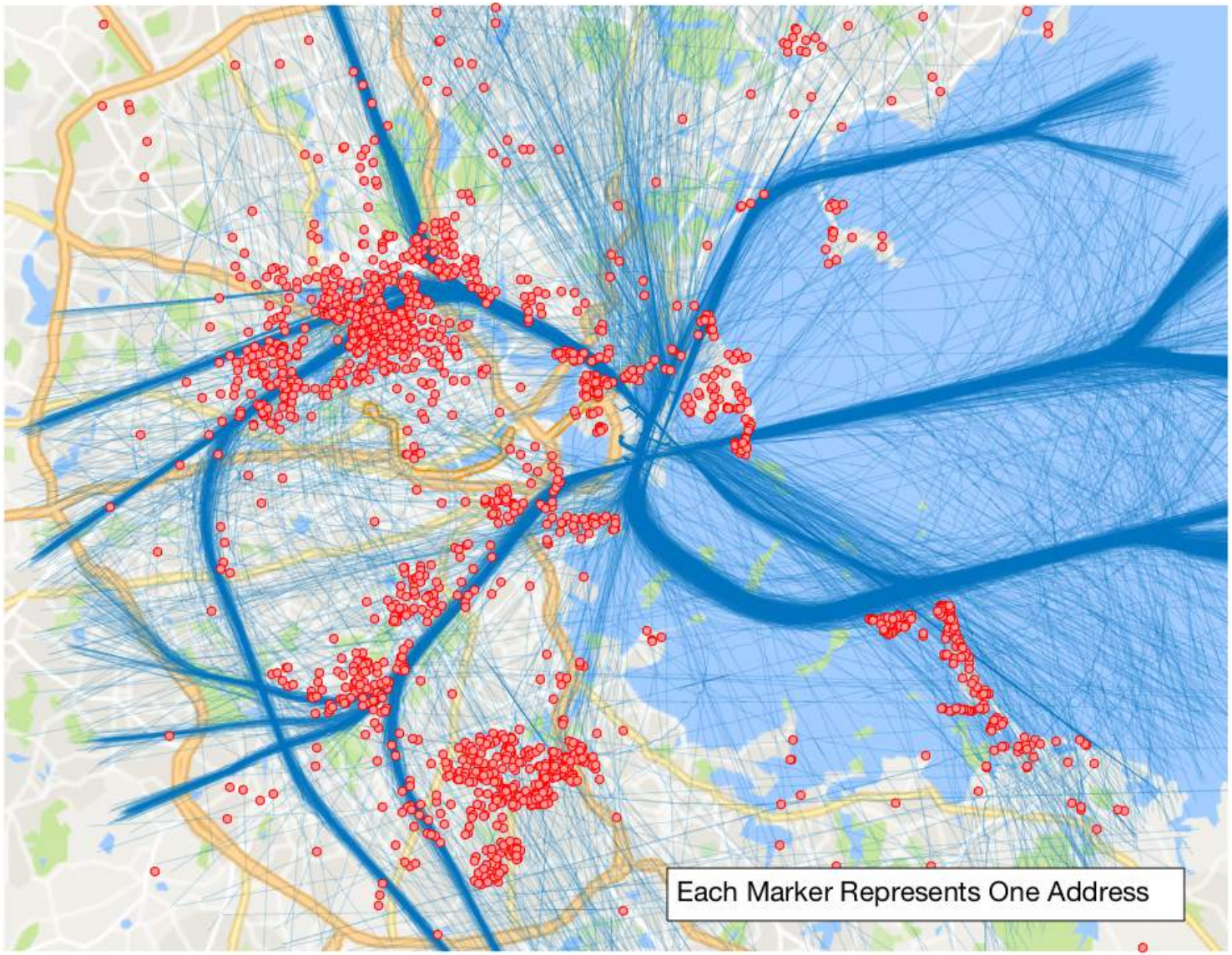
Runway 33L Departures: 2010-2015



Runway 33L Departures: 2010-2015



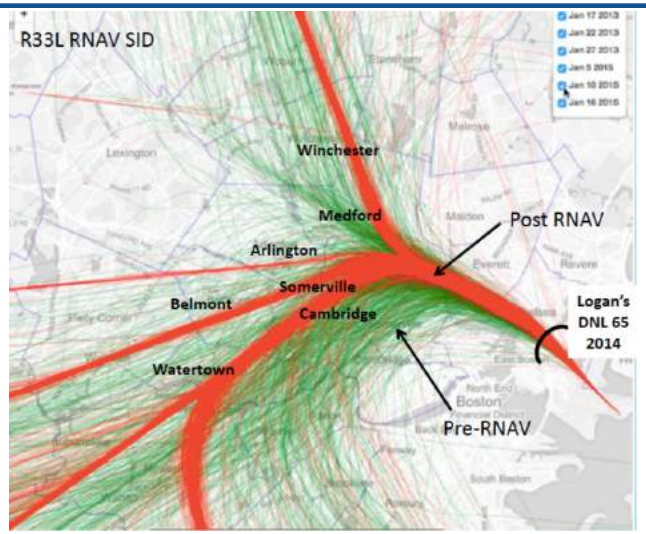
Noise Complaints at BOS



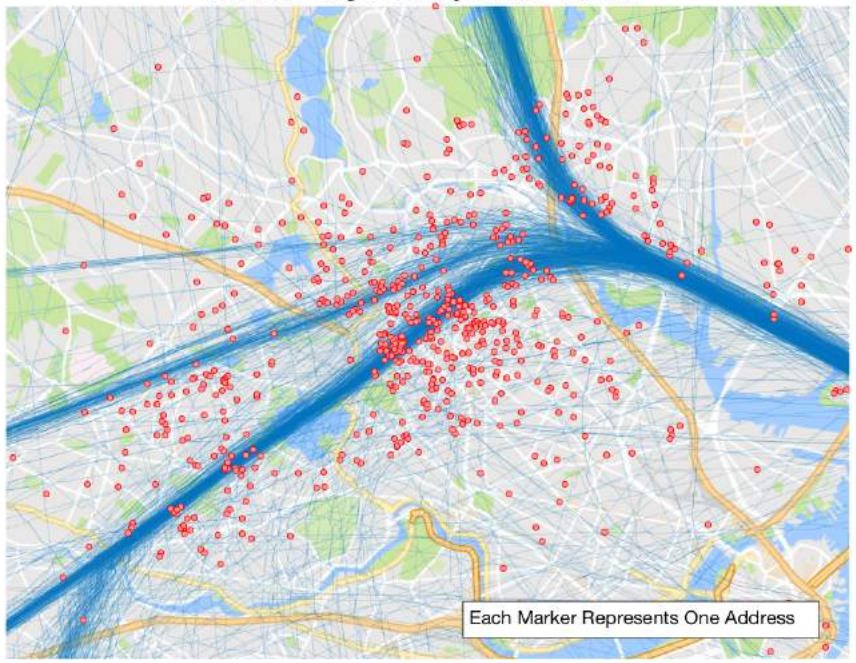
Complaint Data: August 2015– July 2016
Track Data: ASDE-X from 12 days of operation, 2015-2016

Runway 33L Departure Concepts

- **Thrust and Speed Management**
  - Fleet-specific performance analysis and noise modeling
- **Flight track dispersion**
  - **Discontinuous (Open SID) procedures**
    - Initial RNAV segment on departure, transition to vectors to introduce dispersion, return to RNAV

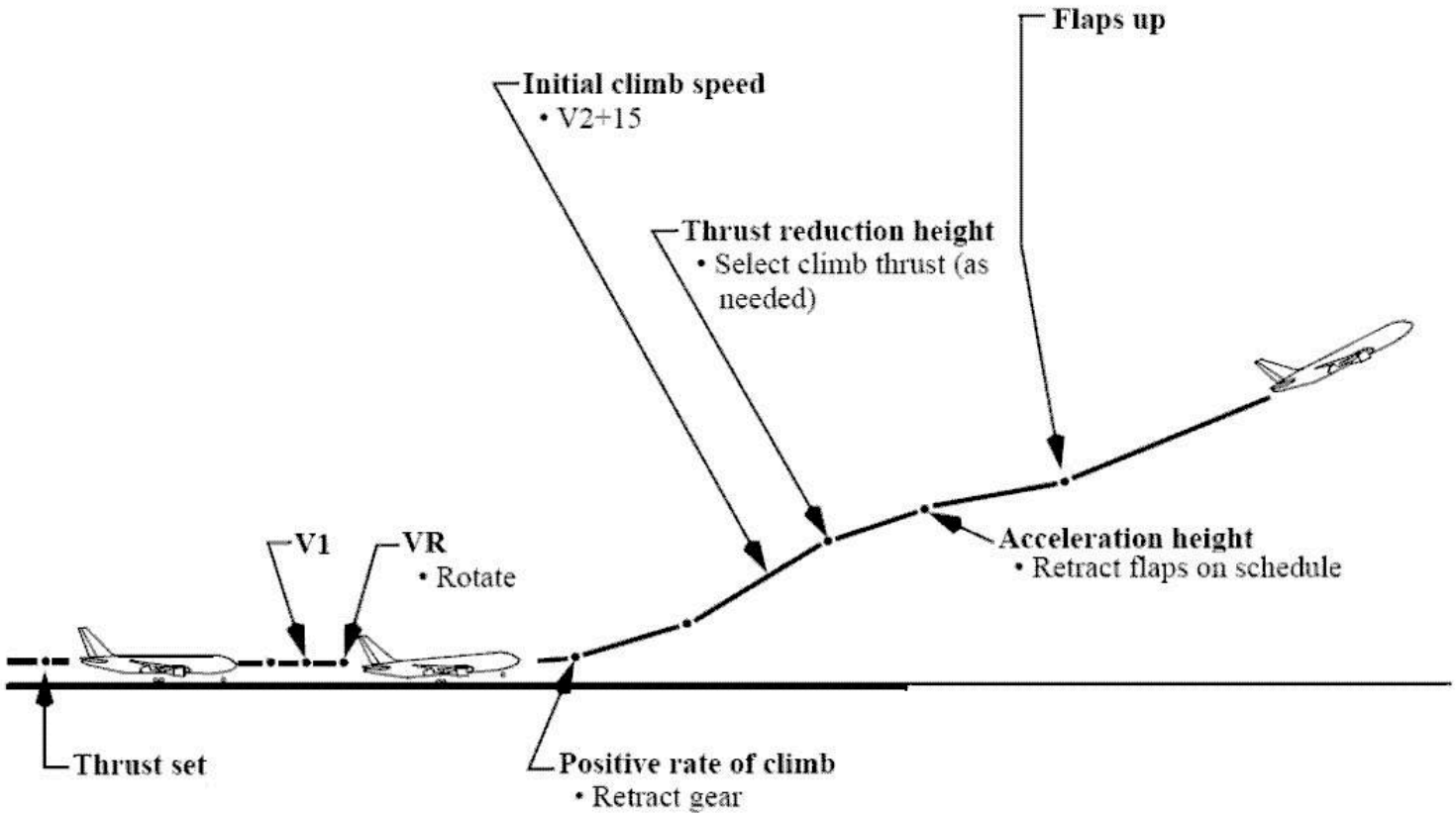


2015-2016 Noise Complaints at BOS with 12 Days of Departure Tracks



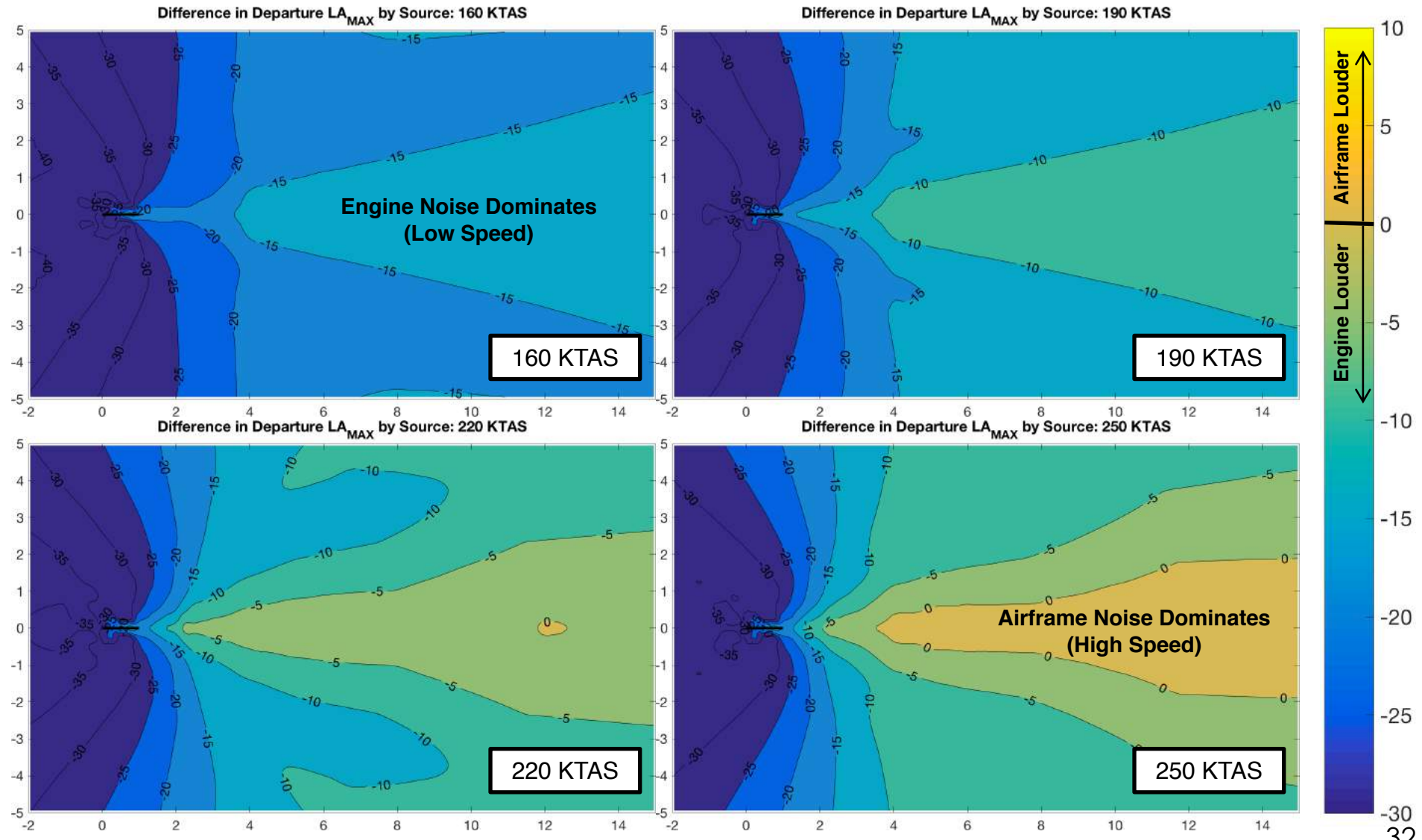
Standard Departure Definition

- Standard departure procedures vary by airline
- Typical profile includes thrust reduction at 1,000' AGL followed by an **acceleration to climb speed** and **flap retraction**



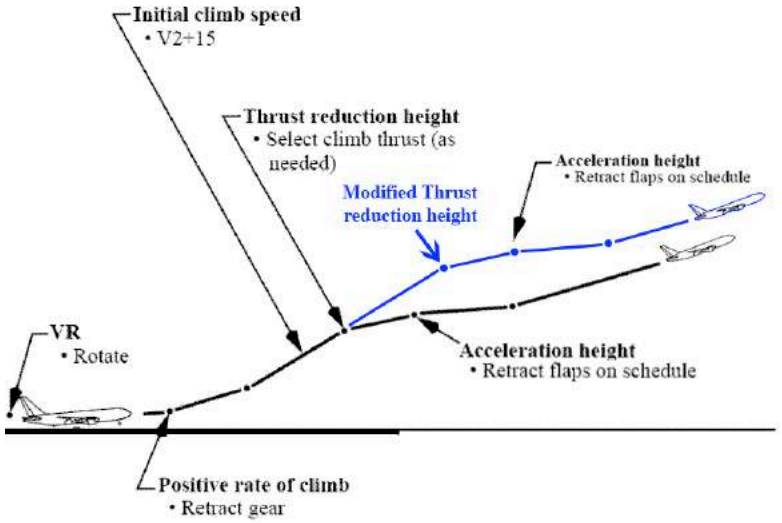
Increasing Speed causes Increased Airframe Noise

As speed increases, airframe noise becomes as loud or louder than engine noise

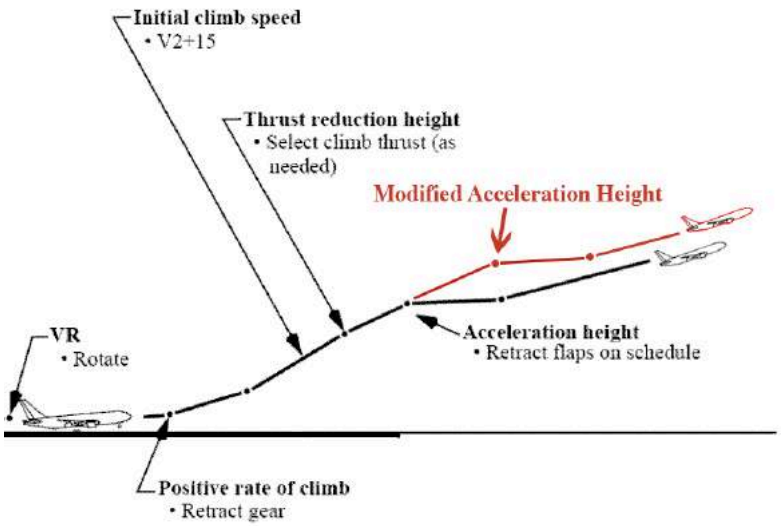


Potential Modifications to Climb Profiles

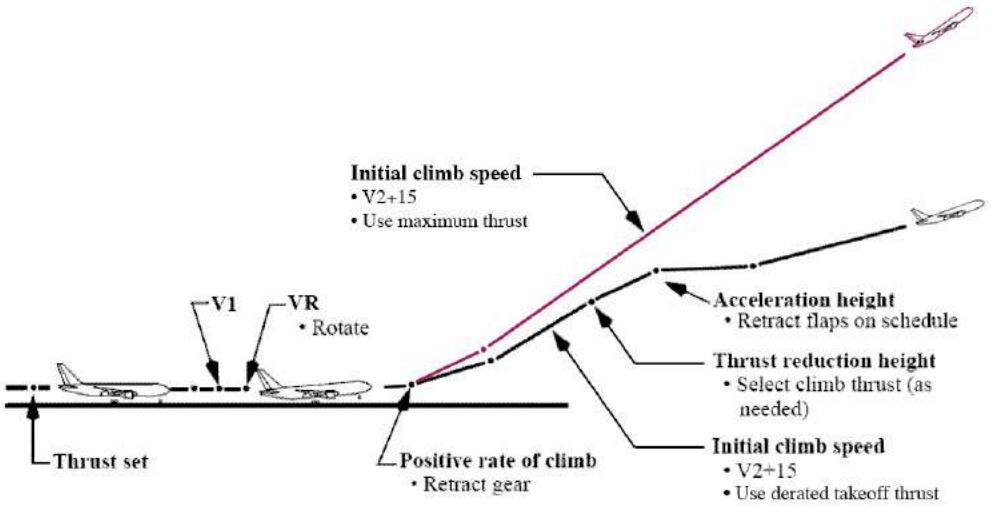
Higher Thrust Reduction Height



Higher Acceleration Height



Maximum Performance Climb



FMS: VNAV Climb Scheduling

- **THR RED: Thrust Reduction Height**
  Altitude (AGL) at which engine thrust is reduced from takeoff to climb thrust.

- **ACC: Acceleration Height**
  Altitude (AGL) at which the aircraft is first pitched down to accelerate. Takeoff climb speed (e.g. V2+15) is maintained up to this altitude.

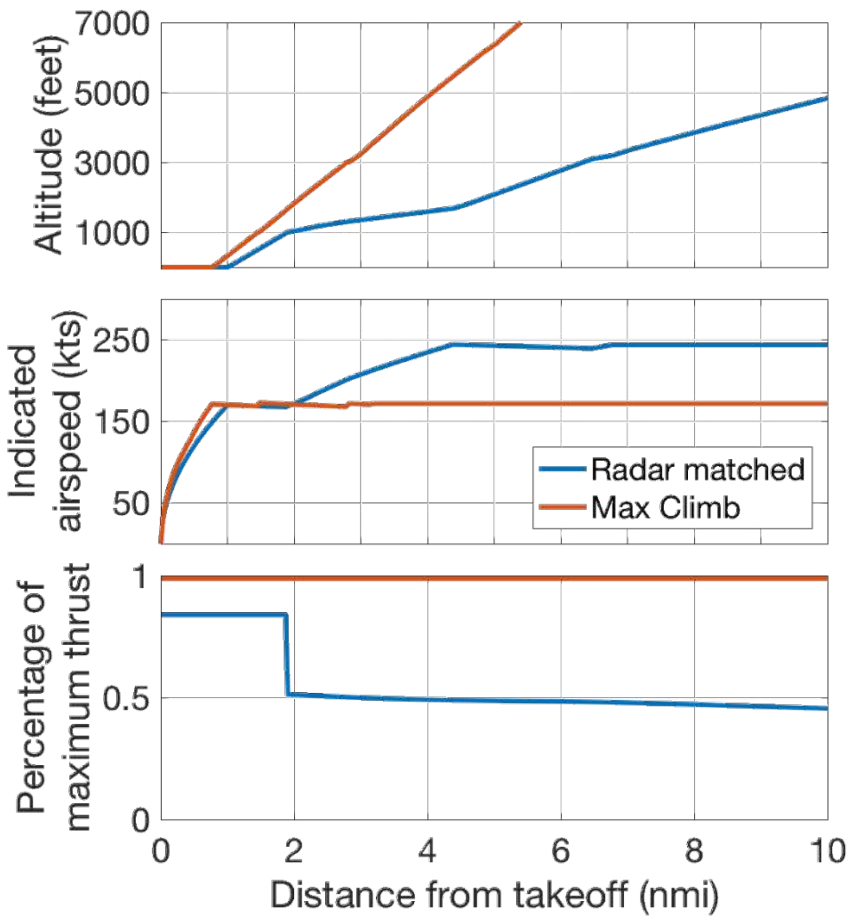
  - These parameters may be set manually and separately.

  - Operators define their own values in their SOP, which can vary based on airports of operation.

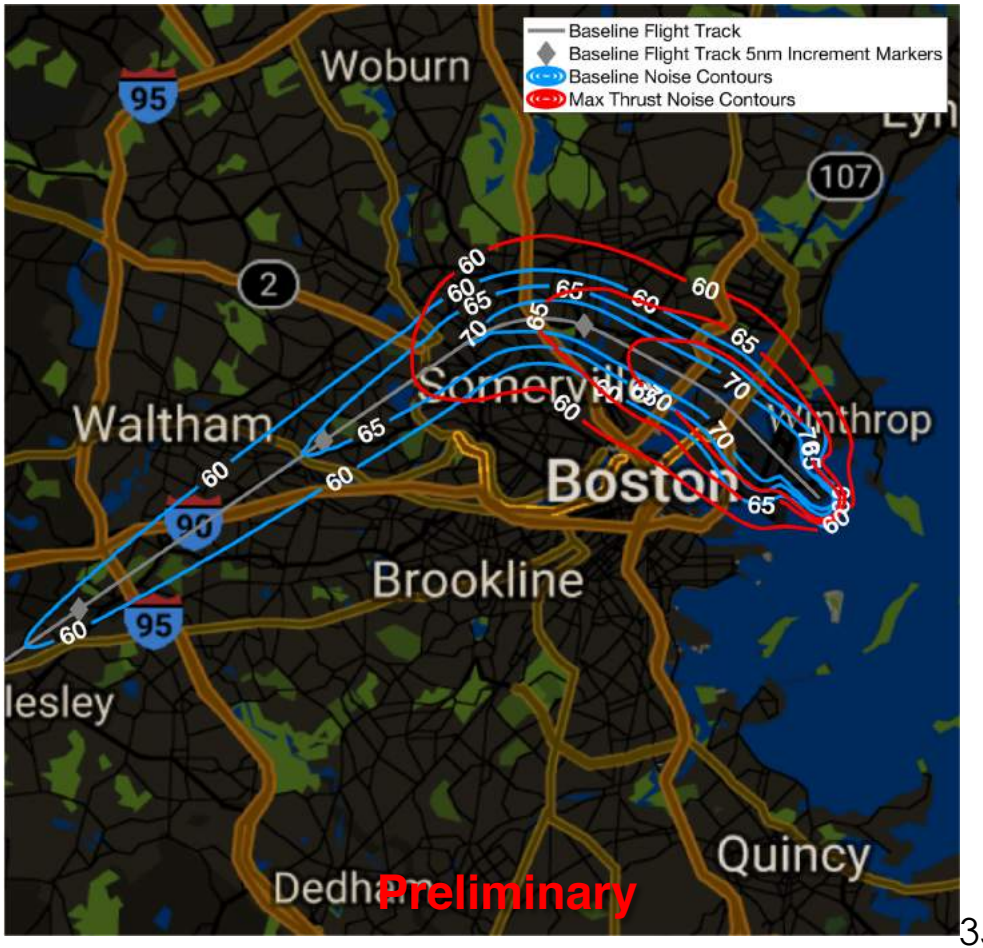
  - Photo on the right shows an Airbus MCDU. The Boeing FMC has identical capabilities.

Graphic Adapted from Airbus

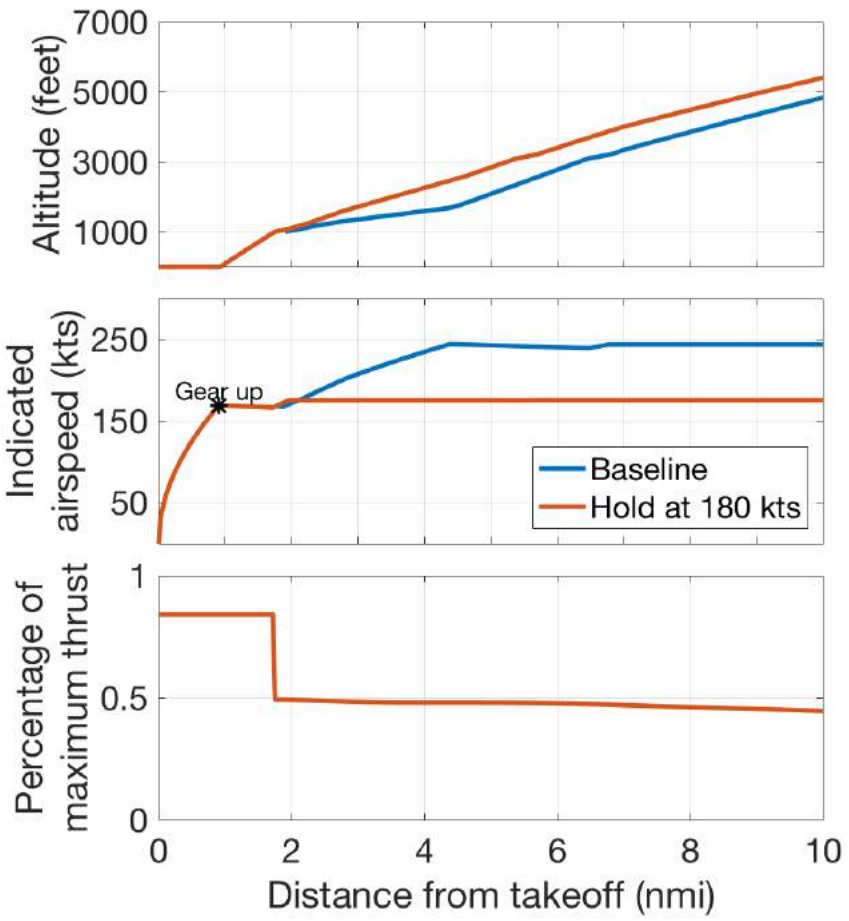
737-800: Maximum Thrust, Reduced-Speed Climb



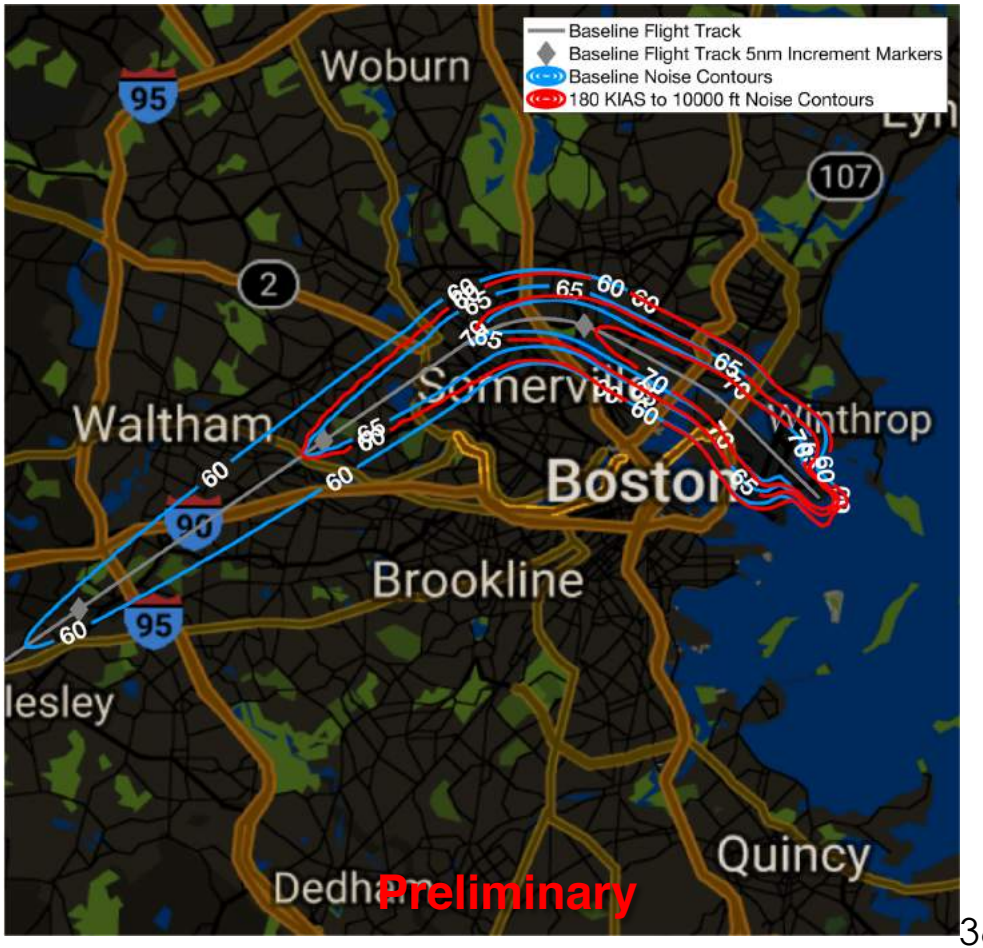
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Maximum Climb Thrust & V_2 to 10,000’



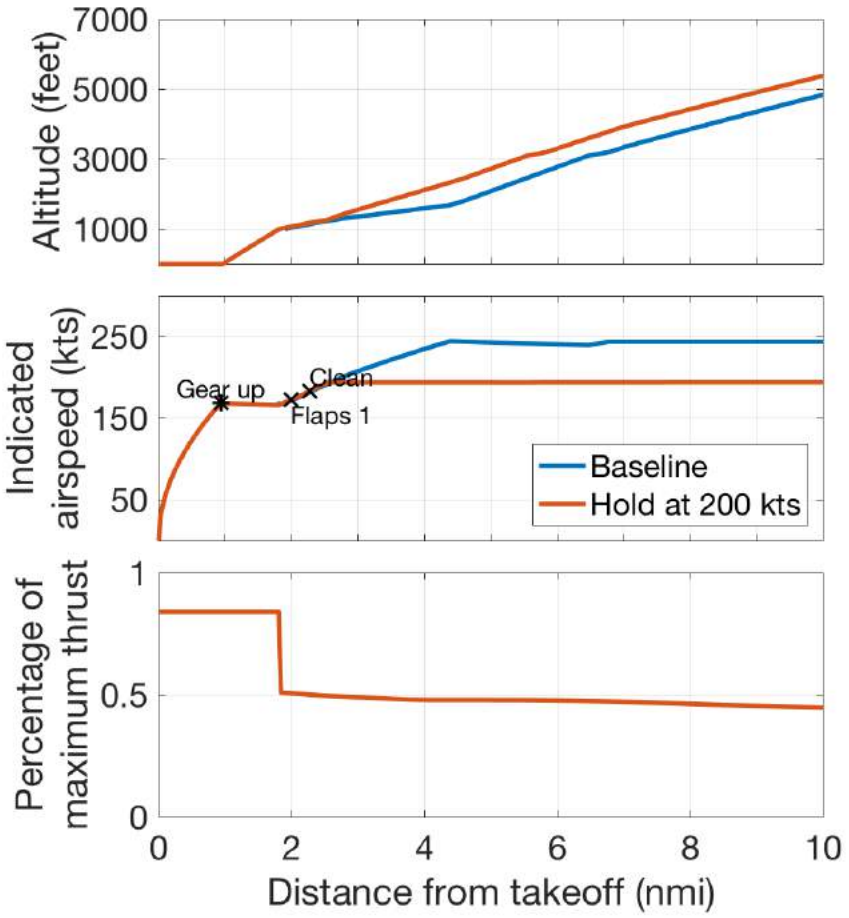
737-800: Delayed Acceleration Climb – 180 knots



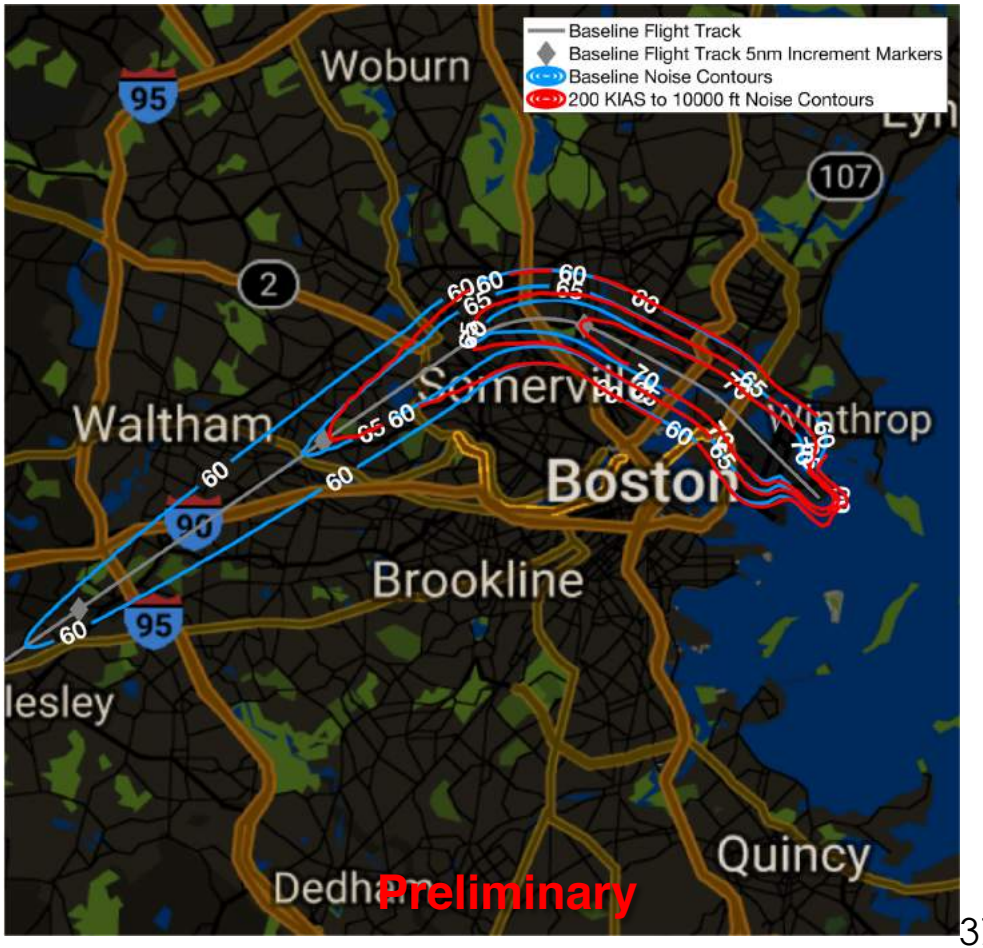
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & 180 KIAS to 10,000’



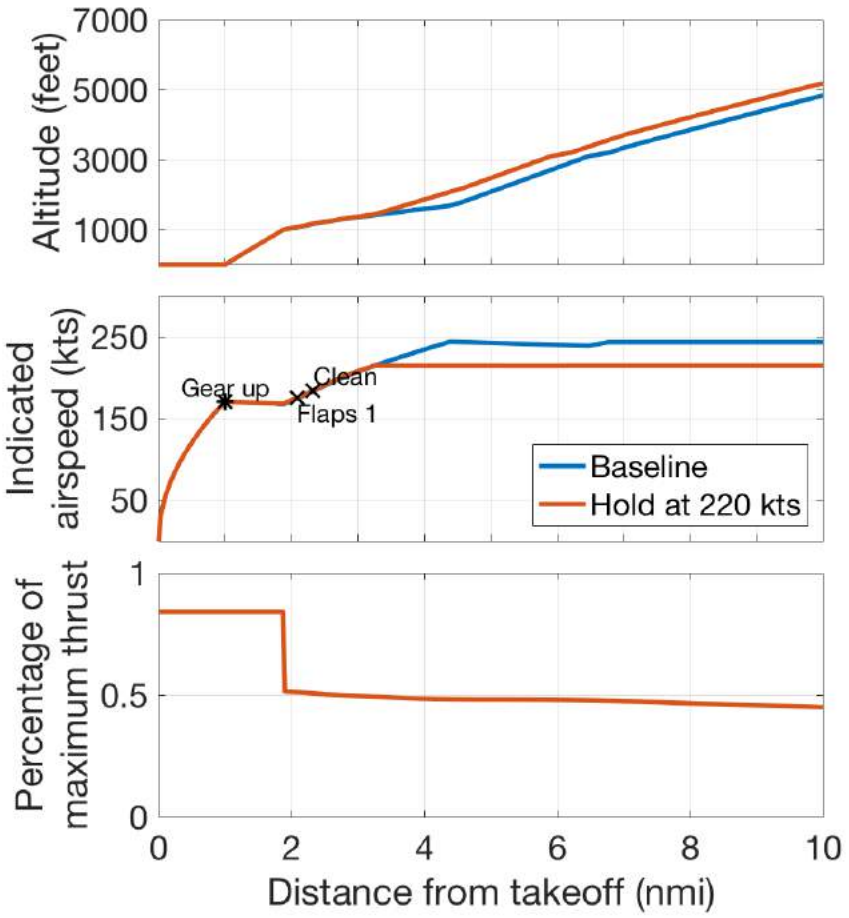
737-800: Delayed Acceleration Climb – 200 knots



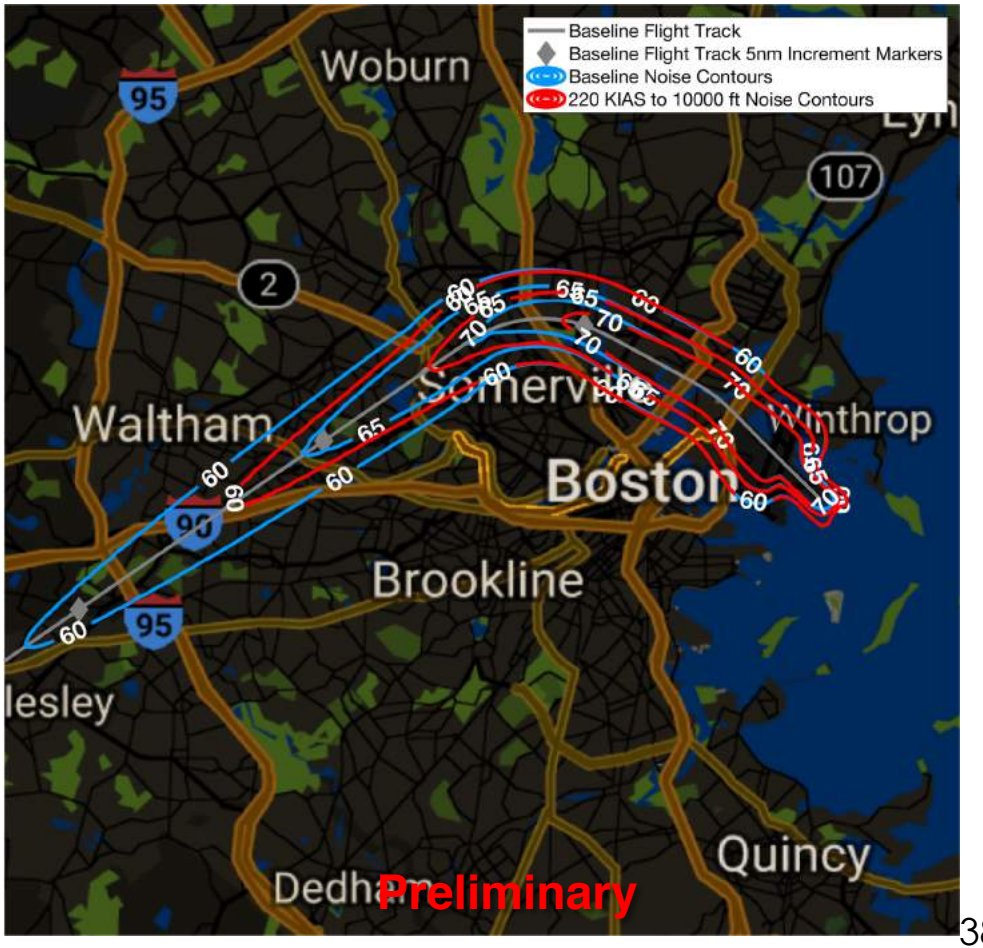
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & 200 KIAS to 10,000’



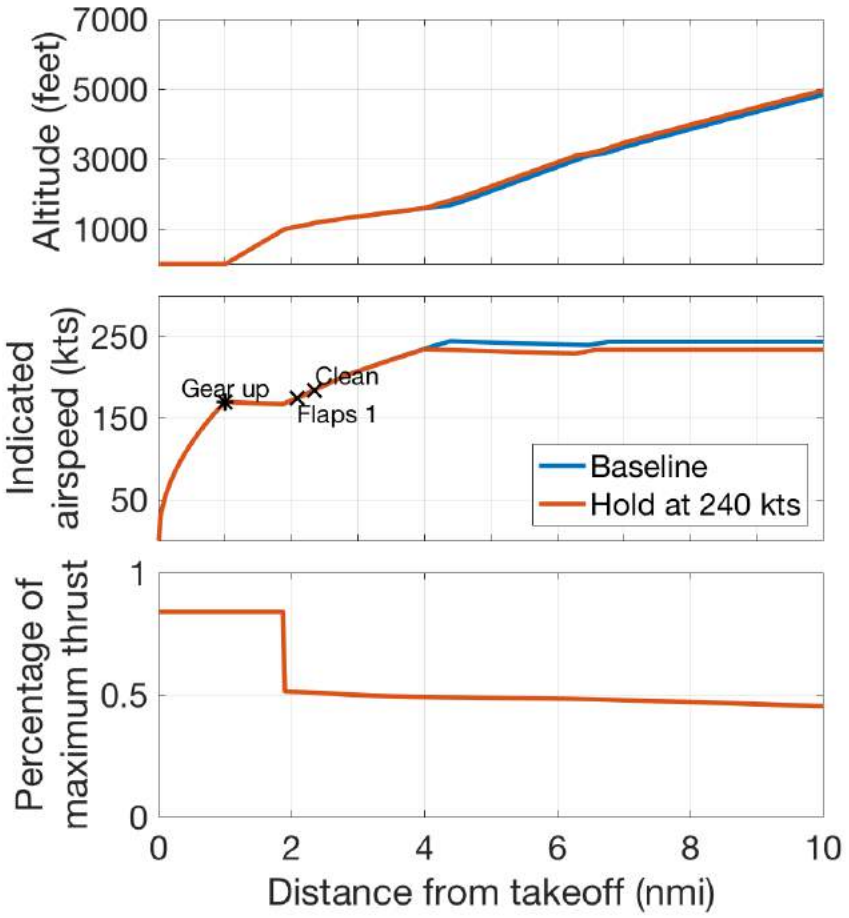
737-800: Delayed Acceleration Climb – 220 knots



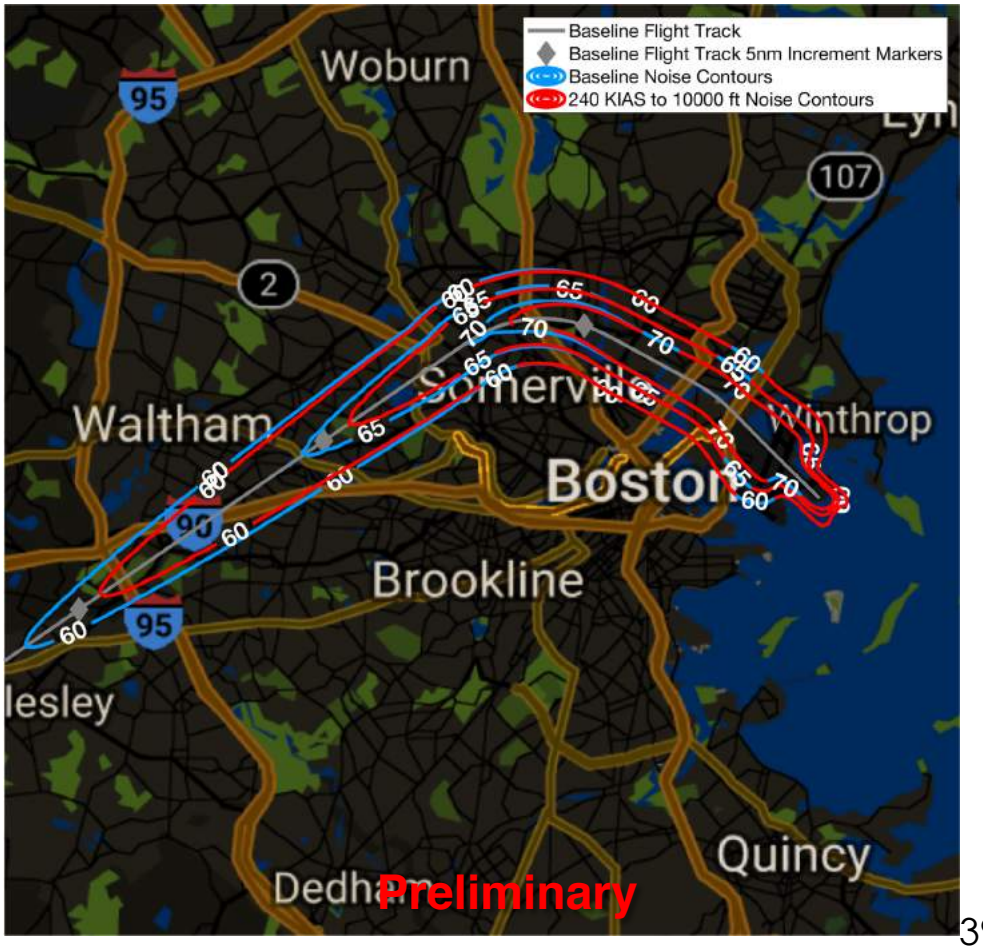
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & 220 KIAS to 10,000’



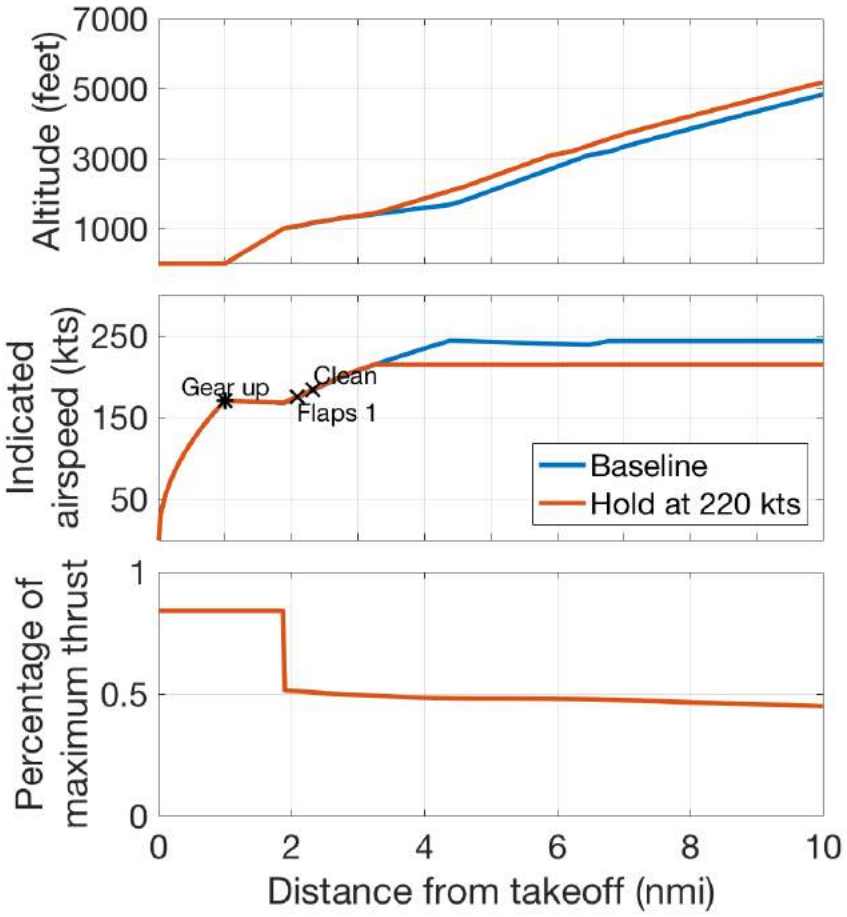
737-800: Delayed Acceleration Climb – 240 knots



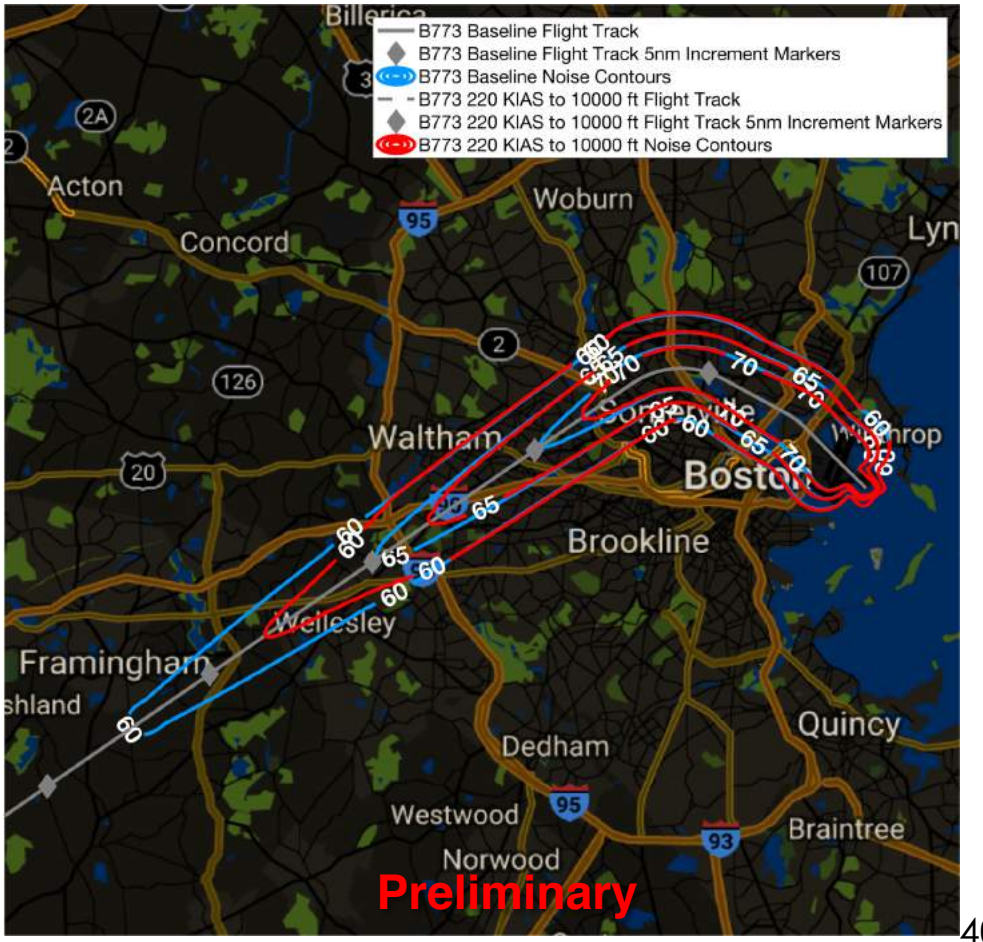
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & 240 KIAS to 10,000’



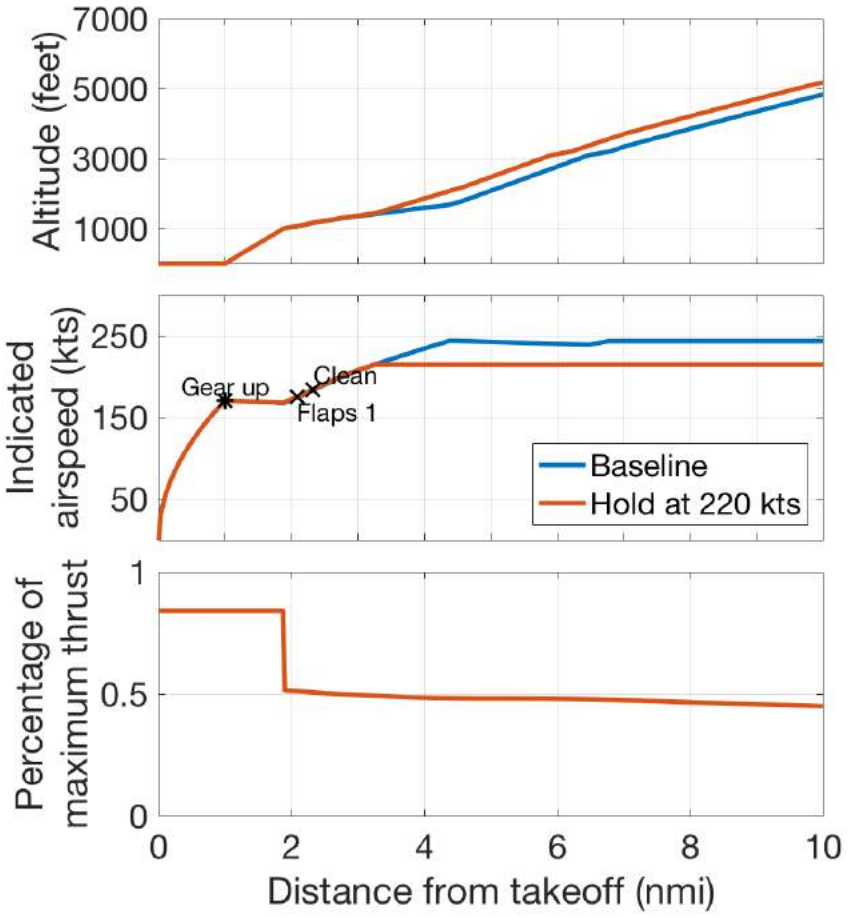
777-300: Delayed Acceleration Climb – 220 knots



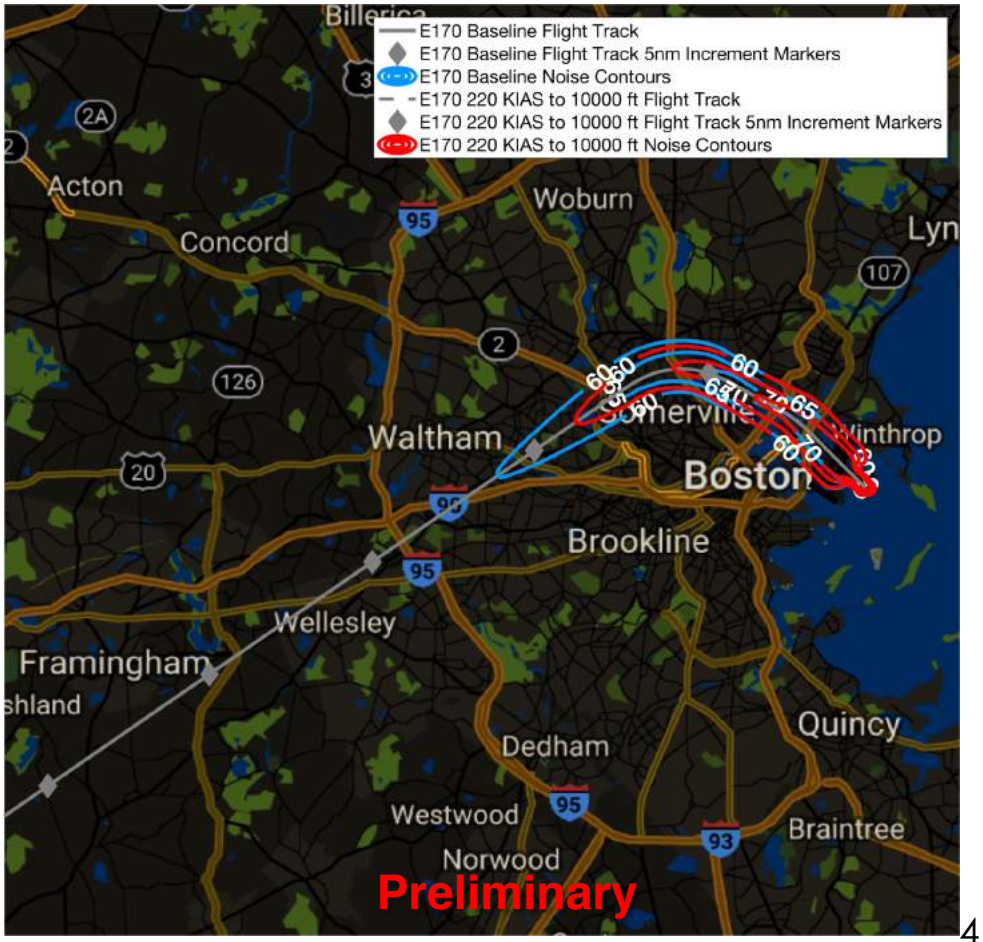
Aircraft	B777-300
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & 220 KIAS to 10,000’



E-170: Delayed Acceleration Climb – 220 knots

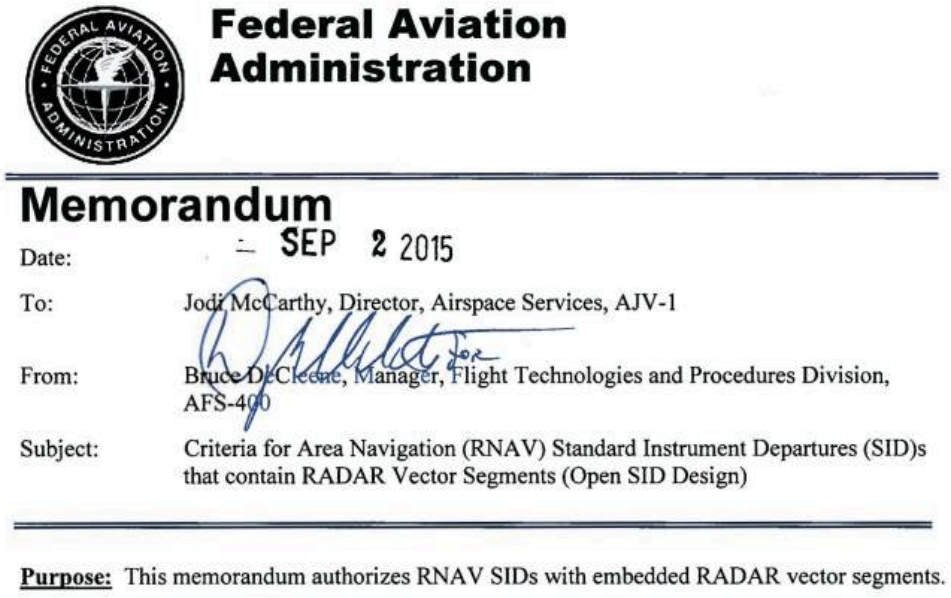


Aircraft	E-170
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 33L: Maintain Standard Climb Thrust & 220 KIAS to 10,000’



Introducing Open SID Concept

- Open SIDs are RNAV departure procedures that allow for embedded ATC radar vector segments.
  - Vectoring can be used to guide an aircraft to join an RNAV track, remove an aircraft from an RNAV track, or a combination of both.
- Open SIDs were authorized by an FAA memo signed in 2015.



Federal Aviation Administration

Memorandum

Date: SEP 2 2015

To: Jodi McCarthy, Director, Airspace Services, AJV-1

From: Bruce DeCleene, Manager, Flight Technologies and Procedures Division, AFS-400

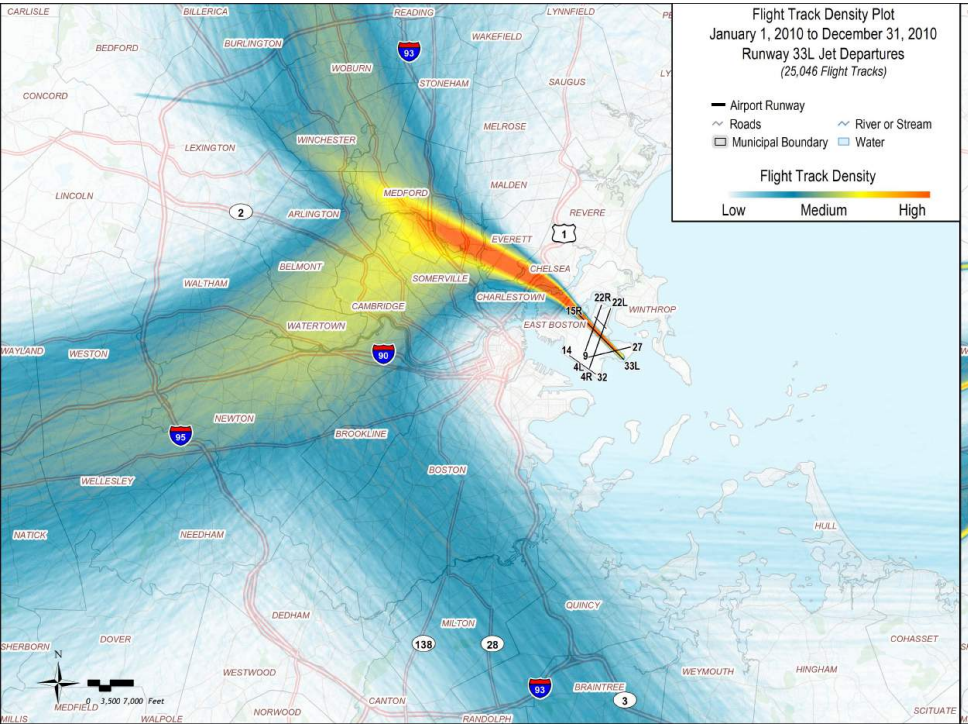
Subject: Criteria for Area Navigation (RNAV) Standard Instrument Departures (SID)s that contain RADAR Vector Segments (Open SID Design)

Purpose: This memorandum authorizes RNAV SIDs with embedded RADAR vector segments.

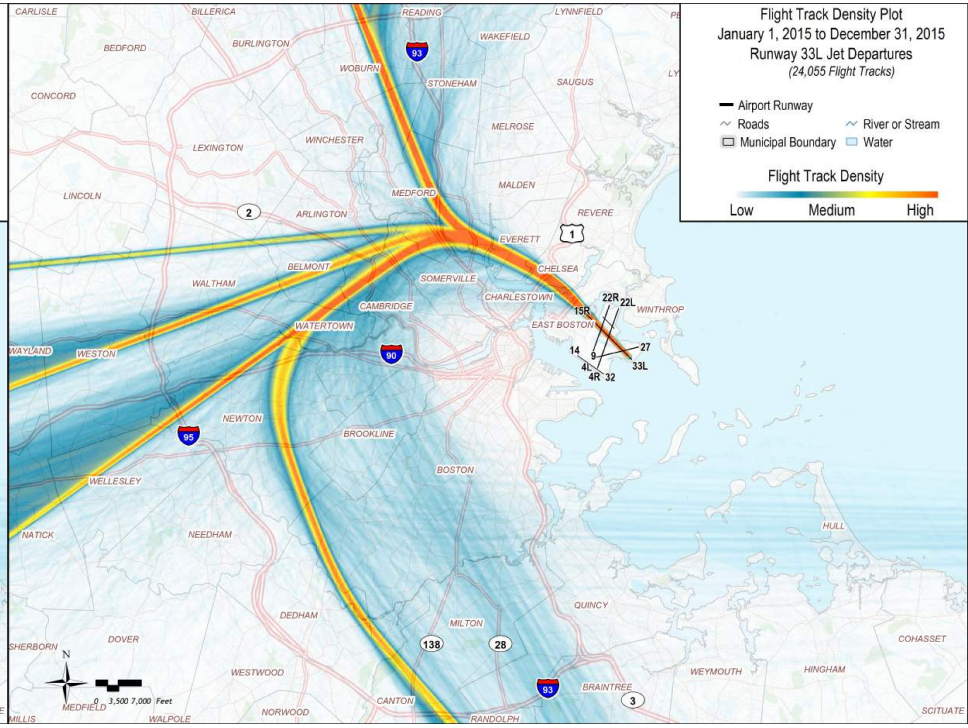
Runway 33L Departures: 2010-2015

Using Open SIDs to Re-introduce Dispersion

2010



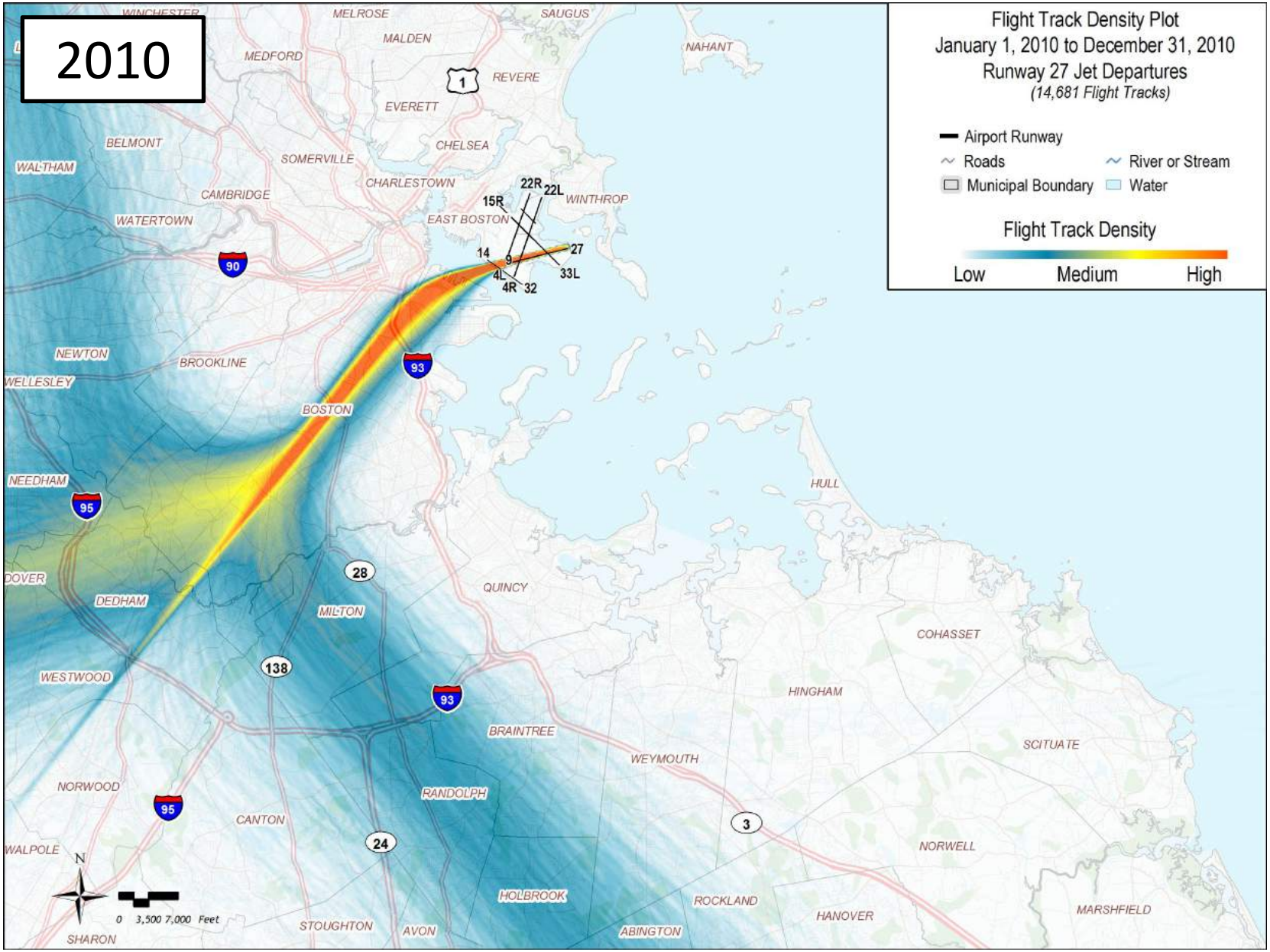
2015



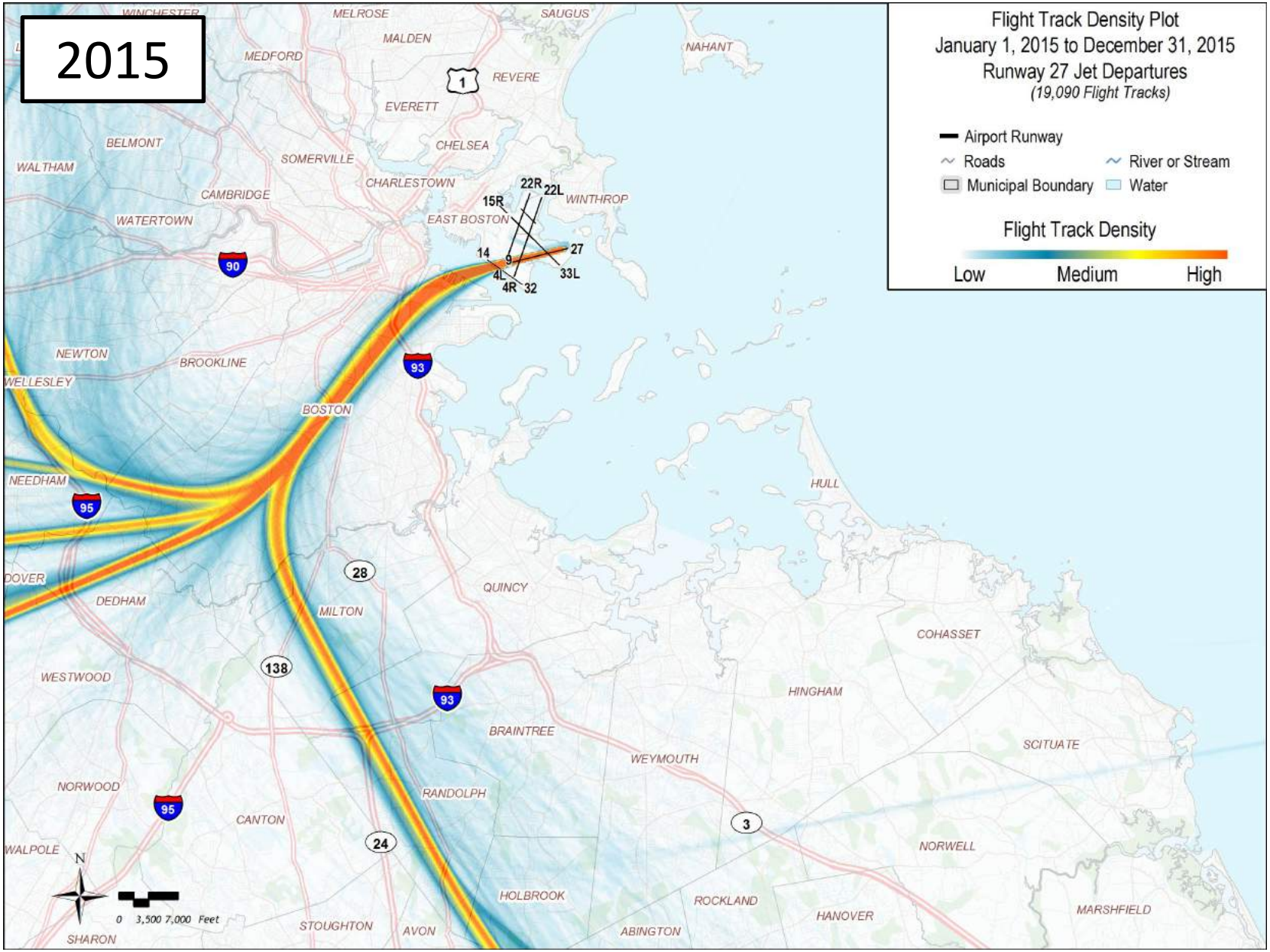
What were design constraints on existing RNAV SID?

Runway 27 Departures

Runway 27 Departures: 2010-2015

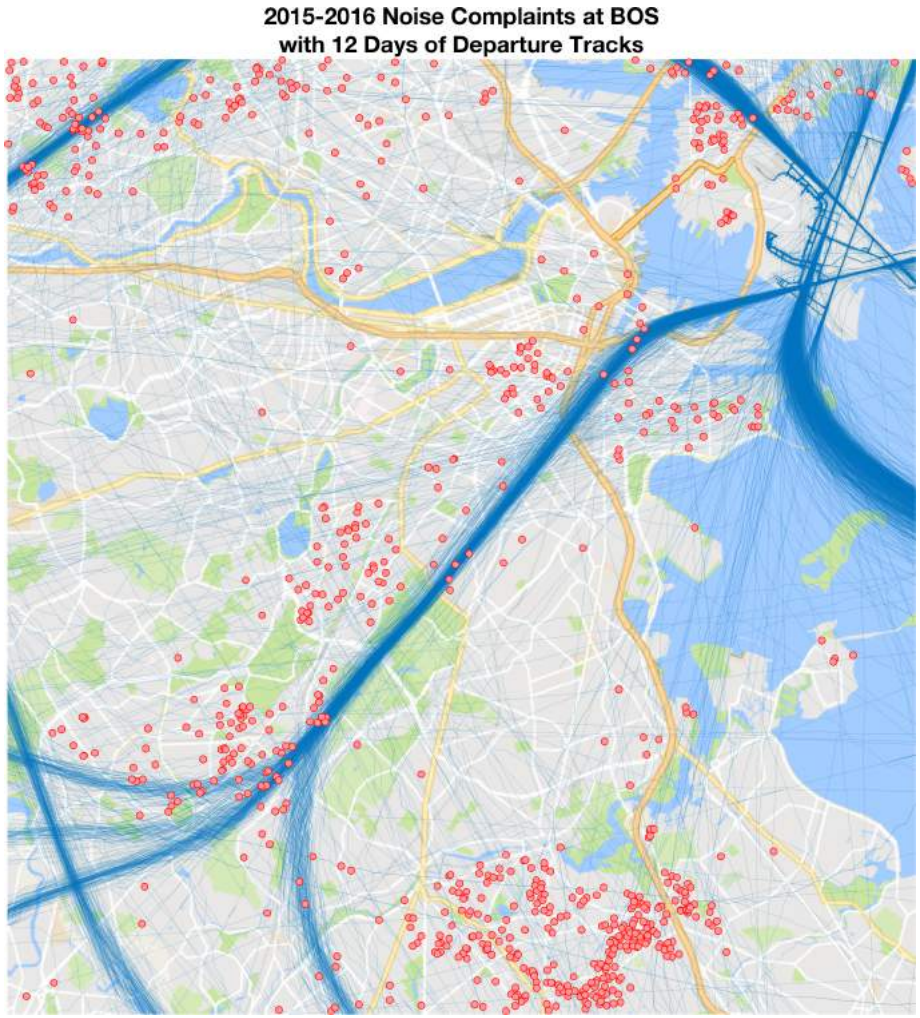


Runway 27 Departures: 2010-2015

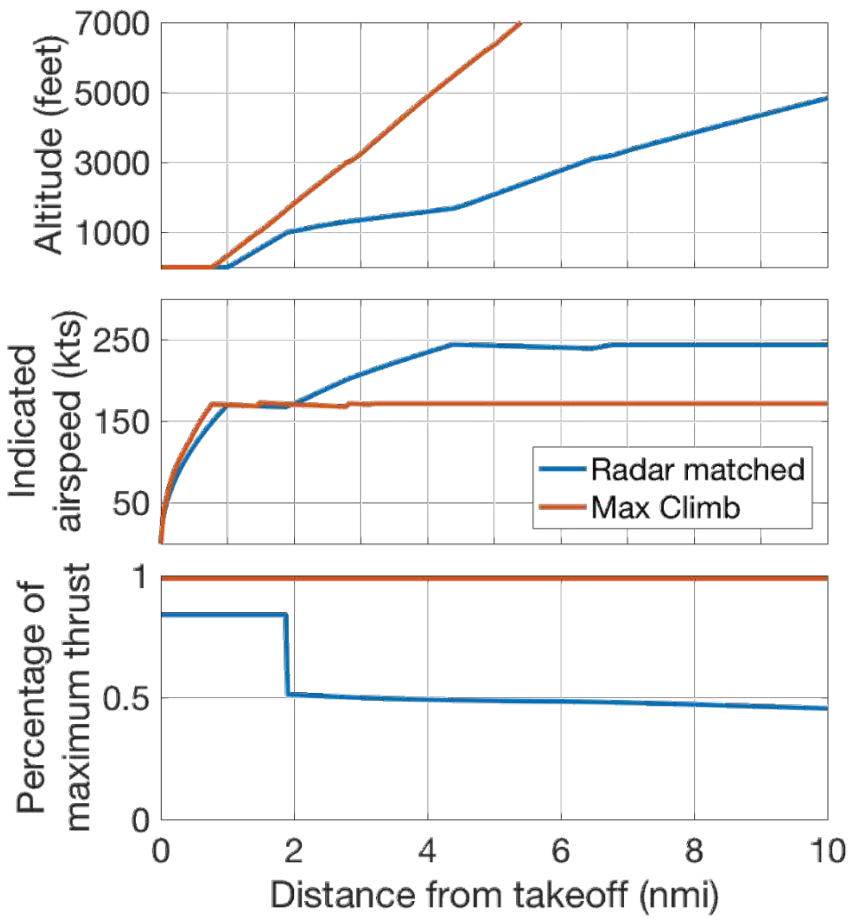


Runway 27 Departure Concepts

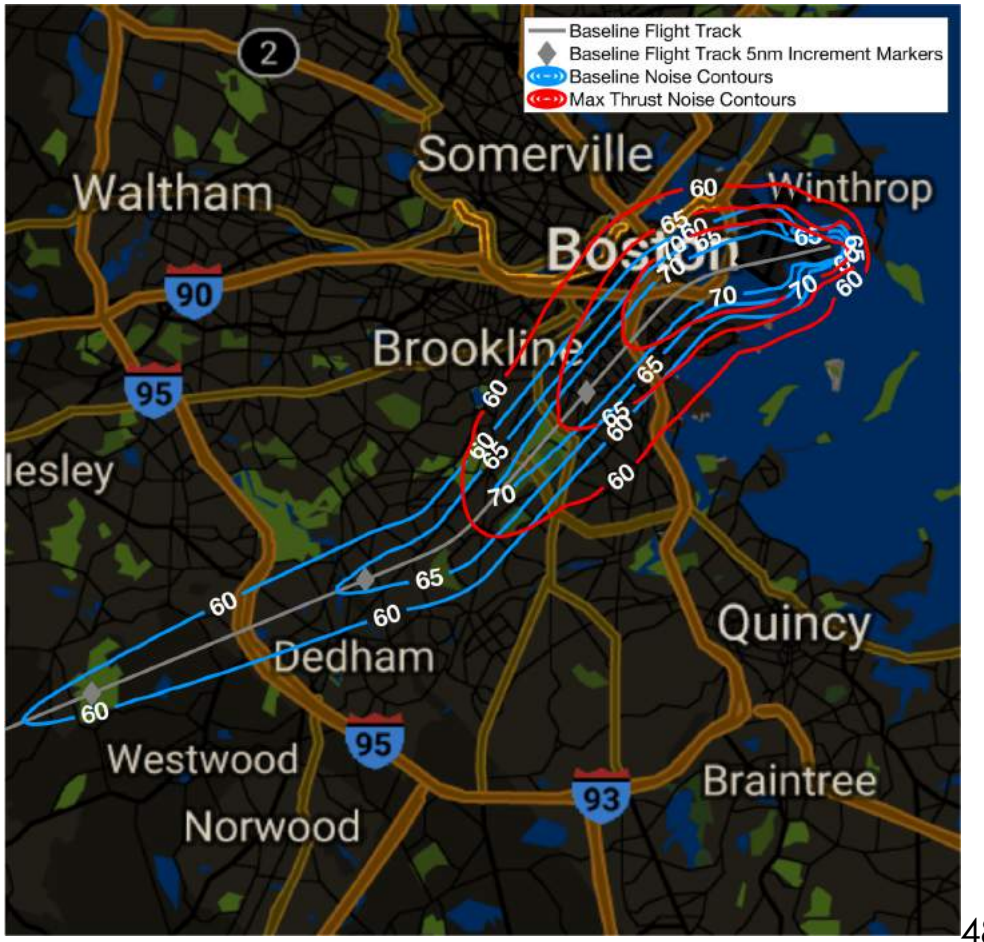
- **Thrust and Speed Management**
- **Open SID Dispersion**



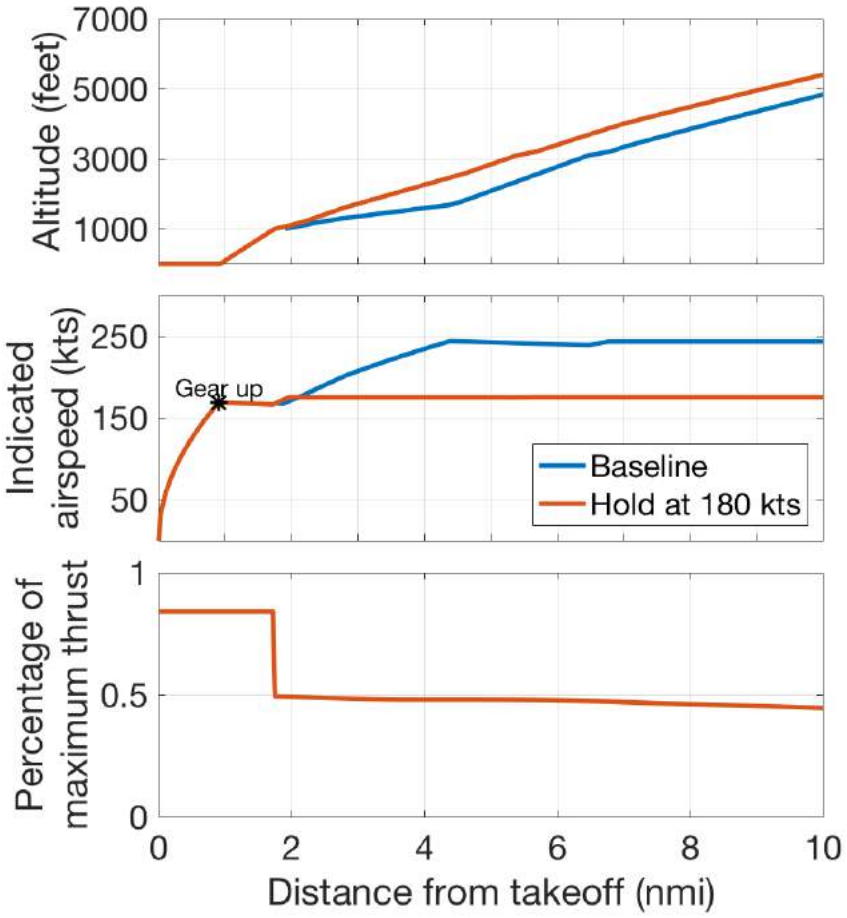
Maximum Thrust, Reduced-Speed Climb



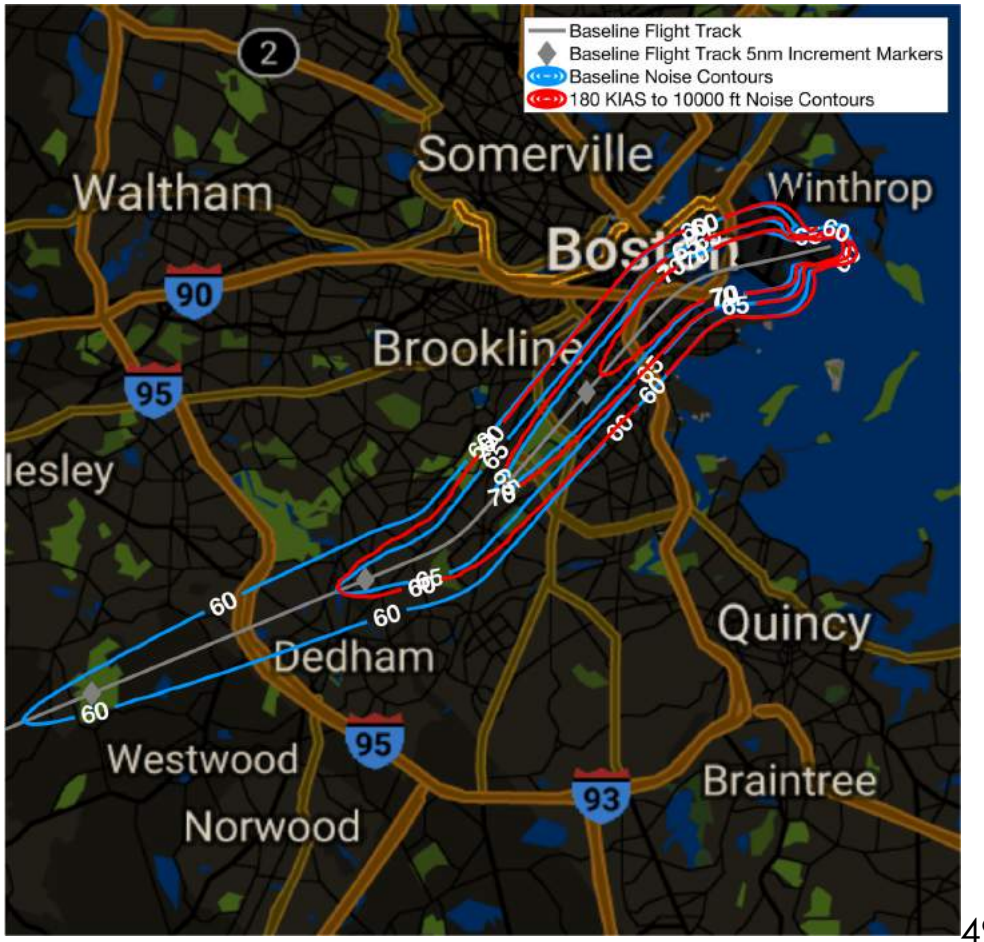
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 27: Maintain Maximum Climb Thrust & V_2 to 10,000’



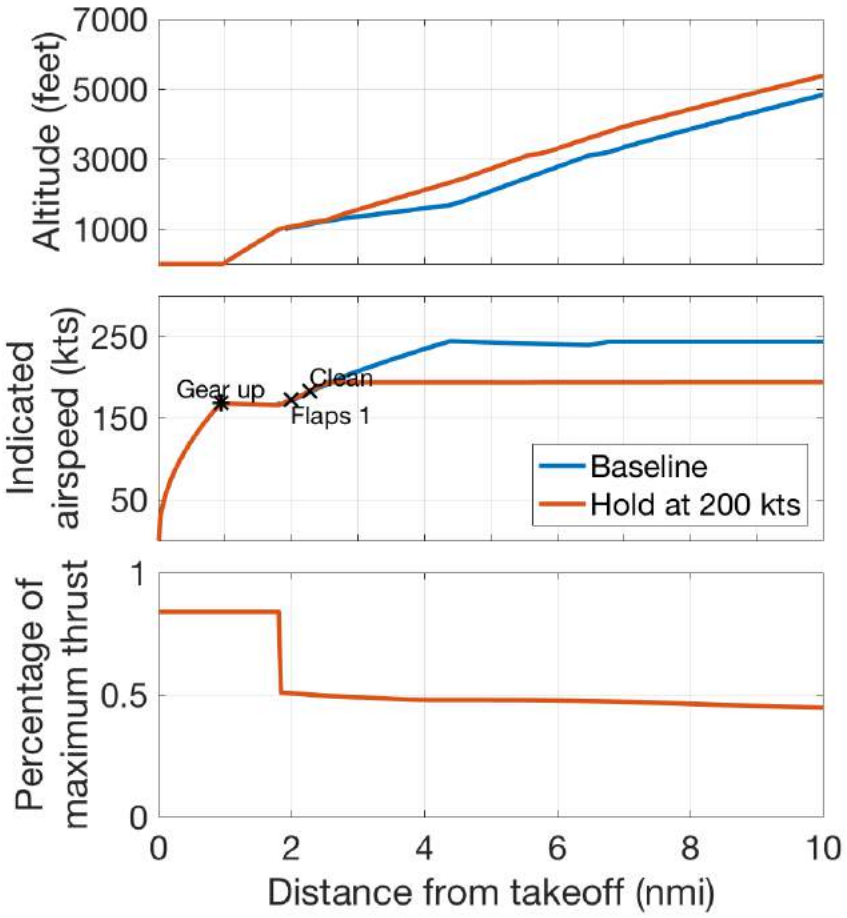
Delayed Acceleration Climb – 180 knots



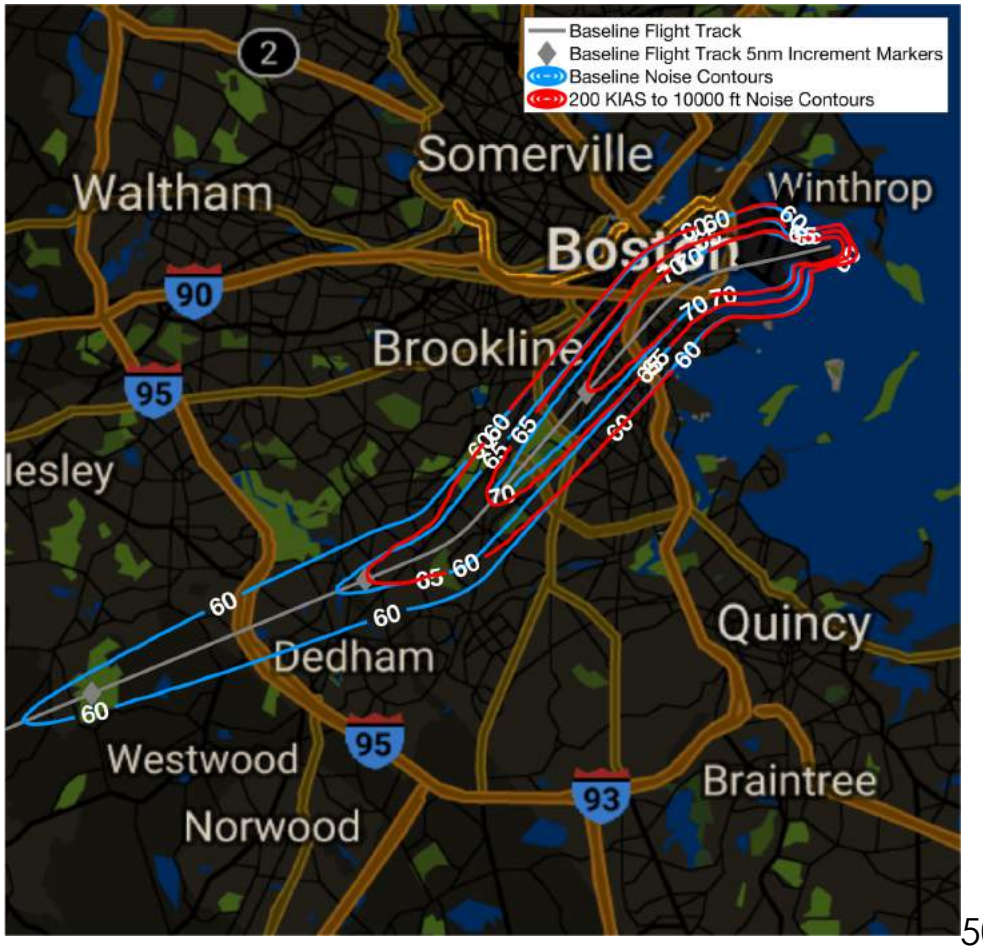
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 27: Maintain Standard Climb Thrust & 180 KIAS to 10,000’



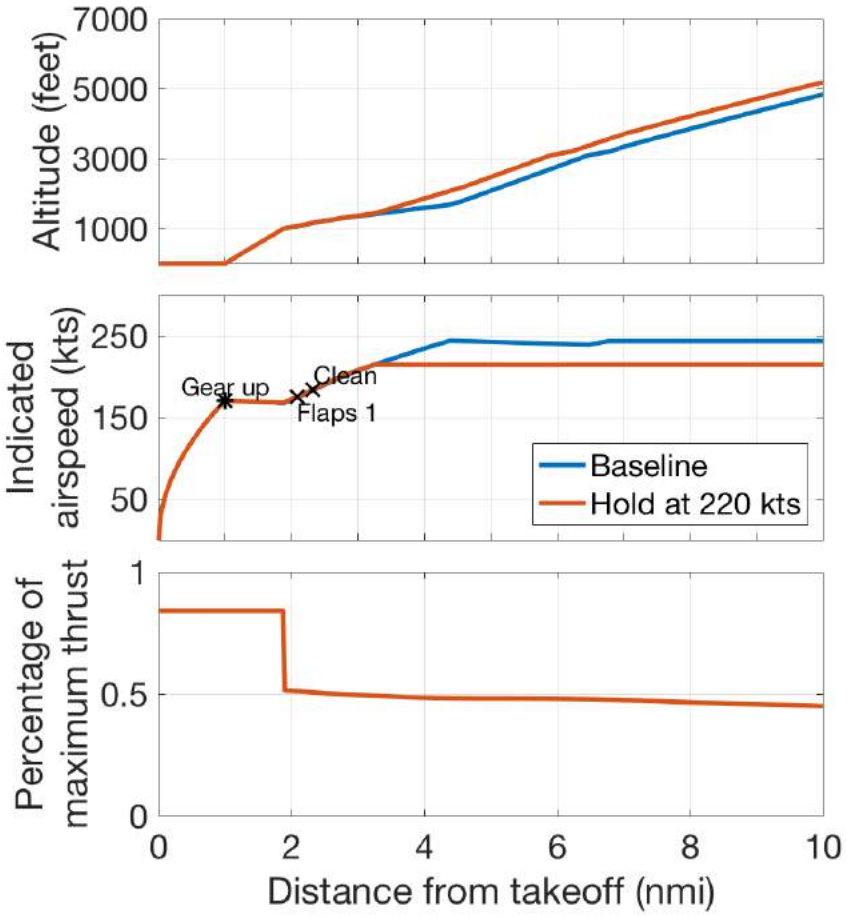
Delayed Acceleration Climb – 200 knots



Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 27: Maintain Standard Climb Thrust & 200 KIAS to 10,000’



Delayed Acceleration Climb – 220 knots



Aircraft	B737-800
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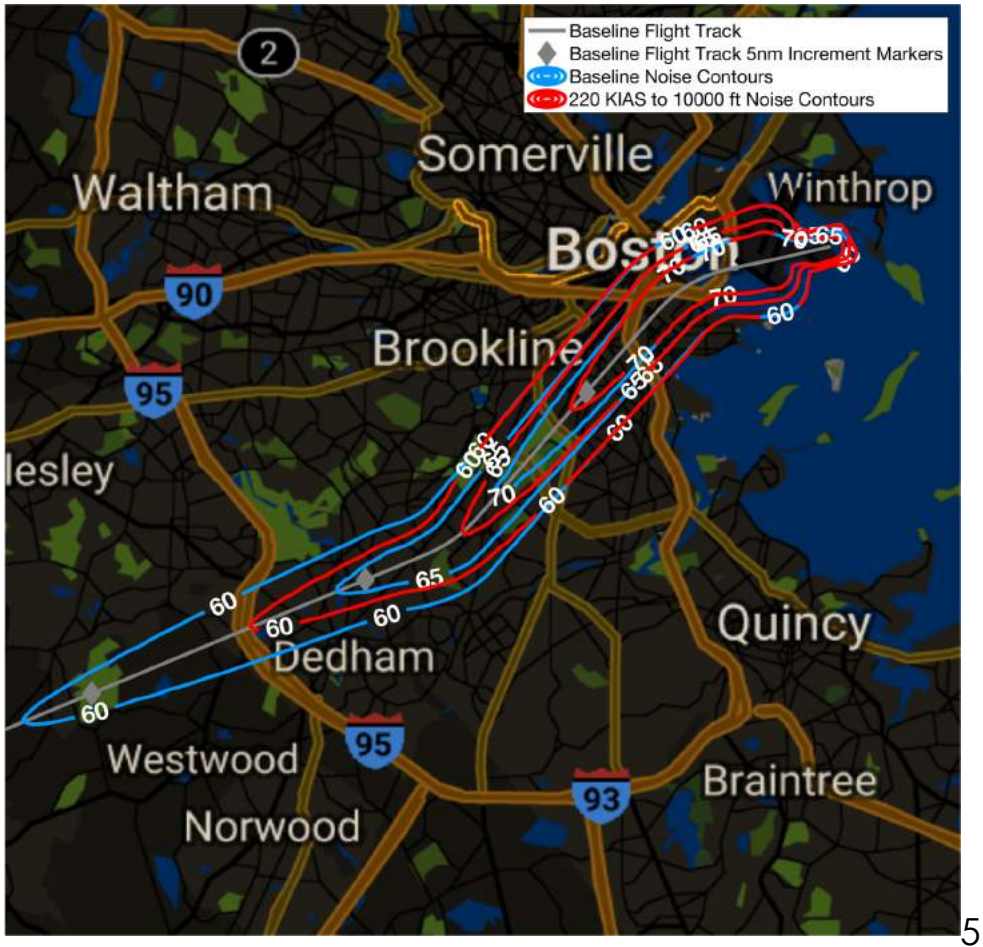
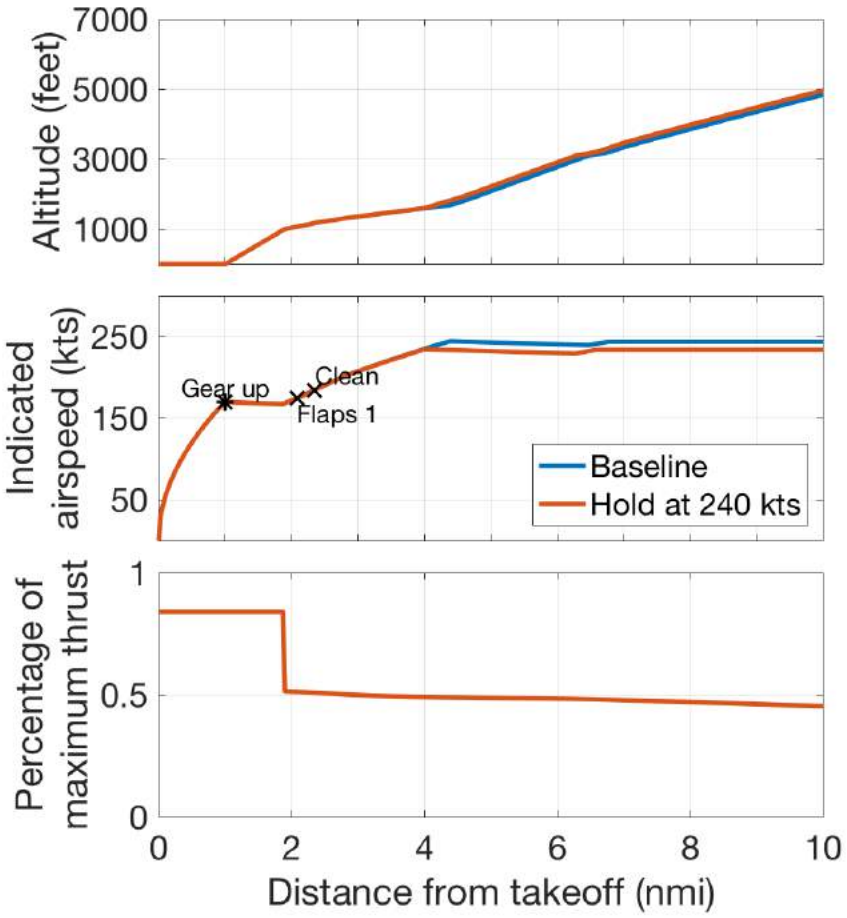
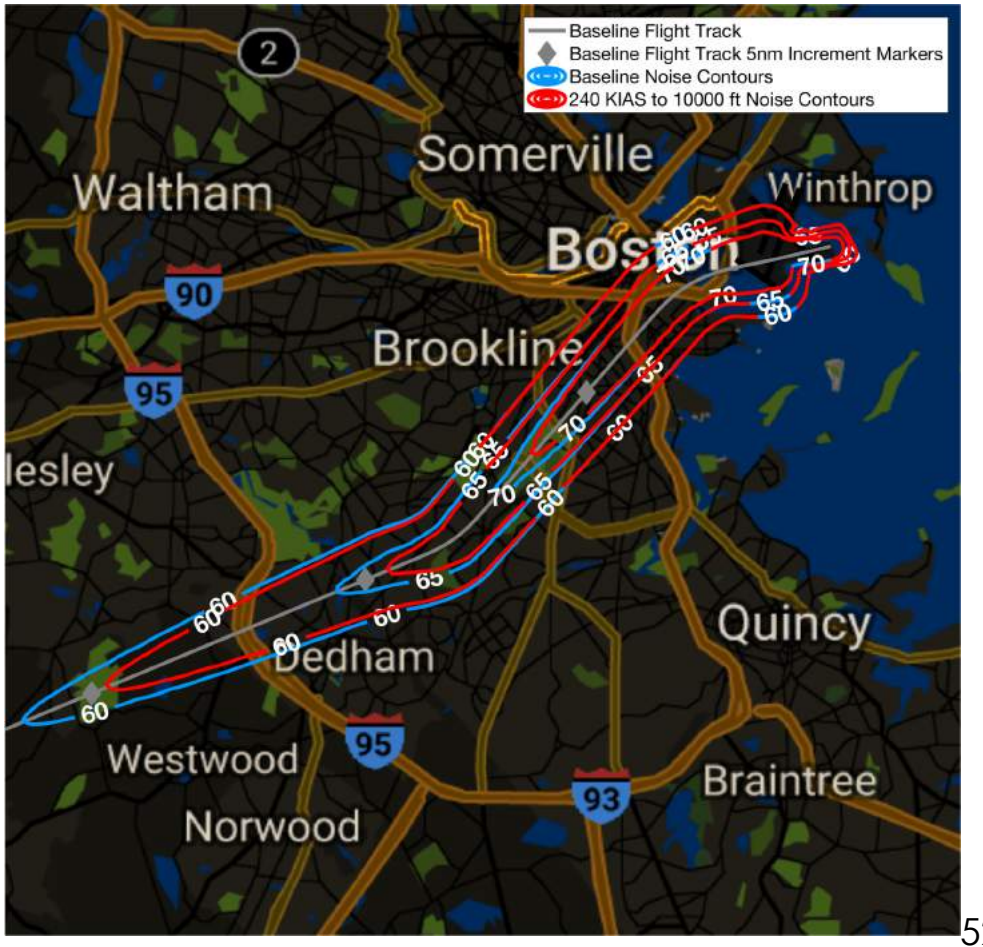


Delayed Acceleration Climb – 240 knots

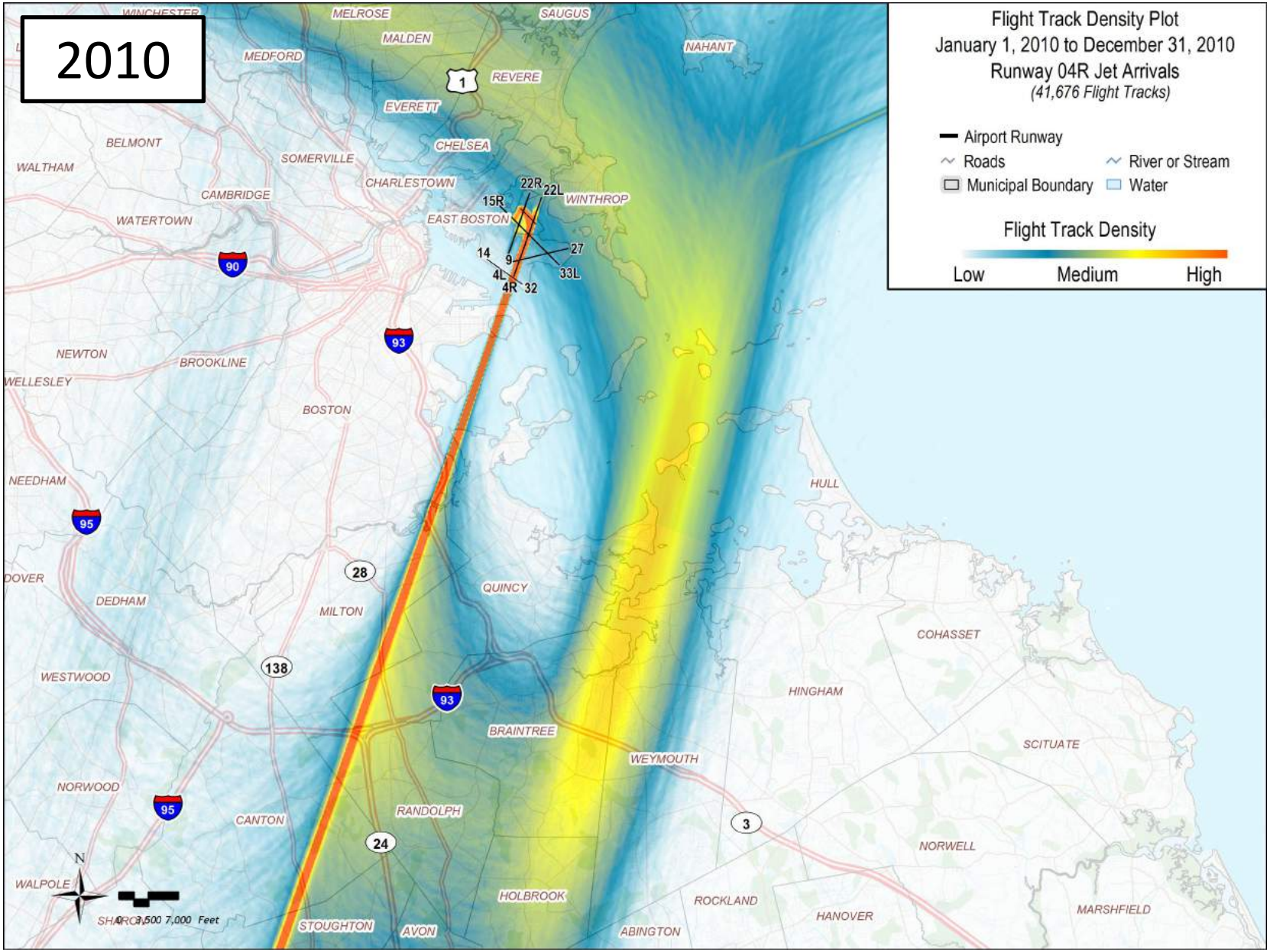


Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	ANOPP
Notes	Runway 27: Maintain Standard Climb Thrust & 240 KIAS to 10,000’

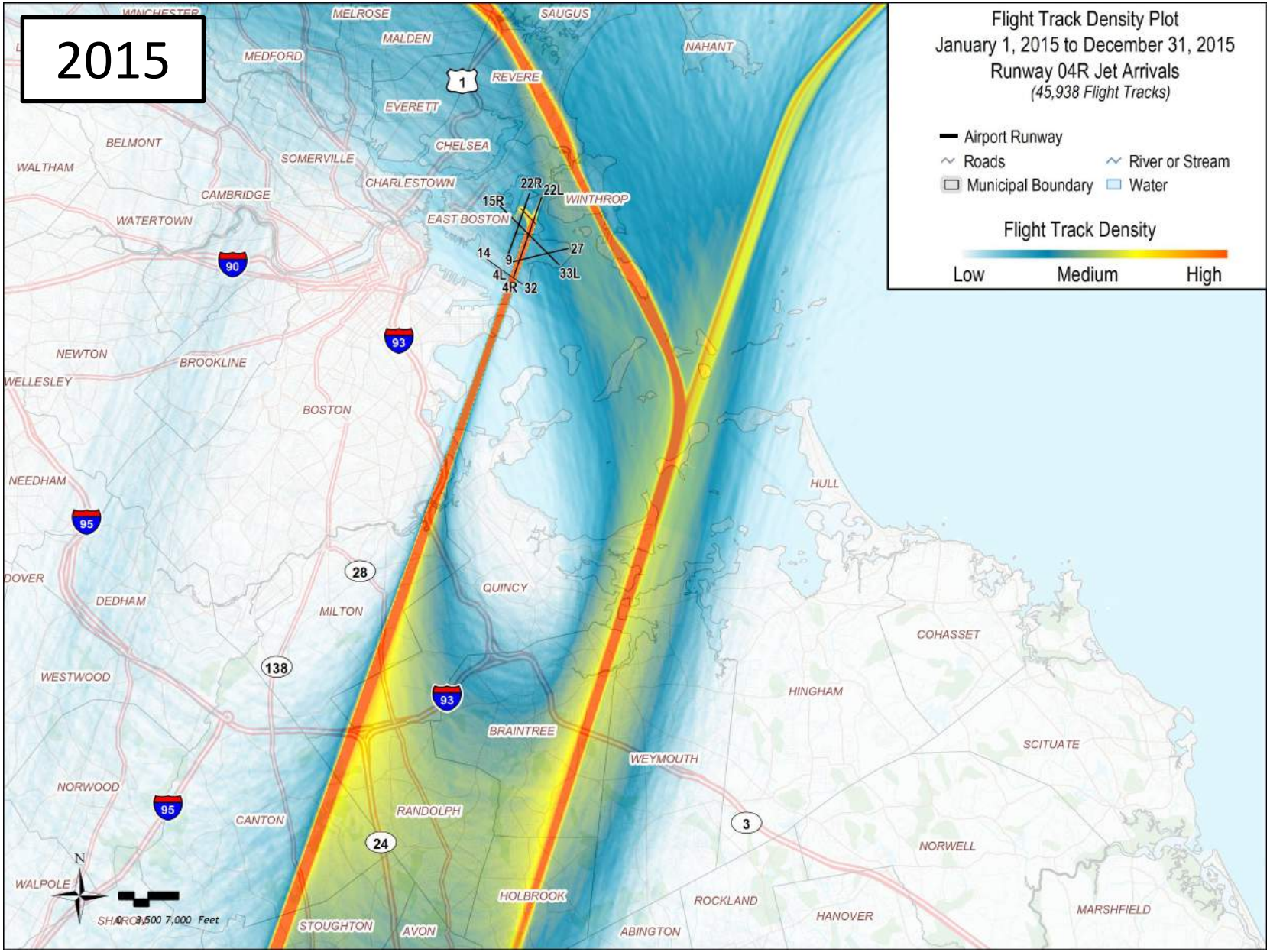


Runway 4R Arrivals

Runway 4R Arrivals: 2010-2015

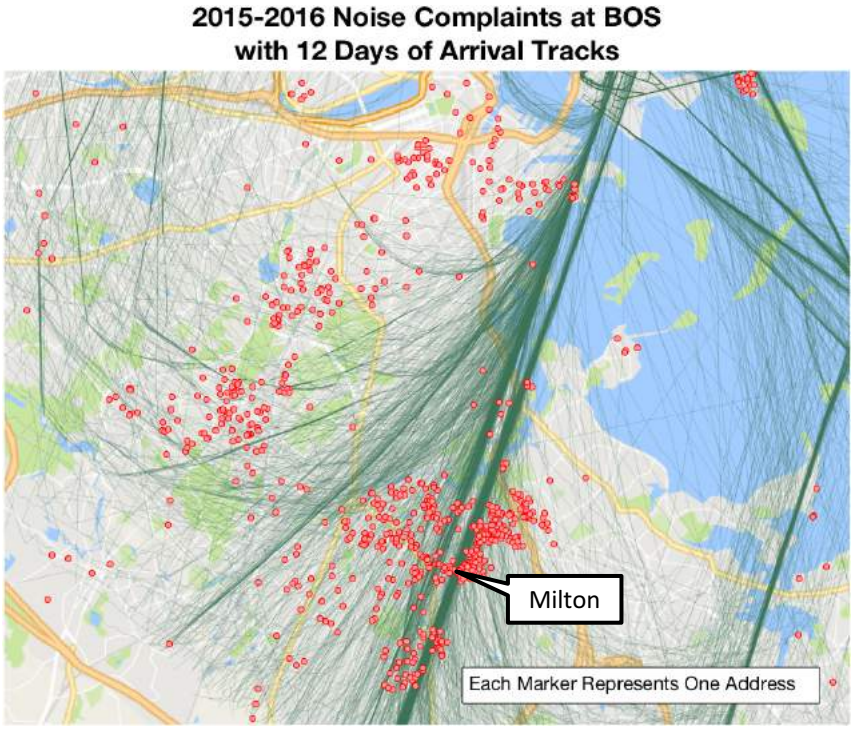


Runway 4R Arrivals: 2010-2015



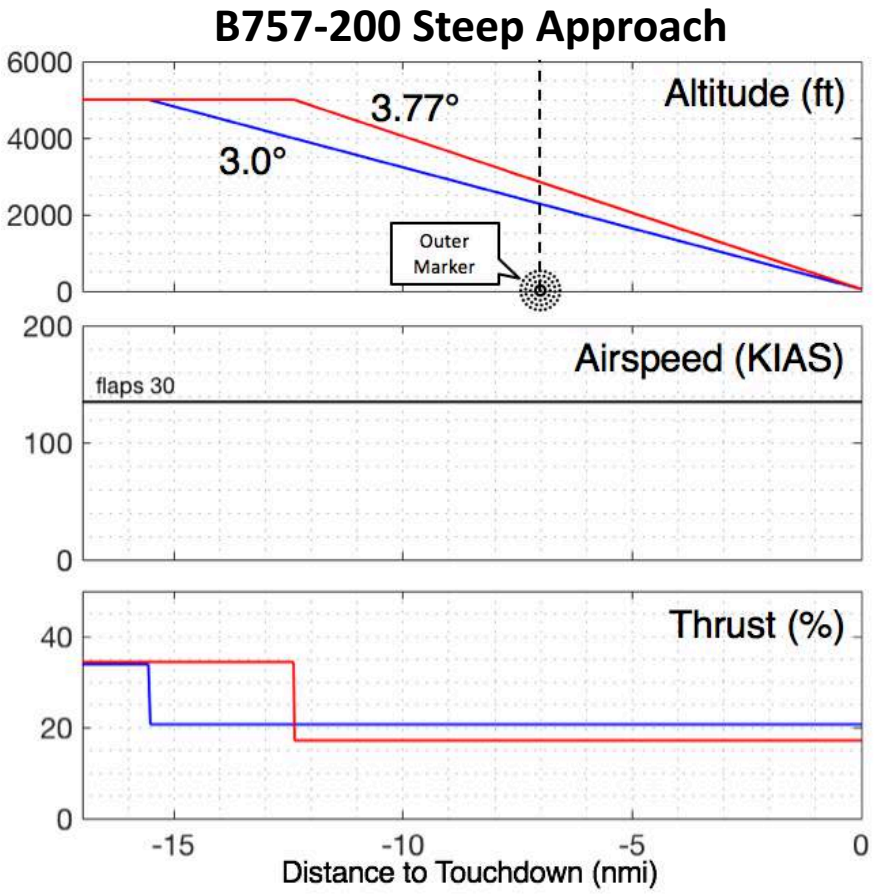
Runway 4R Arrival Noise Mitigations

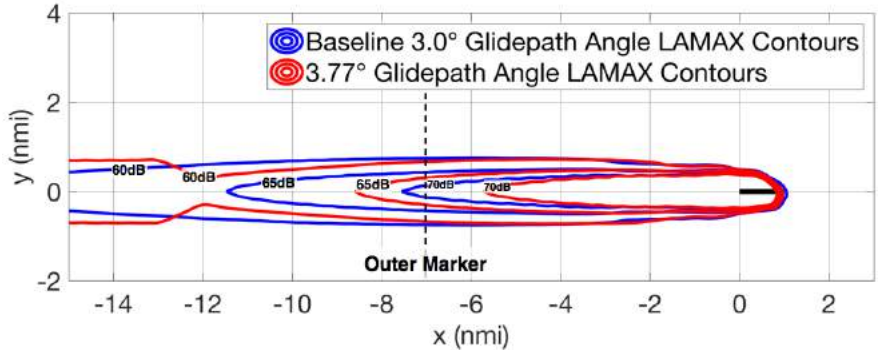
- Standard steep approaches
- 2-segment steep approaches
- Late turn to final
  - RNAV (Lighthouse-like approach paths)
  - RNP(Canarsie-like approach paths)
- Overflight of areas with high ambient noise
  - (i.e. Expressway approach)

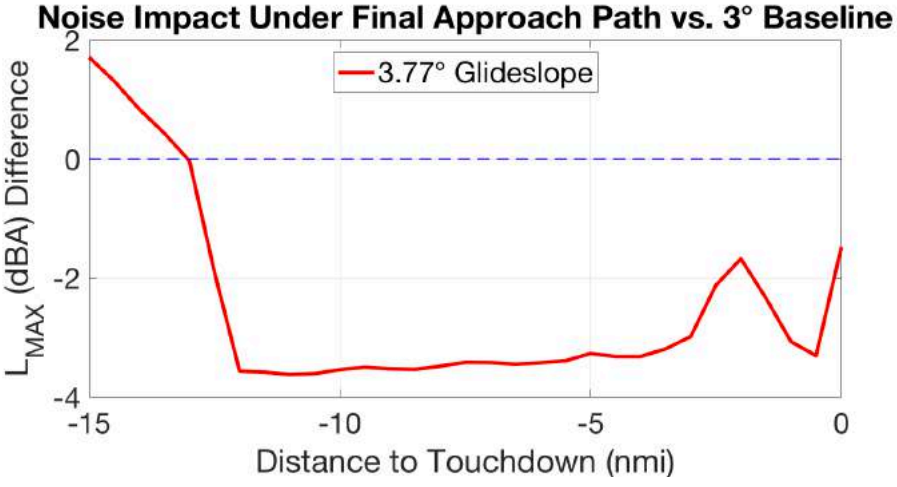


3° and 3.77° Continuous Descent Approach Comparison

- BADA-4 model indicates that steeper glideslopes may be feasible for some aircraft types
- Feedback from operators: Airbus aircraft in planned descent autoflight mode cannot exceed 3.77° glideslope angle

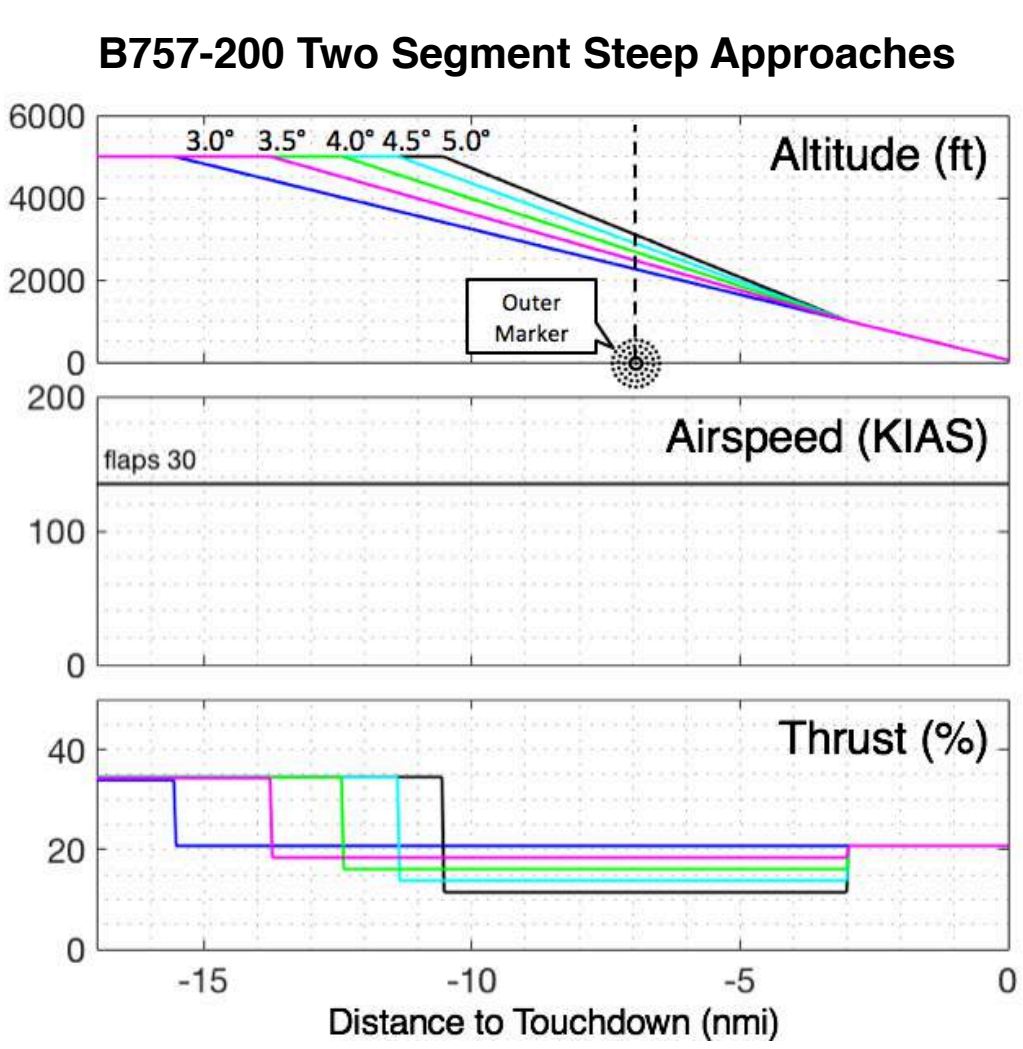


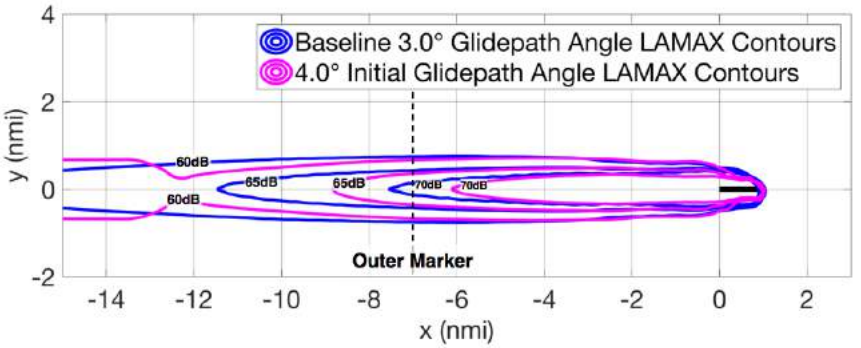


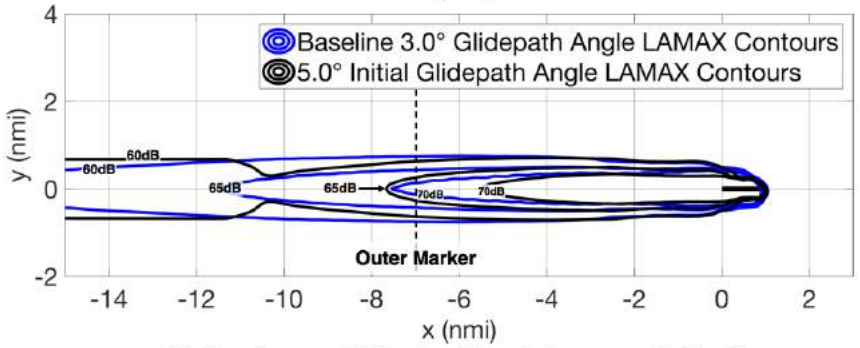


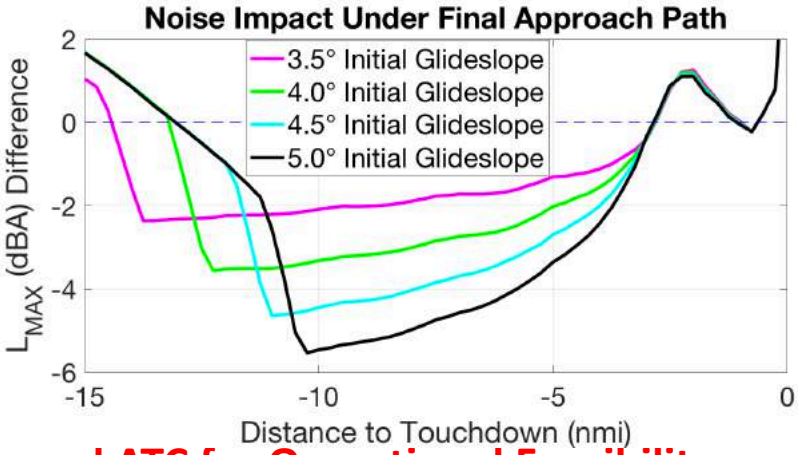
Significant Concerns from Airline Technical Pilots and ATC for Operational Feasibility

Two-Segment Approach Concept







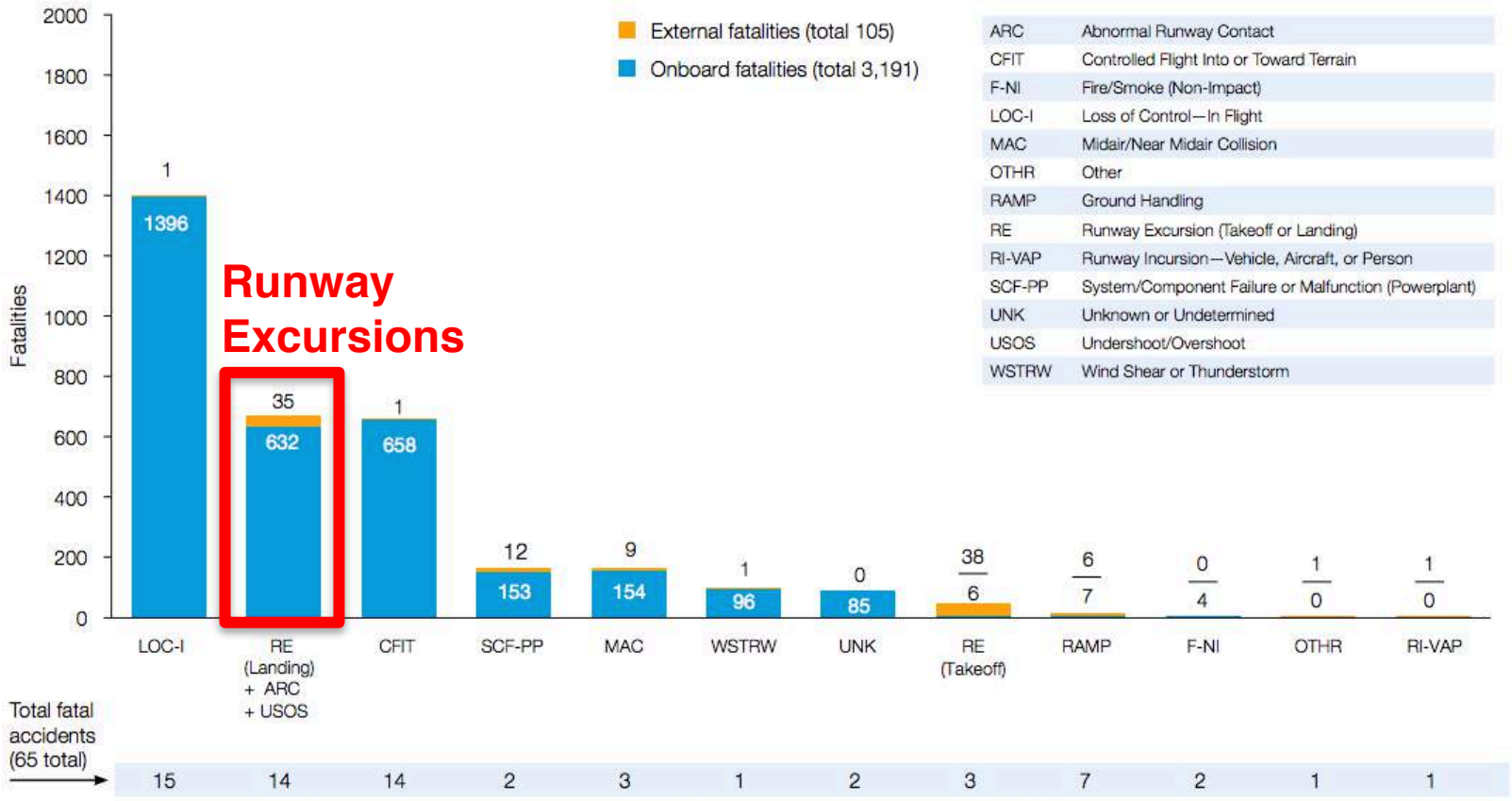


Significant Concerns from Airline Technical Pilots and ATC for Operational Feasibility

Safety Concerns - High-Energy Approaches

Fatalities by CICTT Aviation Occurrence Categories

Fatal Accidents | Worldwide Commercial Jet Fleet | 2006 through 2015



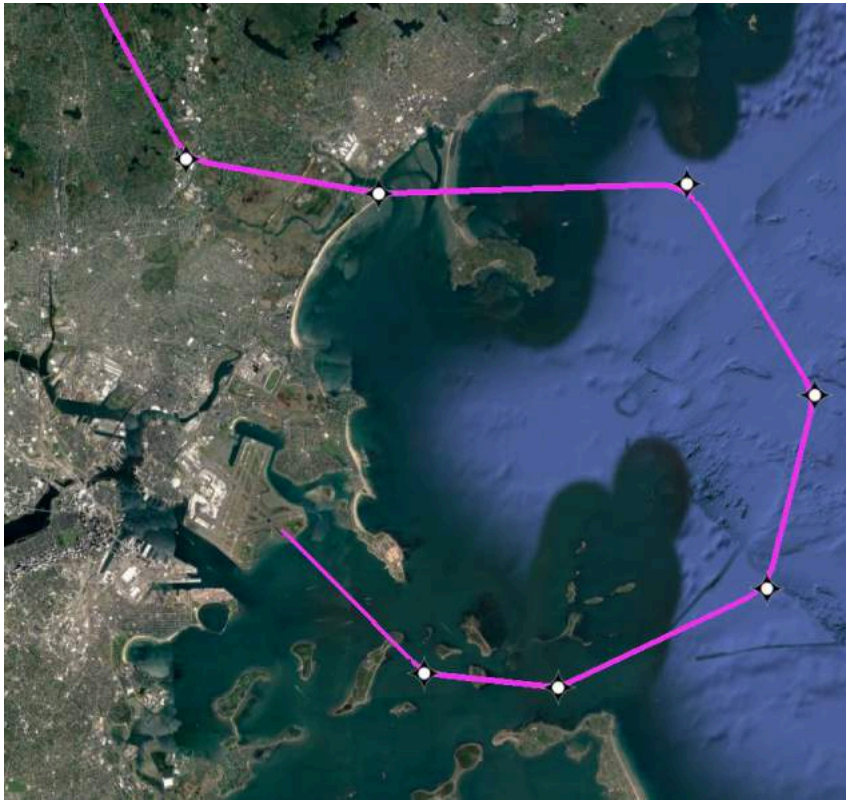
Note: Principal categories as assigned by CAST.

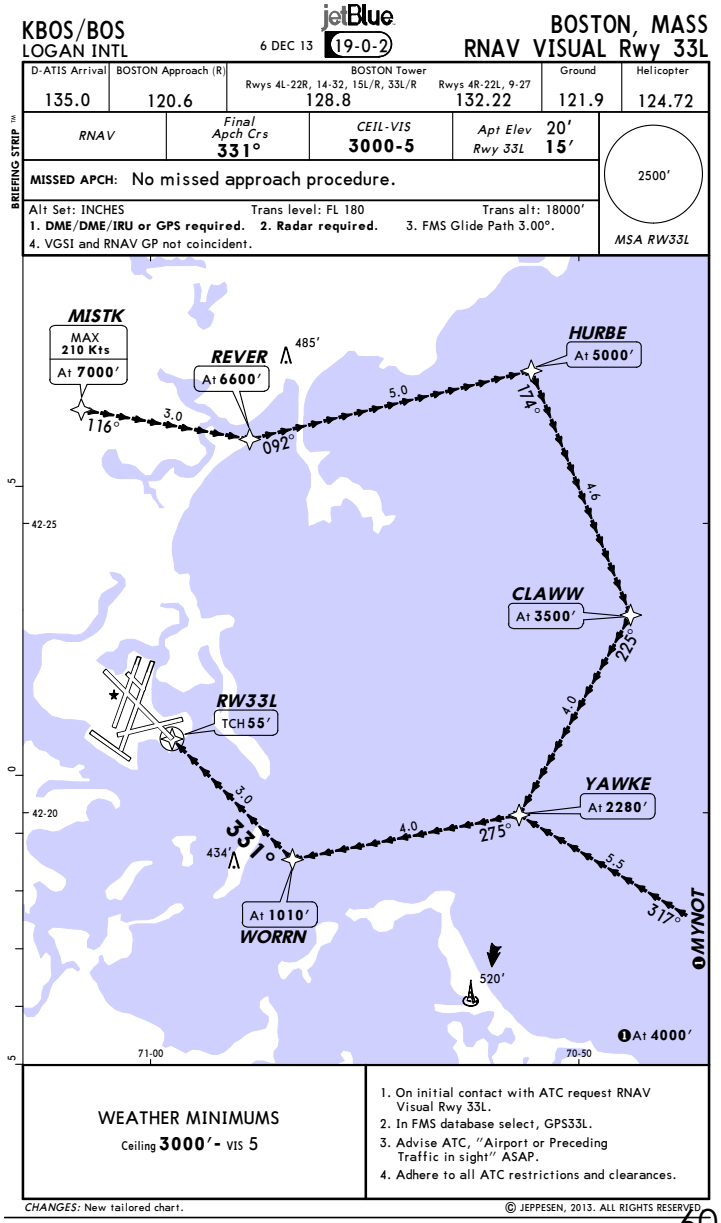
For a complete description of CAST/ICAO Common Taxonomy Team (CICTT) Aviation Occurrence Categories, go to www.intlaviationstandards.org.

Figure source: The Boeing Company http://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf

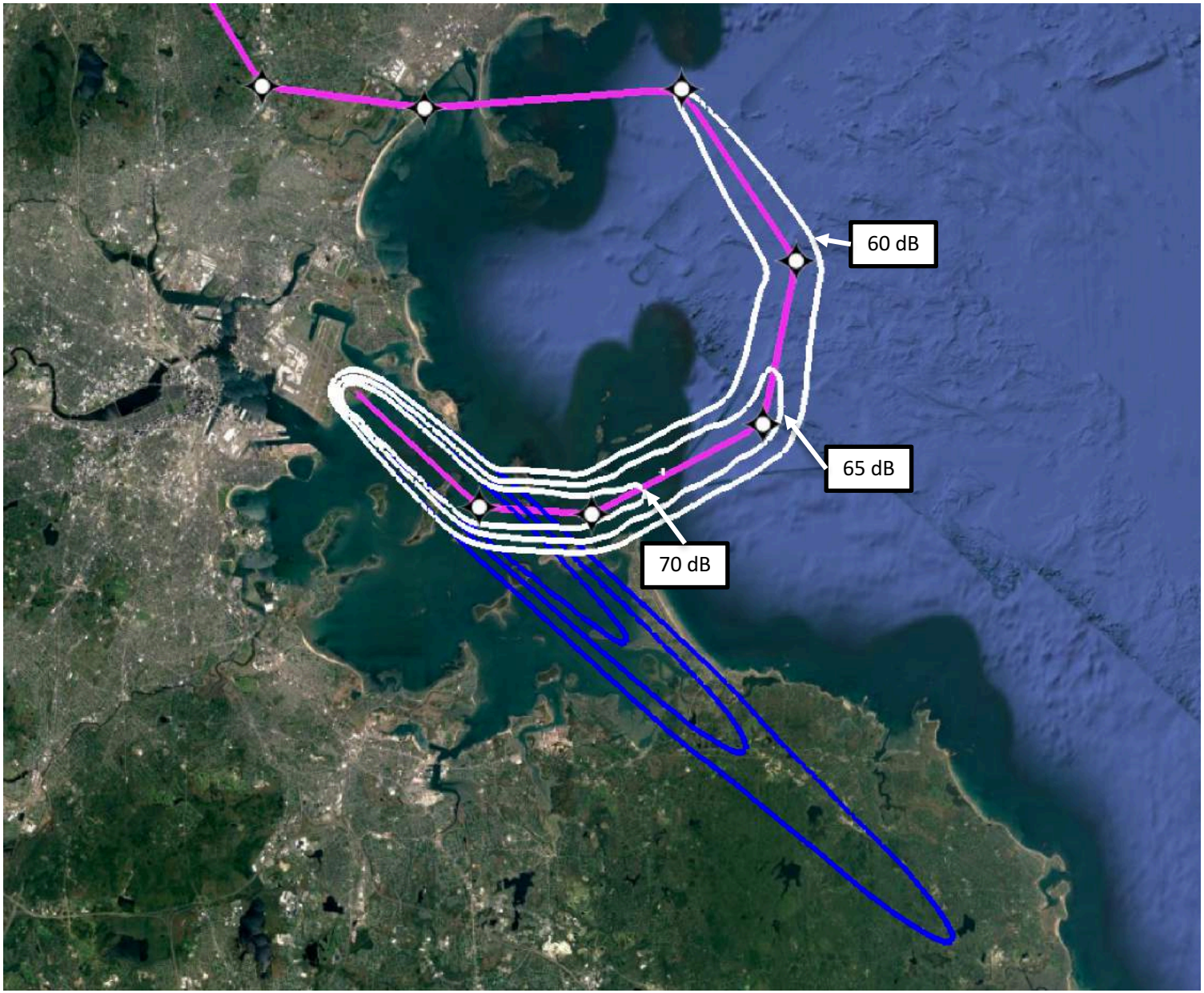
Lighthouse RNAV (GPS) Approach: 33L

- RNAV (GPS) Rwy 33L approach under development based on current JetBlue RNAV special procedure
  - Minor modifications required to meet public procedure design specifications





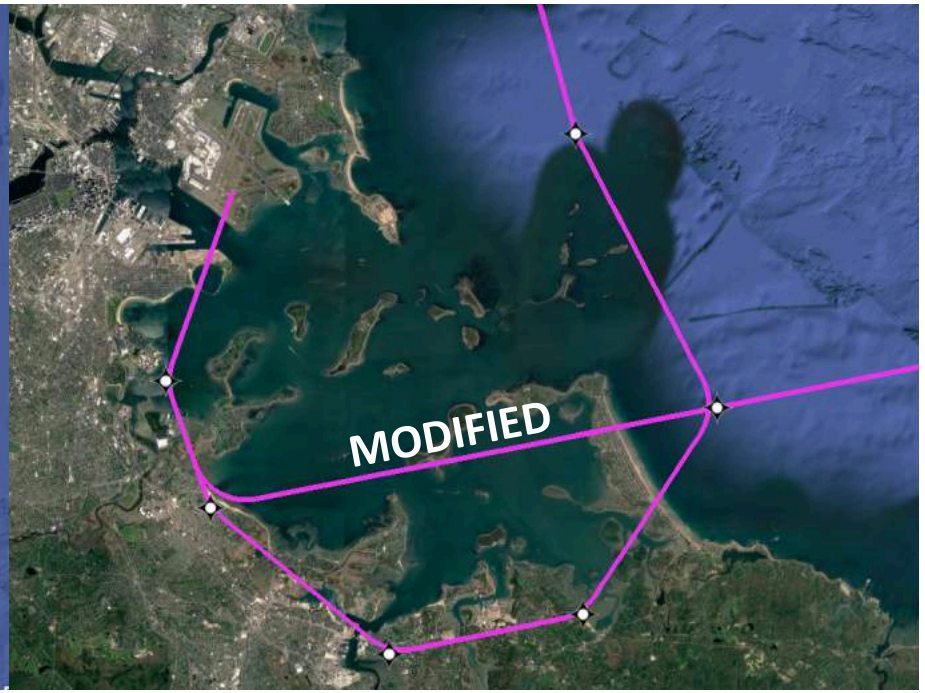
L_{MAX} Impact of Proposed RNAV (GPS) to 33L



RNAV (GPS) Approach: 4R

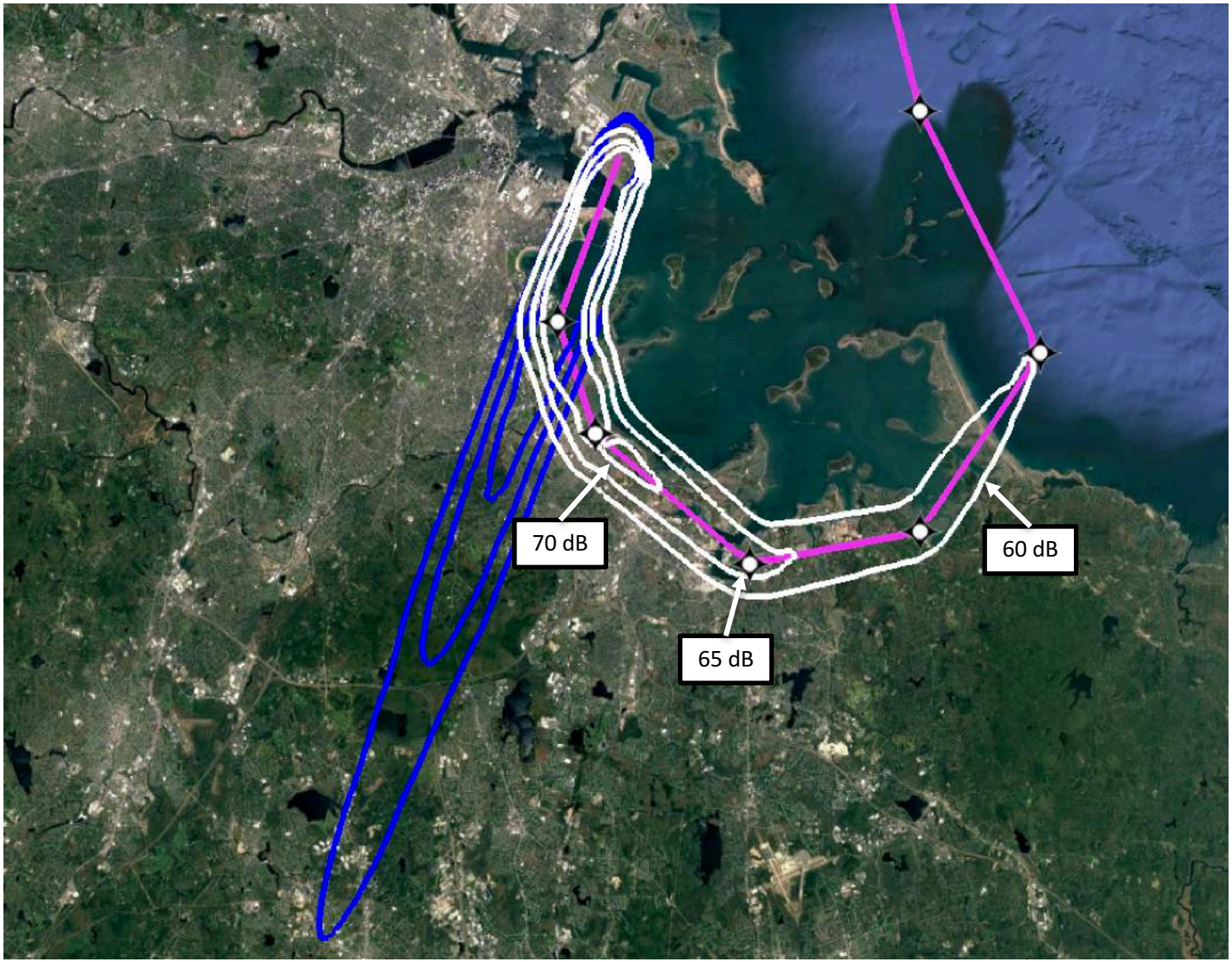
Transposing Lighthouse RNAV from 33L directly to 4R:

Removing intermediate waypoints over land:



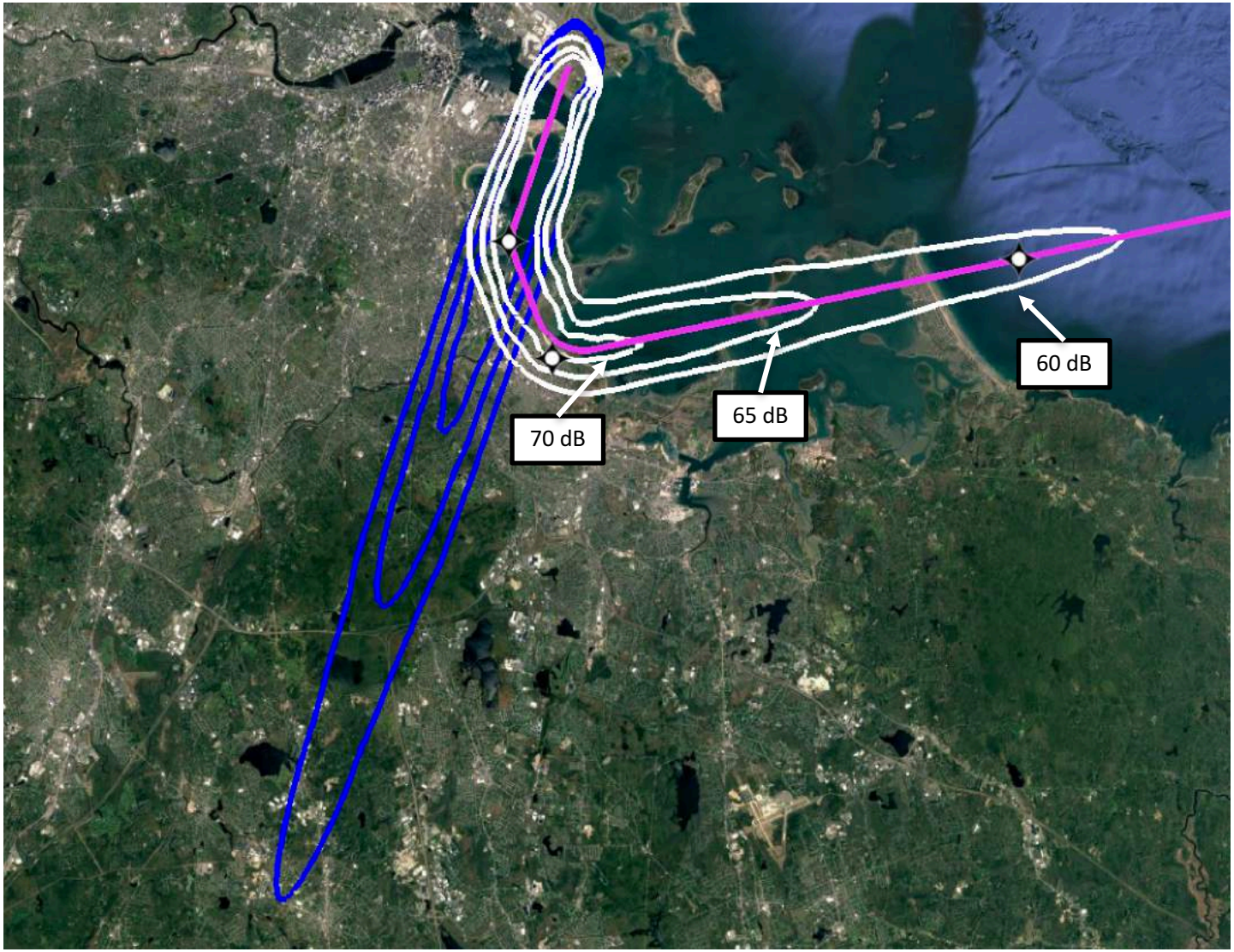
RNAV (GPS) Approach: 4R

- Transposing Lighthouse RNAV from 33L directly to 4R:

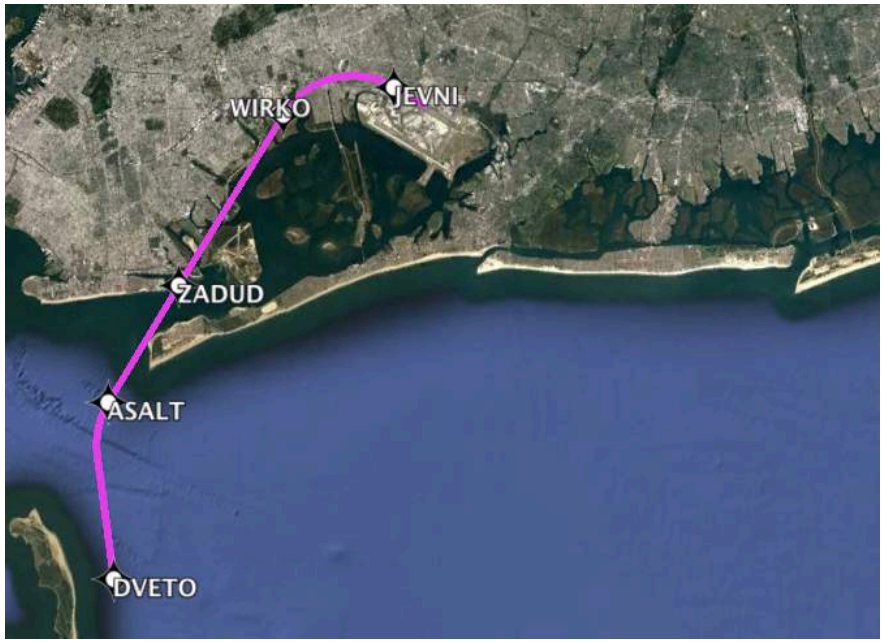


RNAV (GPS) Approach: 4R

- Modified RNAV to 4R:



Canarsie-Like RNAV (RNP) Special



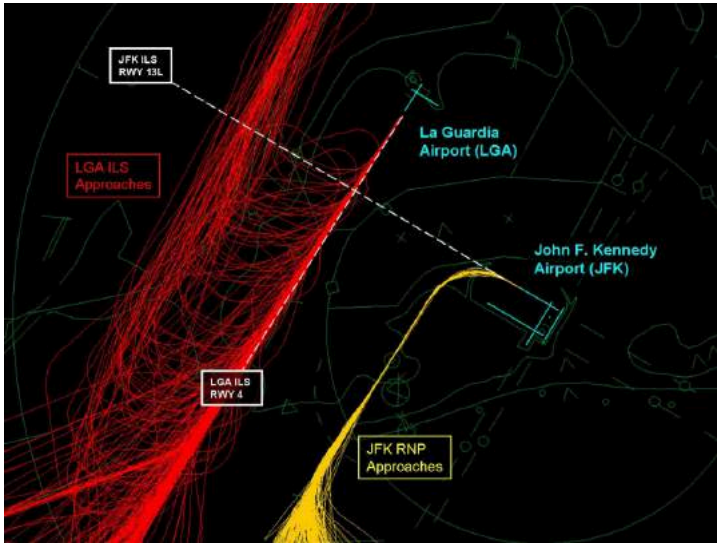
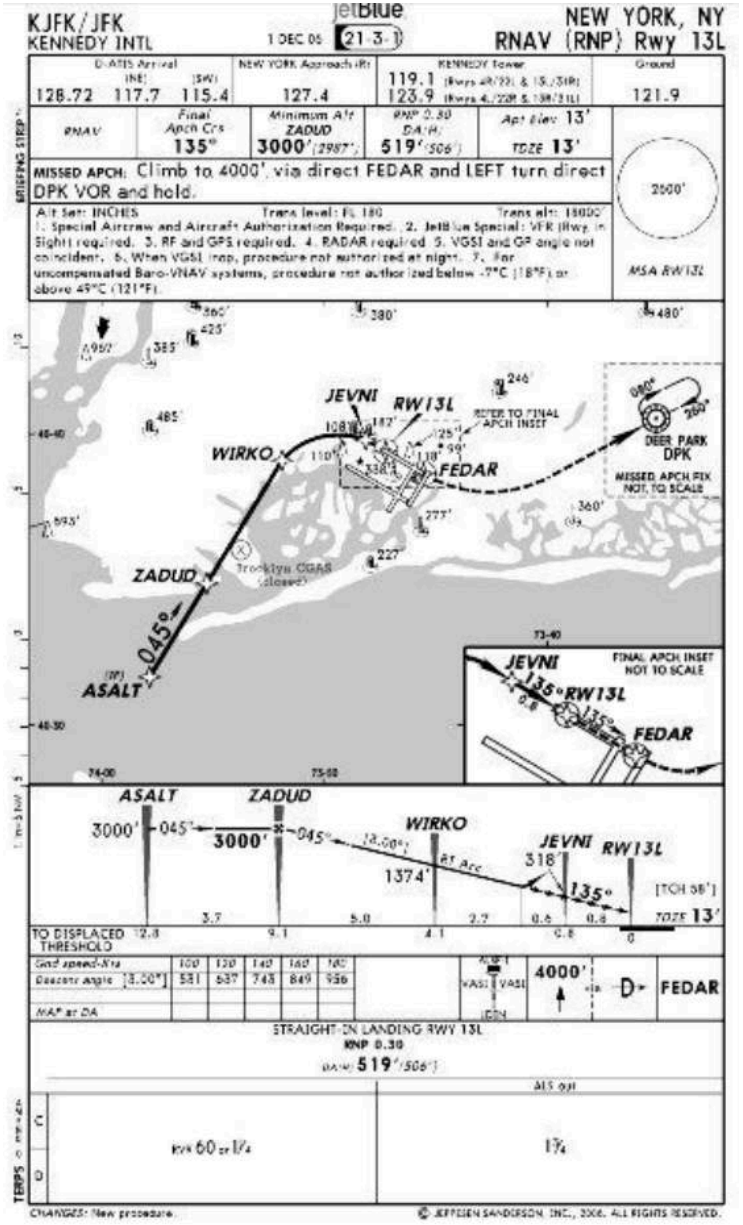
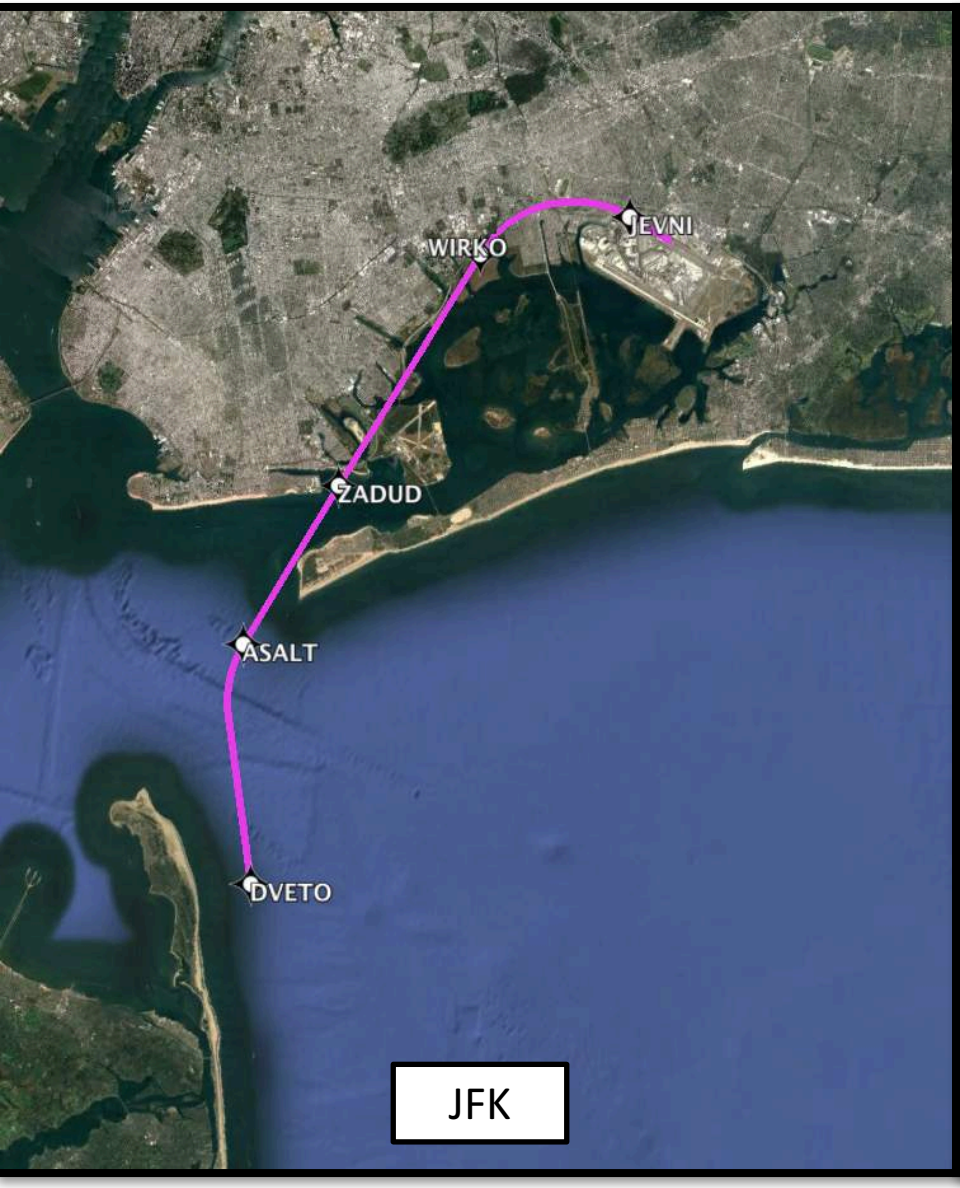
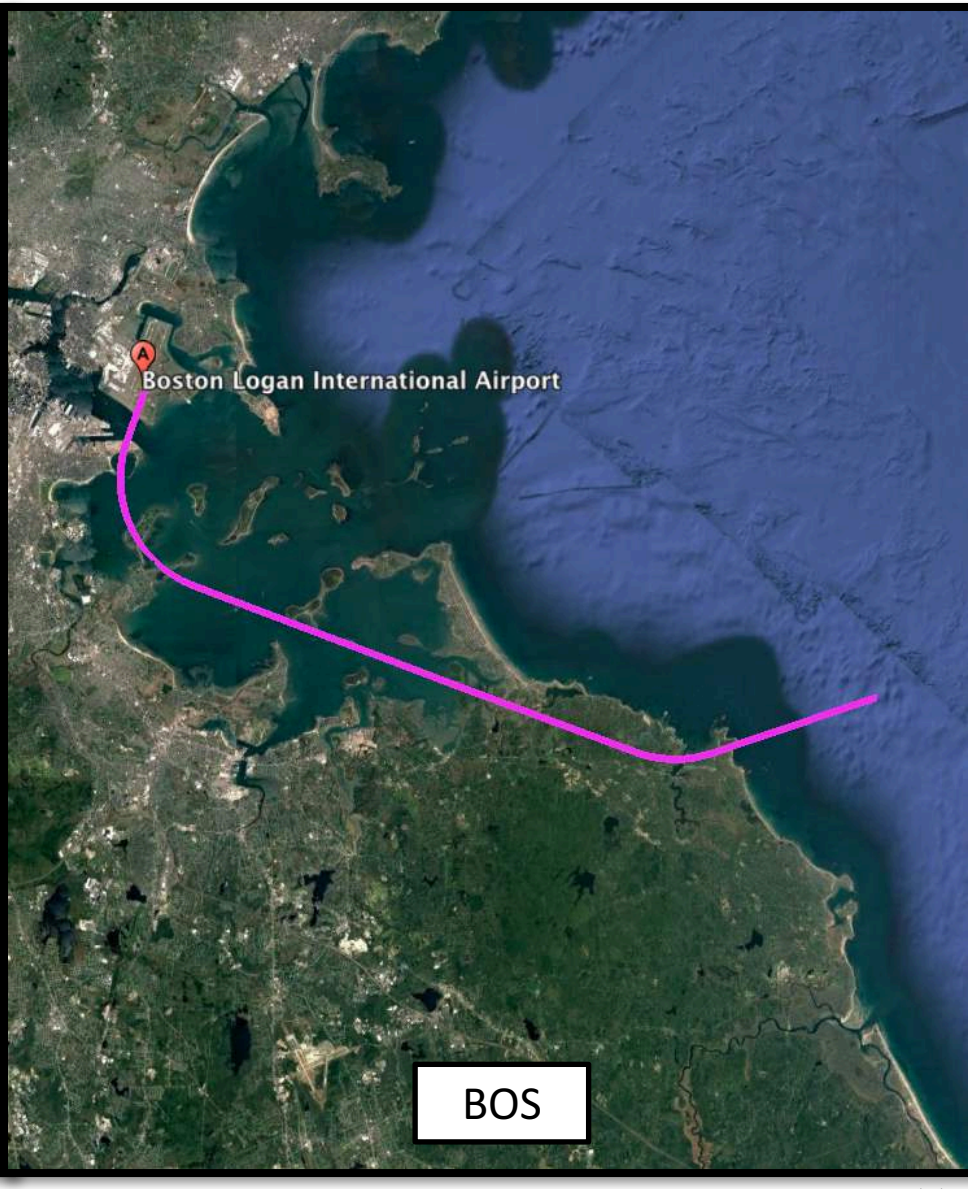


Figure: Honeywell

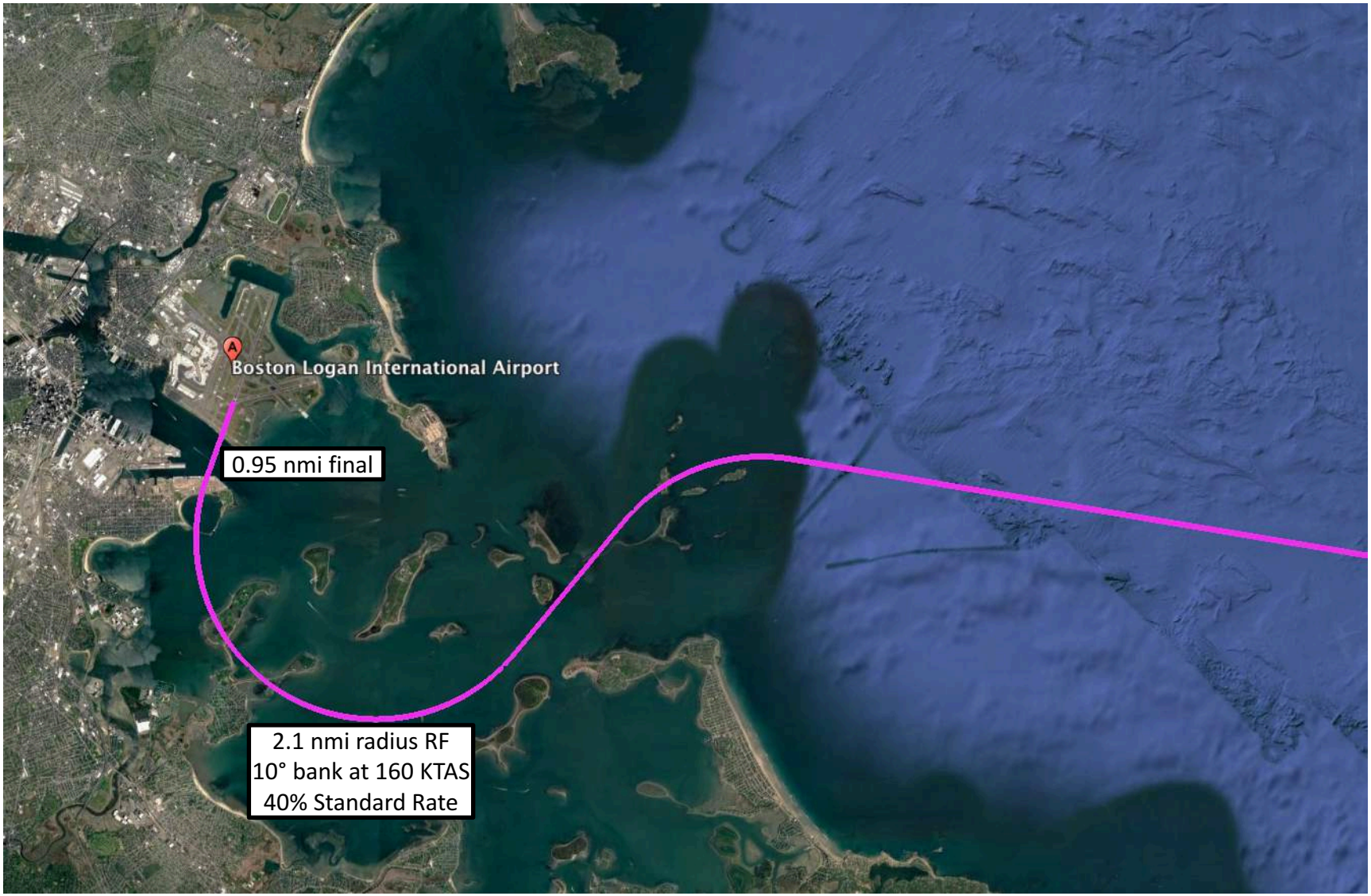


Canarsie-Like RNAV (RNP) Special





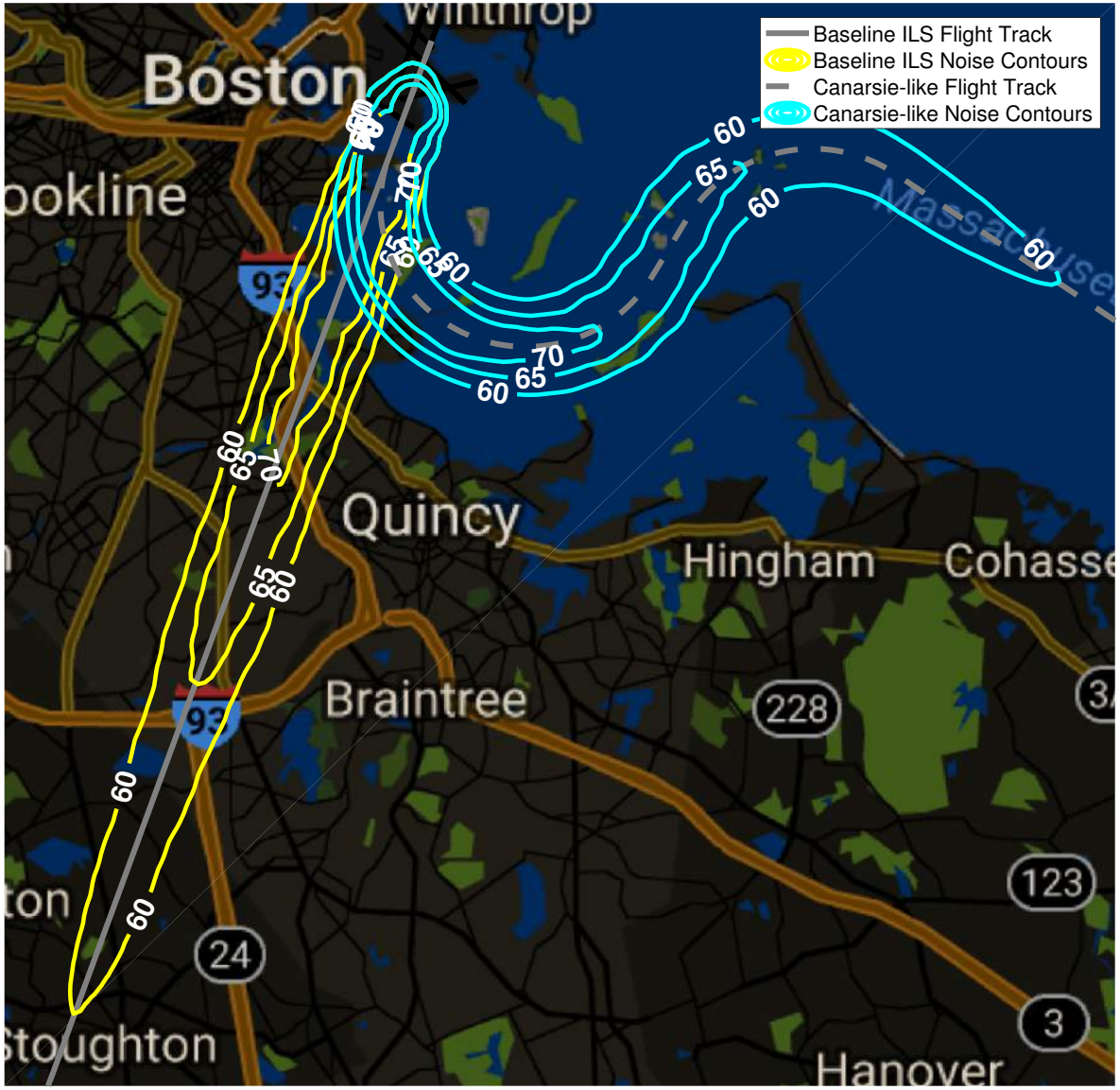
Notional Noise-Driven RNP: BOS Rwy 4R



Noise Exposure: 4R Noise-Driven RNP Approach

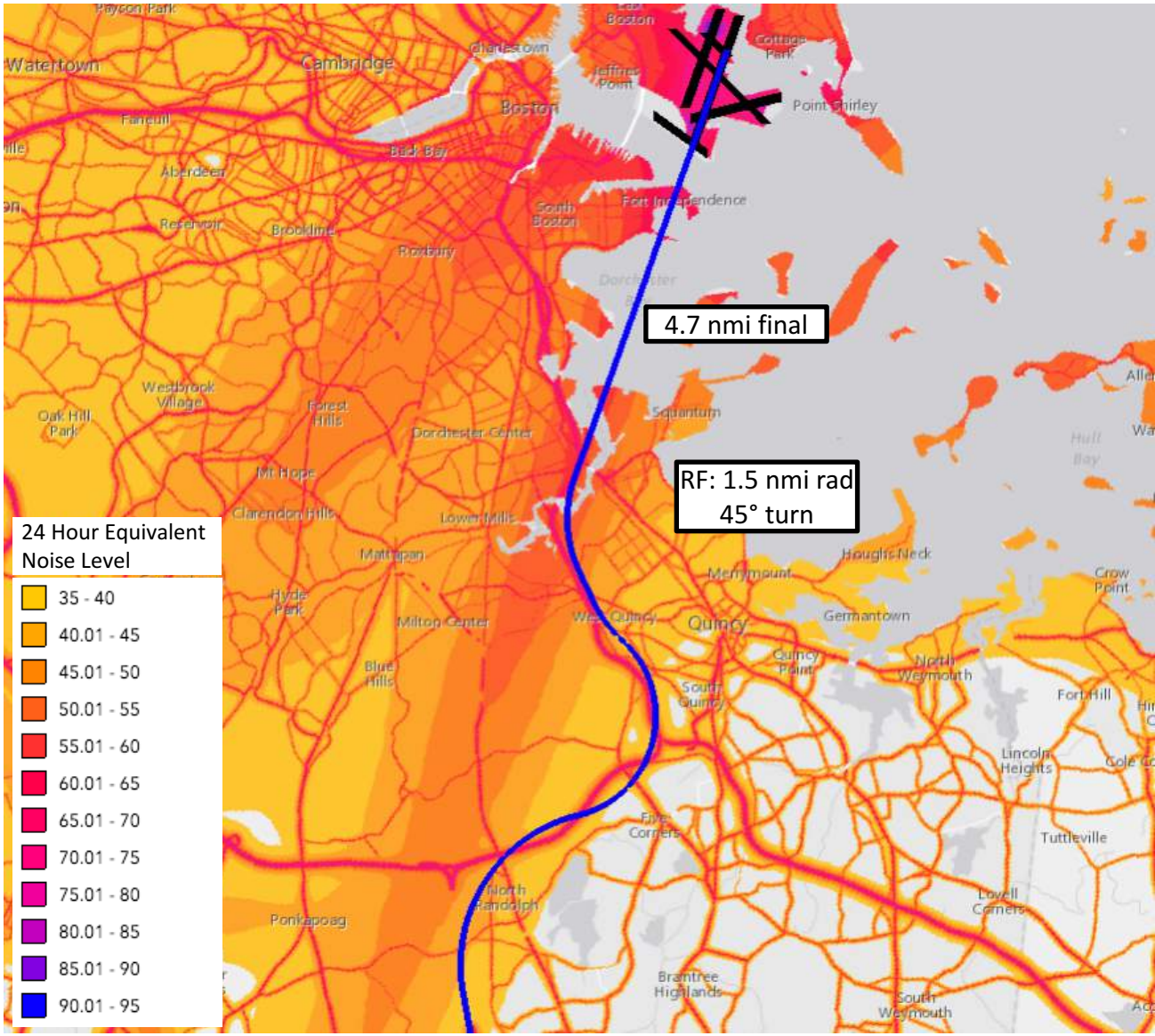
- 4R Noise-Driven RNP Approach
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT

- Issue of mixed equipage and merging on final



Notional 4R Expressway Approach Path

- Concept: move arrival flows over regions of higher ambient noise
  - Highways
  - Industrial areas
- Currently developing prototype arrival profile definitions

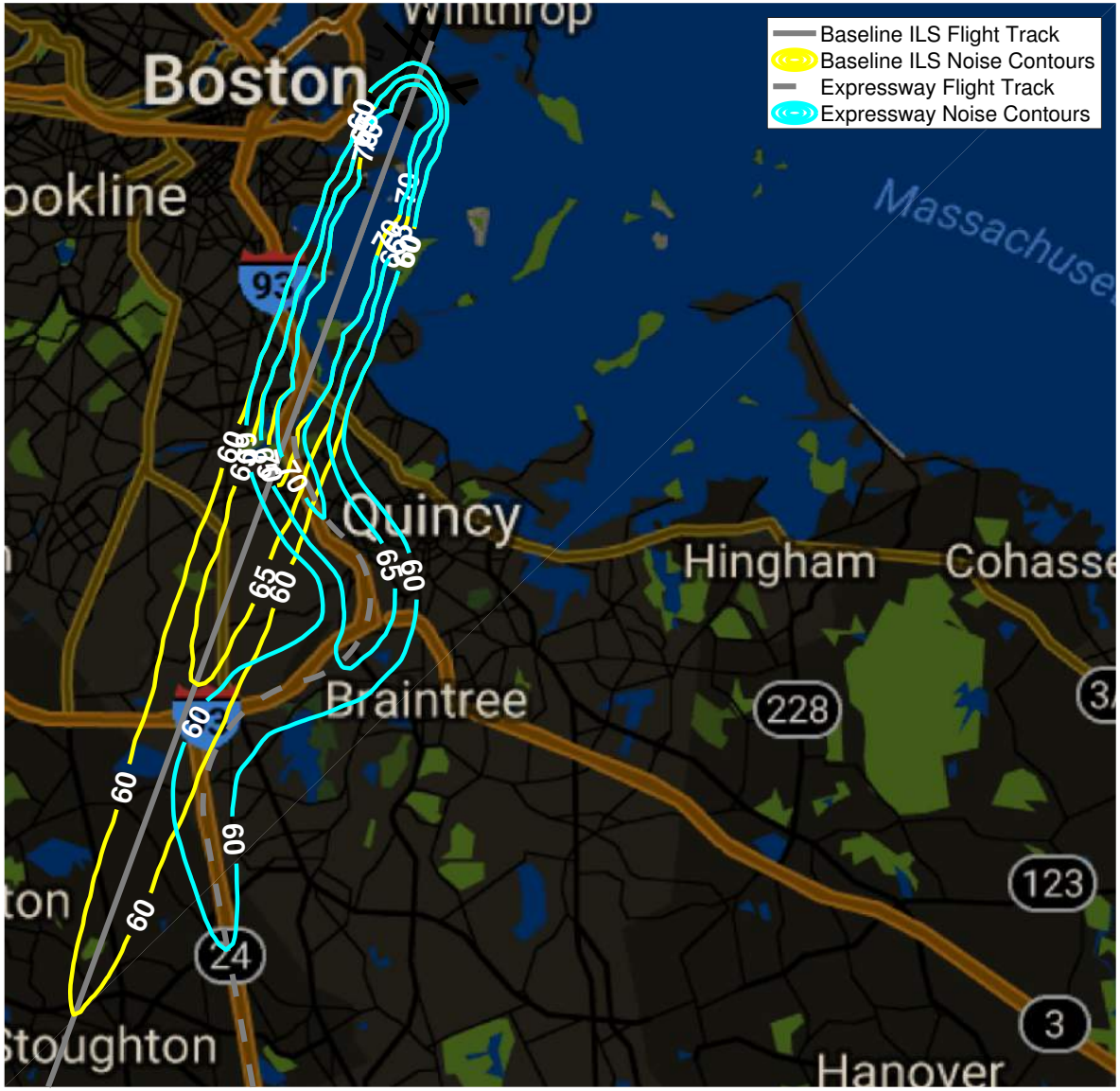


Transportation Noise Data Source: Bureau of Transportation Statistics https://www.rita.dot.gov/bts/press_releases/bts015_17

Noise Exposure: 4R Expressway Approach

- 4R Expressway Approach
- Aircraft: B737-800
- Metric: LAMAX
- Noise Model: AEDT

- Pending analysis of background noise and environmental justice issues



Summary

Most Promising Procedures Block 1 and Block 2

Block 1

Departure Mods

- 22R
  - RNAV Waypoint relocation
  - Early turn after departure
- 15R
  - RNAV Waypoint relocation
- 33L and 27
  - Speed management

Arrival Mods

- 33L
  - Lighthouse RNAV Approach

Block 2

Departure Mods

- 33L and 27
  - Open SID departures to introduce dispersion

Arrival Mods

- 4R
  - RNAV approach to 4R (Lighthouse-like)
  - RNP approach to 4R (Canarsie-like)
  - Noise masking on arrival

Preliminary/Subject to Change

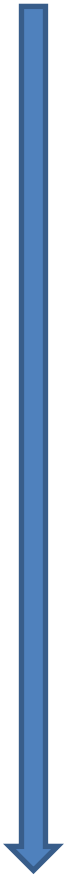
Project Schedule

Technical Approach

- ✓ Collect Data and Evaluate Baseline Conditions
  - Pre and Post RNAV
- ✓ Identify current procedures which appear to have community noise benefit
- Determine Technical and Operational Limitations
  - Aircraft Performance
  - Navigation and Flight Management (FMS)
  - Flight Crew Workload
  - Safety
  - Procedure Design
  - Air Traffic Control Workload
- ✓ Identify Candidate Procedure Modifications
  - ✓ Block 1/Block 2
- ✓ Model Noise Impact
  - Standard and Supplemental Metrics
- Evaluate Implementation Barriers
- Recommend Procedural Modifications to Massport and FAA
- Repeat for Block 2

Project Schedule

- FAA/ Massport Discussions — Winter – Fall 2016
- Announcement — Oct 2016
- Consultant Team Organization — Fall 2016
- Historical Flight Comparison\Analysis — Dec to Feb 2016
- Block 1 Procedure Opportunity — Feb 2017
  - lower complexity, benefits with minimal/no negative impacts
  - DNL and Alternative Metrics (single event above threshold)
- Block 1 Recommendations — Apr 2017
- Block 2 Procedure Opportunity — Jun 2017
  - More complexity, benefits and potential negative impacts
  - DNL and Alternative Metrics (single event above threshold)
- Block 2 Recommendations — Fall 2017
- FAA Review Process — Ongoing/TBD
- Implementation/Final Report — TBD



Review\Input
MPA CAC
At Key Milestones

Preliminary/Subject to Change