Analytical Approach for Quantifying Noise from Advanced Operational Procedures

ASCENT Projects 23,44

October 22, 2019

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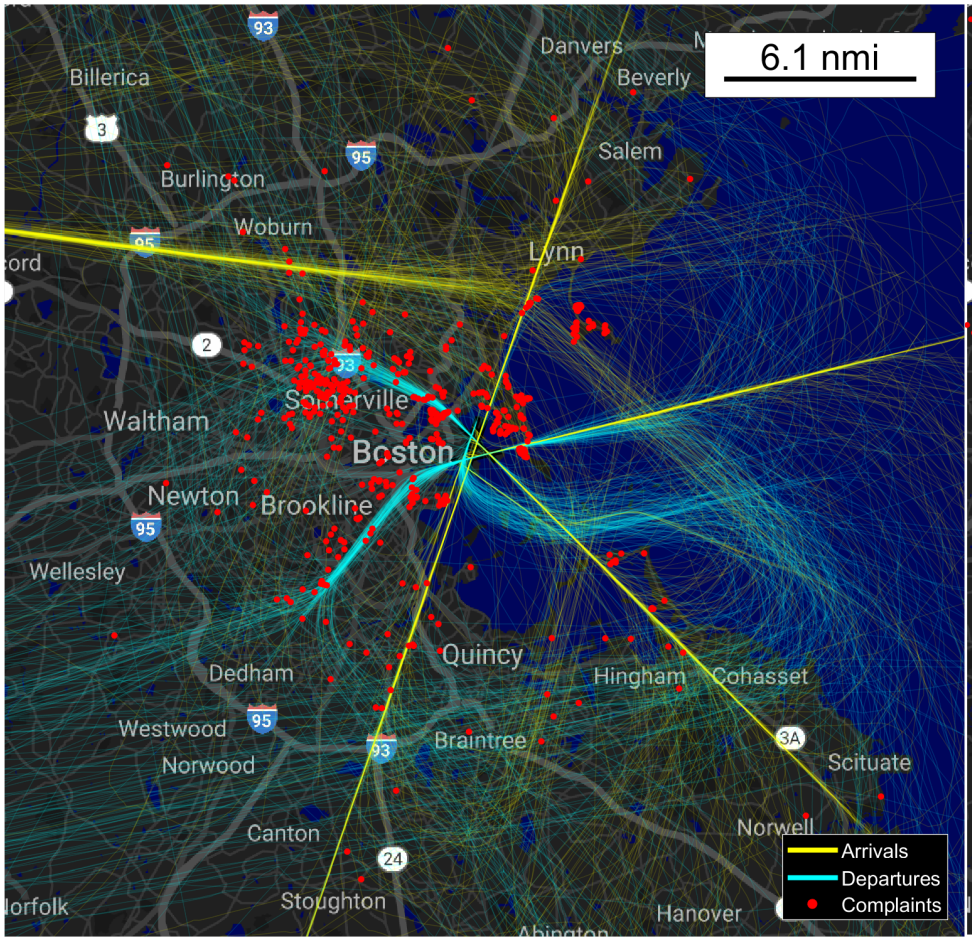
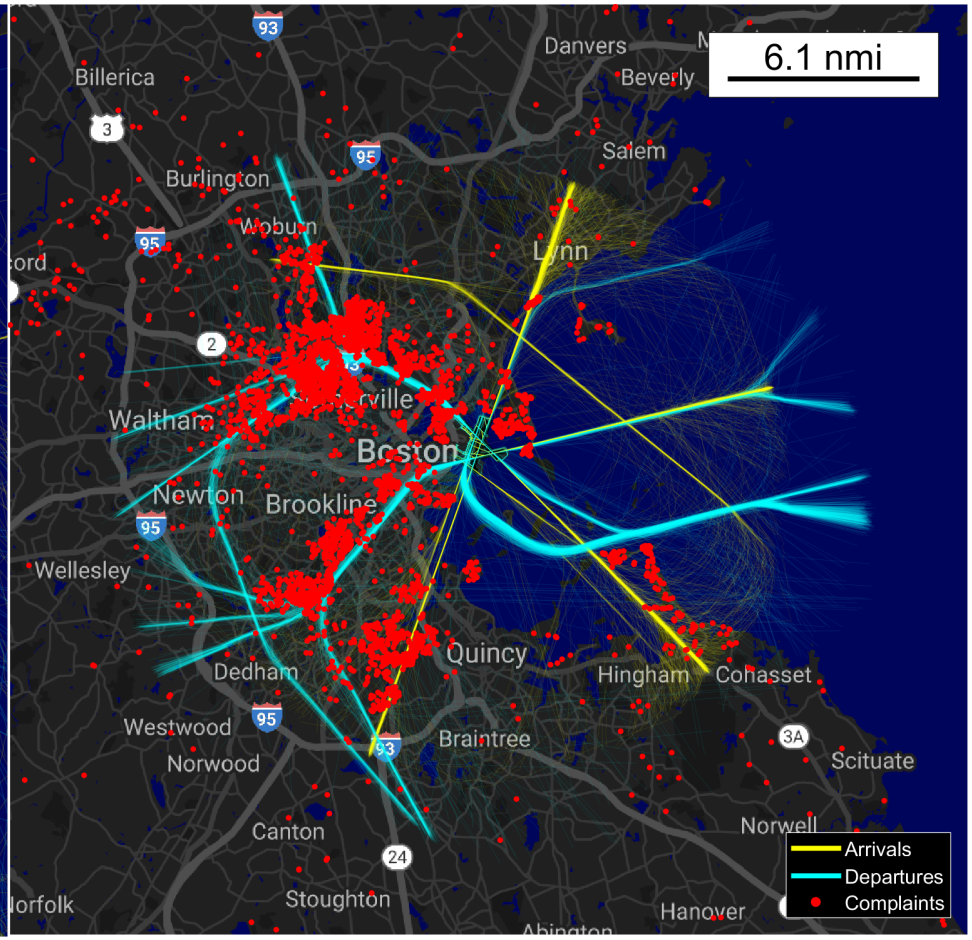
RNAV Track Concentration

2010



2017



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

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

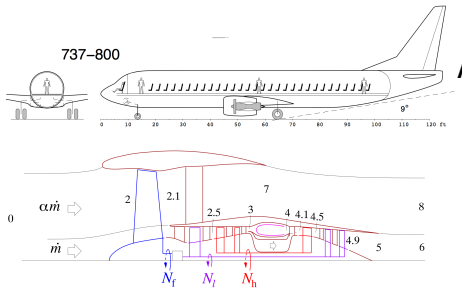
Aircraft Type

Procedure Definition:
Lateral Path
Speeds
Configuration

TASOPT

BADA4 Existing Aircraft Data

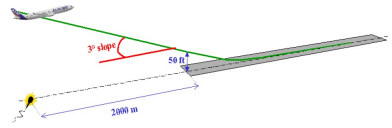
Performance Model Outputs:



Aircraft/engine performance & geometry

Flight Procedure Generator

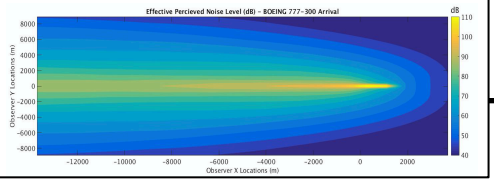
Flight Procedure:
Thrust, velocity, position, gear/flap settings per time



Noise Model Control Inputs:
Propagation Settings
Observer Locations

ANOPP/AEDT

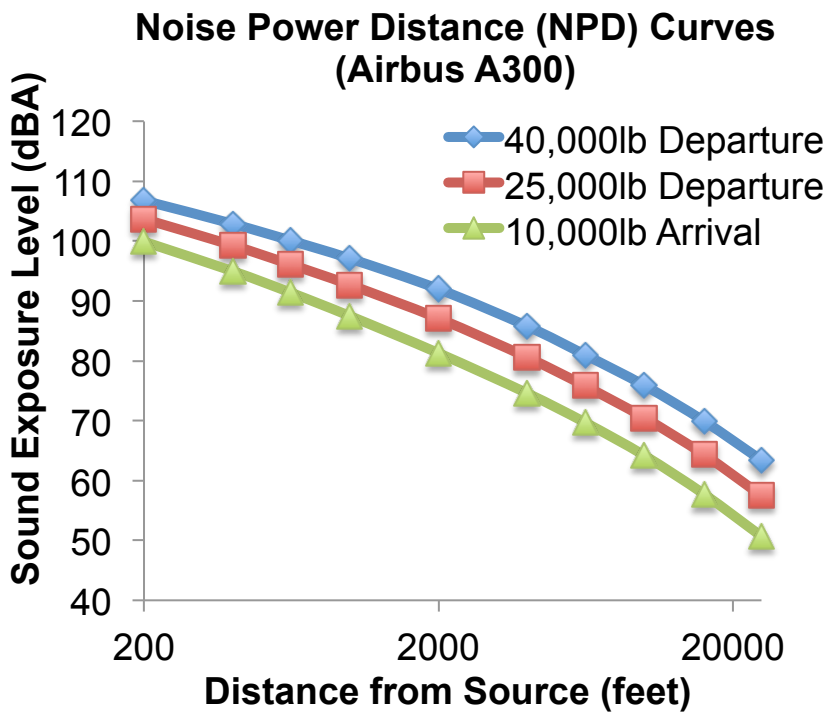
Single-Event Noise Grids



Output to Grid Rotation and Superposition

Noise Models

FAA Standard AEDT



- Noise-Power-Distance (NPD) Curve-Based Noise Computation Method[6]
  - Assumes only thrust & distance determines a change in aircraft noise

NASA ANOPP

ANOPP

Source Noise Components:

Airframe Noise

*Clean Wing/ Tail Noise

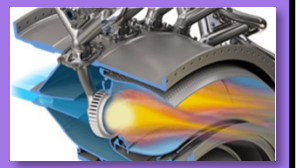
Flap/Slat Noise

Gear Noise

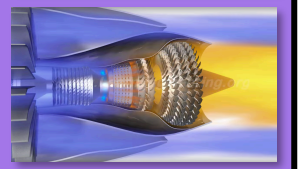
Turbofan Engine Noise

Fan Noise

Combustion Noise

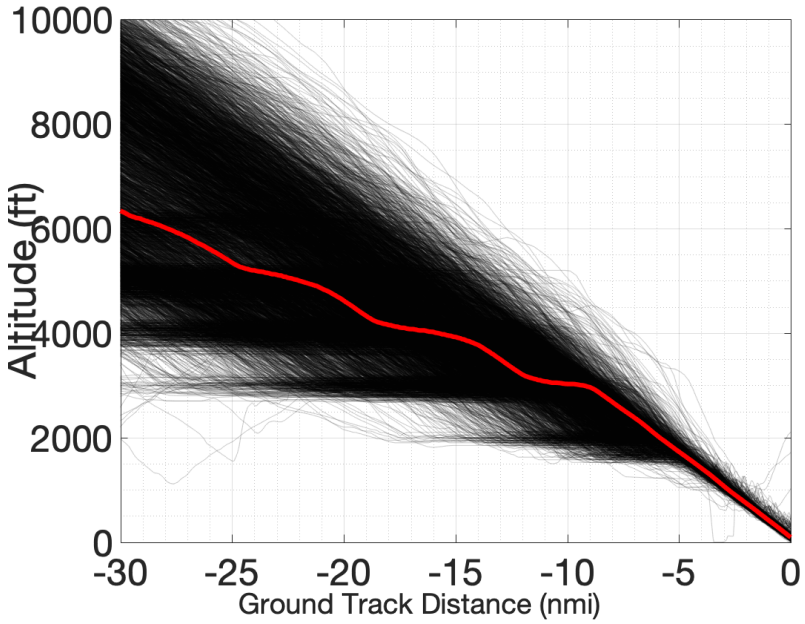


Jet Noise

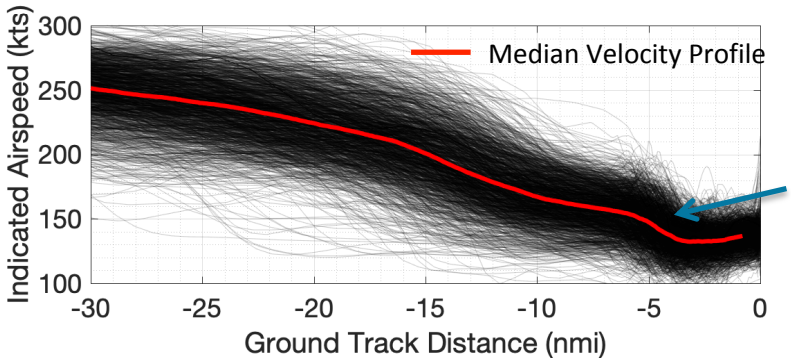


Flight Profile Generation
Example for a B737-800 Approach

Example Approach Radar data in 2017 at BOS, 22L

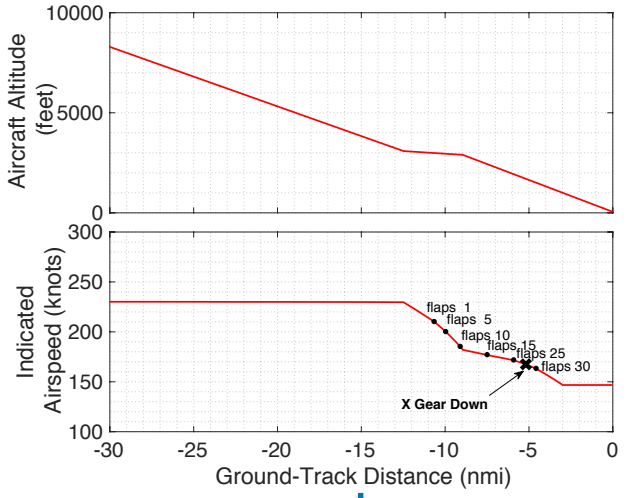


Groundspeed Radar data converted into indicated airspeed, assuming no wind

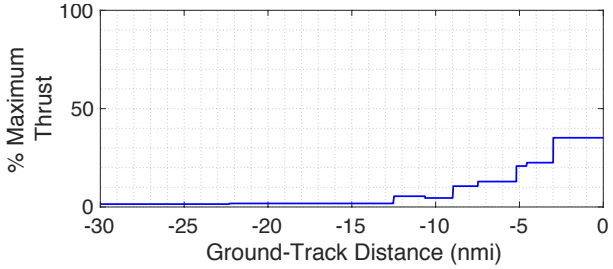


Gear assumed deployed ~6nmi from touchdown based on observed deceleration

- Altitude (3000ft level off in this case only) and Velocity is constrained to the medians of this data
- Flaps assumed deployed within their maximum and minimum speed ranges



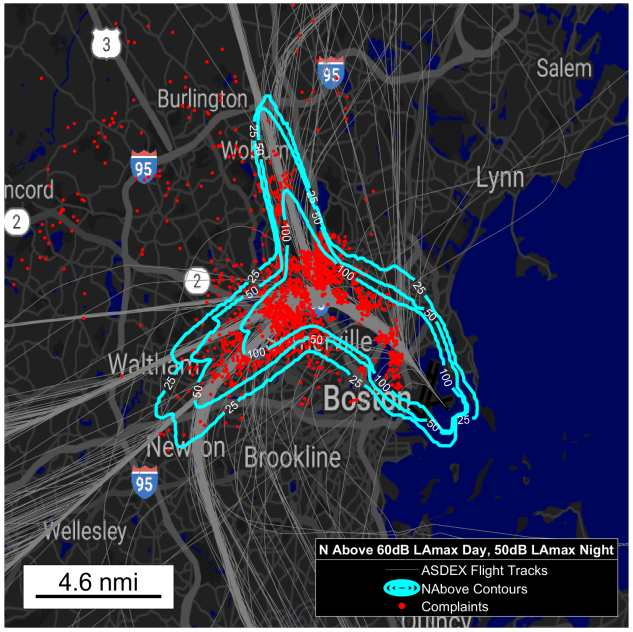
Resulting thrust profile is determined for these profiles from drag data



BOS N_{60} Count Thresholds

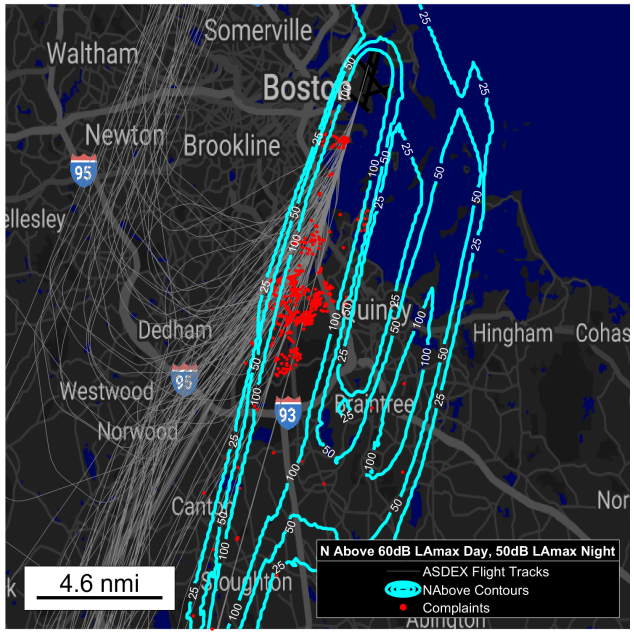
- N_{60} on a peak day with 50 overflights appears to capture complaint threshold in dispersion analysis

33L Departures Peak Day N_{60}



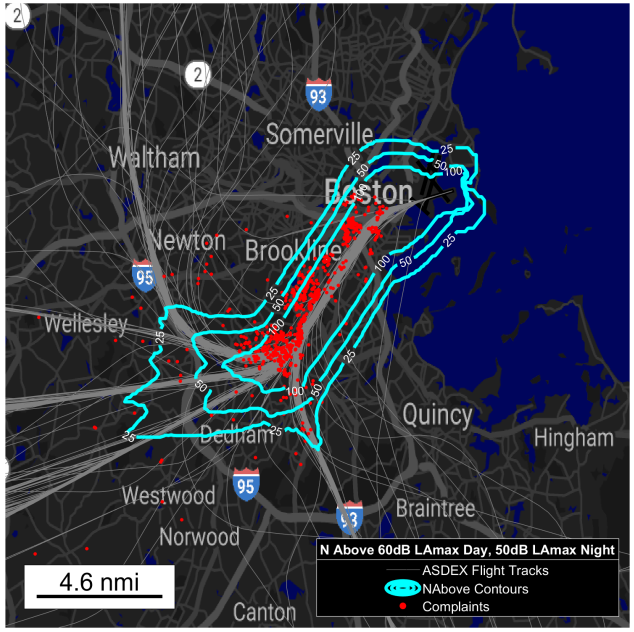
Peak Day N_{60}	Complaints Captured
25x	87.3%
50x	80.9%
100x	59.4%

4L/R Arrivals Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	97.7%
50x	94.7%
100x	81.0%

27 Departures Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	95.4%
50x	92.1%
100x	78.8%

2017 Data

Block 1 Examples:

Clear noise benefit, no equity issues, limited operational/technical barriers

Block 1 Final Recommendations

Proc. ID D = Dep. A = Arr.	Procedure	Primary Benefits
1-D1	Restrict target climb speed for jet departures from Runways 33L and 27 to 220 knots or minimum safe airspeed in clean configuration, whichever is higher.	Reduced airframe and total noise during climb below 10,000 ft (beyond immediate airport vicinity)
1-D2	Modify RNAV SID from Runway 15R to move tracks further to the north away from populated areas.	Departure flight paths moved north away from Hull
1-D3	Modify RNAV SID from Runway 22L and 22R to initiate turns sooner after takeoff and move tracks further to the north away from populated areas.	Departure flight paths moved north away from Hull and South Boston
1-D3a	*Option A*: Climb to intercept course (VI-CF) procedure	
1-D3b	*Option B*: Climb to altitude, then direct (VA-DF) procedure	
1-D3c	*Option C*: Heading-based procedure	
1-A1	Implement an overwater RNAV approach procedure with RNP overlay to Runway 33L that follows the ground track of the jetBlue RNAV Visual procedure as closely as possible.	Arrival flight paths moved overwater instead of over the Hull peninsula and points further south
1-A1a	*Option A*: Published instrument approach procedure	
1-A1b	*Option B*: Public distribution of RNAV Visual procedure	

"Block 1 Procedure Recommendations for Logan Airport Community Noise Reduction"

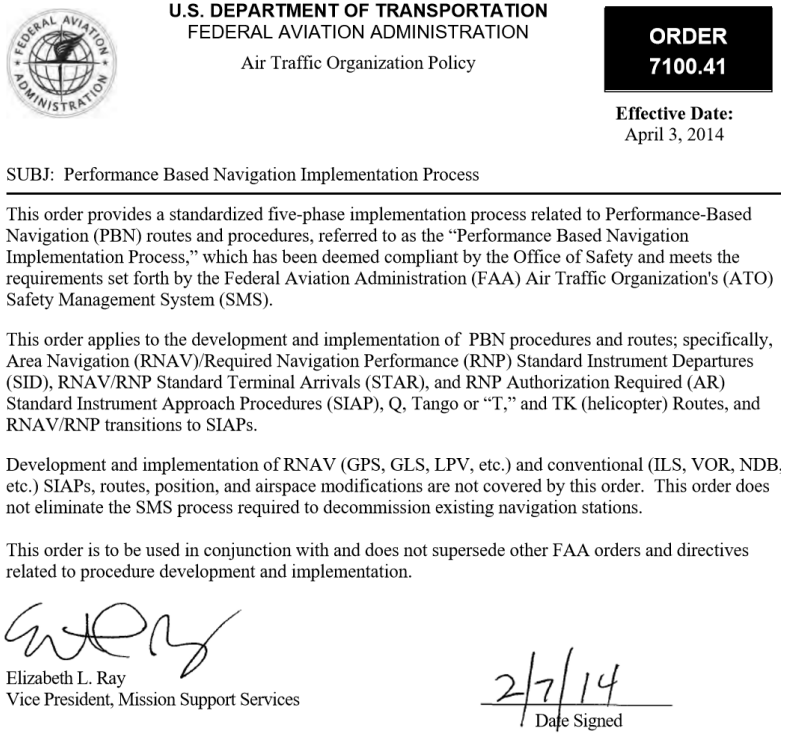
Available at:
http://hdl.handle.net/1721.1/114038

FAA 7100.41 Working Group

- 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



U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Air Traffic Organization Policy

ORDER 7100.41

Effective Date:
April 3, 2014

SUBJ: Performance Based Navigation Implementation Process

This order provides a standardized five-phase implementation process related to Performance-Based Navigation (PBN) routes and procedures, referred to as the "Performance Based Navigation Implementation Process," which has been deemed compliant by the Office of Safety and meets the requirements set forth by the Federal Aviation Administration (FAA) Air Traffic Organization's (ATO) Safety Management System (SMS).

This order applies to the development and implementation of PBN procedures and routes; specifically, Area Navigation (RNAV)/Required Navigation Performance (RNP) Standard Instrument Departures (SID), RNAV/RNP Standard Terminal Arrivals (STAR), and RNP Authorization Required (AR) Standard Instrument Approach Procedures (SIAP), Q, Tango or "T," and TK (helicopter) Routes, and RNAV/RNP transitions to SIAPs.

Development and implementation of RNAV (GPS, GLS, LPV, etc.) and conventional (ILS, VOR, NDB, etc.) SIAPs, routes, position, and airspace modifications are not covered by this order. This order does not eliminate the SMS process required to decommission existing navigation stations.

This order is to be used in conjunction with and does not supersede other FAA orders and directives related to procedure development and implementation.

Elizabeth L. Ray
Vice President, Mission Support Services

2/7/14
Date Signed

https://www.faa.gov/documentLibrary/media/Order/FAA_JO_7100.41_Performance_Based_Navigation_Implementation_Process.pdf

Block 1 Final Recommendations

Proc. ID D = Dep. A = Arr.	Procedure	Primary Benefits
1-D1	Restrict target climb speed for jet departures from Runways 33L and 27 to 220 knots or minimum safe airspeed in clean configuration, whichever is higher	Reduced airframe and total noise during climb below 10,000 ft (beyond immediate airport vicinity)
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1-A1a	*Option A*: Published instrument approach procedure	
1-A1b	*Option B*: Public distribution of RNAV Visual procedure	

Updated airframe noise data from Boeing and NASA indicate noise benefits limited

Issues identified by .41 group. Modified procedures being evaluated

"Block 1 Procedure Recommendations for Logan Airport Community Noise Reduction"

Available at: http://hdl.handle.net/1721.1/114038

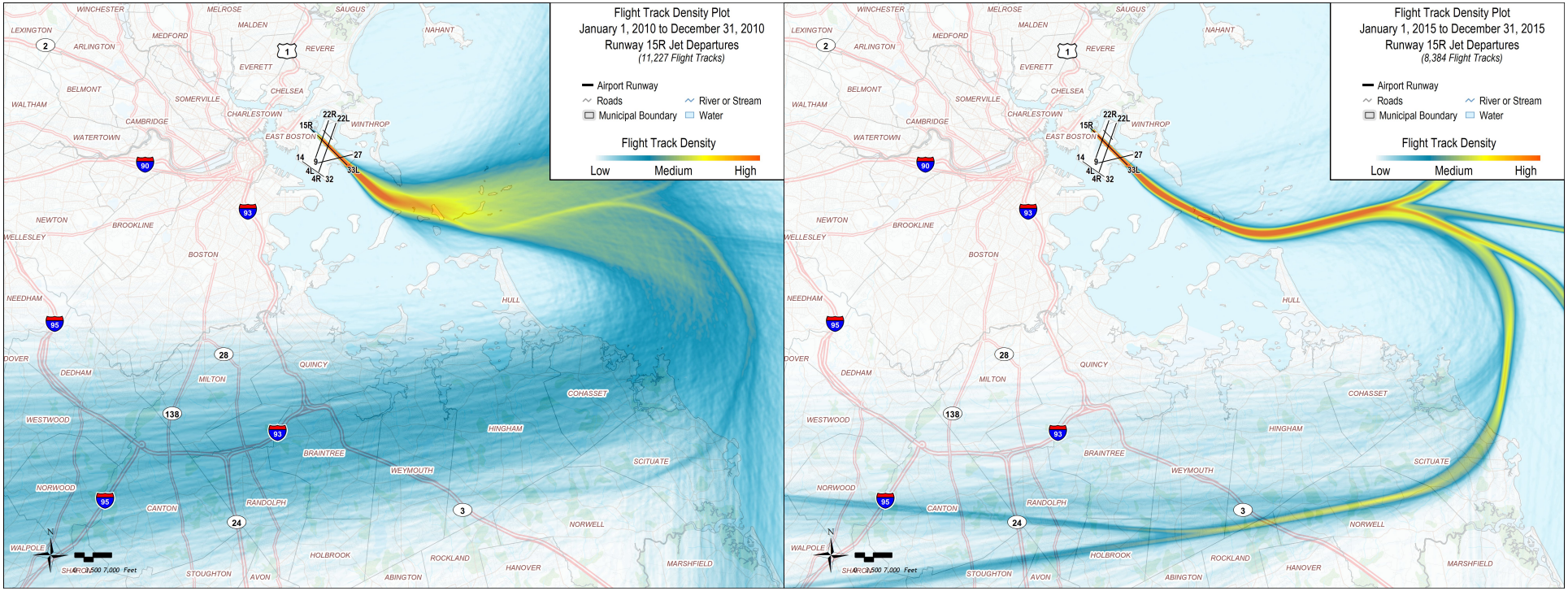
Advanced by .41 group

RUNWAY 15R RNAV WAYPOINT RELOCATION (1-D2)

Runway 15 Departures: 2010-2015

2010

2015



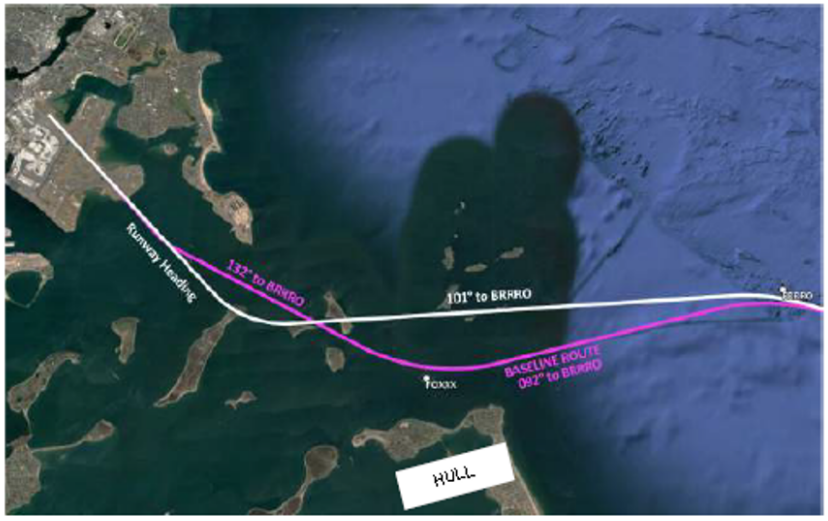
FAA 7100.41 Working Group Procedure Design

(1-D2)

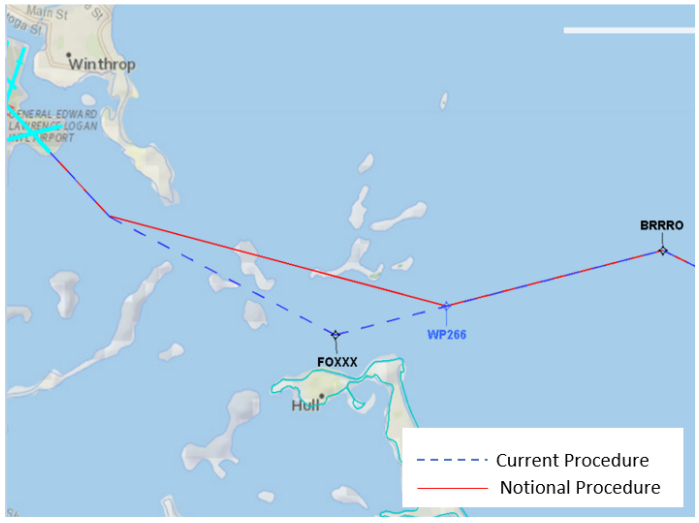
Modify RNAV SID from Runway 15R to move tracks further to the north away from populated areas.

Primary Benefit: Departure flight paths moved north away from Hull

Design recommended by MIT



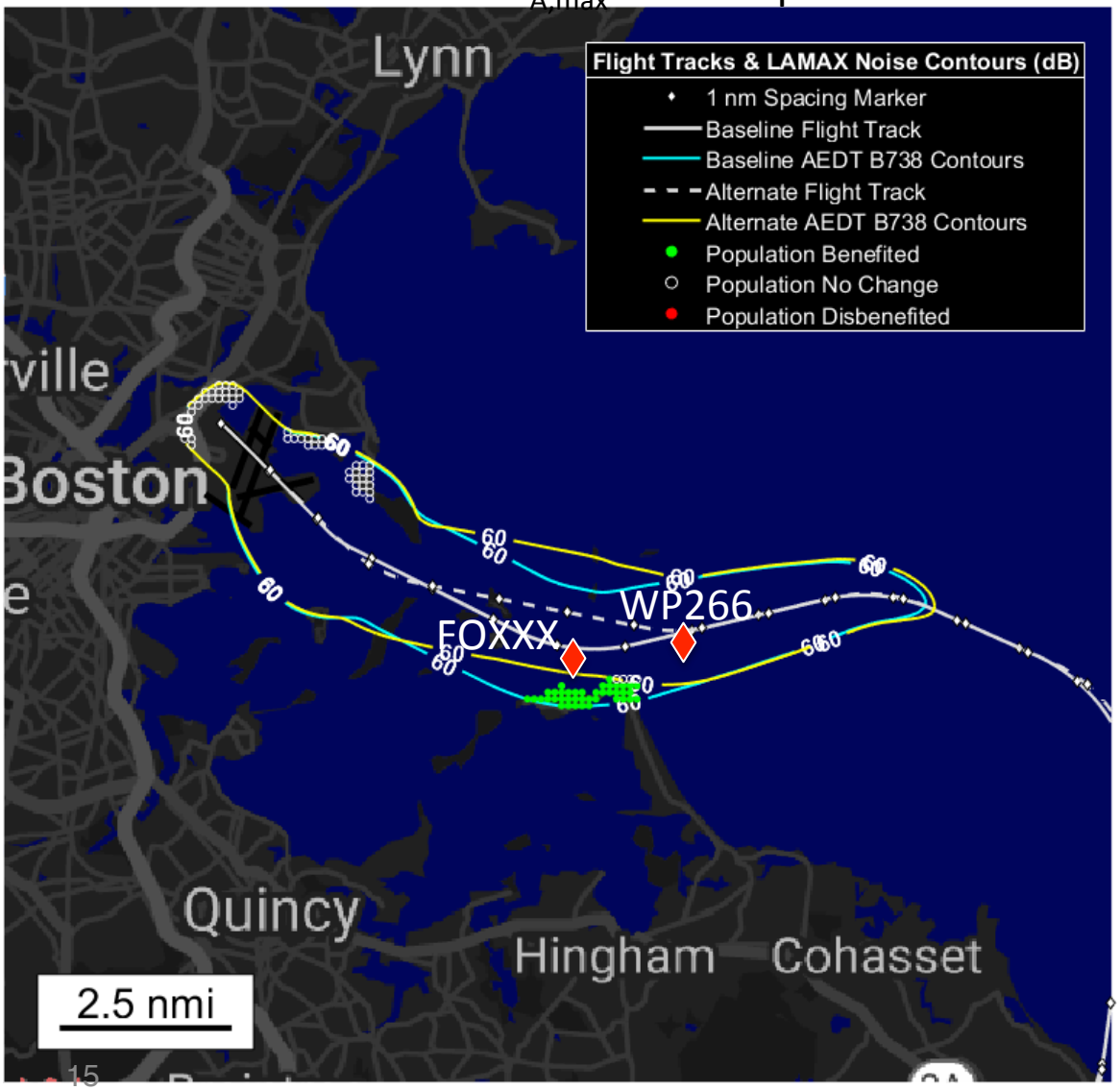
Notional design by Full Work Group as of October 4, 2018



1-D2 15R SID Modification FAA 7100.41 Group Final

Status: Procedure design supported by FAA 7100.41 Group

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



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

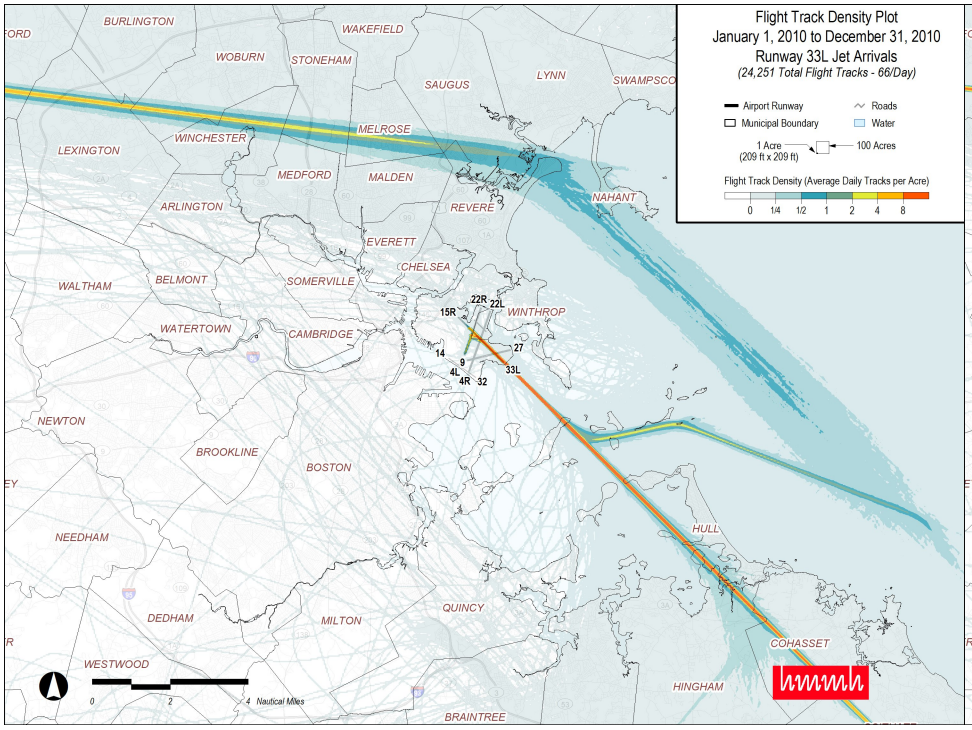
	60dB
Current RNAV	5,838
.41 RNAV	4,815
Current RNAV – .41 RNAV	1,023

Modify RNAV SID from Runway 15R to move tracks further to the north away from populated areas.

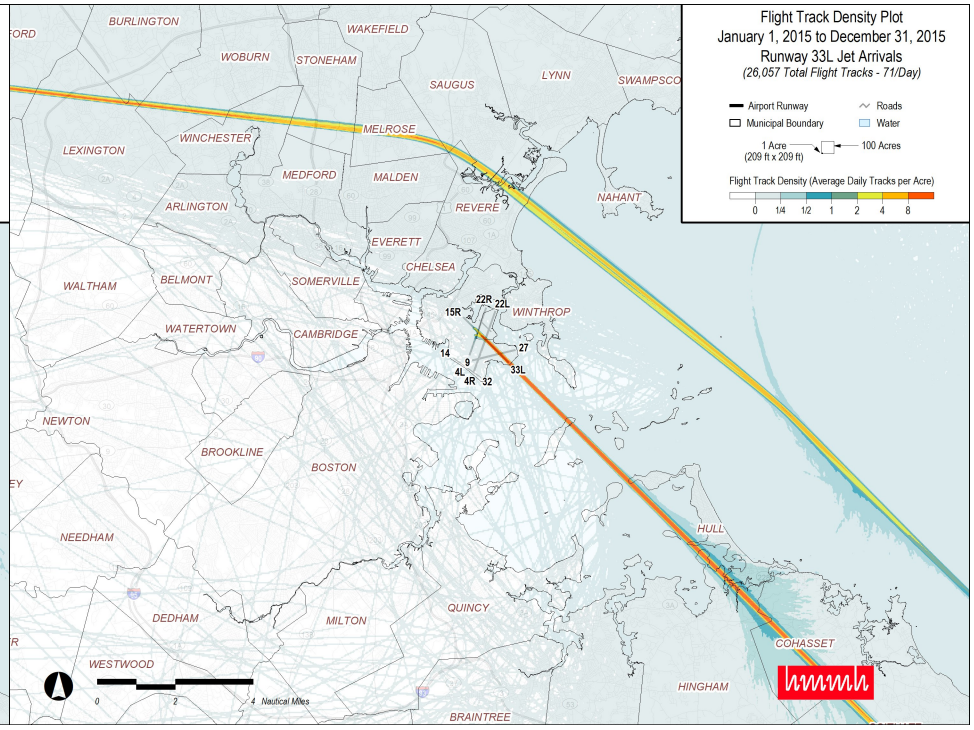
BLOCK 1: RUNWAY 33L
RNAV APPROACH AND RNP APPROACH

Runway 33L Arrivals: 2010-2015

2010

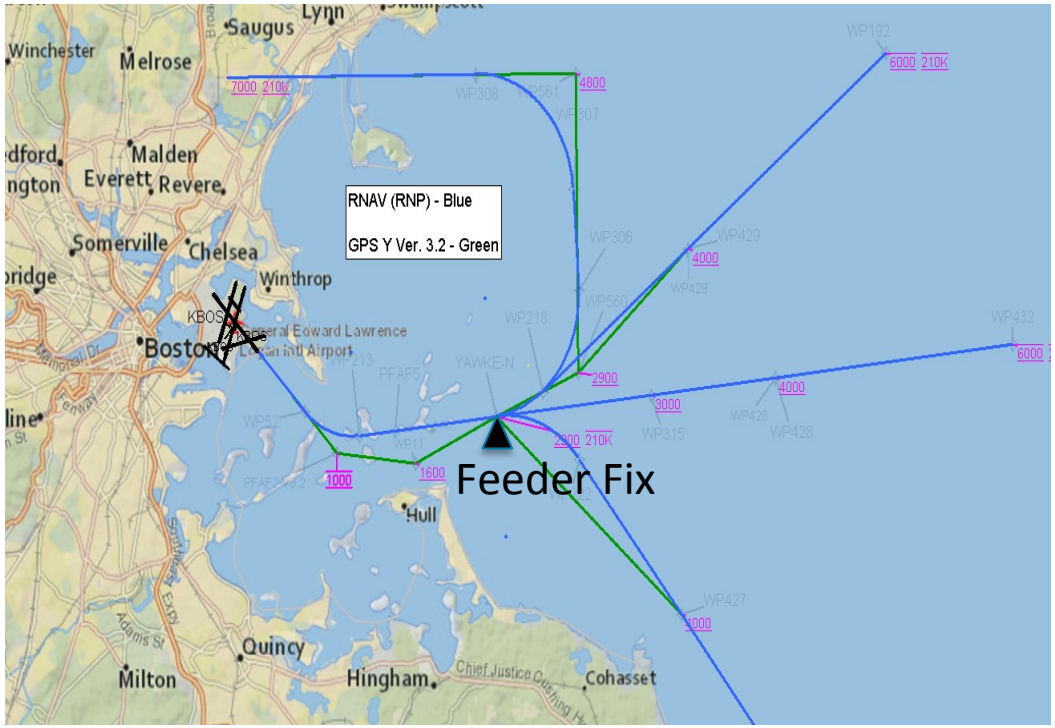


2015



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



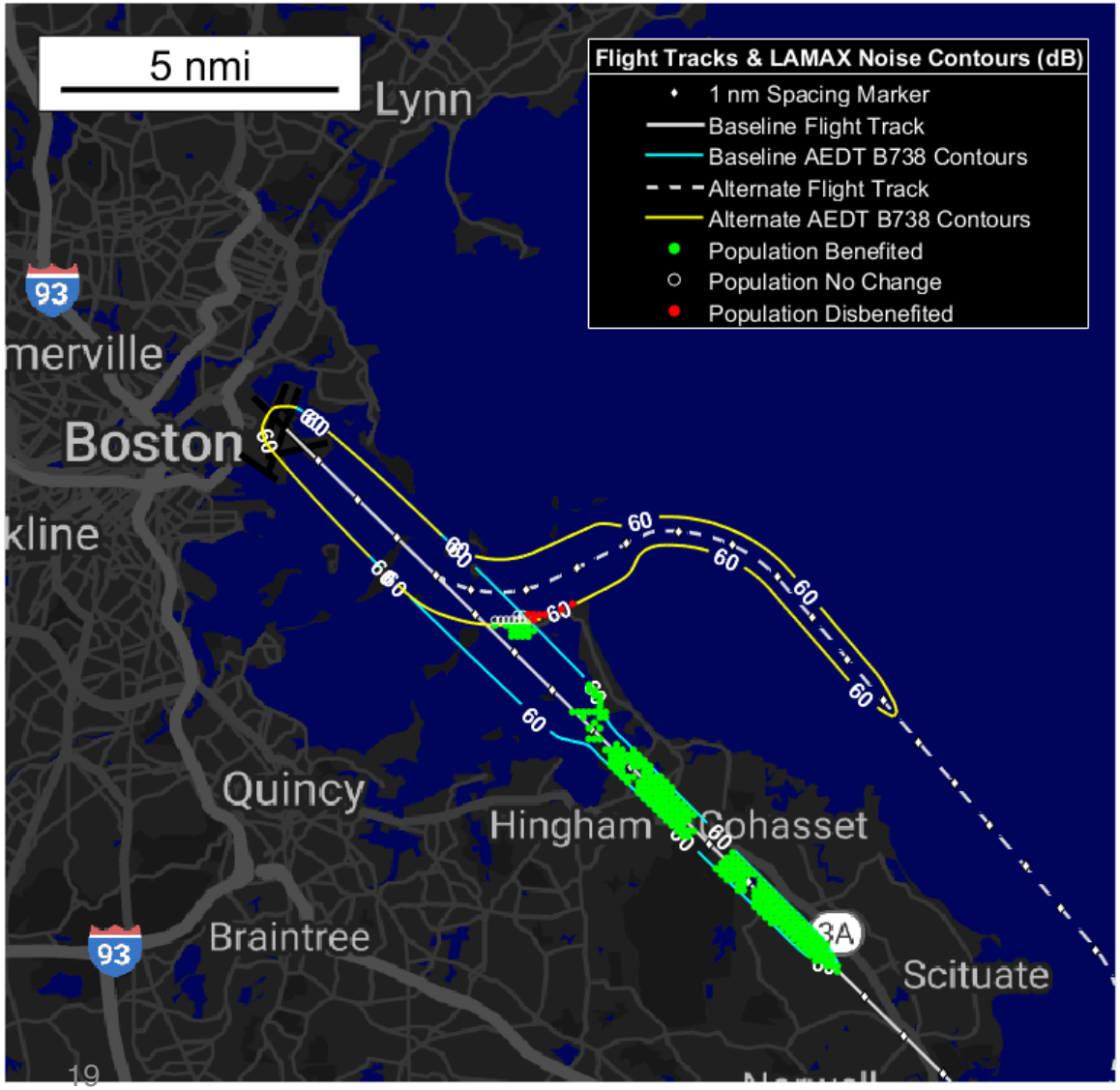
FAA 7100.41 TARGETS file

RNAV Approach in green
RNP Approach in blue

1-A1a 33L RNAV GPS Approach FAA 7100.41 Group Final

Status: Procedure design supported by FAA 7100.41 Group

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



B737-800 60dB $L_{A,max}$
Population Exposure

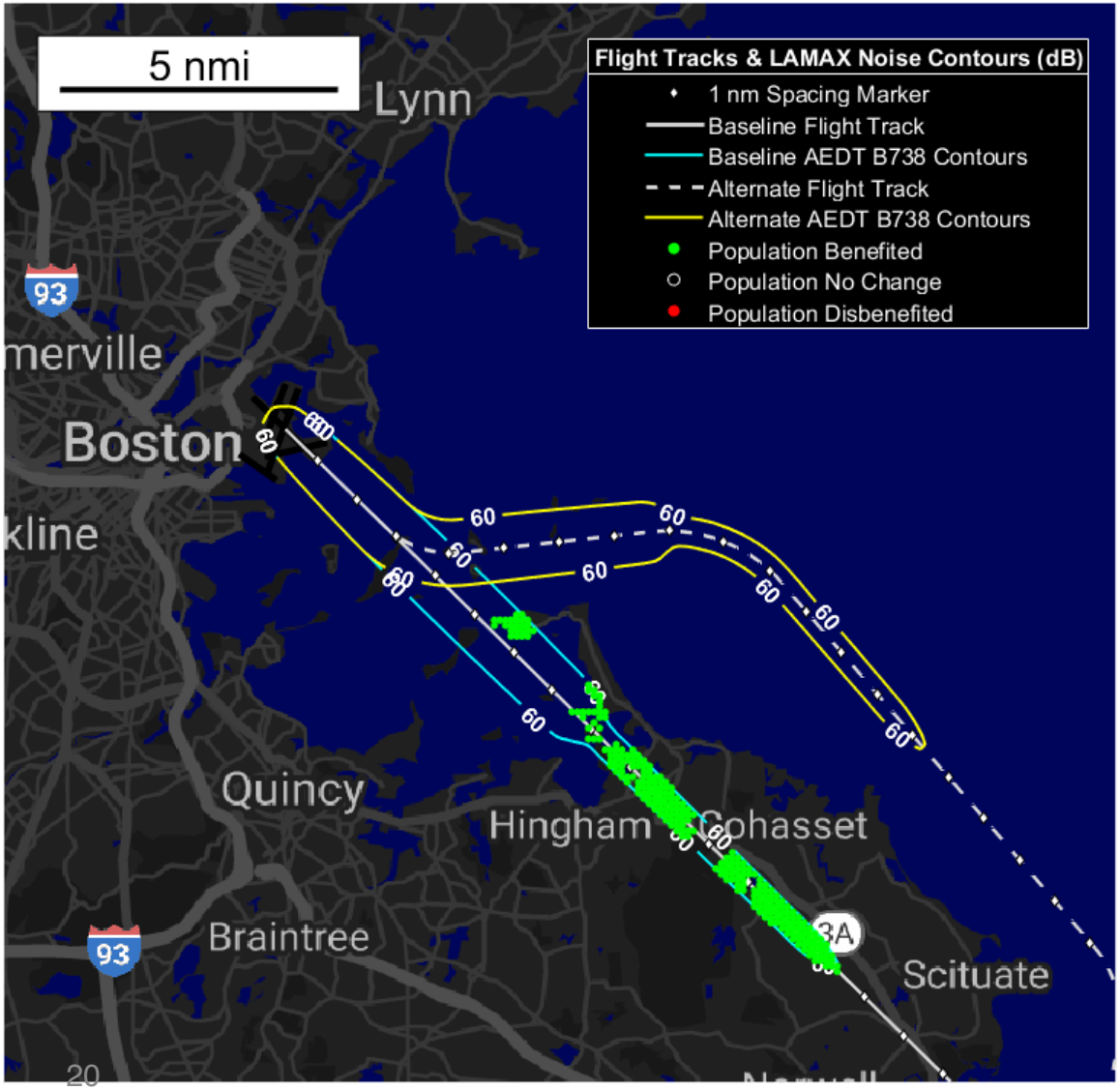
	60dB
Straight In	2,954
.41 RNAV GPS	396
Difference (Straight In– .41 RNAV GPS)	2,558

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

1-A1a 33L RNP Approach FAA 7100.41 Group Final

Status: Procedure design supported by FAA 7100.41 Group

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



B737-800 60dB $L_{A,max}$
Population Exposure

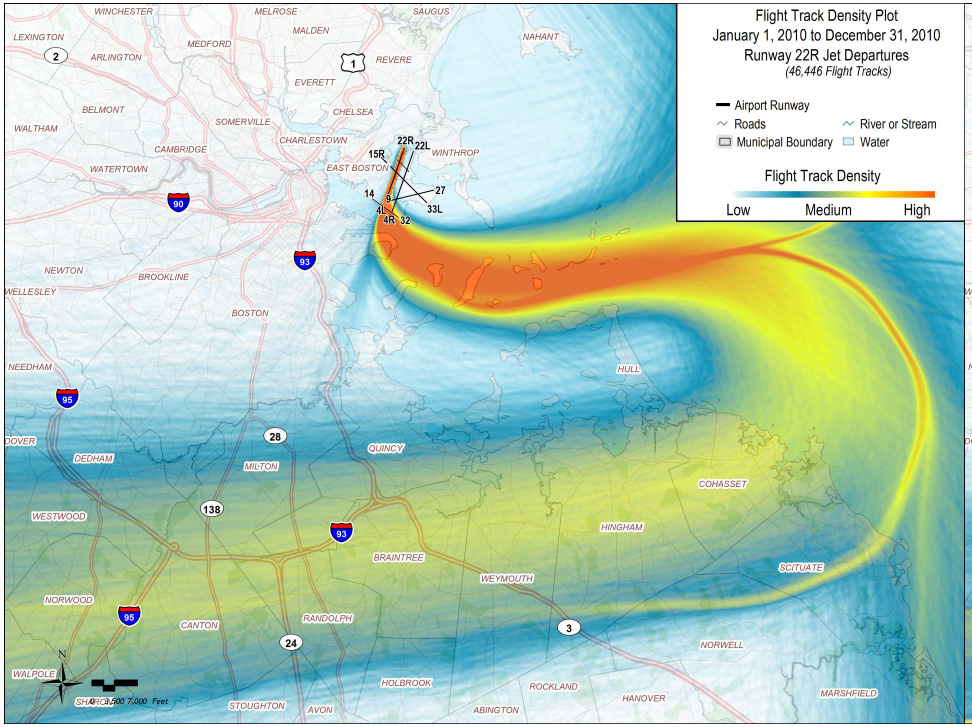
	60dB
Straight In	2,954
RNP	0
Difference (Straight In–RNP)	2,954

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

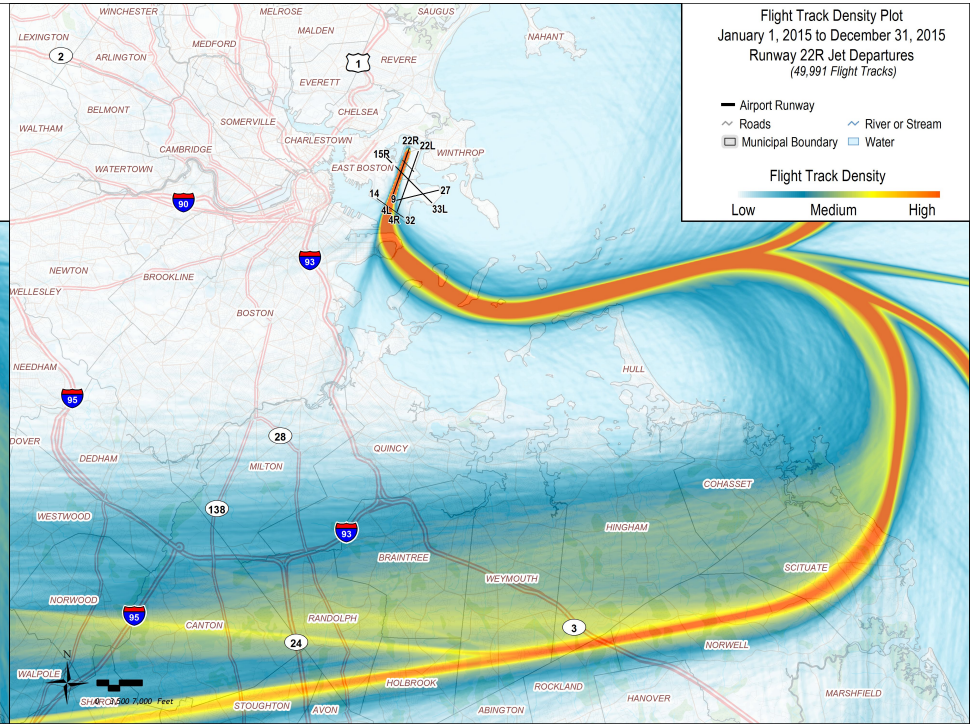
1-A1b: RNAV Visual procedures are distributed through the Lead Carrier who developed the procedure

Runway 22R Departures: 2010-2015

2010



2015

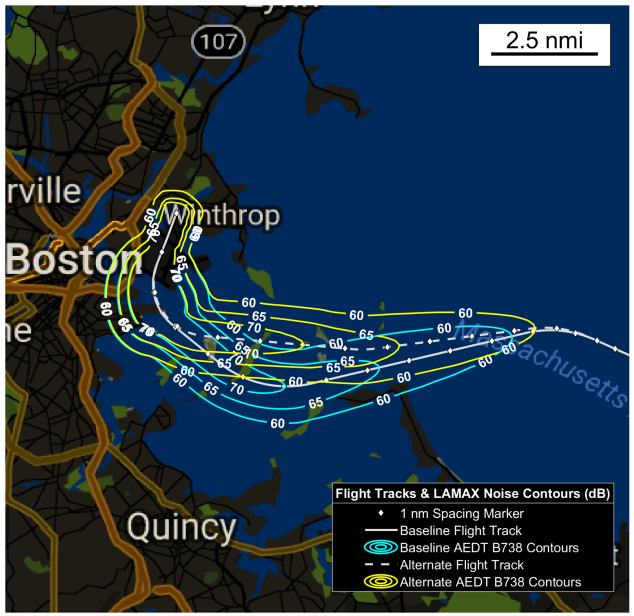


1-D3 Runway 22R SID Modification

Option A – RNAV Climb to Intercept Course

Concerns with:

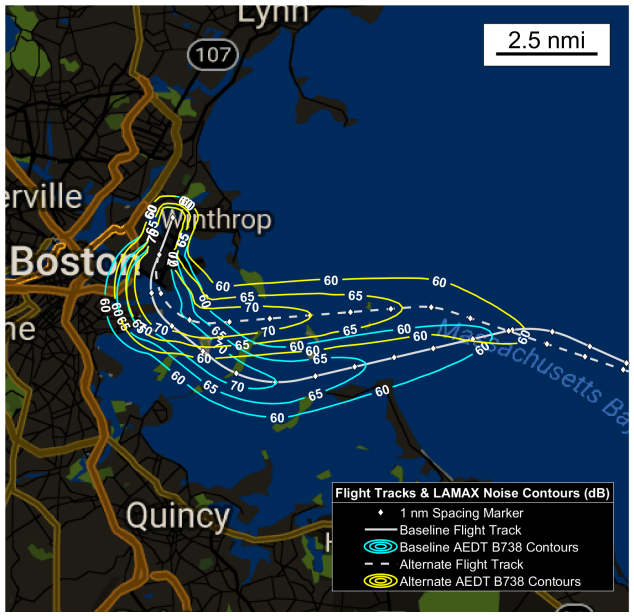
- AC coming off current procedure at turn right off TO under high wind, fast climb
- BRRRO – JAITE spacing too short
- Shoreline crossing at HEWMO at lower altitude



Option B – RNAV Climb to Altitude then Direct

Concerns with:

- Poor predictability of turn location
- Wide splay of tracks
- Additional spacing may be added by ATC due to uncertainty

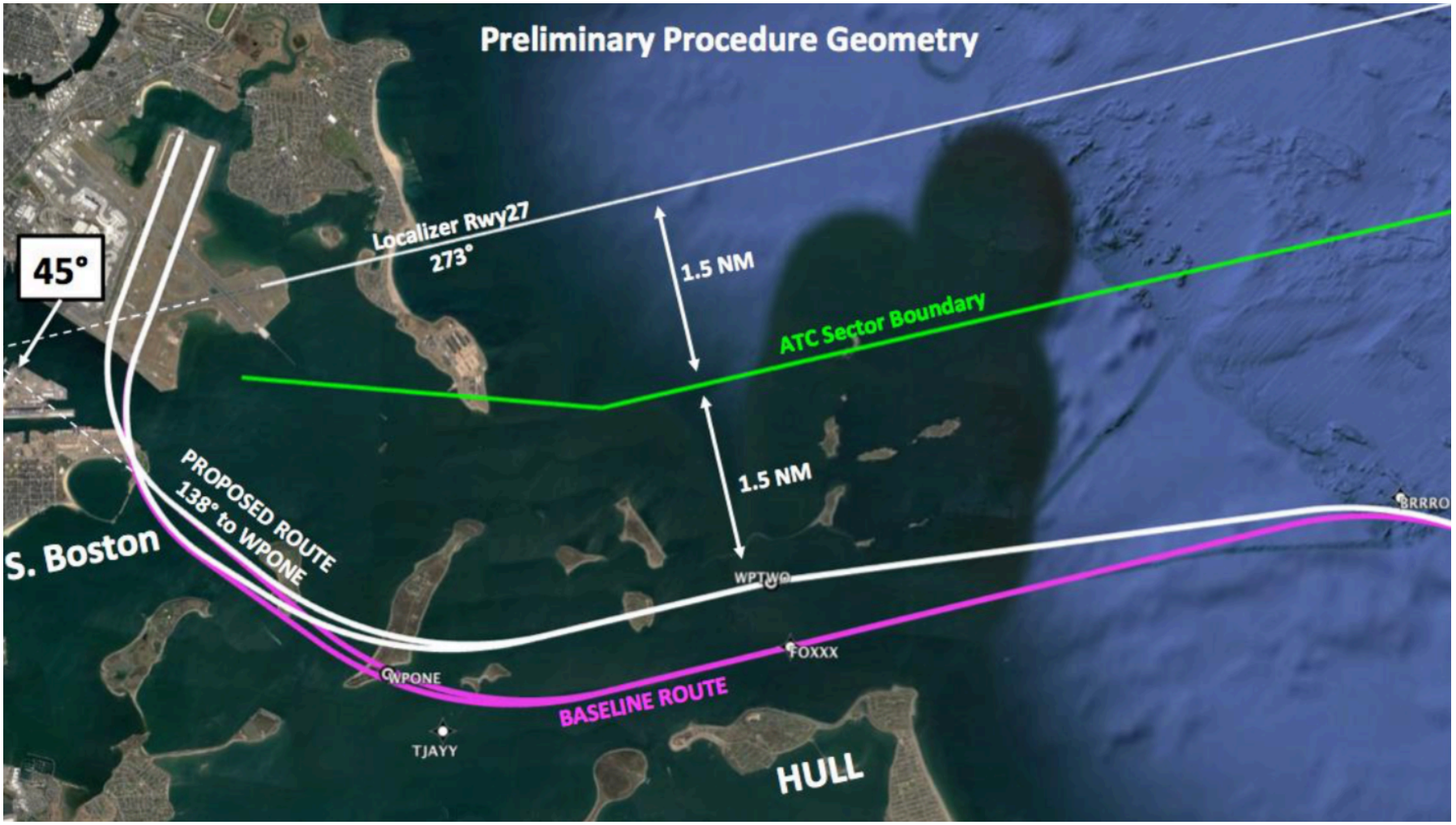


Option C – Heading-Based Departure

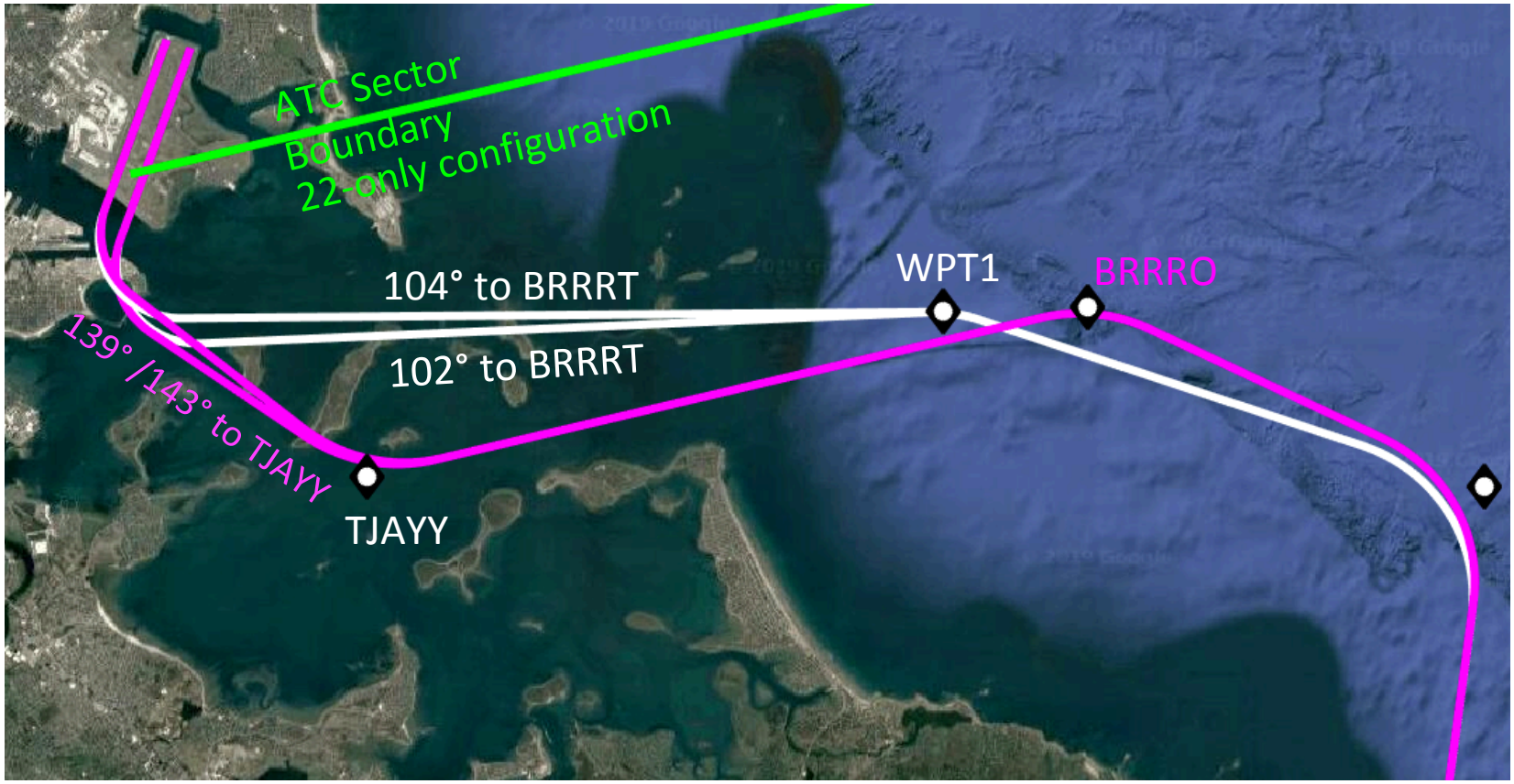
Concerns with:

- Multiple SIDS
- Dispatch/ATC systems defaulting to RNAV SIDS
- Workload and verbiage increase
- Possible late turns over Hull

Original Block I 1-D3A Proposal: VI-CF



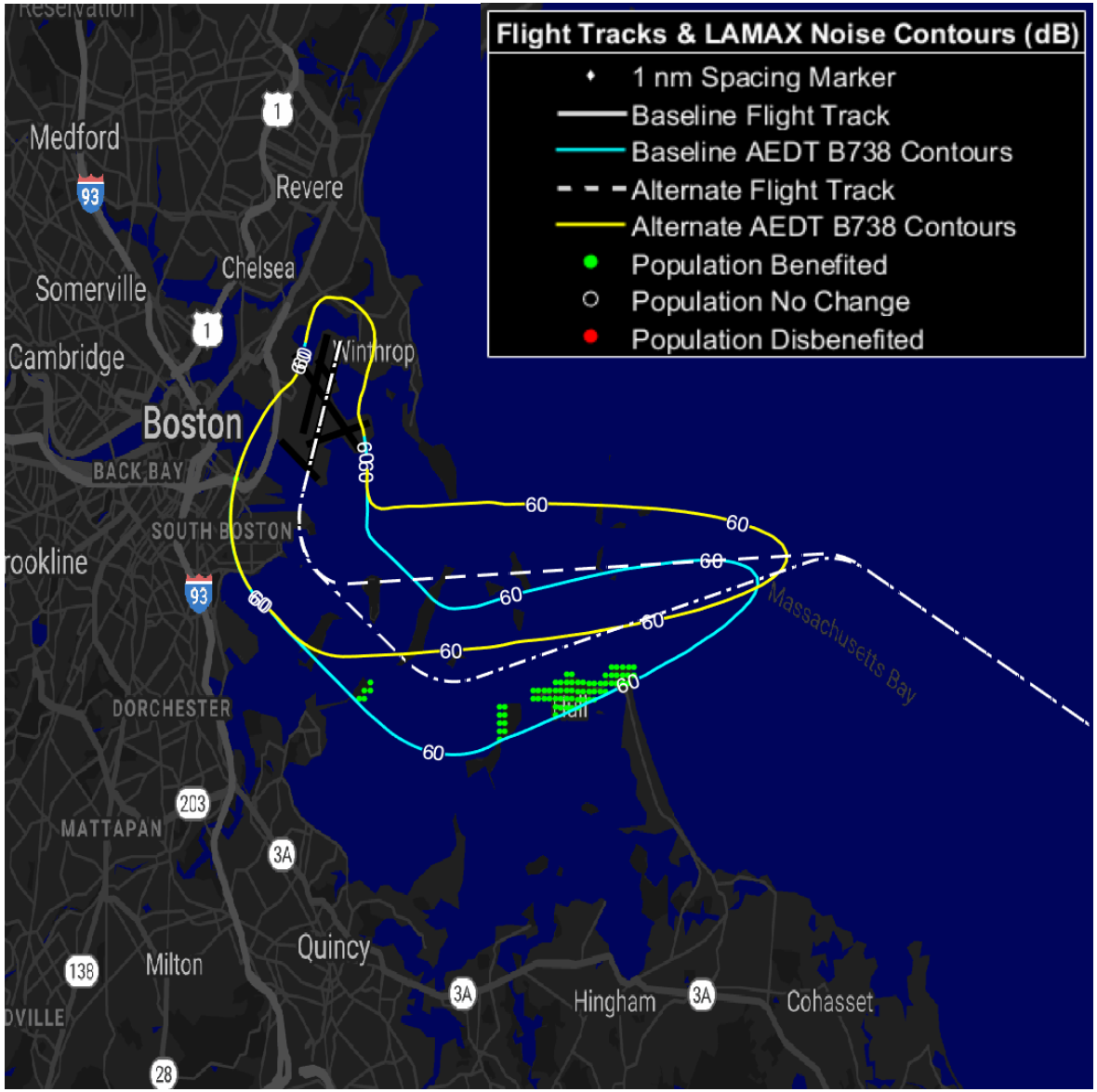
Rework Option A – 22L/R VI-CF when 27 is not in use



- **Shift BRRRO slightly west (new hypothetical waypoint WPT1) to increase its distance to JAITE and resolve minimum path length issues. Specific location of WPT1 TBD**
- **Based on 2018 ASPM data, 27 was primary arrival 9.5% of the time and allowable 24% of time.**

Rework Option A – 22L/R VI-CF Noise Results

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

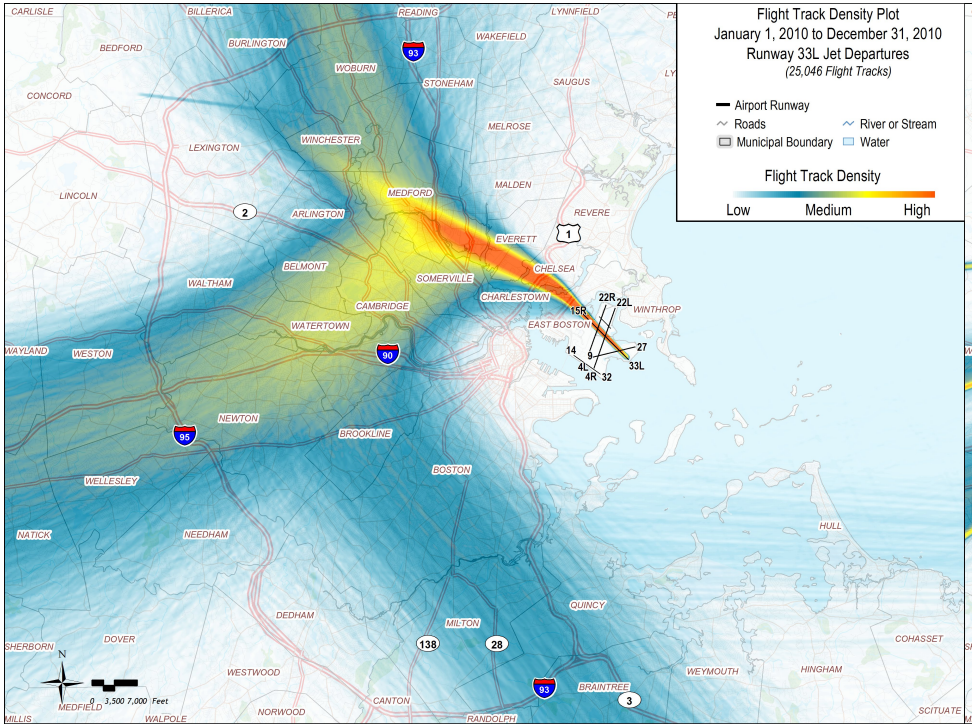


B737-800 60dB $L_{A,max}$
Population Exposure

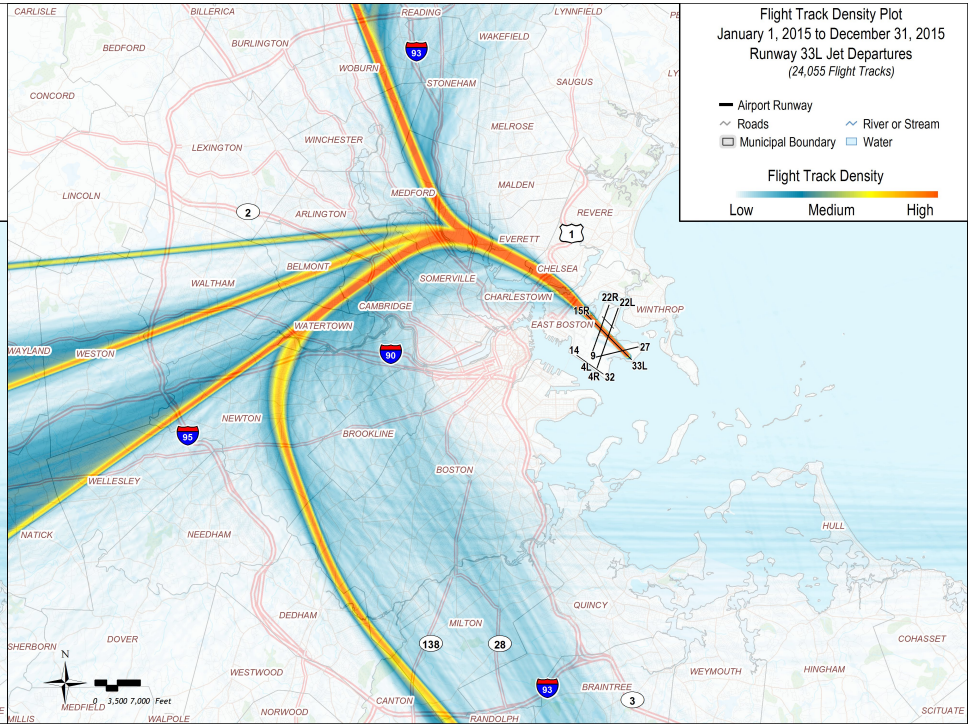
	60 dB
Baseline	19366
Rework	18039
Difference (Baseline-Rework)	1327

Runway 33L Departures: 2010-2015

2010

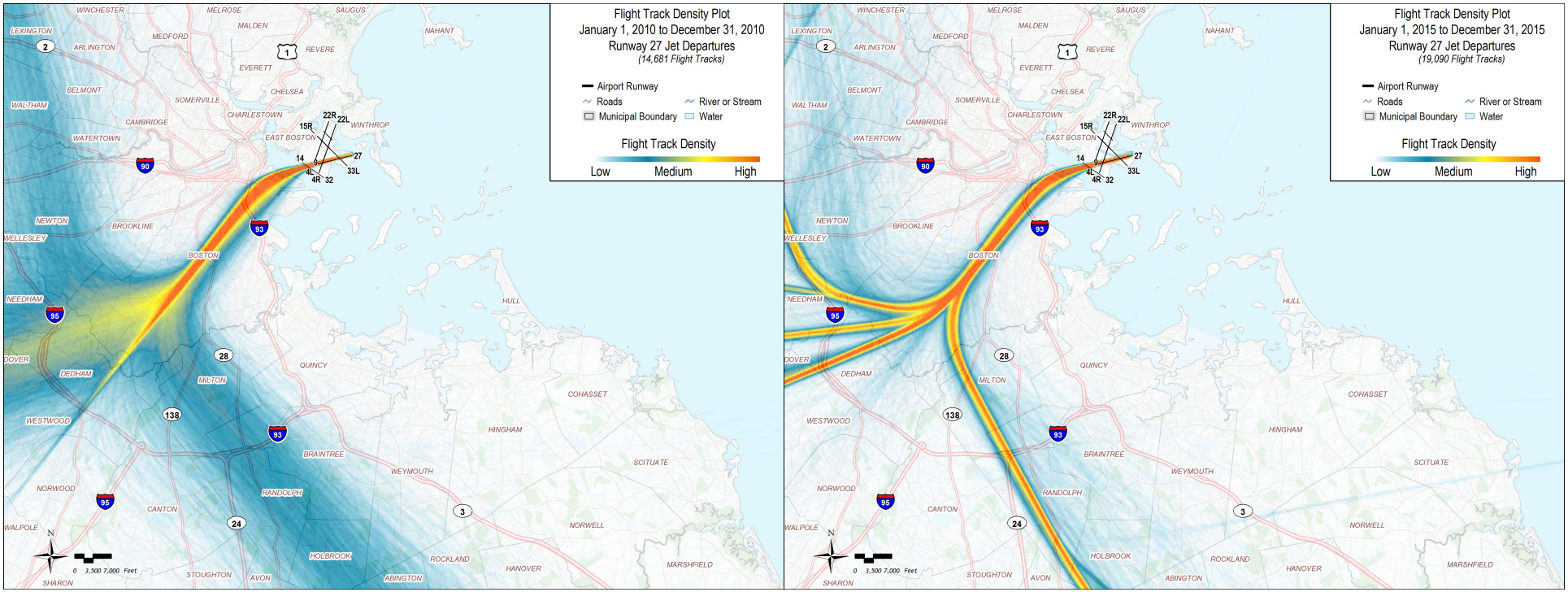


2015



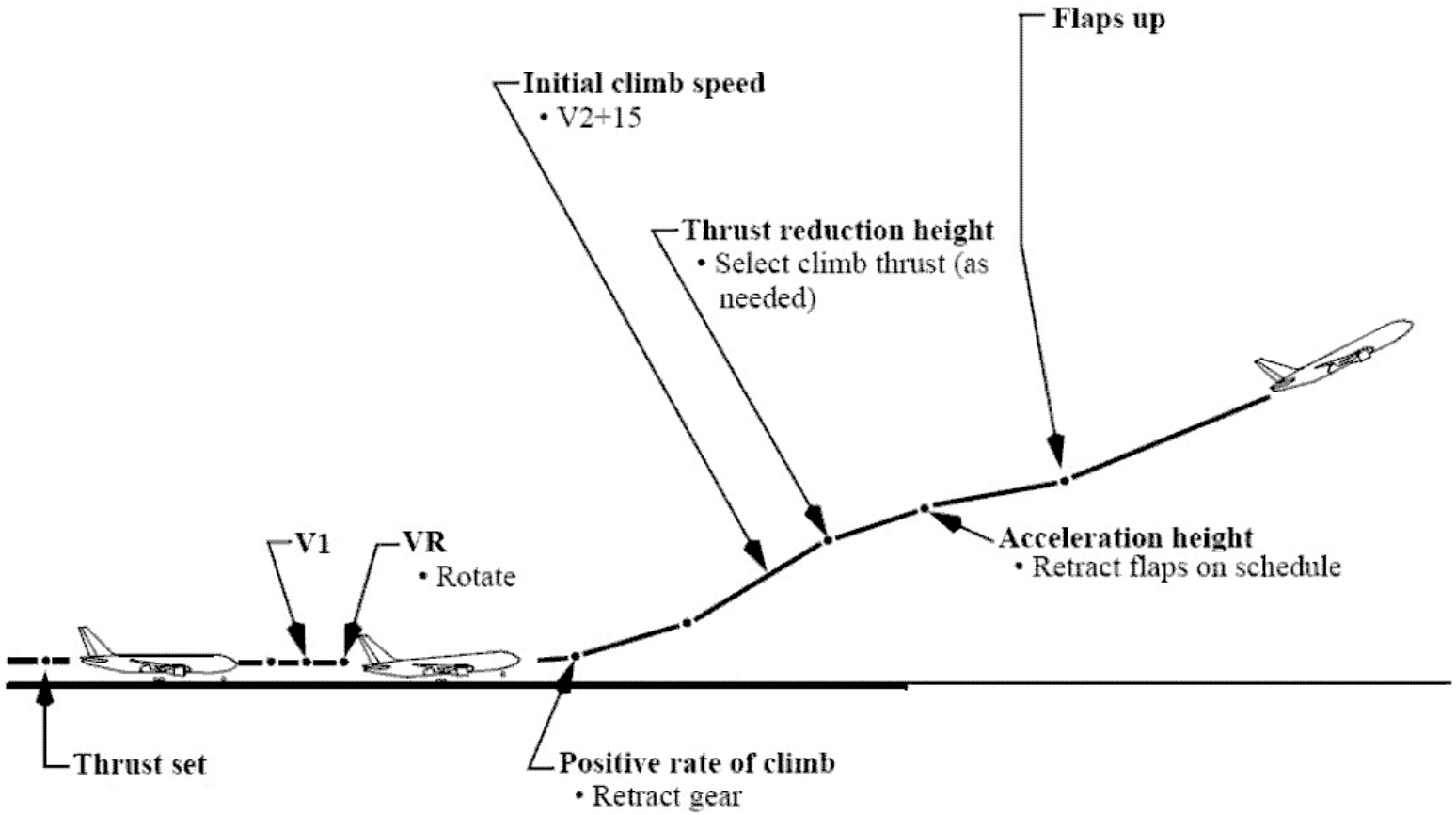
Runway 27 Departures: 2010-2015

2010



2015

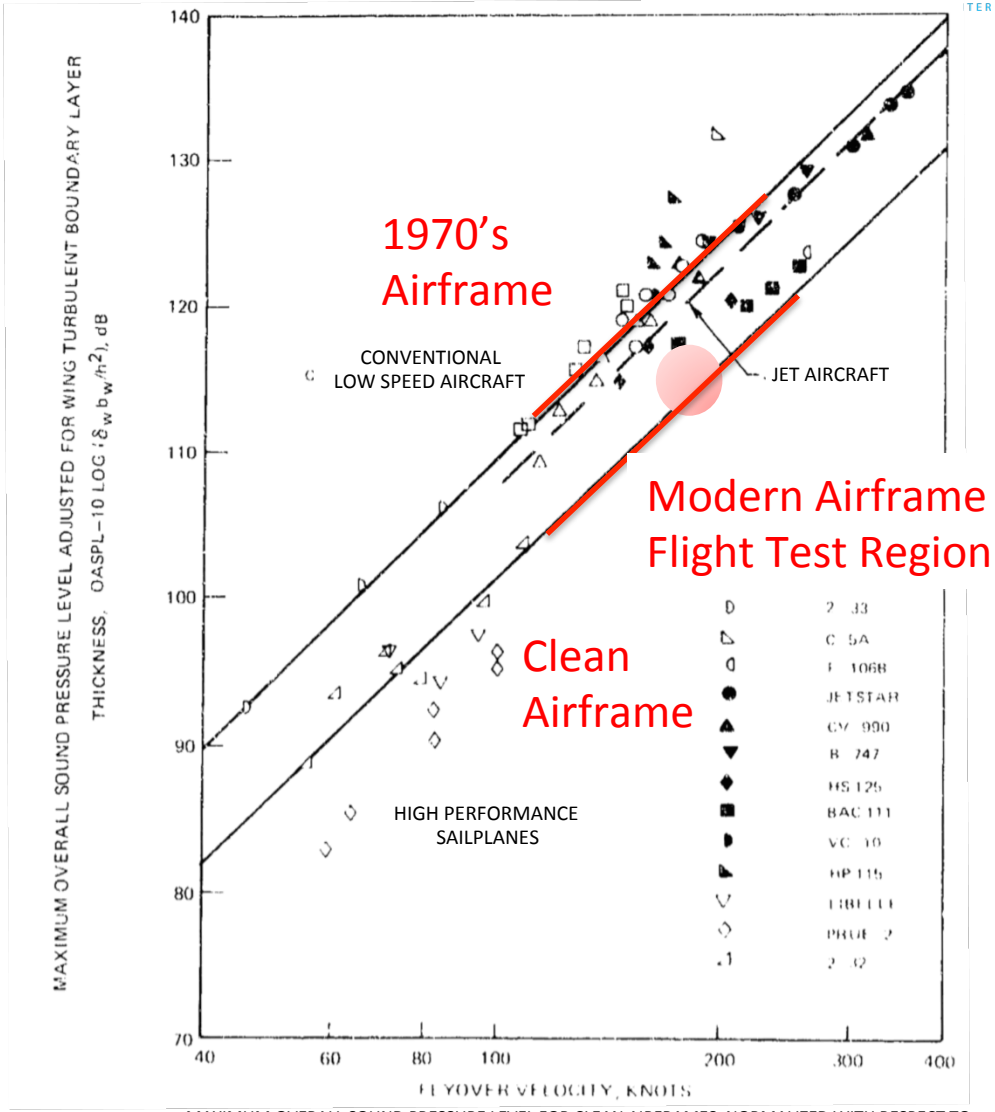
1-D1 Reduced Speed Departures



- **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**

ANOPP Clean Airframe Model

- Modern airplanes may have slightly cleaner airfoils than assumed in ANOPP
- ANOPP clean airframe model developed from over-flight data of variety of aircraft in the 1970s
  - Noise intensity from clean airframes caused by convection of the turbulent boundary layers past the trailing edge
- Proportional to product of the trailing edge turbulent boundary layer thickness δ & V^5
  - Acoustic Intensity $I \approx \delta * V^5$
- ANOPP gives option of computing noise only for these upper & lower bounds
  - $I_{conventional} \approx$ 8dB louder than $I_{sailplanes}$



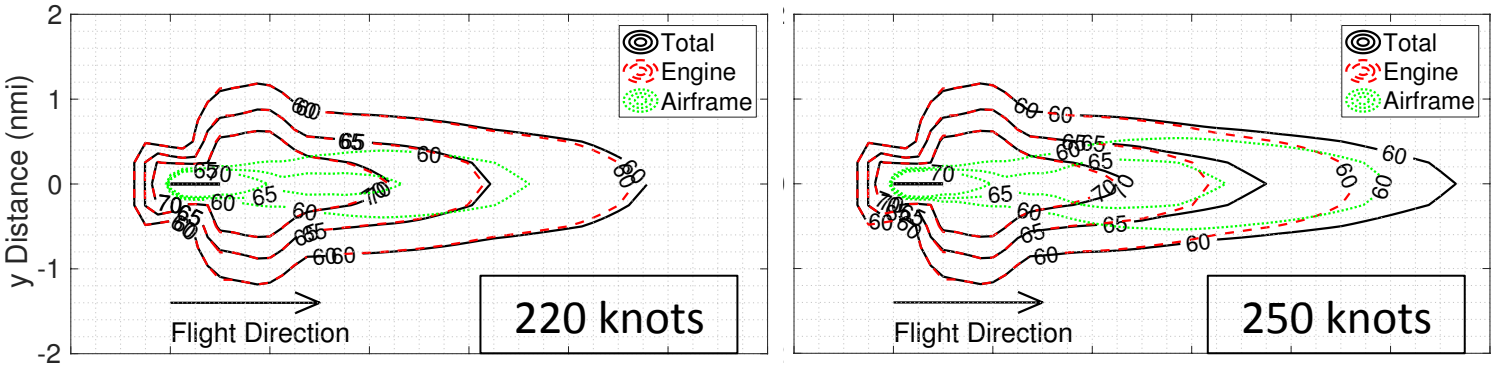
MAXIMUM OVERALL SOUND PRESSURE LEVEL FOR CLEAN AIRFRAMES, NORMALIZED WITH RESPECT TO PRODUCT OF WING SPAN AND WING TRAILING EDGE BOUNDARY LAYER THICKNESS

Source: Fink, M. "Airframe Noise Prediction Method"

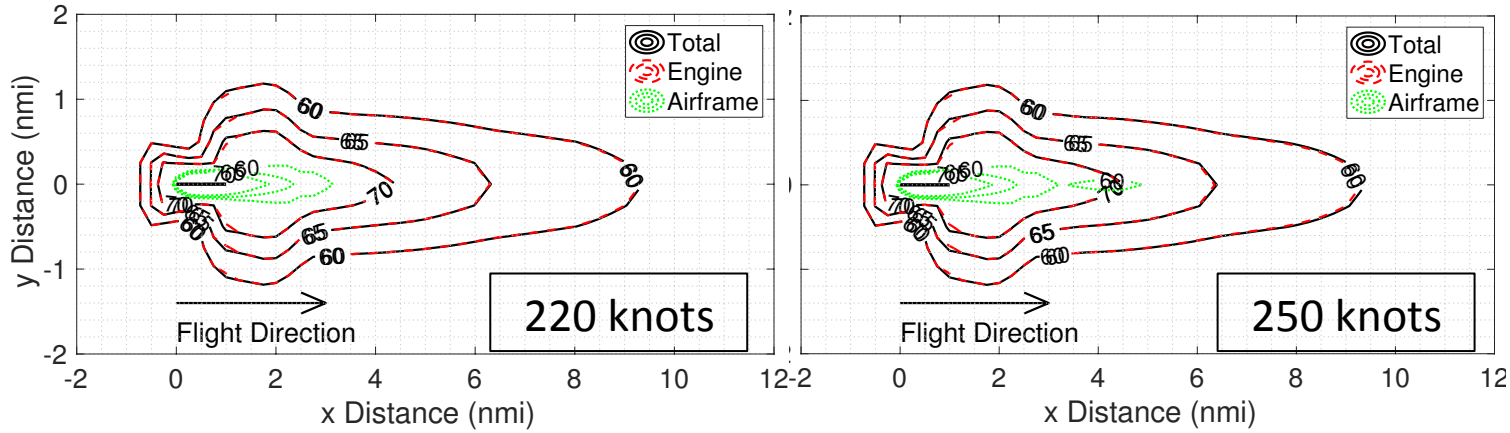
Impact of Climb Speed

Impact Depends on Assumption of Flaps up Airframe Noise

Recent Boeing and NASA data suggests flaps up airframe noise quieter for modern aircraft—thus changing departure climb speed would have minimal impact on departure noise



Flaps up airframe noise data from 1970 flight tests (used in the initial MIT analysis of this procedure)

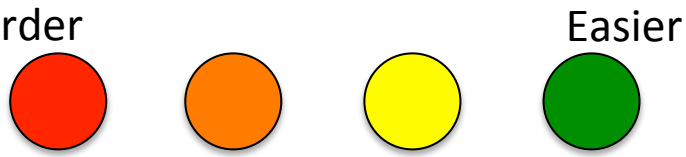


Model using quiet flaps up airframe data for modern aircraft

Block 2 Examples:

More complex due to potential operational/technical barriers or equity issues

Ease of Implementation Scale*



*All Block 2 procedures will be difficult to implement; the color scale only indicates *relative* ease of implementation

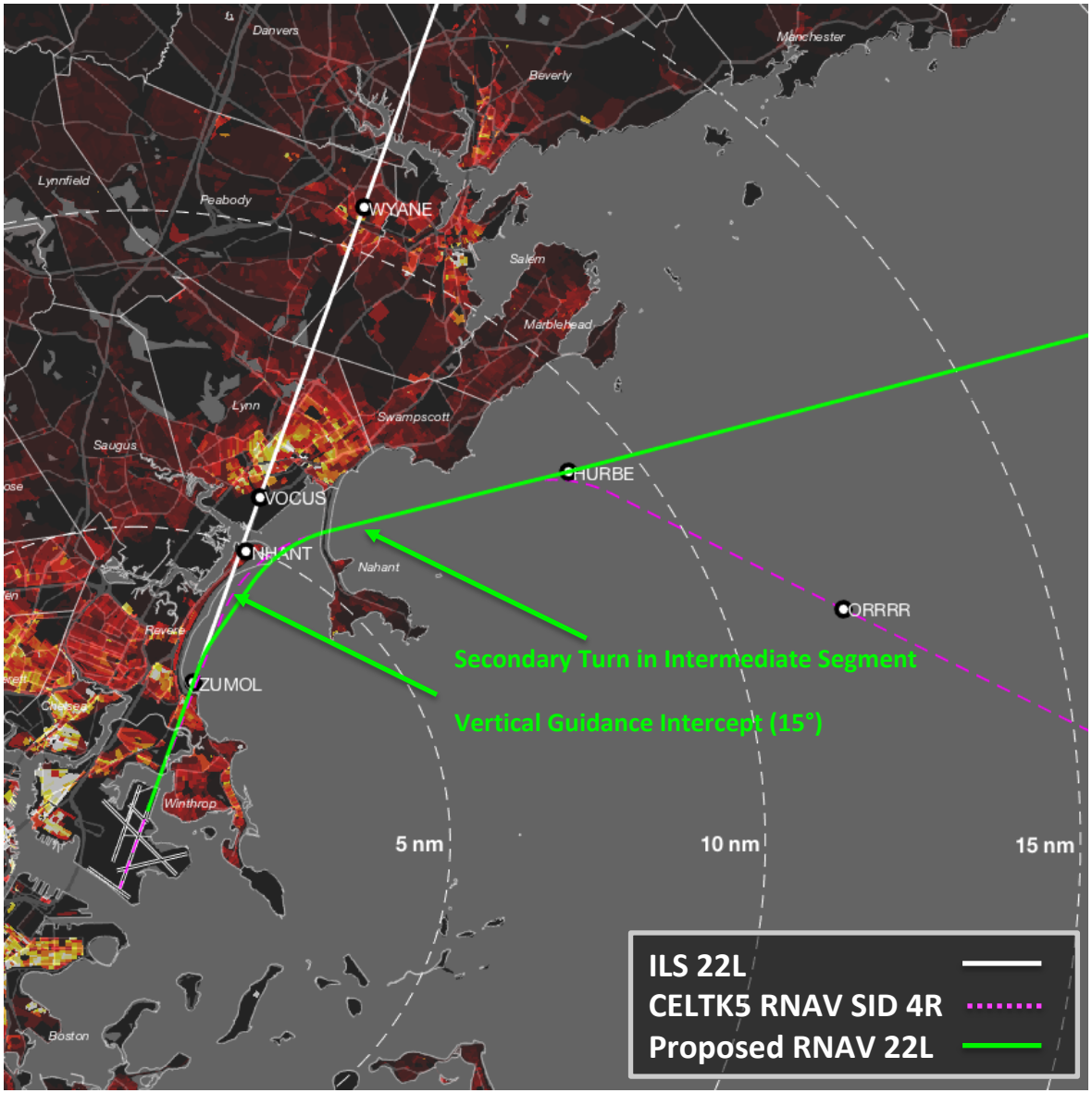
RNAV/RNP LATERAL MODIFICATIONS TO 22L APPROACH PROCEDURE

22L Low-Noise Offset RNAV Approach with RNP Overlay

Overlaying arrival corridor on existing 4R RNAV SID for 22L arrivals

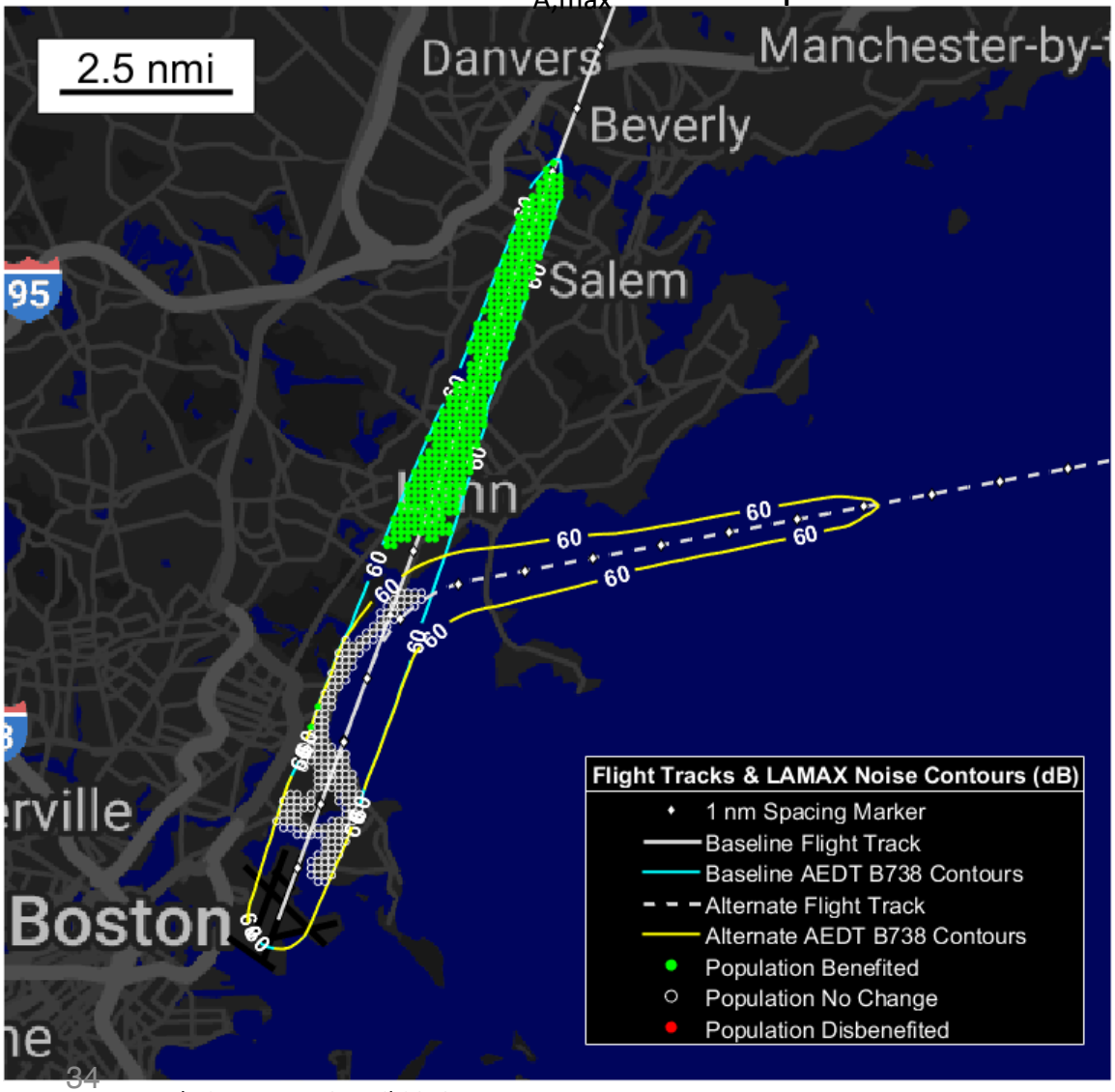
Notes:

- Intended to comply with design criteria for vertical-guidance RNAV
- Overflies midpoint of Nahant causeway at same location as 4R SID departure crossings



22L Arrival RNAV with RNP Overlay vs Straight In Boston Data B737-800 Profile 3000ft Level Off

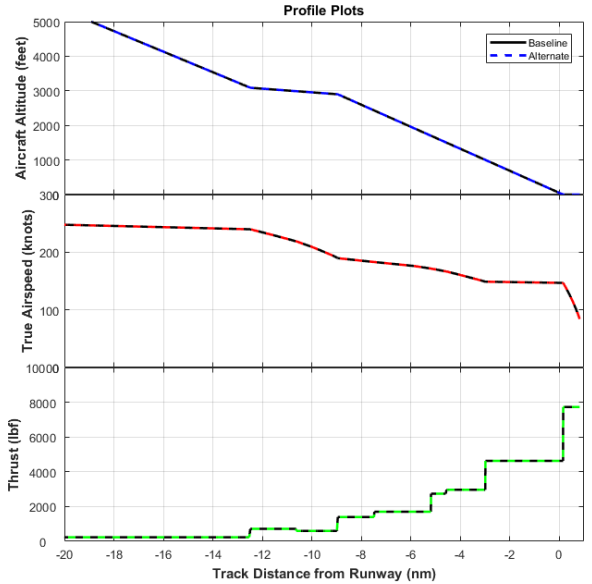
B737-800 60dB $L_{A,max}$ Noise Exposure



Analysis current 19 April 2019

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

	60dB
Straight In	70,198
RNP	24,272
Difference (Straight In – RNP)	45,926



Altitude, speed, and thrust profiles are based on flight profile data from Boston

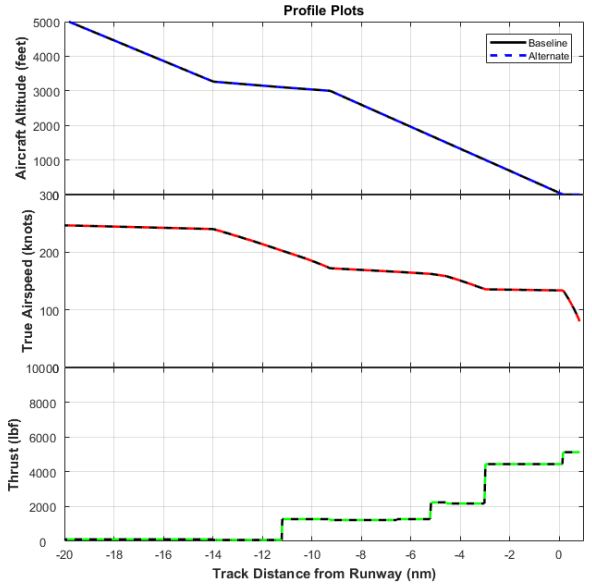
- Procedure within RNAV criteria. Initial .41 review found no major obstacles

22L Arrival RNAV with RNP Overlay vs Straight In Boston Data A320 Profile 3000ft Level Off

A320 60dB $L_{A,max}$ Noise Exposure

A320
Population Exposure ($L_{A,MAX}$)

	60dB
Straight In	73,173
RNP	22,003
Difference (Straight In – RNP)	51,170



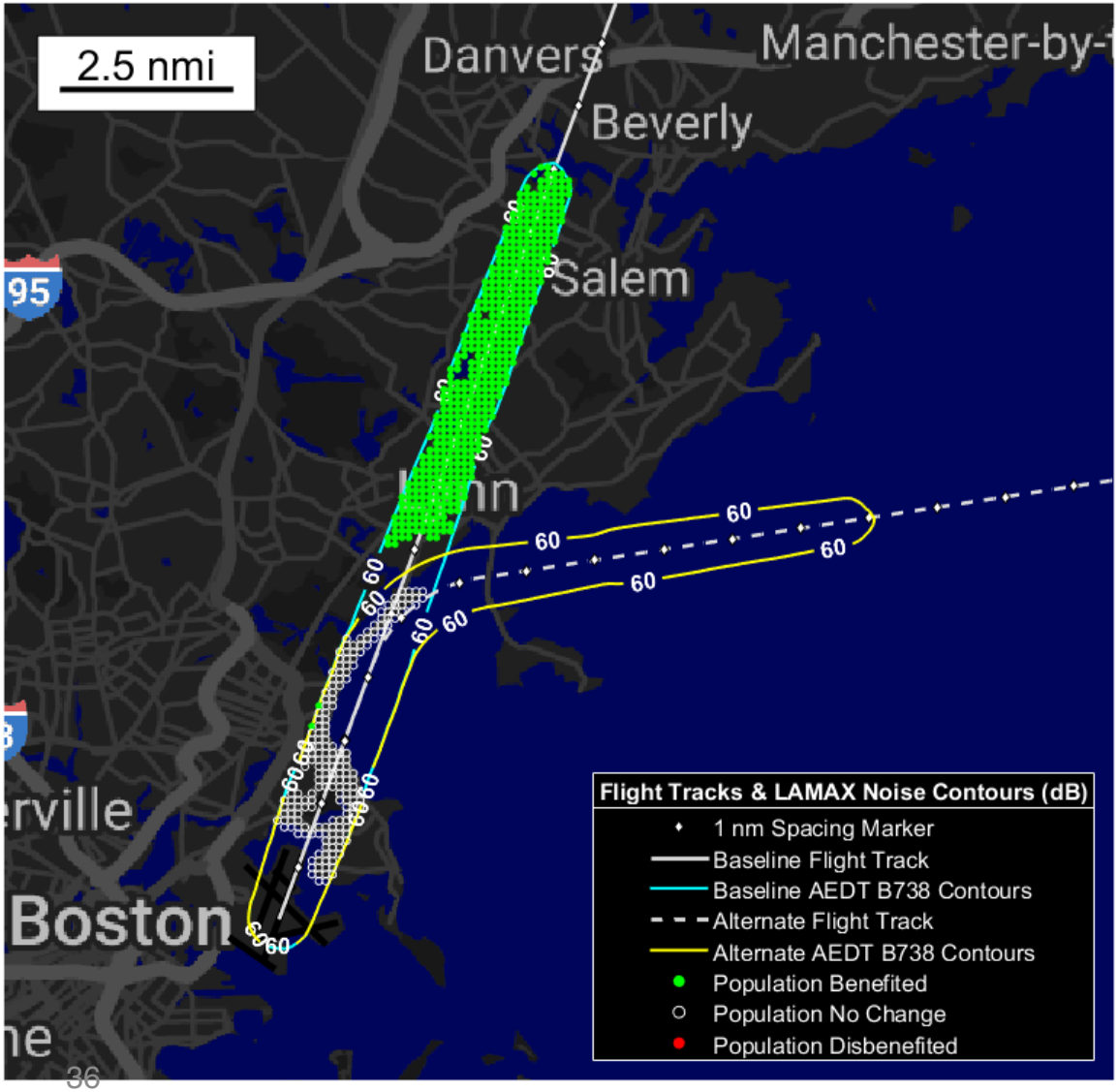
Altitude, speed, and thrust profiles are based on flight profile data from Boston

- Procedure within RNAV criteria. Initial .41 review found no major obstacles

Analysis current 19 April 2019

22L Arrival RNAV with RNP Overlay vs Straight In
B738 Profile Generator 60dB $L_{A,max}$ Noise Exposure

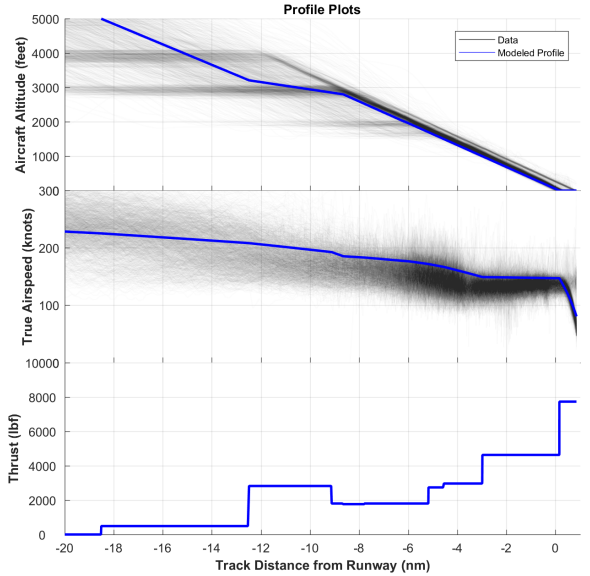
B737-800 60dB $L_{A,max}$ Noise Exposure



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

15% of aircraft fleet

	60dB
Straight In	77,418
RNP	24,272
Difference (Straight In – RNP)	53,146

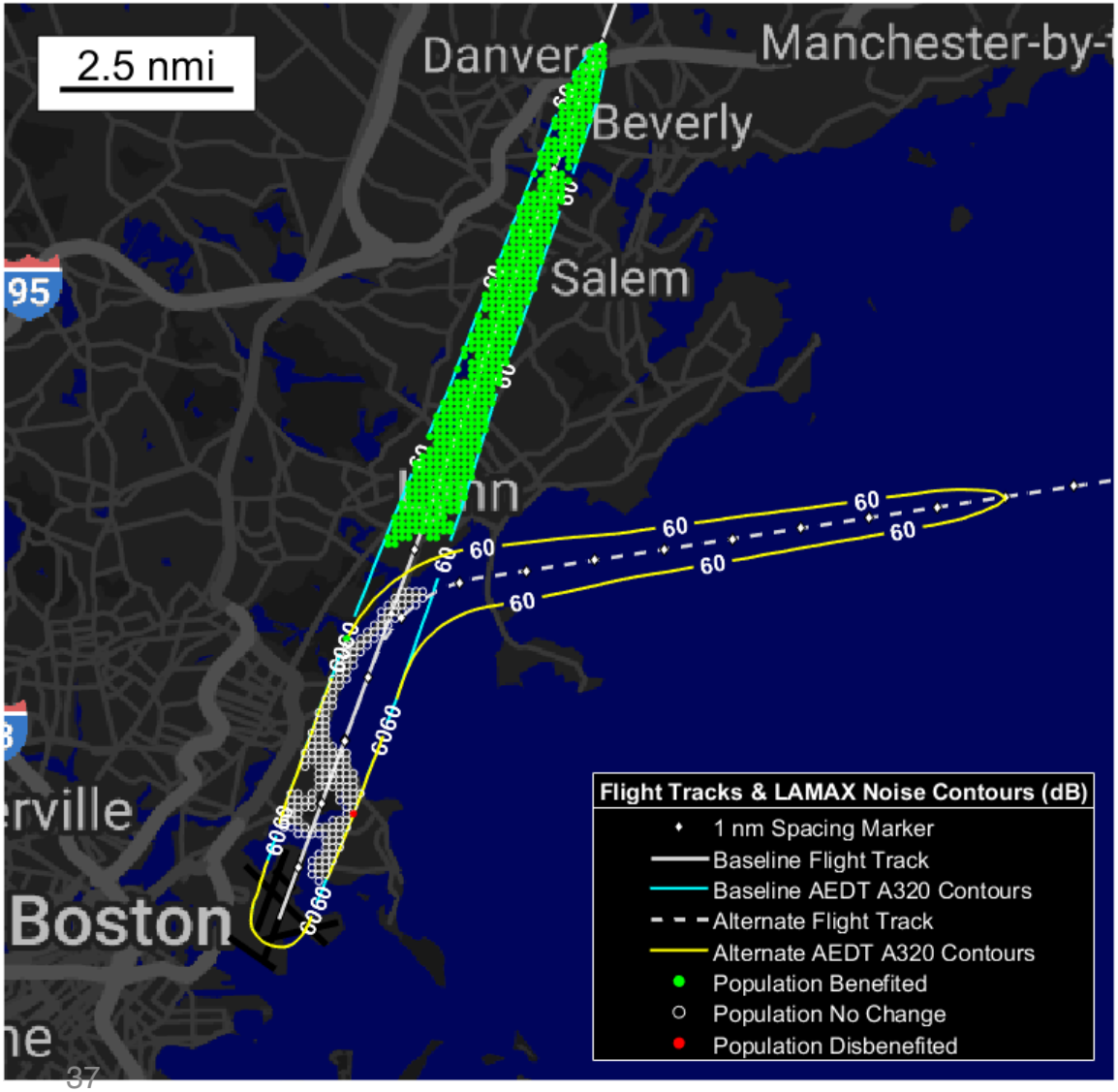


Altitude, speed, and thrust profiles are based on flight profile data from Boston. Slightly adjusted inbound heading

- Procedure within RNAV criteria. Initial .41 review found no major obstacles

22L Arrival RNAV with RNP Overlay vs Straight In
A320 Profile Generator 60dB $L_{A,max}$ Noise Exposure

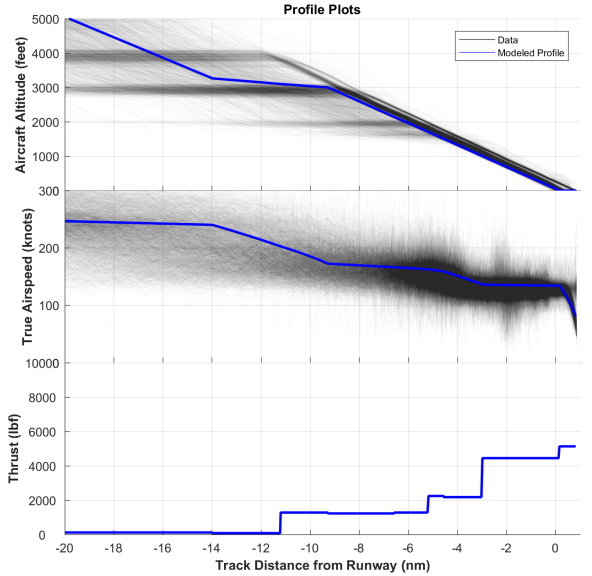
A320 60dB $L_{A,max}$ Noise Exposure



A320 Population Exposure ($L_{A,MAX}$)

27% of aircraft fleet

	60dB
Straight In	73,173
RNP	22,003
Difference (Straight In – RNP)	51,170

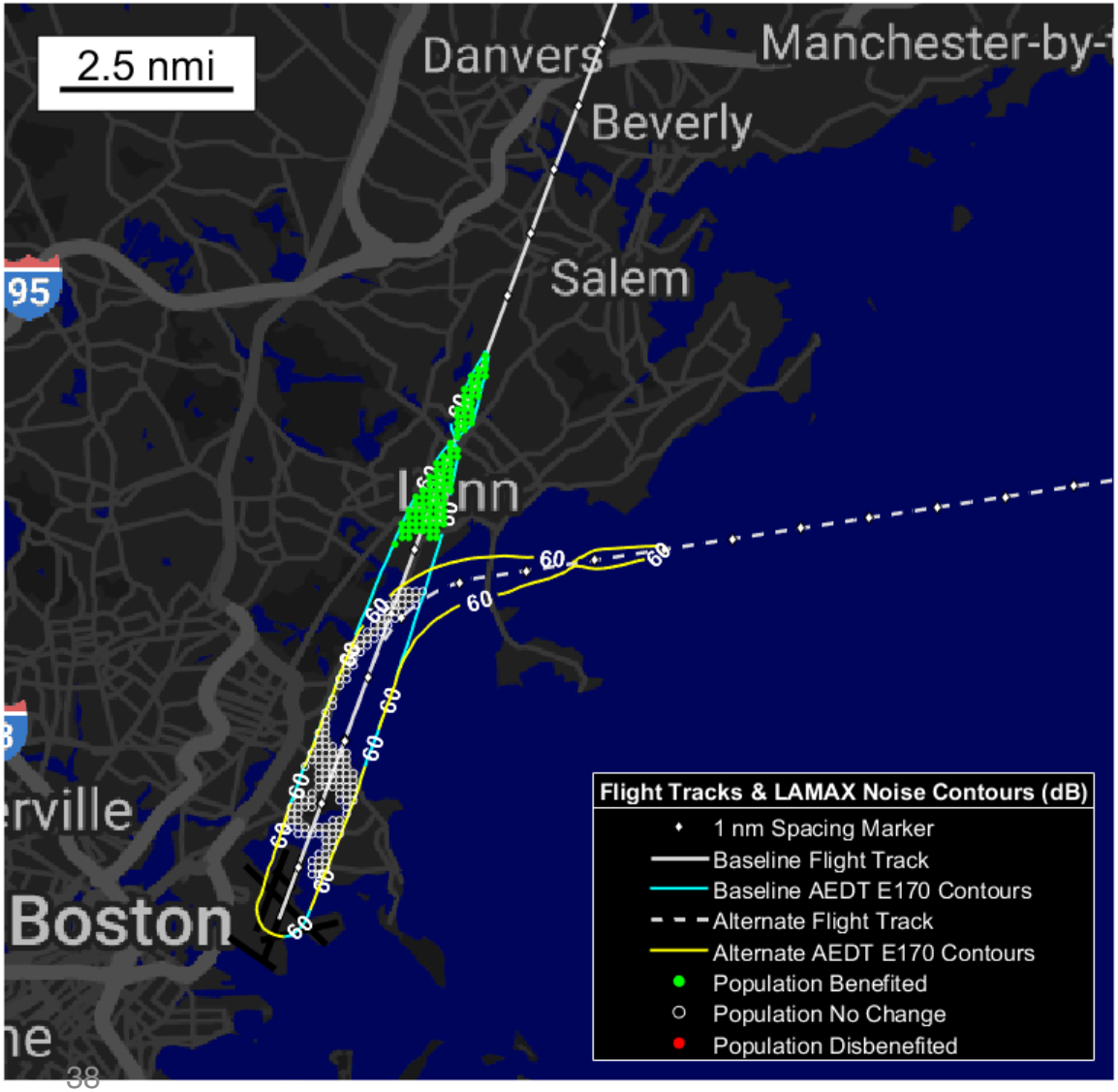


Altitude, speed, and thrust profiles are based on flight profile data from Boston. Slightly adjusted inbound heading

- Procedure within RNAV criteria. Initial .41 review found no major obstacles

22L Arrival RNAV with RNP Overlay vs Straight In
E170 Profile Generator 60dB $L_{A,max}$ Noise Exposure

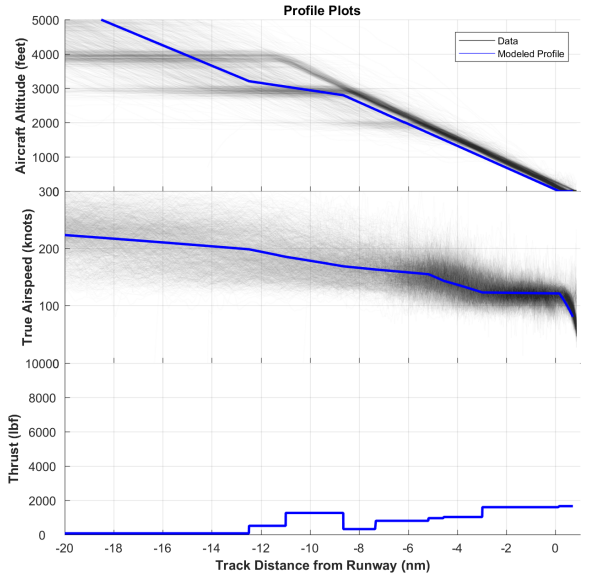
E170 60dB $L_{A,max}$ Noise Exposure



E170 Population Exposure ($L_{A,MAX}$)

24% of aircraft fleet

	60dB
Straight In	36,581
RNP	16,972
Difference (Straight In – RNP)	19,609

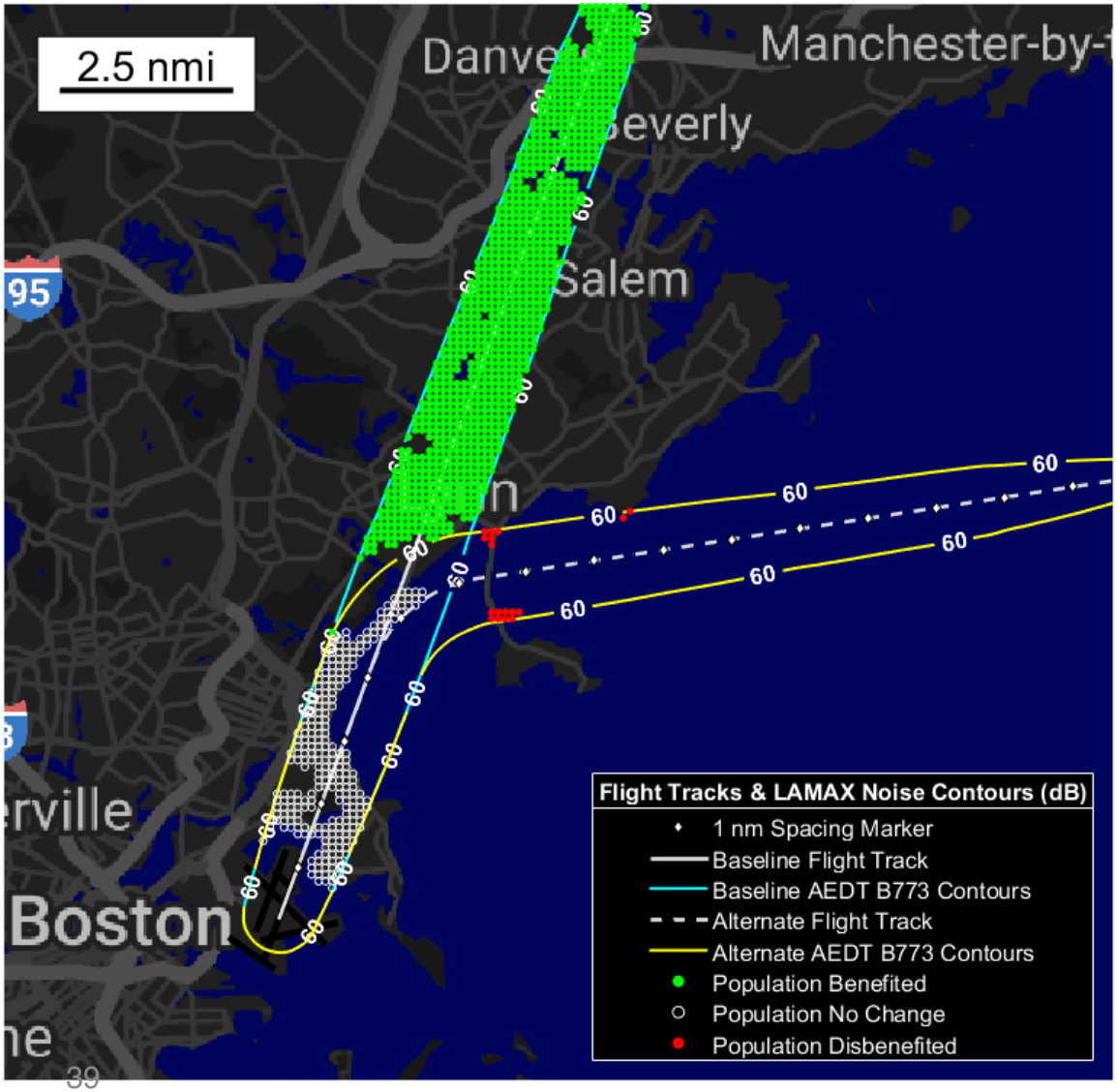


Altitude, speed, and thrust profiles are based on flight profile data from Boston. Slightly adjusted inbound heading

- Procedure within RNAV criteria. Initial .41 review found no major obstacles

22L Arrival RNAV with RNP Overlay vs Straight In
B773 Profile Generator 60dB $L_{A,max}$ Noise Exposure

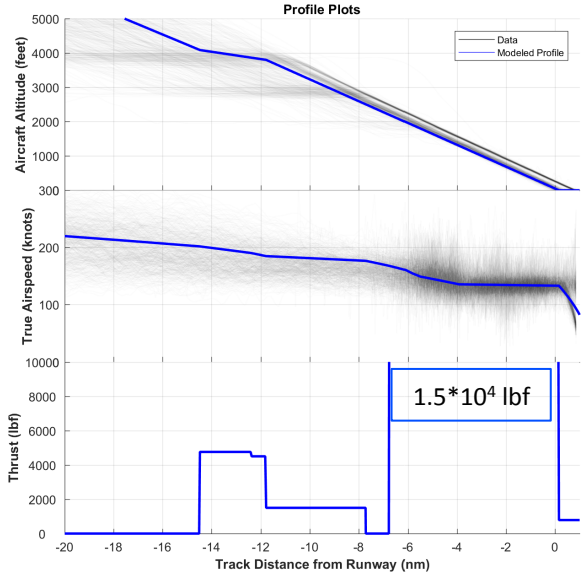
B777-300 60dB $L_{A,max}$ Noise Exposure



B777-300 Population Exposure ($L_{A,MAX}$)

6% of aircraft fleet

	60dB
Straight In	119,392
RNP	33,145
Difference (Straight In – RNP)	86,247



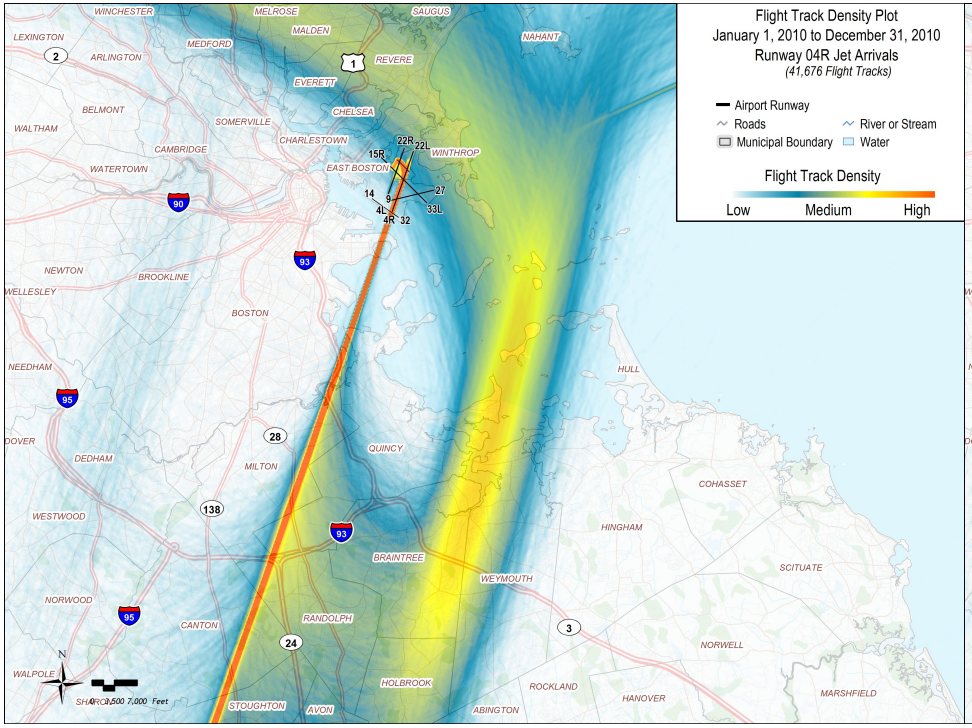
Altitude, speed, and thrust profiles are based on flight profile data from Boston. Slightly adjusted inbound heading

- Procedure within RNAV criteria. Initial .41 review found no major obstacles

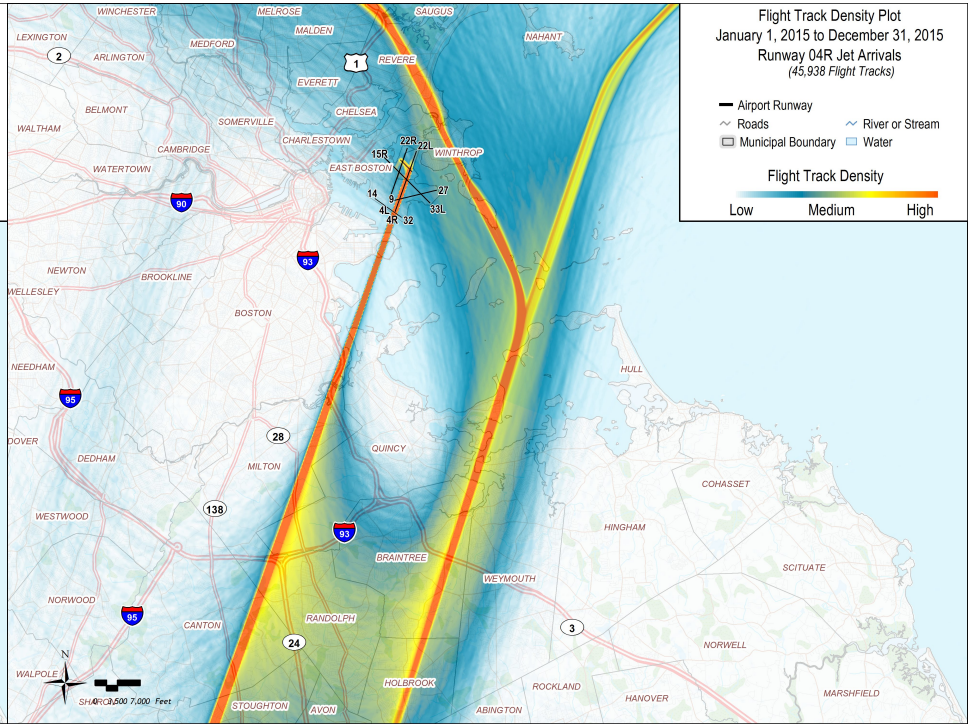
RNAV/RNP LATERAL MODIFICATIONS TO 4R APPROACH PROCEDURE

Runway 4R Arrivals: 2010-2015

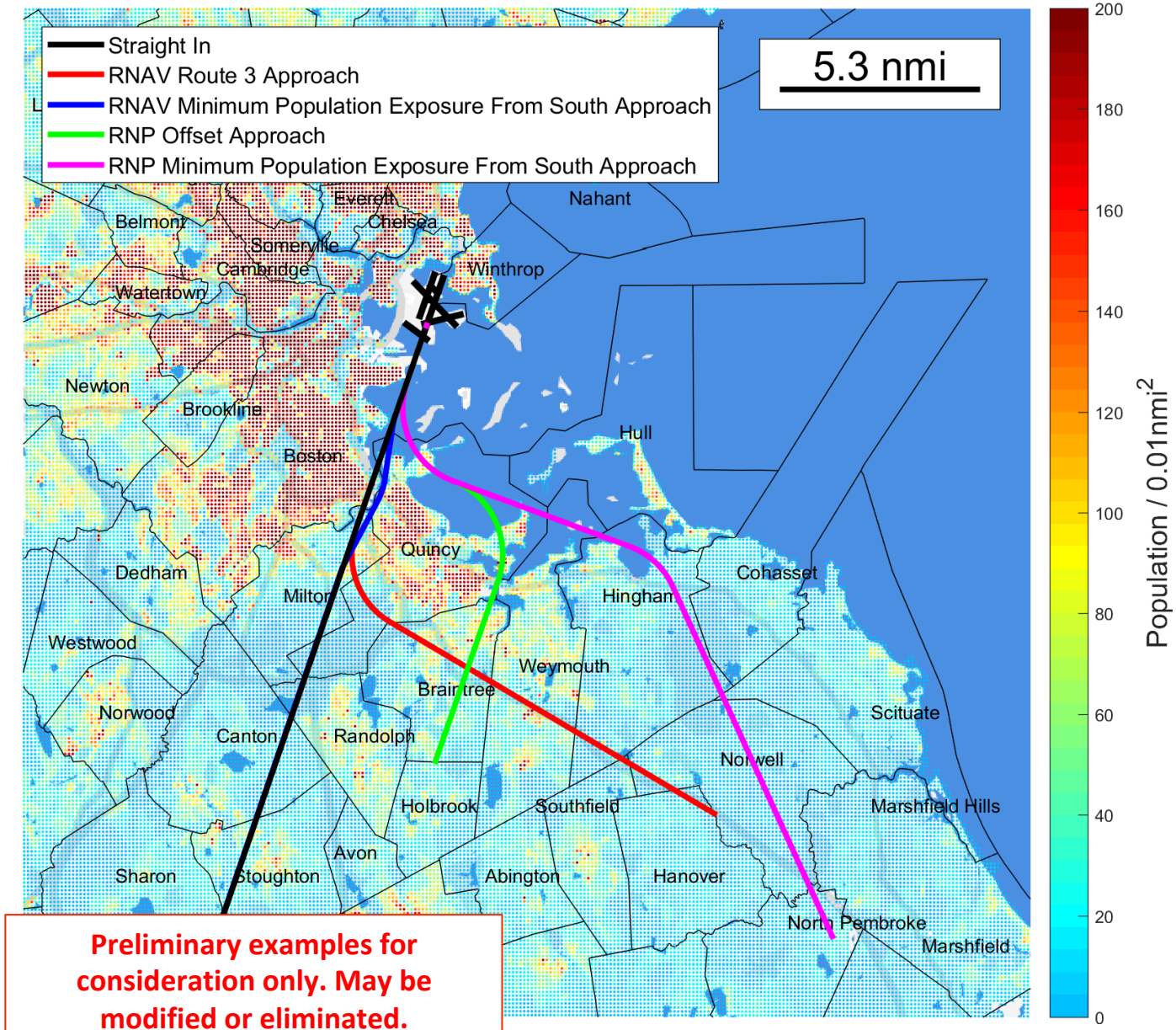
2010



2015



Example 4R RNAV and RNP Approaches

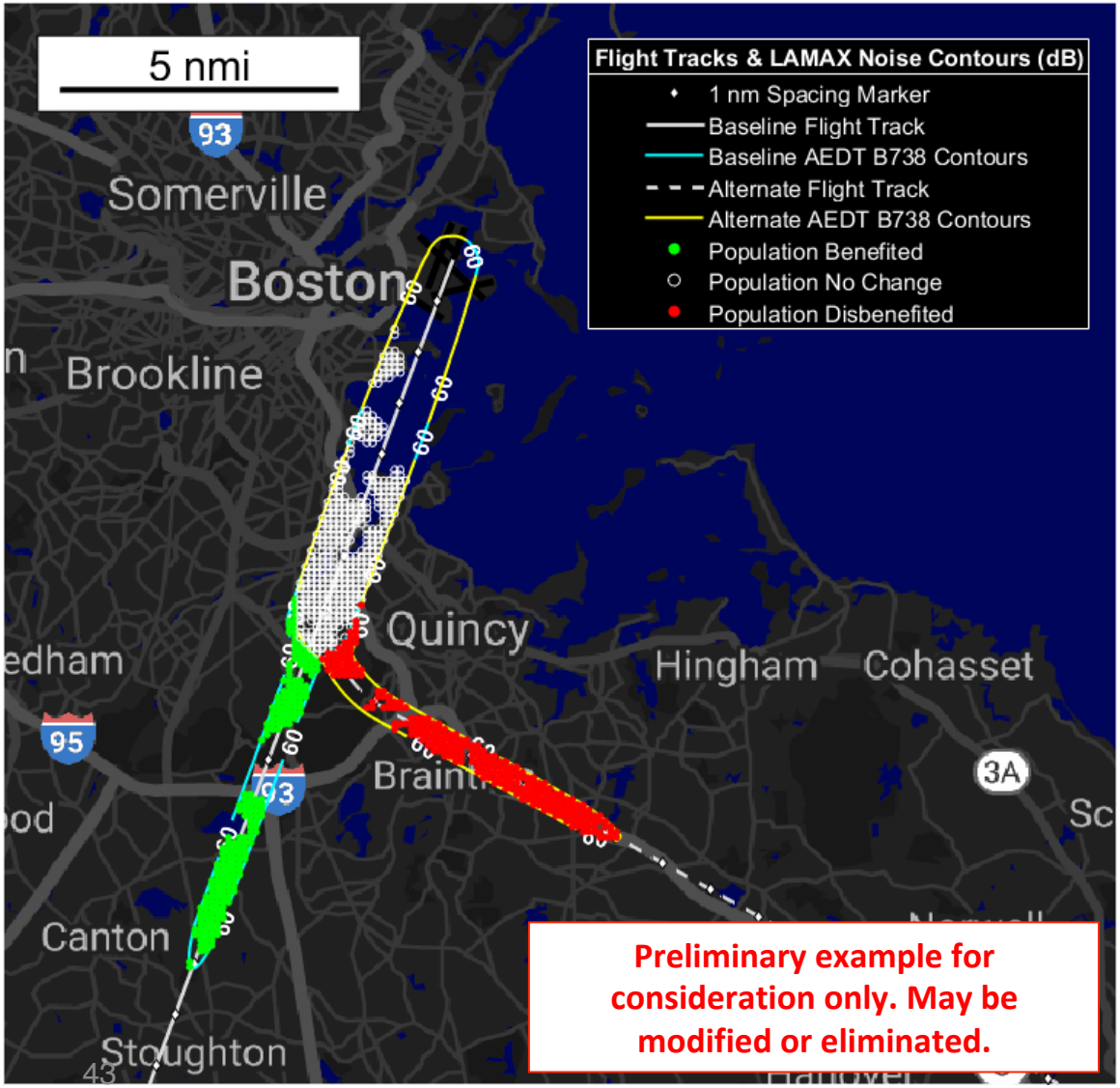


Preliminary examples for consideration only. May be modified or eliminated.

- Several approaches to 4R shown as examples
- RNP technology allows approach to be kept overwater near final approach

4R RNAV Approach – Route 3 Initial

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



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

	60dB
Straight In	32,232
RNP	38,353
Difference (Straight In – RNP)	-6,121

5.5nmi final segment
80° 2nmi radius-to-fix turn

Population exposure calculations do not take advantage of noise masking

- Procedure within RNAV criteria.
- Air traffic control concerns with merging with straight-in flight track.
- Community support unclear.

4R RNAV Approach – Minimum Population Exposure From South

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

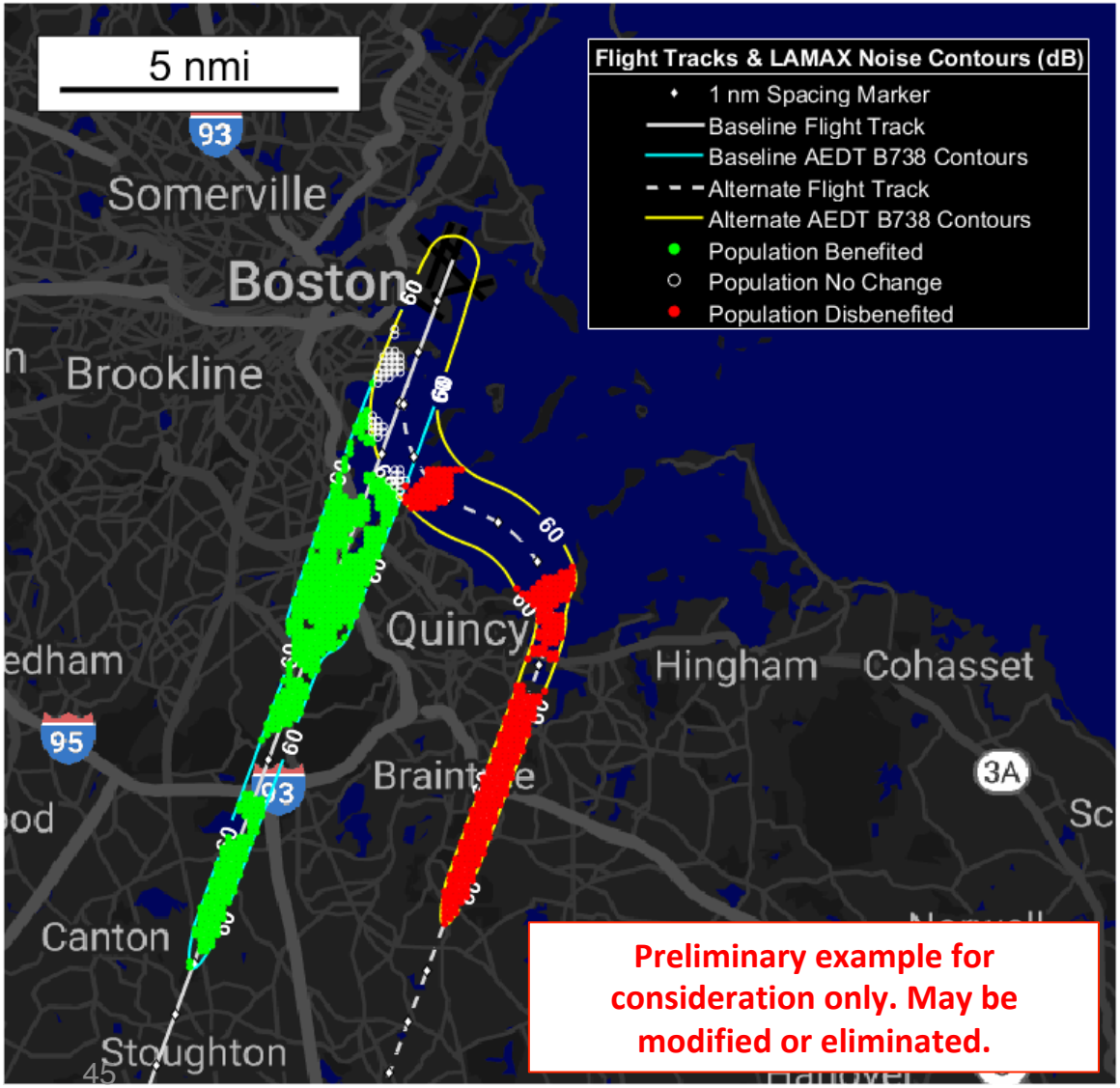
B737-800
Population Exposure ($L_{A,MAX}$)

	60dB
Straight In	32,232
RNP	32,018
Difference (Straight In – RNP)	214

- Procedure within RNAV criteria.
- Community support unclear.

4R RNP Approach – Offset Initial

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



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

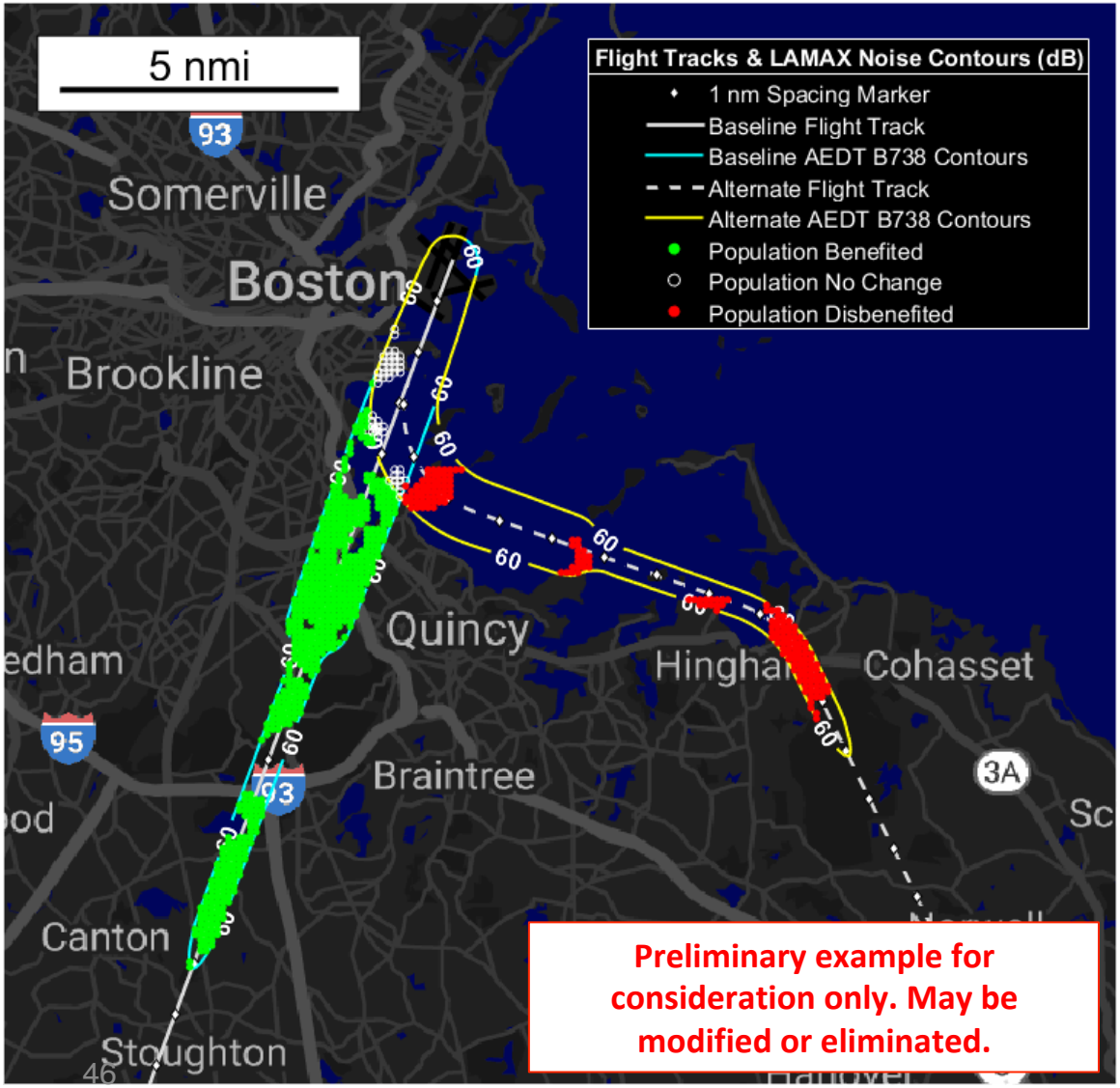
	60dB
Straight In	32,232
RNP	25,106
Difference (Straight In – RNP)	7,126

1.5nmi final segment
90° 2nmi radius-to-fix turn
90° 2nmi radius-to-fix turn

- Procedure within RNP criteria.
- Community support unclear.

4R RNP Approach – Min Population Exposure from South

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



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

	60dB
Straight In	32,232
RNP	11,682
Difference (Straight In – RNP)	20,550

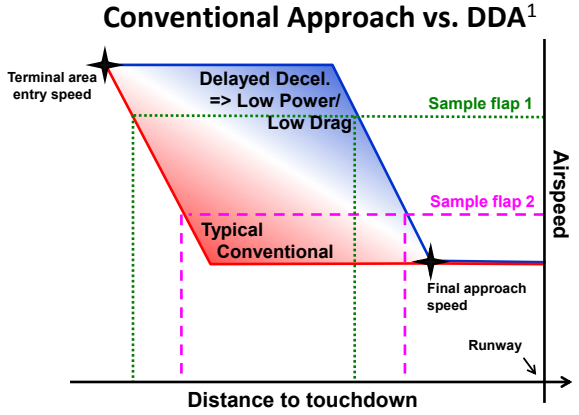
1.5nmi final segment
90° 2nmi radius-to-fix turn
5nmi straight segment
45° 2nmi radius-to-fix turn

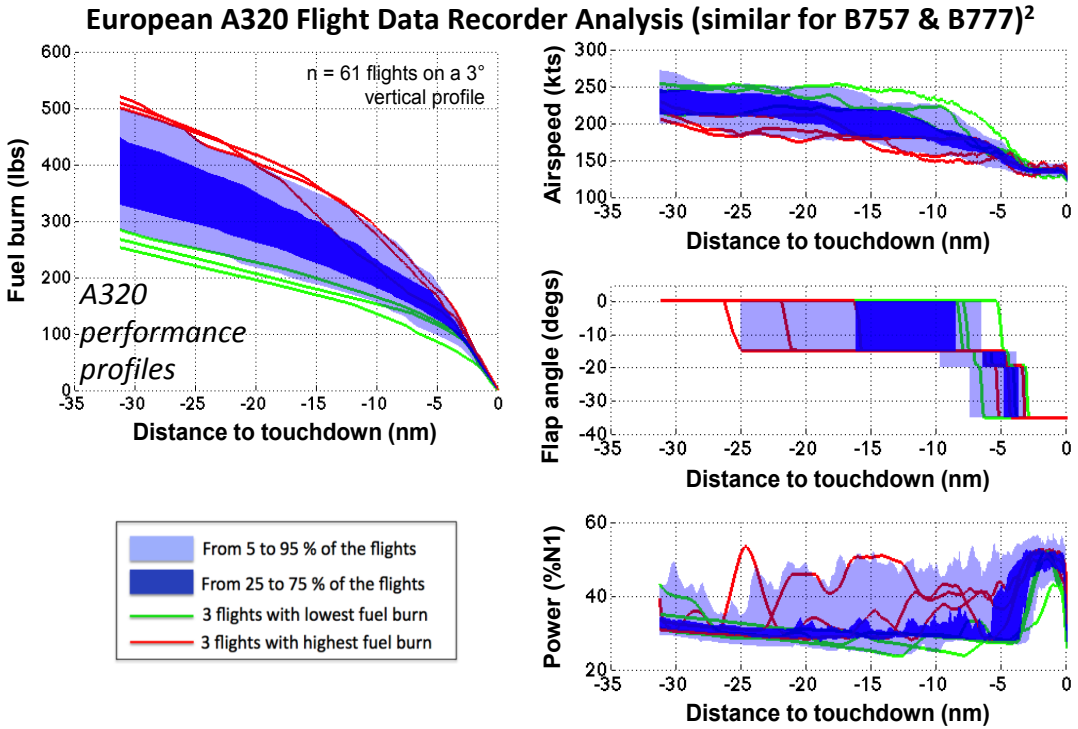
- Procedure within RNP criteria.
- Community support unclear.
- Possible flyability issues need to be tested.
- Air traffic merging concern with straight-in traffic.

DELAYED DECELERATION APPROACHES

Delayed Deceleration Approaches (DDAs)

- In conventional approaches, aircraft decelerate early in the approach
- DDAs provide potential for fuel burn & noise reduction[1]
- 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

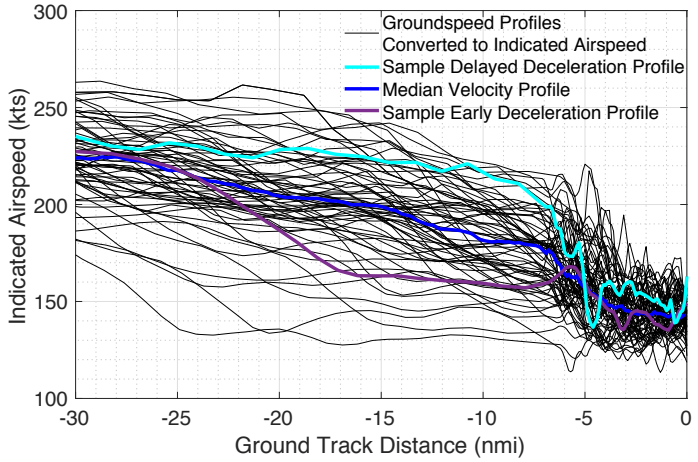




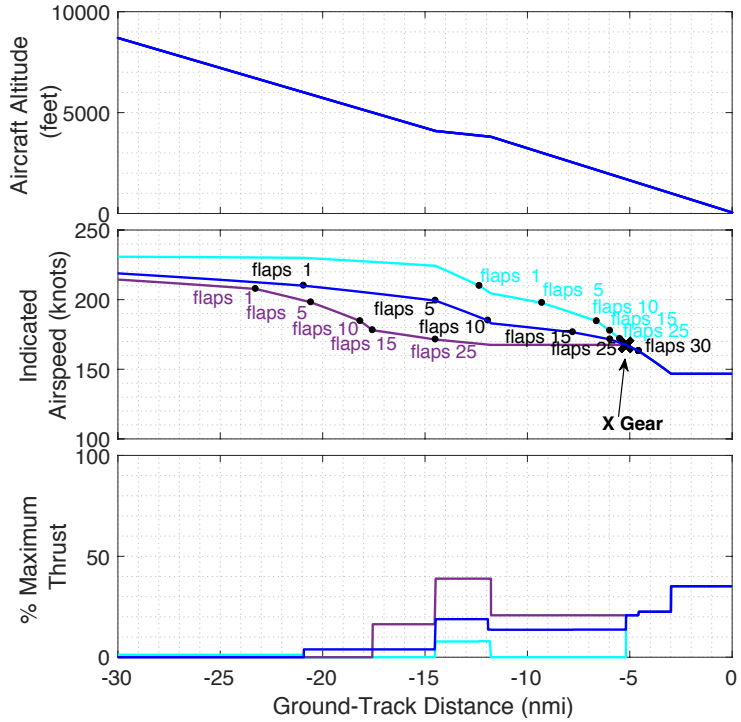
[1] Dumont, J., et al. (2012)
[2] Dumont, J., et al. (2011)

Delayed Deceleration Approaches

Velocity Radar Data for B737-800 4000ft Level Offs into 4R

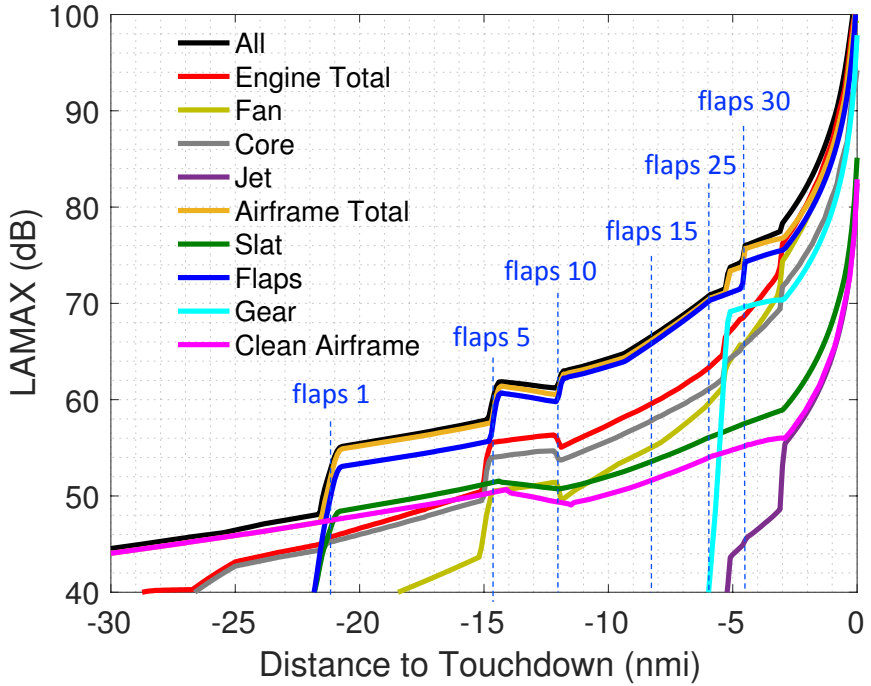


Modeled Profiles



- Reduce noise by delaying extension of flaps
- Potential concerns from ATC and pilots regarding different deceleration rates and managing traffic
- Must decelerate early enough to assure stable approach criteria

Example Noise Component Breakdown Under the Flight Track

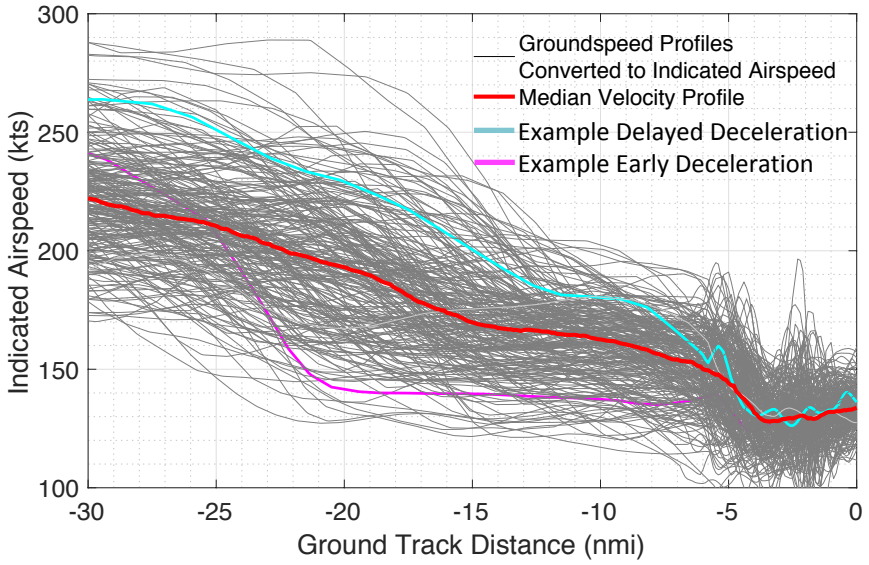


B737-800 Example

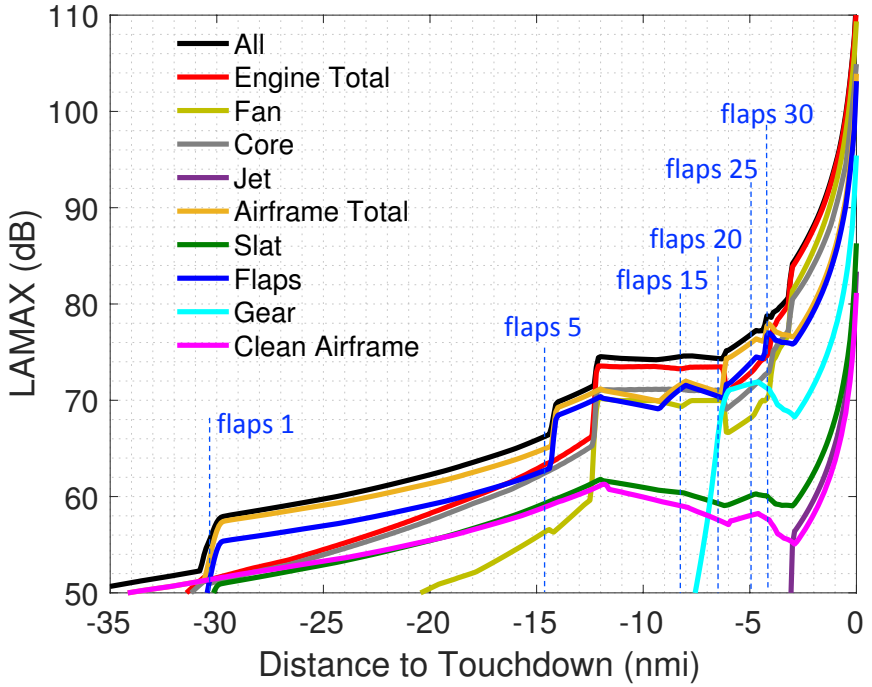
Delayed Deceleration Approaches

- Reduce noise by delaying extension of flaps and increased thrust
- Potential concerns from ATC and pilots regarding different deceleration rates and managing traffic
- Must decelerate early enough to assure stable approach criteria

Observed Velocity Variation from Radar Data for B777 4000ft Level Offs at BOS

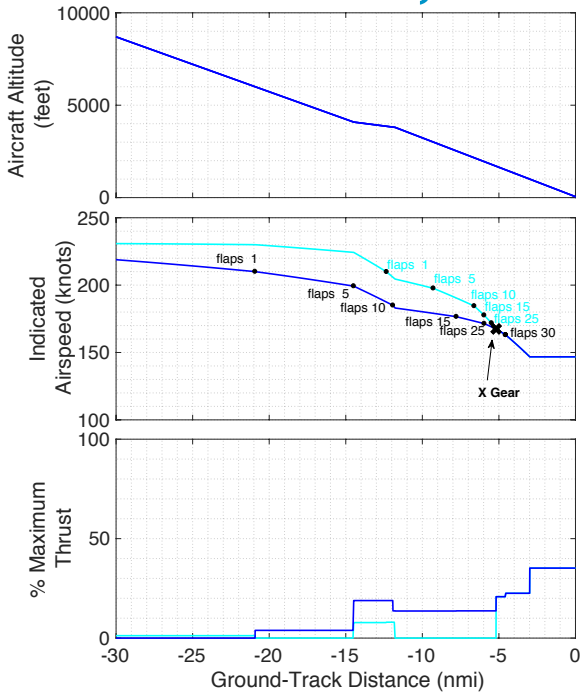


Example Noise Component Breakdown Under the Flight Track for Approach with Median Velocity Profile

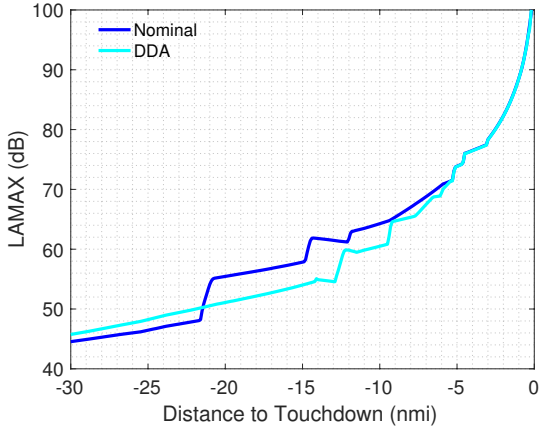


B777 Example

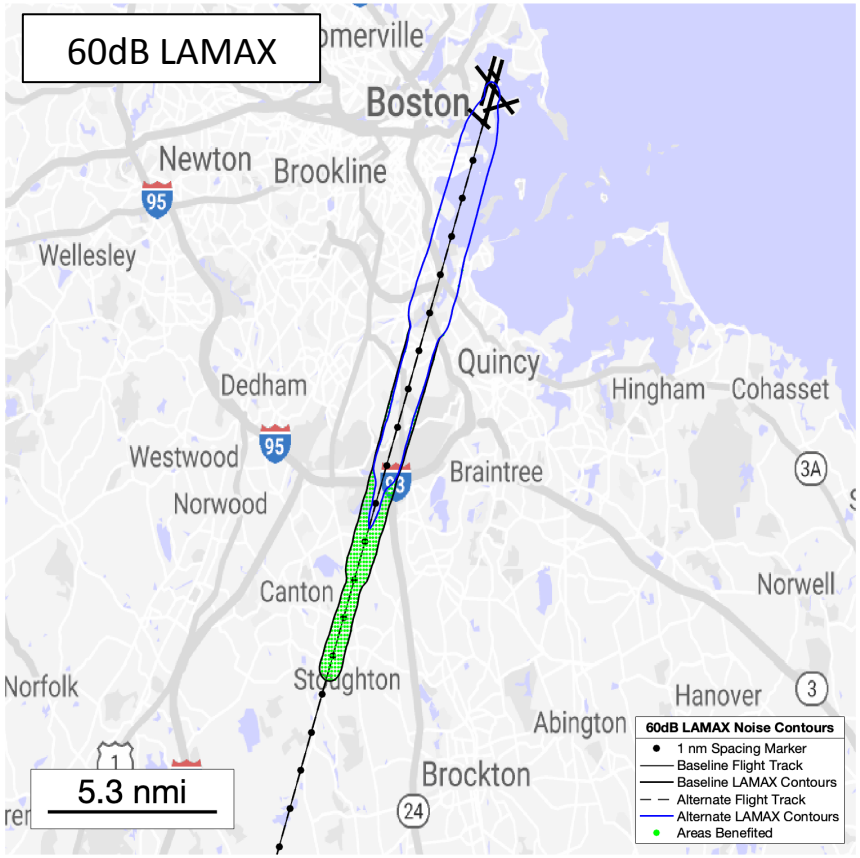
DDA vs Nominal Approach from South with 4000 ft Level Off, B737-800



Total Undertrack LAMAX (dB)



60 dB Contour Comparison

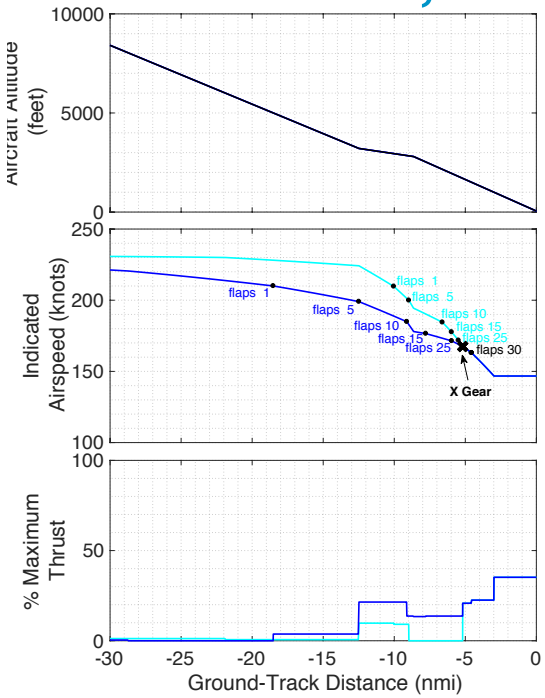


Population Exposure

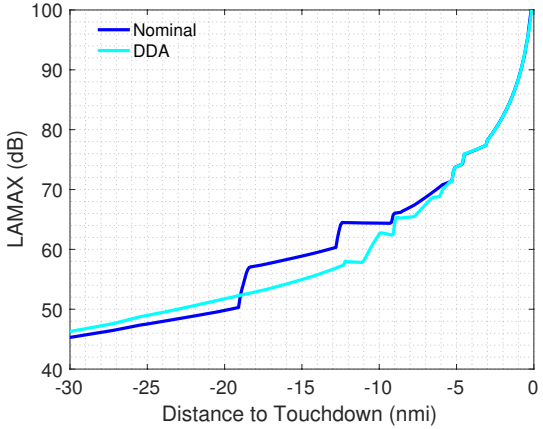
$L_{A,max}$	60 dB	65 dB	70 dB
Nominal	37,621	14,912	4,936
DDA	31,835	13,927	4,784
Difference	5,786	985	152

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

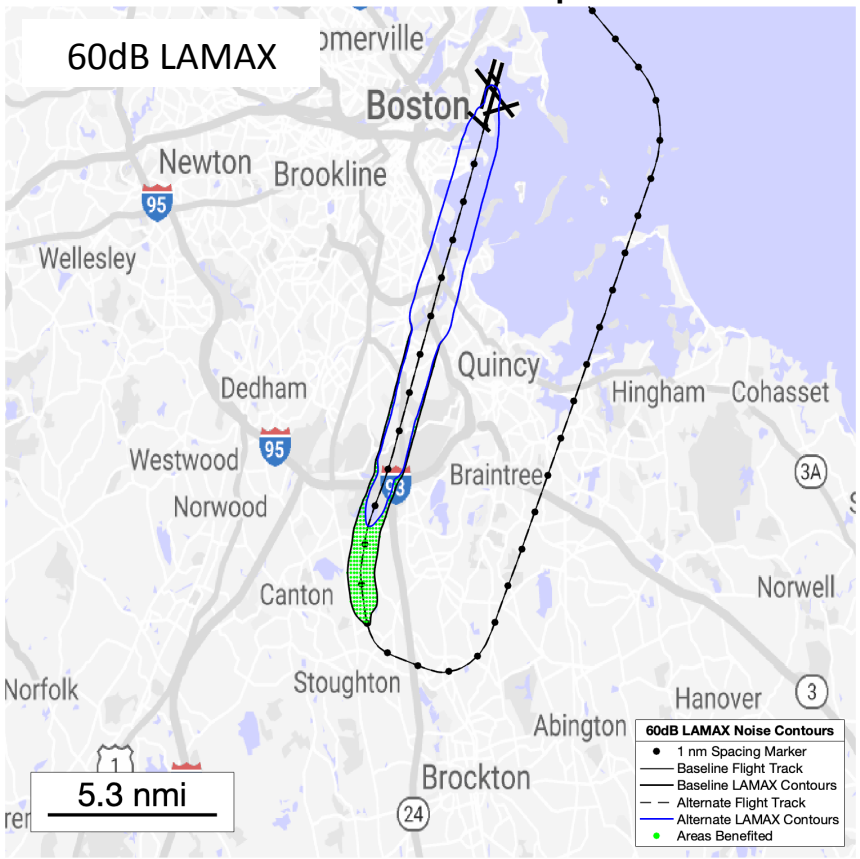
DDA vs Nominal Approach from North with 3000 ft Level Off, B737-800



Total Undertrack LAMAX (dB)



60 dB Contour Comparison



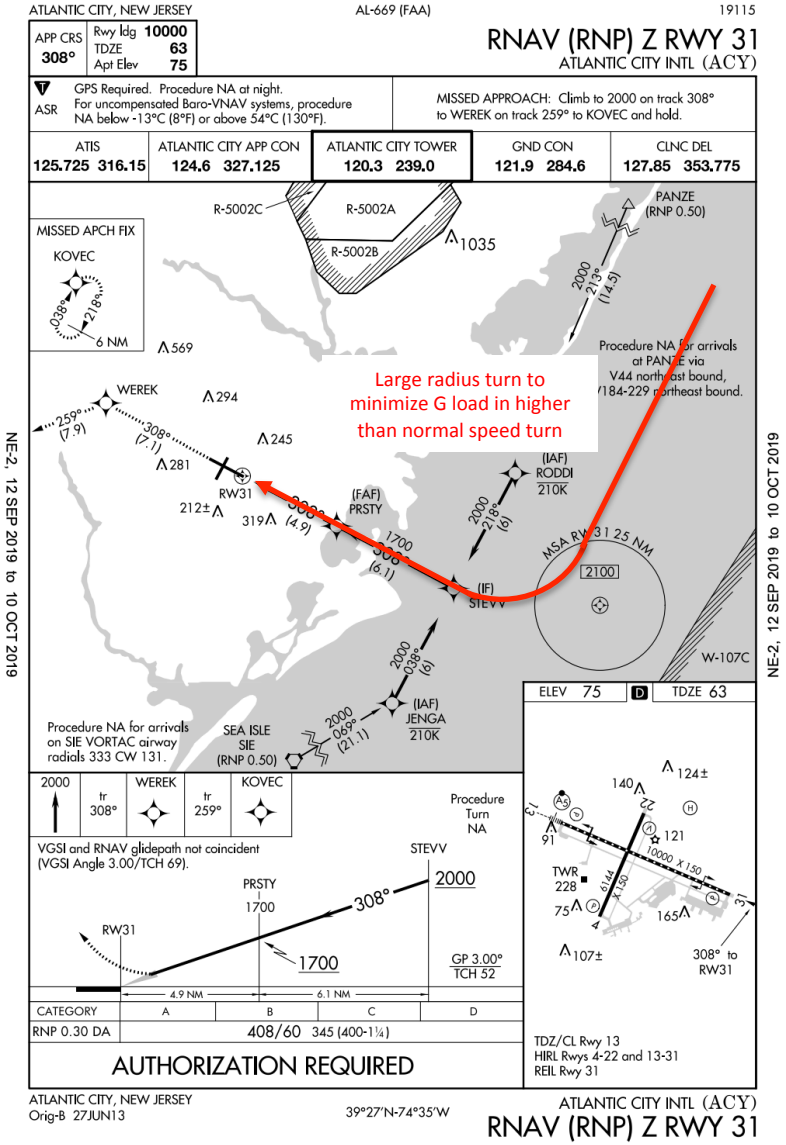
Population Exposure

$L_{A,max}$	60 dB	65 dB	70 dB
Nominal	33,227	14,448	3,969
DDA	30.925	13,687	3,741
Difference	2,302	761	228

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

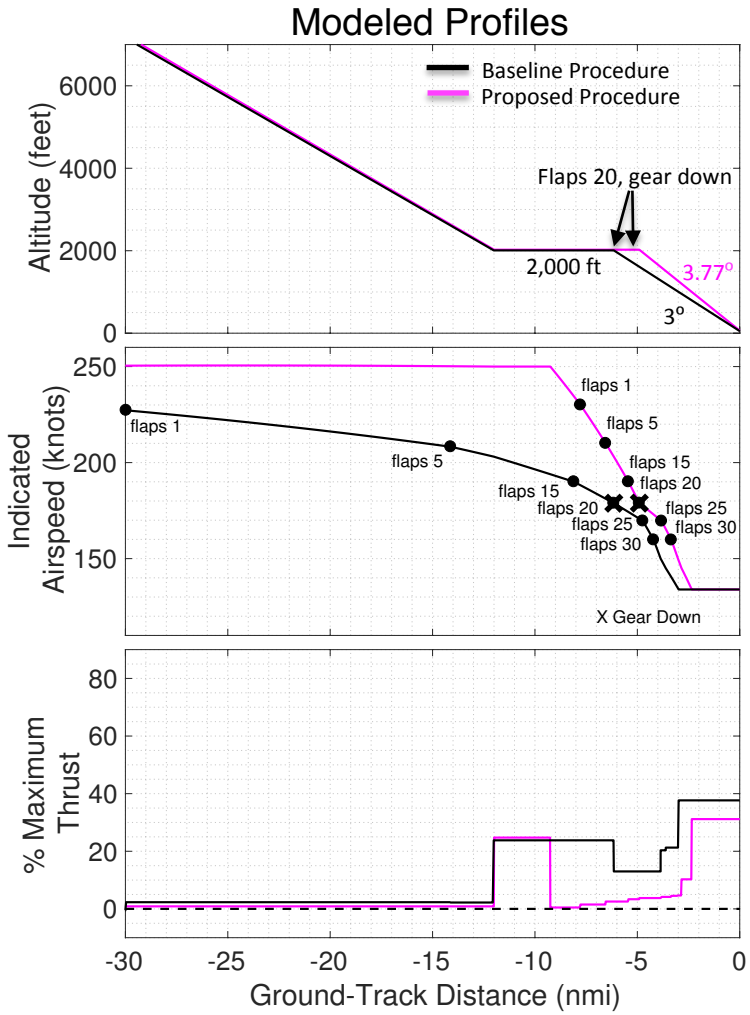
Proposed ecoDemonstrator Test

DDA Coupled with 3.77° Steeper Approach



Tentatively Planned Flight Nov. 21 2019

Proposed Procedure Modeled Profiles



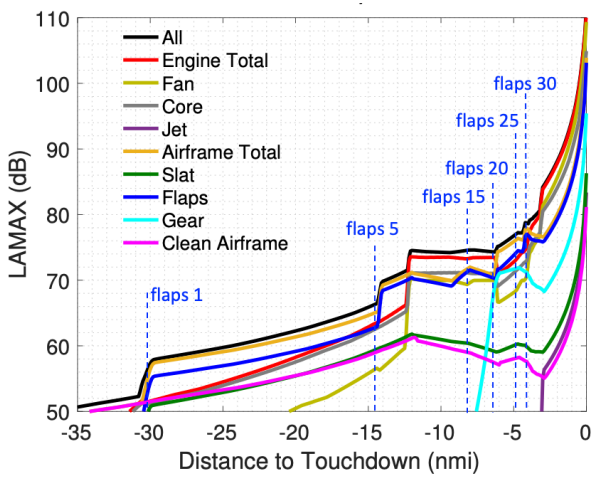
Assumed aircraft condition for modeling:

- Boeing 777-200, pw4080 engine
- 380,000 lbs
- Zero wind

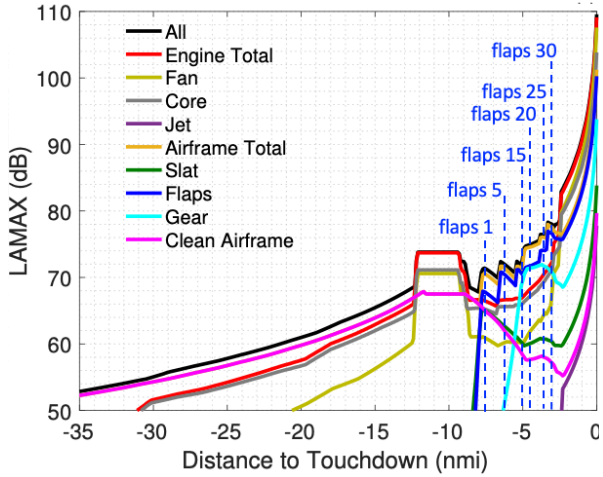
- Baseline Procedure (black):
  - 3.0º glideslope
    - Flaps 20, gear assumed at glideslope intercept
  - Standard deceleration
    - Speed and deceleration based on median speeds from ASDEX data (KBOS)
- Proposed Procedure (magenta):
  - 3.77º glideslope
    - Flaps 20, gear assumed at glideslope intercept
  - Delayed Deceleration
    - Begins on level segment from 250 kts at a point such that with idle thrust, velocity is flap 20 speed (180 kts) at glide slope intercept

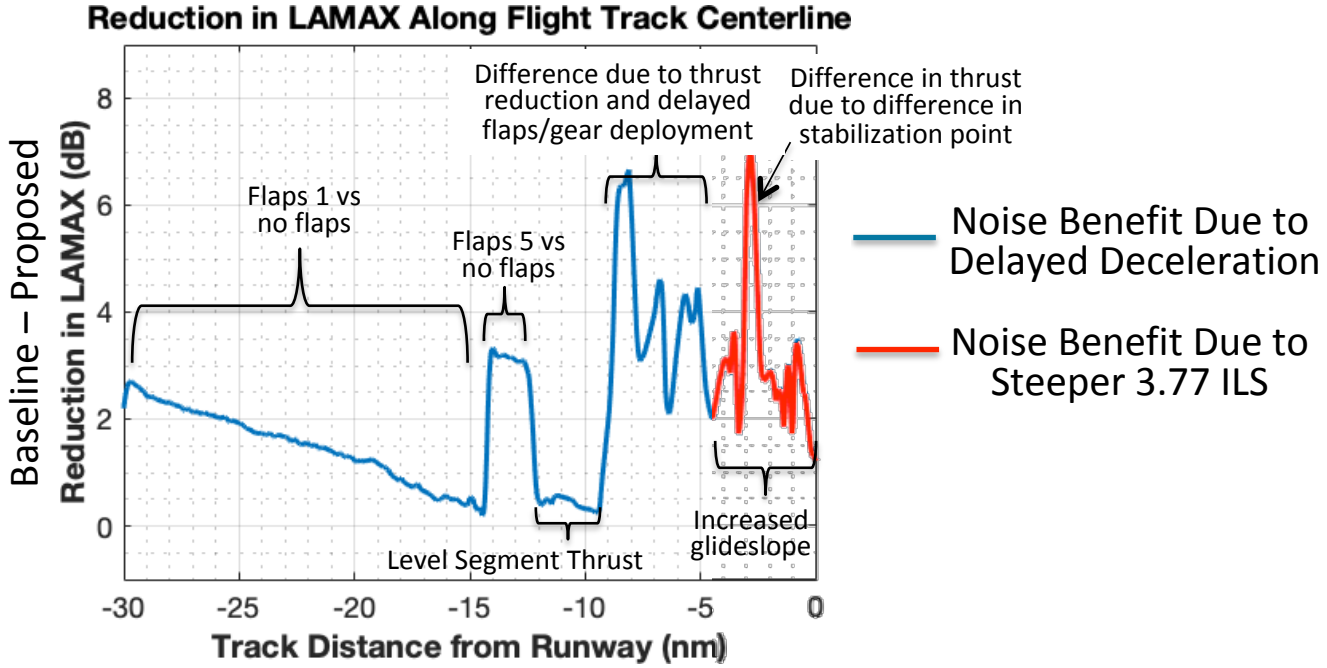
Noise Component Breakdown & Reduction Under the Flight Track

Baseline Procedure



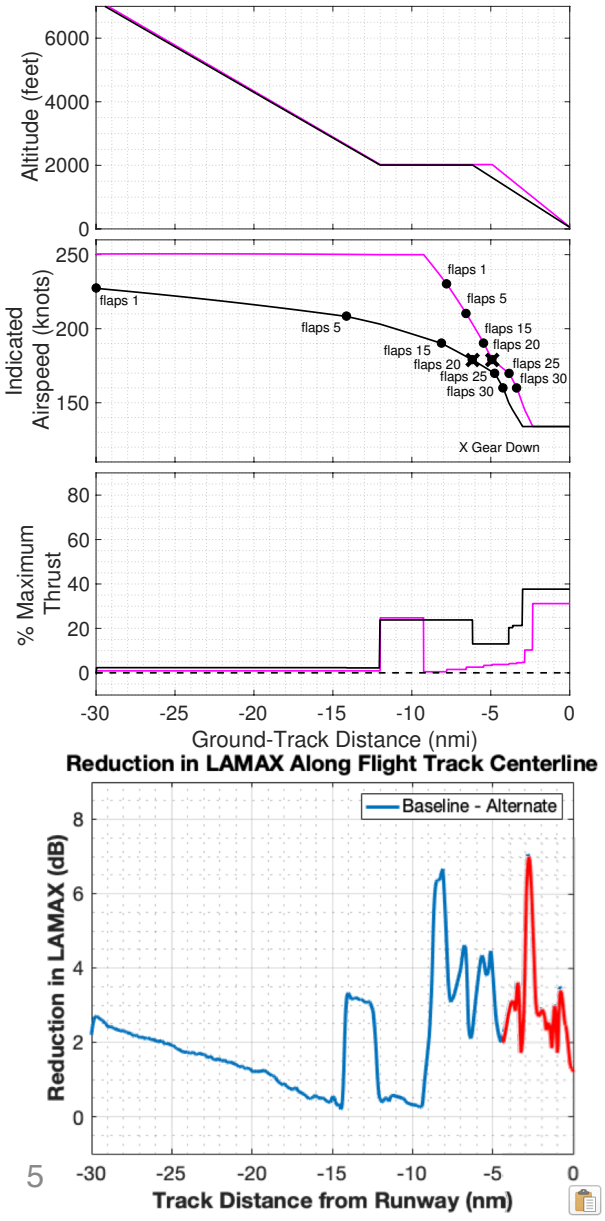
Proposed Procedure



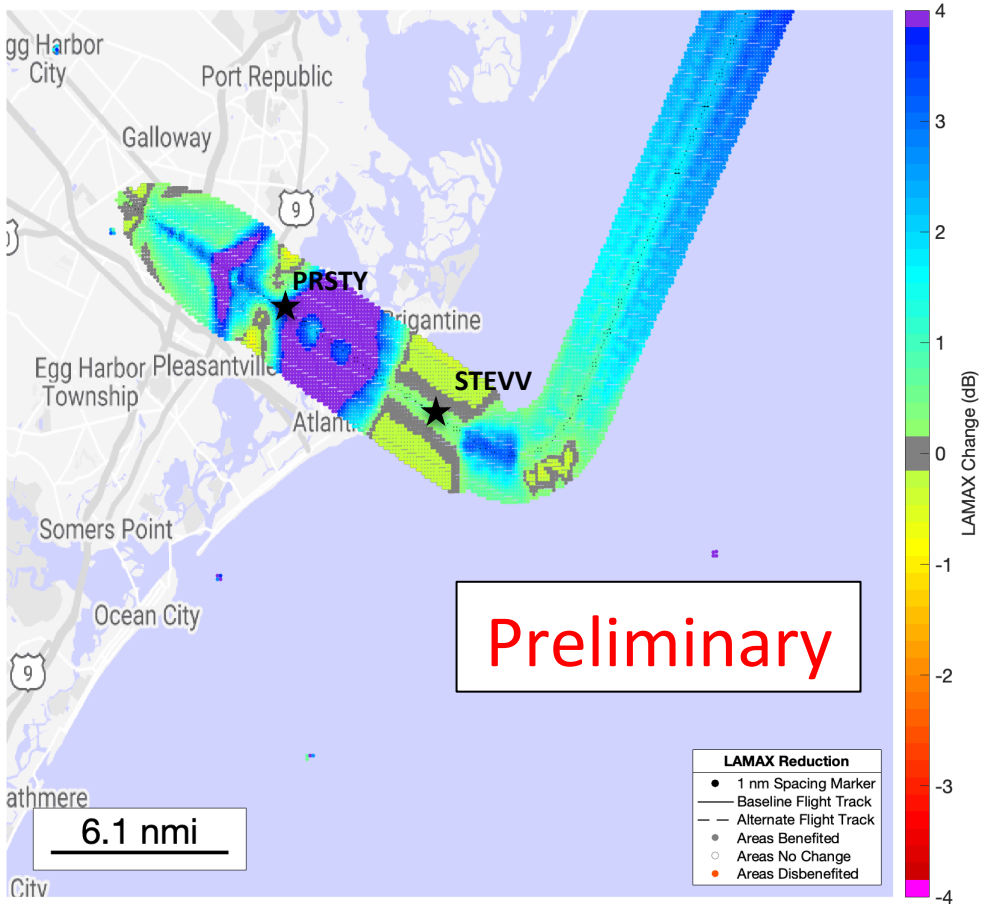


Preliminary

Modeled Noise Impact
Proposed Procedure vs Baseline



LAMAX Delta to 50 dB Contour



Assumed aircraft condition for modeling:

- Boeing 777-200, pw4080 engine
- 380,000 lbs
- Zero wind

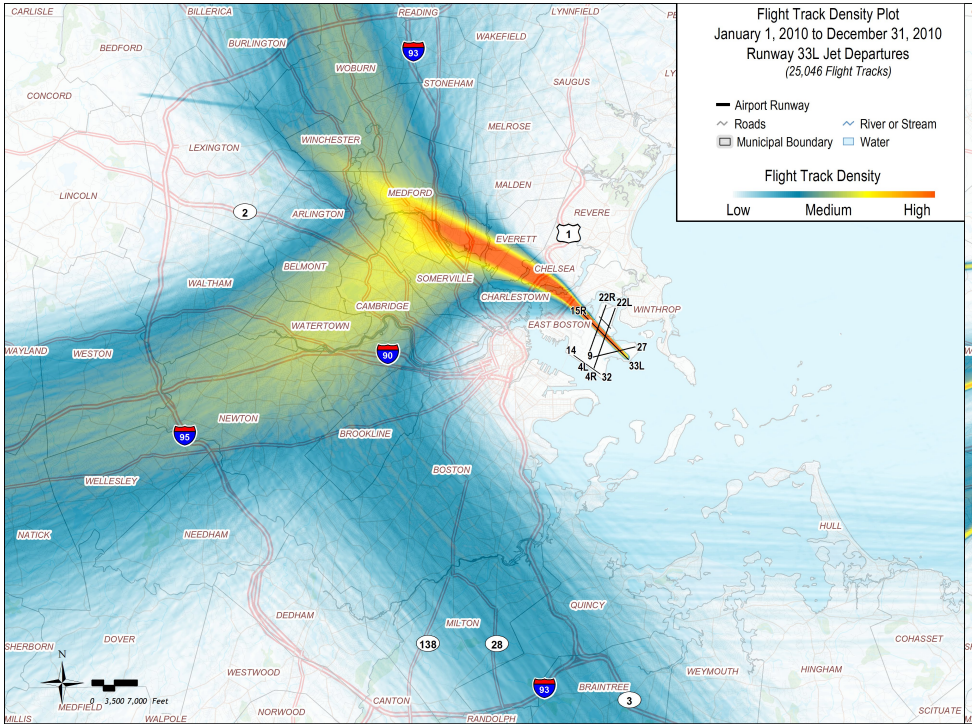
Population Exposure

$L_{A,max}$	60 dB	65 dB	70 dB
3° and Standard	15439	10107	6743
3.77° and DDA	13182	8458	4246
Difference	2248	1649	2497

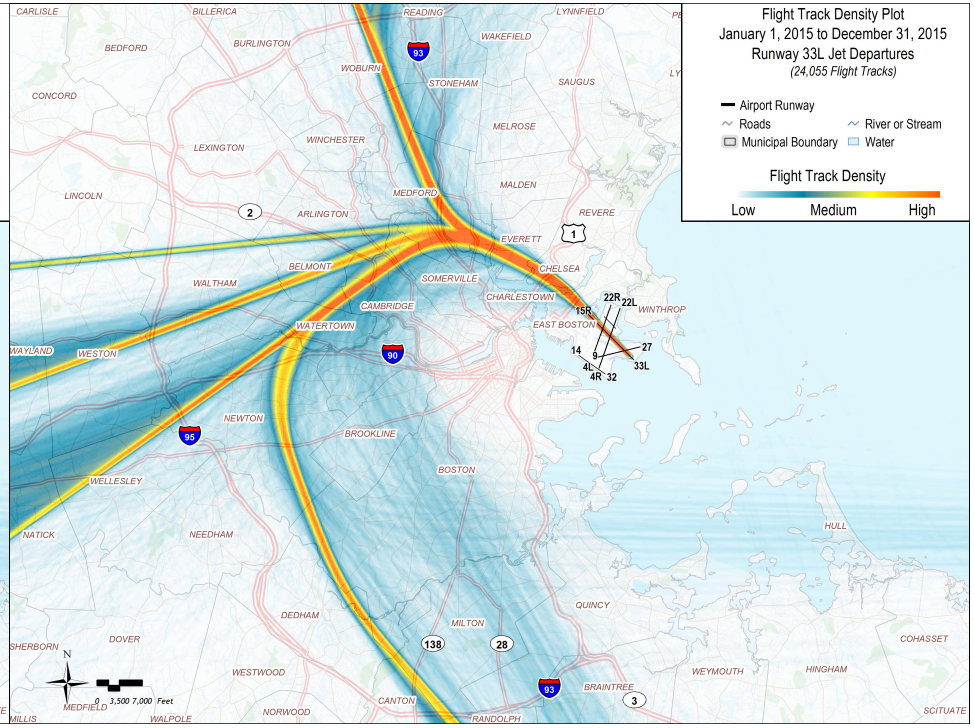
BLOCK 2: RUNWAY 33L AND 27 DEPARTURES – INTRODUCE DISPERSION

Runway 33L Departures: 2010-2015

2010

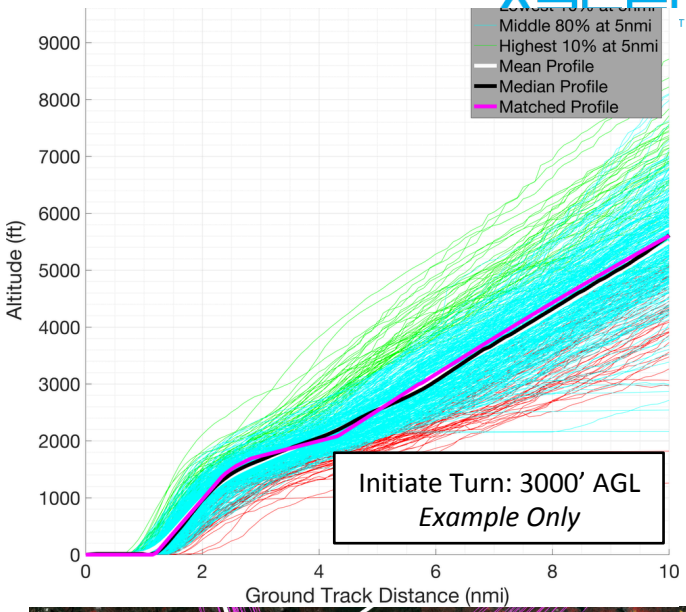


2015

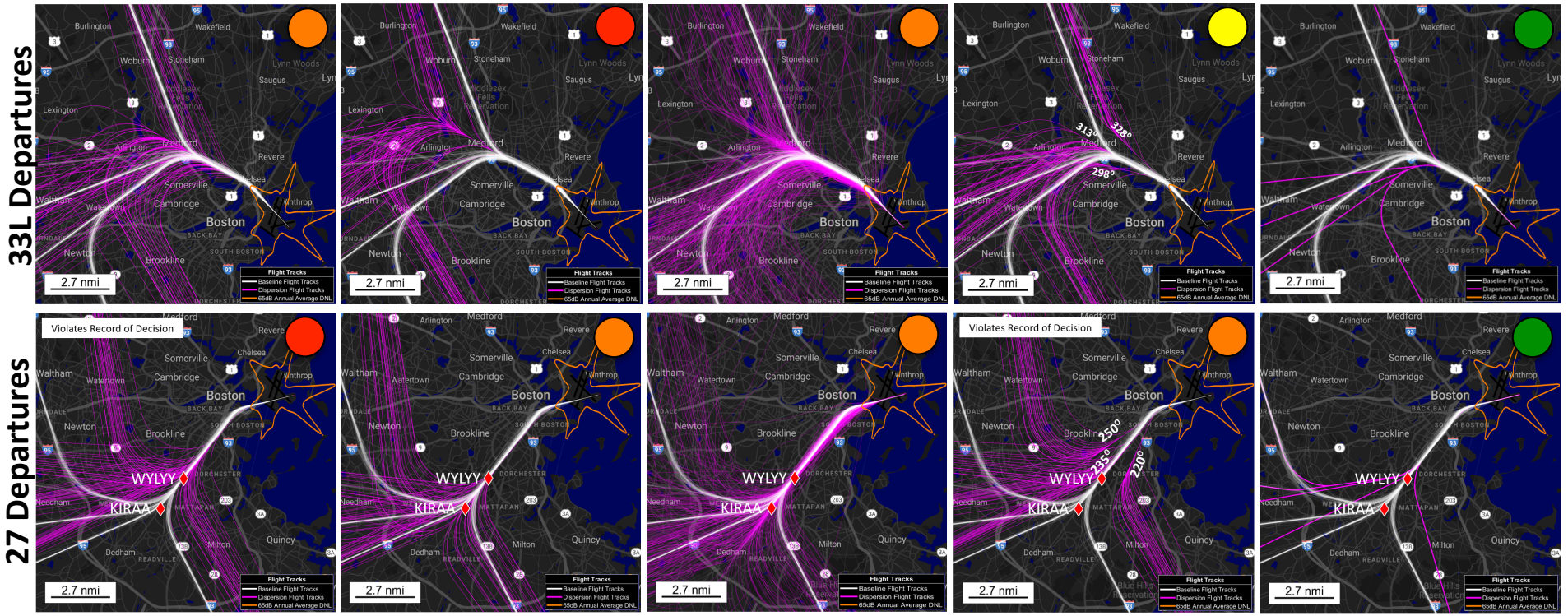


Dispersion Concepts

- Altitude-based dispersion
  - Direct routing to transition waypoint upon reaching specific altitude
- Controller-based dispersion
  - Dispersion arising from radar vectoring
  - 2010 flight track data normalized for comparison with 2017 data
  - Comparison between pre-RNAV and RNAV flight tracks
- Divergent heading dispersion
  - 15^0 divergent headings then direct routing to transition waypoint upon reaching 3000ft
- RNAV Waypoint Relocation
  - Moving the waypoint at which the RNAV tracks branch off could allow for population exposure reduction



Dispersion Concepts

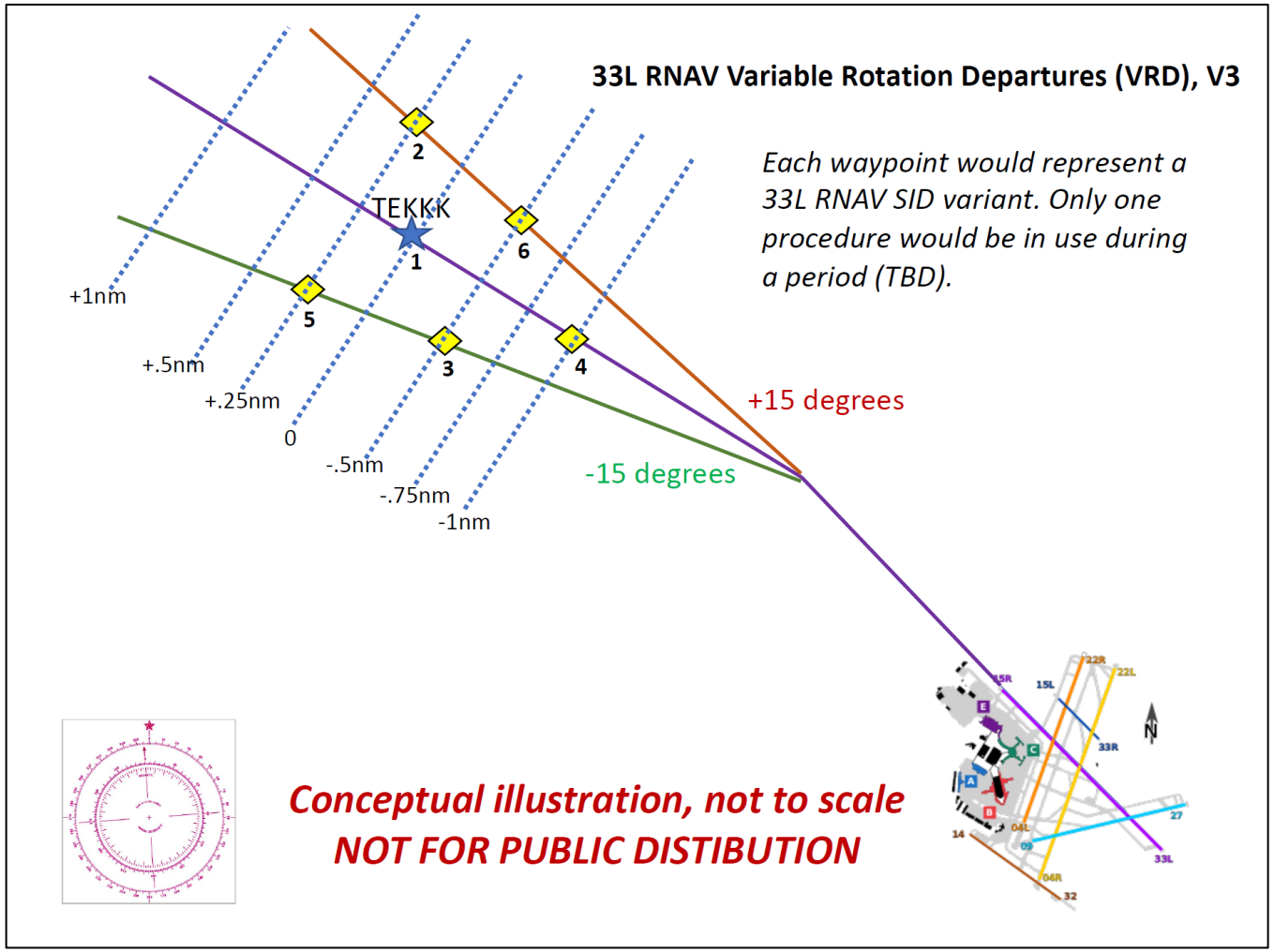


Altitude-Based 3000ft | Altitude-Based 4000ft | Controller-Based | Divergent Headings | RNAV Waypoint Relocation

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

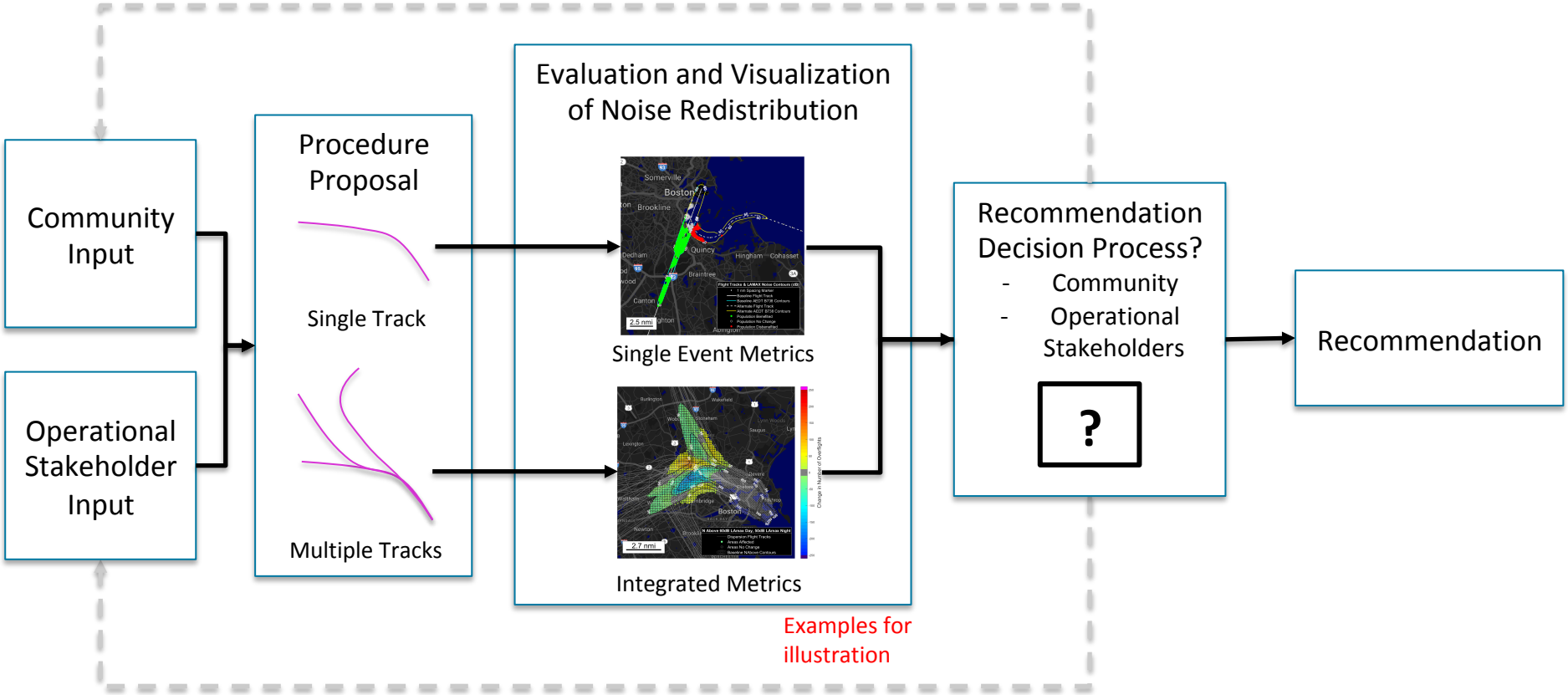
Community Dispersion Suggestion
Variable Rotation Departures (VRD)

Analysis done on full peak day of operation using a single waypoint
Other rotations possible.



- Complex procedures for ATC and Pilots
- Requires numerous procedures in the Flight Management System
- Rotating between waypoints from day to day does not take advantage of the separation requirements satisfied by divergent headings

Need for Community Decision Process for Procedures with Noise Redistribution



Analysis Thresholds

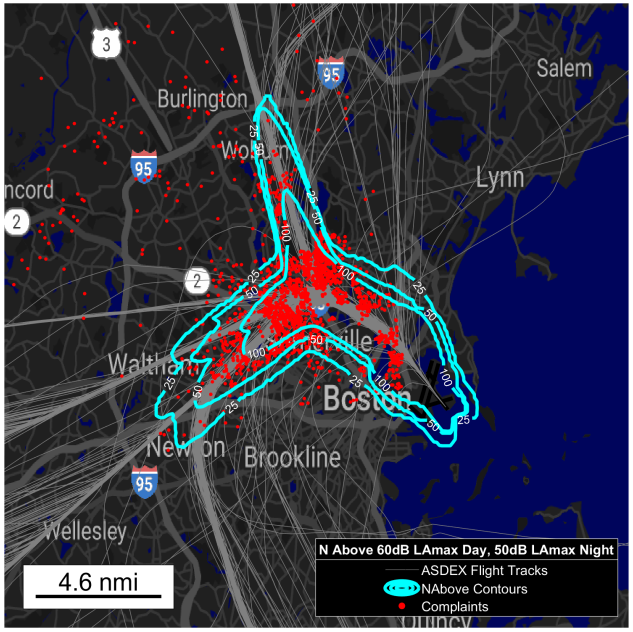
Single event metrics: $L_{A,max}$ = 60dB during the day, 50dB during the night

Integrated metrics: N_{60} greater than 50 events per peak day

BOS N_{60} Count Thresholds

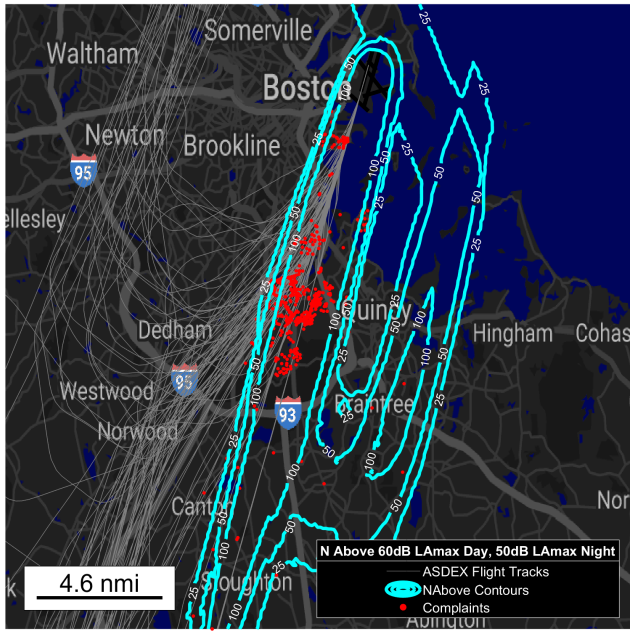
- N_{60} on a peak day with 50 overflights appears to capture complaint threshold in dispersion analysis

33L Departures Peak Day N_{60}



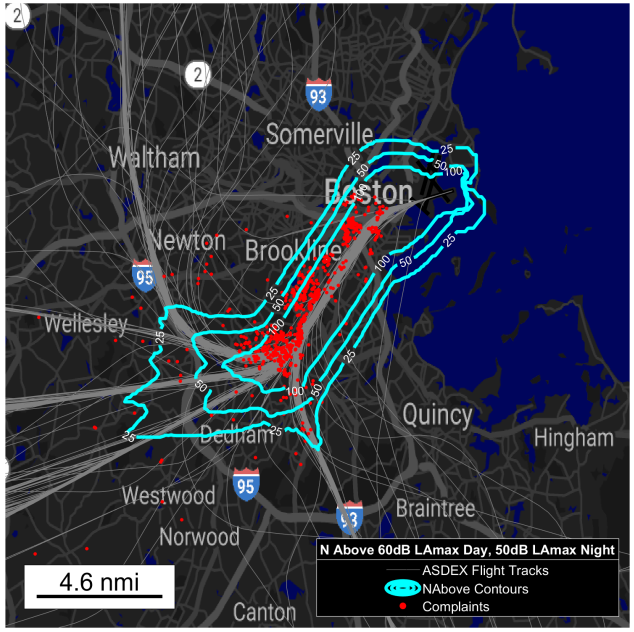
Peak Day N_{60}	Complaints Captured
25x	87.3%
50x	80.9%
100x	59.4%

4L/R Arrivals Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	97.7%
50x	94.7%
100x	81.0%

27 Departures Peak Day N_{60}

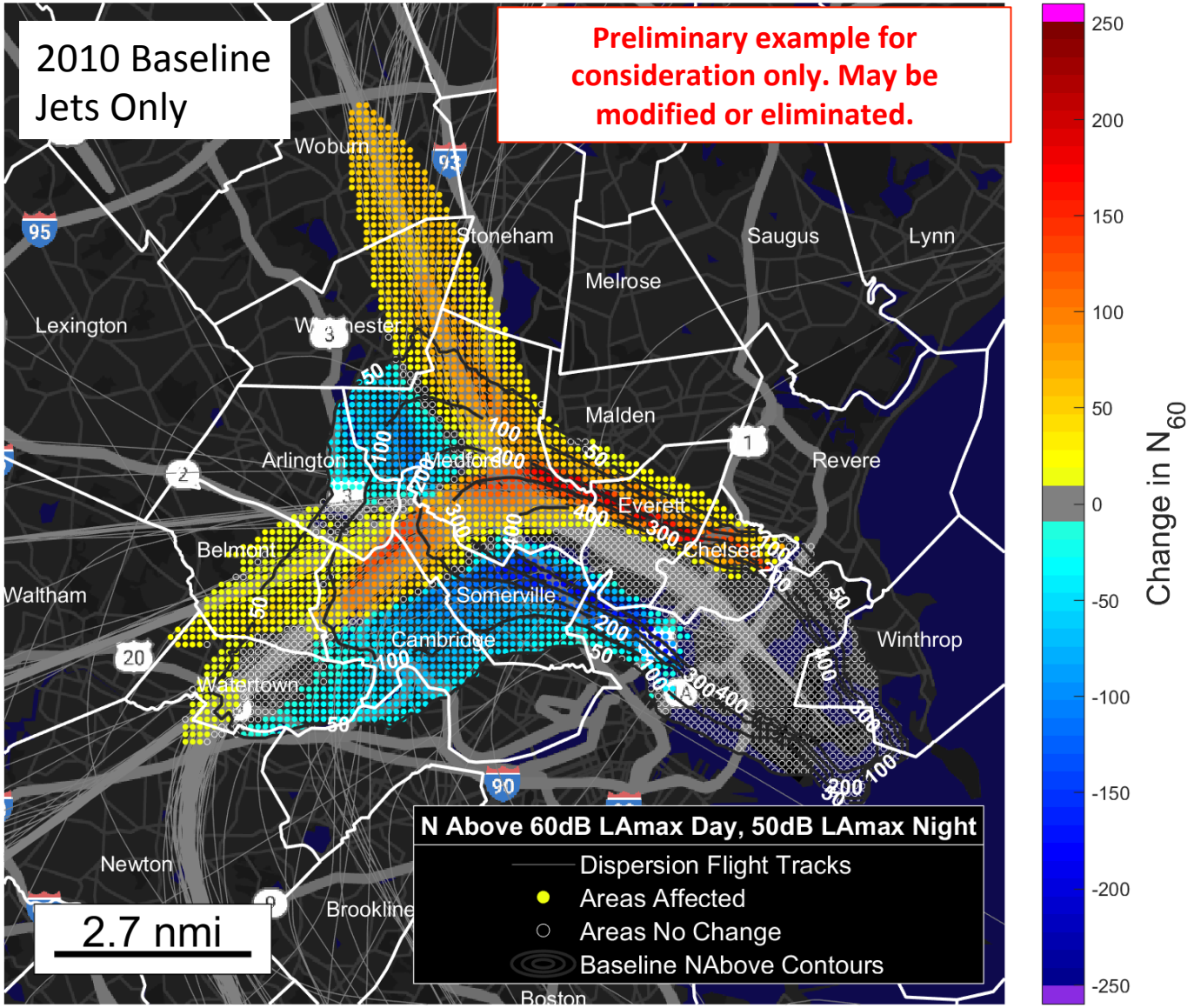


Peak Day N_{60}	Complaints Captured
25x	95.4%
50x	92.1%
100x	78.8%

2017 Data

Effect of RNAV Concentration on 33L Departures

Change in N_{60} from 2010 to 2017



Population Exposure

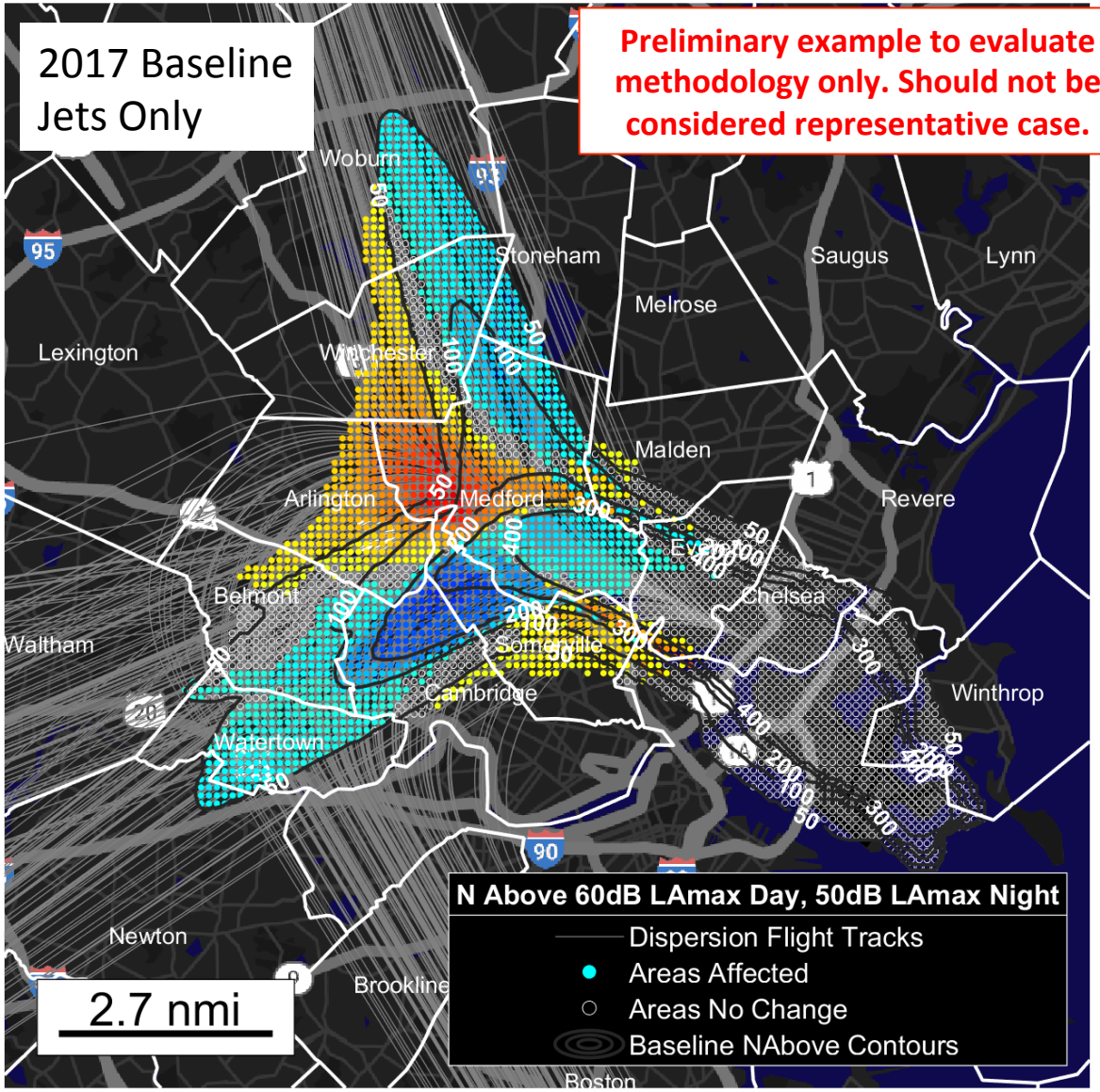
N_{60}	50x
Baseline 2017	356,852
Dispersion	335,823
Baseline - Dispersion	21,040

Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

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

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

33L Departures Altitude-Based Dispersion at 3000ft Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	363,759
Baseline - Dispersion	-5,151

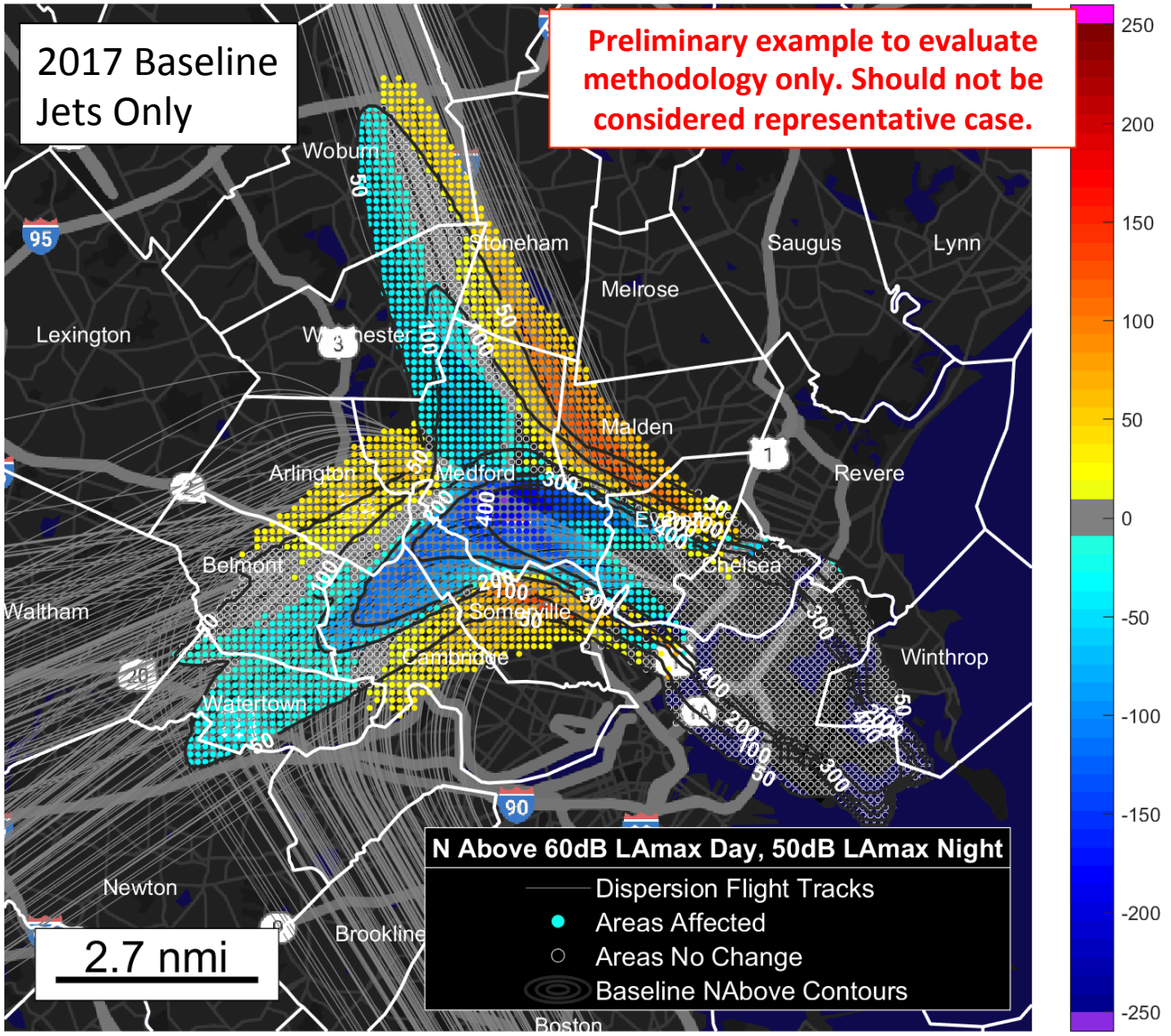
Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

- Controller concerns about variability in flight path length

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

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

33L Departures Divergent Headings Dispersion Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	363,759
Baseline - Dispersion	-27,936

Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

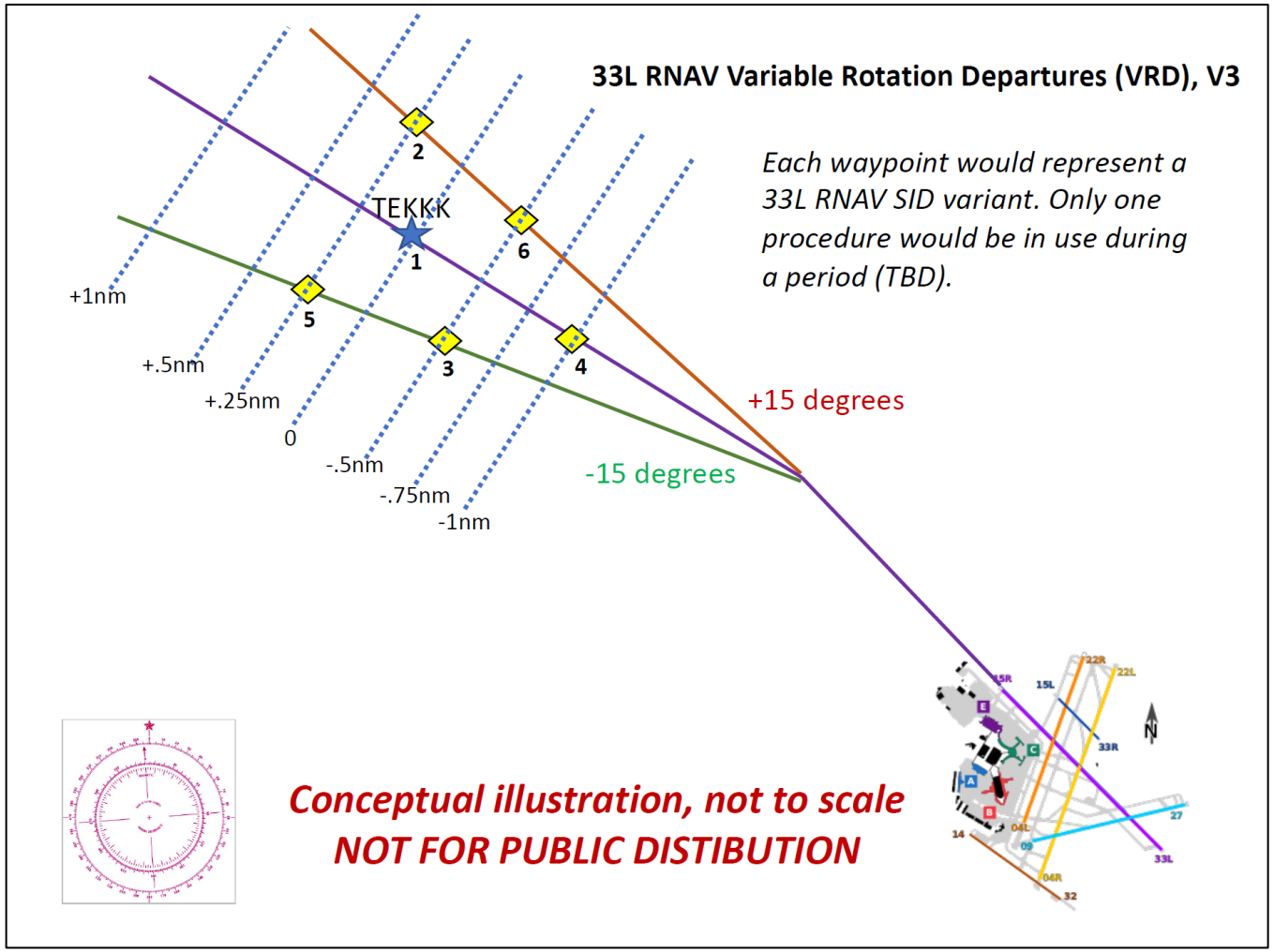
- Divergent headings help to maintain aircraft separation criteria

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

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

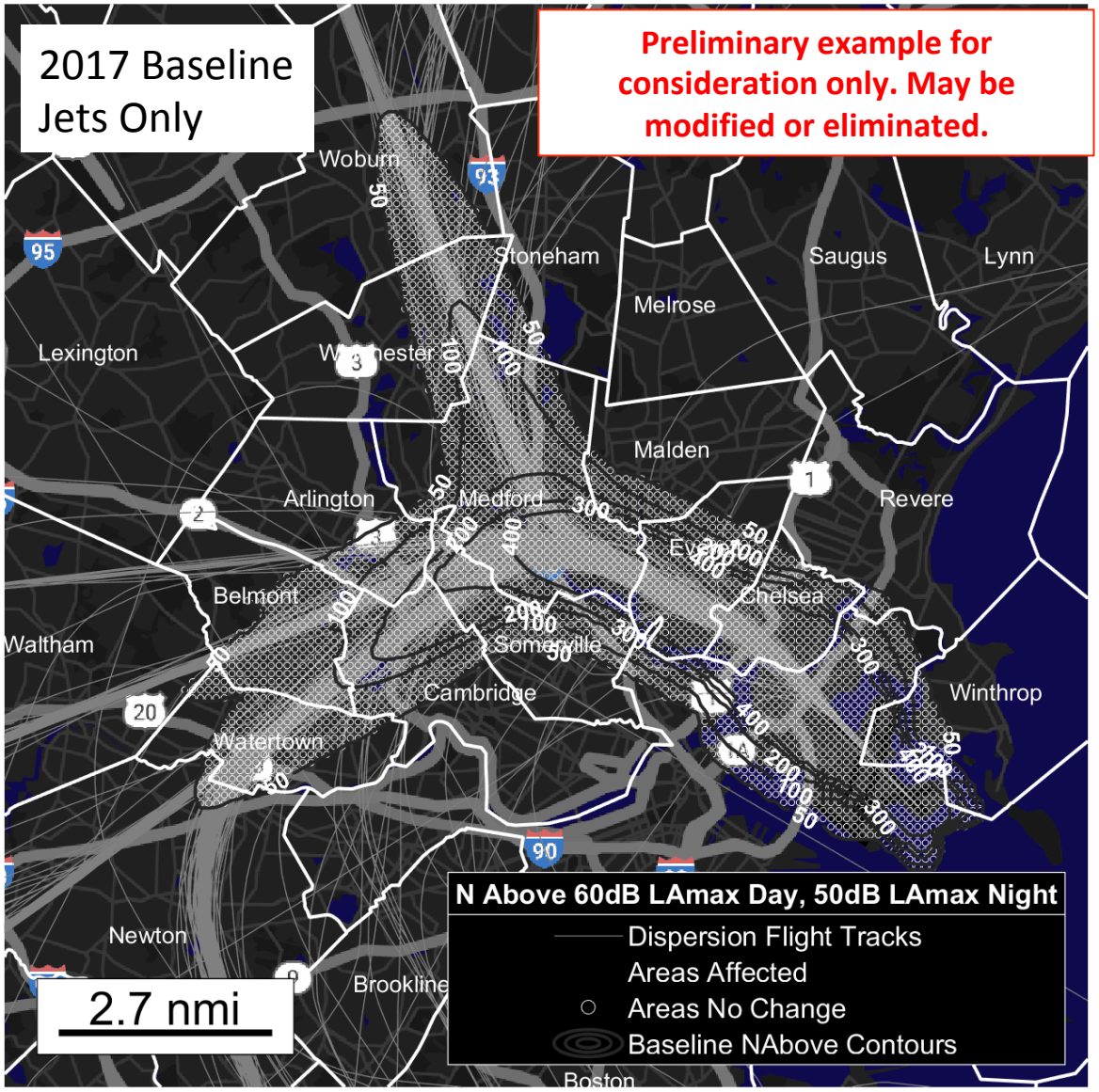
Community Dispersion Suggestion
Variable Rotation Departures (VRD)

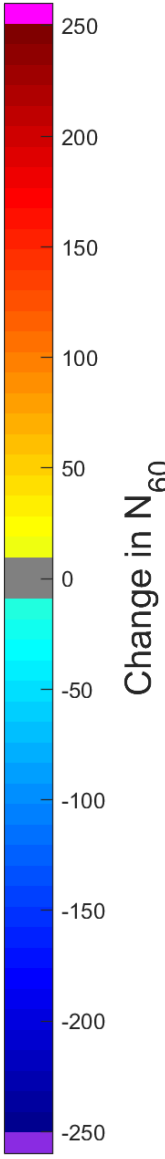
Analysis done on full peak day of operation using a single waypoint
Other rotations possible.



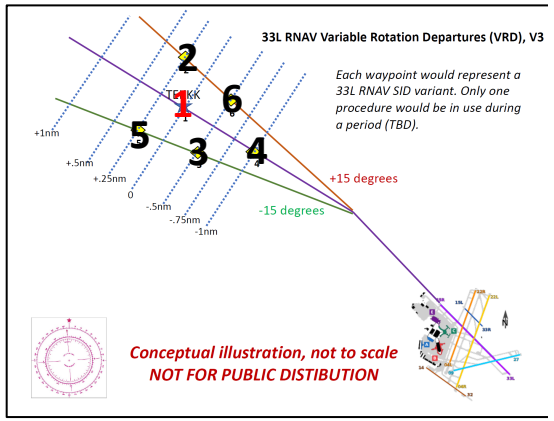
- Complex procedures for ATC and Pilots
- Requires numerous procedures in the Flight Management System
- Rotating between waypoints from day to day does not take advantage of the separation requirements satisfied by divergent headings

33L Departures VRD Waypoint #1 Change in N_{60} Compared to 2017





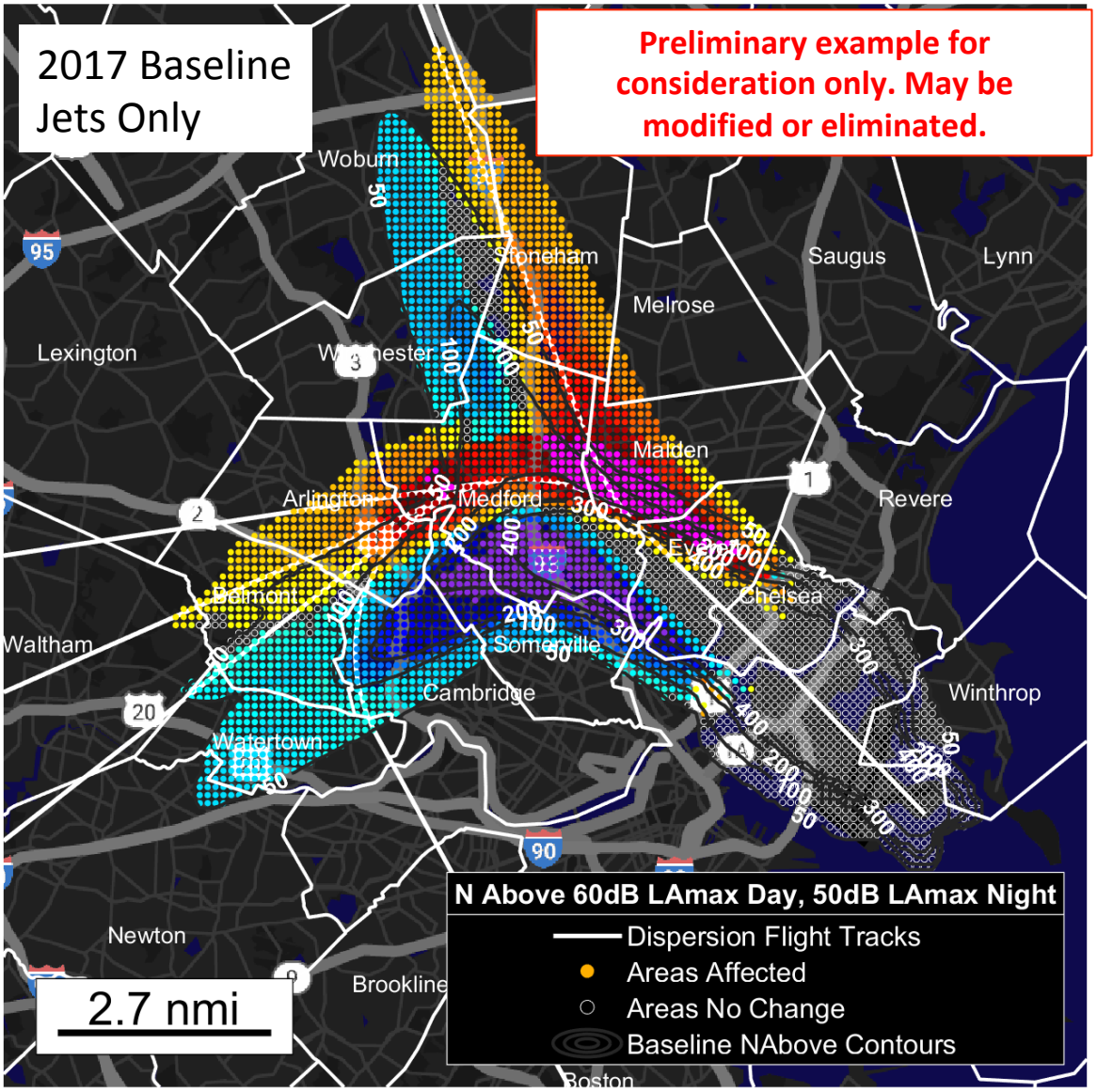
N_{60}	50x
Baseline 2017	335,823
Dispersion	335,823
Baseline - Dispersion	0

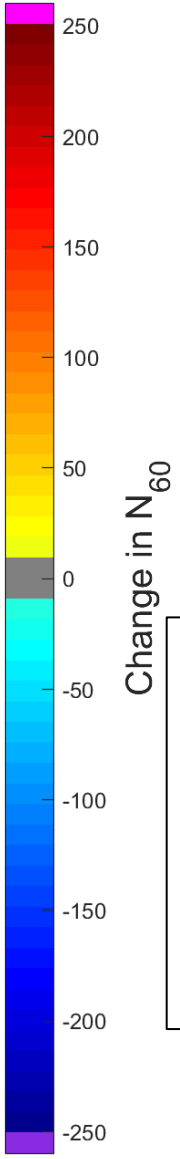


N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

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

33L Departures VRD Waypoint #2
Change in N_{60} Compared to 2017

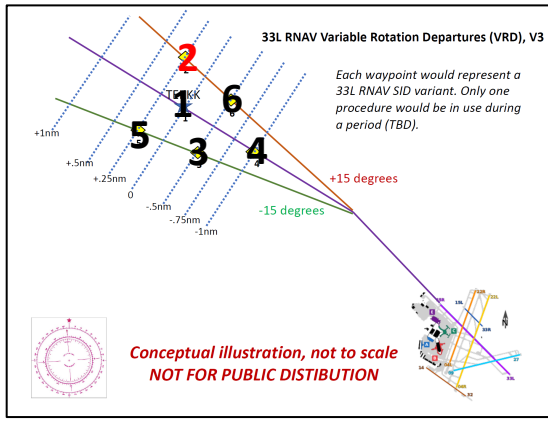




Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	269,491
Baseline - Dispersion	66,332

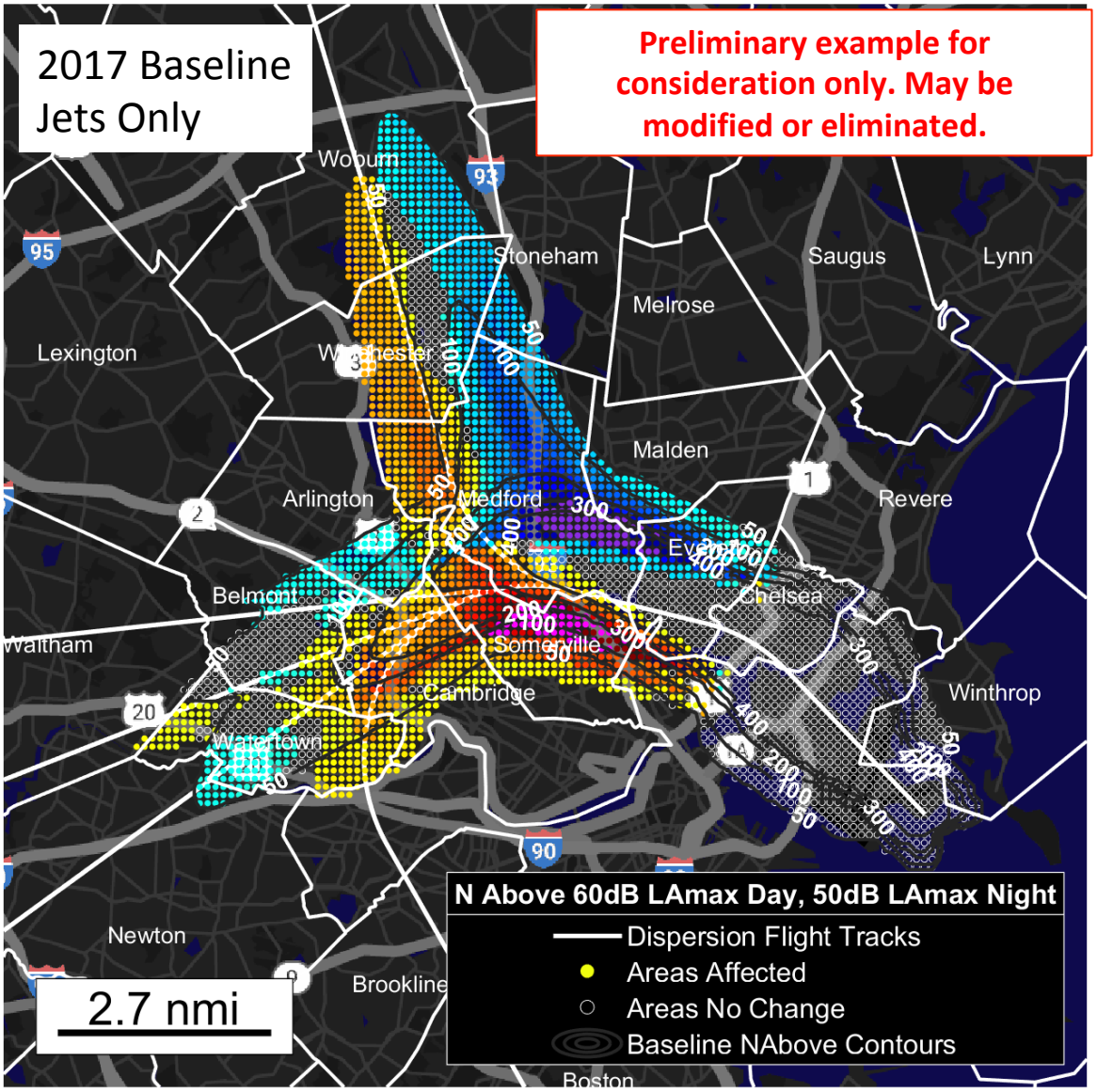
Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

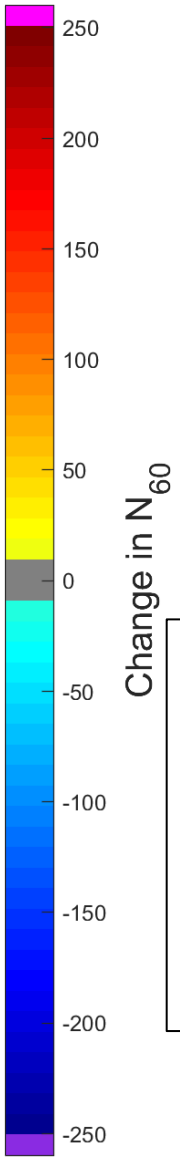


Analysis based on peak day operations; only includes 33L departures

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

33L Departures VRD Waypoint #3
Change in N_{60} Compared to 2017

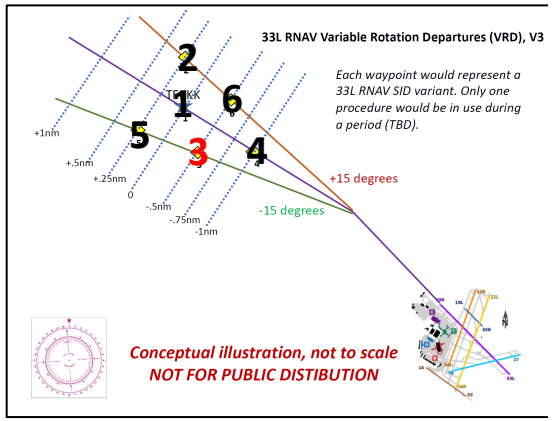




Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	334,570
Baseline - Dispersion	1,253

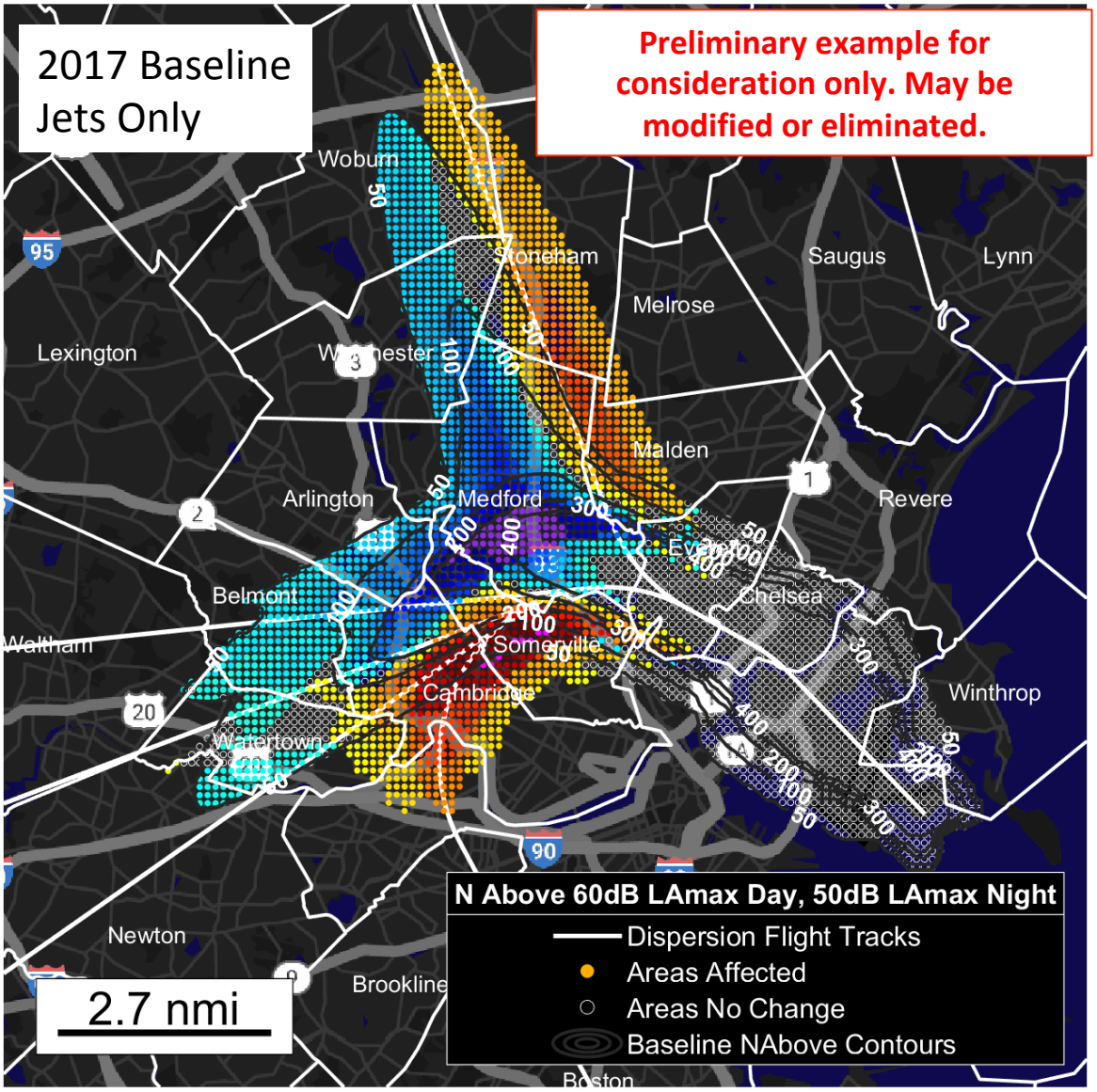
Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

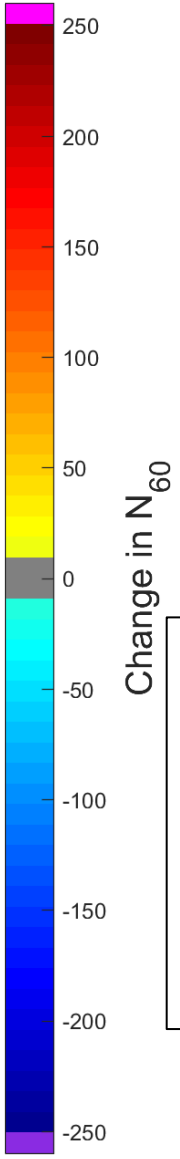


Analysis based on peak day operations; only includes 33L departures

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

33L Departures VRD Waypoint #4 Change in N_{60} Compared to 2017

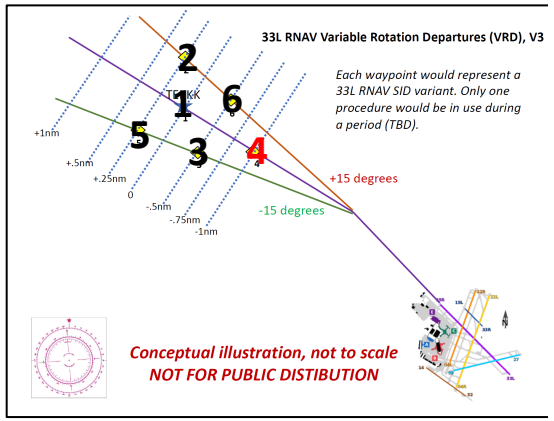




Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	345,368
Baseline - Dispersion	-9,545

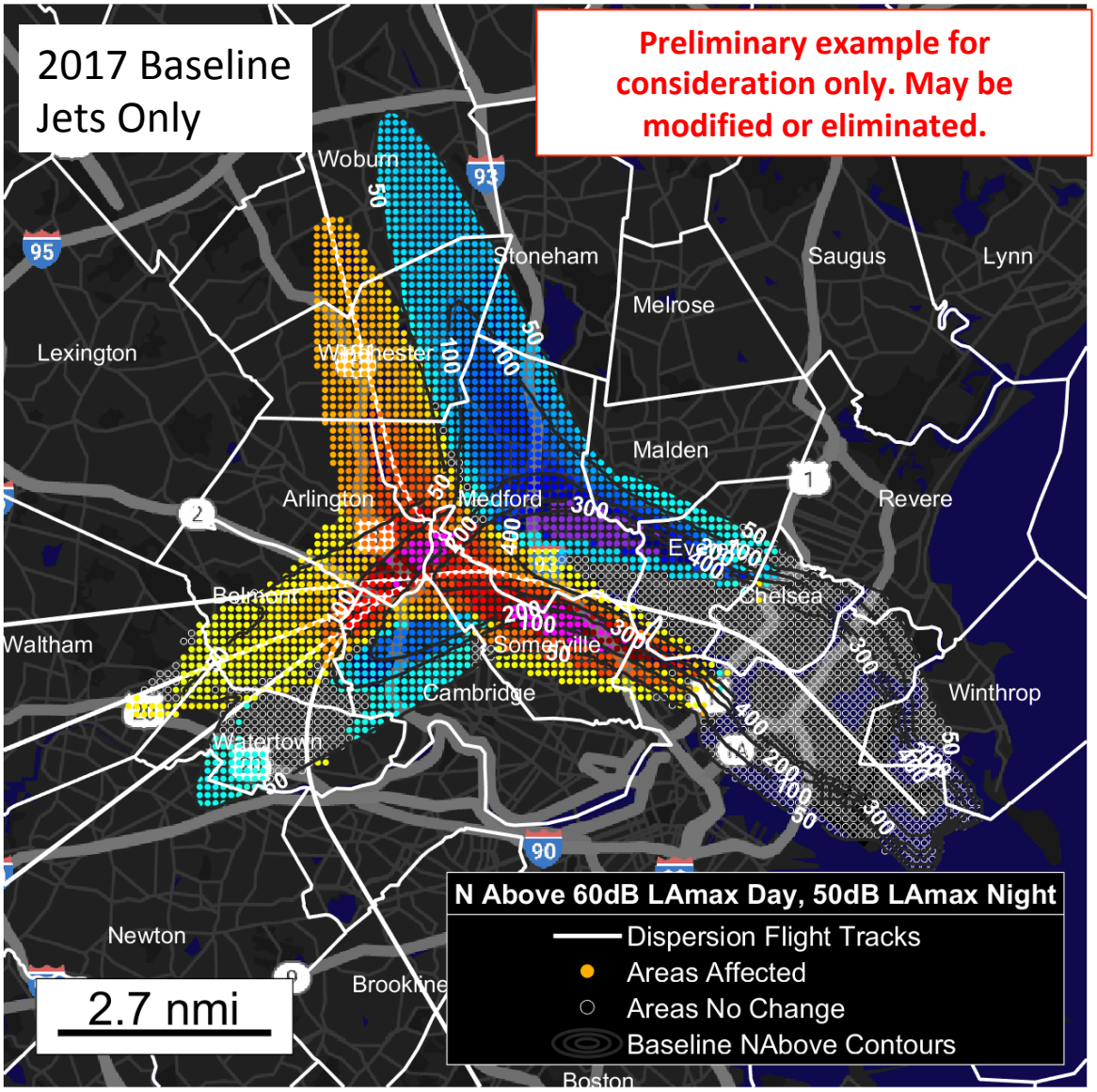
Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

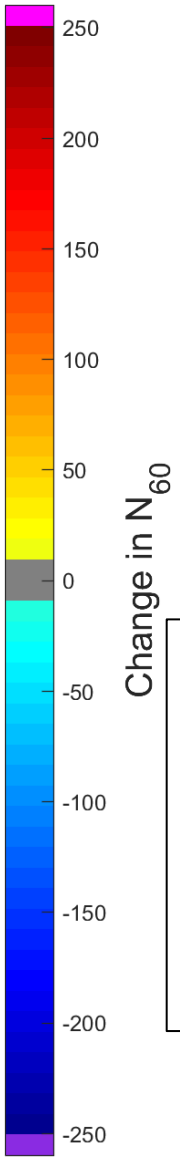


Analysis based on peak day operations; only includes 33L departures

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

33L Departures VRD Waypoint #5 Change in N_{60} Compared to 2017

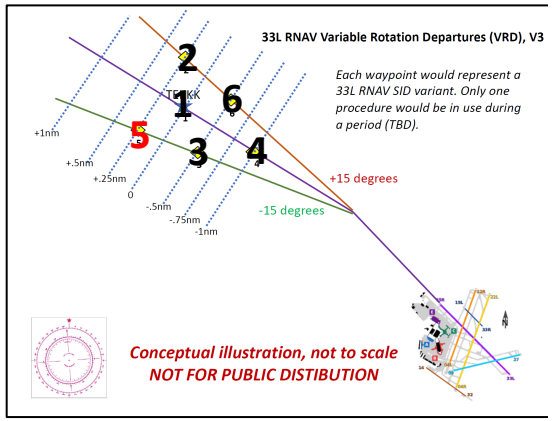




Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	321,688
Baseline - Dispersion	14,135

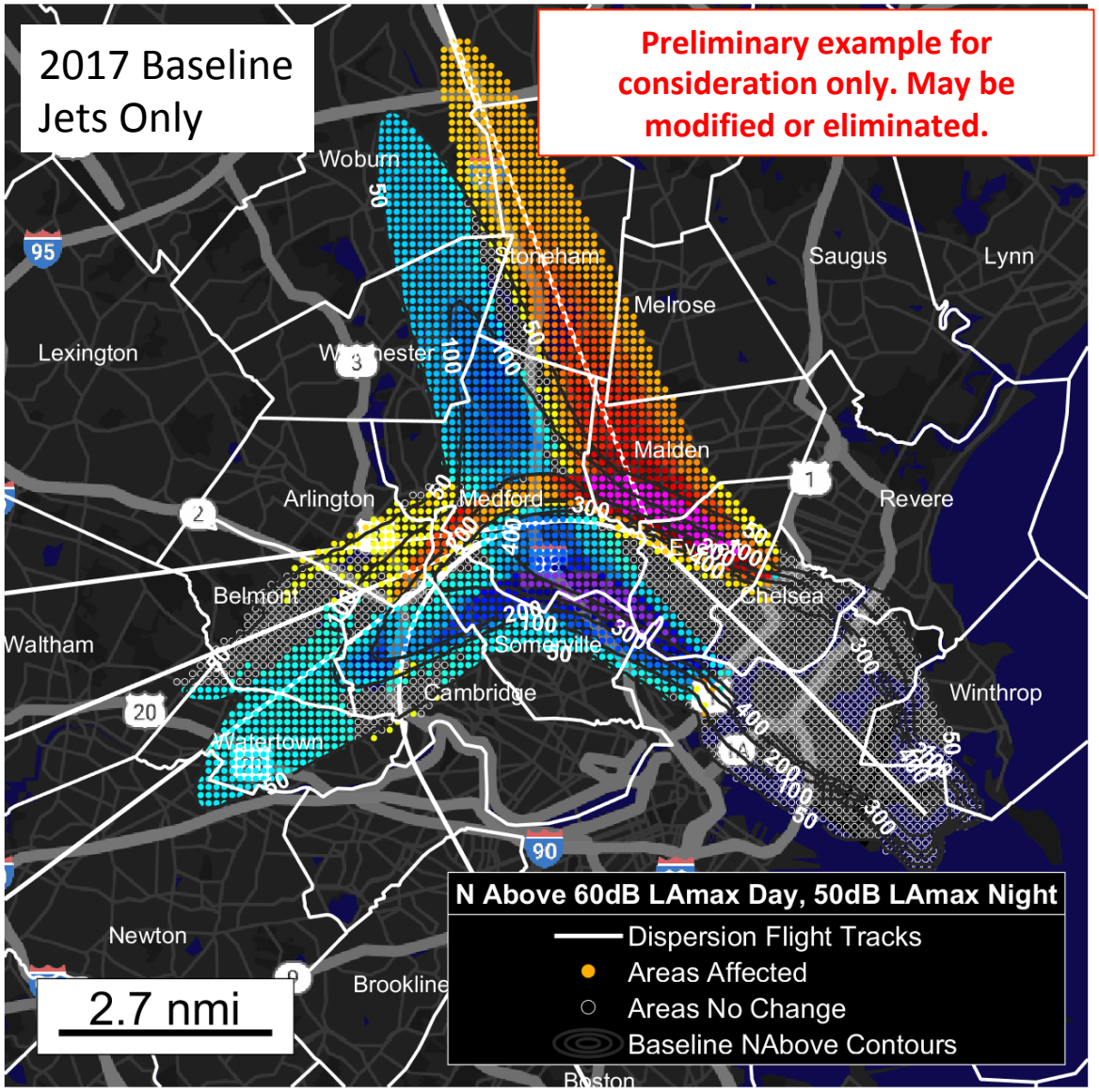
Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

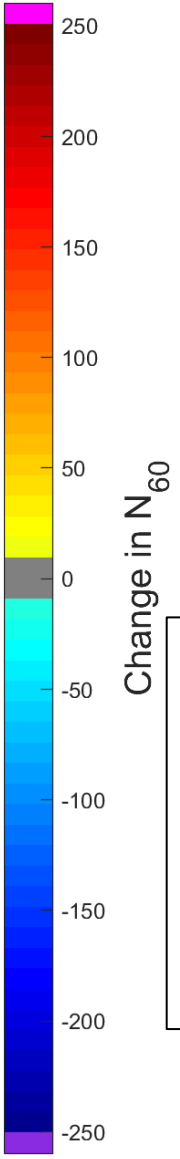


Analysis based on peak day operations; only includes 33L departures

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

33L Departures VRD Waypoint #6 Change in N_{60} Compared to 2017

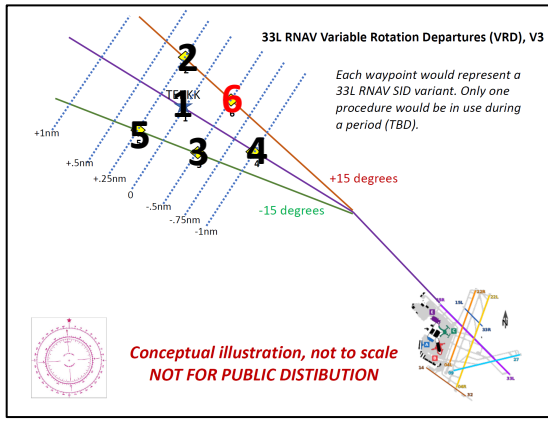




Population Exposure

N_{60}	50x
Baseline 2017	335,823
Dispersion	319,040
Baseline - Dispersion	16,783

Analysis updated Oct. 17 2019 to remove Turboprops and refine lateral tracks

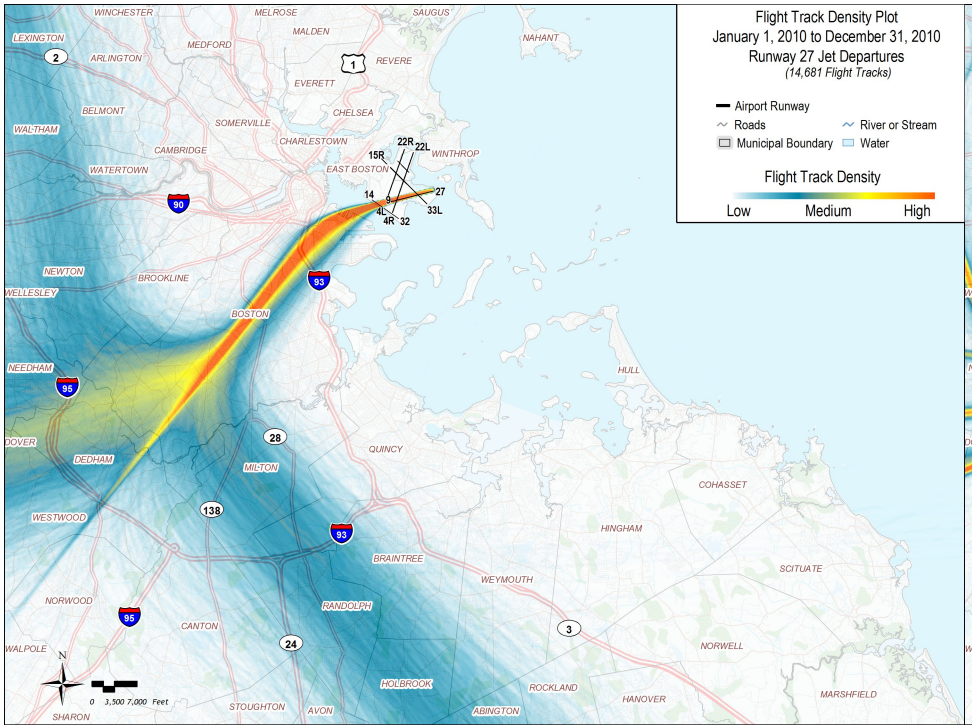


N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

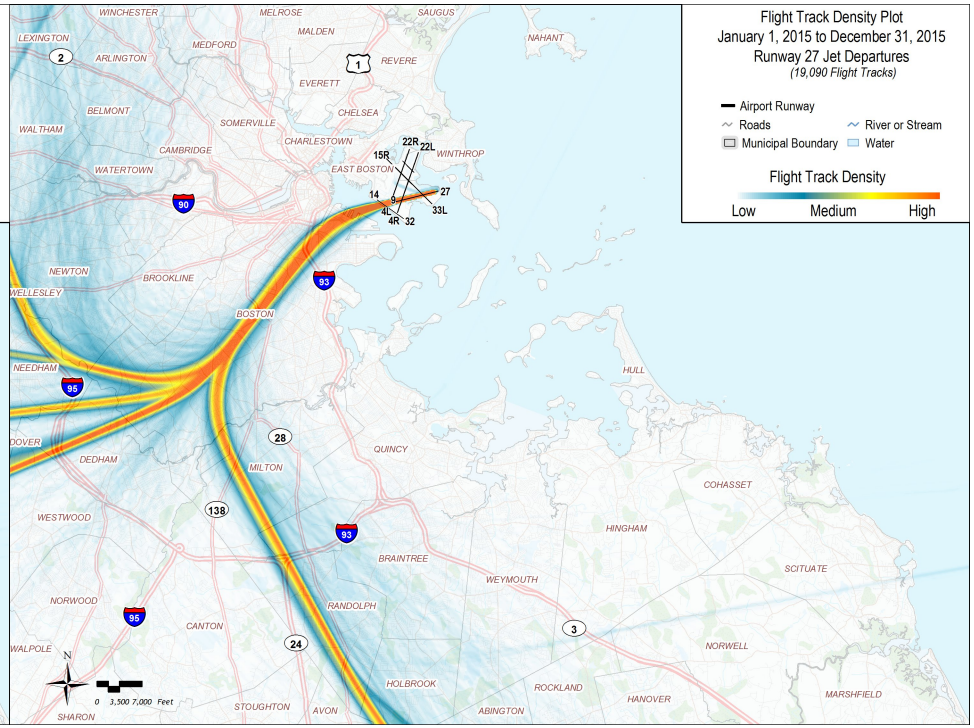
Analysis based on peak day operations; only includes 33L departures

Runway 27 Departures: 2010-2015

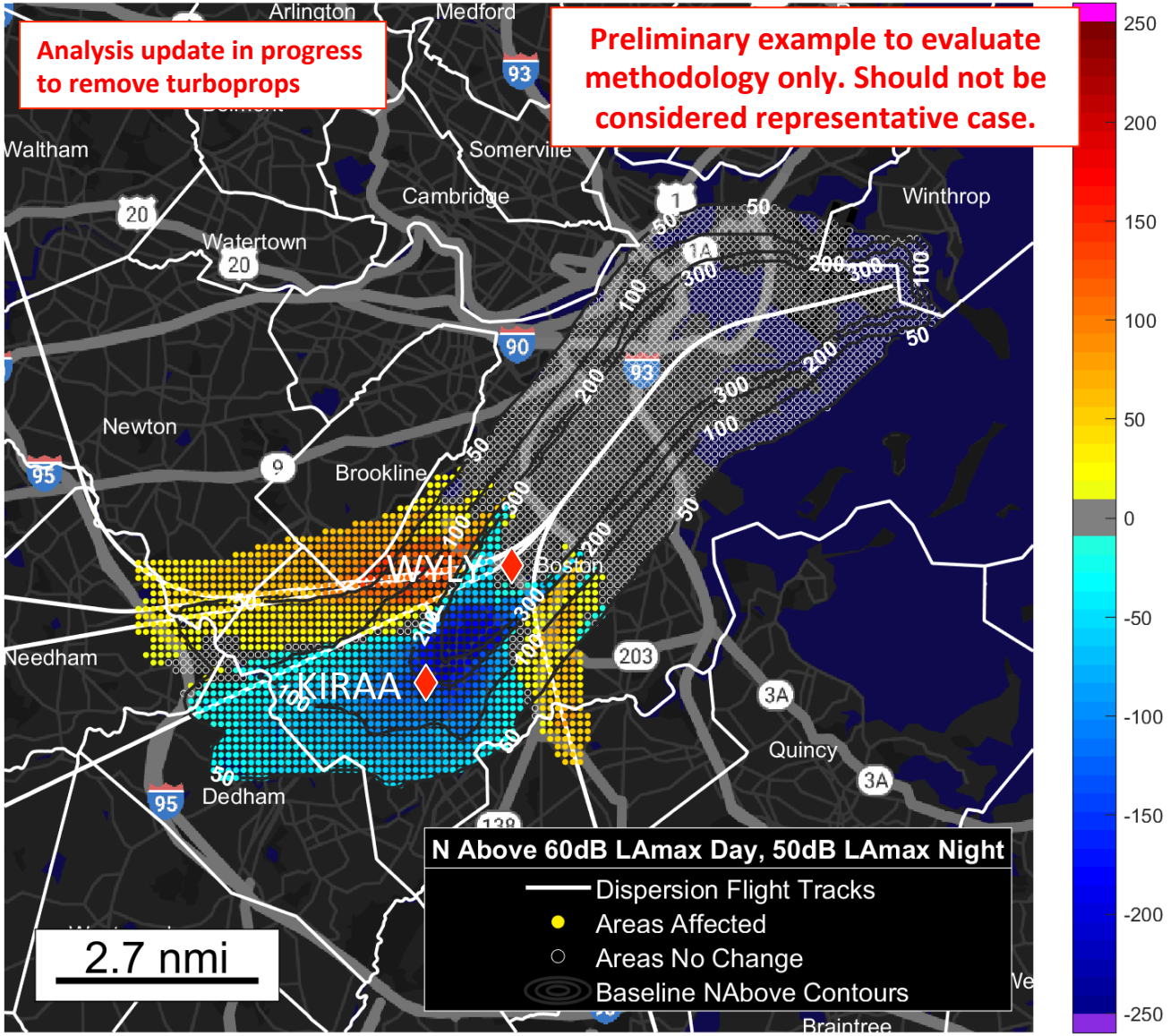
2010



2015



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



Population Exposure

N_{60}	50x
Baseline 2017	407,357
Dispersion	388,449
Baseline - Dispersion	18,908

Analysis updated Dec 4 2018 to correct for discretization differences

- Modification to existing RNAV procedure

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

Analysis based on peak day operations; only includes 27 departures

DISCUSSION