Analytical Approach for Quantifying Noise from Advanced Operational Procedures

ASCENT Project 23

April 19, 2019

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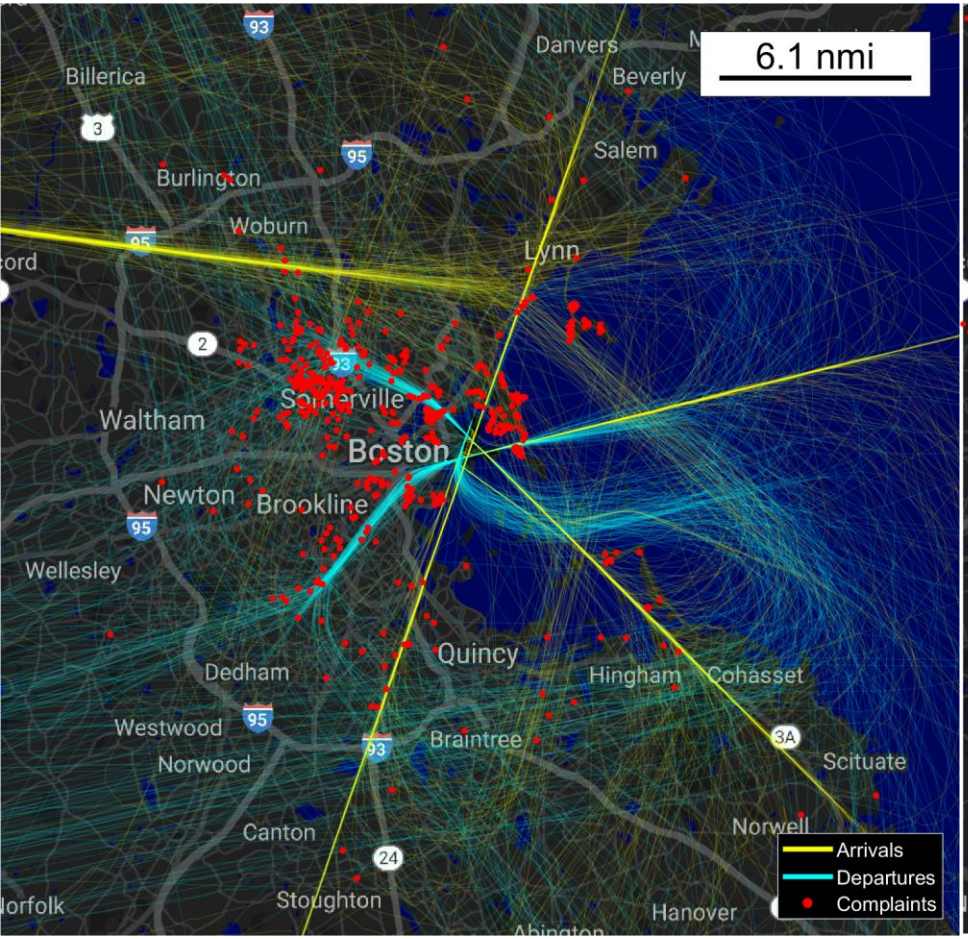
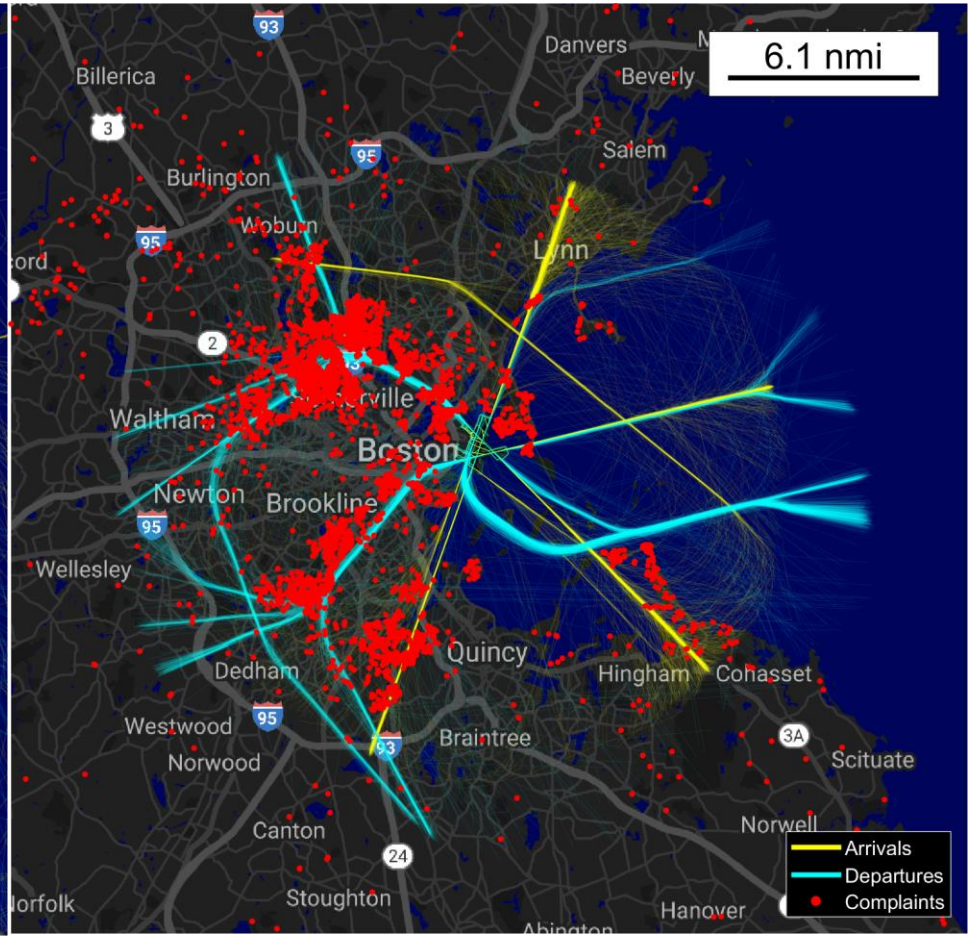
RNAV Track Concentration

2010

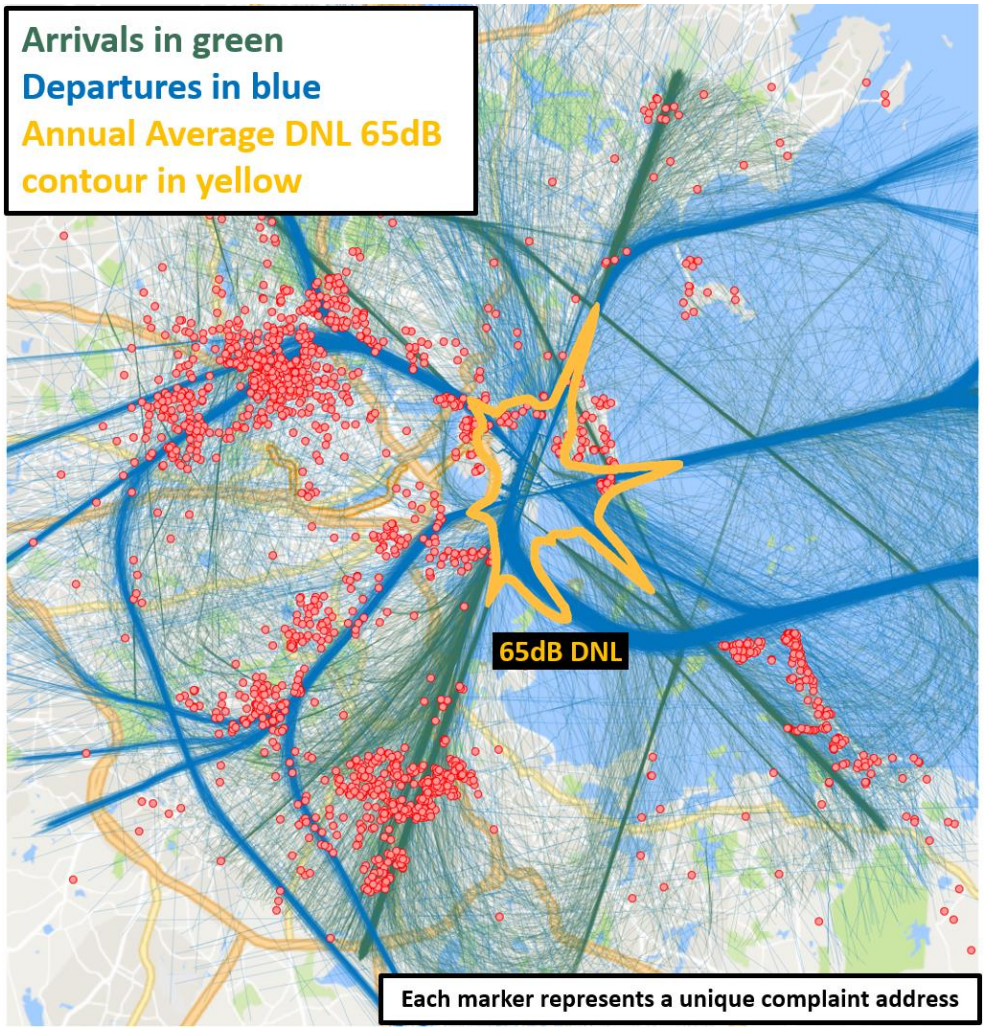


2017



Alternative Metrics to Capture RNAV Concentration Impacts

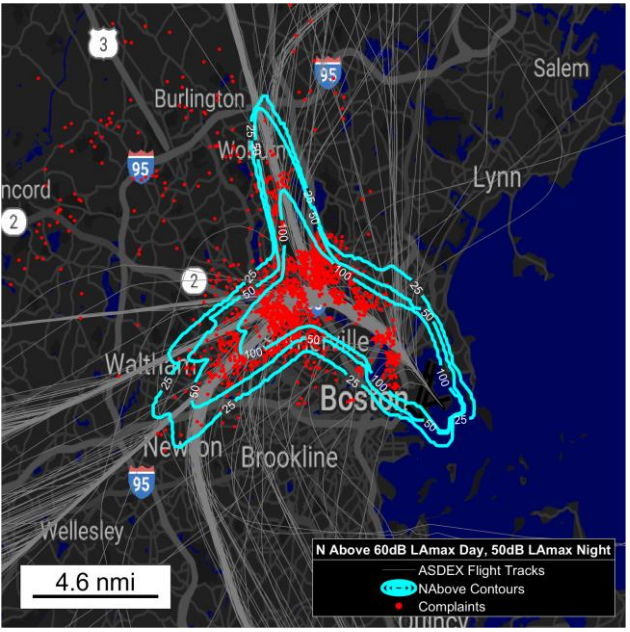
- RNAV concentration issue outside of Annual Average DNL 65dB contour
- Analysis performed by this research team at BOS, MSP, CLT, and LHR indicates that N_{60} on a Peak Day with 50 overflights represents the noise threshold for complaints



BOS N_{60} Count Thresholds

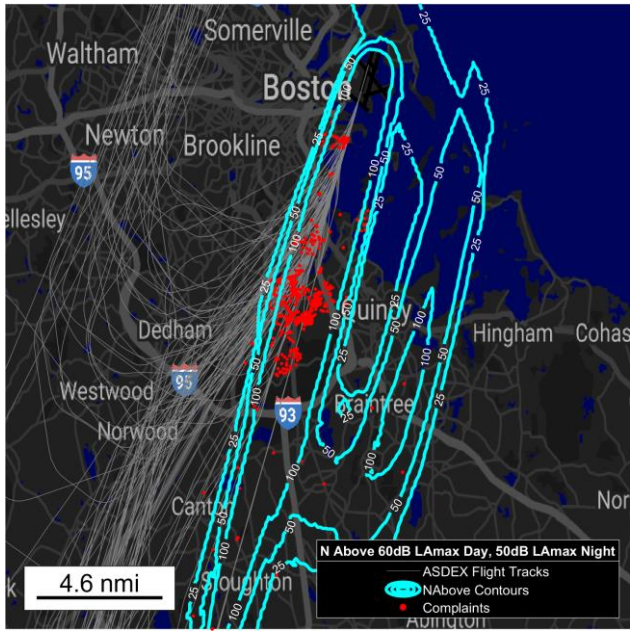
- N_{60} on a peak day with 50 overflights appears to capture complaint threshold in dispersion analysis

33L Departures Peak Day N_{60}



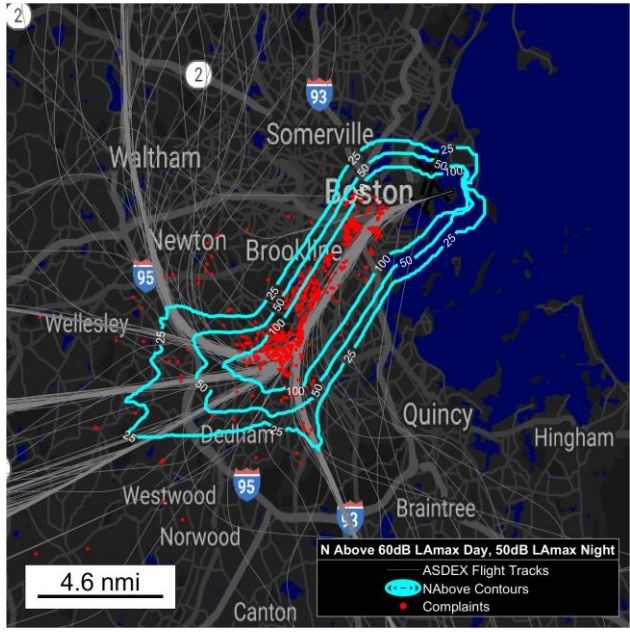
Peak Day N_{60}	Complaints Captured
25x	87.3%
50x	80.9%
100x	59.4%

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}



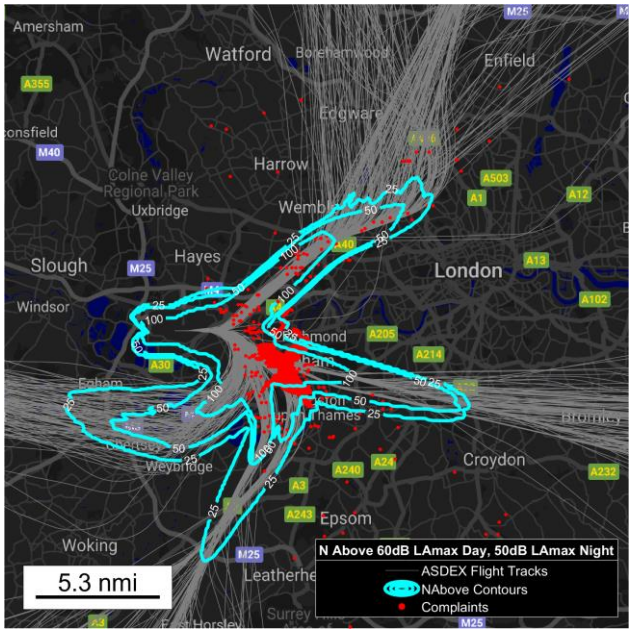
Peak Day N_{60}	Complaints Captured
25x	95.4%
50x	92.1%
100x	78.8%

2017 Data

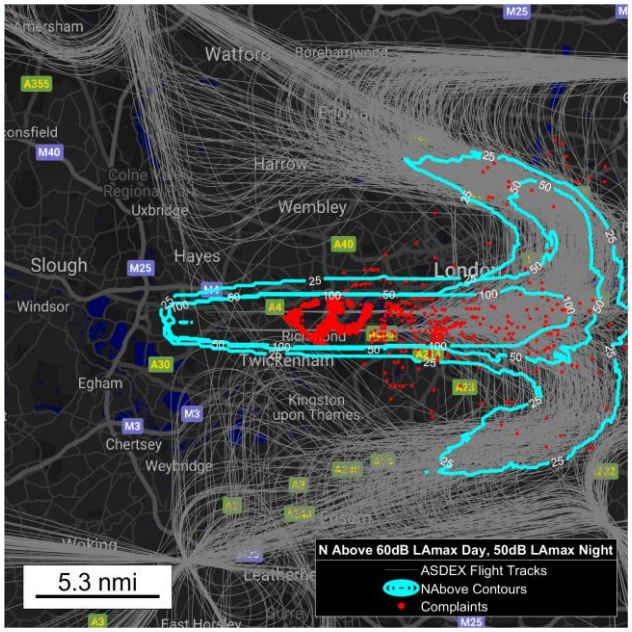
LHR N_{60} Count Thresholds

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

09 Departures Peak Day N_{60}



27 Arrivals Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	91.0%
50x	82.6%
100x	61.4%

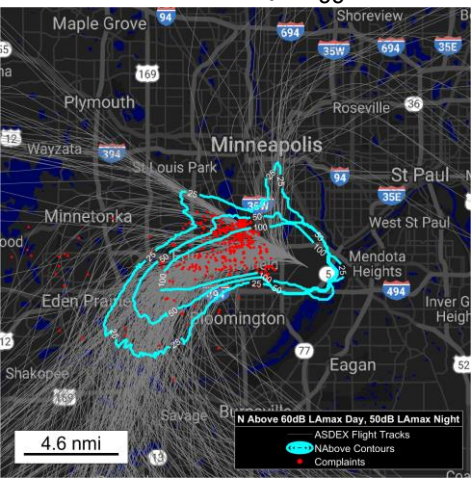
Peak Day N_{60}	Complaints Captured
25x	93.2%
50x	84.9%
100x	80.2%

2017 Data

MSP N_{60} Count Thresholds

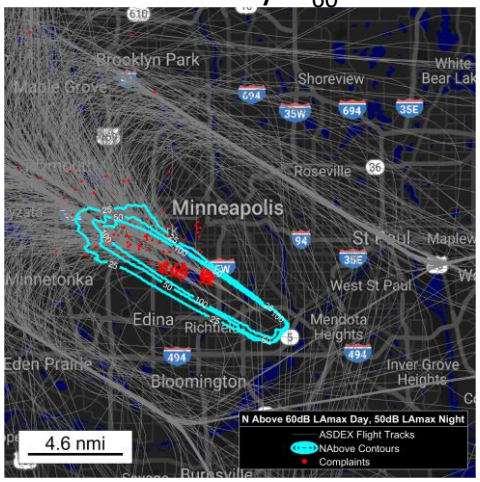
- N_{60} on a peak day with 50 overflights appears to capture complaint threshold in dispersion analysis

30L Departures
Peak Day N_{60}



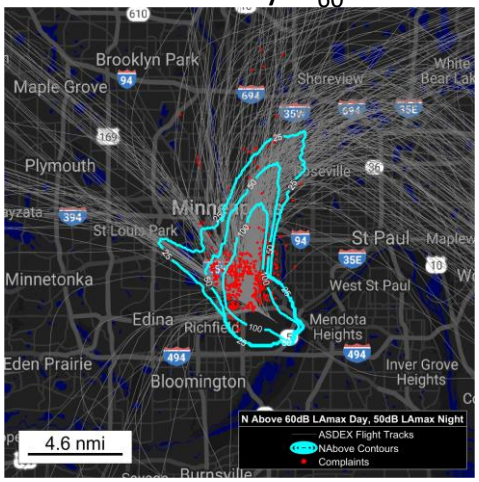
Peak Day N_{60}	Complaints Captured
25x	92.7%
50x	83.1%
100x	55.7%

12L/R Departures
Peak Day N_{60}



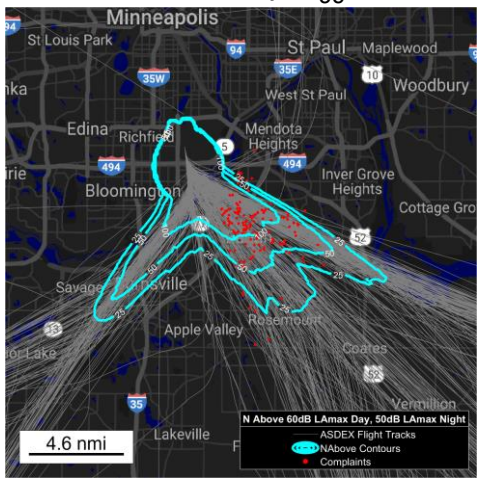
Peak Day N_{60}	Complaints Captured
25x	85.4%
50x	77.6%
100x	70.7%

30R Departures
Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	91.9%
50x	87.2%
100x	69.4%

17 Departures
Peak Day N_{60}



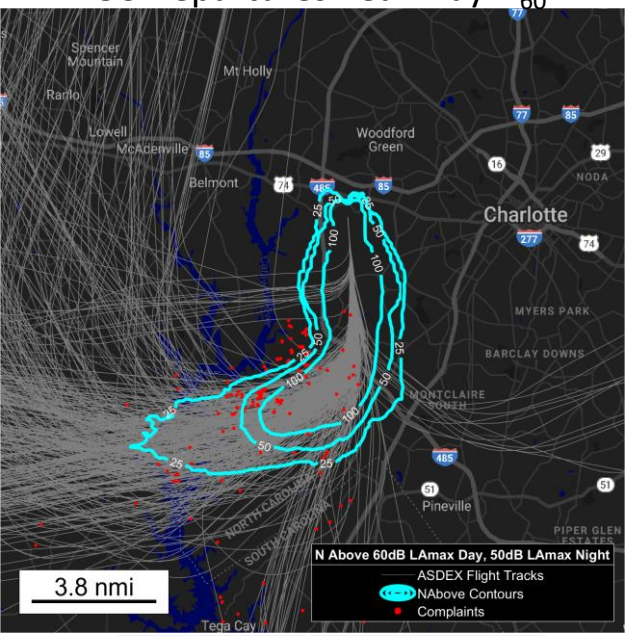
Peak Day N_{60}	Complaints Captured
25x	90.3%
50x	83.2%
100x	53.5%

2017 Data

CLT N_{60} Count Thresholds

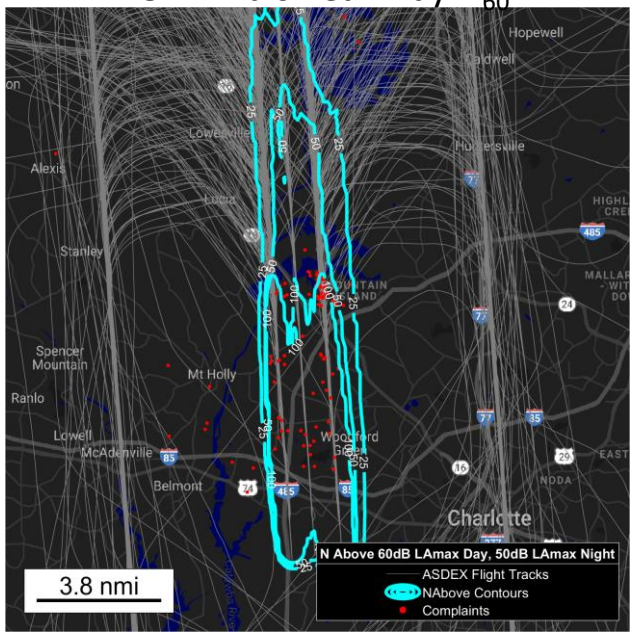
- N_{60} on a peak day with 50 overflights appears to capture complaint threshold in dispersion analysis
- Communities around CLT appear to have increased sensitivity

18C Departures Peak Day N_{60}



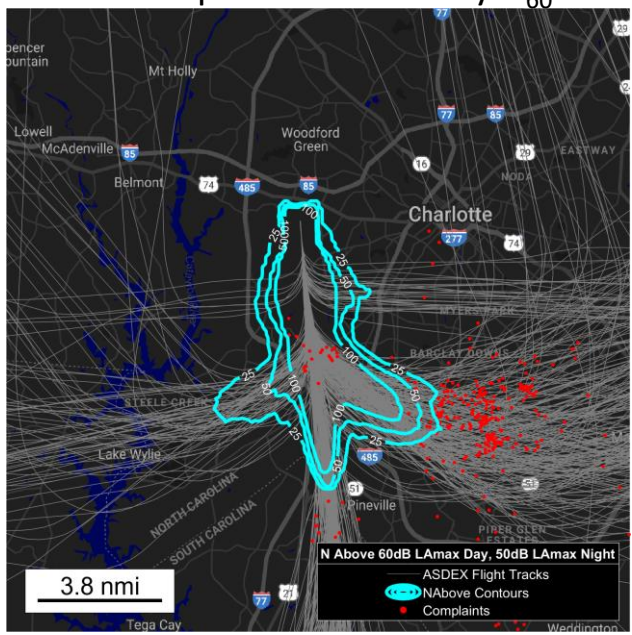
Peak Day N_{60}	Complaints Captured
25x	53.1%
50x	34.0%
100x	13.6%

18 Arrivals Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	83.5%
50x	80.7%
100x	59.6%

18L Departures Peak Day N_{60}



Peak Day N_{60}	Complaints Captured
25x	9.7%
50x	7.1%
100x	6.2%

2017 Data

Massport/FAA MOU
MIT Technical Approach

- Collect Data and Evaluate Baseline Conditions
  - Pre and Post RNAV
  - Community Input (Meetings and MCAC)
- Identify Candidate Procedure Modifications
  - Block 1
    - Clear noise benefit, no equity issues, limited operational/technical barriers
  - Block 2
    - More complex due to potential operational/technical barriers or equity issues
- Model Noise Impact
  - Standard and Supplemental Metrics
- Evaluate Implementation Barriers
  - Aircraft Performance
  - Navigation and Flight Management (FMS)
  - Flight Crew Workload
  - Safety
  - Procedure Design
  - Air Traffic Control Workload
- Recommend Procedural Modifications to Massport and FAA
- Repeat for Block 2

Noise Modeling Framework

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

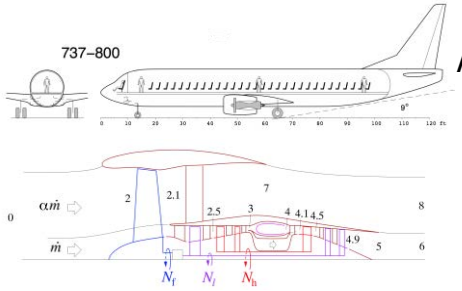
Aircraft Type

Procedure Definition:
Lateral Path
Speeds
Configuration

TASOPT

BADA4 Existing Aircraft Data

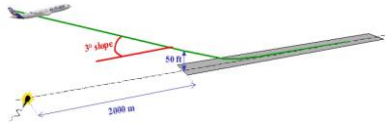
Performance Model Outputs:



Aircraft/engine performance & geometry

Flight Procedure Generator

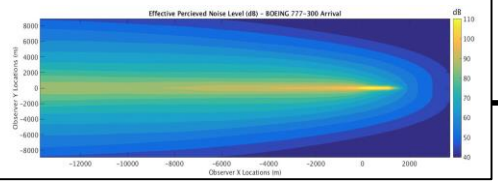
Flight Procedure:
Thrust, velocity, position, gear/flap settings per time



Noise Model Control Inputs:
Propagation Settings
Observer Locations

ANOPP/AEDT

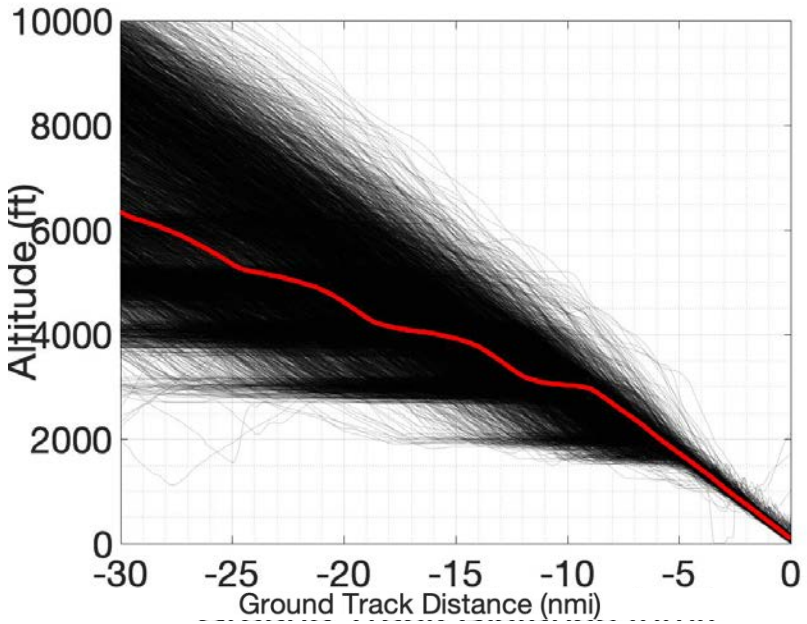
Single-Event Noise Grids



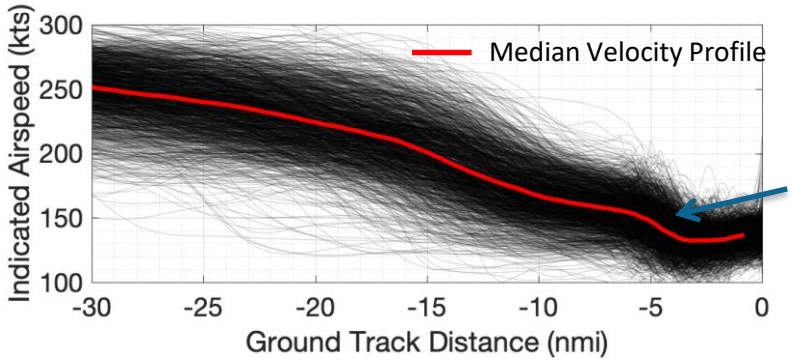
Output to Grid Rotation and Superposition

Flight Profile Generation
Example for a B737-800 Approach

Example Approach Radar data in 2017 at BOS, 22L

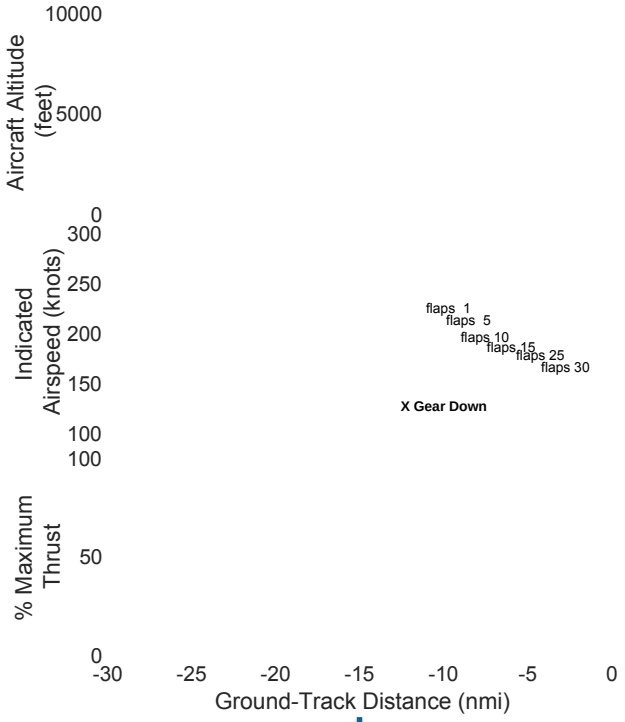


Groundspeed Radar data converted into indicated airspeed, assuming no wind

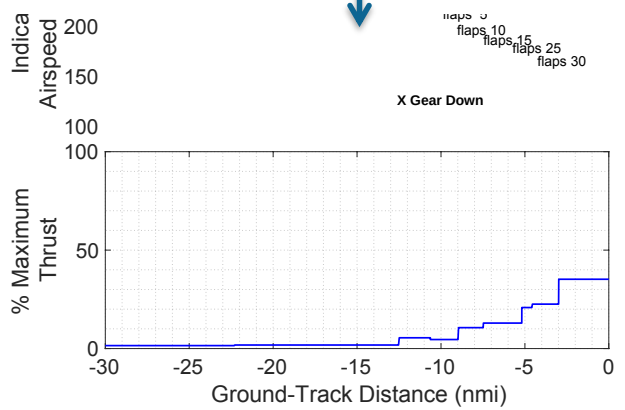


Gear assumed deployed ~6nmi from touchdown based on observed deceleration

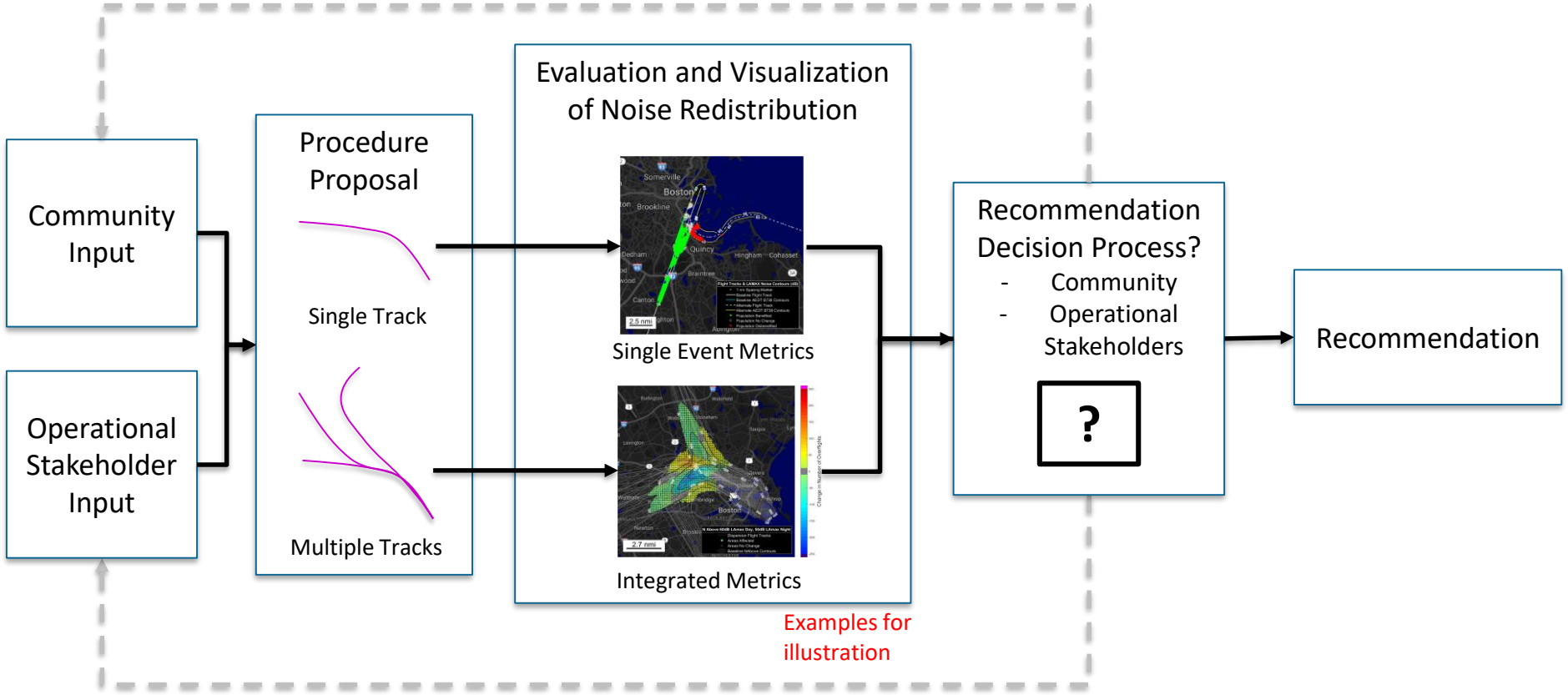
- A
- F



Res



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

Block 1 Example:

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"

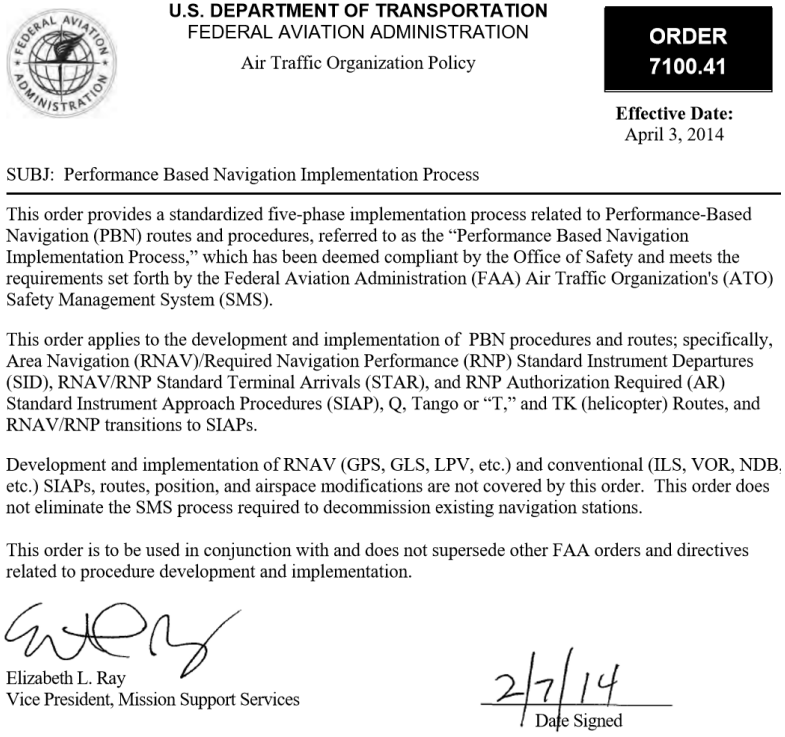
Available at: http://hdl.handle.net/1721.1/114038

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)
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"

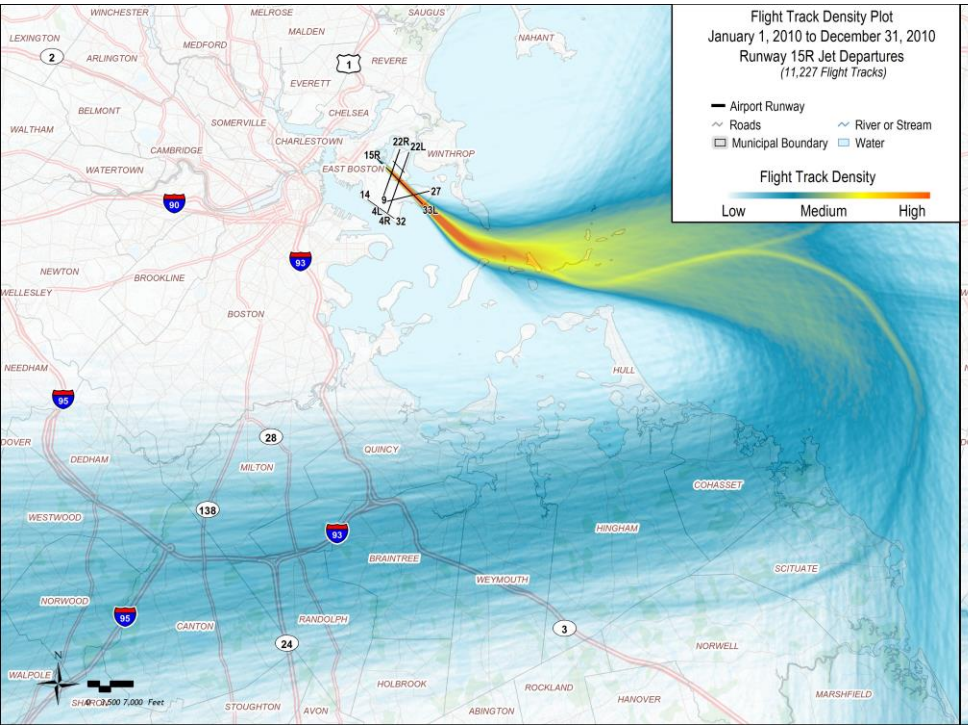
Available at: http://hdl.handle.net/1721.1/114038

Advanced by .41 group

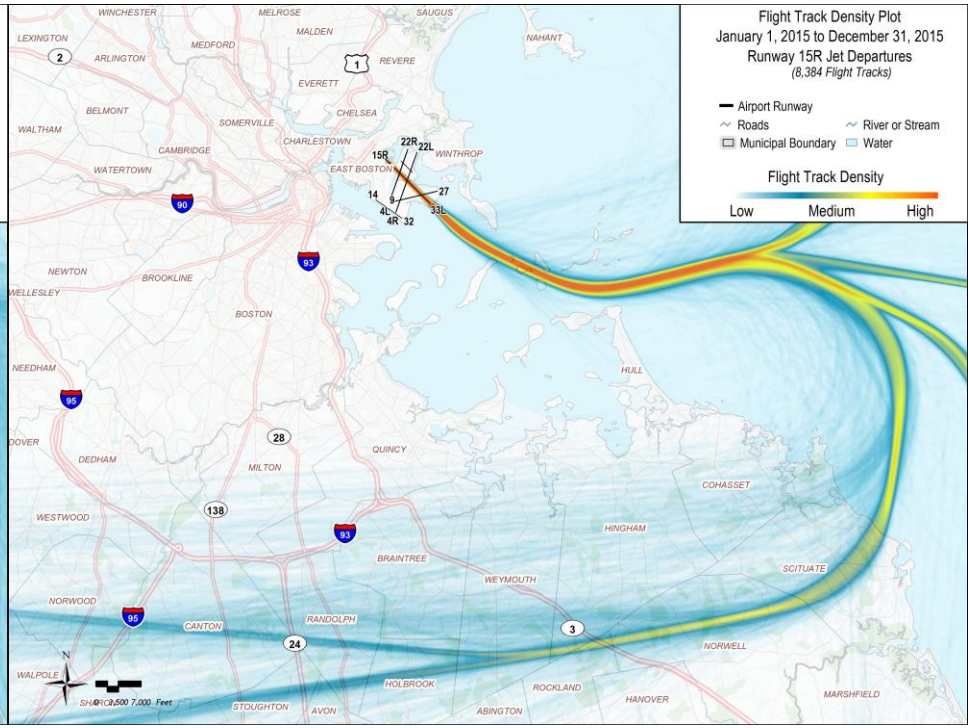
RUNWAY 15R RNAV WAYPOINT RELOCATION (1-D2)

Runway 15 Departures: 2010-2015

2010



2015



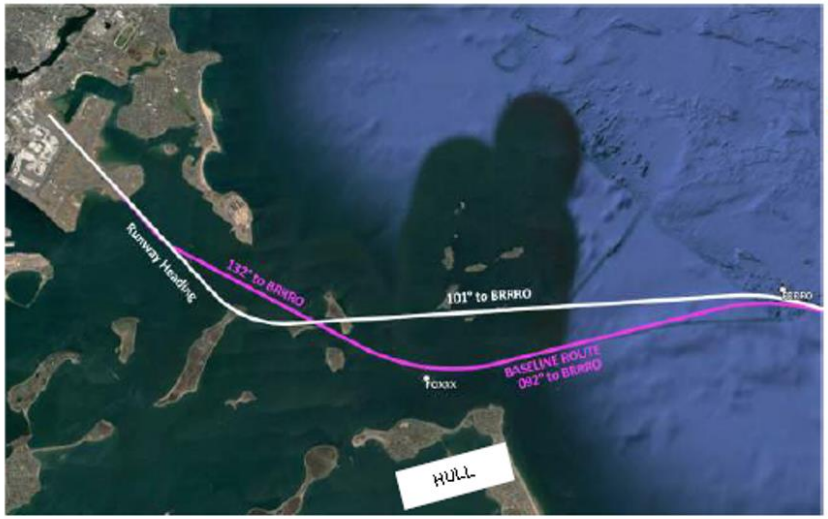
FAA 7100.41 Working Group Procedure Design

(1-D2)

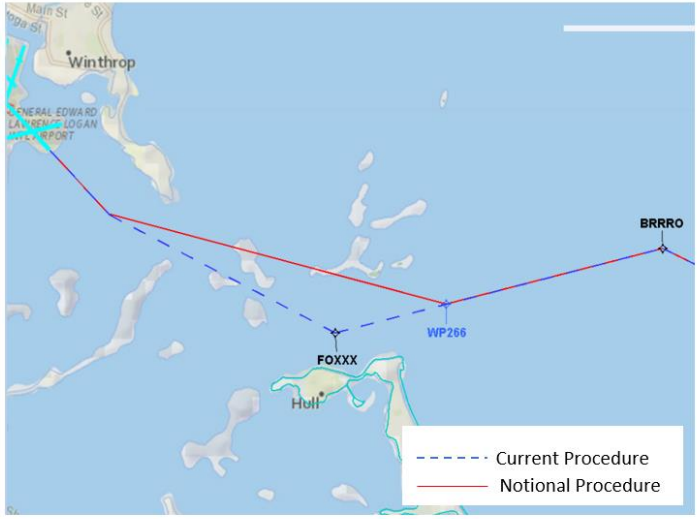
Modify RNAV SID from Runway 15R to move tracks further to the north away from populated areas.

Primary Benefit: Departure flight paths moved north away from Hull

Design recommended by MIT



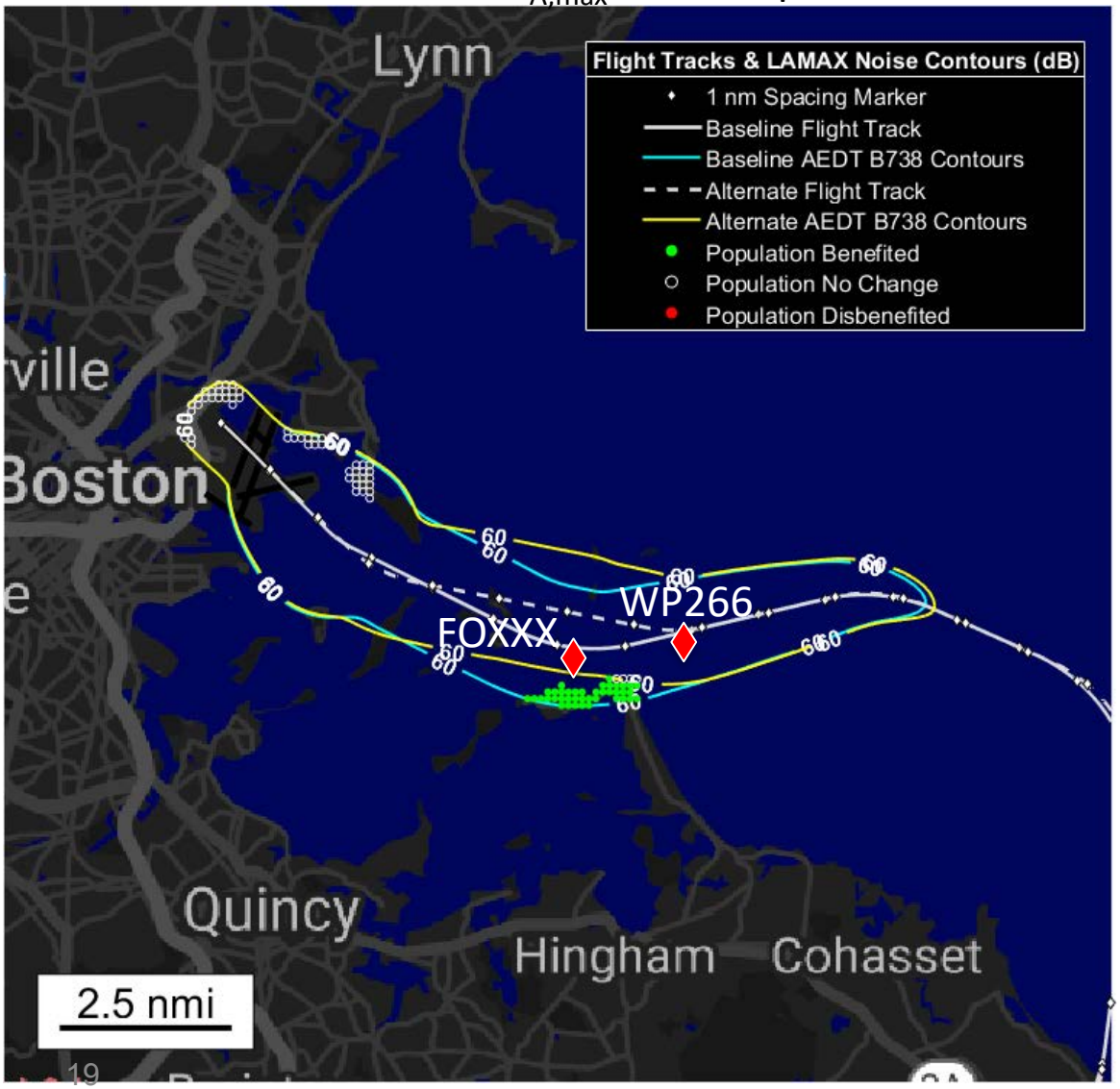
Notional design by Full Work Group as of October 4, 2018



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 ($L_{A,MAX}$)

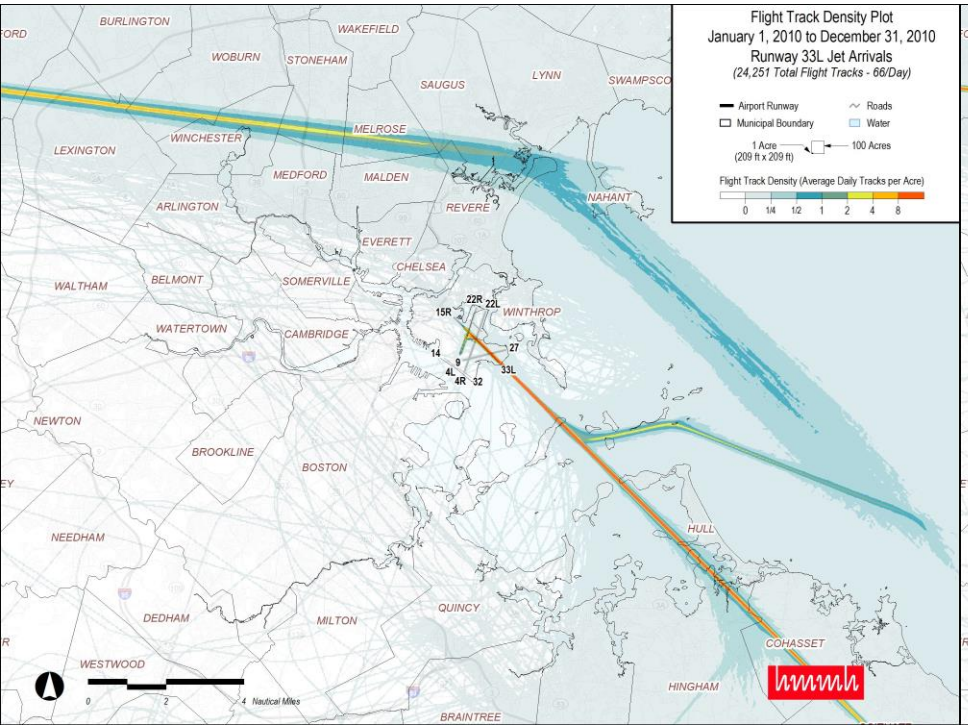
	60dB
Current RNAV	5,838
.41 RNAV	4,815
Current RNAV – .41 RNAV	1,023

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

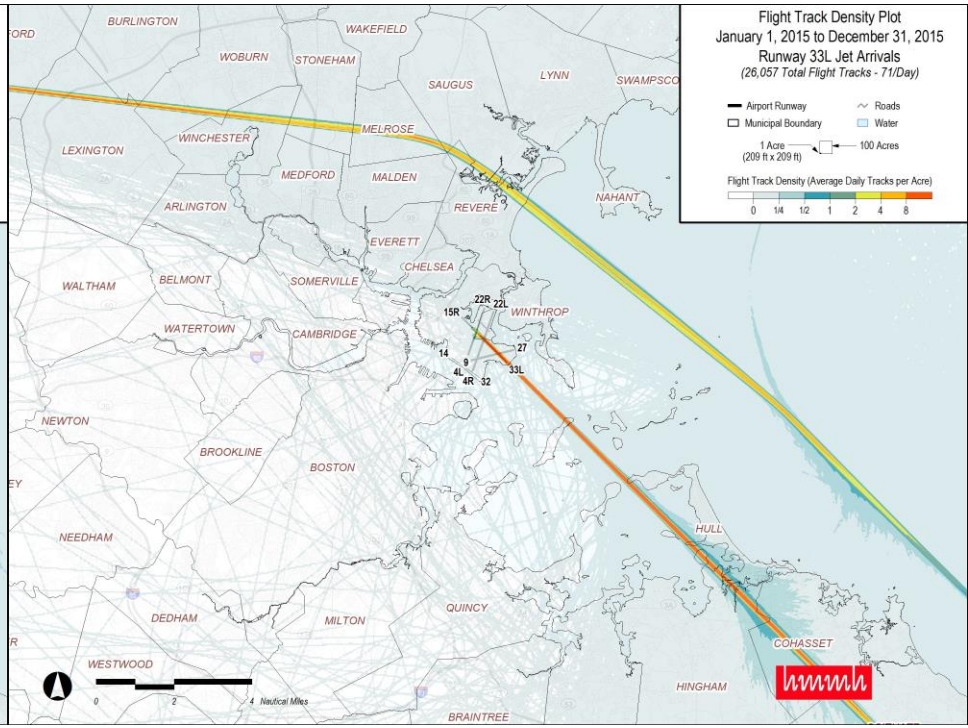
BLOCK 1: RUNWAY 33L
RNAV APPROACH AND RNP APPROACH

Runway 33L Arrivals: 2010-2015

2010

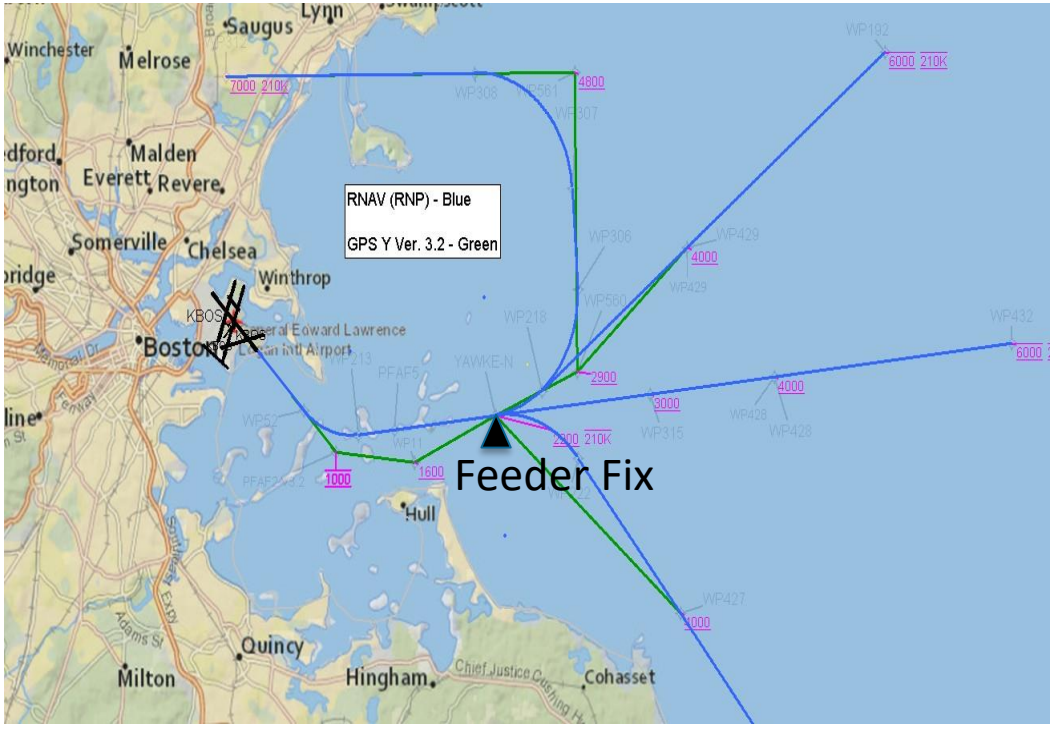


2015



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



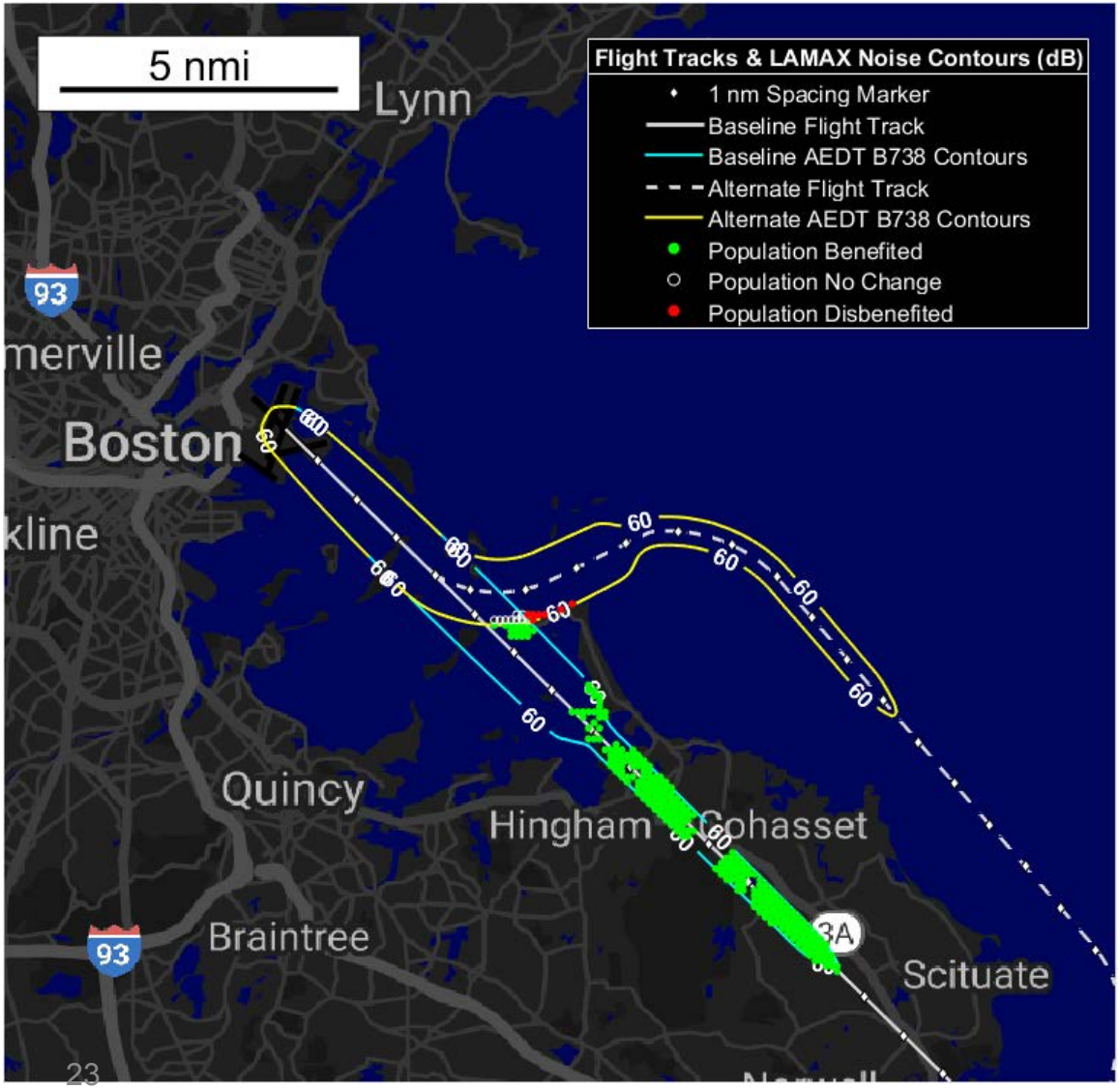
FAA 7100.41 TARGETS file

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

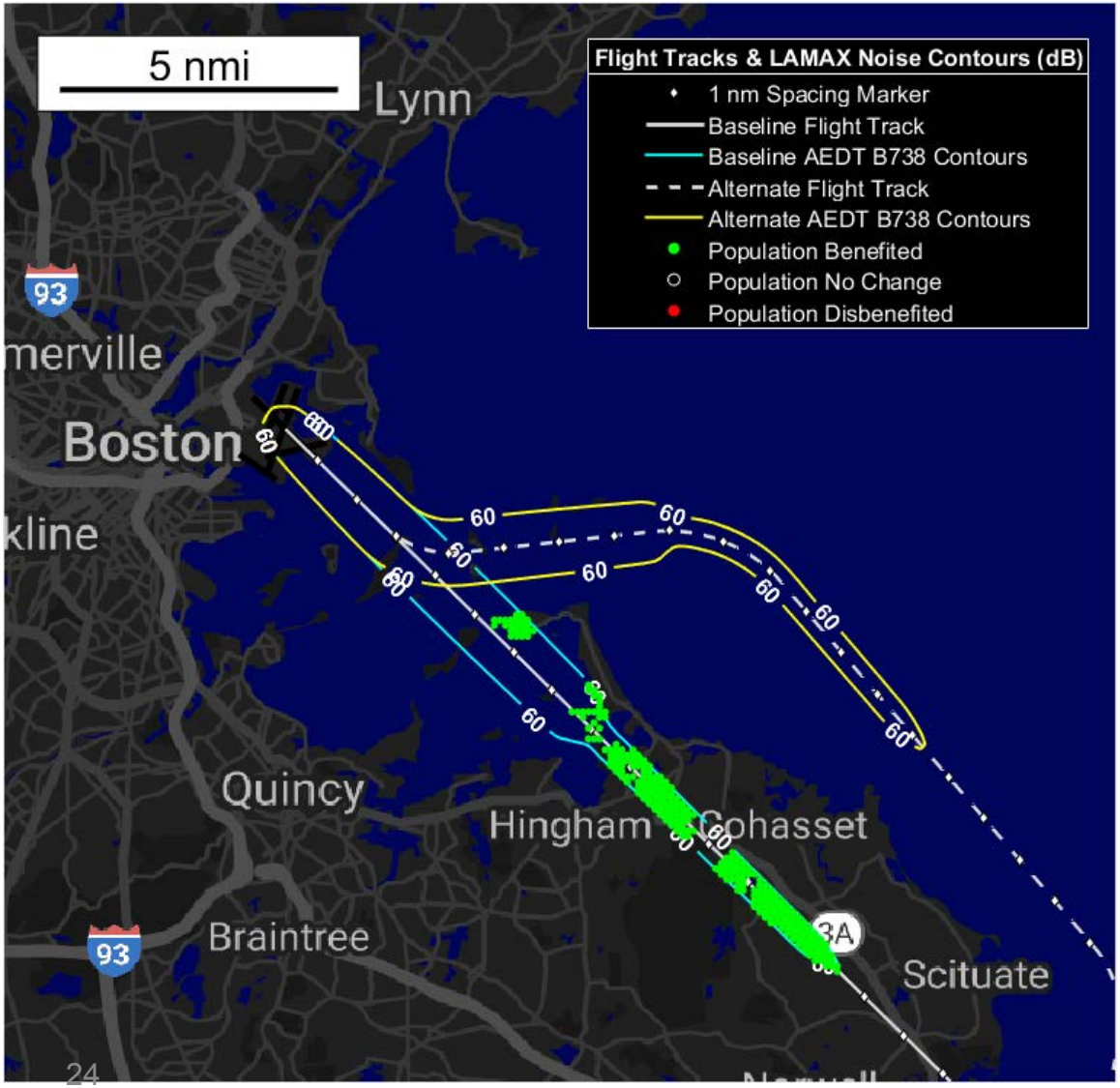
	60dB
Straight In	2,954
.41 RNAV GPS	396
Difference (Straight In– .41 RNAV GPS)	2,558

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

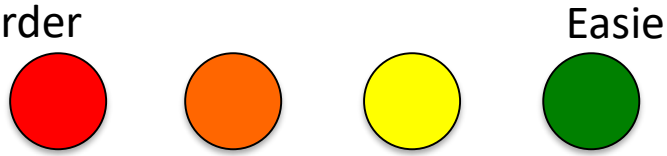
Implement an overwater RNP approach procedure to Runway 33L that follows the ground track of the jetBlue RNAV Visual procedure as closely as possible.

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

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

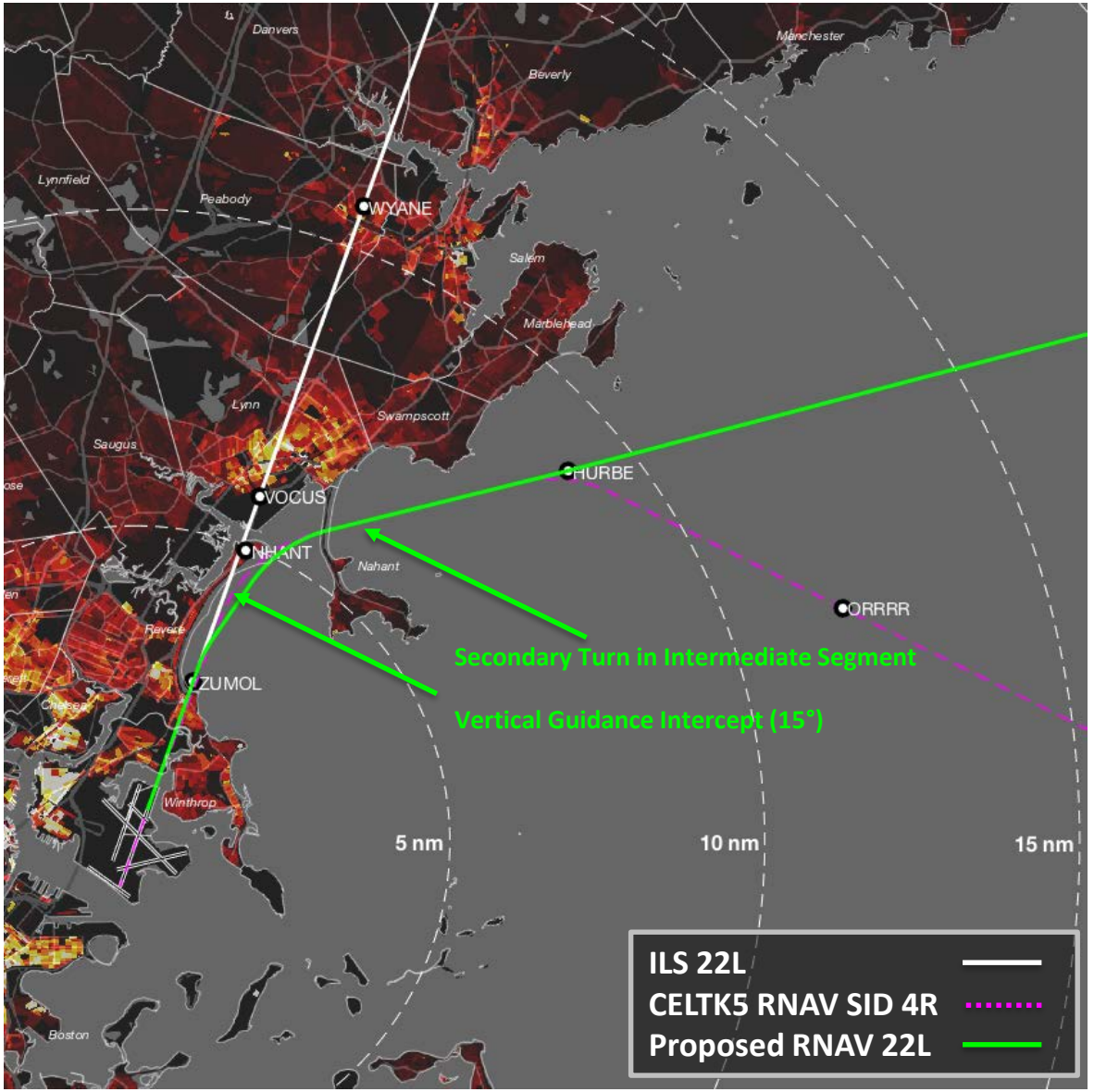
RNAV/RNP LATERAL MODIFICATIONS TO 22L APPROACH PROCEDURE

22L Low-Noise Offset RNAV Approach with RNP Overlay

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

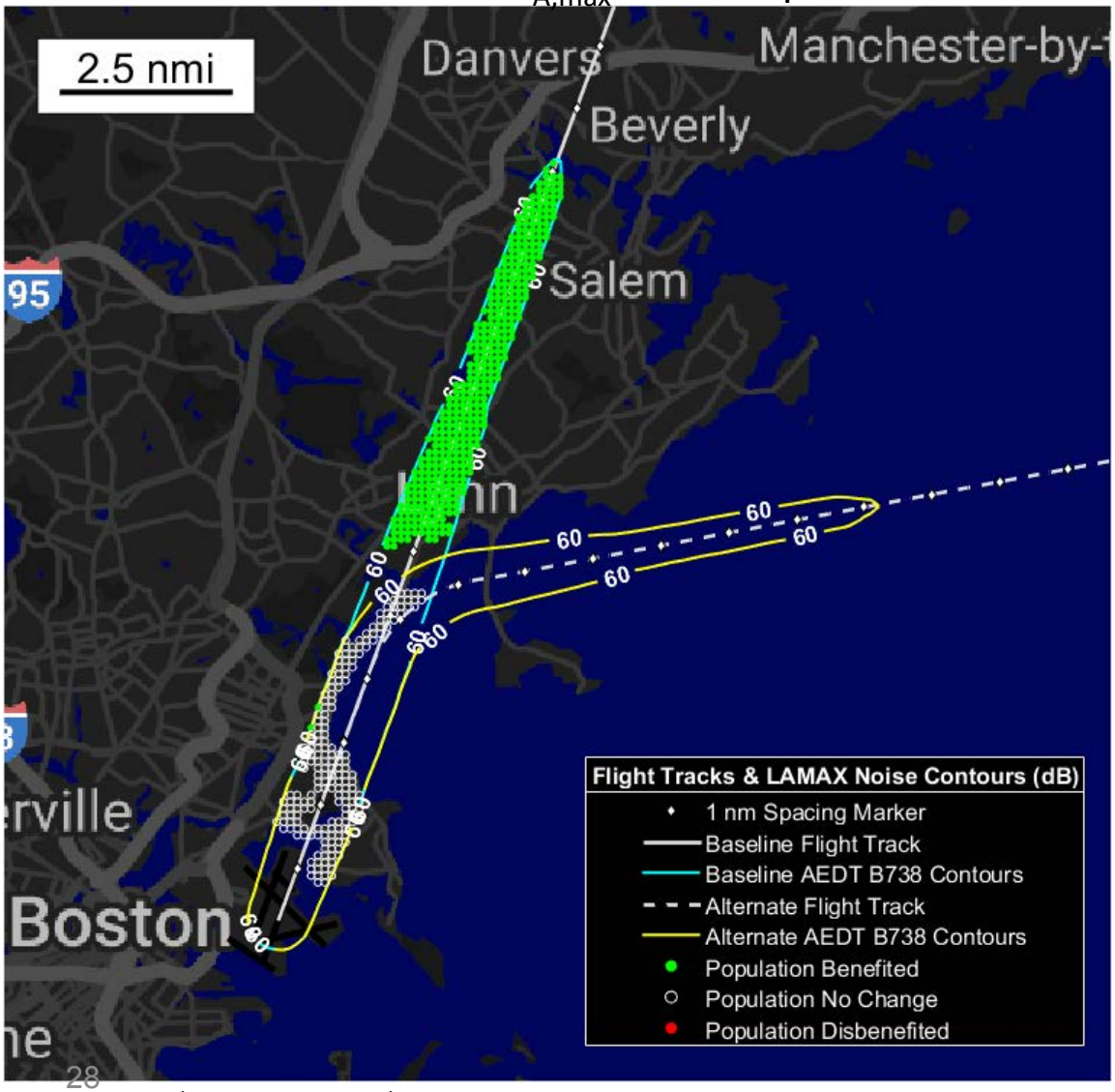
Notes:

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



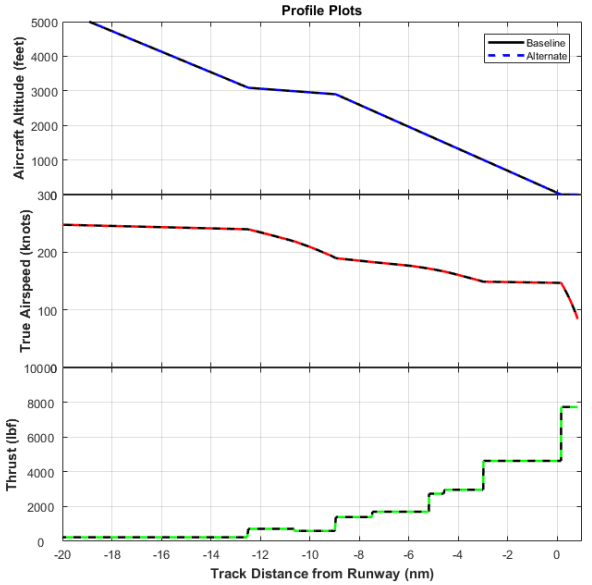
22L Arrival RNAV with RNP Overlay vs Straight In Boston Data B737-800 Profile 3000ft Level Off

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



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

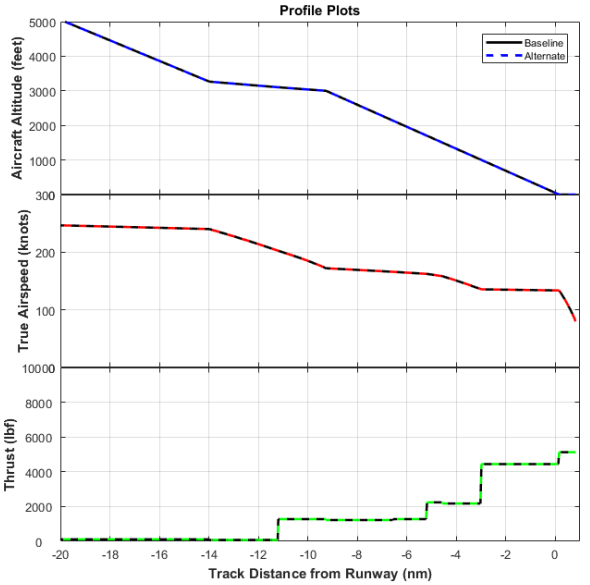
Analysis current 19 April 2019

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

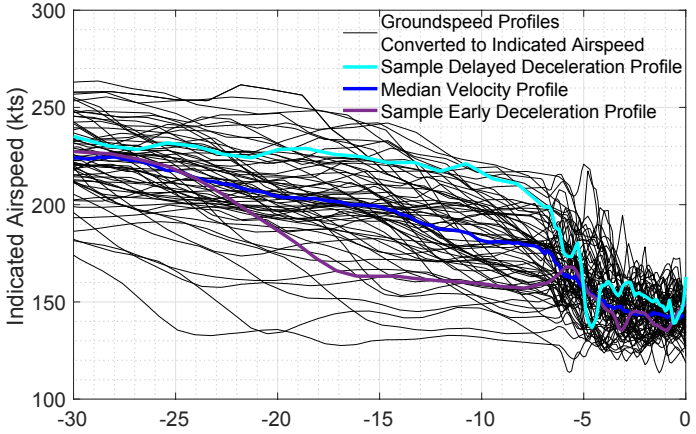
- Procedure within RNAV criteria. Initial .41 review found no major obstacles

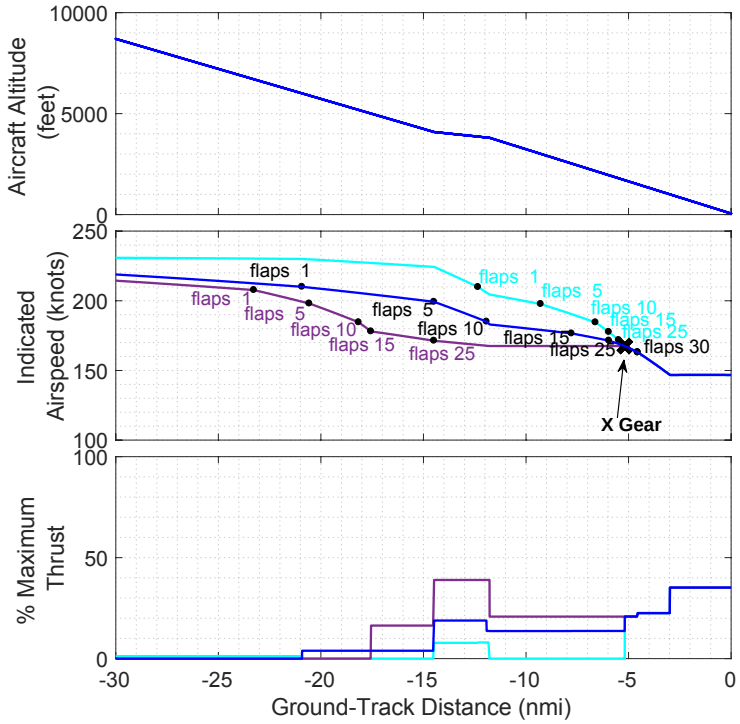
Analysis current 19 April 2019

DELAYED DECELERATION APPROACHES

Delayed Deceleration Approaches

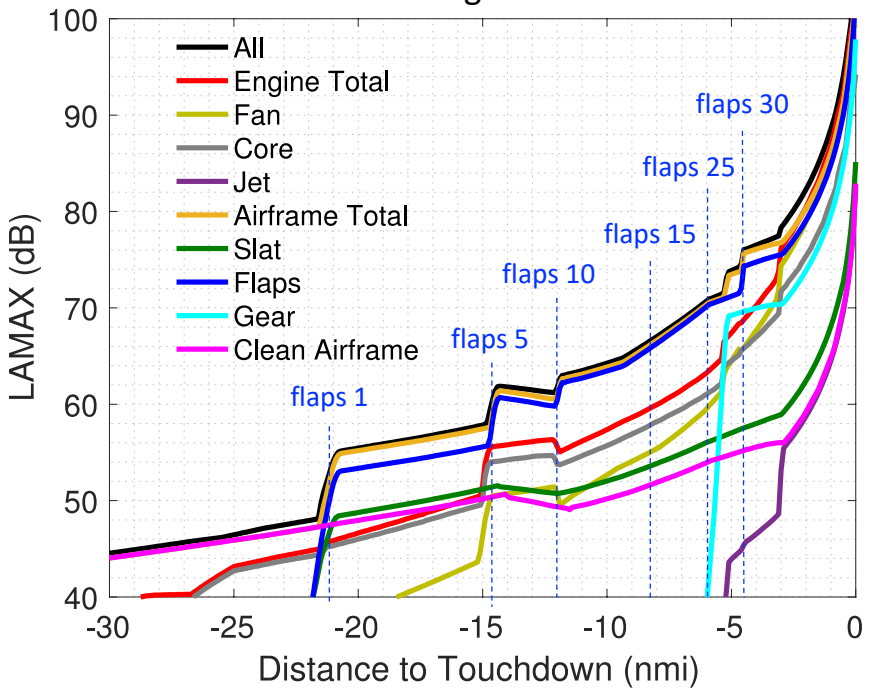
Velocity Radar Data for B737-800 4000ft Level Offs into 4R



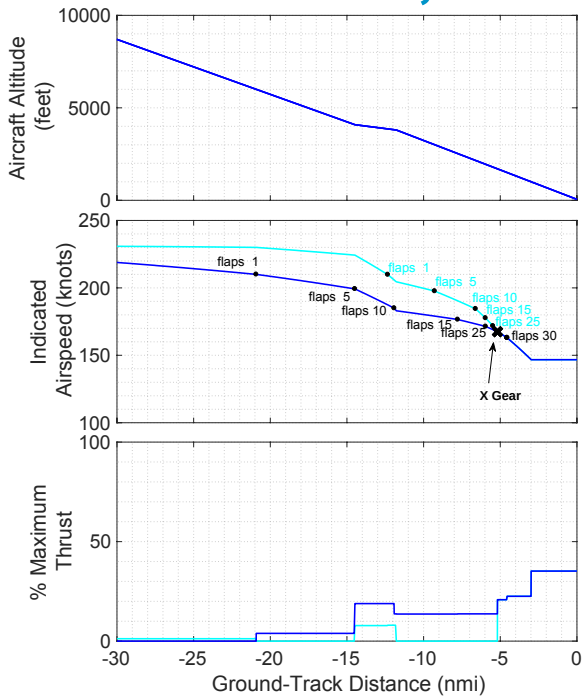


- Reduce noise by delaying extension of flaps
- Potential concerns from ATC and pilots regarding different deceleration rates and managing traffic
- Must decelerate early enough to assure stable approach criteria

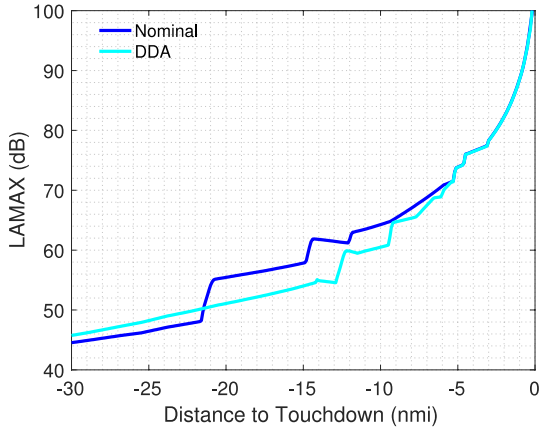
Example Noise Component Breakdown Under the Flight Track



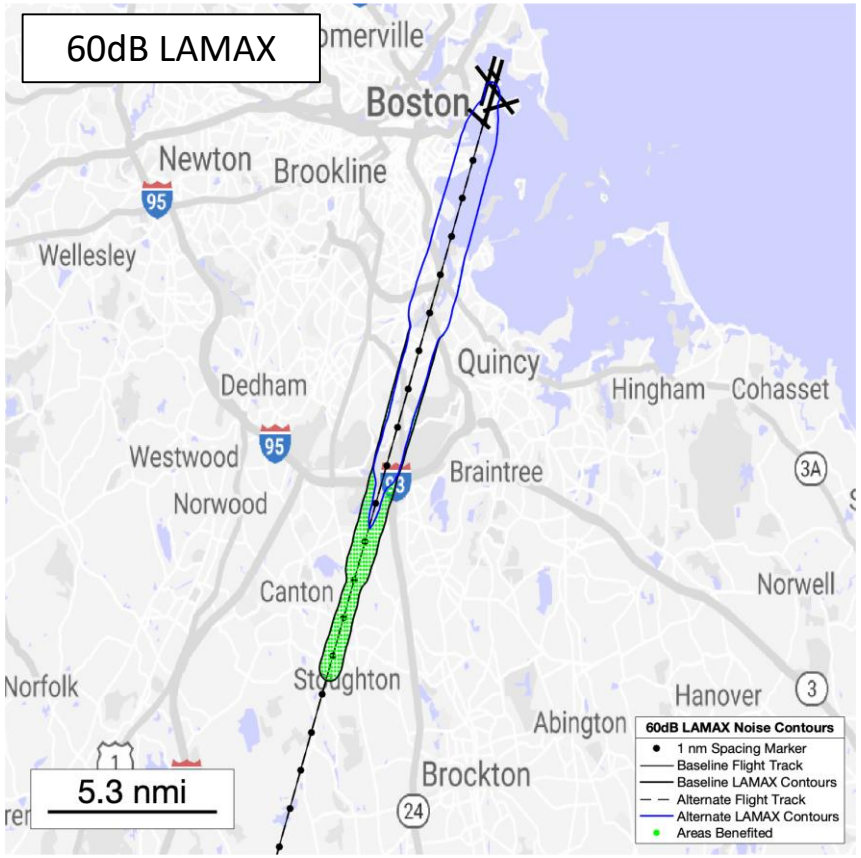
DDA vs Nominal Approach from South with 4000 ft Level Off, B737-800



Total Undertrack LAMAX (dB)



60 dB Contour Comparison

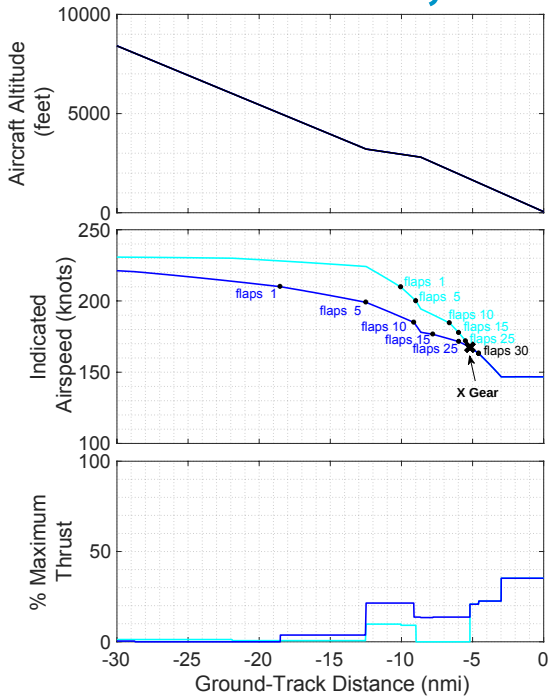


Population Exposure

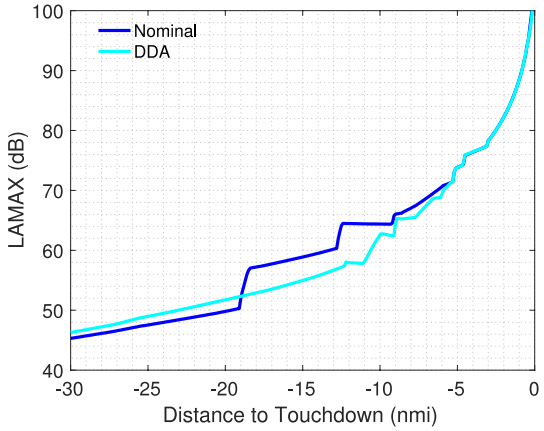
$L_{A,max}$	60 dB	65 dB	70 dB
Nominal	37,621	14,912	4,936
DDA	31,835	13,927	4,784
Difference	5,786	985	152

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

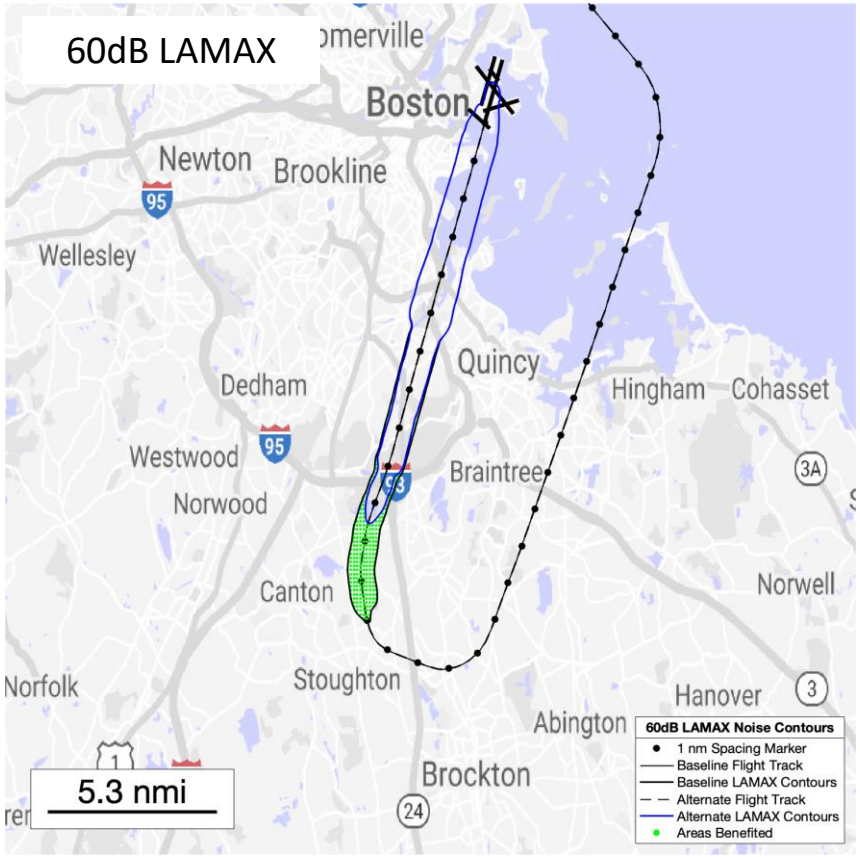
DDA vs Nominal Approach from North with 3000 ft Level Off, B737-800



Total Undertrack LAMAX (dB)



60 dB Contour Comparison



Population Exposure

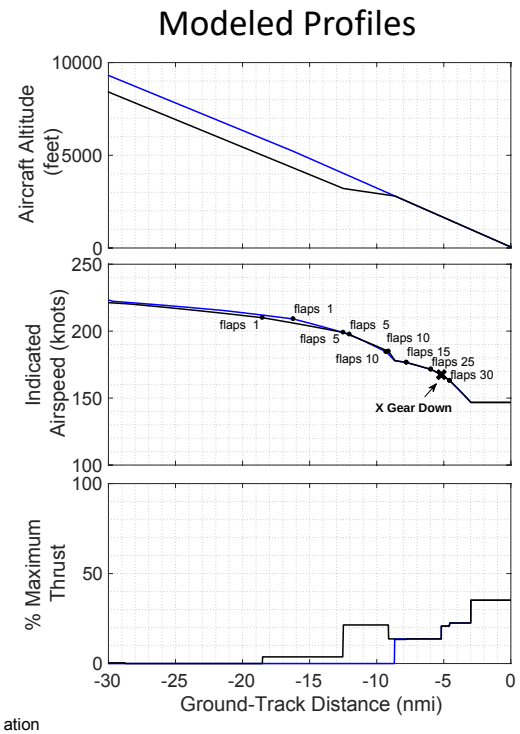
$L_{A,max}$	60 dB	65 dB	70 dB
Nominal	33,227	14,448	3,969
DDA	30.925	13,687	3,741
Difference	2,302	761	228

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

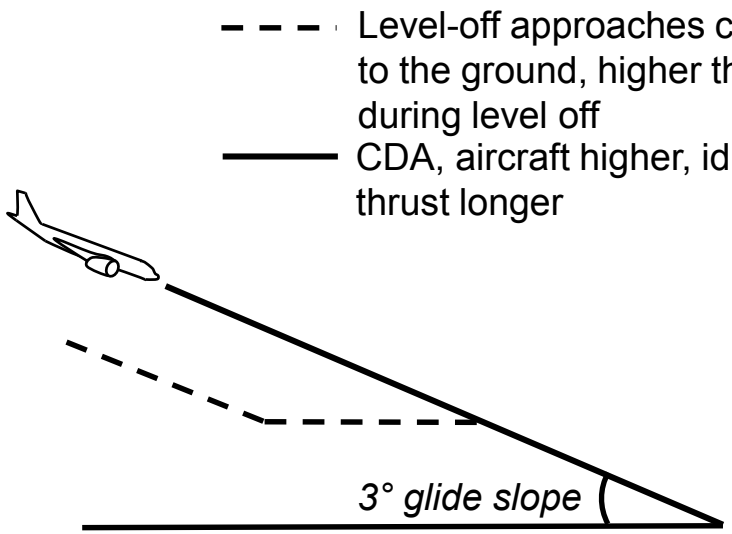
CONTINUOUS DESCENT APPROACHES

Continuous Descent Approaches

- Reduce noise by removing level-off segment
  - Reduces thrust
  - Aircraft at a higher altitude for more of the procedure
- Continuous descent approaches could be achieved through RNAV procedures or RNP procedures



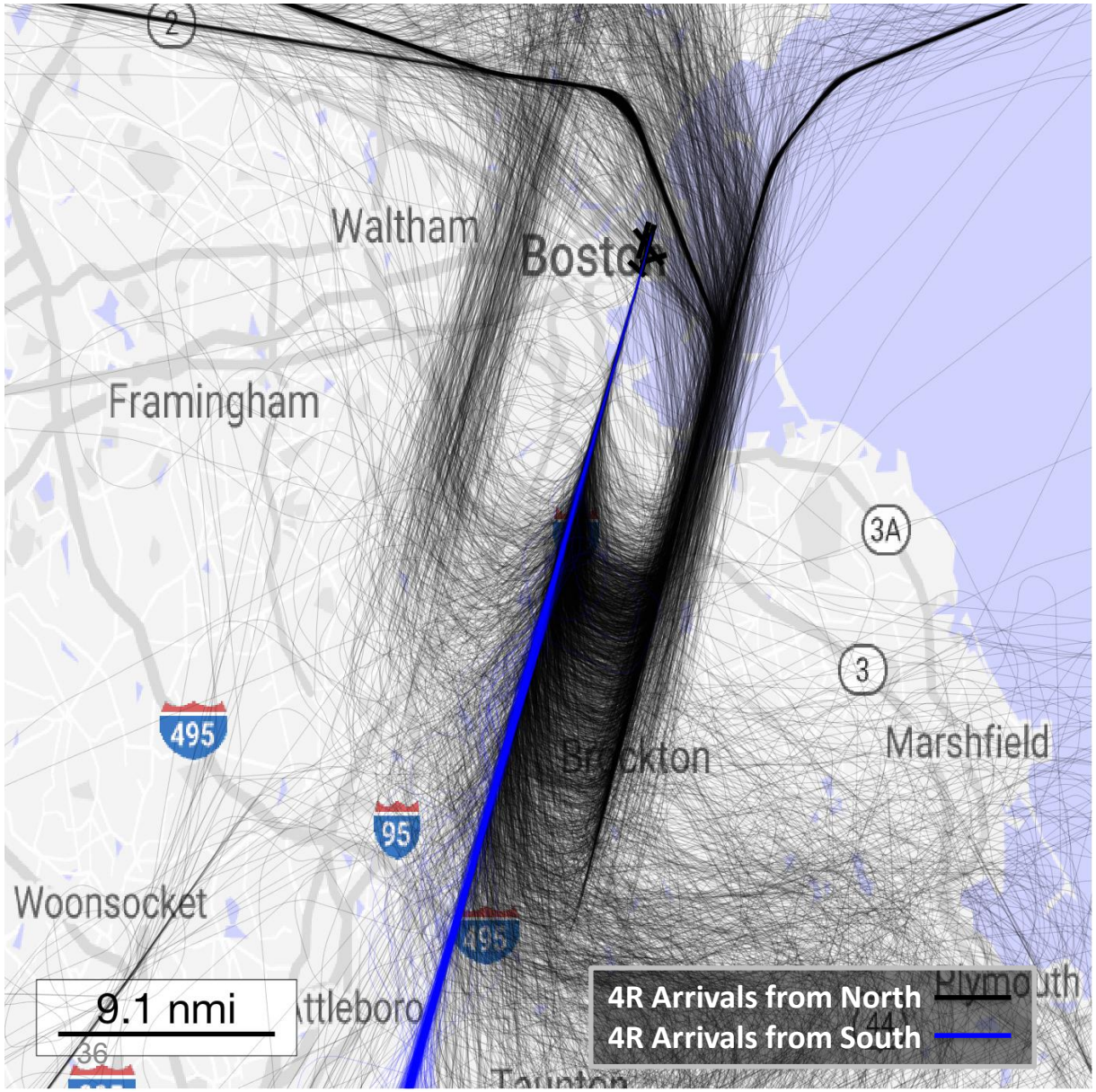
Continuous Descent Approaches (CDA)



- Difficult for vectored procedures where distance to go is ambiguous e.g. trombone downwind.
- Potential ATC workload for merging procedures

ation

Baseline: 2017 Arrivals to Runway 4R



Notes:

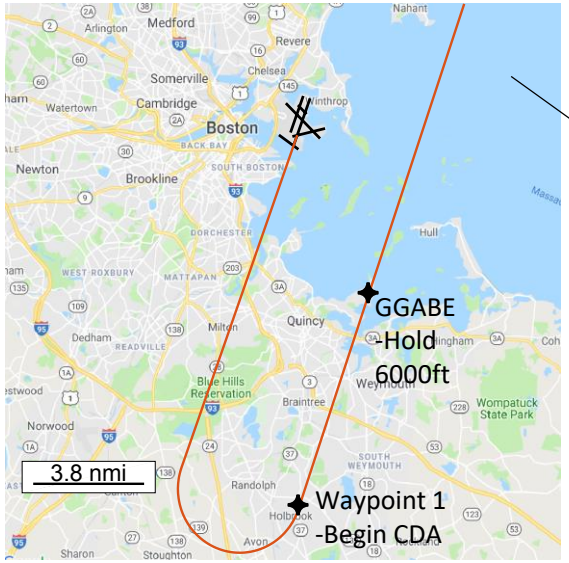
- 39,615 Arrivals to Rwy 4R in 2017 (jet & prop):
- Figure shows 10% of all 2017 arrivals selected at random
- Data Source: Flight Tracks, Massport Noise and Operations Management System (NOMS)

- **51%** of Rwy4R arrivals came from south on a 2017 peak day

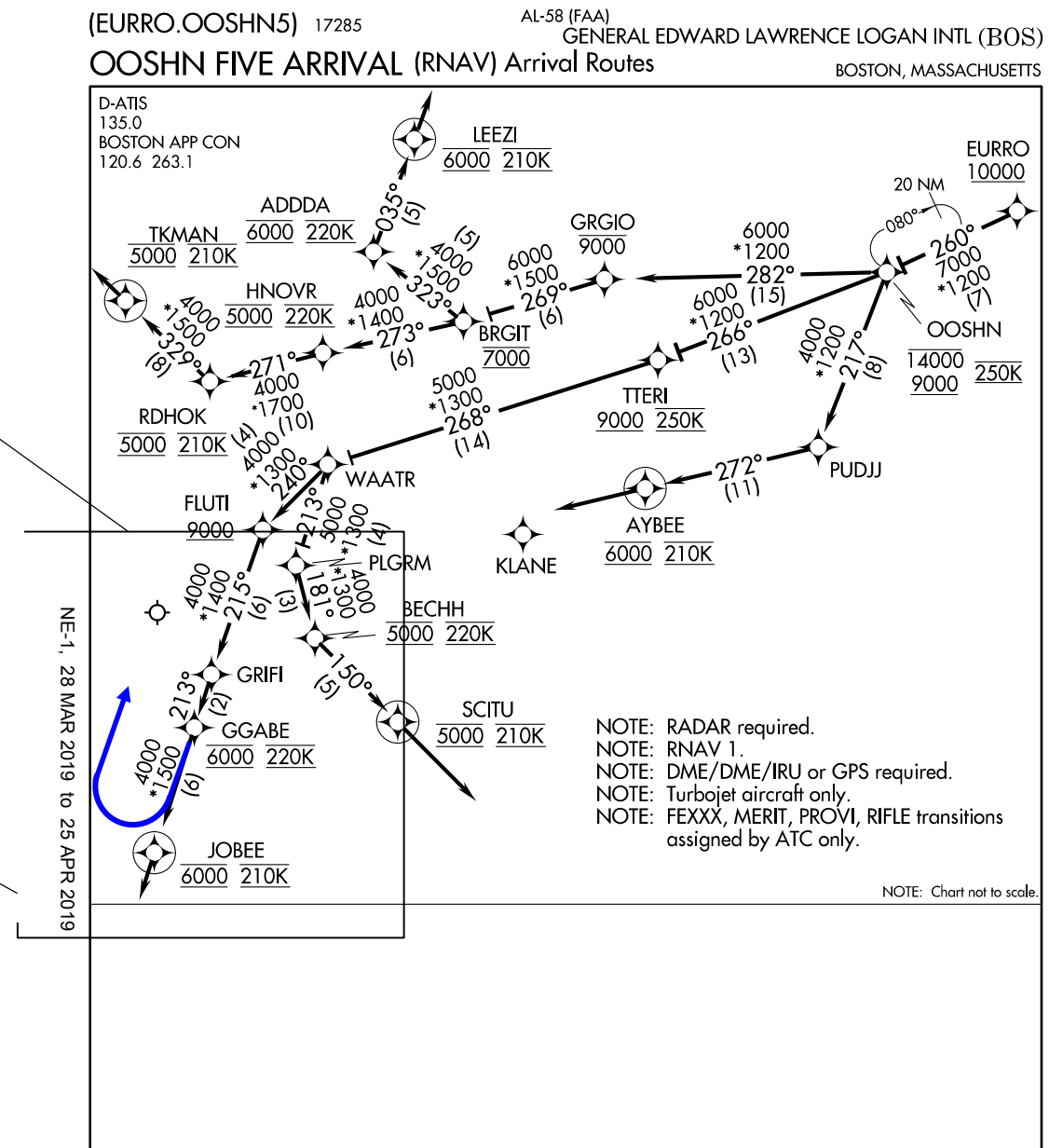
Altitude Profiles	Arrivals from South	Arrivals from North
% Continuous Descent Profiles	38	6
% Non-Continuous Descent (level-off) Profiles	62	94
Median level-off altitude (Non-Continuous Descent Profiles)	4,000 ft	3,000 ft

Continuous Descent Approaches (CDAs)

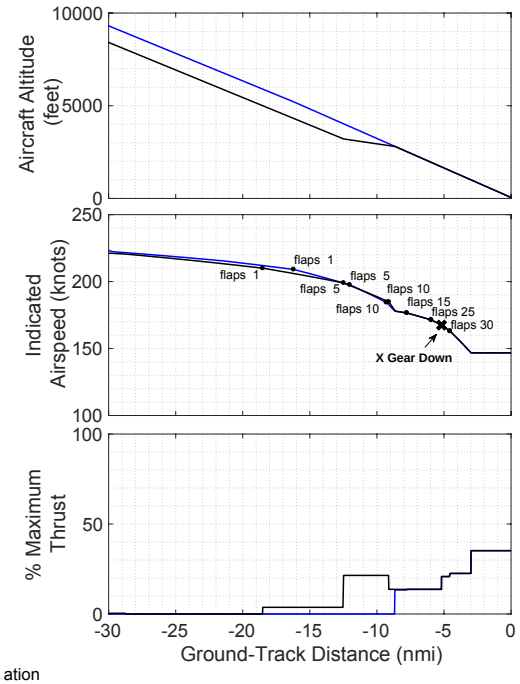
- 4R RNAV CDA from the north



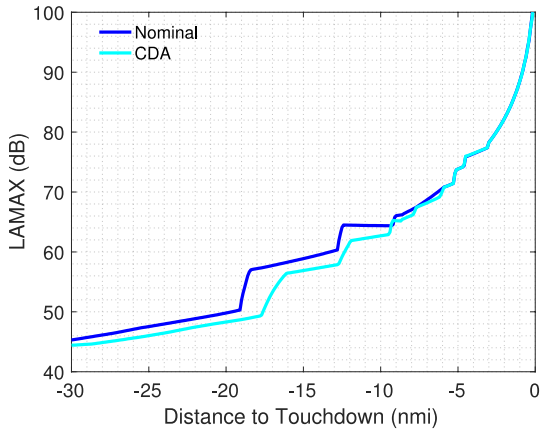
workload to merge traffic

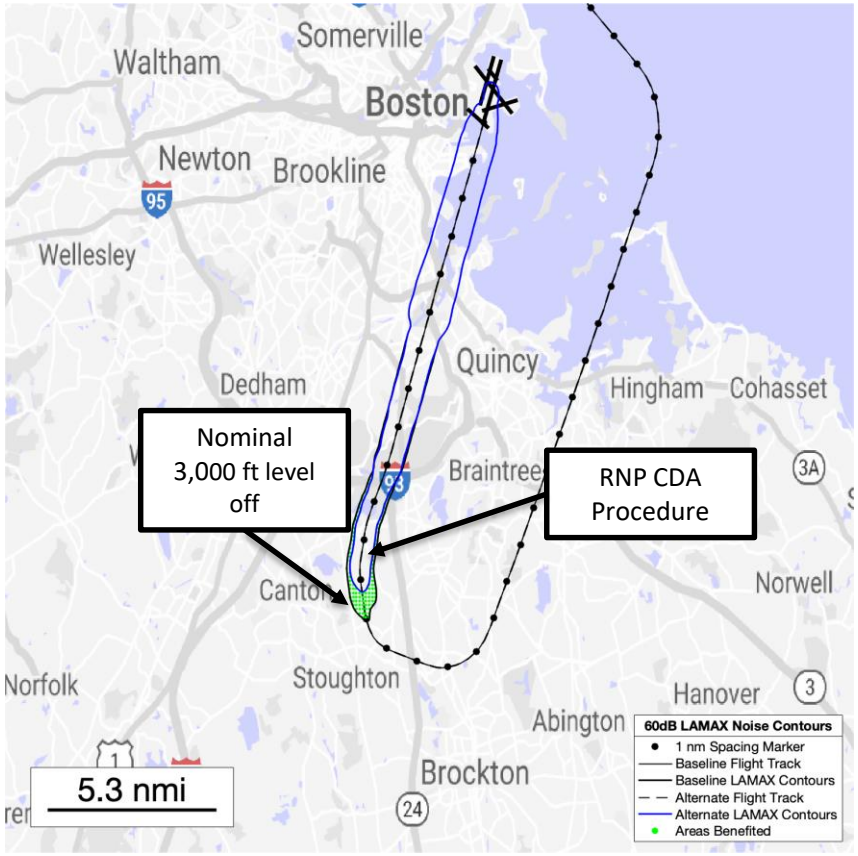


Continuous Descent Approaches (CDAs) from the North



ation



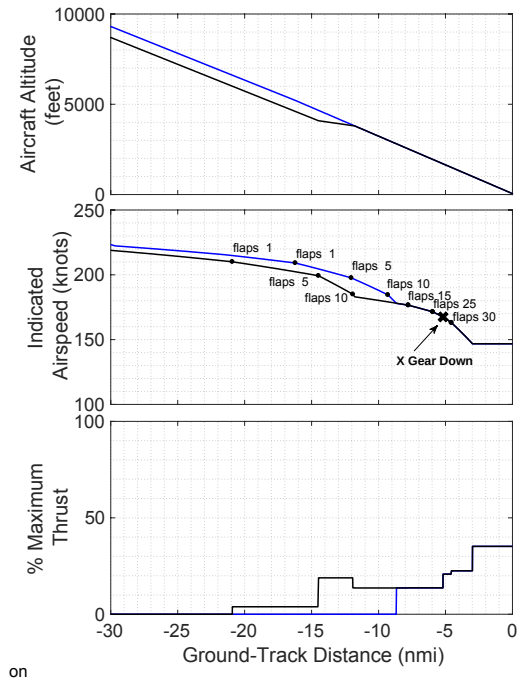


Population Exposure

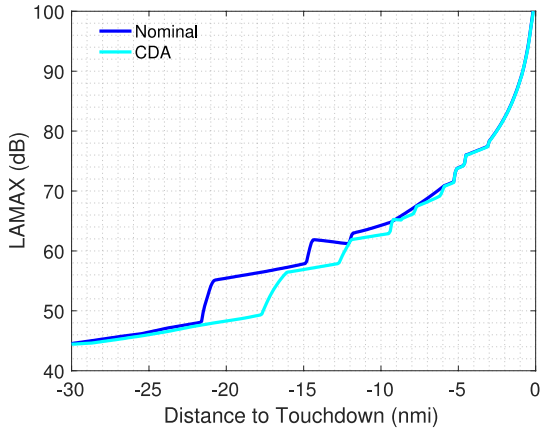
$L_{A,max}$	60 dB	65 dB	70 dB
Nominal	33,227	14,448	3,969
DDA	32,231	14,233	3,912
Difference	996	215	57

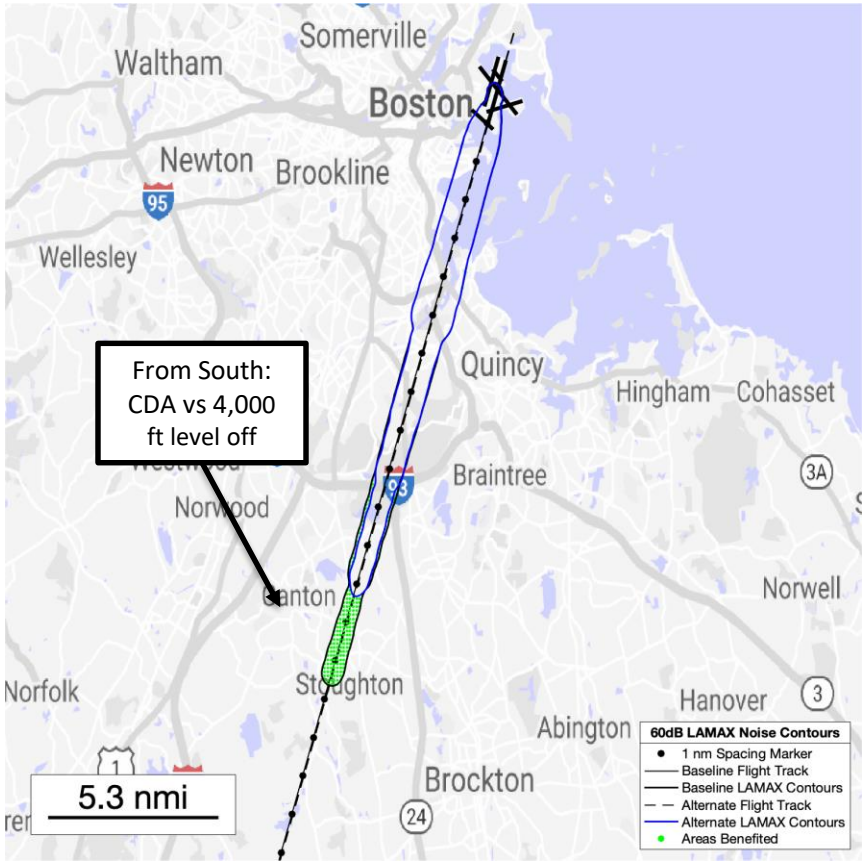
Preliminary example to evaluate methodology only. Should not be considered representative case.

Continuous Descent Approaches (CDAs) from the South



on
n





Population Exposure

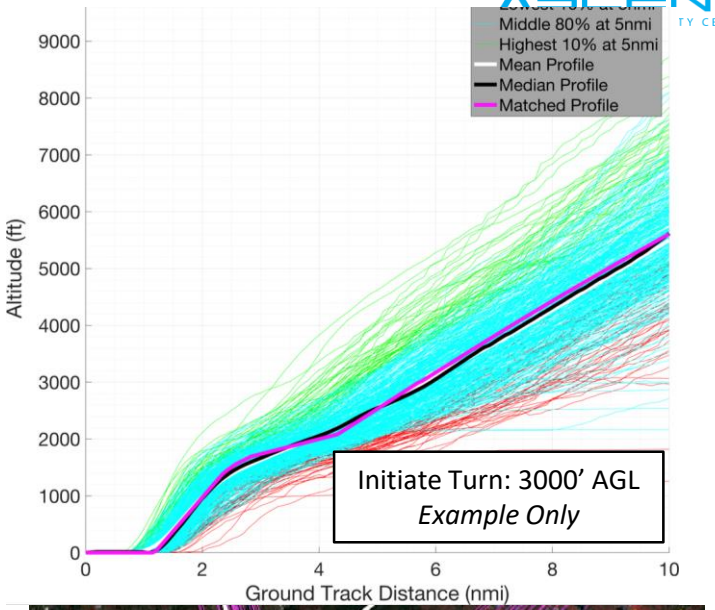
$L_{A,max}$	60 dB	65 dB	70 dB
Nominal	37,621	14,912	4,936
CDA	34,099	14,628	4,936
Difference	3,522	284	0

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

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

Dispersion Concepts

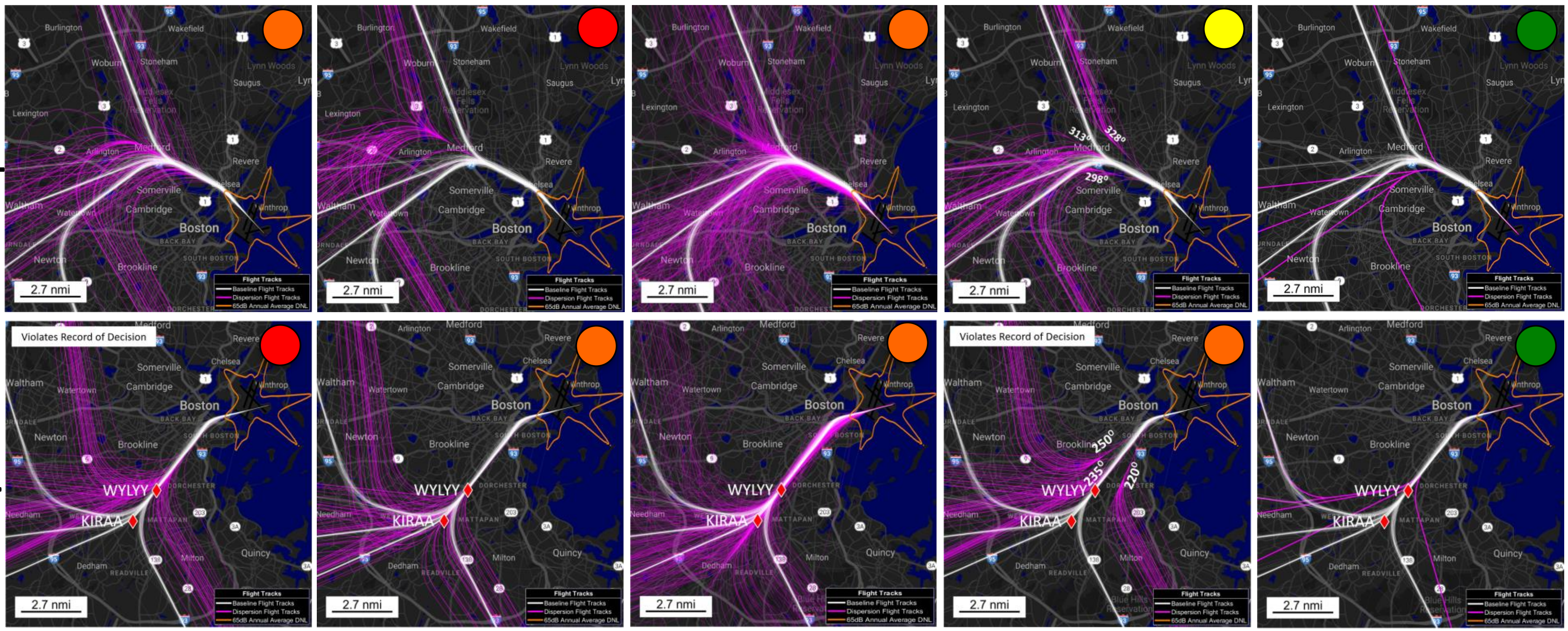
- Altitude-based dispersion
  - Direct routing to transition waypoint upon reaching specific altitude
- Controller-based dispersion
  - Dispersion arising from radar vectoring
  - 2010 flight track data normalized for comparison with 2017 data
  - Comparison between pre-RNAV and RNAV flight tracks
- Divergent heading dispersion
  - 15º 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

33L Departures

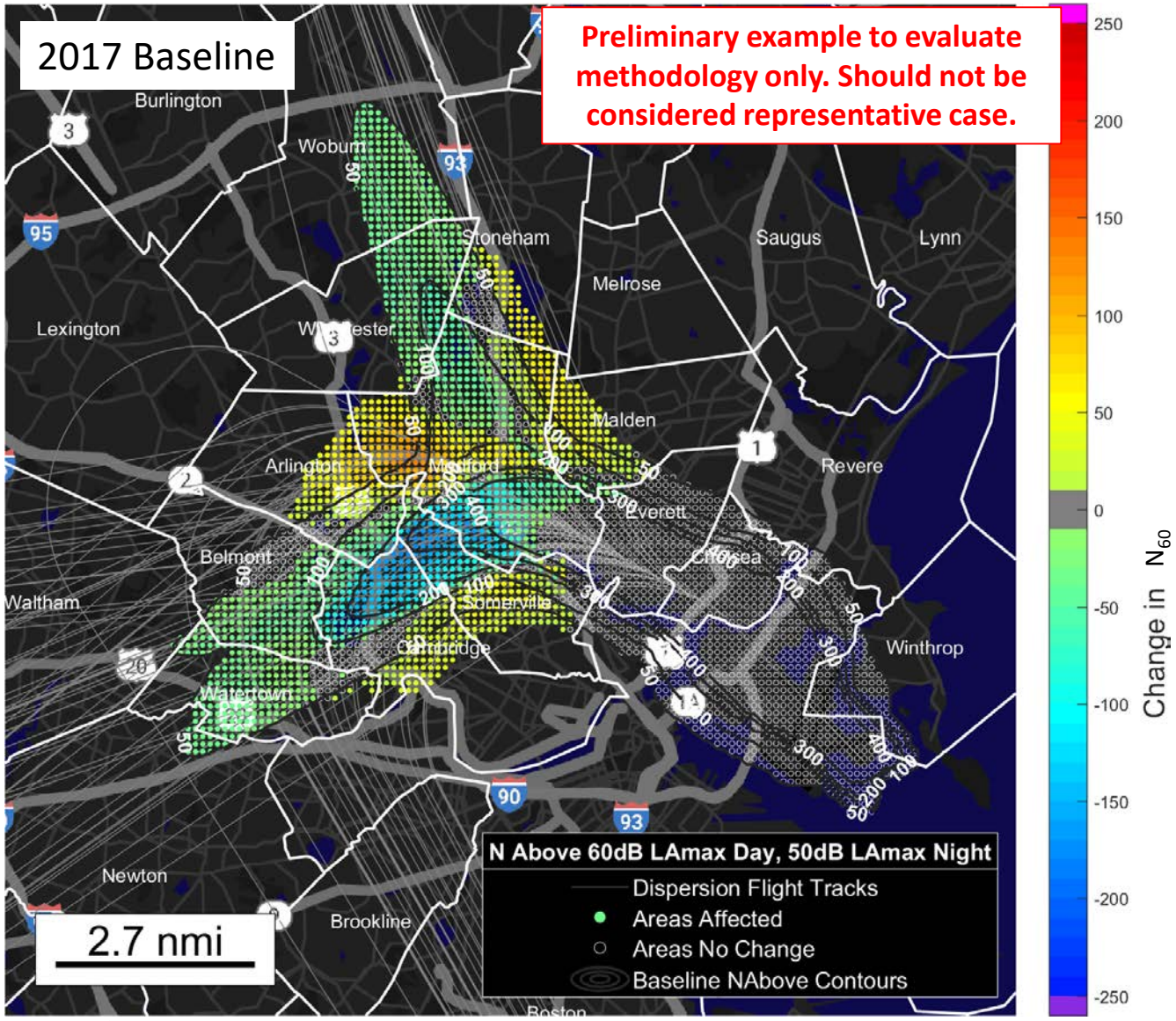
27 Departures



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.

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



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	342,387
Baseline - Dispersion	-5,744

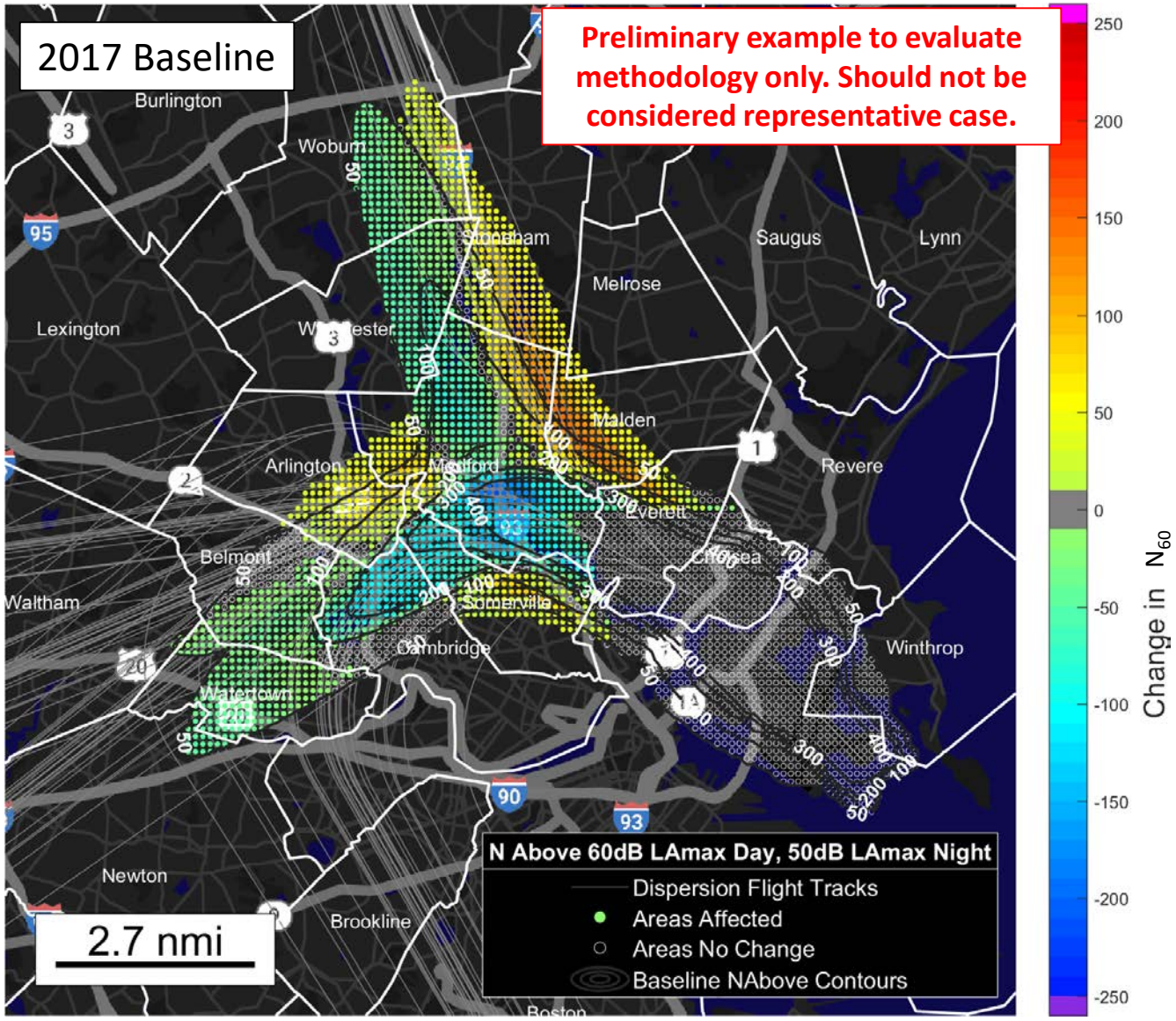
Analysis updated Dec 4 2018 to correct for discretization differences

- 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	336,643
Dispersion	334,305
Baseline - Dispersion	2,338

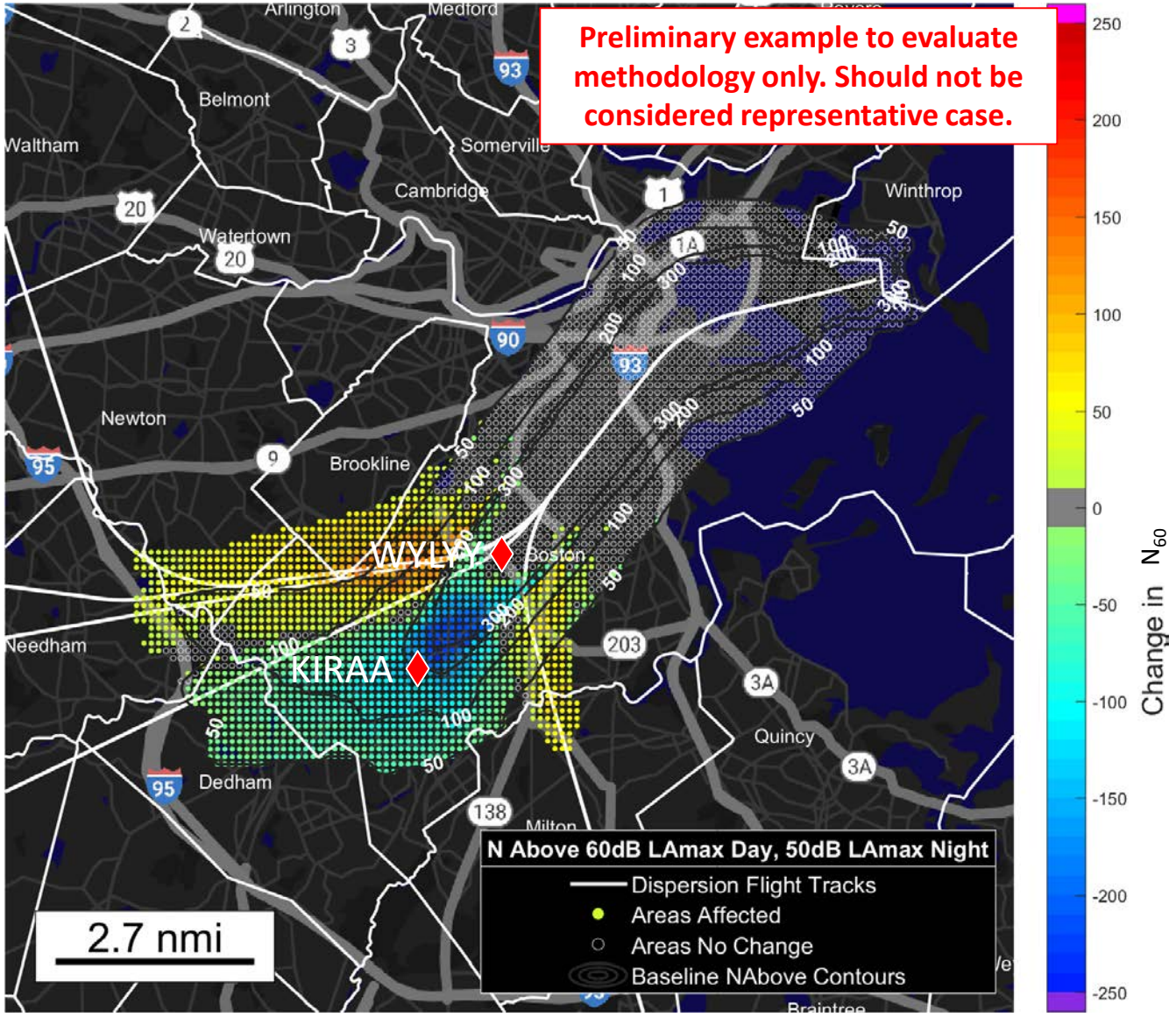
Analysis updated Dec 4 2018 to correct for discretization differences

- 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

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

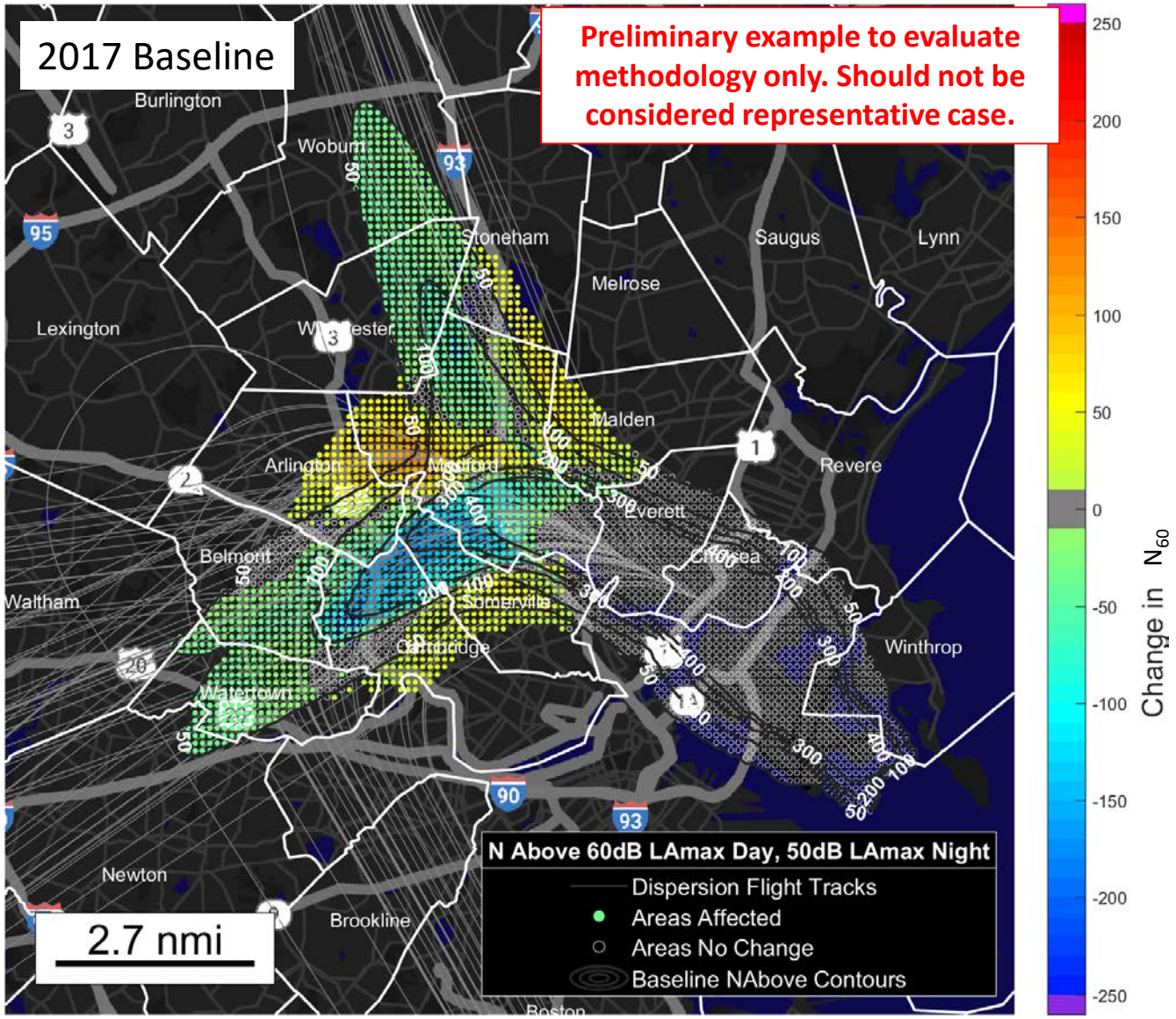
Analysis based on peak day operations; only includes 27 departures

DISCUSSION

BACKUP

33L DEPARTURES DISPERSION ANALYSIS

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



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	342,387
Baseline - Dispersion	-5,744

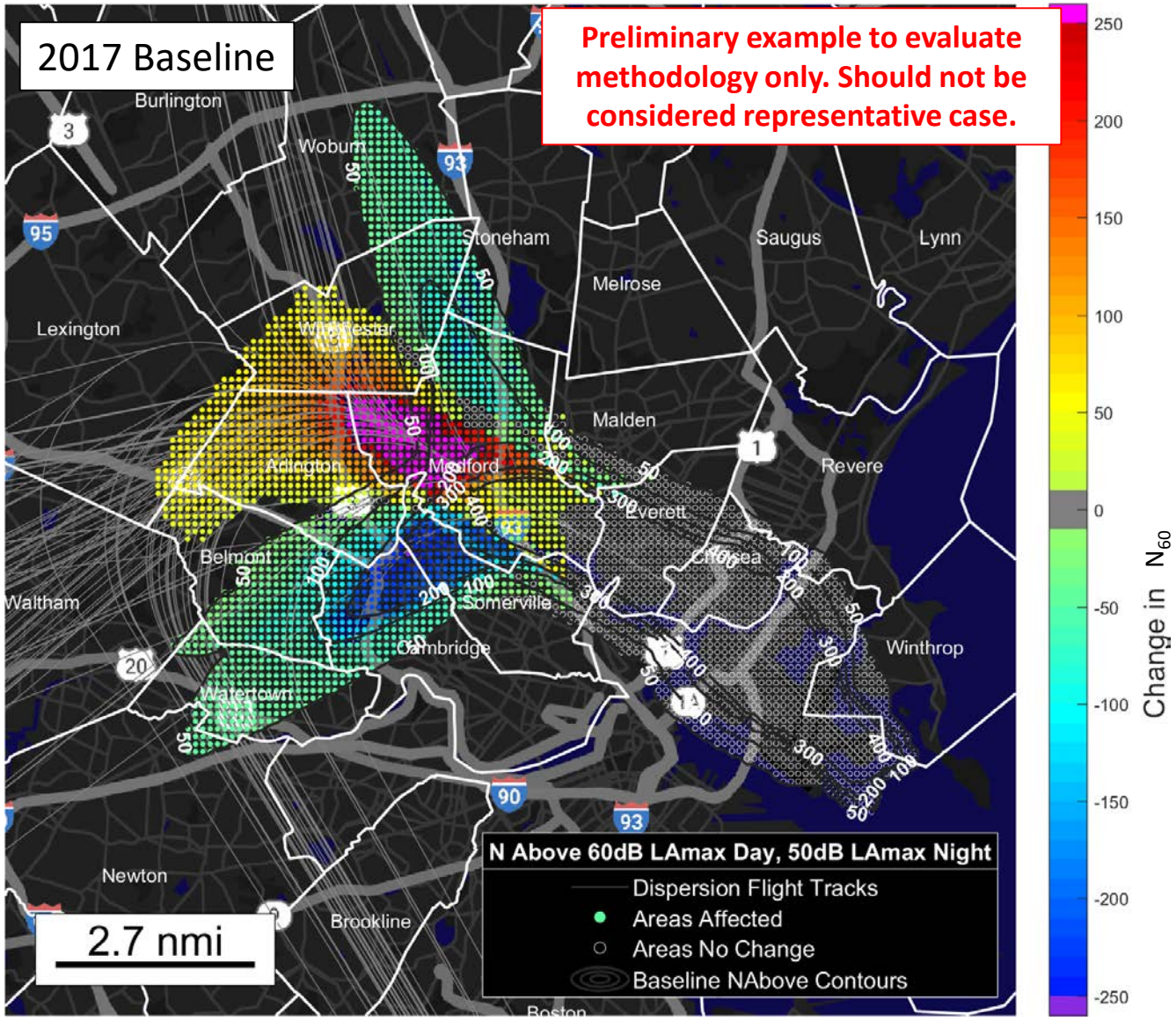
Analysis updated Dec 4 2018 to correct for discretization differences

- 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 Altitude-Based Dispersion at 4000ft Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	273,878
Baseline - Dispersion	62,765

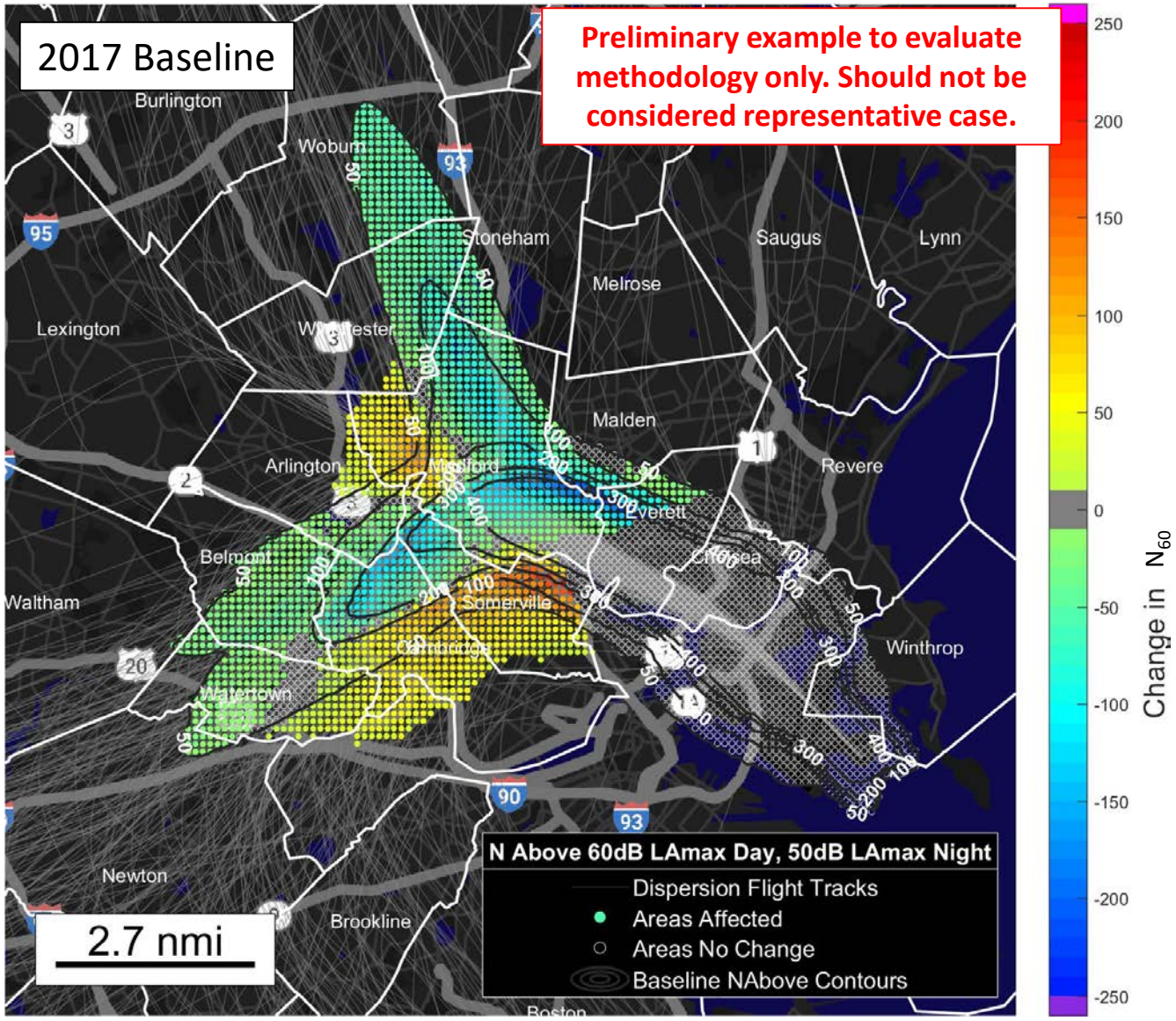
Analysis updated Dec 4 2018 to correct for discretization differences

- Controller concerns about variability in flight path length Conflicts with airspace at Hanscom Airport

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 Controller-Based Dispersion Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	349,359
Baseline - Dispersion	-12,716

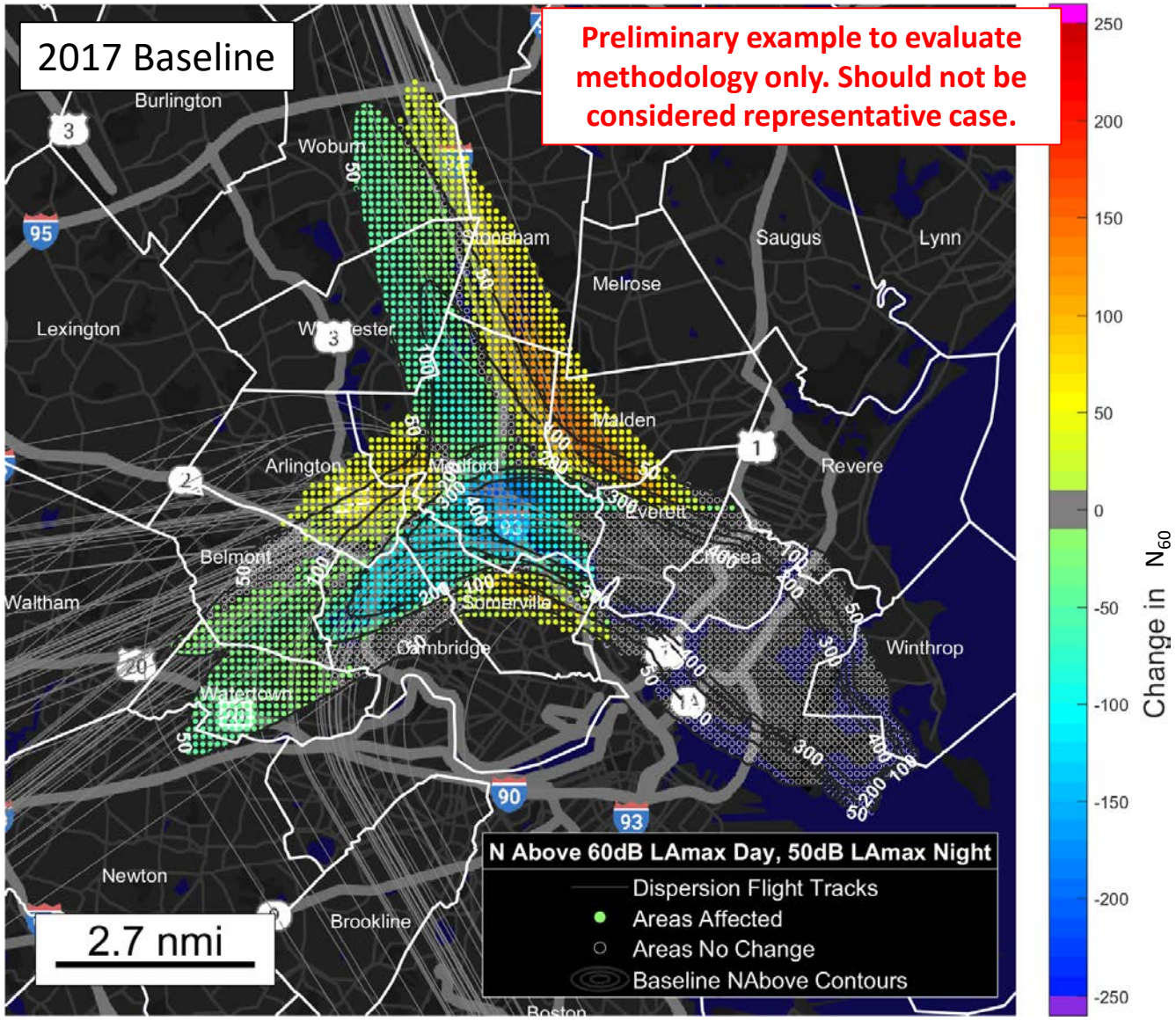
Analysis updated Dec 4 2018 to correct for discretization differences

- 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	336,643
Dispersion	334,305
Baseline - Dispersion	2,338

Analysis updated Dec 4 2018 to correct for discretization differences

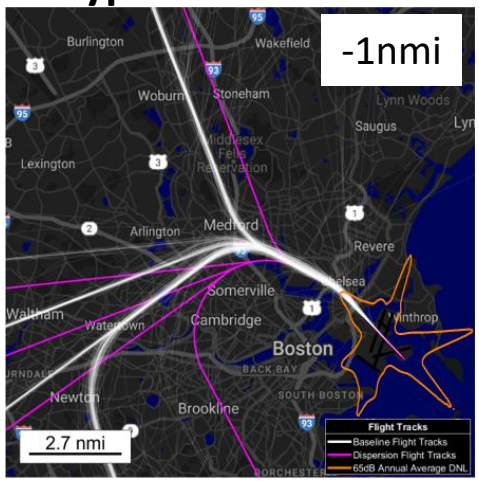
- Divergent headings help to maintain aircraft separation criteria

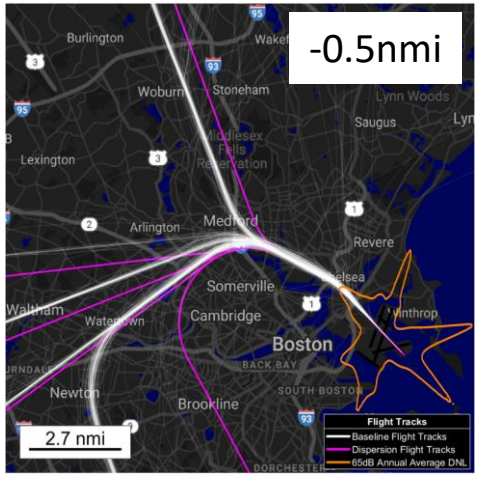
N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

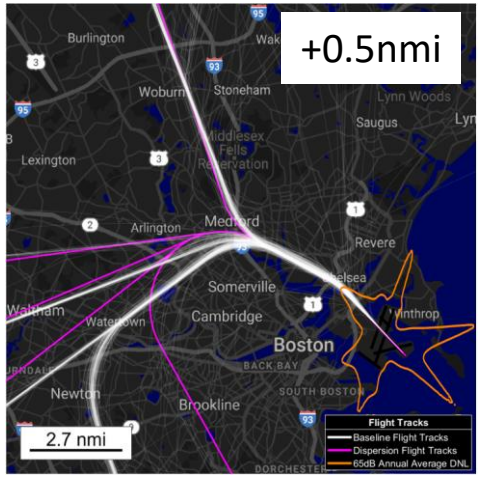
Analysis based on peak day operations; only includes 33L departures

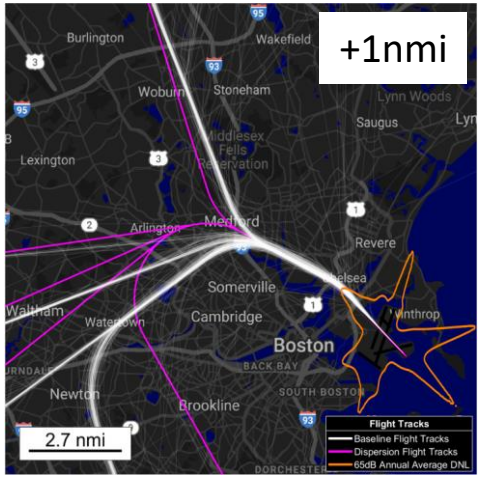
33L Departures RNAV Waypoint Relocation

Waypoint moved:



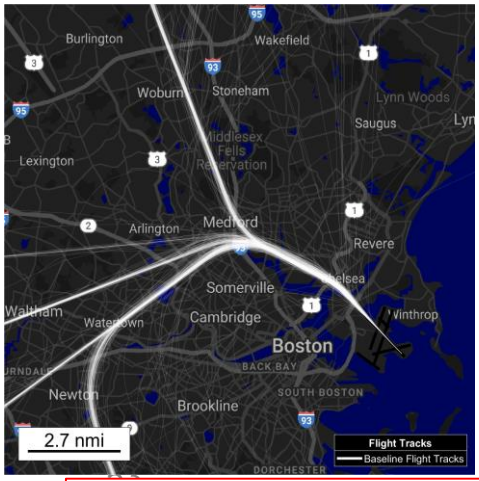






50 N_{60} Population Exposure Change (Baseline – Alternate):

-1nmi	-0.5nmi	+0.5nmi	+1nmi
-43,835	-1,576	36,006	42,659

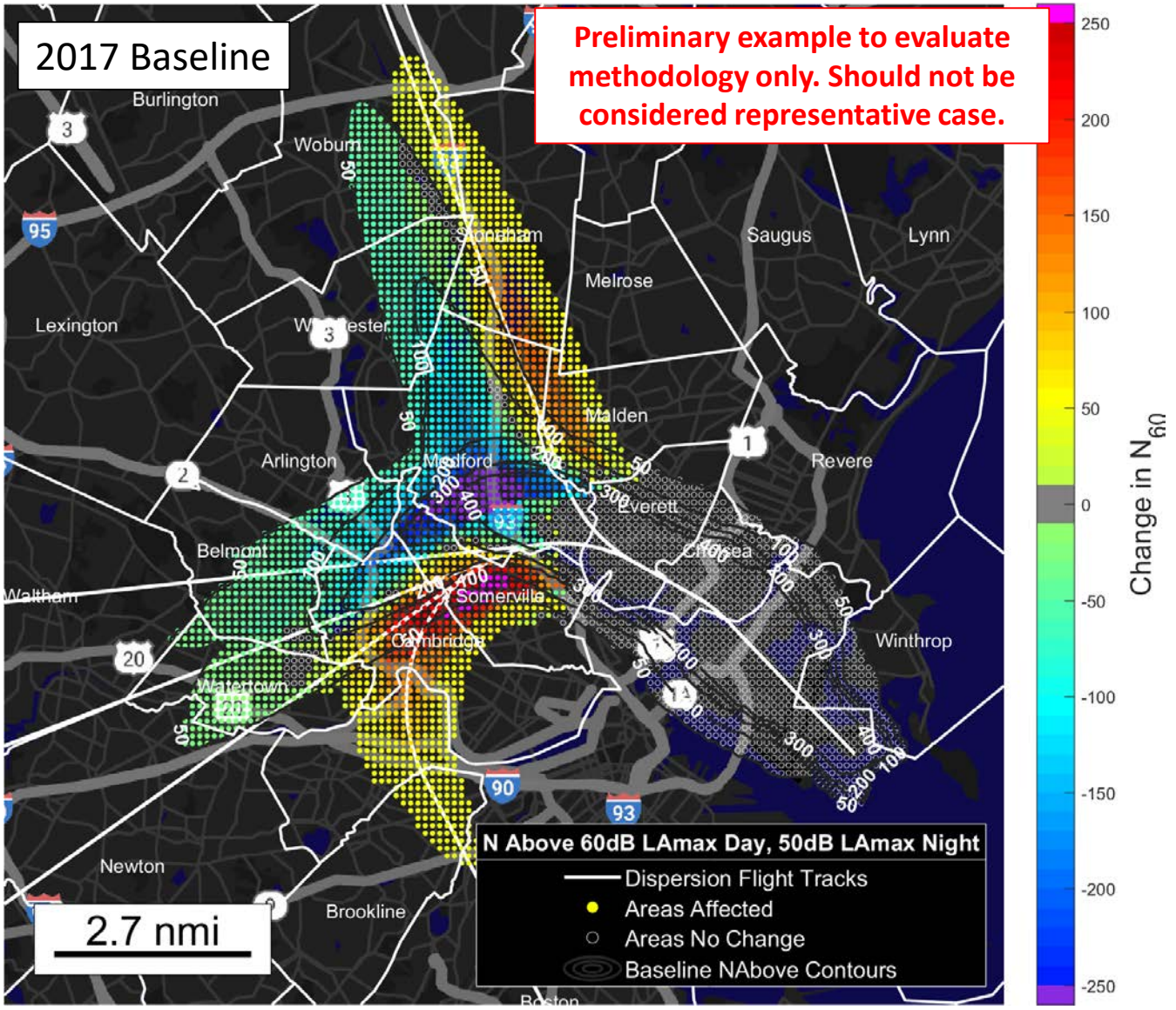


RNAV N_{60} Population Exposure:
336,643

Modification to existing RNAV procedure

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

33L Departures RNAV Waypoint Relocation -1nmi
Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	380,478
Baseline - Dispersion	-43,835

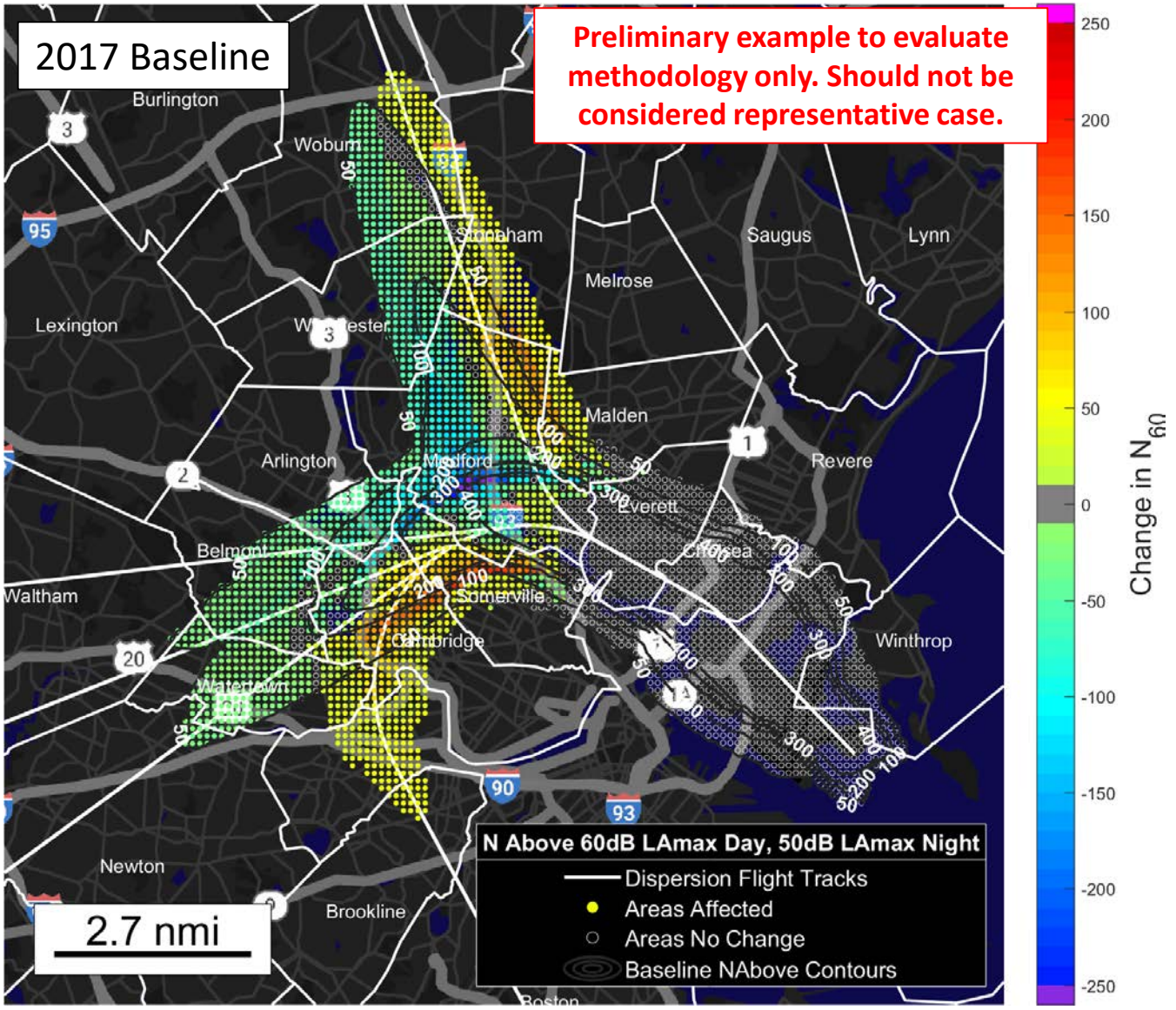
Analysis updated Dec 4 2018 to correct for discretization differences

- 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 33L departures

33L Departures RNAV Waypoint Relocation -0.5nmi Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	338,219
Baseline - Dispersion	-1,576

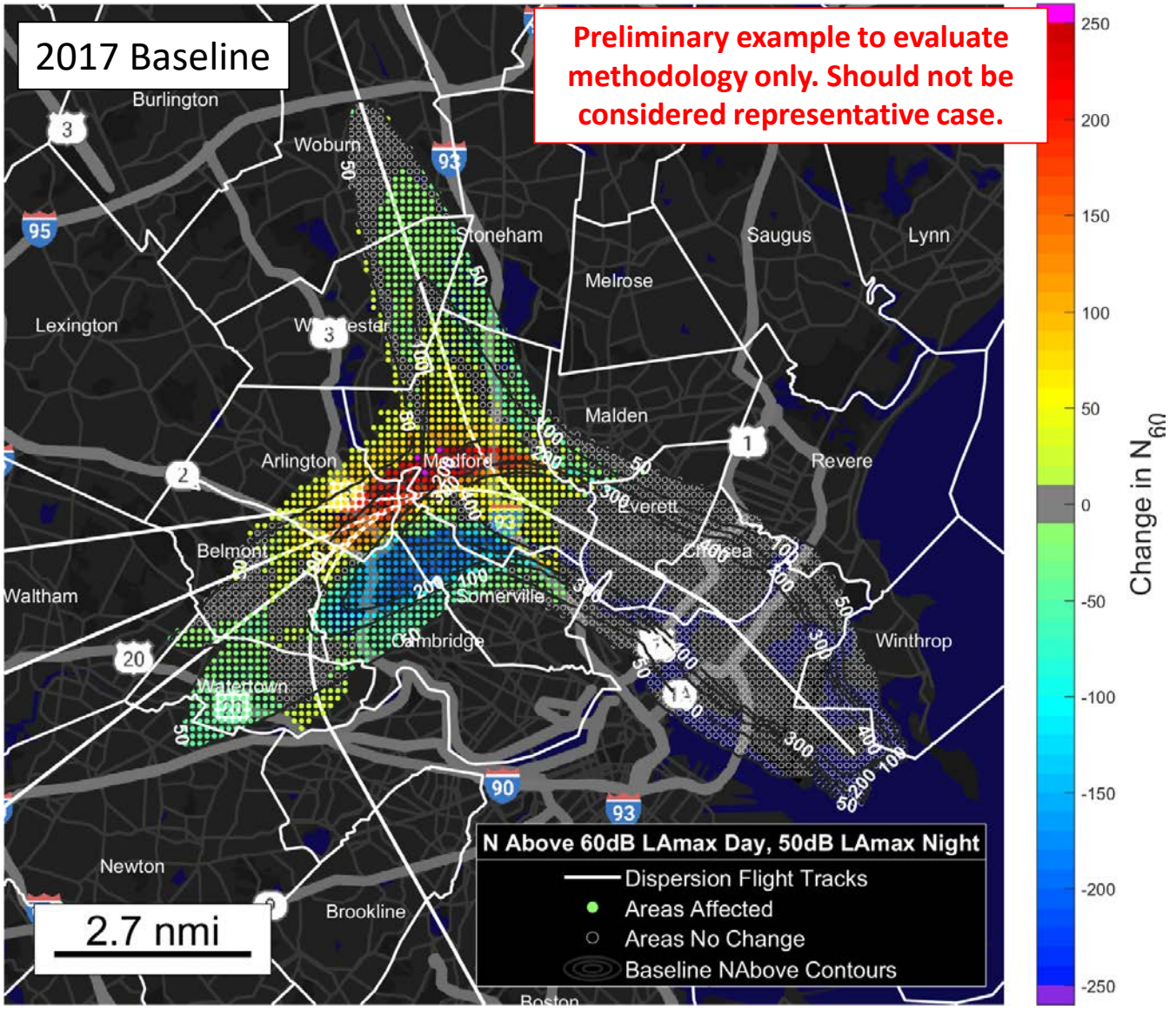
Analysis updated Dec 4 2018 to correct for discretization differences

- 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 33L departures

33L Departures RNAV Waypoint Relocation +0.5nmi Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	300,637
Baseline - Dispersion	36,006

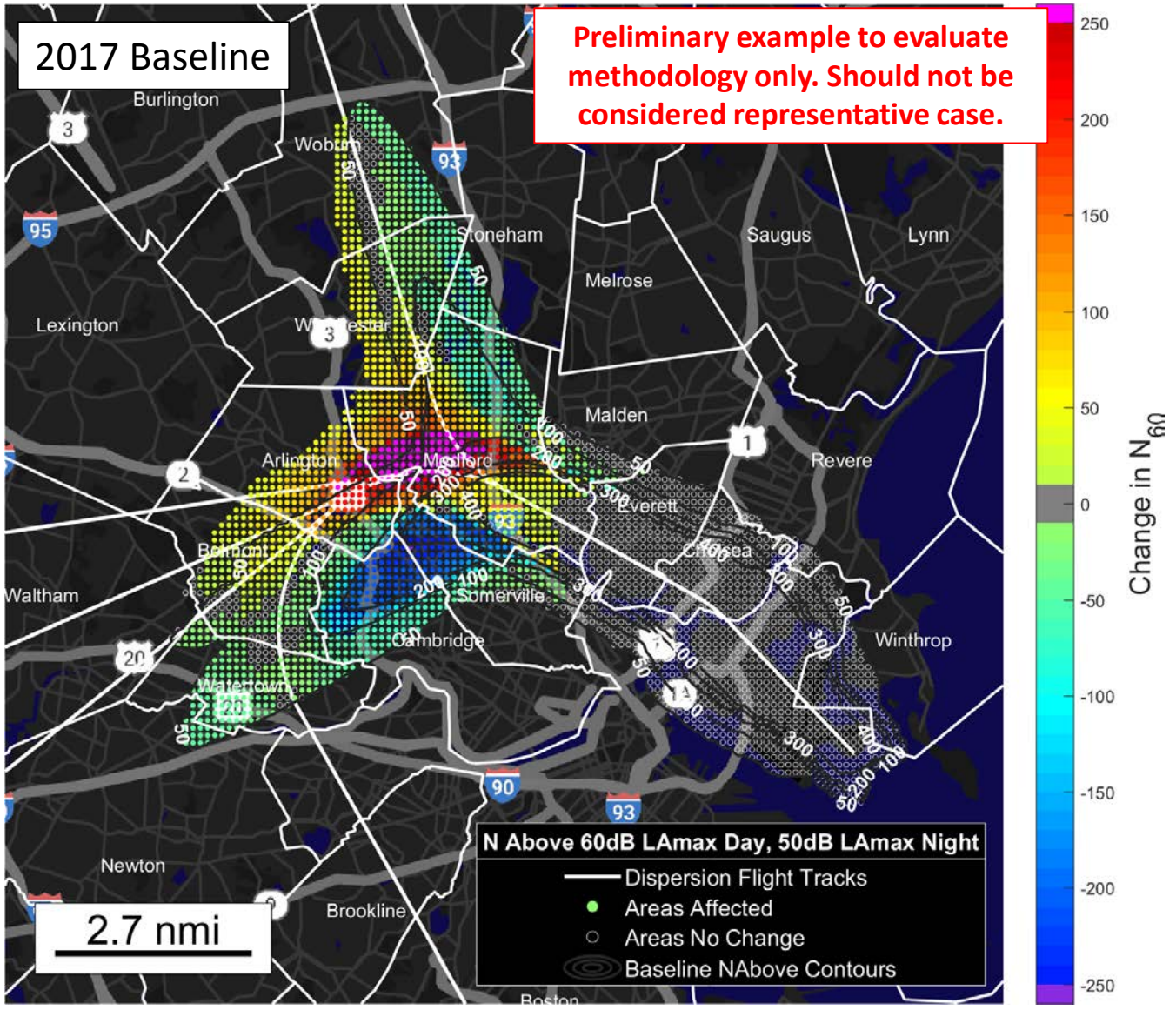
Analysis updated Dec 4 2018 to correct for discretization differences

- 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 33L departures

33L Departures RNAV Waypoint Relocation +1nmi Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	336,643
Dispersion	293,984
Baseline - Dispersion	42,659

Analysis updated Dec 4 2018 to correct for discretization differences

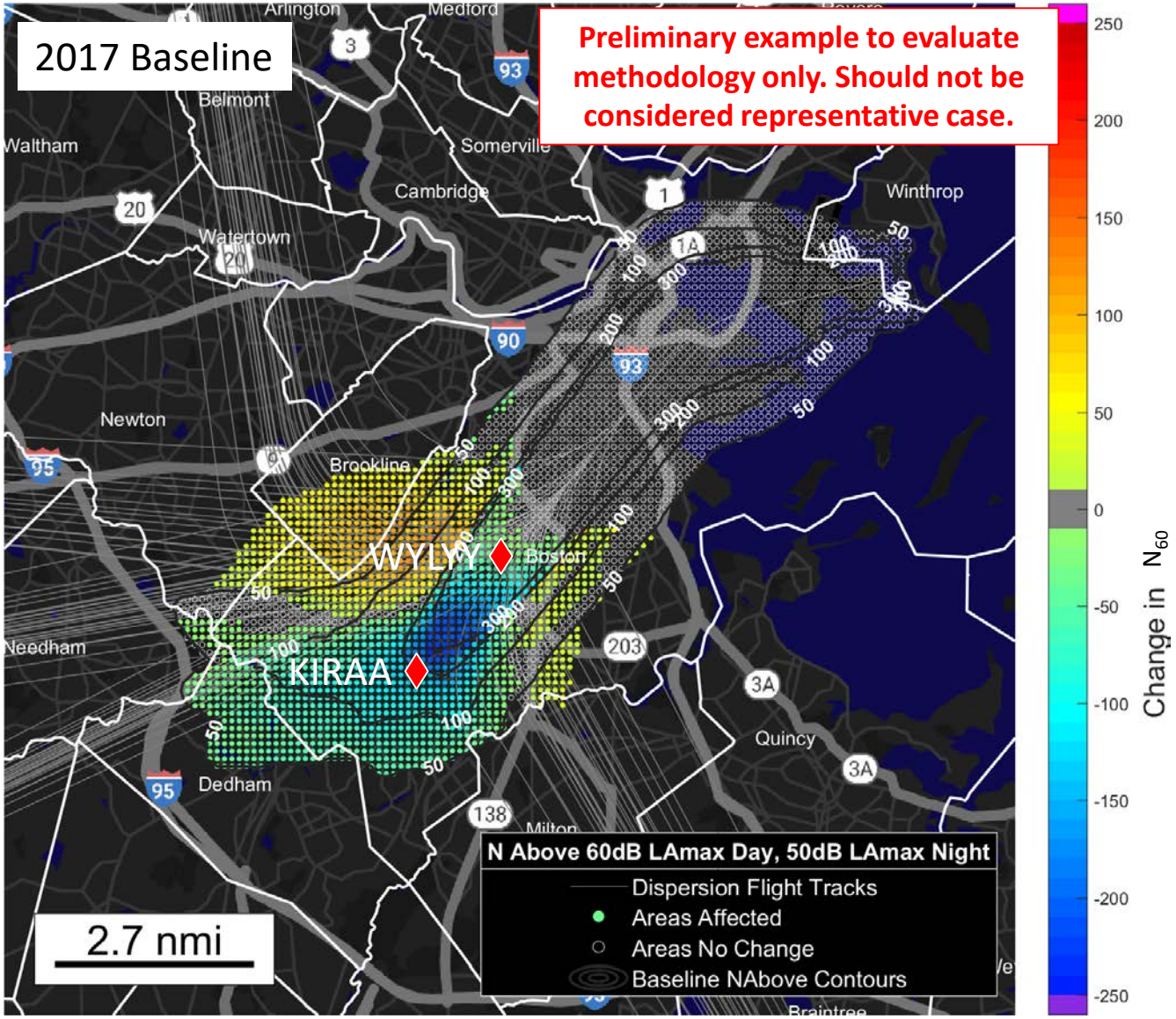
- Modification to existing RNAV procedure

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

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

27 DEPARTURES DISPERSION ANALYSIS

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



Population Exposure

N_{60}	50x
Baseline 2017	407,357
Dispersion	384,114
Baseline - Dispersion	23,243

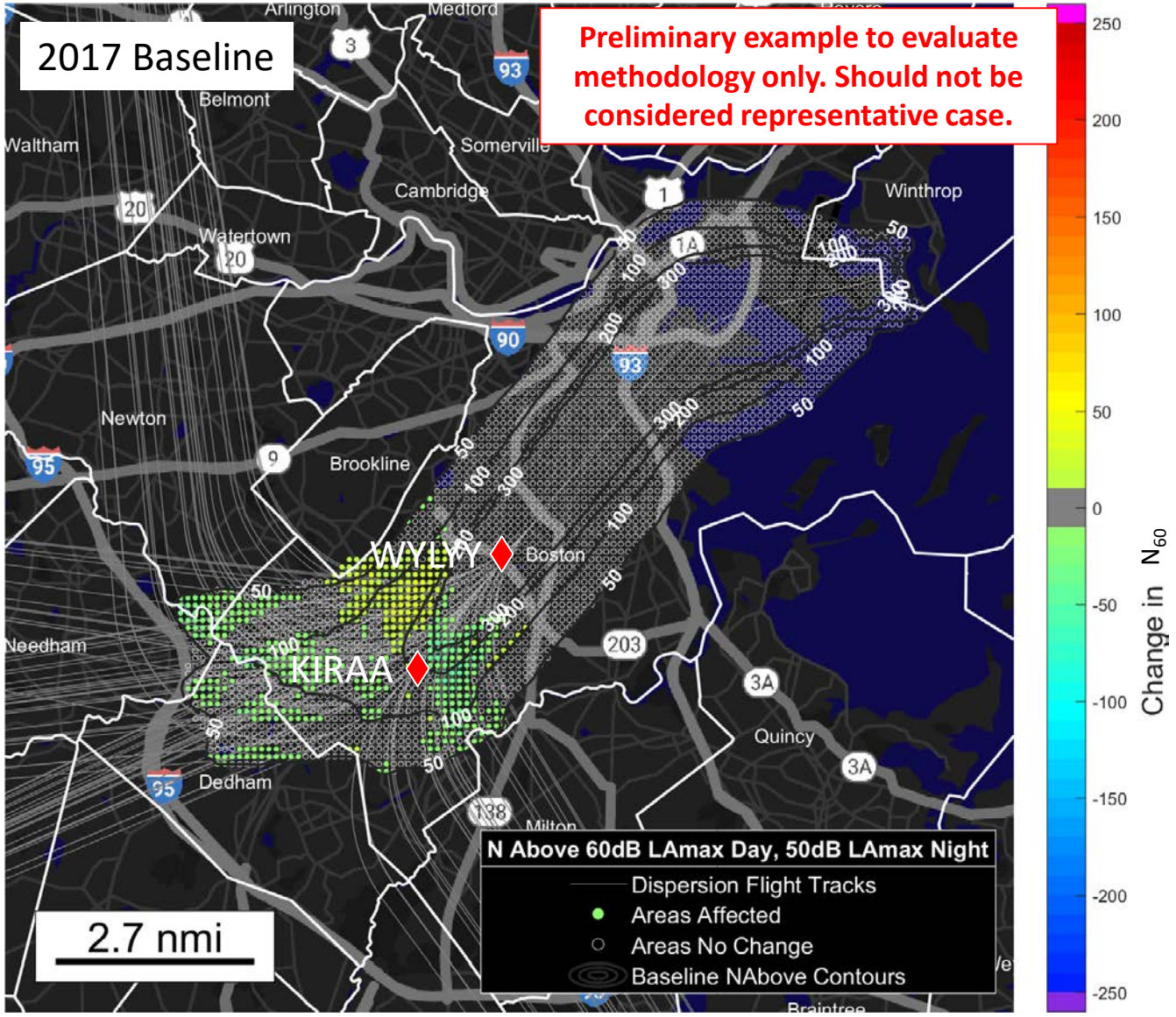
Analysis updated Dec 4 2018 to correct for discretization differences

- Controller concerns about variability in flight path length Violates Record of Decision

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

Analysis based on peak day operations; only includes 27 departures

27 Departures Altitude-Based Dispersion at 4000ft Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	407,357
Dispersion	405,385
Baseline - Dispersion	1,972

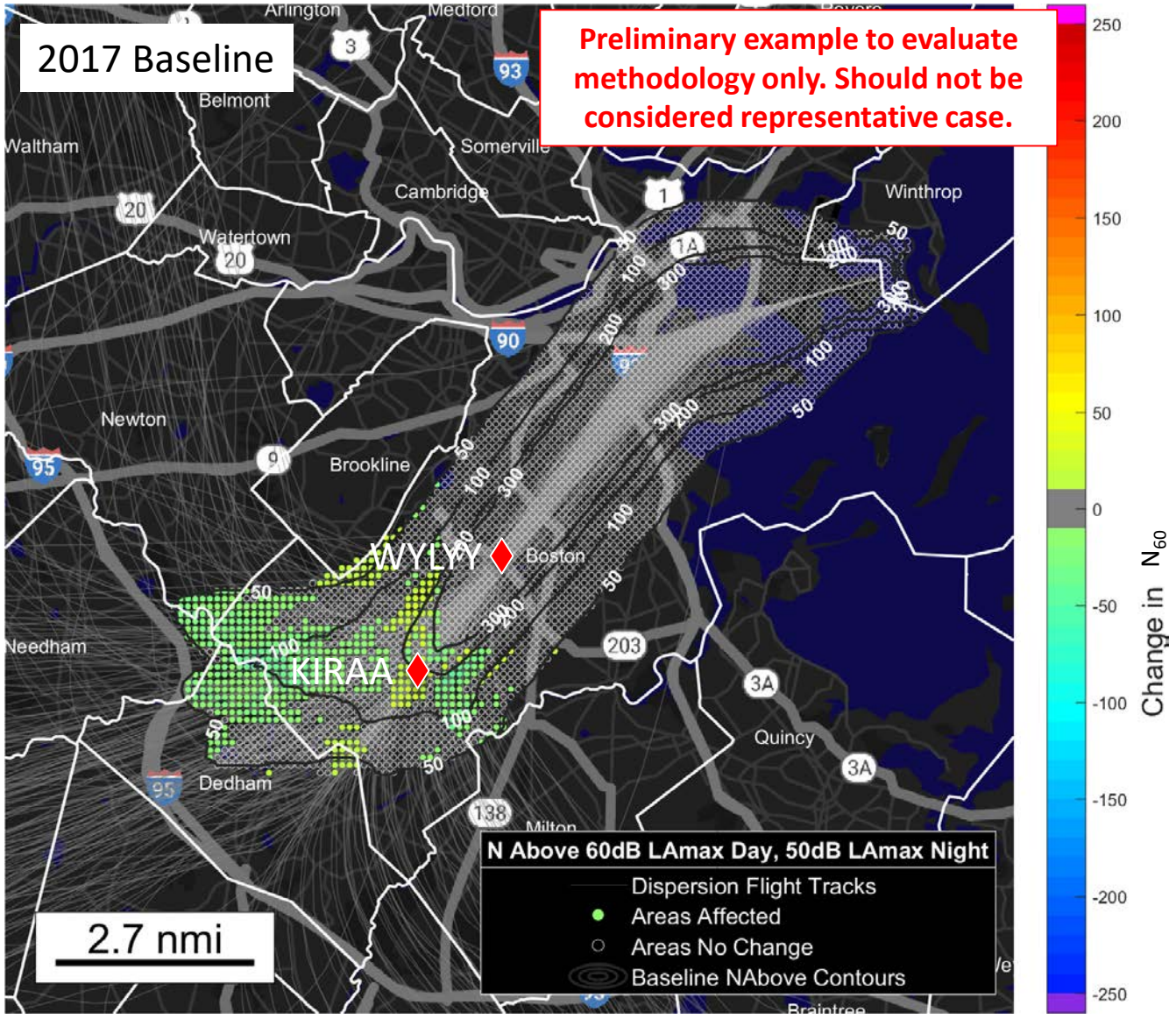
Analysis updated Dec 4 2018 to correct for discretization differences

- 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 27 departures

27 Departures Controller-Based Dispersion Change in N_{60} Compared to 2017



Population Exposure

N_{60}	50x
Baseline 2017	407,357
Dispersion	407,001
Baseline - Dispersion	356

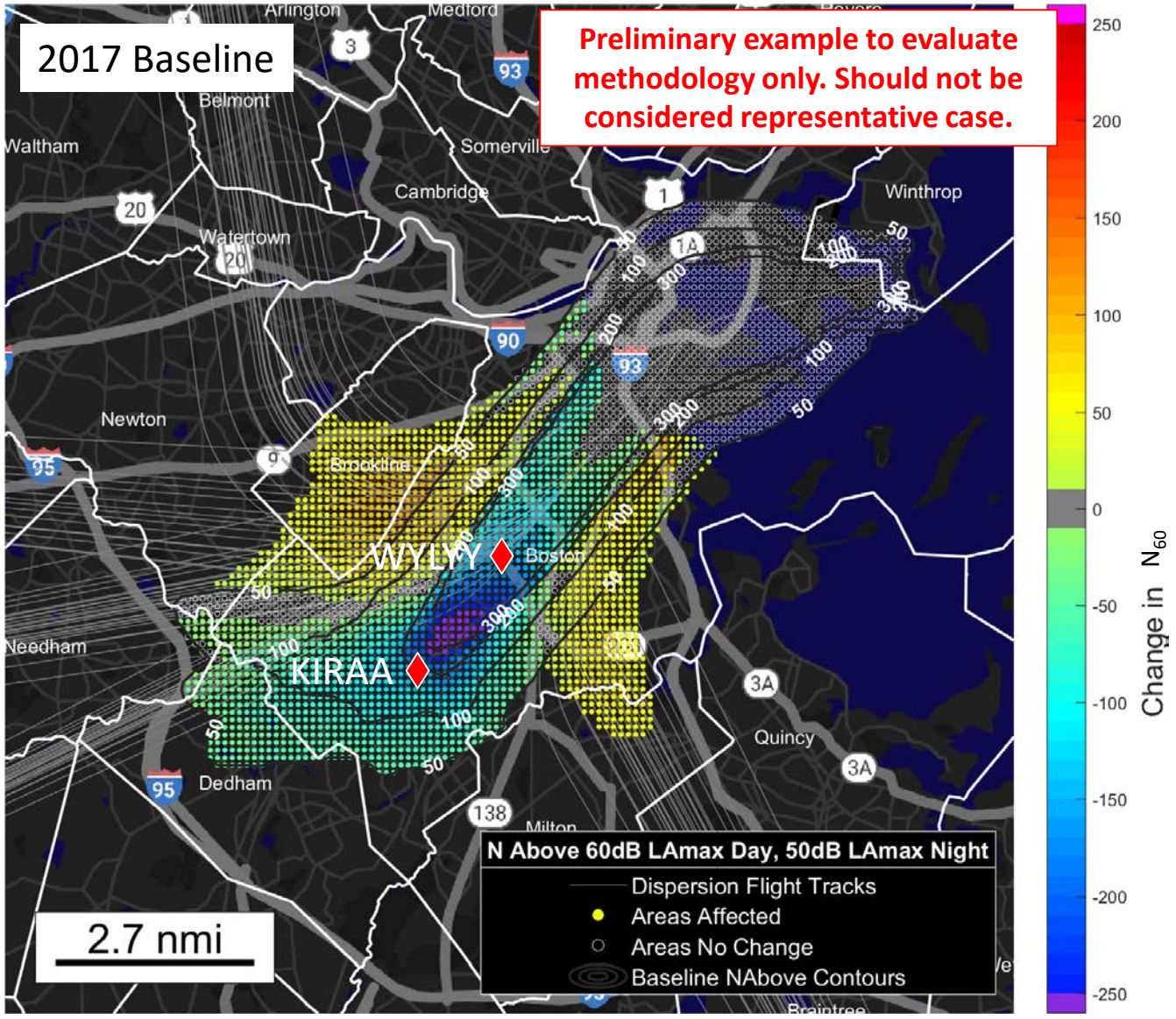
Analysis updated Dec 4 2018 to correct for discretization differences

- 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 27 departures

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



Population Exposure

N_{60}	50x
Baseline 2017	407,357
Dispersion	399,883
Baseline - Dispersion	7,474

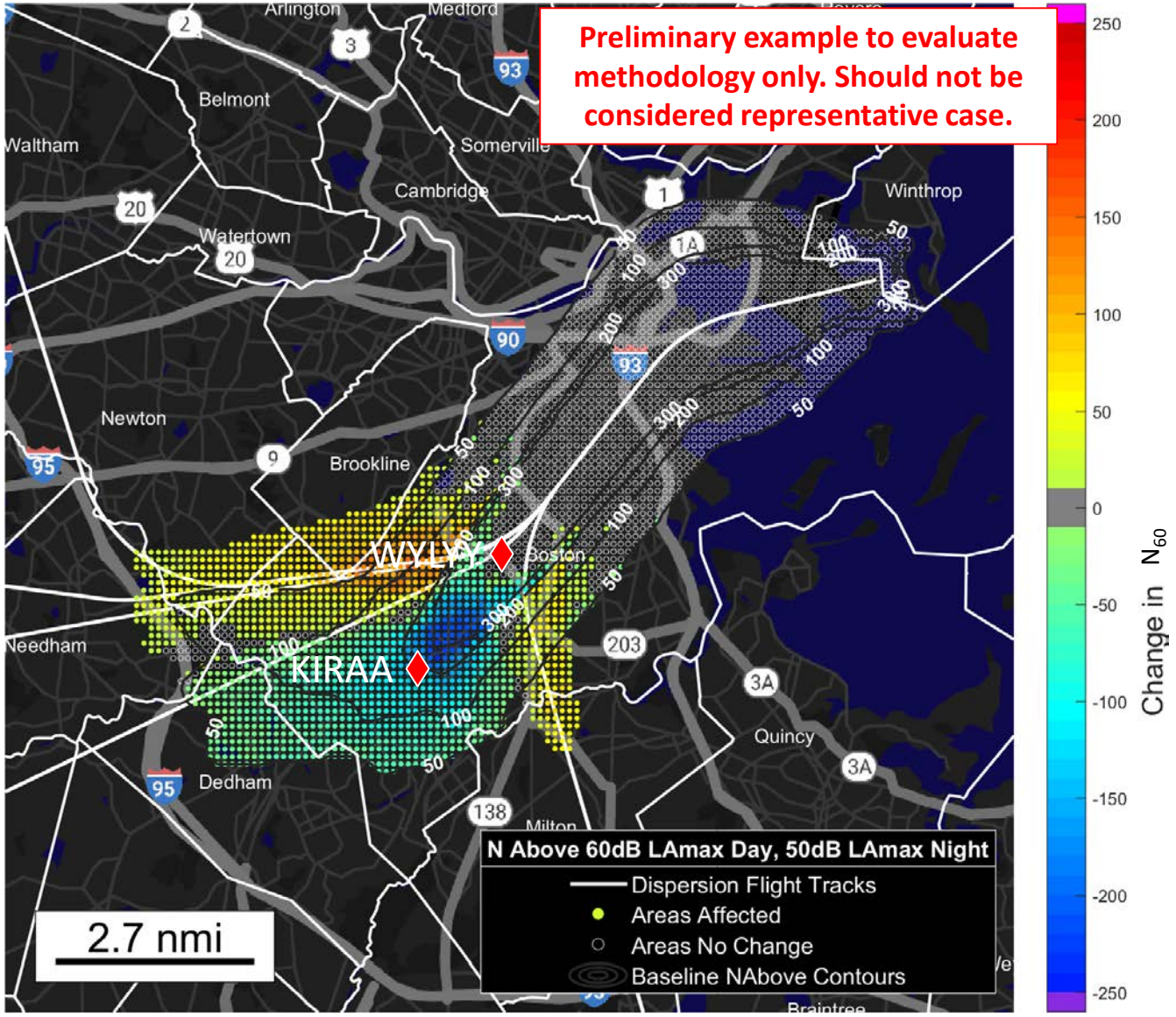
Analysis updated Dec 4 2018 to correct for discretization differences

● Violates Record of Decision

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

Analysis based on peak day operations; only includes 27 departures

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

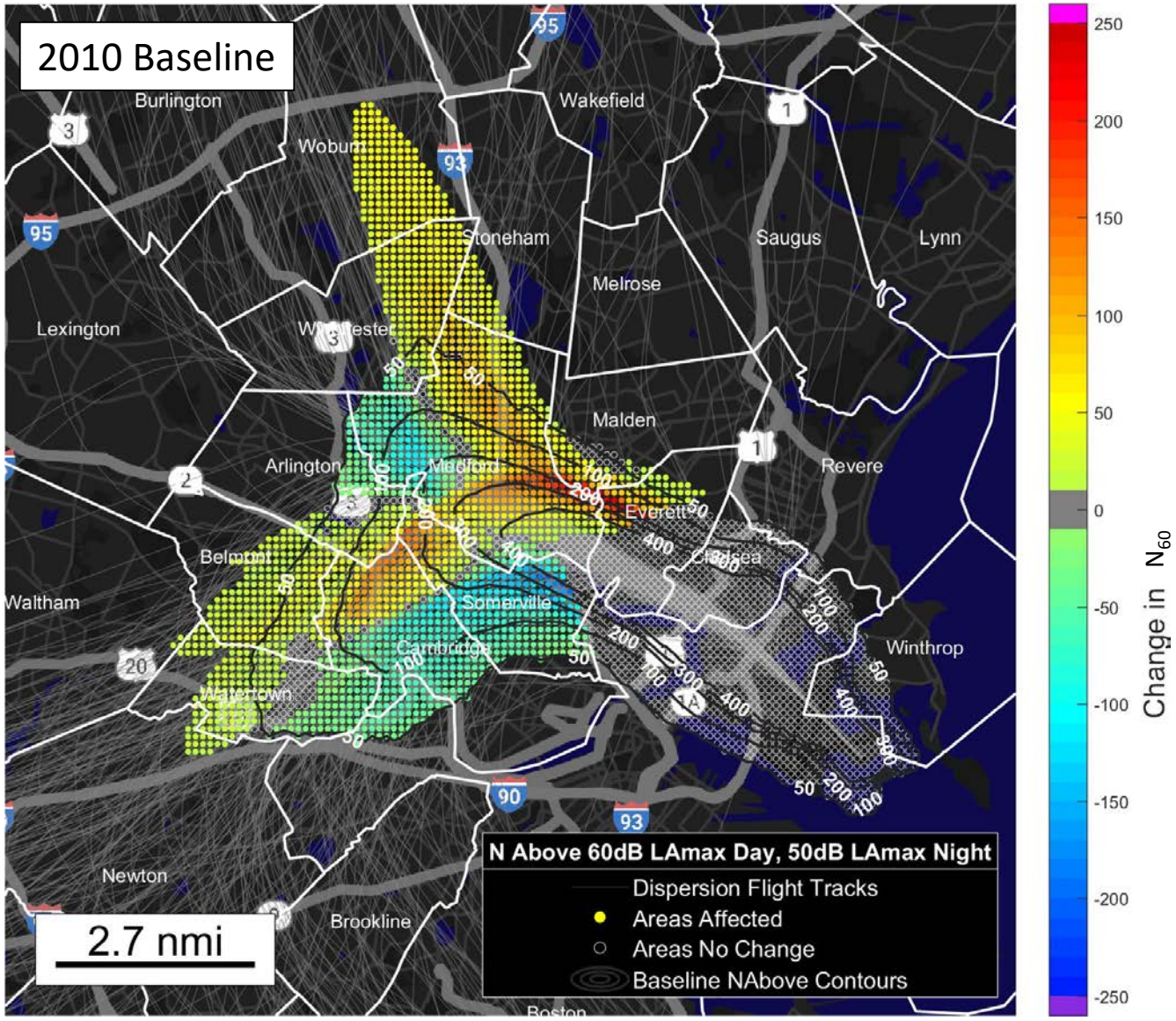
- Modification to existing RNAV procedure

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

Analysis based on peak day operations; only includes 27 departures

COMPARISON BETWEEN 2010 AND 2017 FOR REFERENCE PER COMMUNITY REQUEST

Effect of RNAV Concentration on 33L Departures 2010 to 2017



Population Exposure

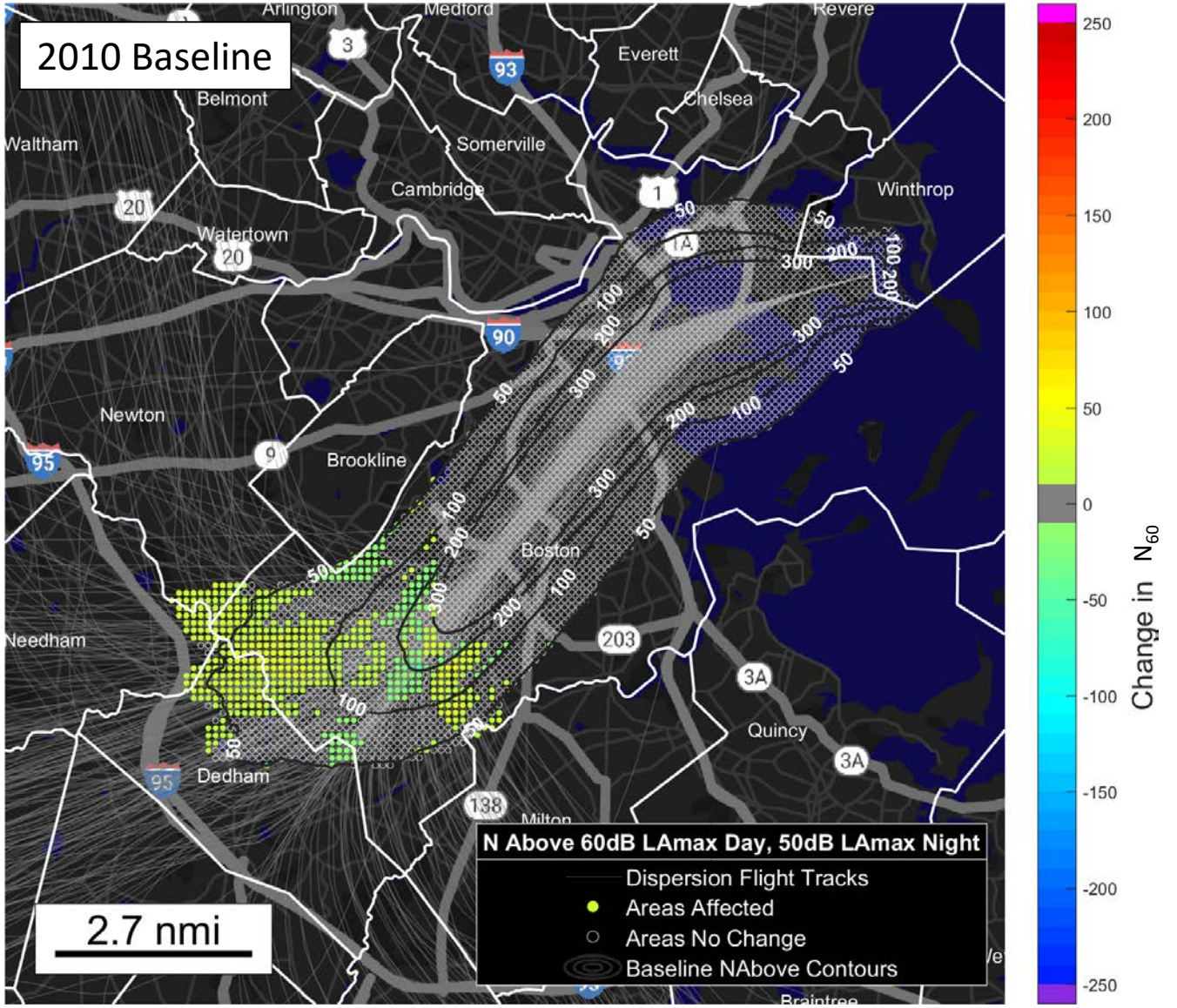
N_{60}	50x
Dispersion	356,960
RNAV	344,244
RNAV Benefit	12,716

Analysis updated Dec 4 2018 to correct for discretization differences

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

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

Effect of RNAV Concentration on 27 Departures 2010 to 2017



Population Exposure

N_{60}	50x
Dispersion	407,001
RNAV	407,357
RNAV Benefit	-356

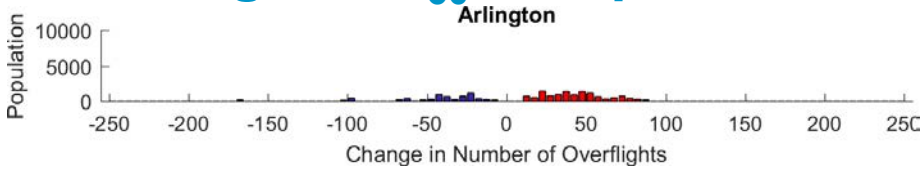
Analysis updated Dec 4 2018 to correct for discretization differences

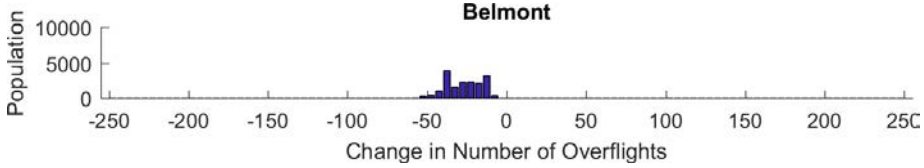
N_{60} Thresholds:
60dB $L_{A,max}$ Day, 50dB $L_{A,max}$ Night

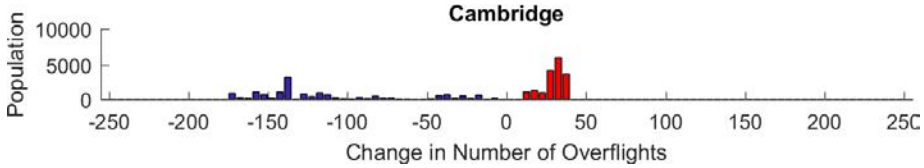
Analysis based on peak day operations; only includes 33L departures

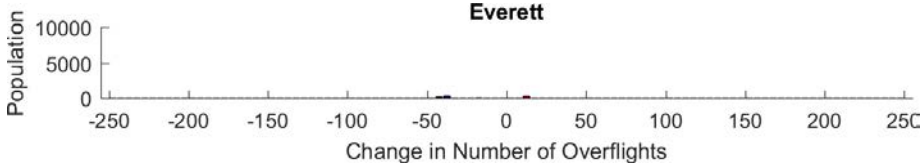
APPENDIX:
DISPERSION HISTOGRAMS

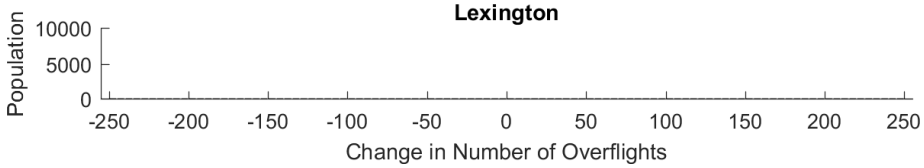
33L Departures Altitude-Based Dispersion at 3000ft Change in N_{60} Compared to 2017

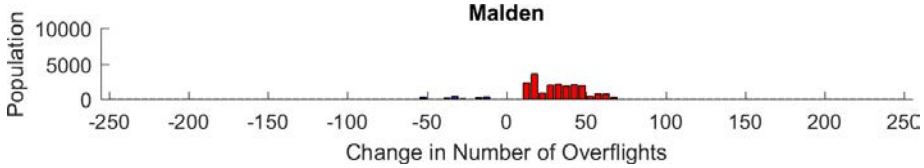


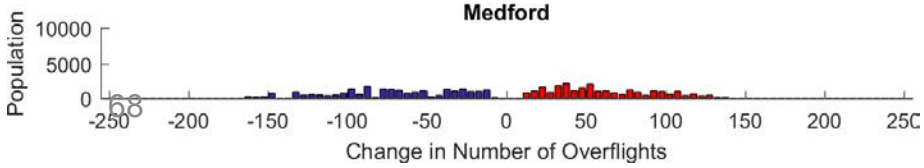


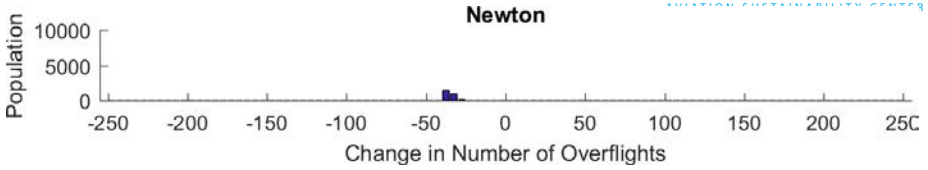


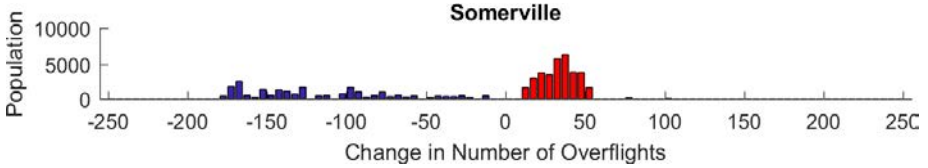


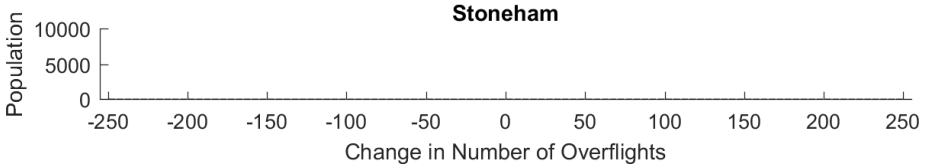


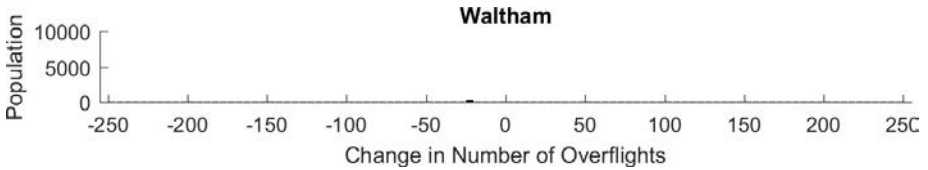


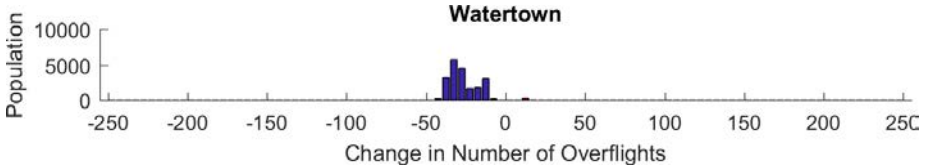


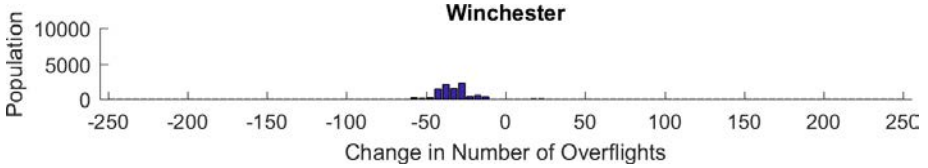


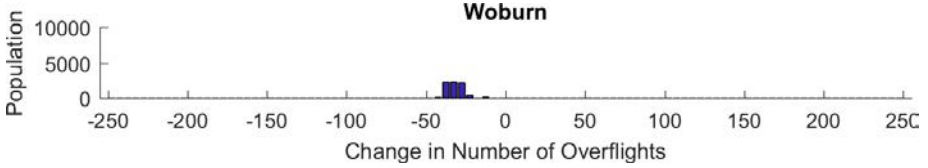




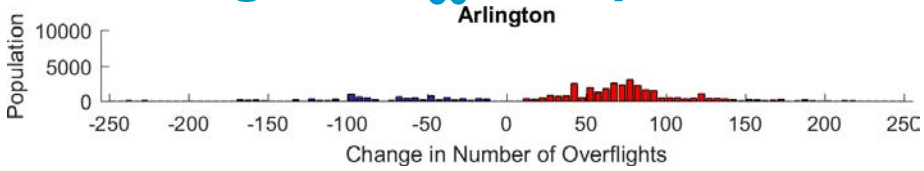


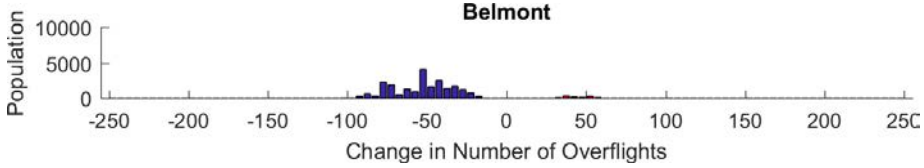


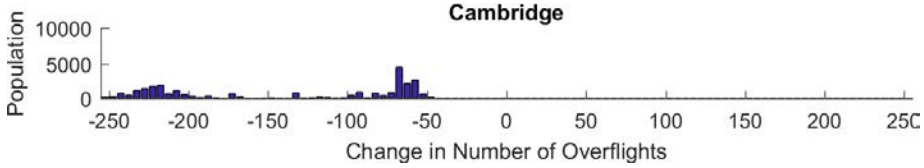


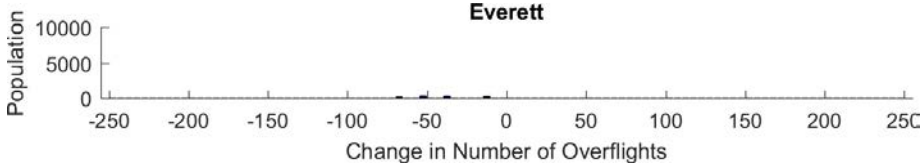


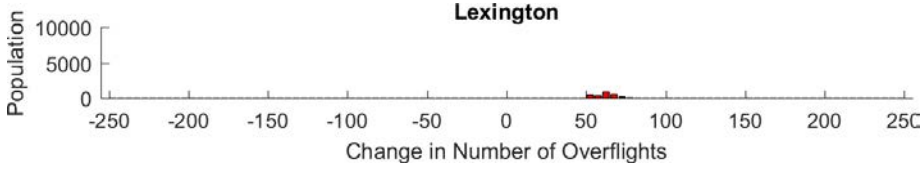
33L Departures Altitude-Based Dispersion at 4000ft
Change in N_{60} Compared to 2017

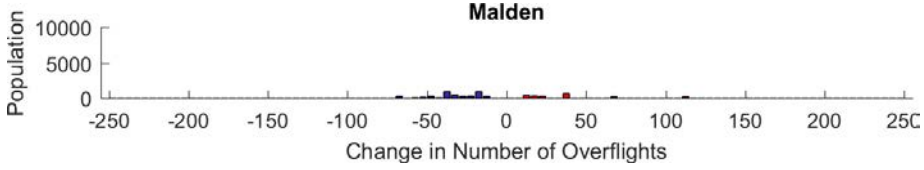


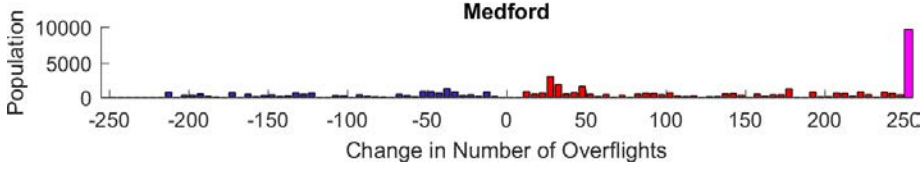


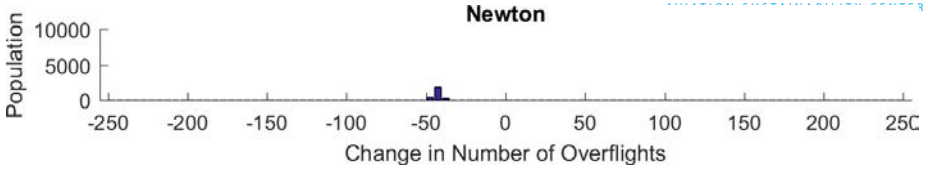


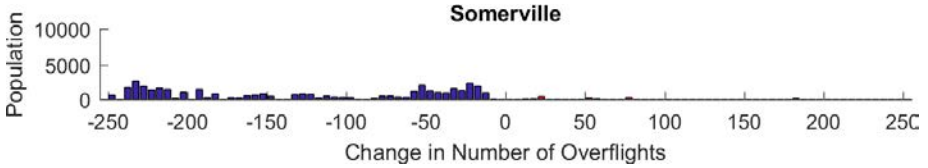


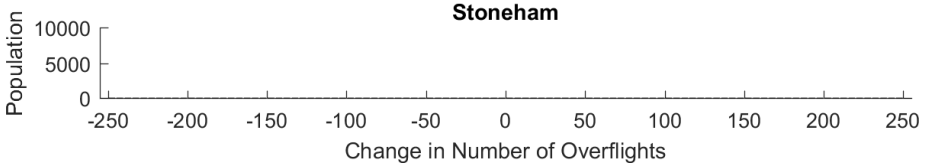


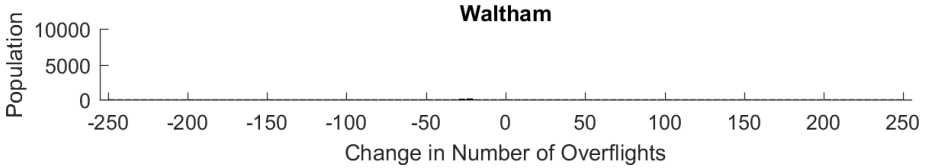


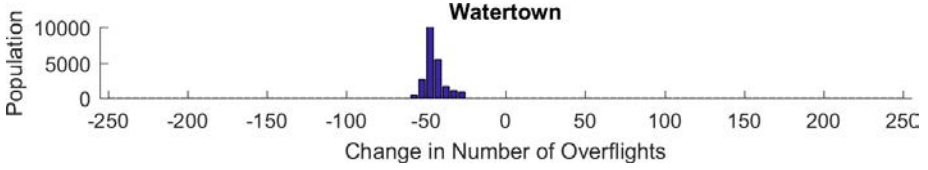


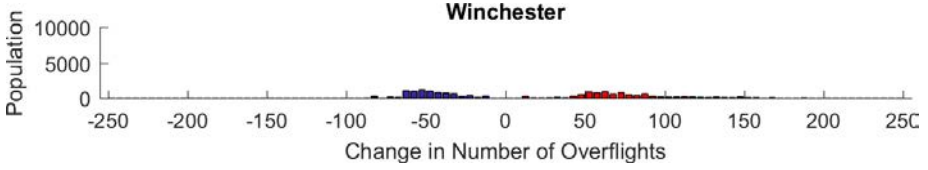


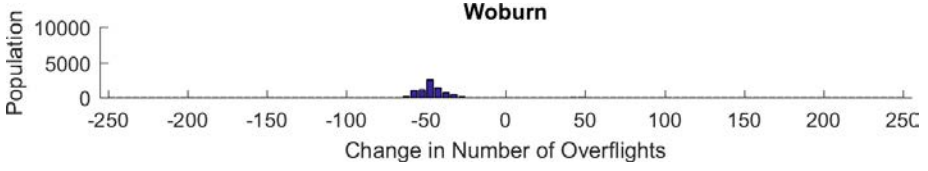




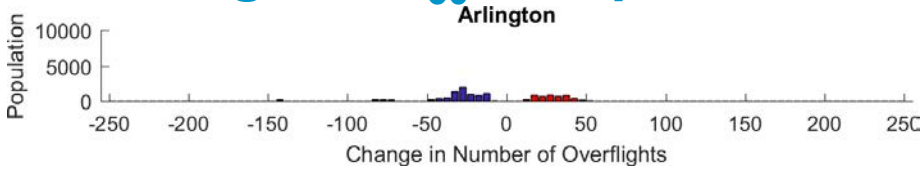


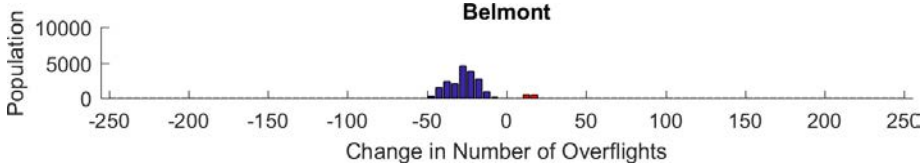


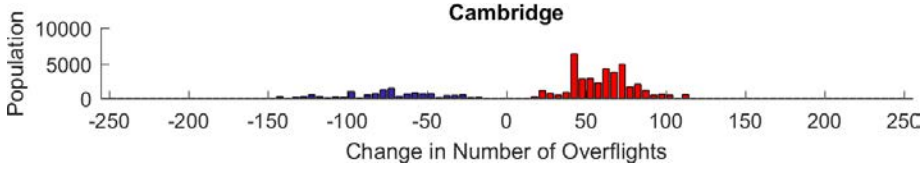


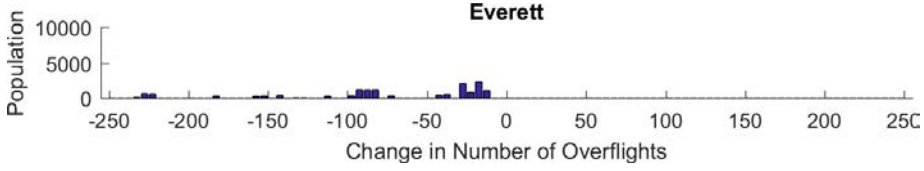


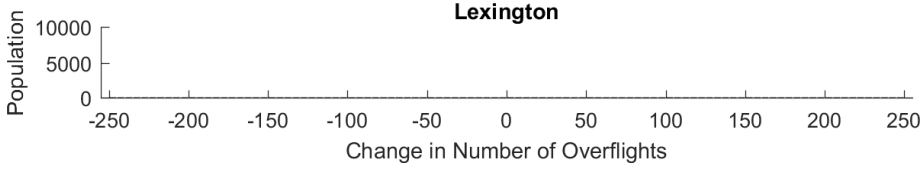
33L Departures Controller-Based Dispersion Change in N_{60} Compared to 2017

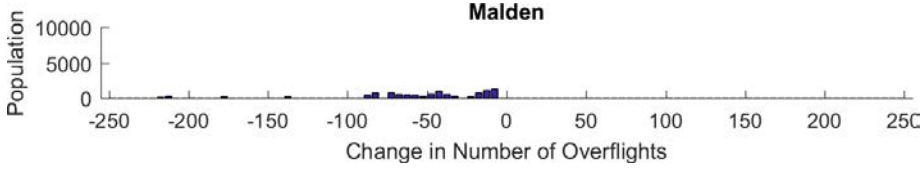


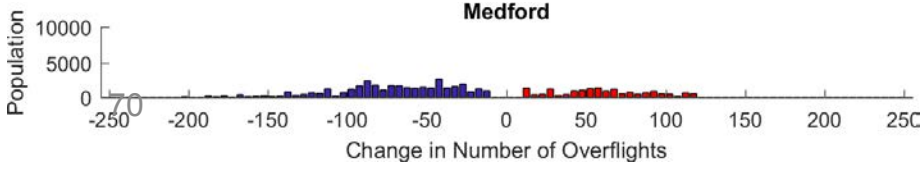


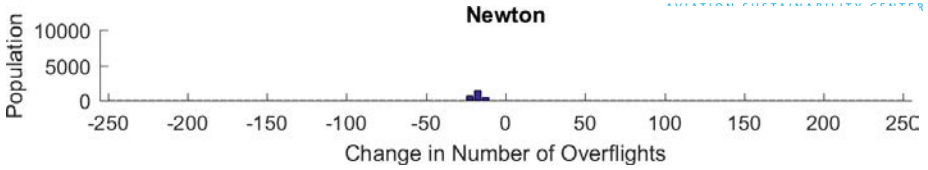


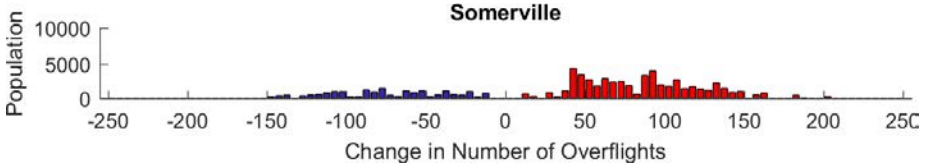


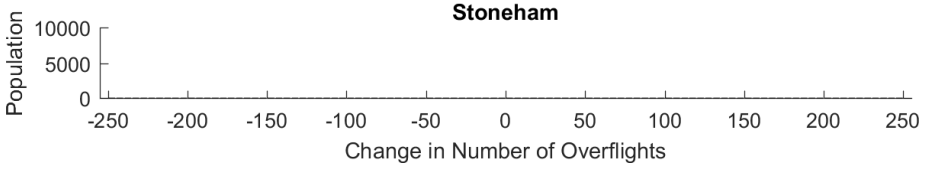


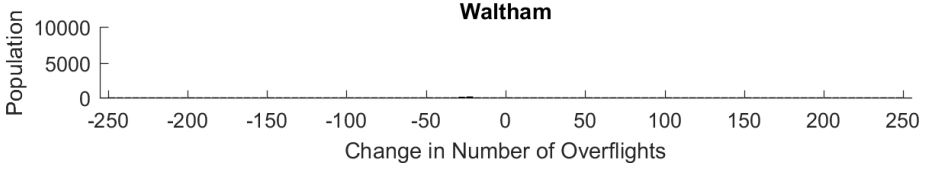


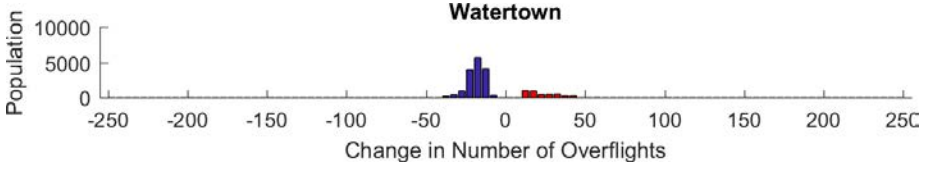


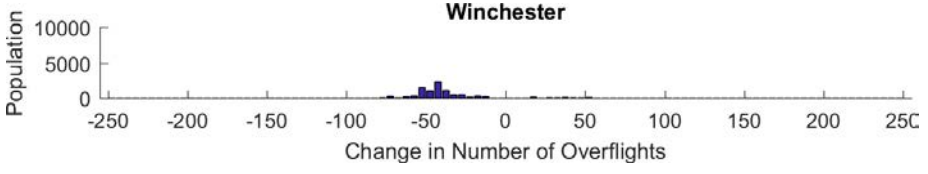


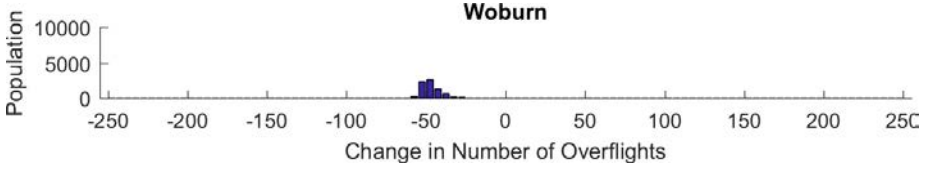




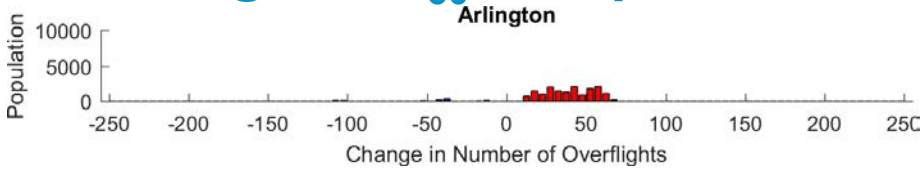


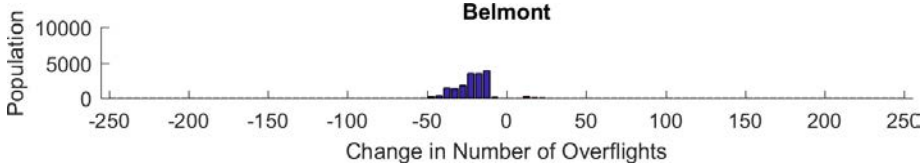


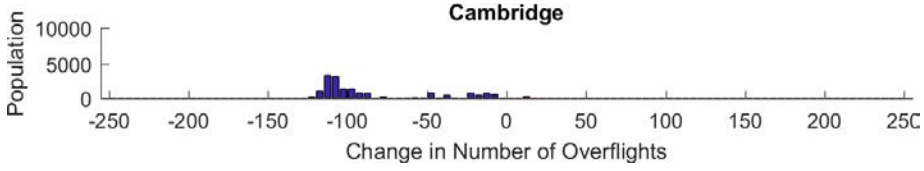


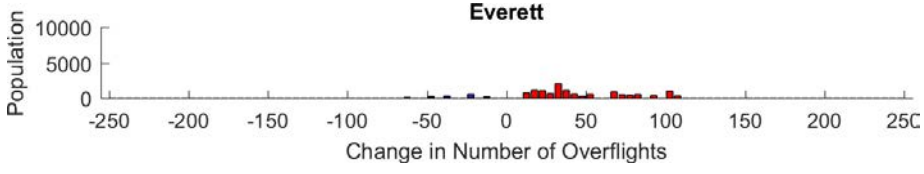


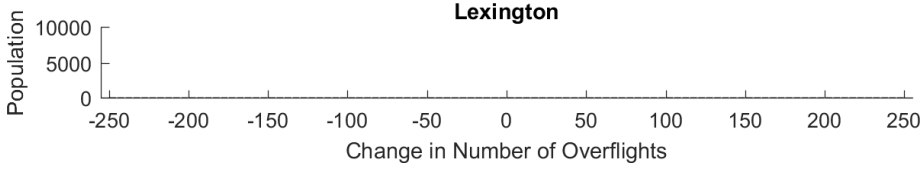
33L Departures Divergent Headings Dispersion Change in N_{60} Compared to 2017

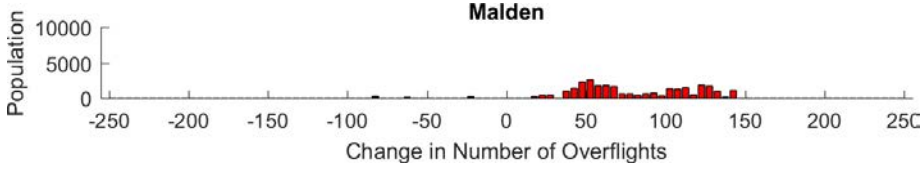


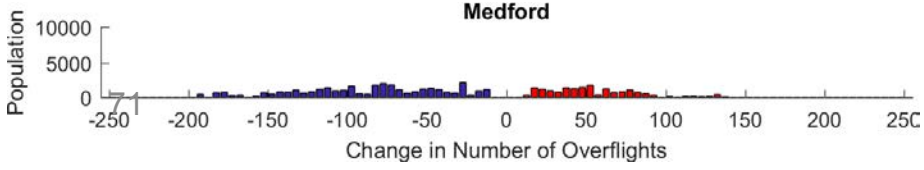


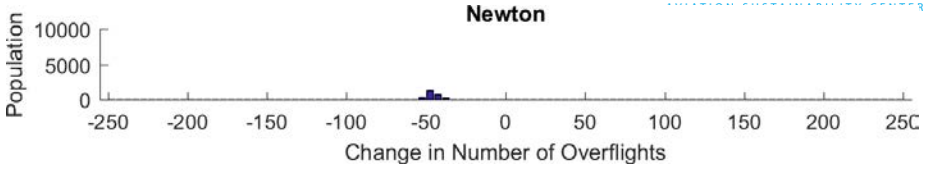


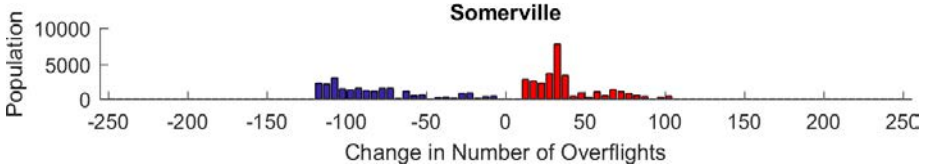


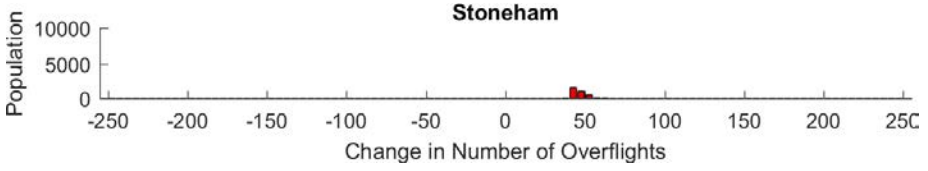


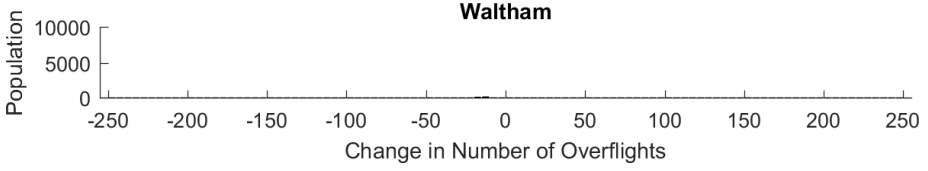


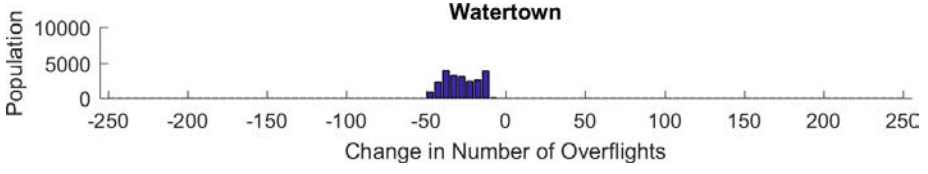


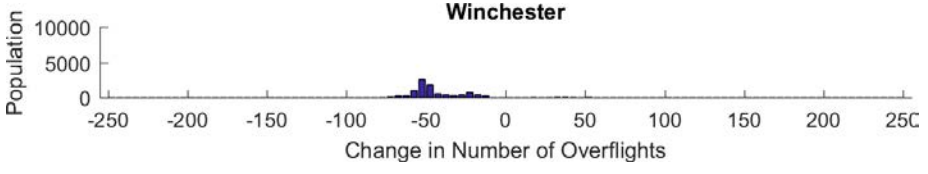


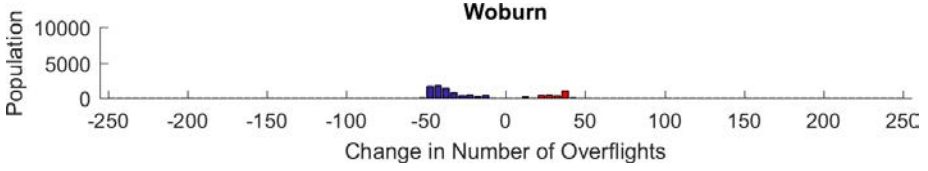




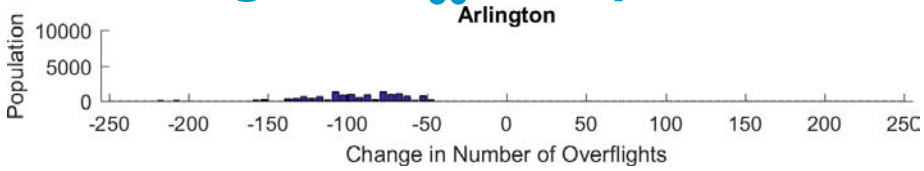


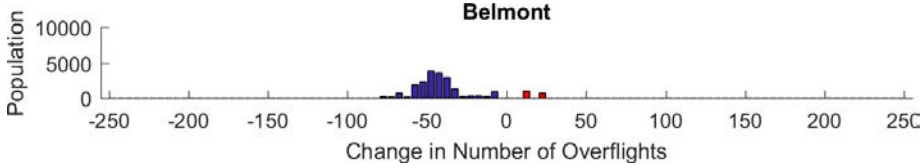


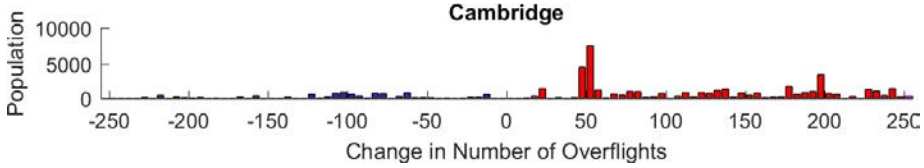


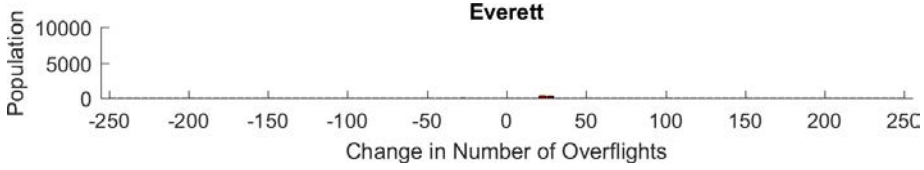


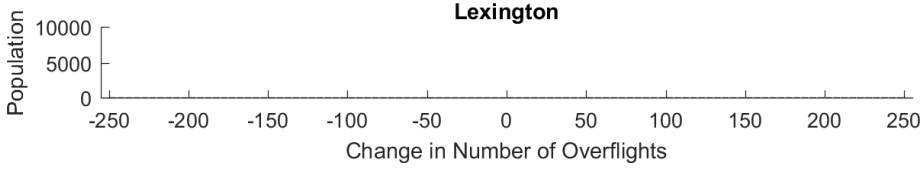
33L Departures RNAV Waypoint Relocation -1nmi Change in N_{60} Compared to 2017

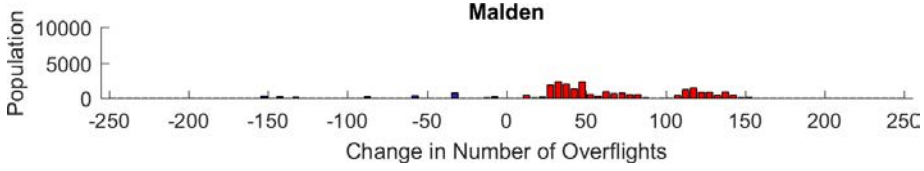


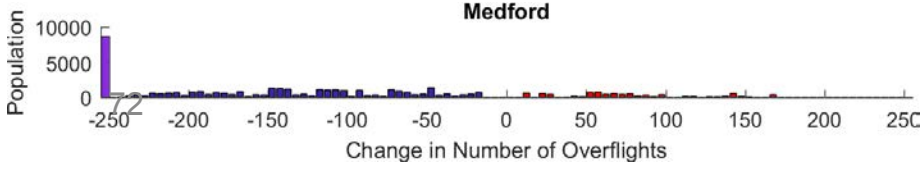


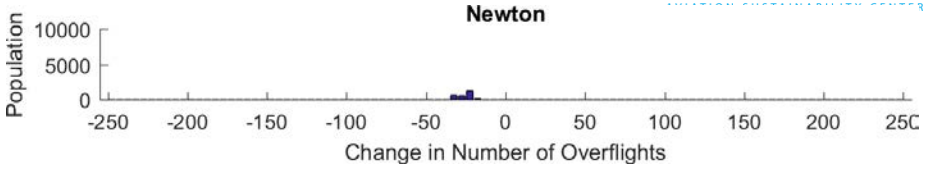


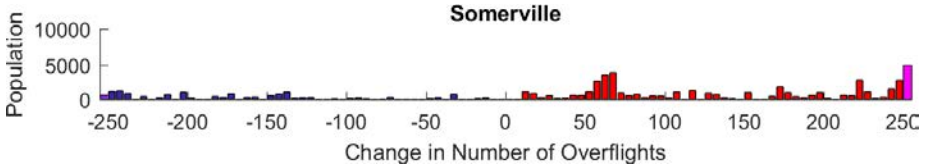


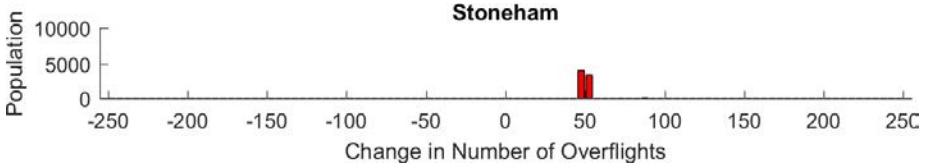


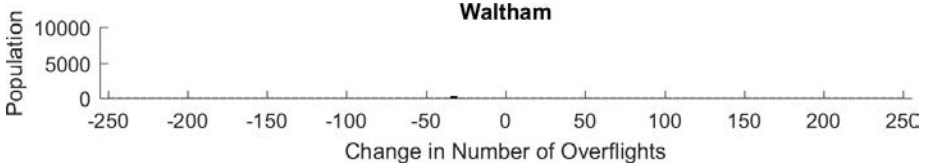


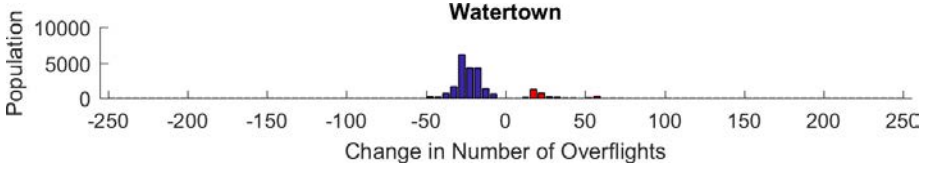


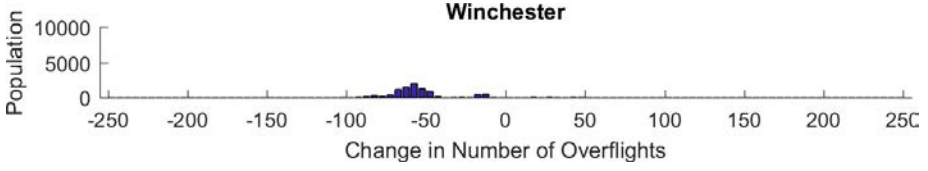


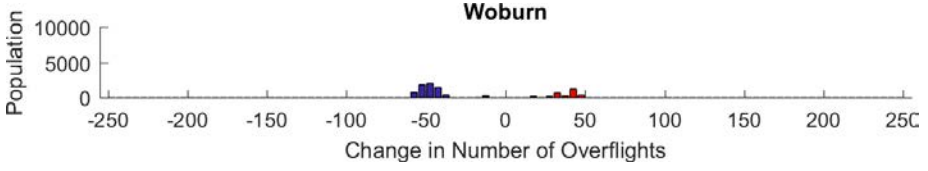




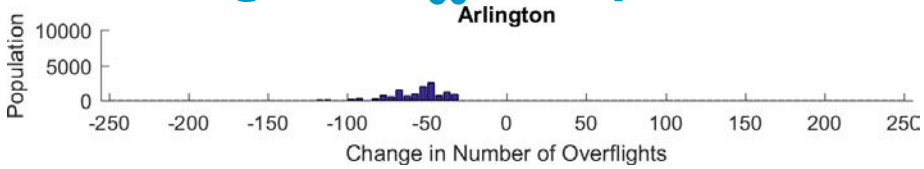


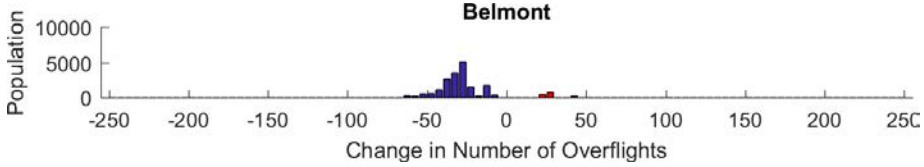


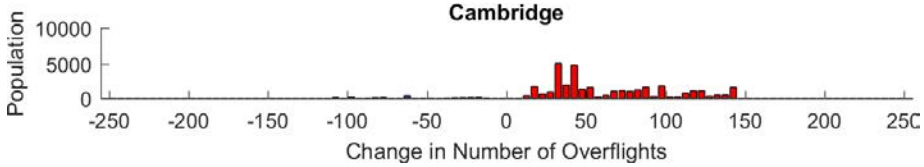


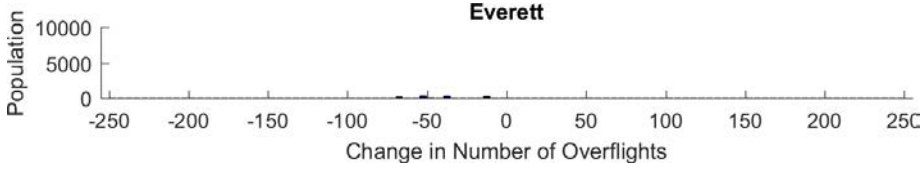


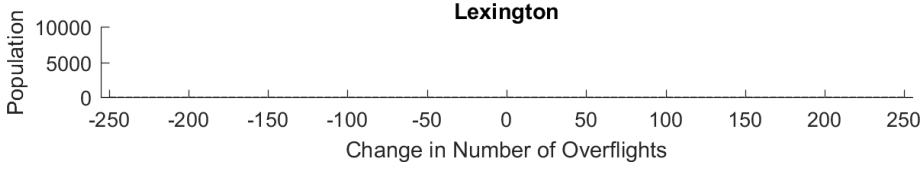
33L Departures RNAV Waypoint Relocation -0.5nmi Change in N_{60} Compared to 2017

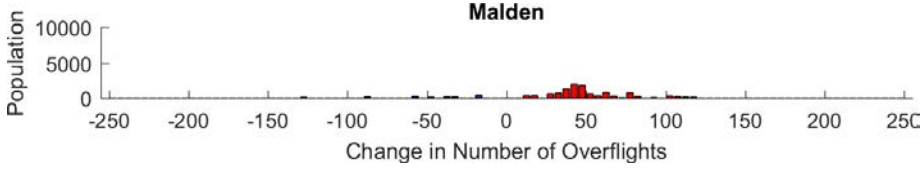


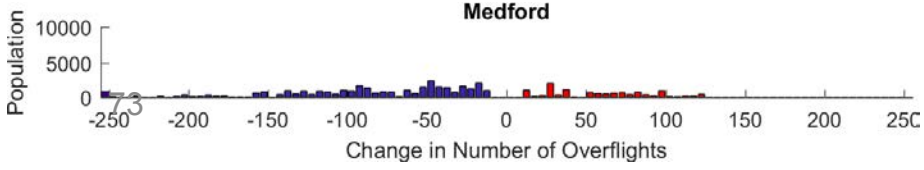


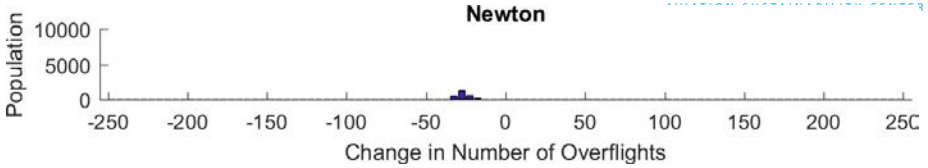


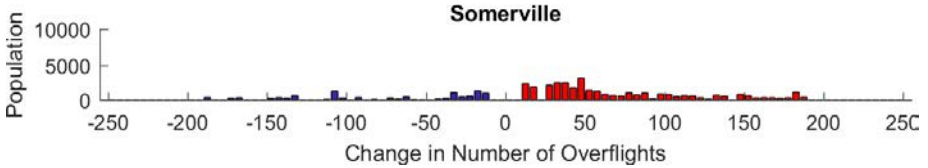


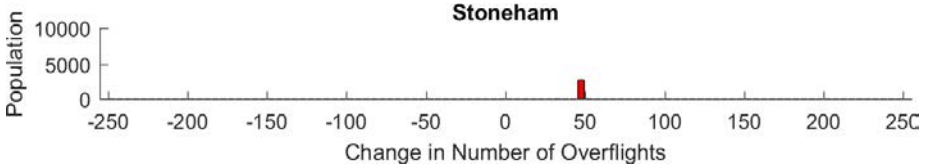


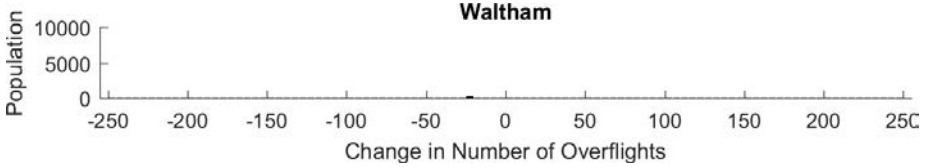


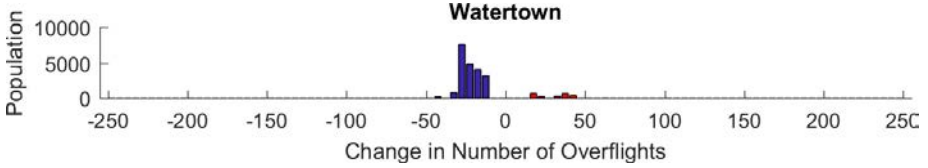


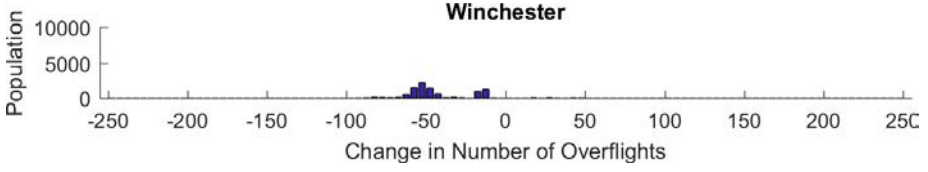


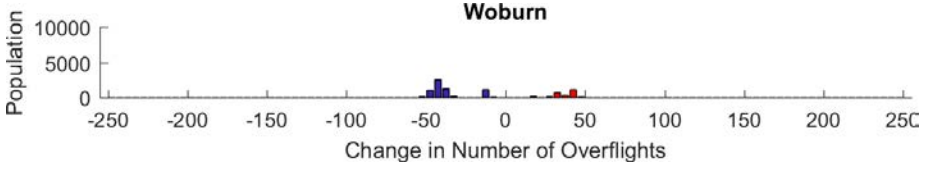




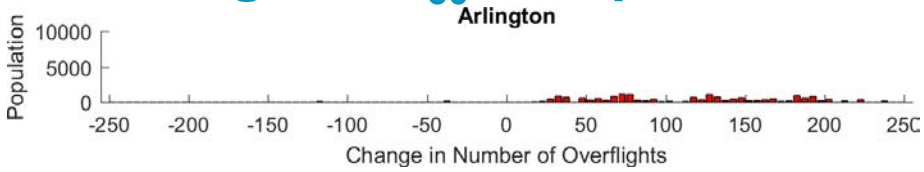


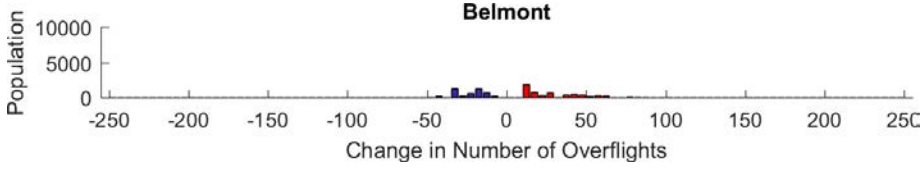


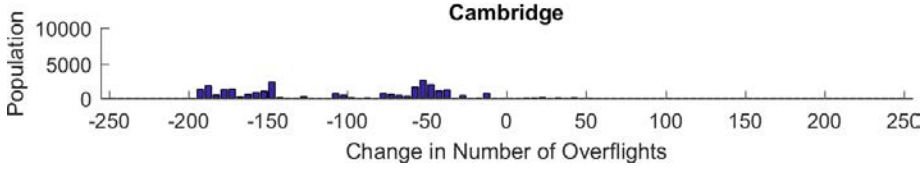


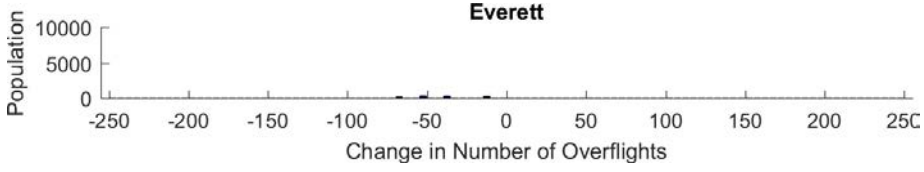


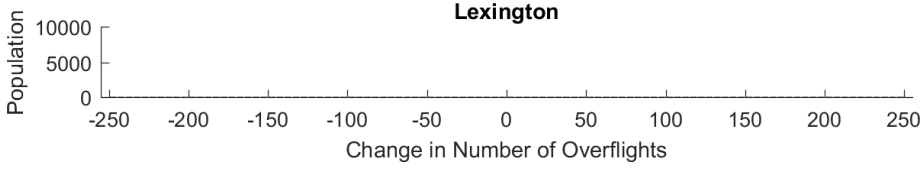
33L Departures RNAV Waypoint Relocation +0.5nmi Change in N_{60} Compared to 2017

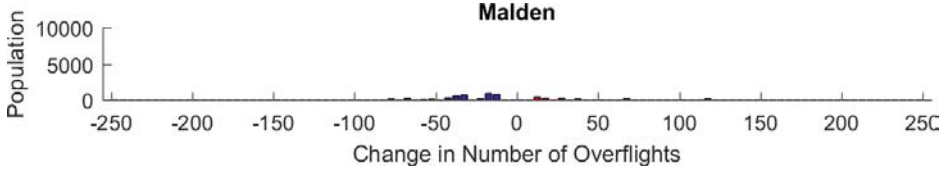


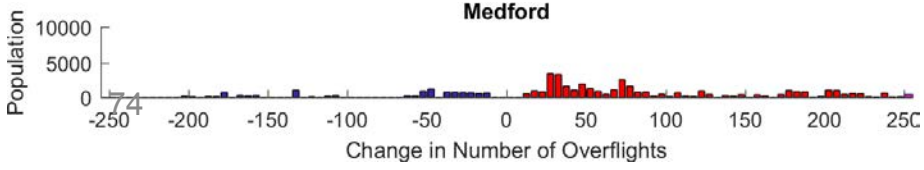


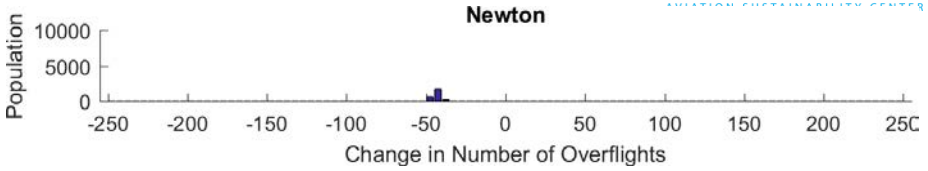


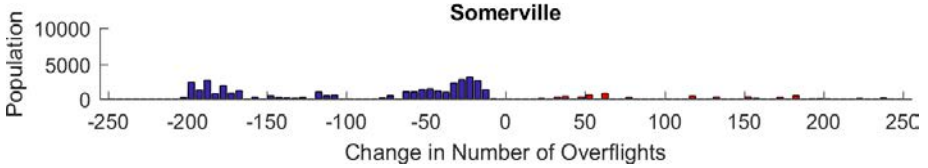


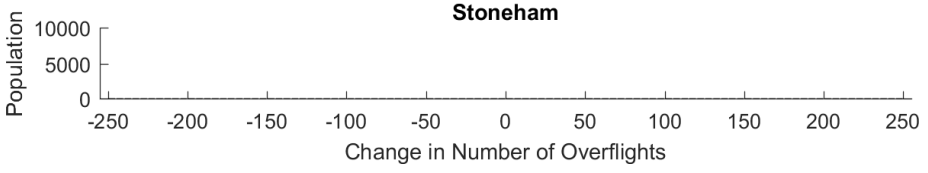


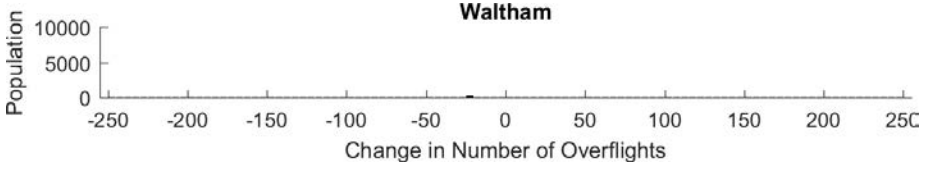


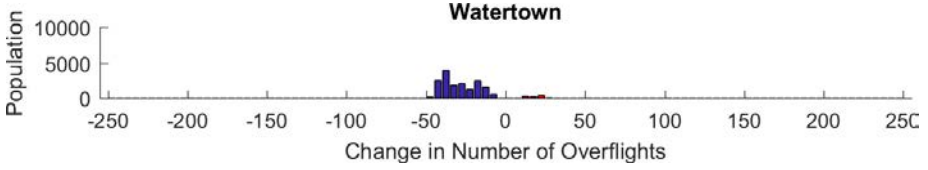


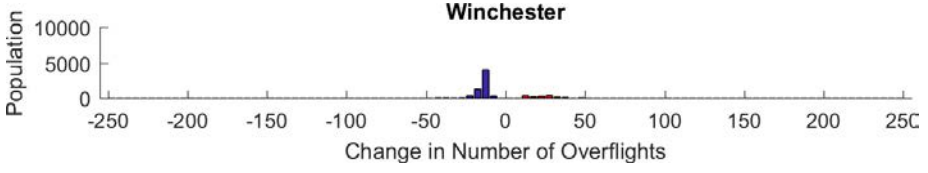


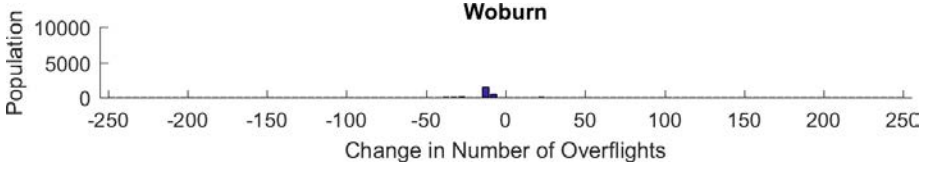




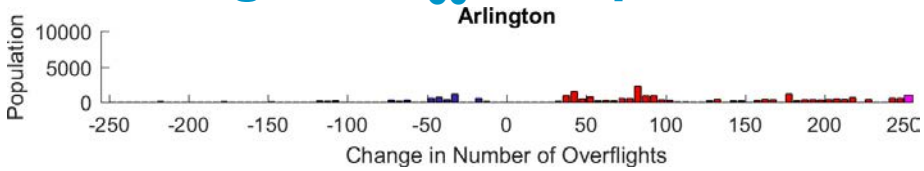


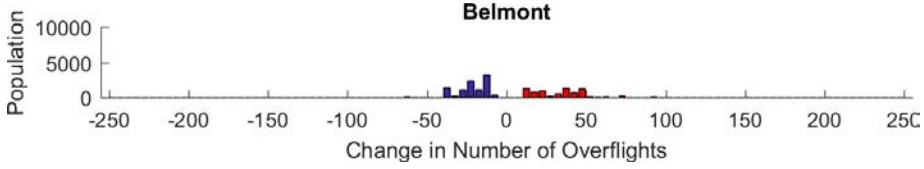


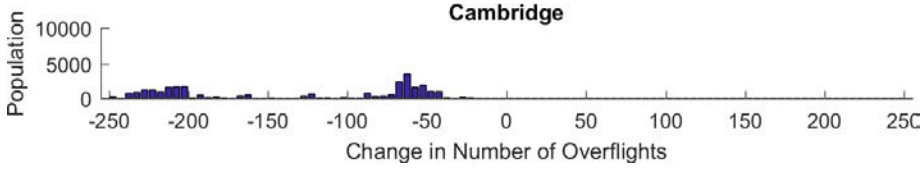


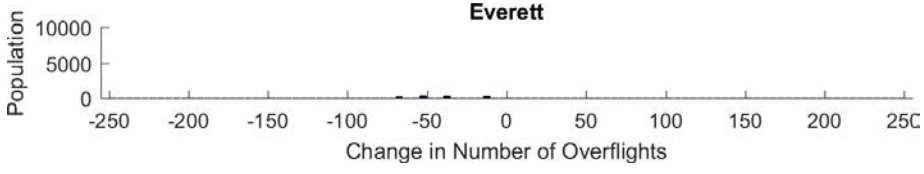


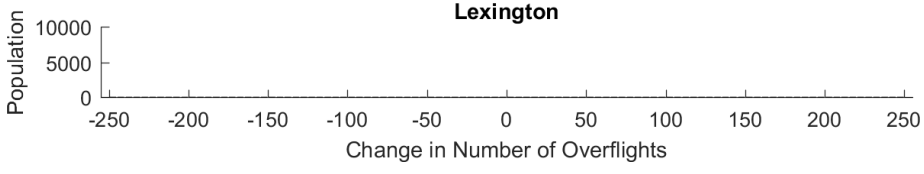
33L Departures RNAV Waypoint Relocation +1nmi Change in N_{60} Compared to 2017

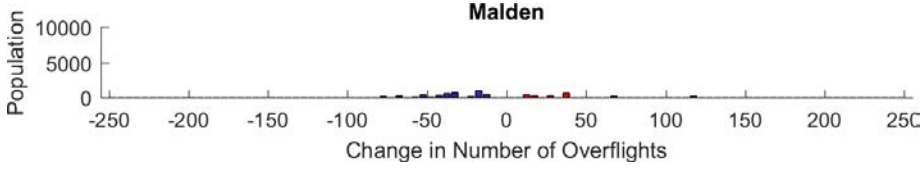


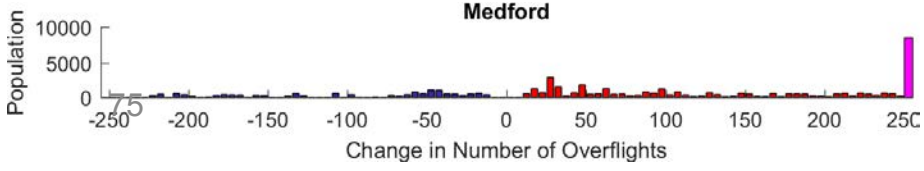


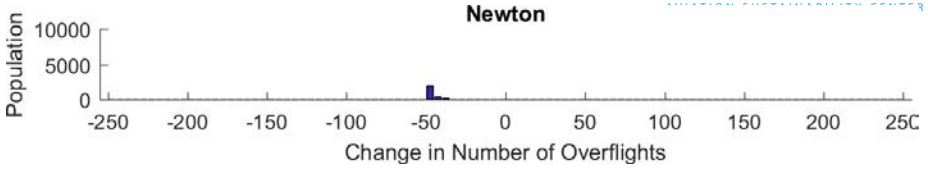


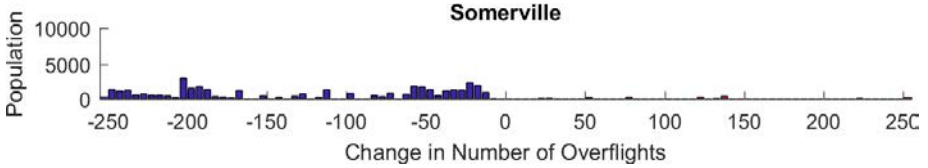


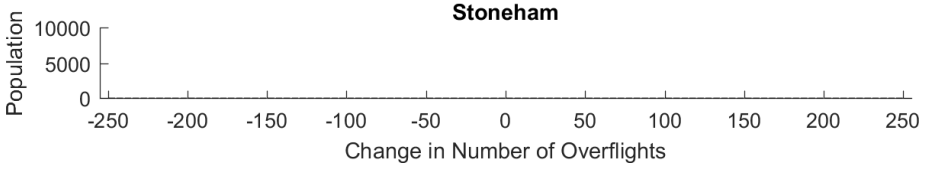


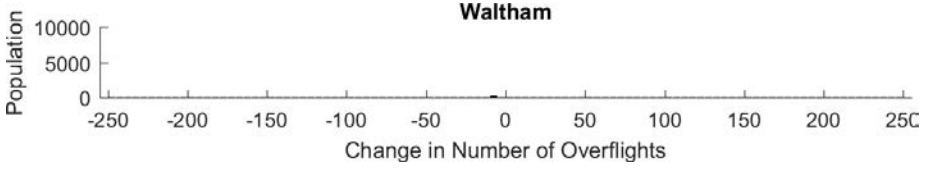


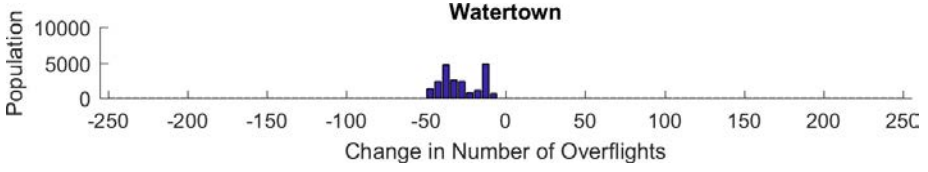


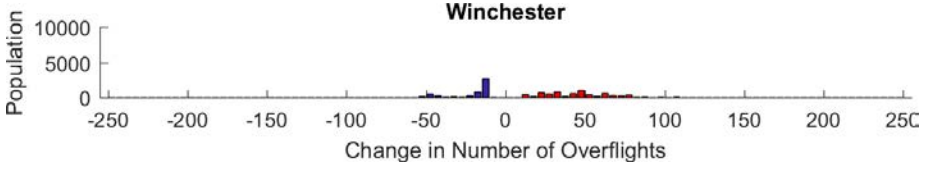


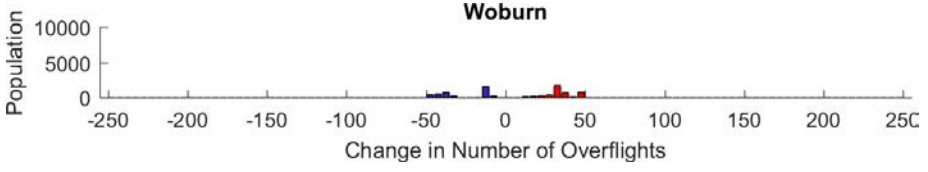




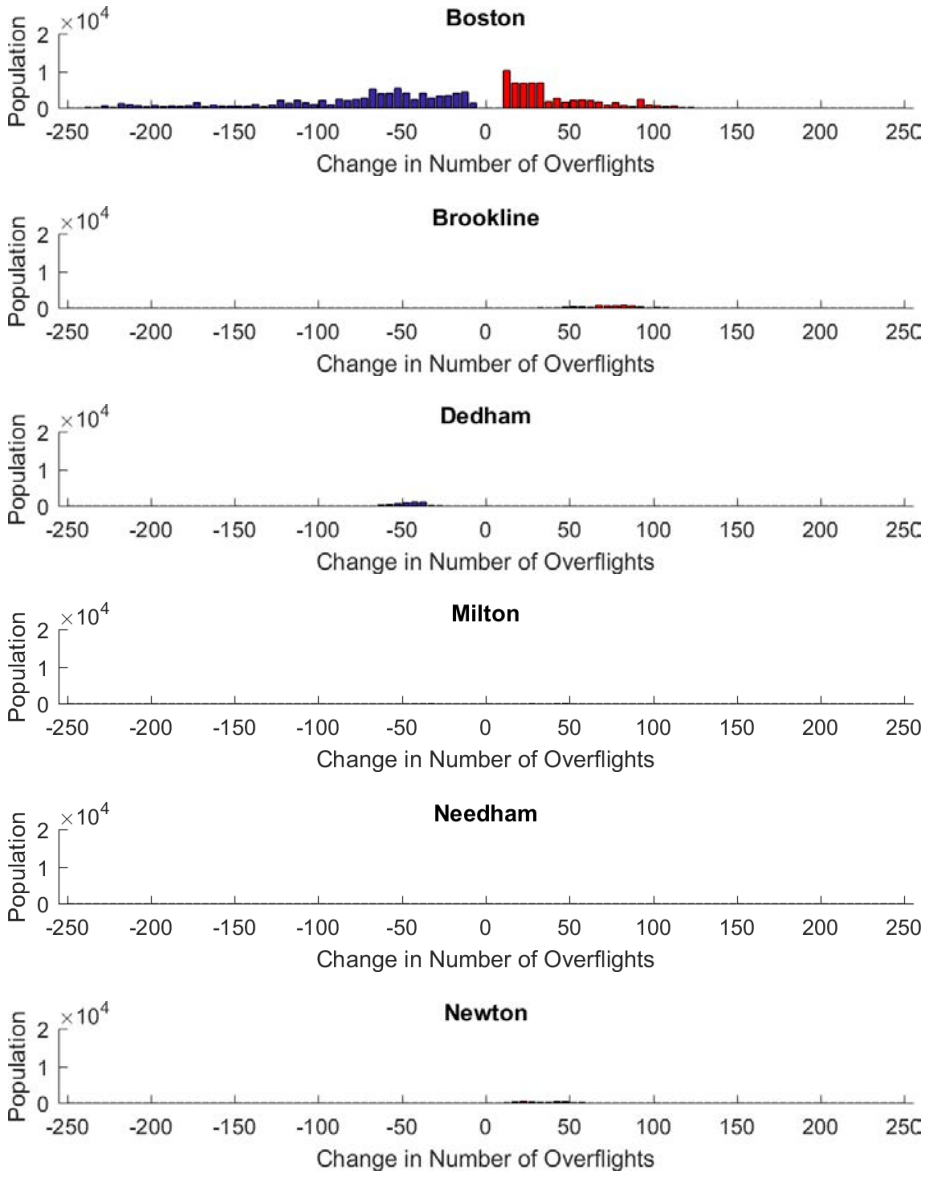




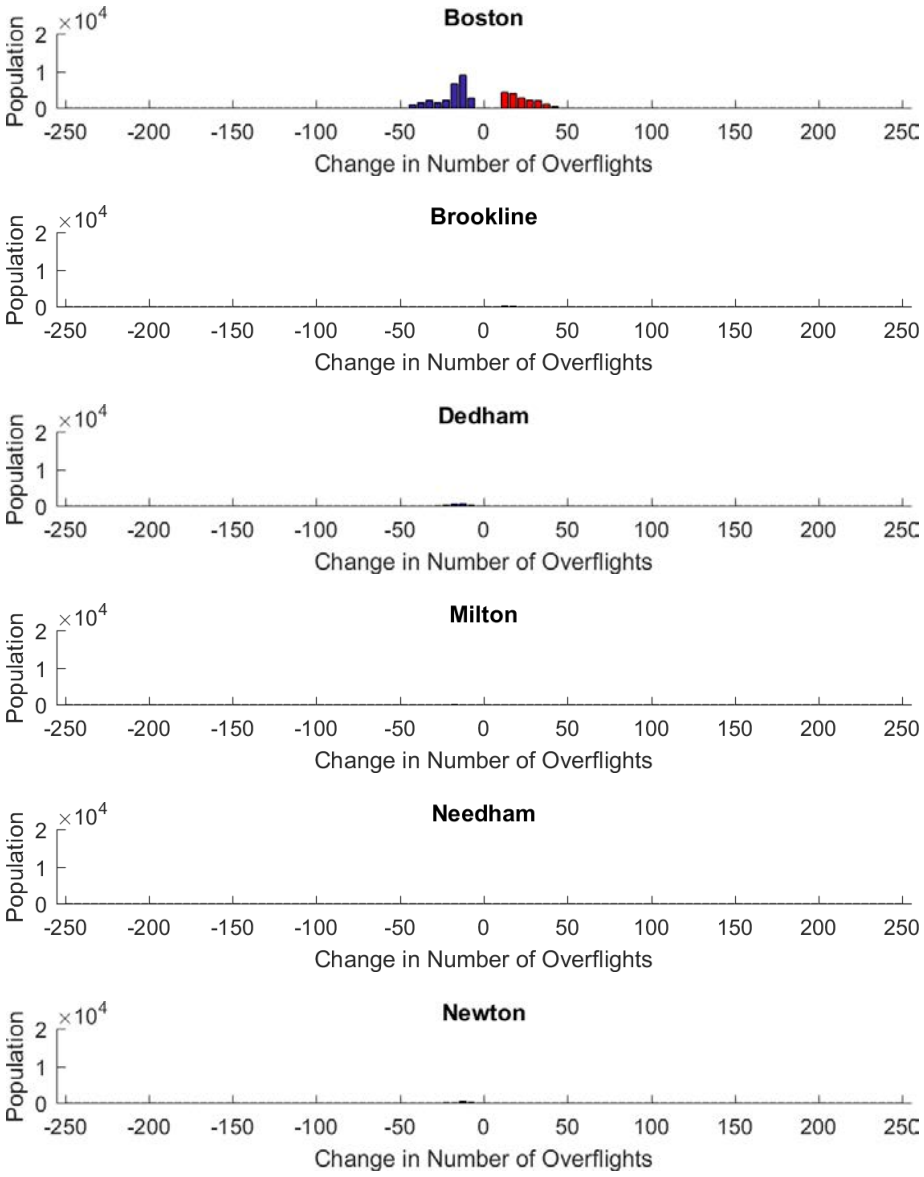




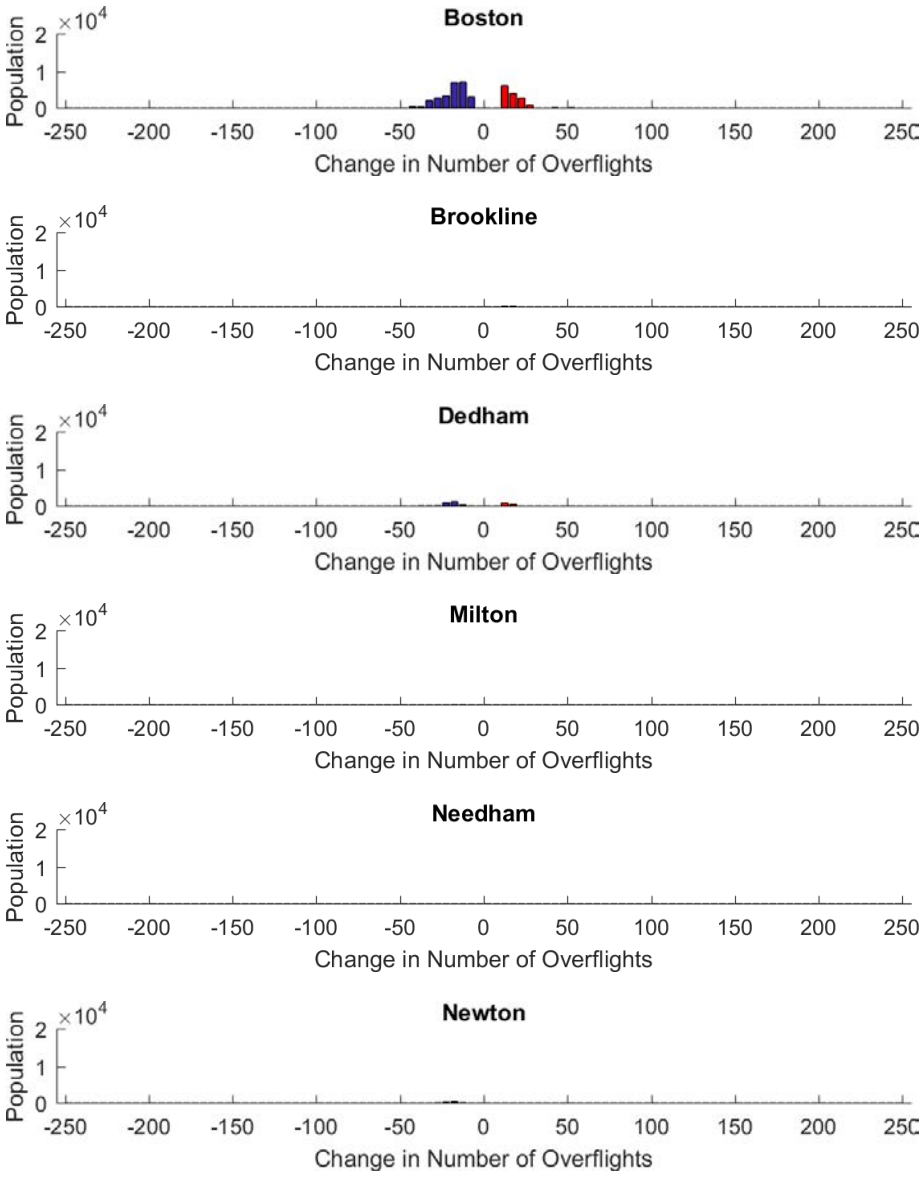
27 Departures Altitude-Based Dispersion at 3000ft Change in N_{60} Compared to 2017



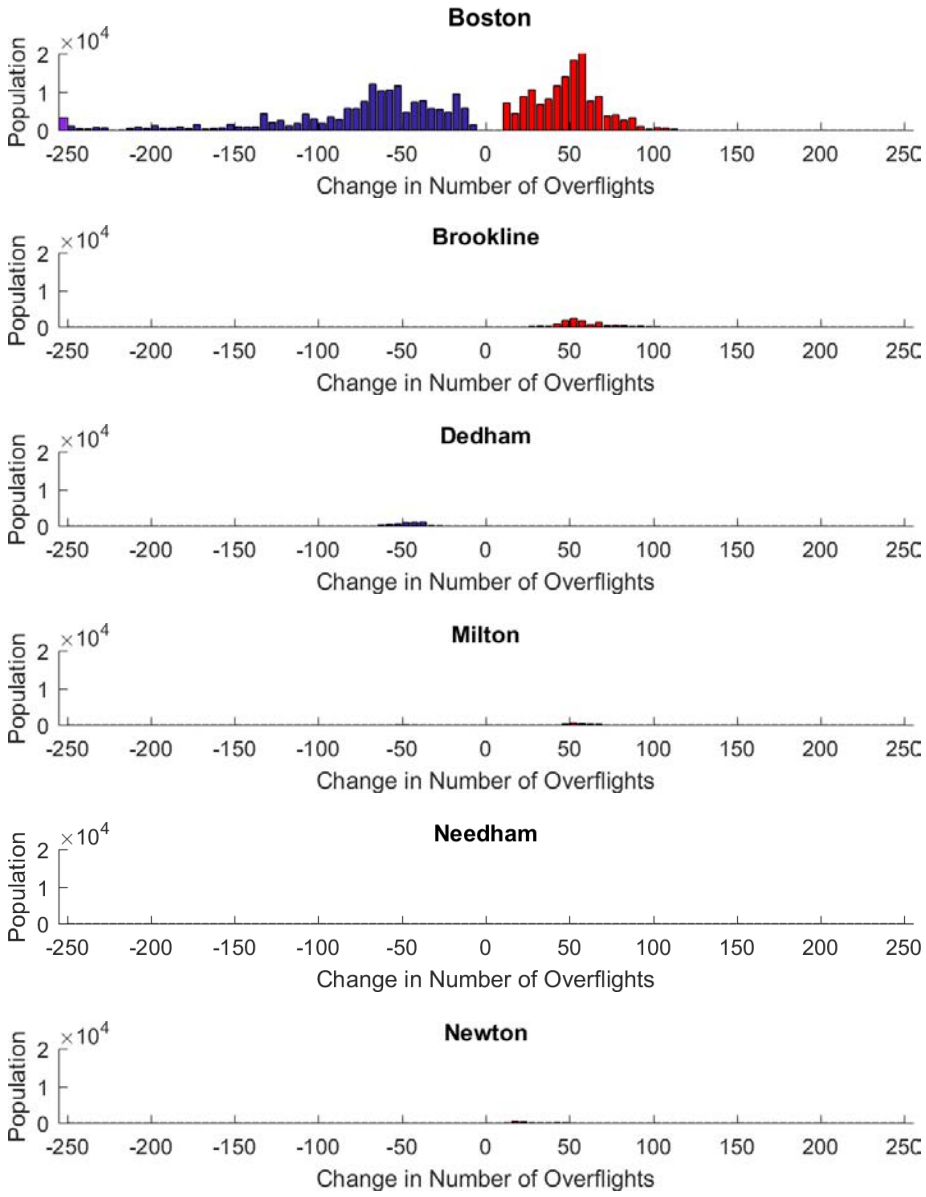
27 Departures Altitude-Based Dispersion at 4000ft Change in N_{60} Compared to 2017



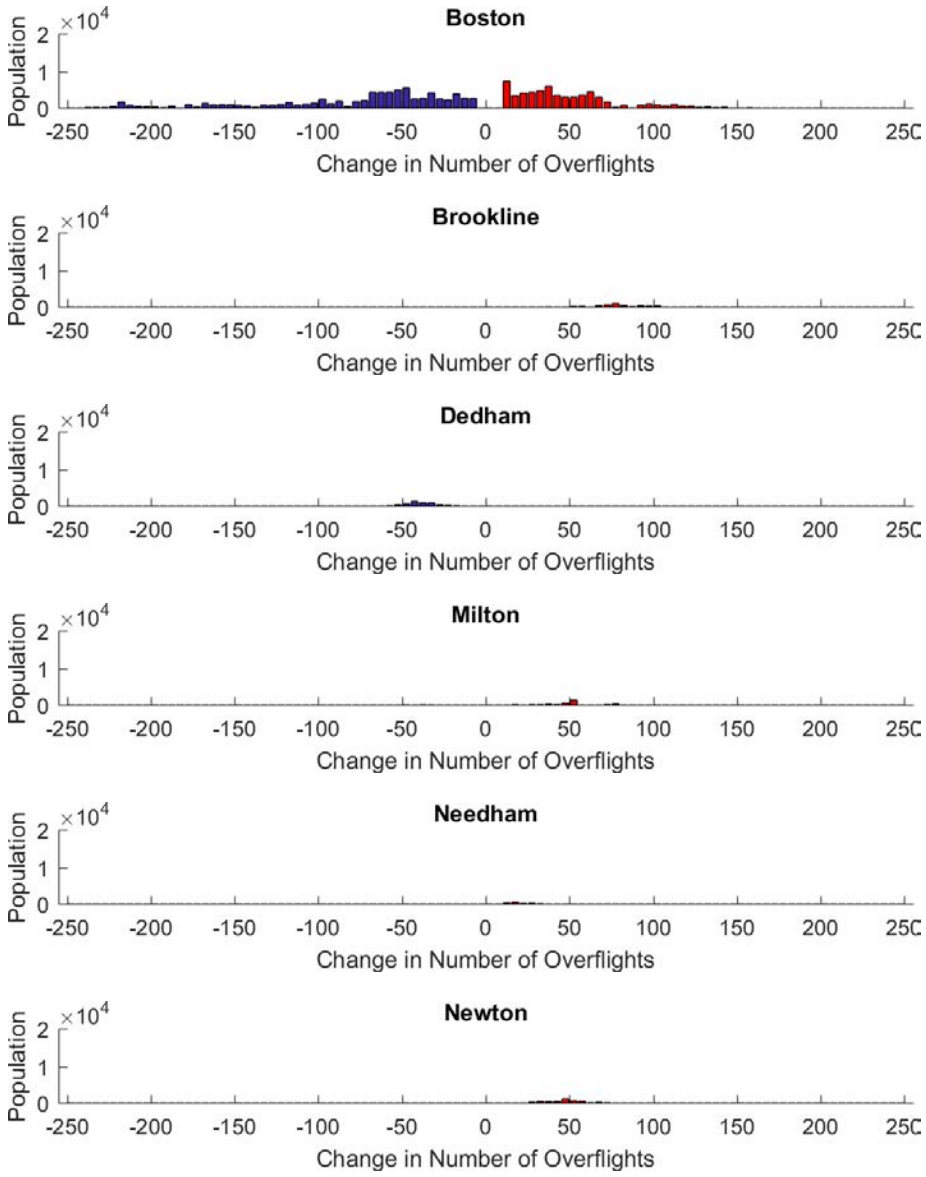
27 Departures Controller-Based Dispersion Change in N_{60} Compared to 2017



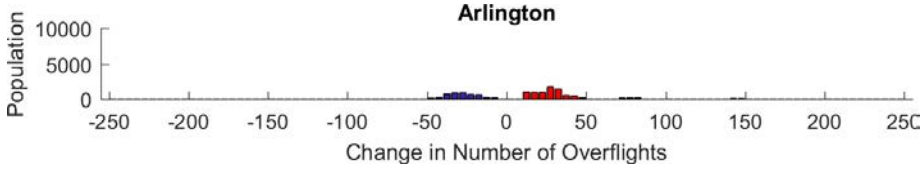
27 Departures Divergent Headings Dispersion Change in N_{60} Compared to 2017

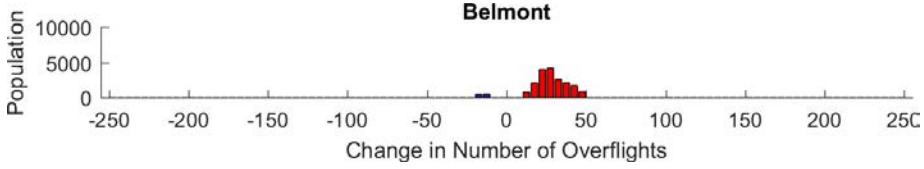


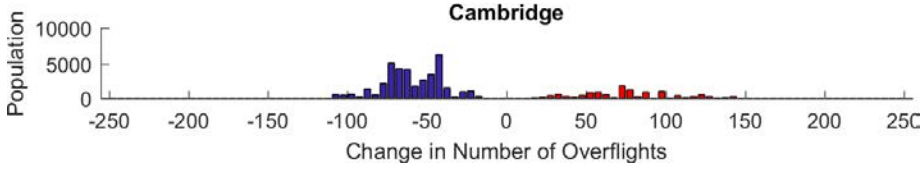
27 Departures RNAV Waypoint Relocation Change in N_{60} Compared to 2017

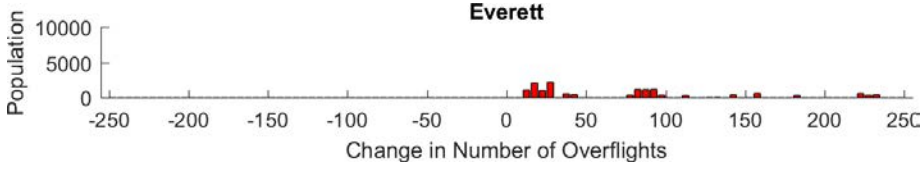


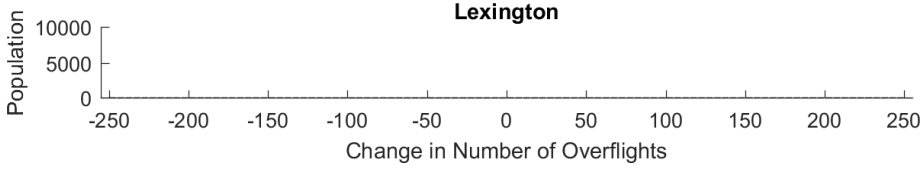
Effect of RNAV Concentration on 33L Departures 2010 to 2017

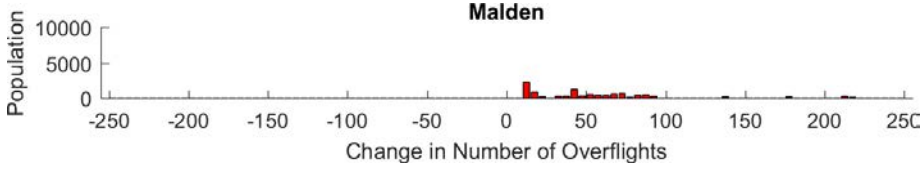


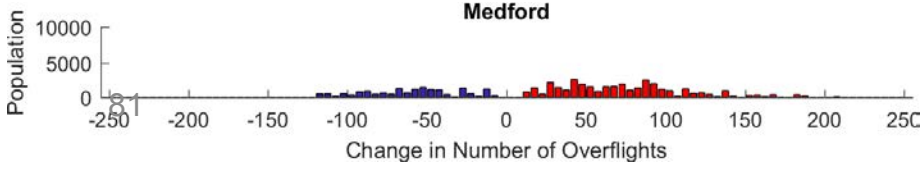


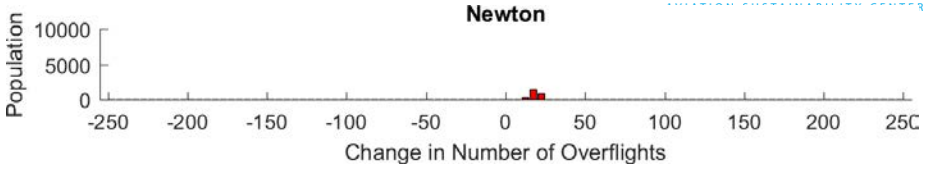


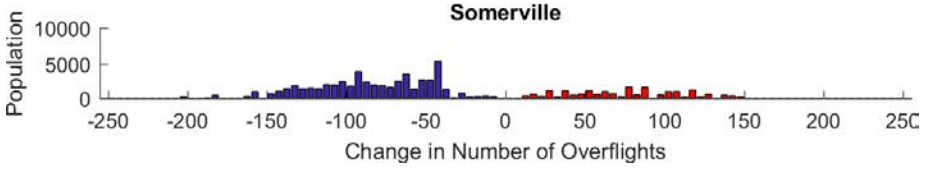


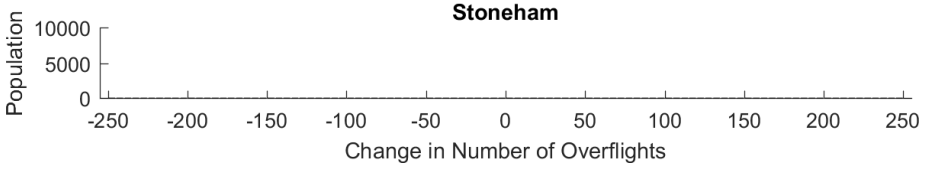


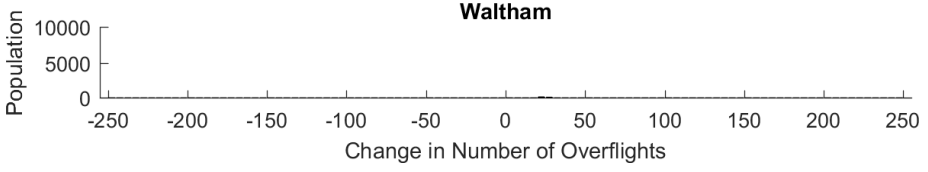


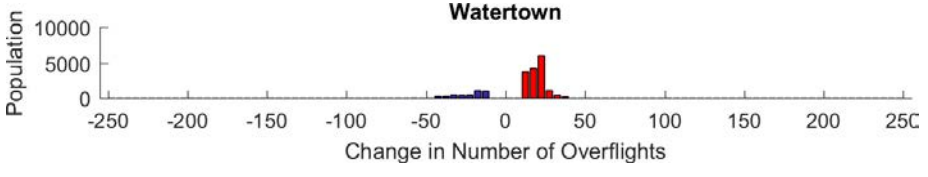


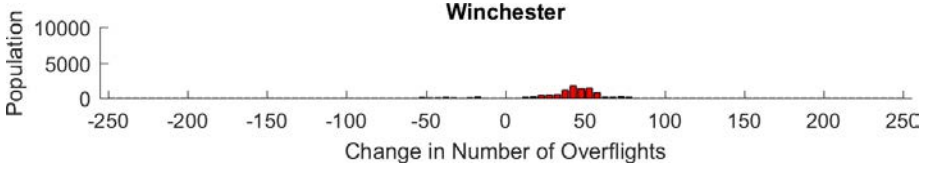


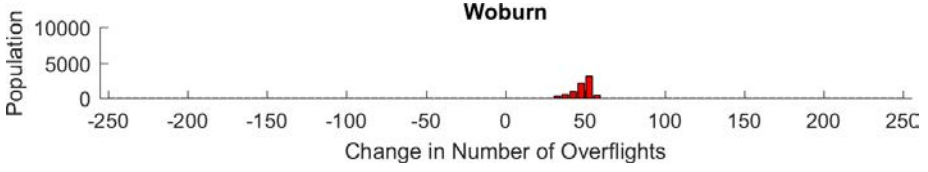












Effect of RNAV Concentration on 27 Departures 2010 to 2017