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May 3rd, 2018

Via Electronic Mail
David Carlon, Chairman
Massport Community Advisory Committee
dcarlonmcac@gmail.com

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

RE: *RNAV Presentation Provided to the Aviation Subcommittee on April 18th, 2017*

Dear Chairman Carlon and Subcommittee Chair Dormitzer:

As requested, please see the attached presentation deck. This presentation provided by MIT (Massport and the FAA's lead technical consultant) at the April 18th Massport CAC Aviation Subcommittee meeting includes material identified by MIT as "(a) preliminary example to evaluate methodology only (and) should not be considered a representative case."

We strongly urge the Massport CAC and its members to avoid drawing any specific conclusions from this preliminary material or using the material to advocate for or against any specific idea. We look forward to the Massport CAC providing Massport with feedback and further suggestions for evaluation as Block 2 progresses.

Sincerely,

Anthony J. Gallagher
Massport Community Relations

Cc: (Via Electronic Mail)
Flavio Leo, Elizabeth Becker

MIT International Center for Air Transportation

Block 2: Preliminary Procedure Design Input Meeting for Logan Airport Community Noise Reduction

R. John Hansman

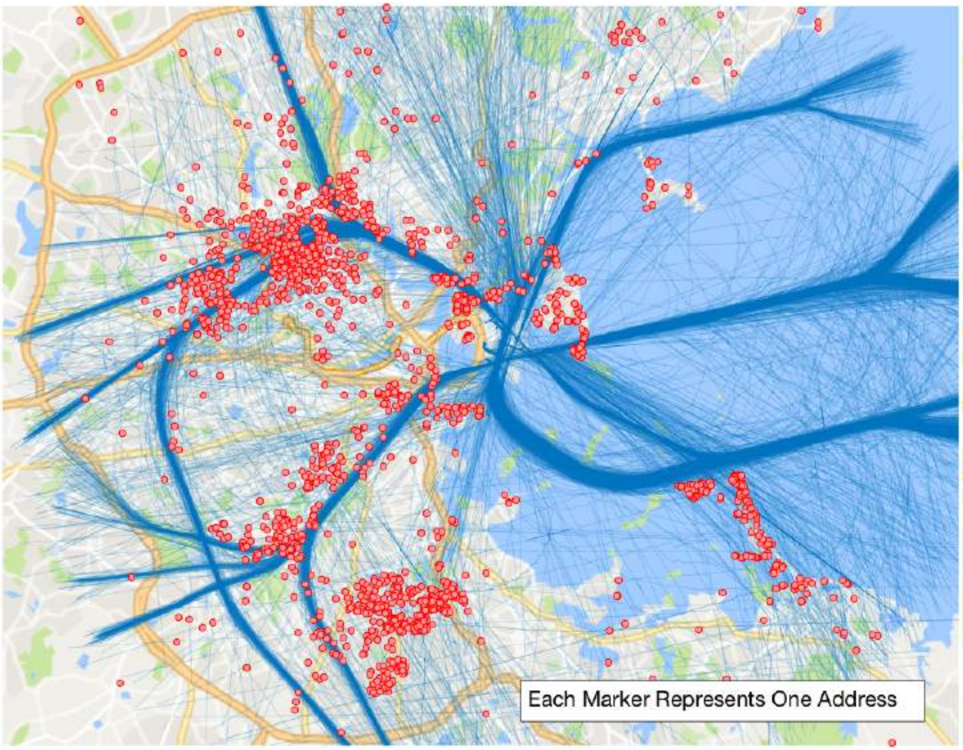
rjhans@mit.edu

Technical support from MIT ICAT students, HMMH, and Massport

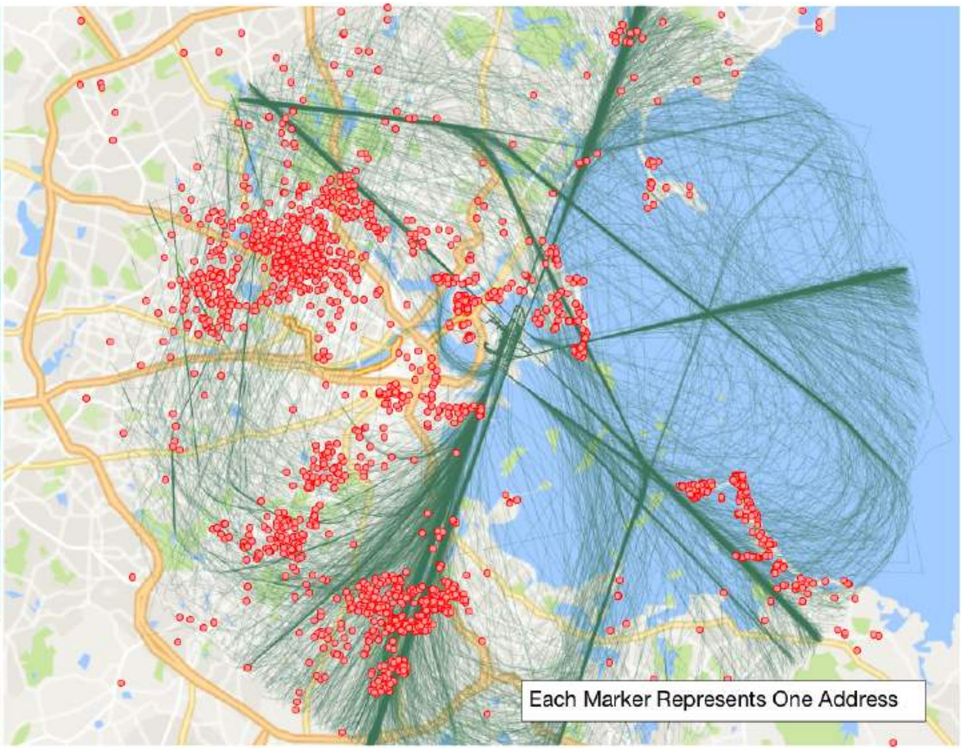
Noise Complaints at BOS: One Dot per Address

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

Departures



Arrivals



Complaint Data: August 2015– July 2016

Track Data: ASDE-X from 12 days of operation, 2015-2016

Technical Approach

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

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 2 Procedures Under Consideration

Block 2 Arrival Mods

- Low-noise overwater approach procedures
  - Runway 4L and/or 4R
    - RNAV approach with RNP Overlay
    - RNP approach
  - Runway 22L
    - RNAV approach with RNP Overlay
- Steep approaches
  - All runways
- Dispersion
  - Runway 4L/4R
    - Set of procedures rotated by time, day, or other method
    - Dispersion generated through random process
- **Additional suggestions?**

Block 2 Departure Mods

- Dispersion
  - Runway 33L and 27
  - Open SID or direct-to flexibility for ATC on RNAV procedures
- **Additional suggestions?**

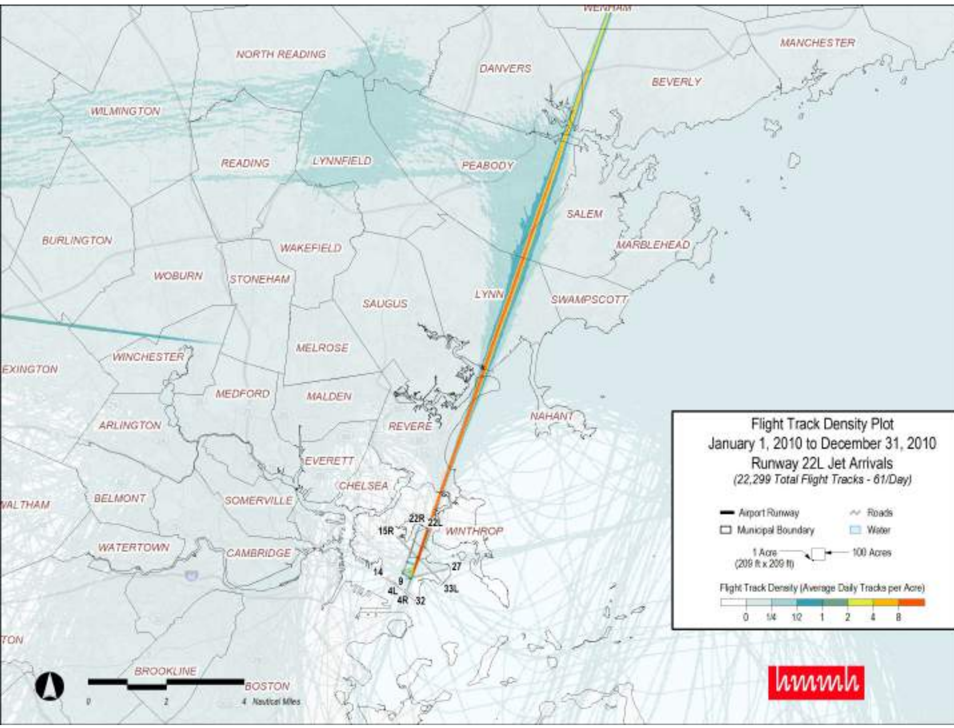
Preliminary/Subject to Change

Runway 22L & 4R Arrivals

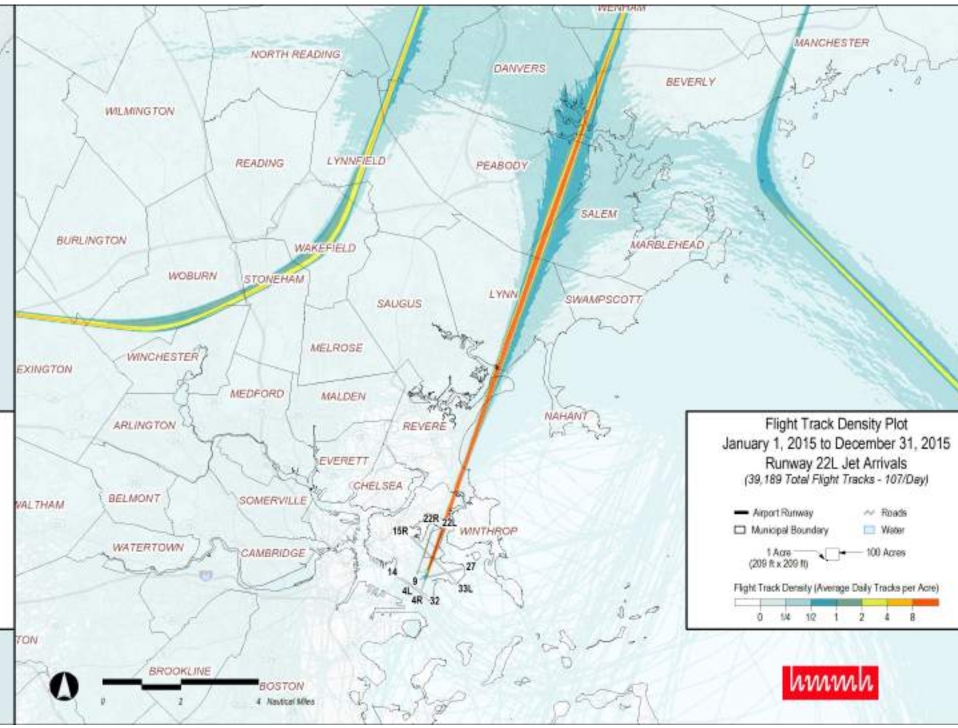
Low-Noise Overwater Approach Procedures

Runway 22L Arrivals: 2010-2015

2010



2015



Vertical Guidance vs. Non-Vertical Guidance Procedures

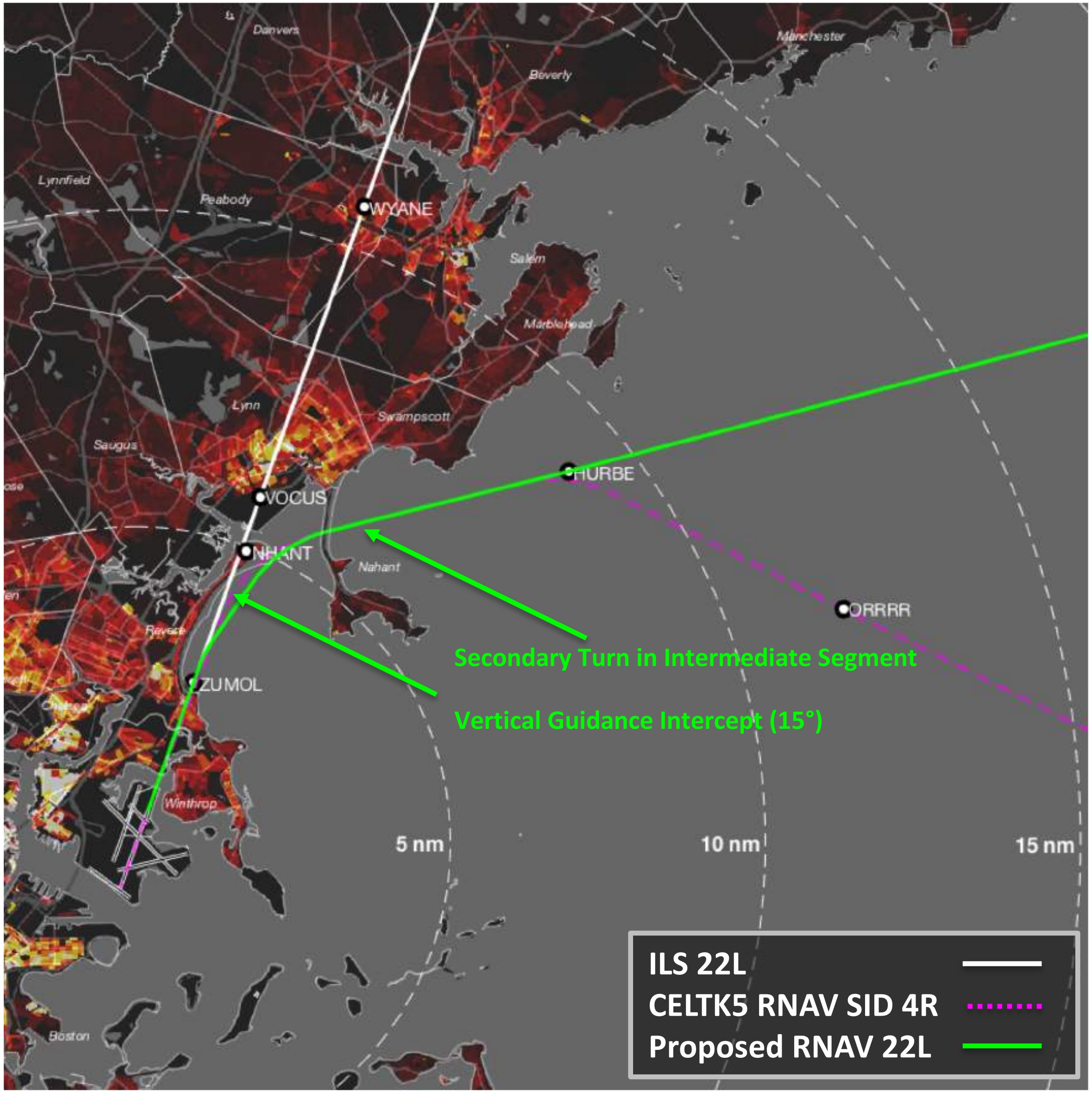
Procedure Type	Minimum Final Level Segment Length	Maximum Final Approach Intercept Angle
RNAV (Vertical Guidance) **LPV** **LNAV/VNAV**	Distance where Glidepath Angle intercepts Intermediate Segment minimum altitude	15° at Final Approach Fix
RNAV (Non-Vertical Guidance) **LP** **LNAV**	Distance where Visual Descent Angle intercepts Intermediate Segment minimum altitude	30° at Final Approach Fix
RNP	Final Rollout at farthest of: • 500' altitude • 15 or 50 seconds before Decision Altitude (depending on RNP level)	Radius to Fix Turn from Final Approach Fix to Rollout Point

22L Low-Noise Offset RNAV Approach with RNP Overlay

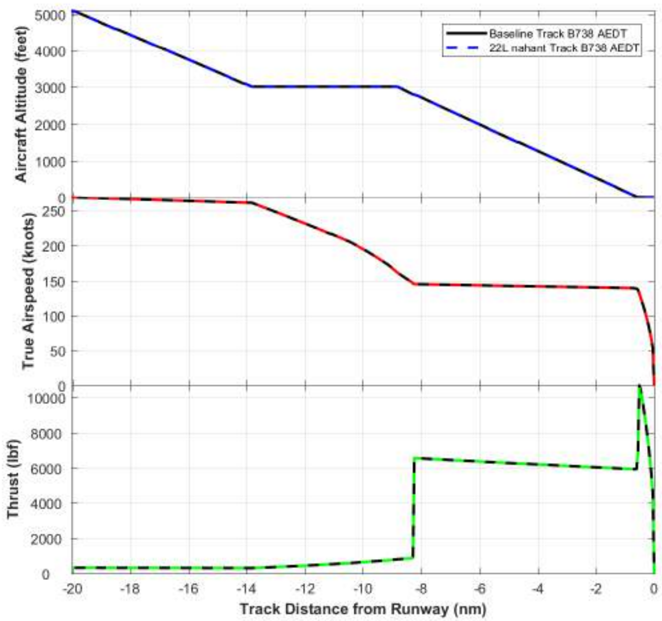
Overlaying arrival corridor on existing 4R RNAV SID for 22L arrivals

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 Low-Noise Offset RNAV Approach with RNP Overlay: Noise Exposure

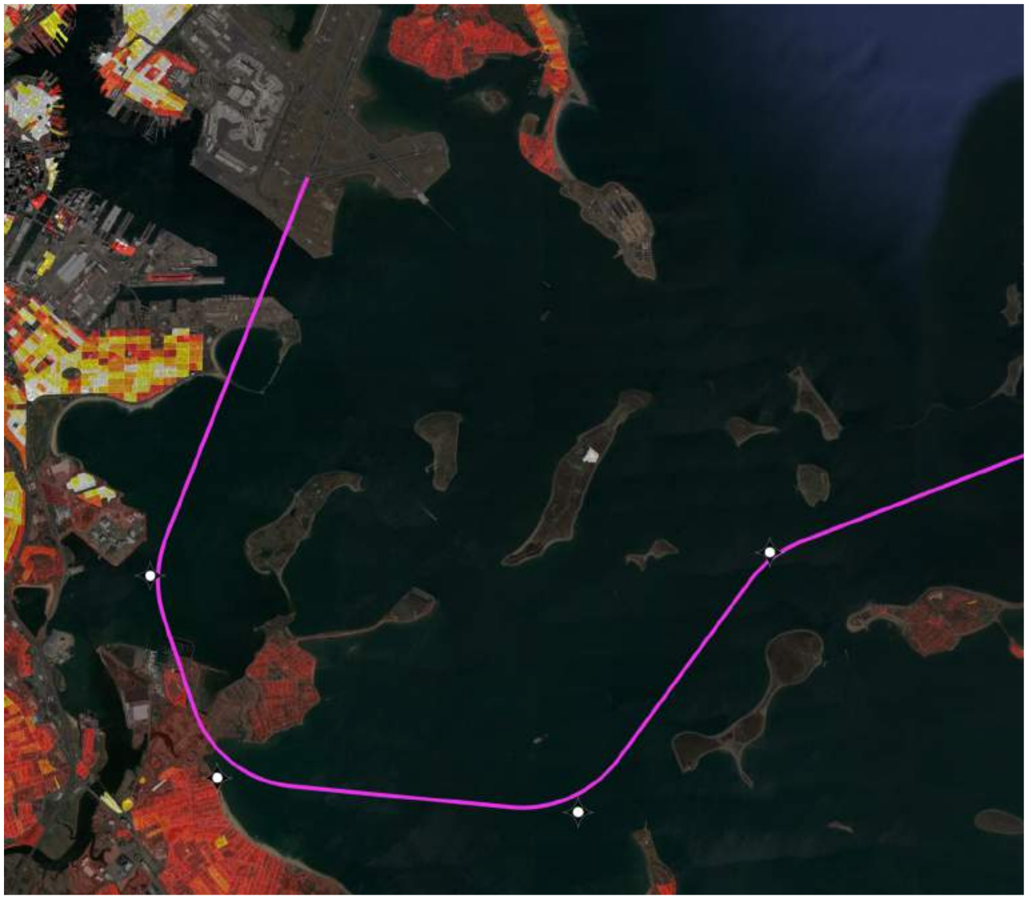


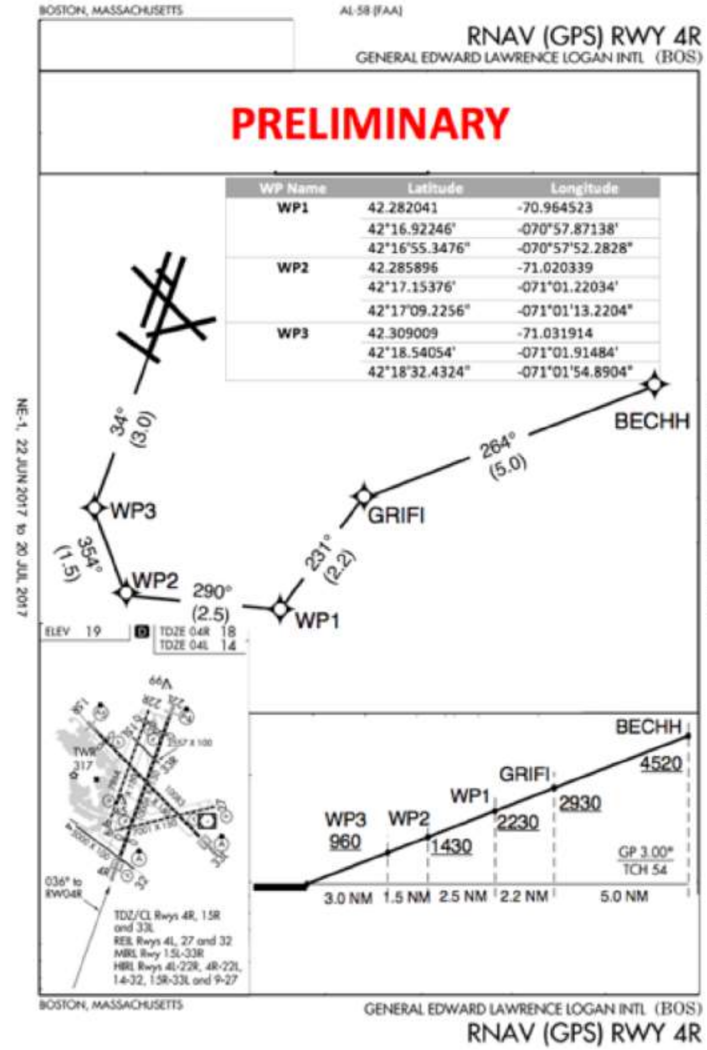
Population Exposure (L_{MAX})

	60dB	65dB	70dB
Straight In	82,162	36,698	7,609
Modified Procedure	27,547	14,816	7,362
Reduction	54,615	21,882	247

Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	AEDT
Notes	Standard AEDT arrival profile

4R Low-Noise Overwater RNAV Approach with RNP Overlay

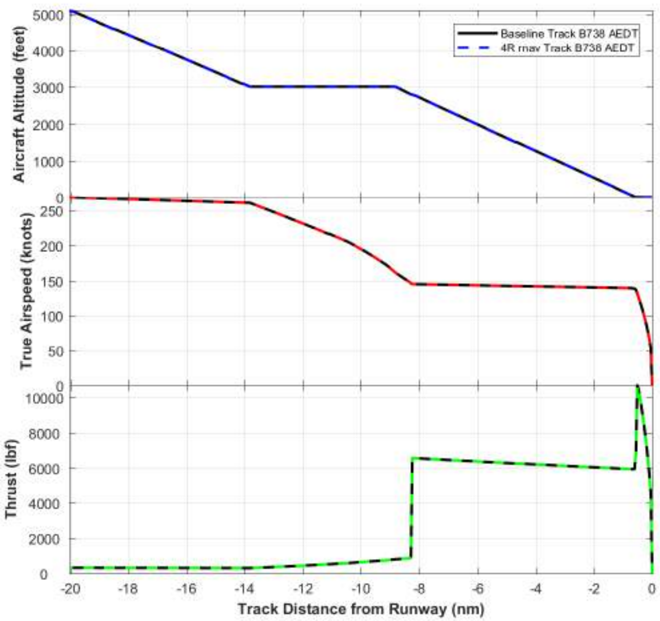


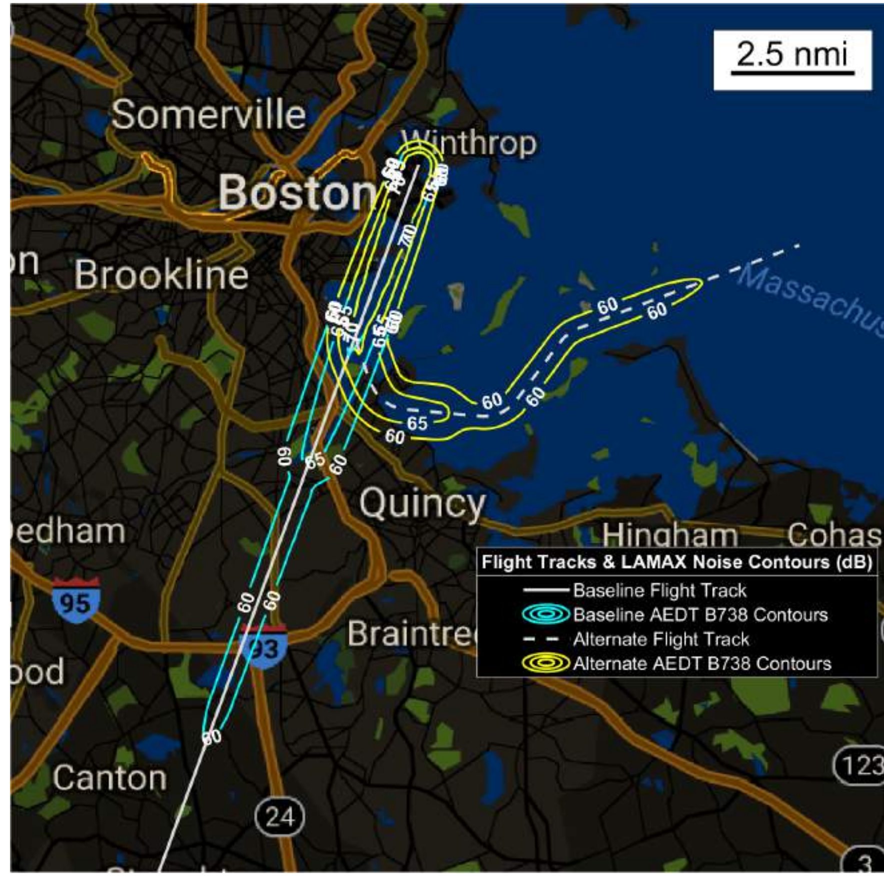


WP Name	Latitude	Longitude
WP1	42.282041	-70.964523
	42°16.92246'	-070°57.87138'
	42°16'55.3476"	-070°57'52.2828"
WP2	42.285896	-71.020339
	42°17.15376'	-071°01.22034'
	42°17'09.2256"	-071°01'13.2204"
WP3	42.309009	-71.031914
	42°18.54054'	-071°01.91484'
	42°18'32.4324"	-071°01'54.8904"

- **Advantage of overwater approach**
- **Known issue of concern regarding initial approach path**

4R Low-Noise Overwater RNAV Approach with RNP Overlay: Noise Exposure





Population Exposure (L_{MAX})

	60dB	65dB	70dB
Straight In	30,239	7,468	530
Modified Procedure	18,283	5,792	529
Reduction	11,956	1,676	1

Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	AEDT
Notes	Standard AEDT arrival profile

Canarsie RNAV (RNP) Special

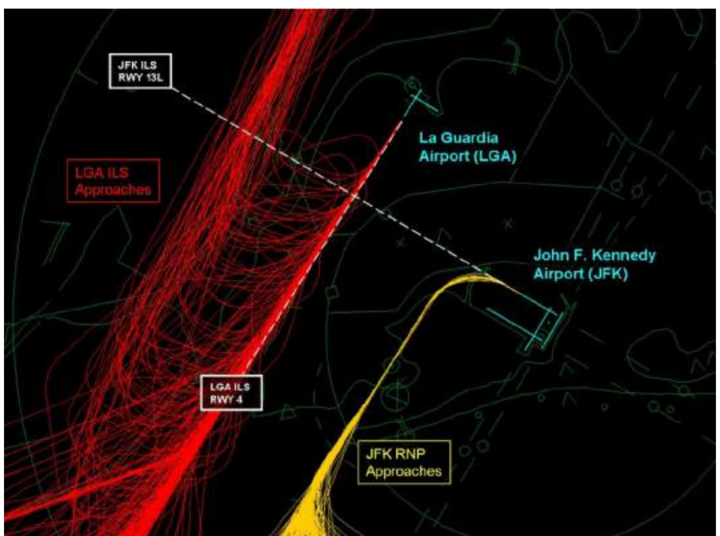
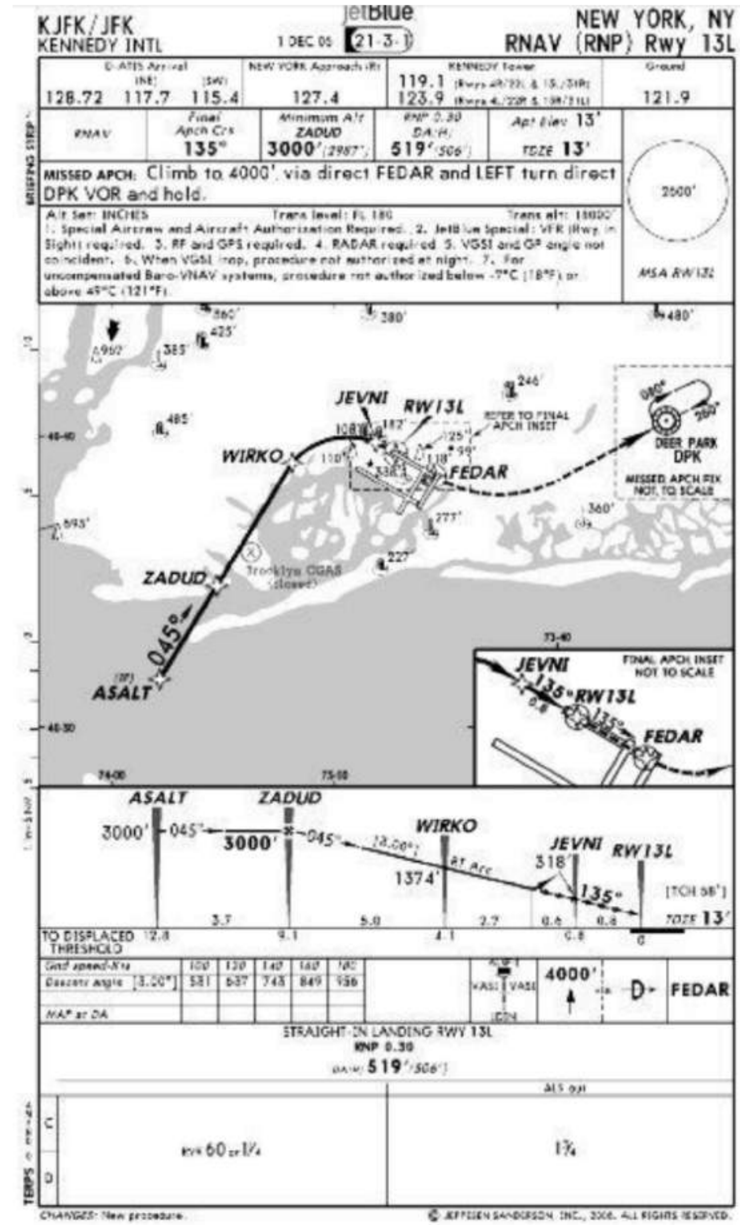
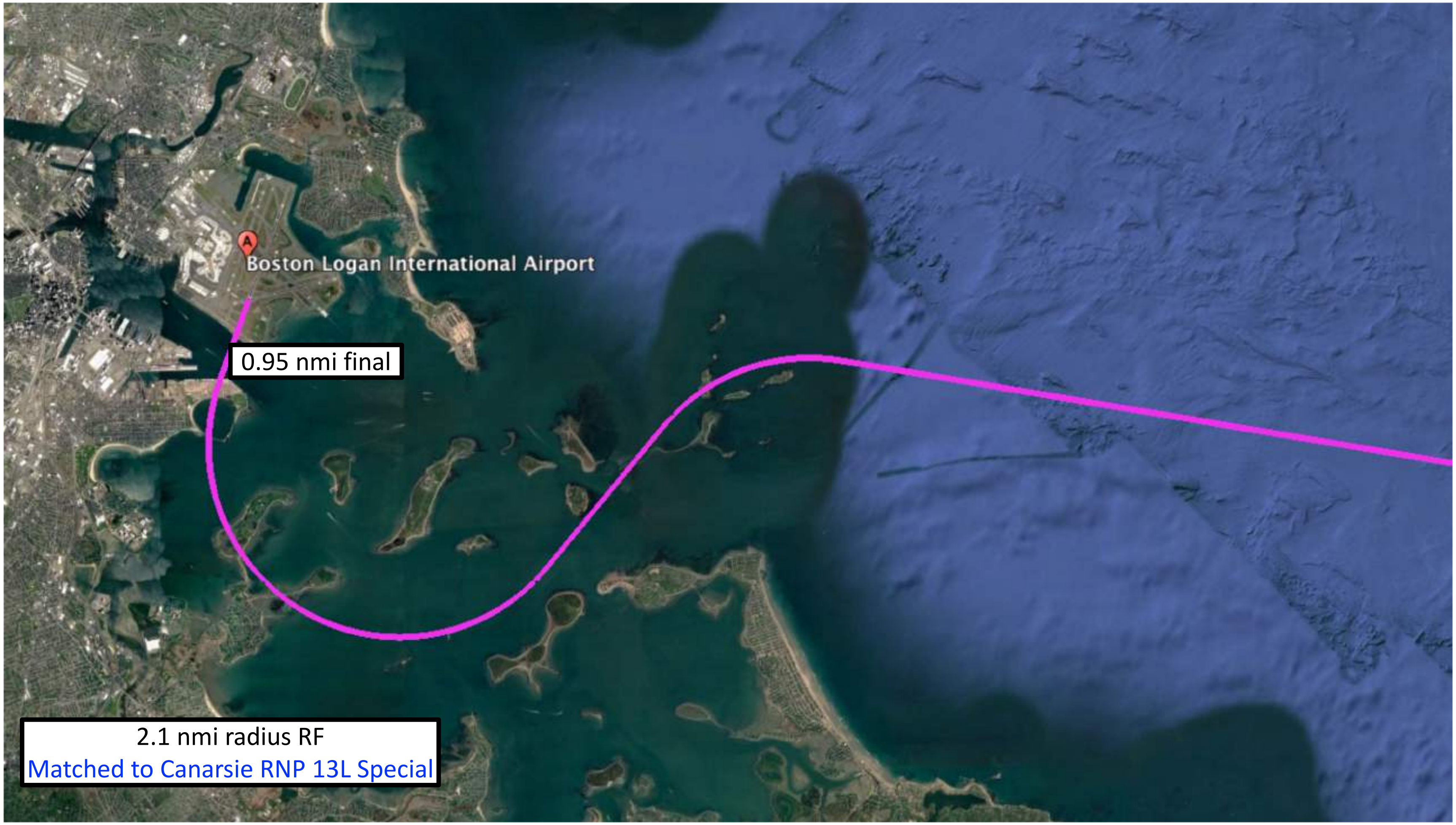


Figure: Honeywell

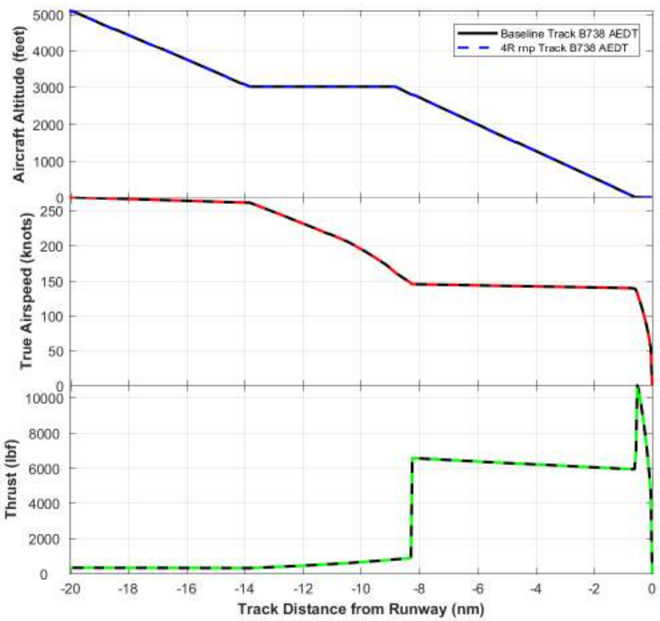


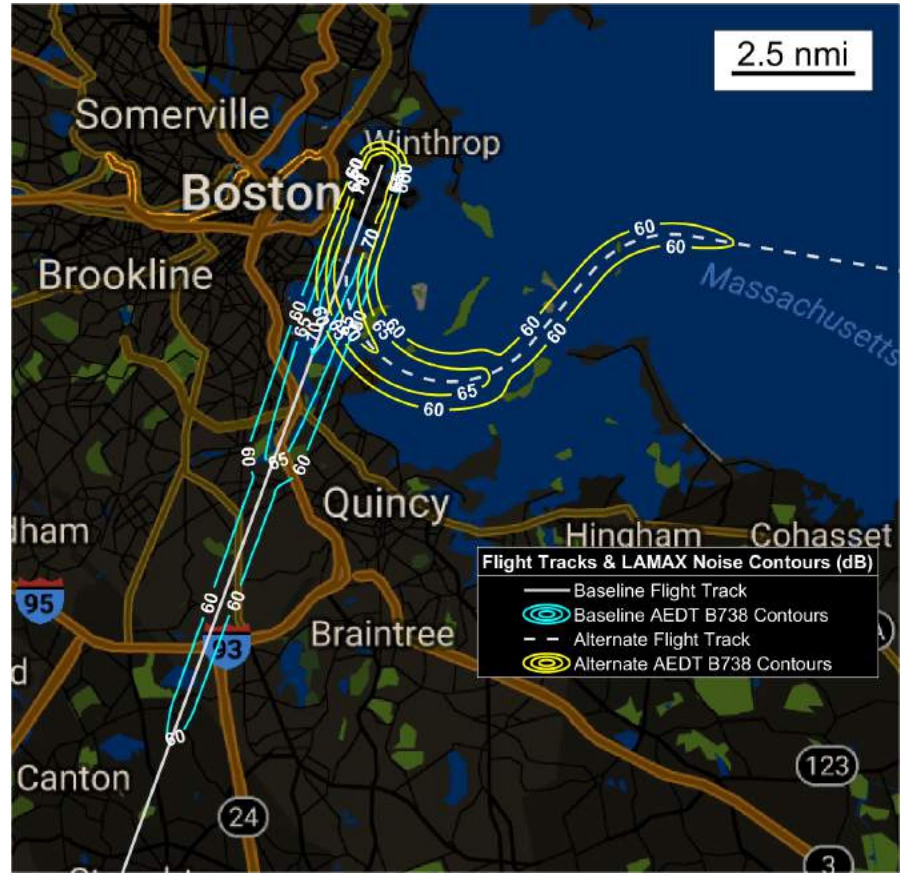
Notional Low-Noise Overwater RNP: BOS Rwy 4R



- **Advantage of overwater approach**
- **Known issue of concern regarding initial approach path**
- **RNP adds additional flexibility vs RNAV, but lower equipage levels**

4R Low-Noise Overwater RNP Approach: Noise Exposure





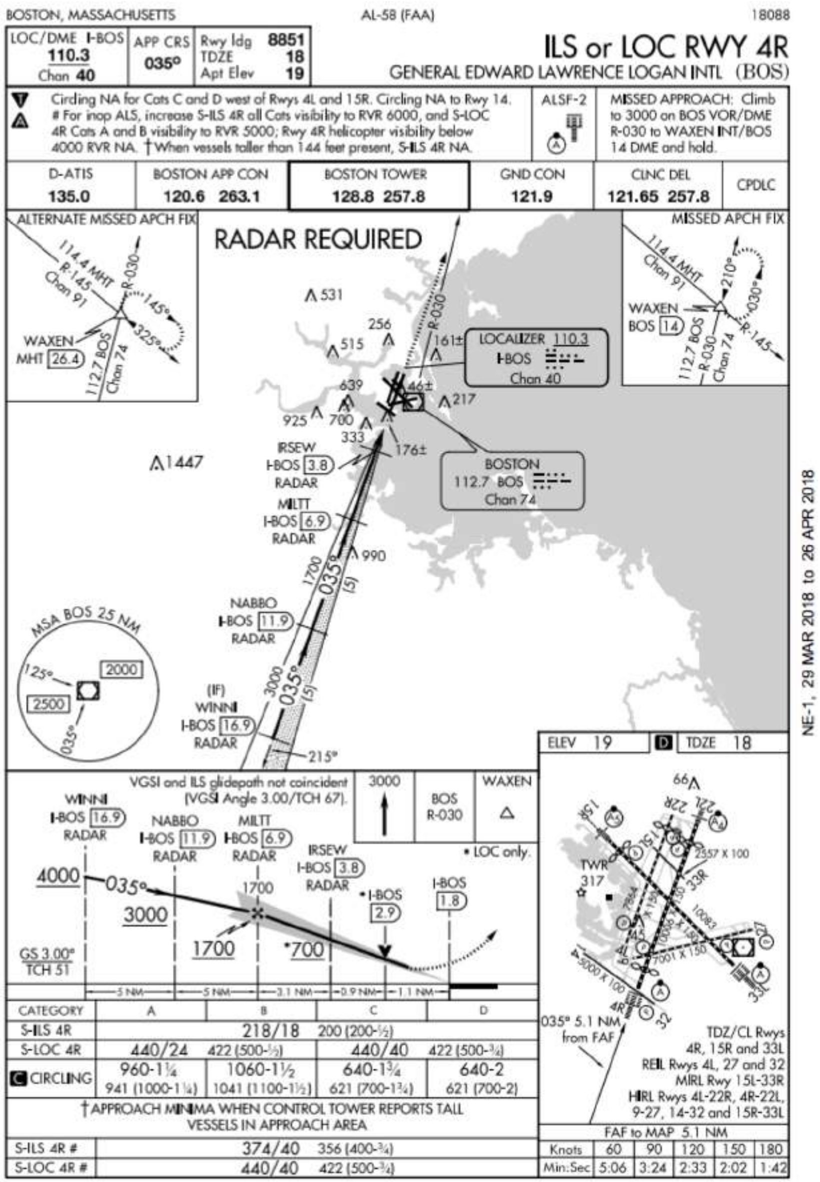
Population Exposure (L_{MAX})

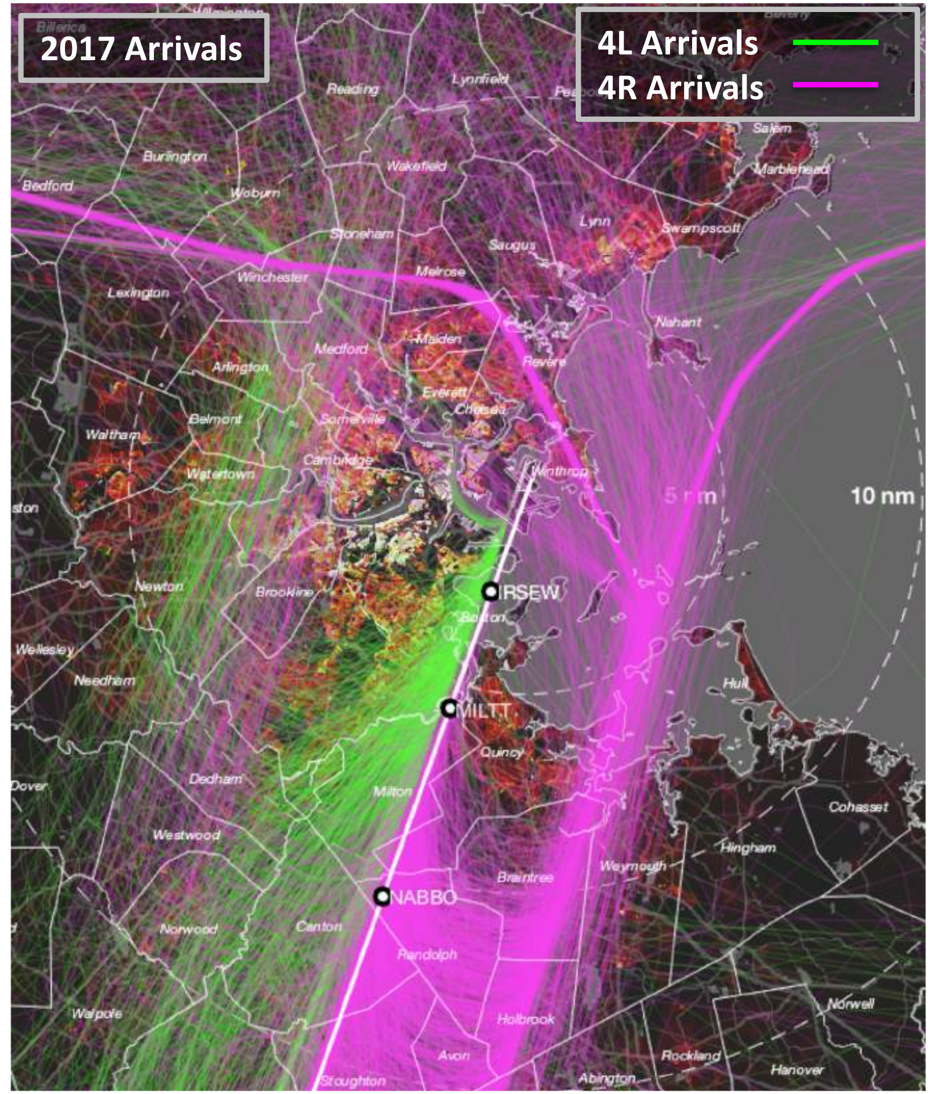
	60dB	65dB	70dB
Straight In	30,239	7,468	530
Modified Procedure	6,887	2,161	0
Reduction	23,352	5,307	530

Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	AEDT
Notes	Standard AEDT arrival profile

Continuous Descents and Steeper Approaches

ILS Runway 4R

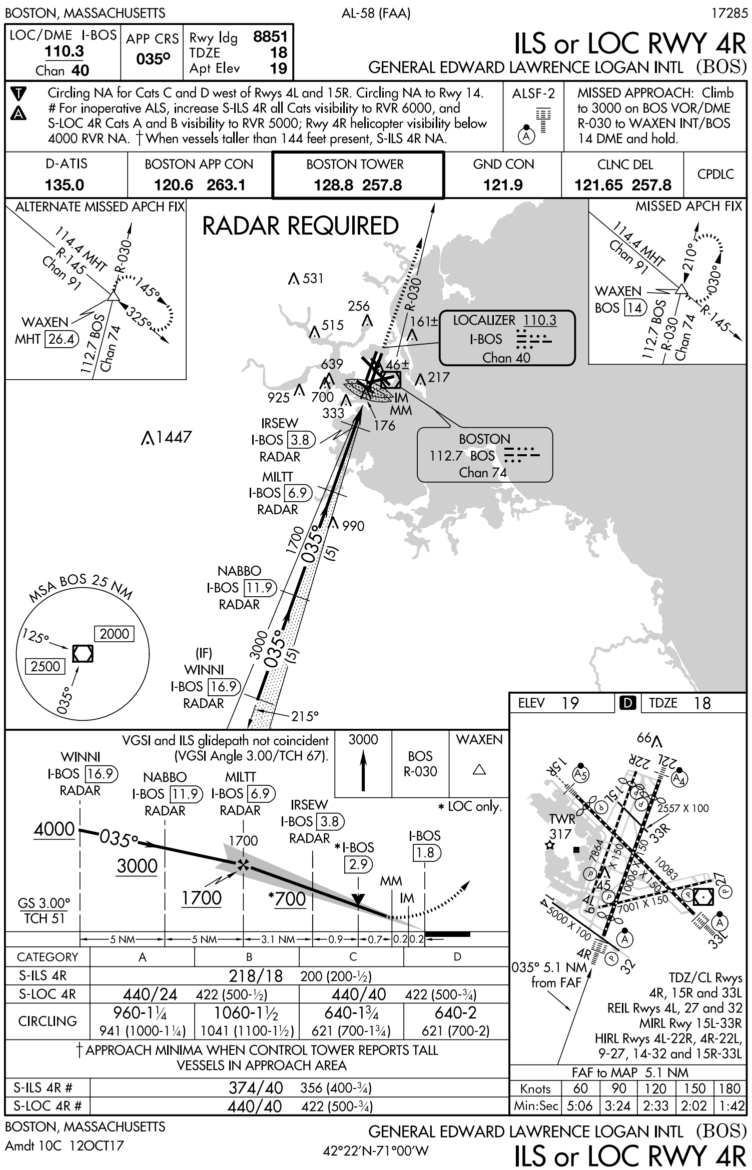




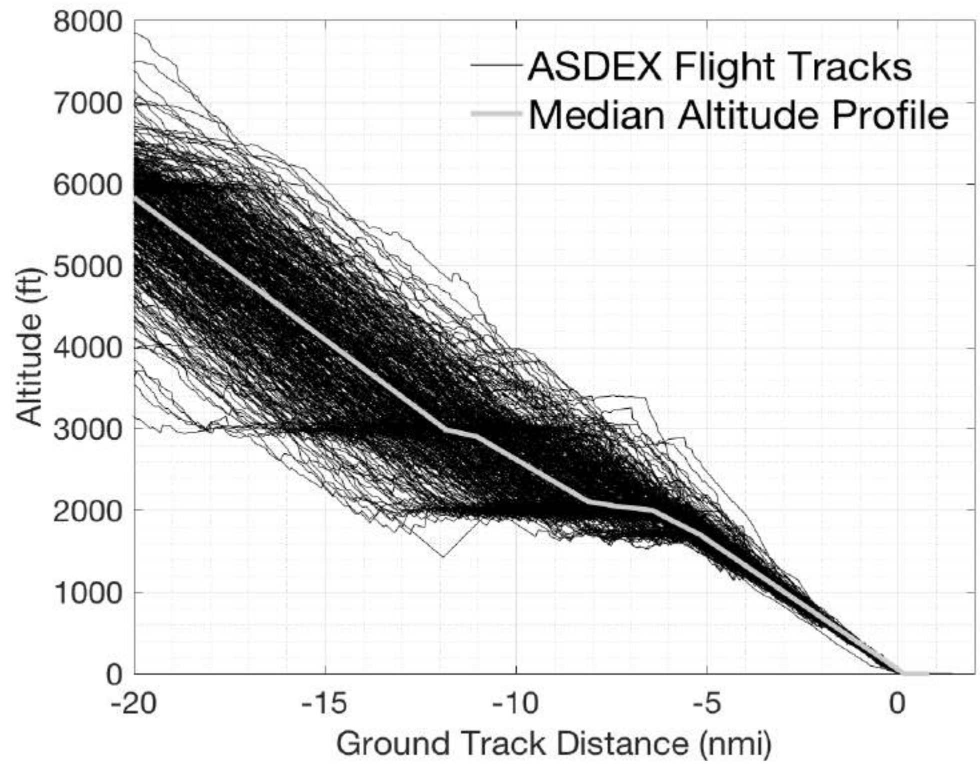
Notes:

- 2017 Arrival Counts (jet & prop): Rwy 4R: 39,615 Rwy 4L: 12,311
- Figure shows 10% of all 2017 arrivals selected at random
- Data Source: Flight Tracks, Massport Noise and Operations Management System (NOMS)

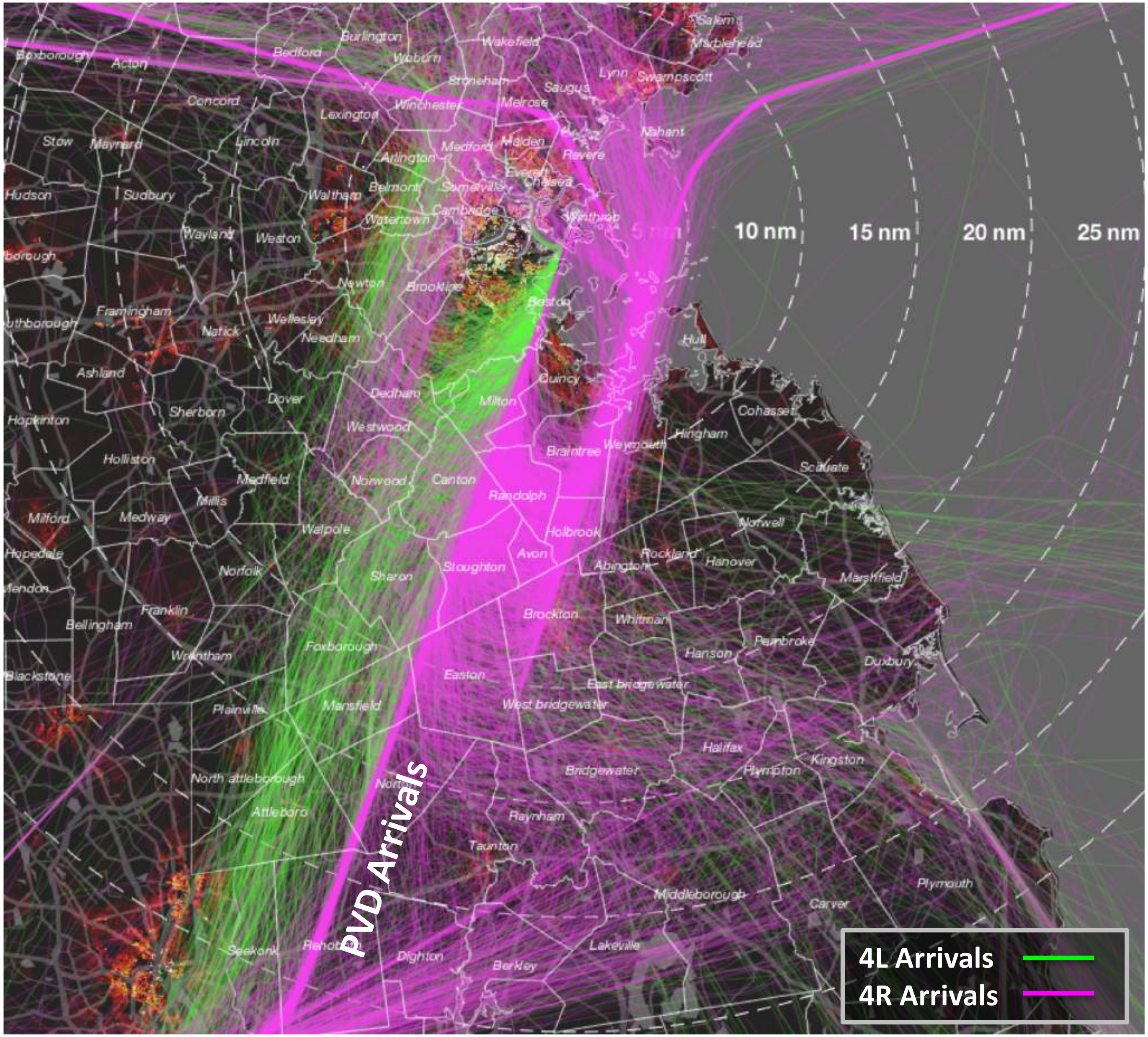
Baseline Altitude Profile from 2015/2016 ASDEX Radar Profile



ASDEX-All A320s on 4R (20 days of data)



Baseline: 2017 Arrivals to Runway 4L and 4R



Notes:

- 2017 Arrival Counts (jet & prop):
  - Rwy 4R: 39,615
  - Rwy 4L: 12,311
- Figure shows 10% of all 2017 arrivals selected at random
- Data Source: Flight Tracks, Massport Noise and Operations Management System (NOMS)

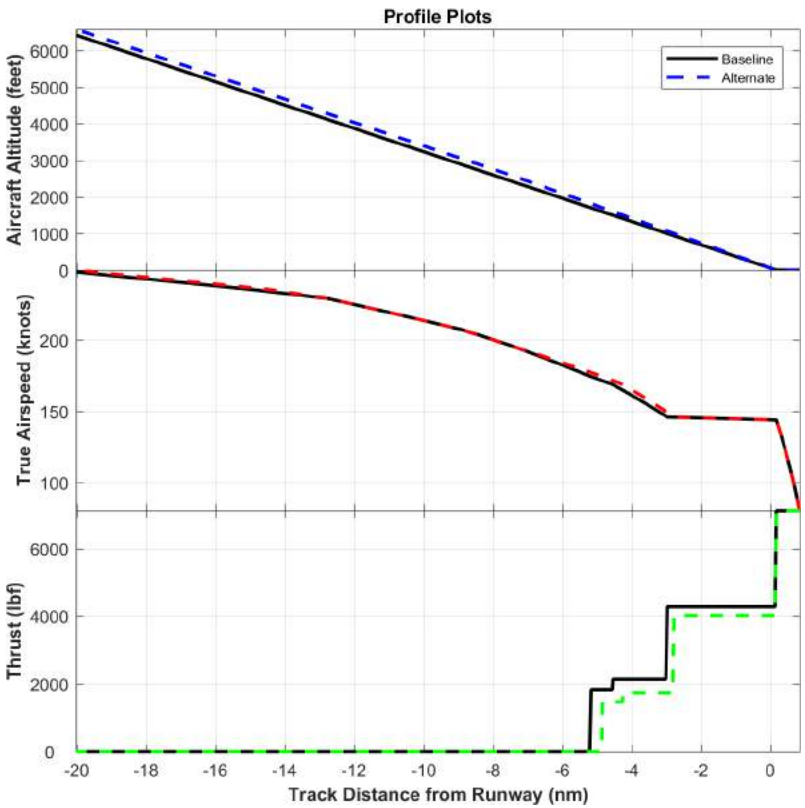
Comparison of Continuous Steep Approach Profiles

Case 1: Compare benefits of continuous descent vs. benefits of steeper glide path angle

3.2^{o} Continuous Descent

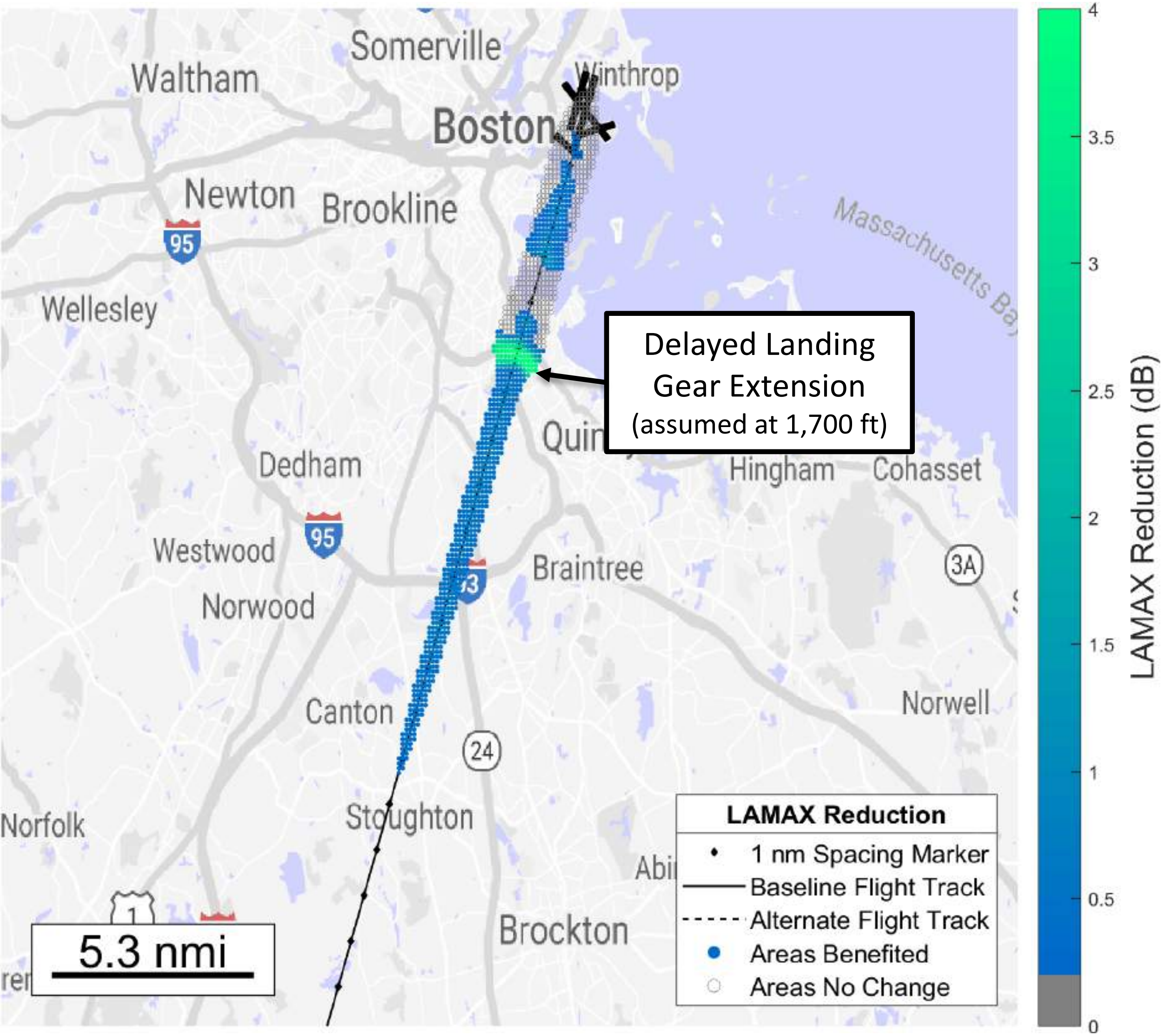
vs

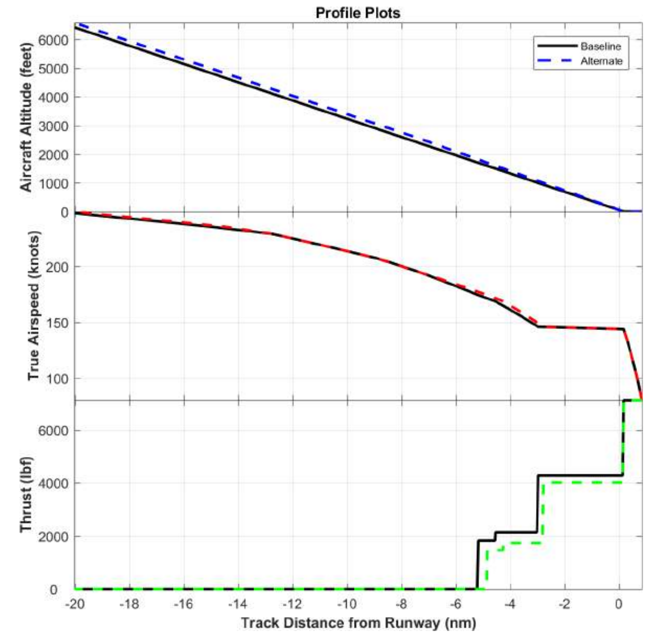
3.0^{o} Continuous Descent



3.2^{o} is the maximum approach angle for an RNAV approach

3.2^0 Continuous Descent vs 3.0^0 Continuous Descent LAMAX Reduction





Population Exposure

LAMAX Reduction	Population Exposure
4dB	415
3dB	3,236
2dB	4,817
1dB	6,204

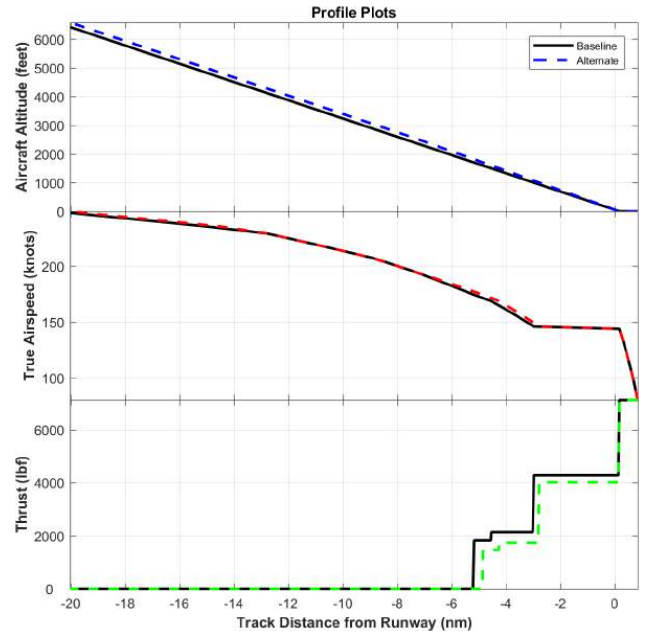
Illustration example only to evaluate methodology. Should not be considered representative case.

3.2^0 Continuous Descent vs 3.0^0 Continuous Descent LAMAX Exposure

- Population exposure reduction at each noise level

Population Exposure

$L_{A,max}$	50 dB	55 dB	60 dB
Baseline 3.0°	136,352	72,385	27,953
Alternate 3.2°	133,096	69,003	25,440
Reduction	3,256	3,382	2,513



50dB LAMAX Areas Benefited

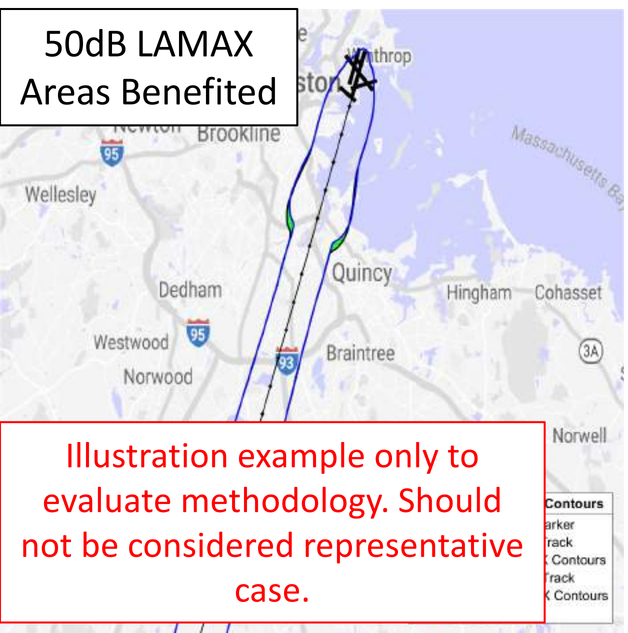
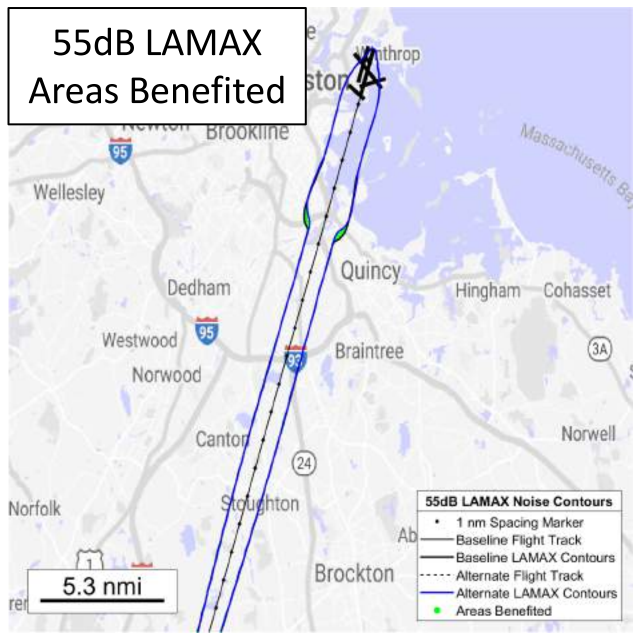
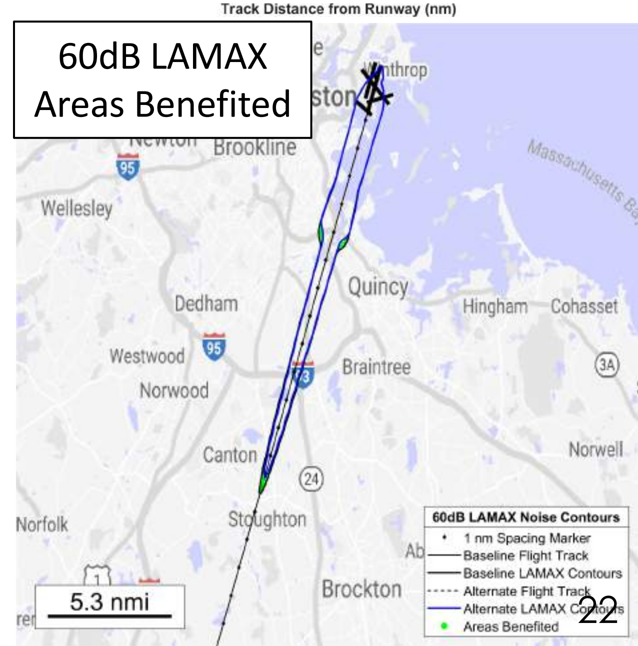


Illustration example only to evaluate methodology. Should not be considered representative case.

55dB LAMAX Areas Benefited



60dB LAMAX Areas Benefited



Safety Concerns - High-Energy Approaches

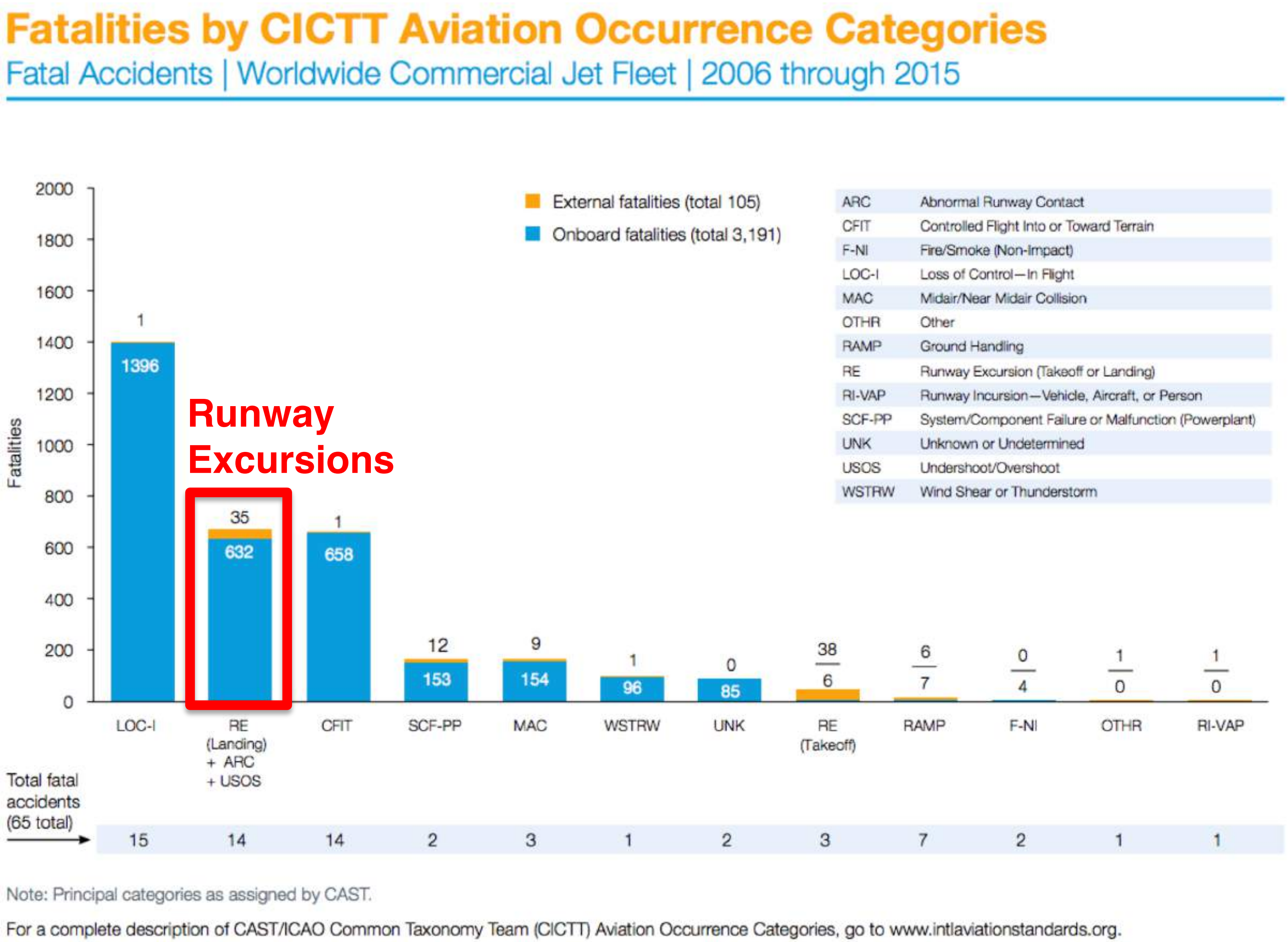
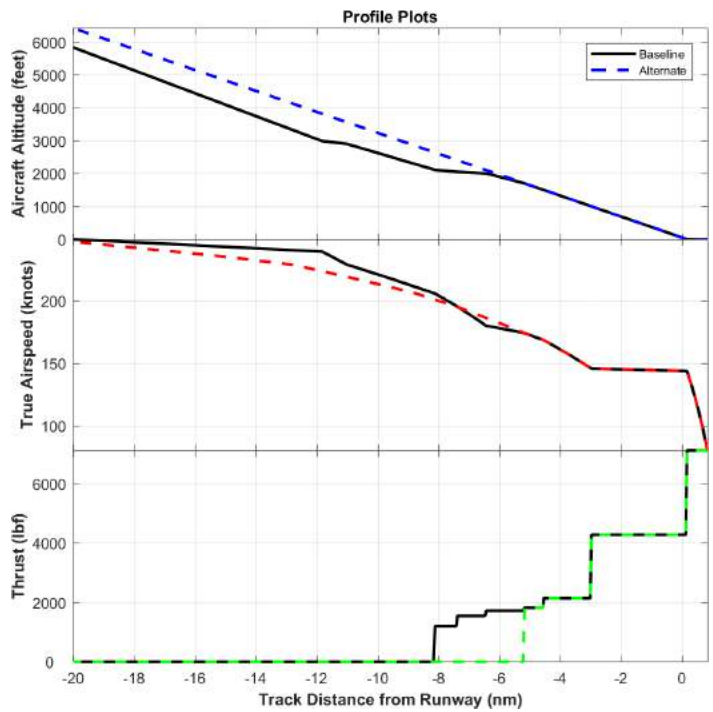


Figure source: The Boeing Company http://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf

Continuous Descent Profiles

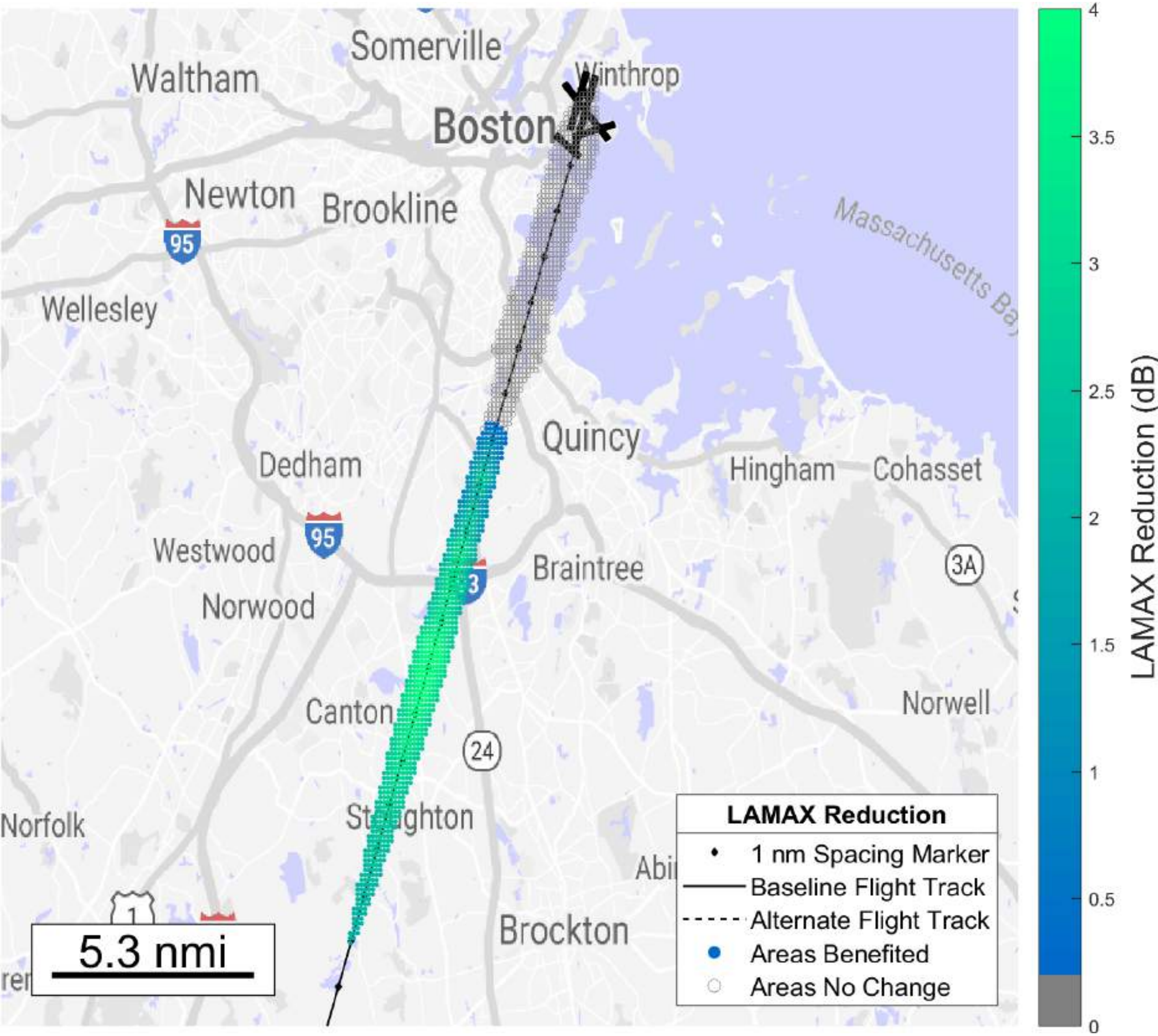
Case 2: Maintain current glide path angle **without** level-off segments

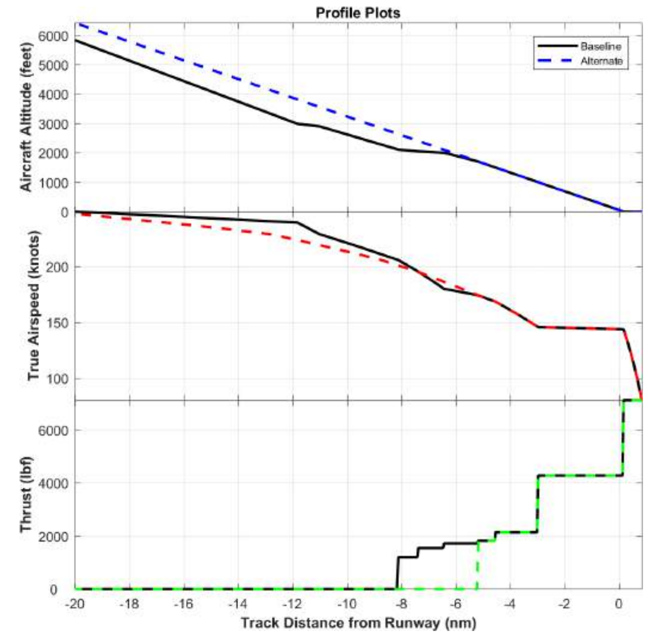
3.0^{o} Continuous Descent
vs
Baseline Stepped Descent



Baseline approach profiles from straight-in arrivals from PVD
Baseline altitude profile from 2015/2016 ASDE-X Radar Profile

3.0° Continuous Descent vs Baseline Stepped Descent LAMAX Reduction





Population Exposure

LAMAX Reduction	Population Exposure
4dB	445
3dB	3,023
2dB	8,502
1dB	10,210

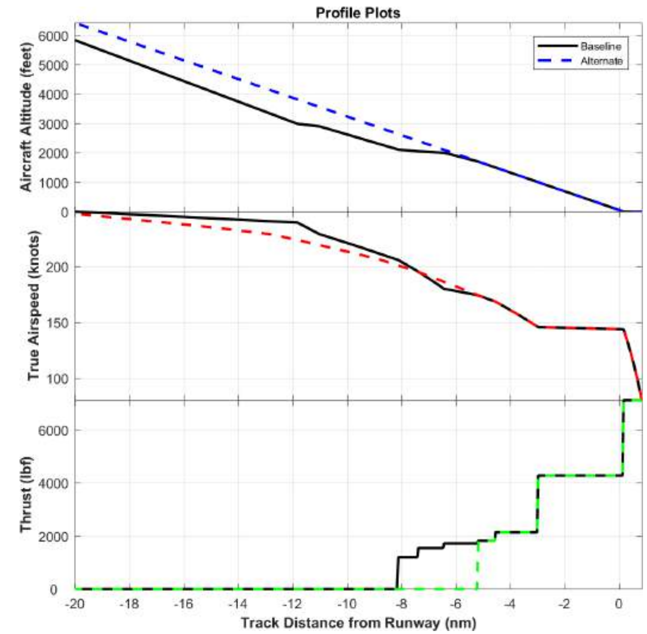
Illustration example only to evaluate methodology. Should not be considered representative case.

3.0⁰ Continuous Descent vs Baseline Stepped Descent LAMAX Exposure

- Population exposure reduction at each noise level

Population Exposure

$L_{A,max}$	50 dB	55 dB	60 dB
Baseline ASDEX	140,466	76,578	34,699
Alternate 3.0°	136,352	72,385	27,953
Reduction	4,114	4,193	6,746



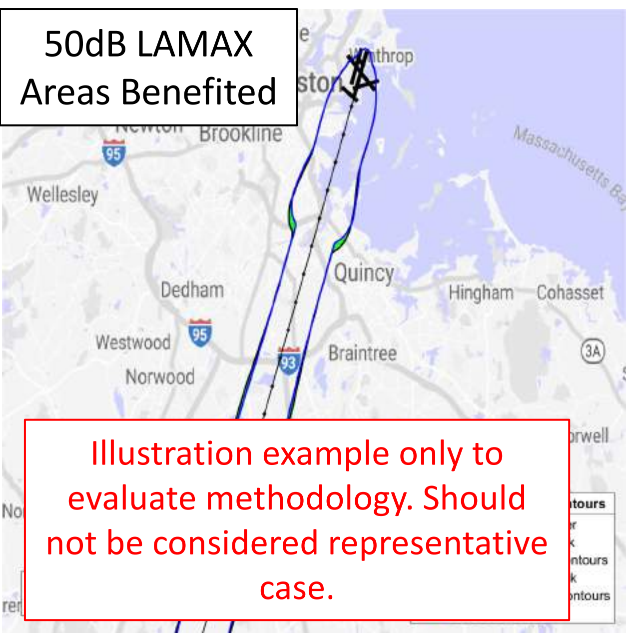
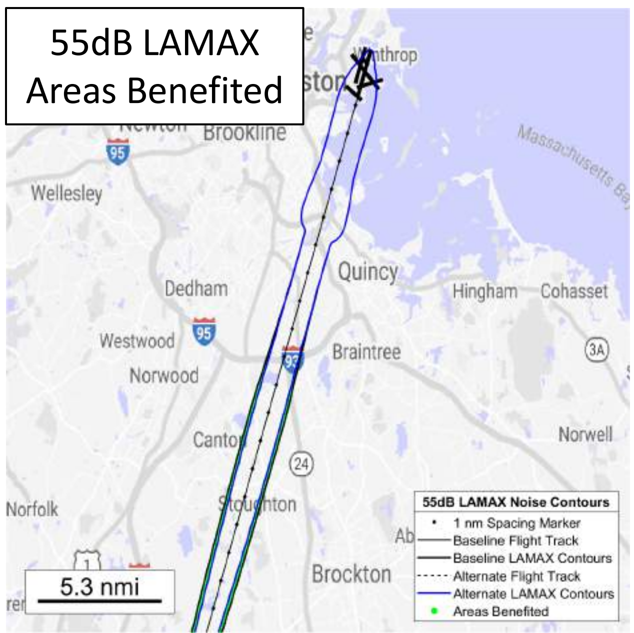
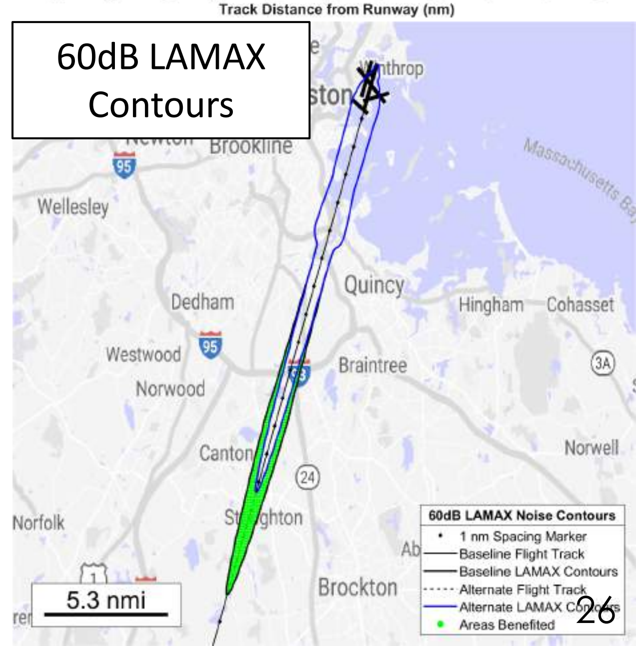


Illustration example only to evaluate methodology. Should not be considered representative case.

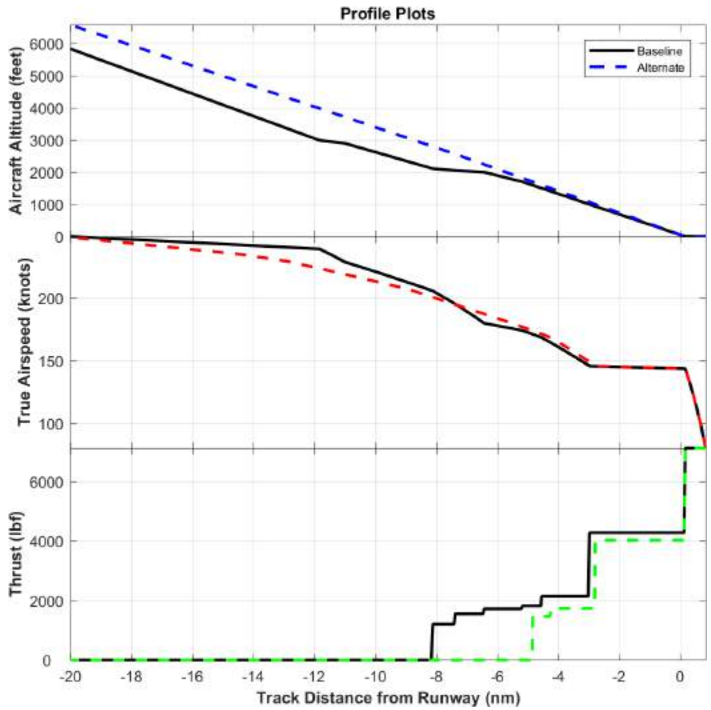




Steeper (3.2^0) Continuous Descent Profiles

Case 3: Steepen glide path angle
to max allowable (for ILS)
without level-off segments

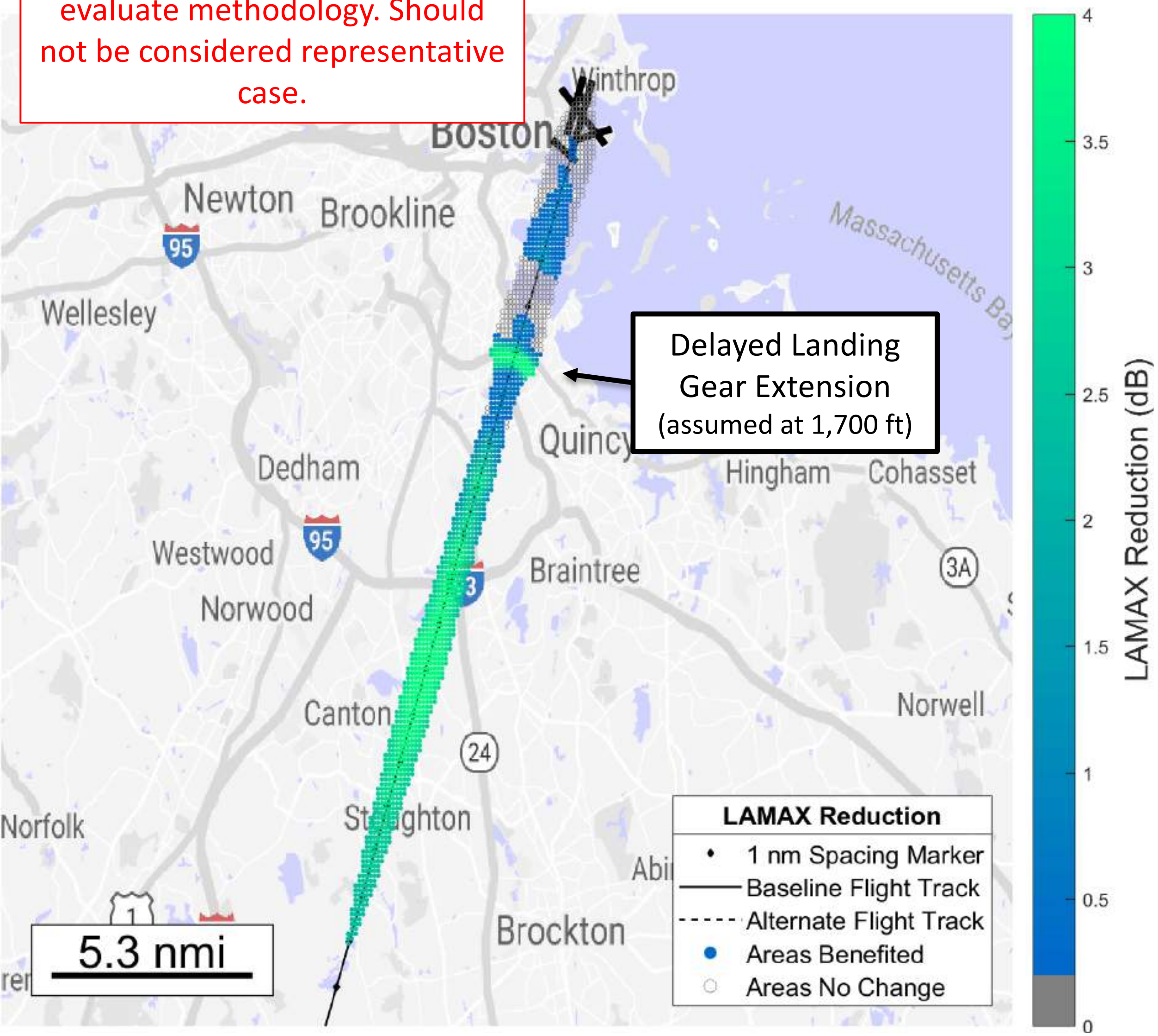
3.2^{o} Continuous Descent
vs
Baseline Stepped Descent

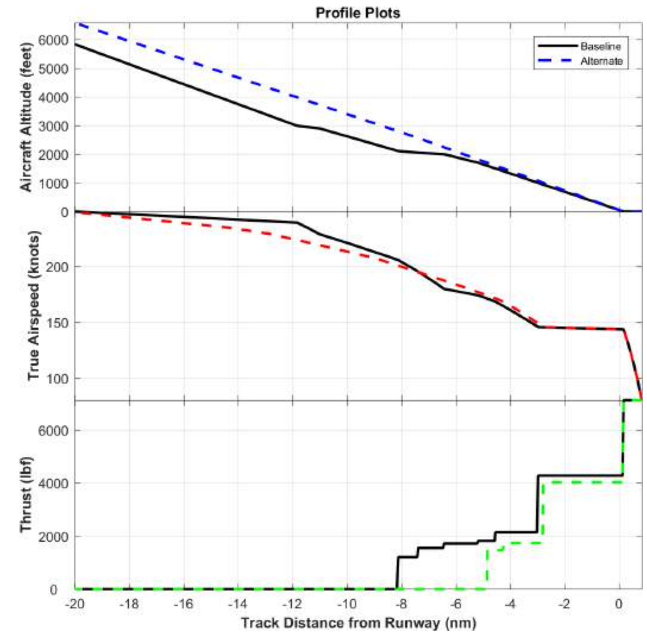


Baseline approach profiles from straight in arrivals from PVD

3.2⁰ Continuous Descent vs Baseline Stepped Descent LAMAX Reduction

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





Population Exposure

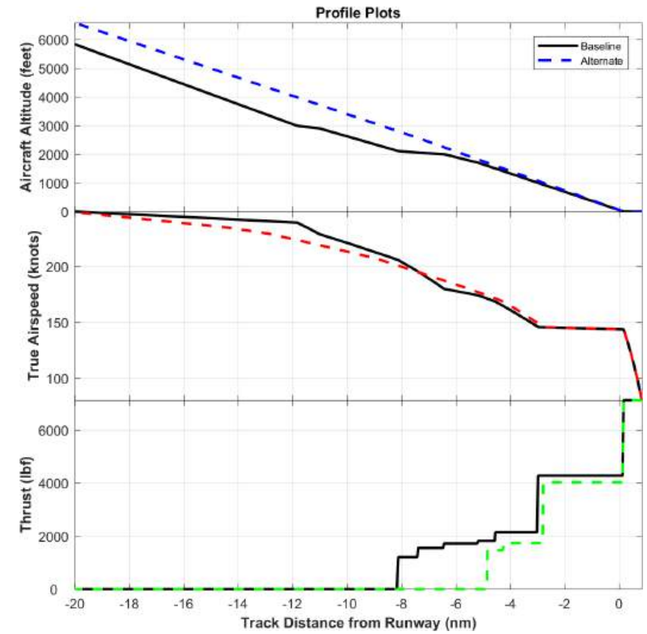
LAMAX Reduction	Population Exposure
4dB	1,435
3dB	8,248
2dB	14,206
1dB	17,512

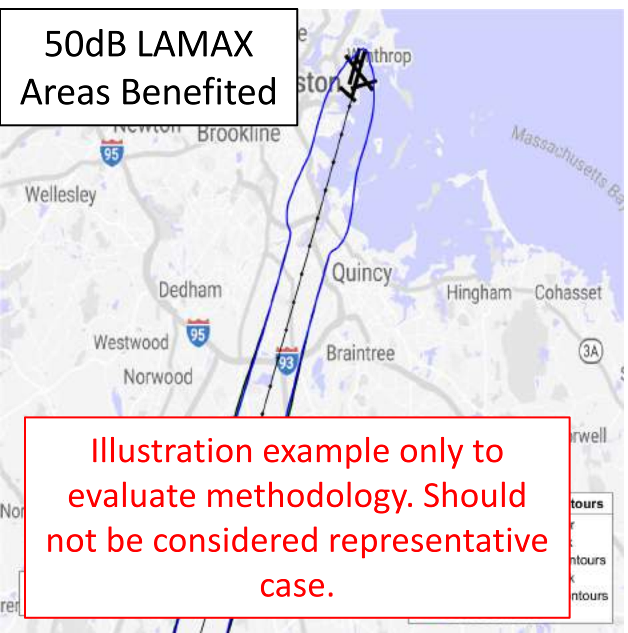
3.2⁰ Continuous Descent vs Baseline Stepped Descent LAMAX Exposure

- Population exposure reduction at each noise level

Population Exposure

$L_{A,max}$	50 dB	55 dB	60 dB
Baseline ASDEX	140,466	76,578	34,699
Alternate 3.2⁰	133,096	69,003	25,440
Reduction	7,370	7,575	9,259





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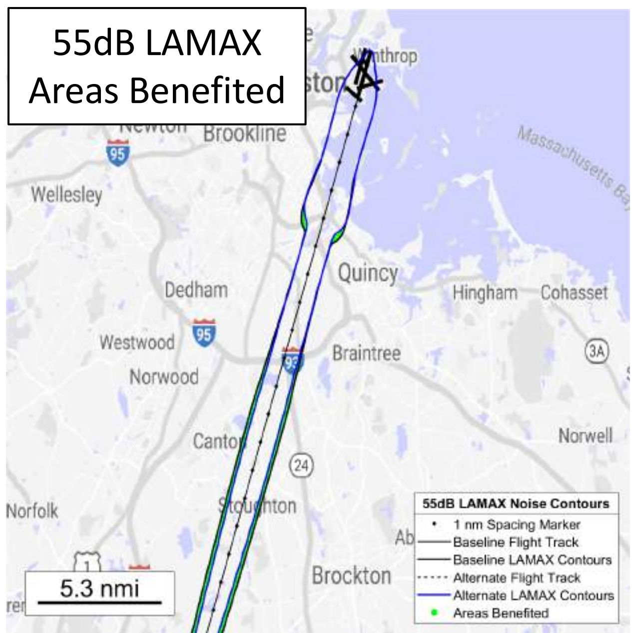
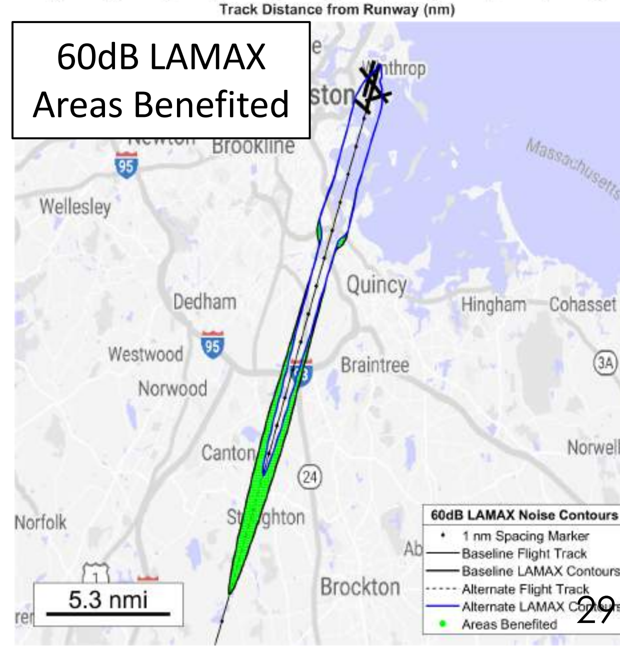




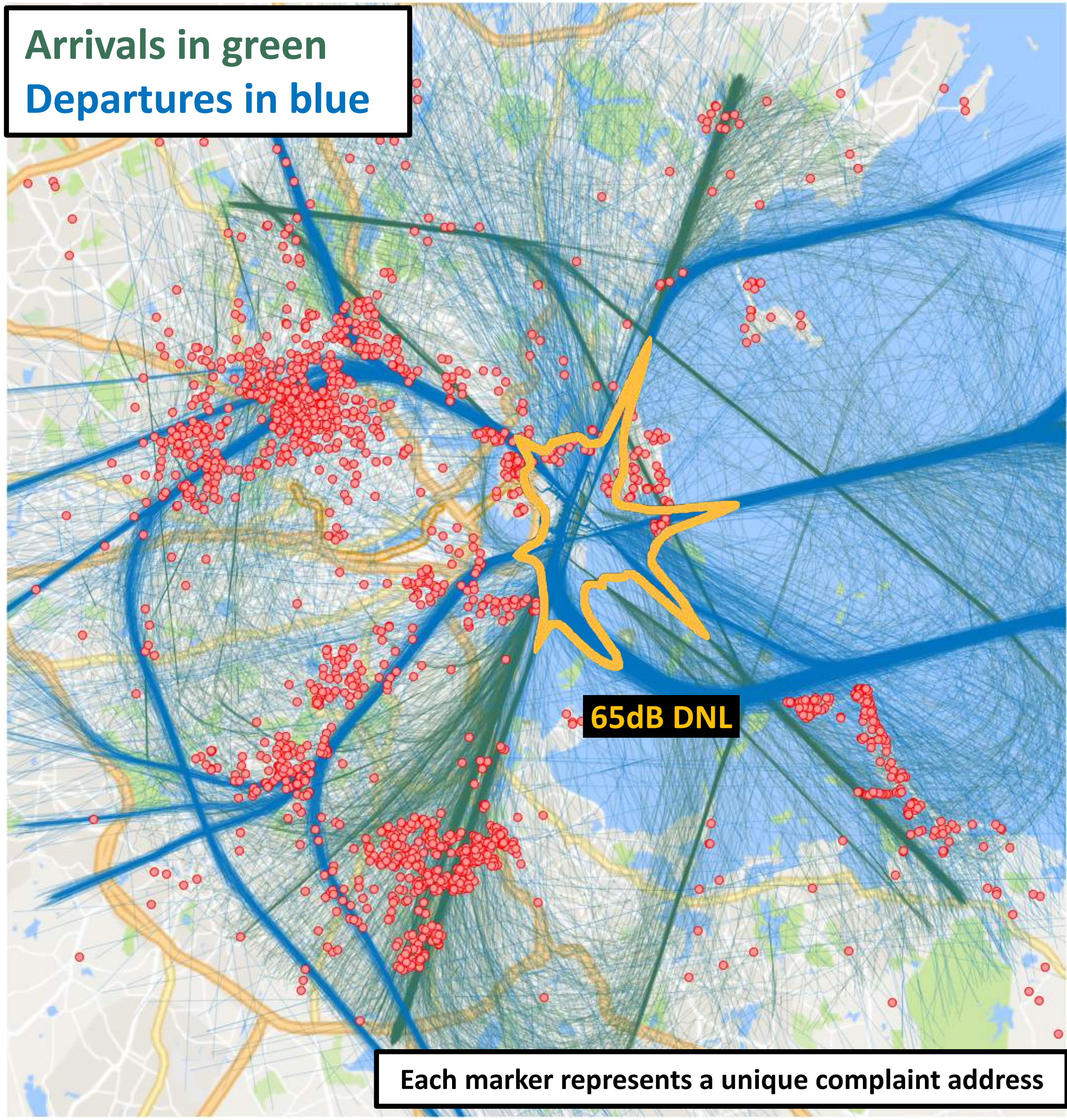
Dispersion

Preliminary Approach for Analysis

Need metrics and analysis which consider cumulative effects of multiple overflights

Complaint Data and Annual Average DNL

- Current US federal regulation definition of significant noise exposure, 65dB Annual Average DNL, does not sufficiently capture complaint data from frequent, low-noise events
- Is there a metric/threshold that does better?
  - Application for dispersion analysis?

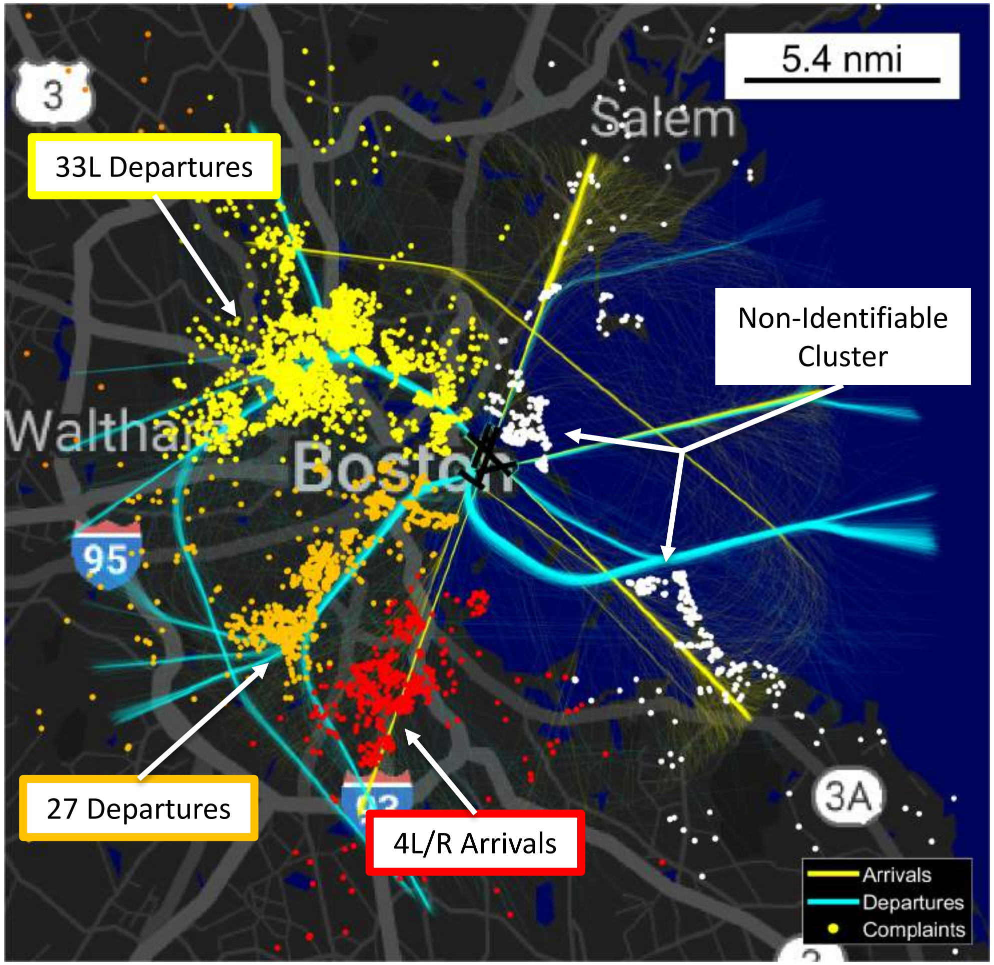


Integrated Exposure Metrics Averaging Times

- Metrics
  - **N Above**: number of flights above a defined A-weighted maximum sound level ($L_{A,max}$) threshold
  - **Day-Night Average Sound Level (DNL)**: calculated from a summation of Sound Exposure Level (SEL) data averaged over a 24-hour period
  - **Equivalent Sound Level (L_{EQ})**: calculated from a summation of Sound Exposure Level (SEL) data averaged over a specified time period
- Averaging Times
  - **Annual Average Day**: flight data based on average number of flights per day over a year
  - **Peak Day**: flight data based on day with most departures/arrivals from a runway in a year

Evaluating Representative Exposure Basis

- Complaints clustered using k-means algorithm
- Complaints identifiable by runway procedure used in determining N_{Above} thresholds

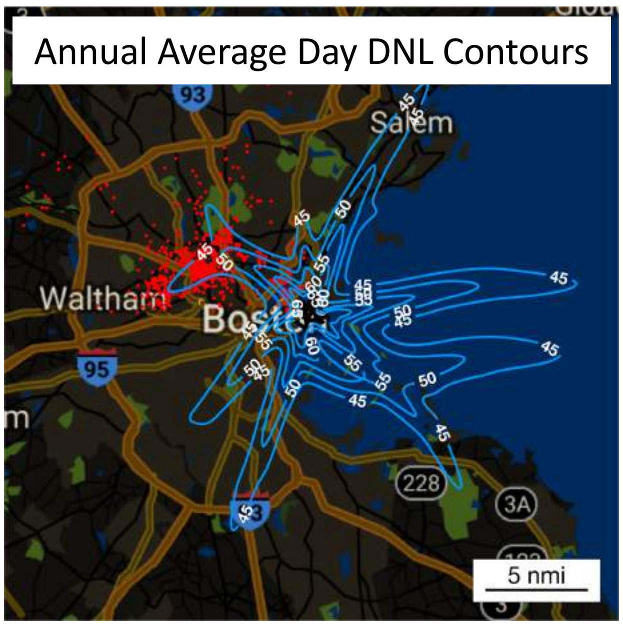


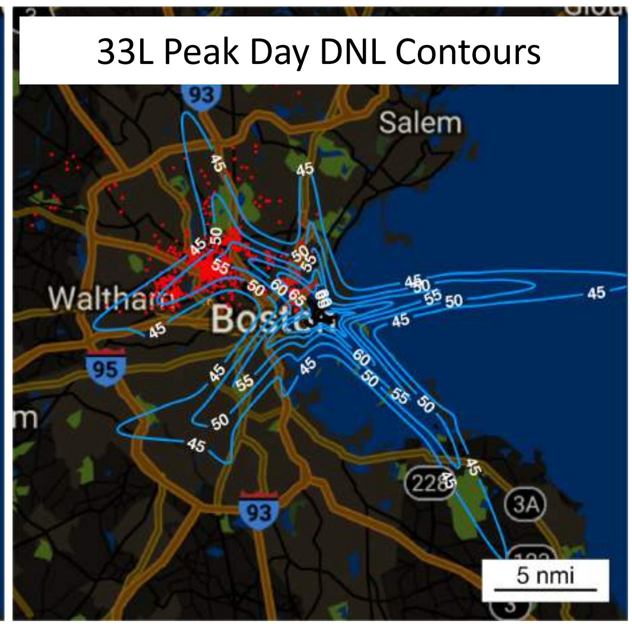
Peak Day vs. Annual Average Day DNL Thresholds

- **Peak Day 45dB DNL**
  - Captures 87% of complaints
  - Used as surrogate for complaint threshold in subsequent analysis

33L Departures Complainant Coverage for All Scenarios by DNL Contour Level

Contour Level	Annual Average Day	33L Peak Day
45dB DNL	54.21%	87.26%
50dB DNL	14.66%	66.11%
55dB DNL	8.05%	21.27%
60dB DNL	3.49%	8.53%
65dB DNL	0.12%	5.17%



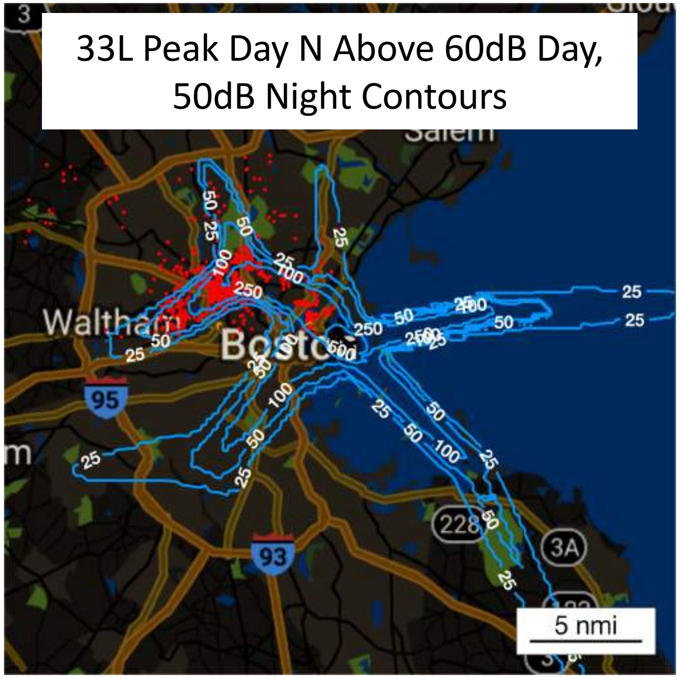


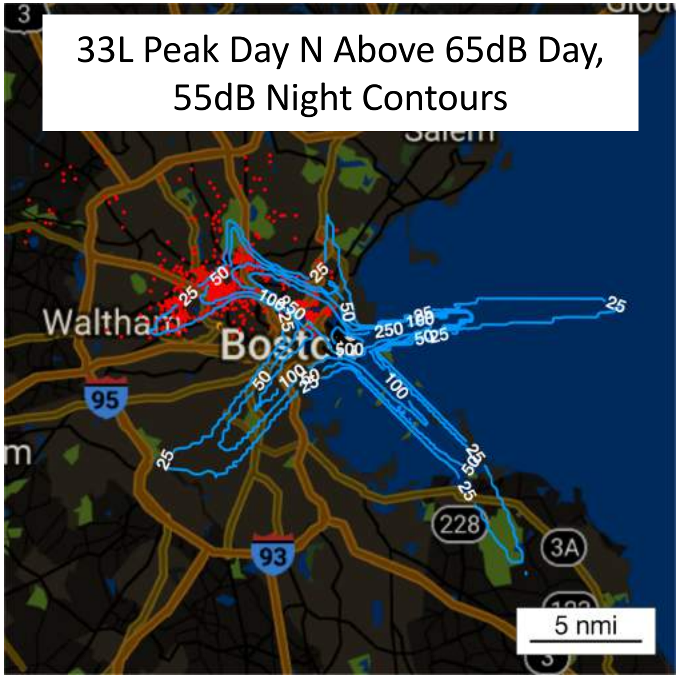
N_{Above} Noise Thresholds

- **Peak Day N_{Above} 60dB L_{AMAX} day, 50dB L_{AMAX} night with 25 overflights**
  - Captures 84% of complaints
  - Used as surrogate for complaint threshold in subsequent analysis

33L Departures Complainant Coverage for Peak Day by N Above Thresholds

Contour Level	N_{above} 60dB day, 50dB night	N_{above} 65dB day, 55dB night
25 flights	84.25%	67.07%
50 flights	77.52%	47.60%
100 flights	55.53%	16.95%
250 flights	20.31%	9.74%
500 flights	0.00%	0.00%

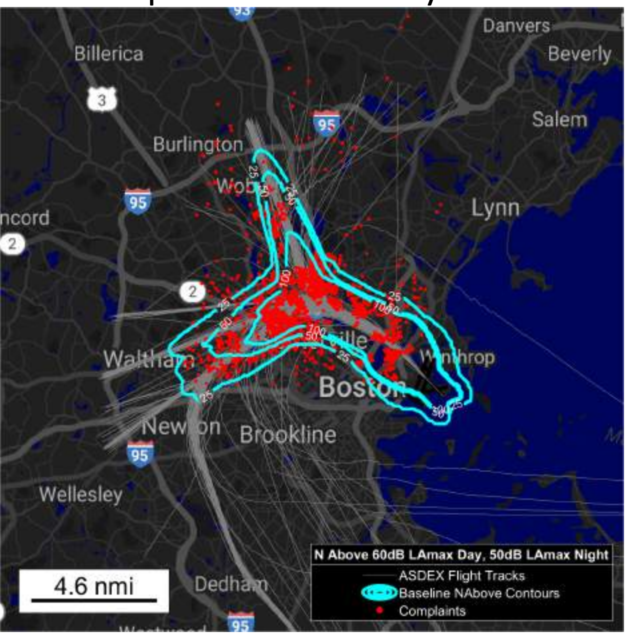




N_{Above} Thresholds

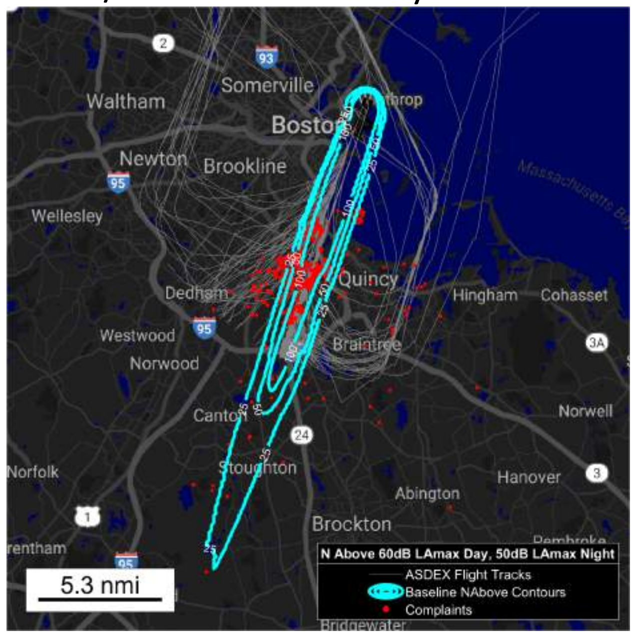
- 25 N_{Above} 60dB $L_{A,max}$ day, 50dB $L_{A,max}$ night appears to capture complaint threshold in dispersion analysis

33L Departures Peak Day N Above



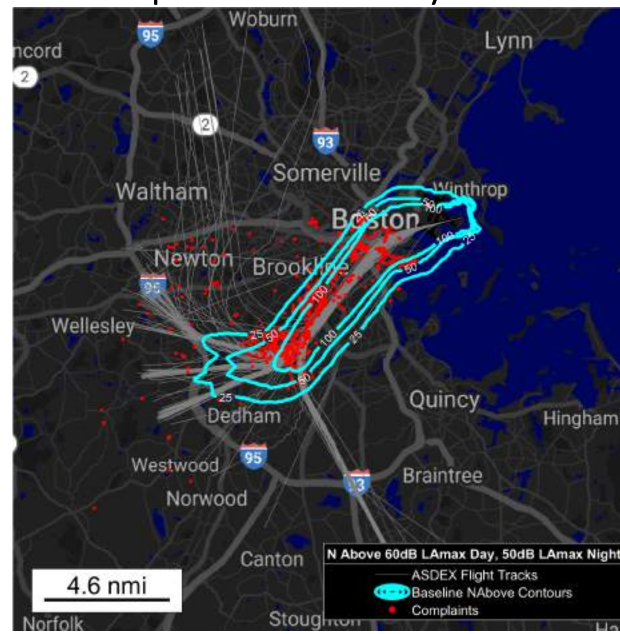
Peak Day N Above	Complaints Captured
25x	96.9%
50x	90.8%
100x	59.0%

4L/R Arrivals Peak Day N Above



Peak Day N Above	Complaints Captured
25x	83.6%
50x	67.6%
100x	43.8%

27 Departures Peak Day N Above



Peak Day N Above	Complaints Captured
25x	92.2%
50x	82.5%
100x	60.5%

Difference from prior slide due to more comprehensive traffic analysis

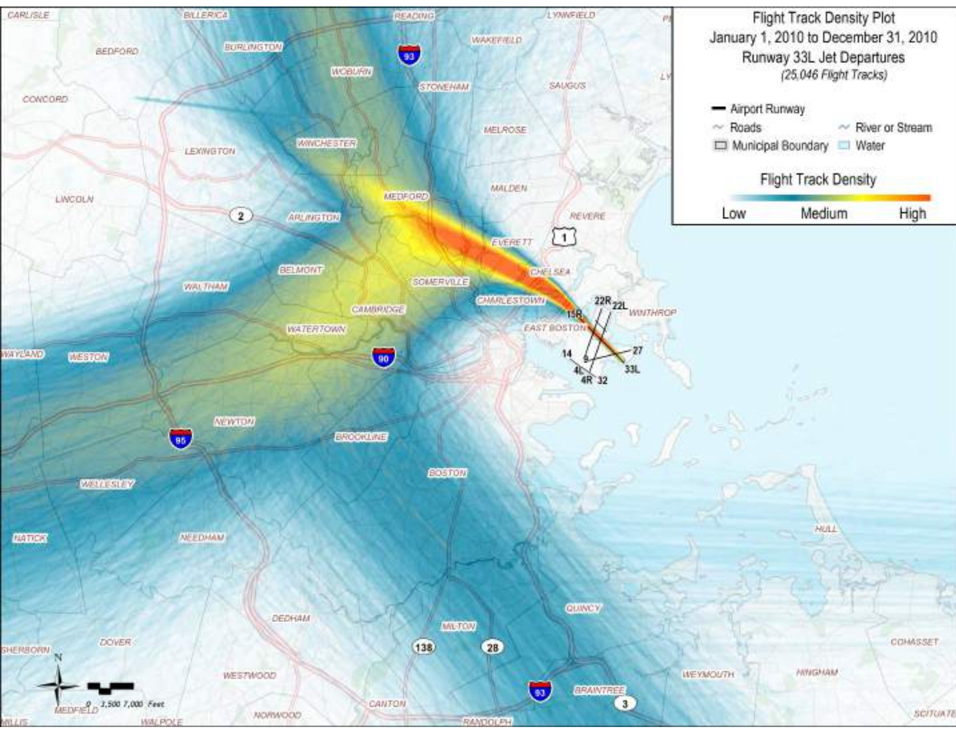
Departure Dispersion:
Runway 33L and 27

MIT ICAT

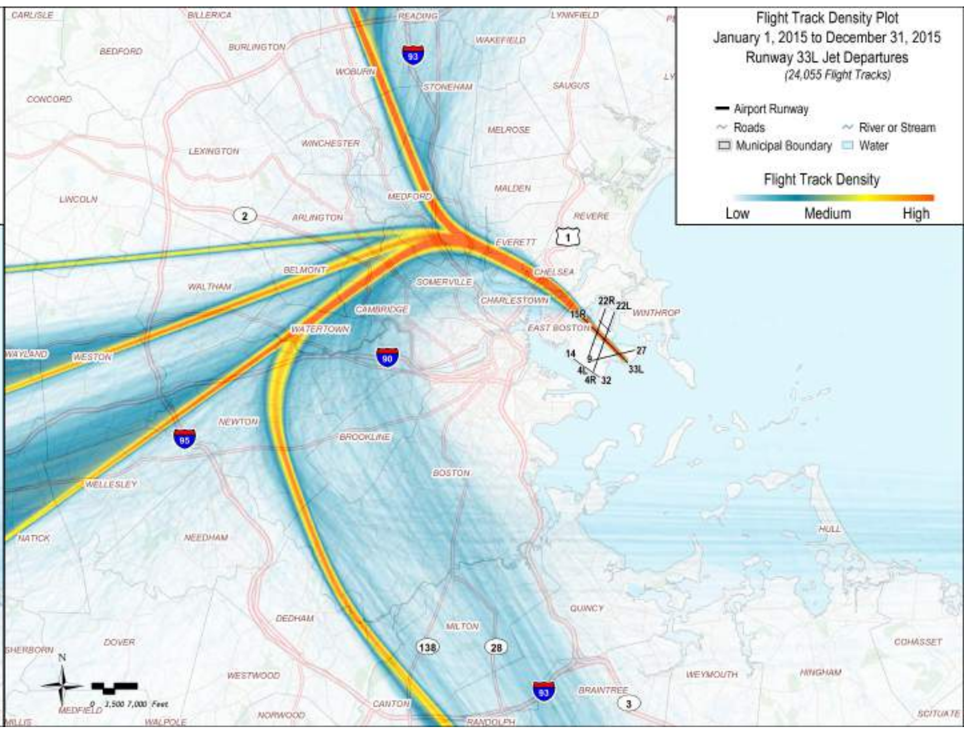
Runway 33L Departures: 2010-2015

Using Open SIDs or Flexible SIDs to Re-introduce Dispersion

2010

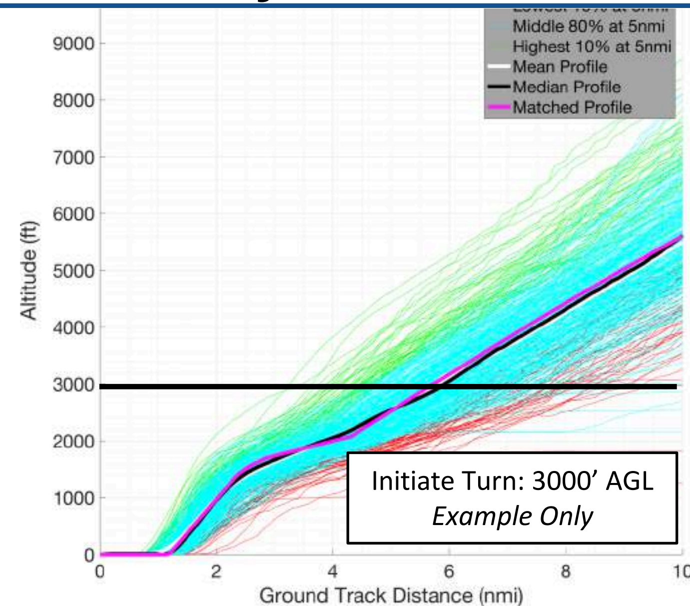


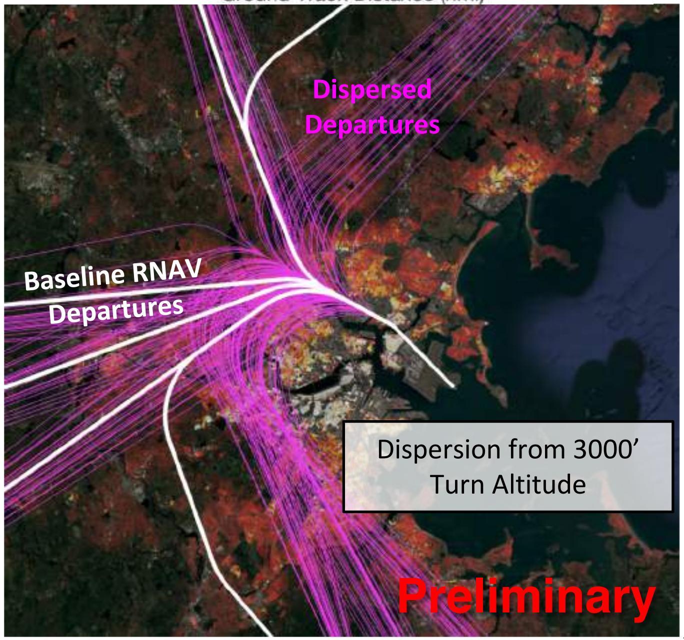
2015

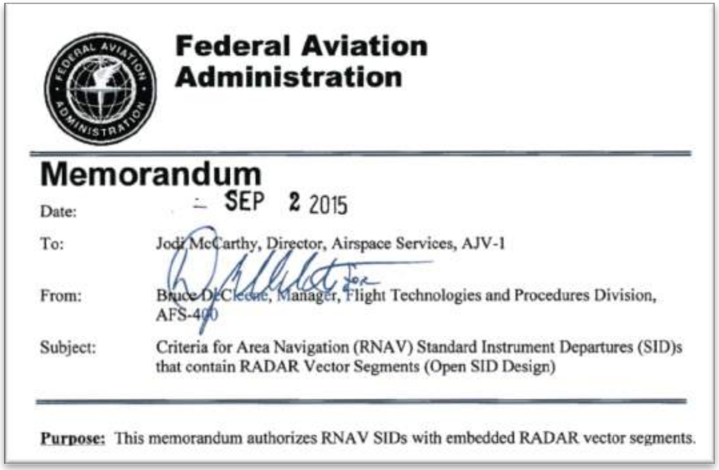


Dispersion Concepts: Open SID or Increased Controller Flexibility

1. Open SIDs are RNAV departure procedures that include ATC radar vector segments.
   - Authorized by FAA in 2015
   - Proven in operation (e.g. CLT, LAX)
2. Dispersion may also be introduced by direct ATC instruction (vector-based or direct-to) based on aircraft altitude or other criteria
   - Allows greater ATC flexibility based on traffic levels and flows
   - Would result in track length reduction with corresponding fuel savings







Federal Aviation Administration

Memorandum

Date: SEP 2 2015

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

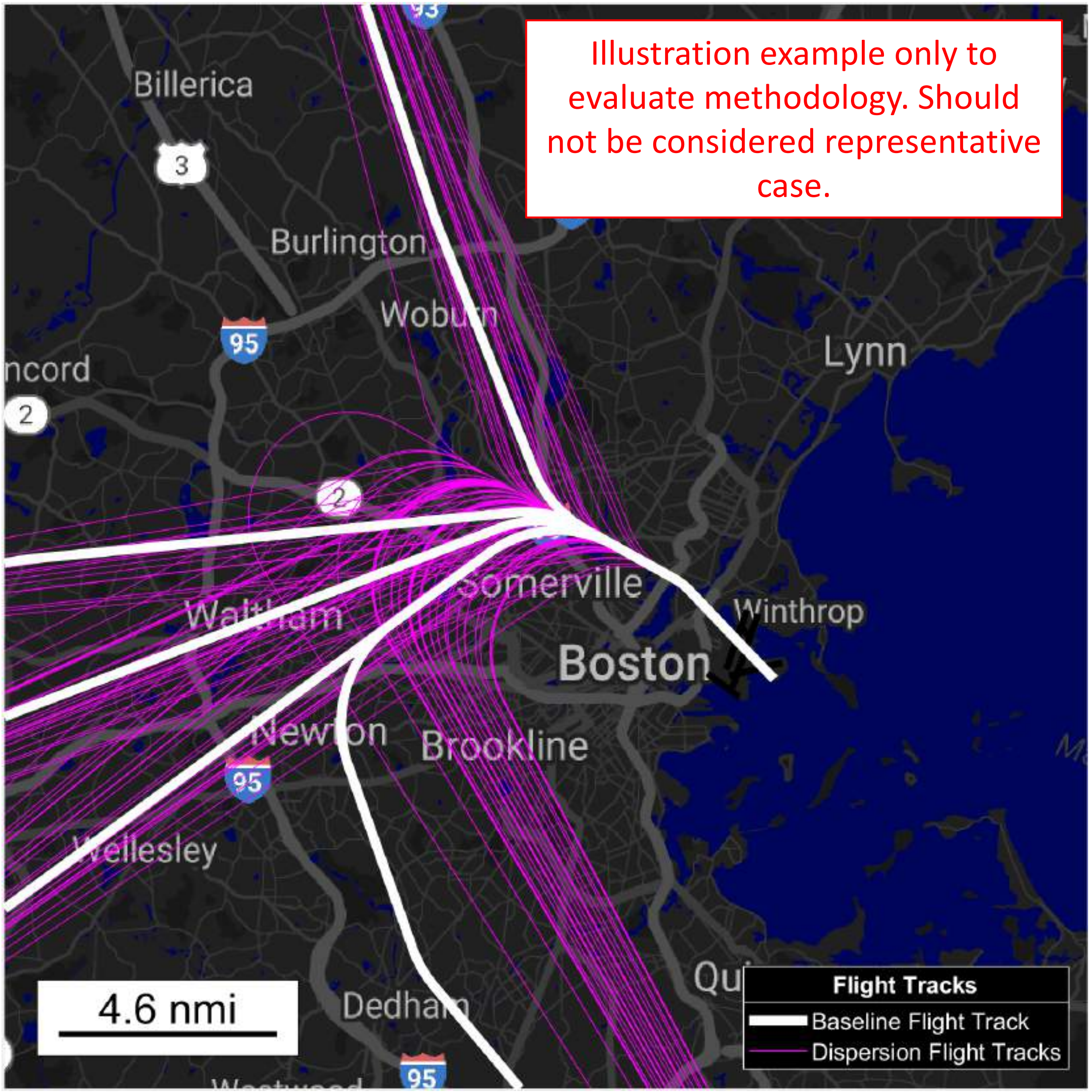
From: Bruce DeCleene, Manager, Flight Technologies and Procedures Division, AFS-400

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

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

33L Peak Day Example Dispersion Tracks

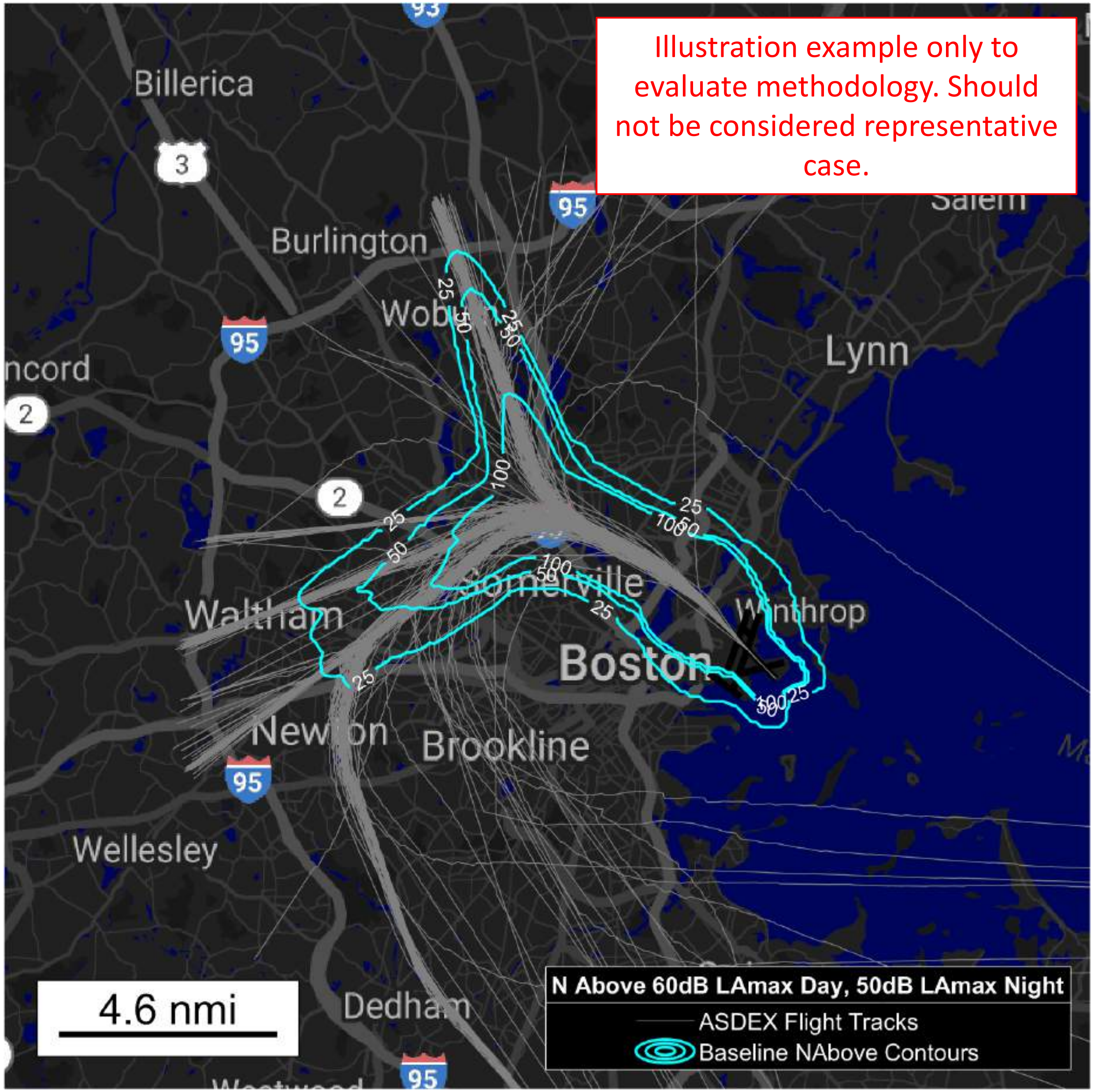
Dispersion arising from direct routing to transition waypoint upon reaching 3,000ft



Dispersed flight tracks may have both positive and negative consequences:

- Reduced noise directly under existing flight tracks
- Increase in overall number of people impacted by noise
- Redistribution of noise between communities

33L Departure Baseline Peak Day N_{Above}

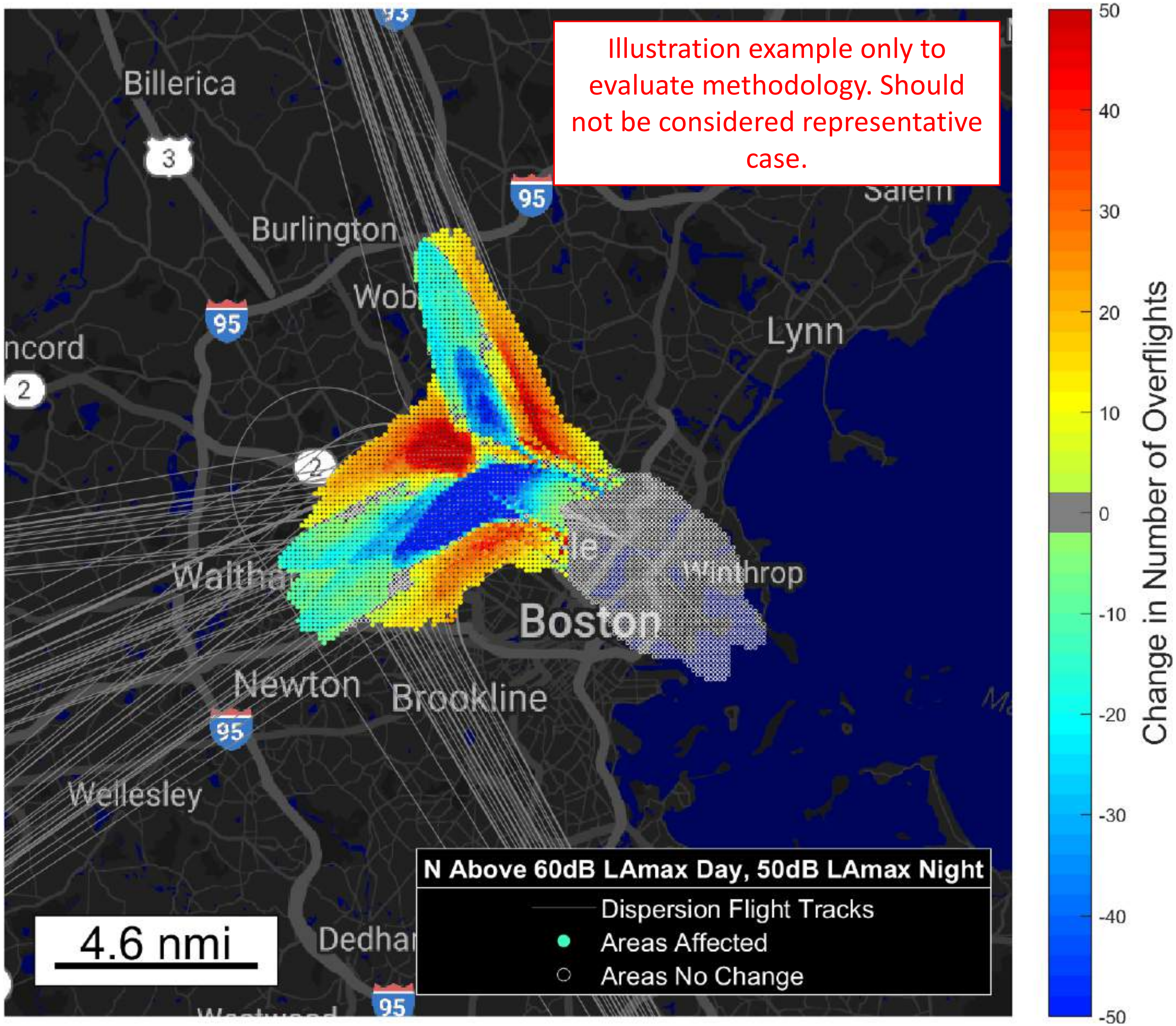


N_{Above} Thresholds:
60dB $L_{A,max}$ Day
50dB $L_{A,max}$ Night

Population Exposure

N Above	25x	50x	100x
Baseline	408,104	259,907	188,492

Example of Altitude-Based 33L Departure Dispersion Change in N_{Above}



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

Population Exposure

Change In N Above	Population Exposure
+50x	8,950
+25x	69,543
-25x	75,874
-50x	49,562

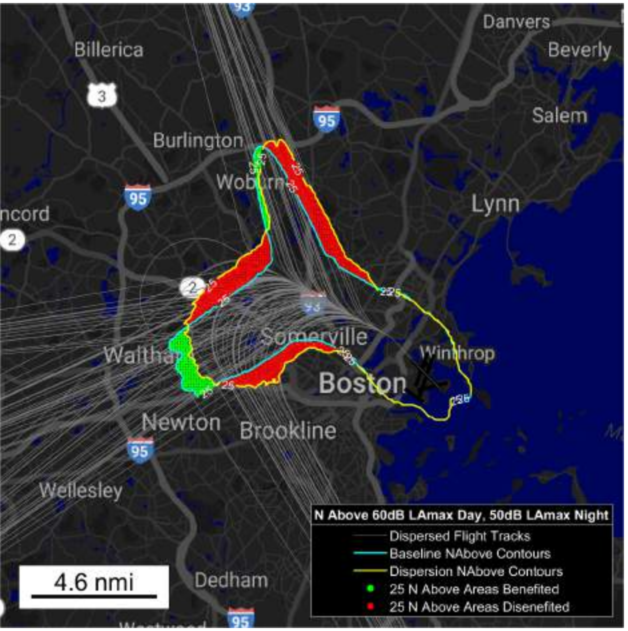
Example of Altitude-Based 33L Departure Dispersion N_{Above} Exposure

Population Exposure

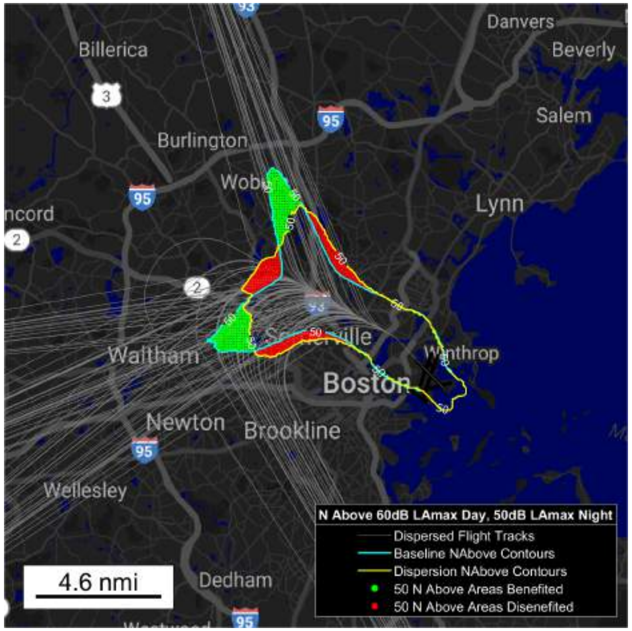
N Above	25x	50x	100x
Baseline	408,104	259,907	188,492
Dispersion	455,267	284,083	176,300
Baseline - Dispersion	-47,163	-24,176	12,192

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

25 N Above



50 N Above



100 N Above

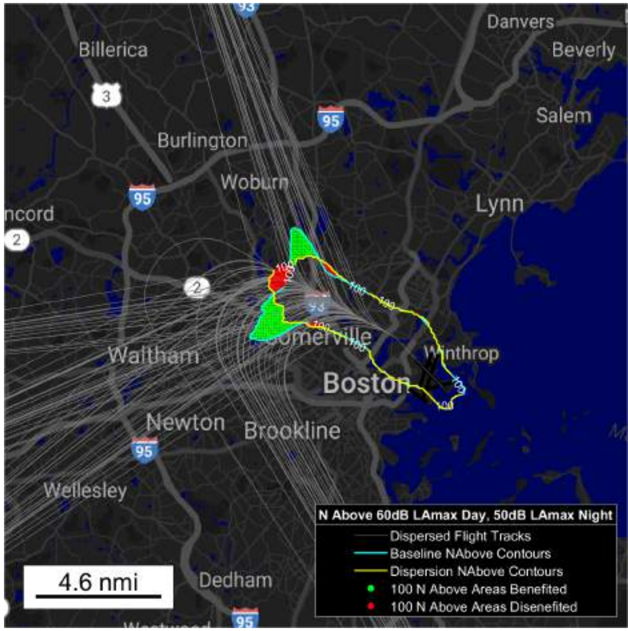
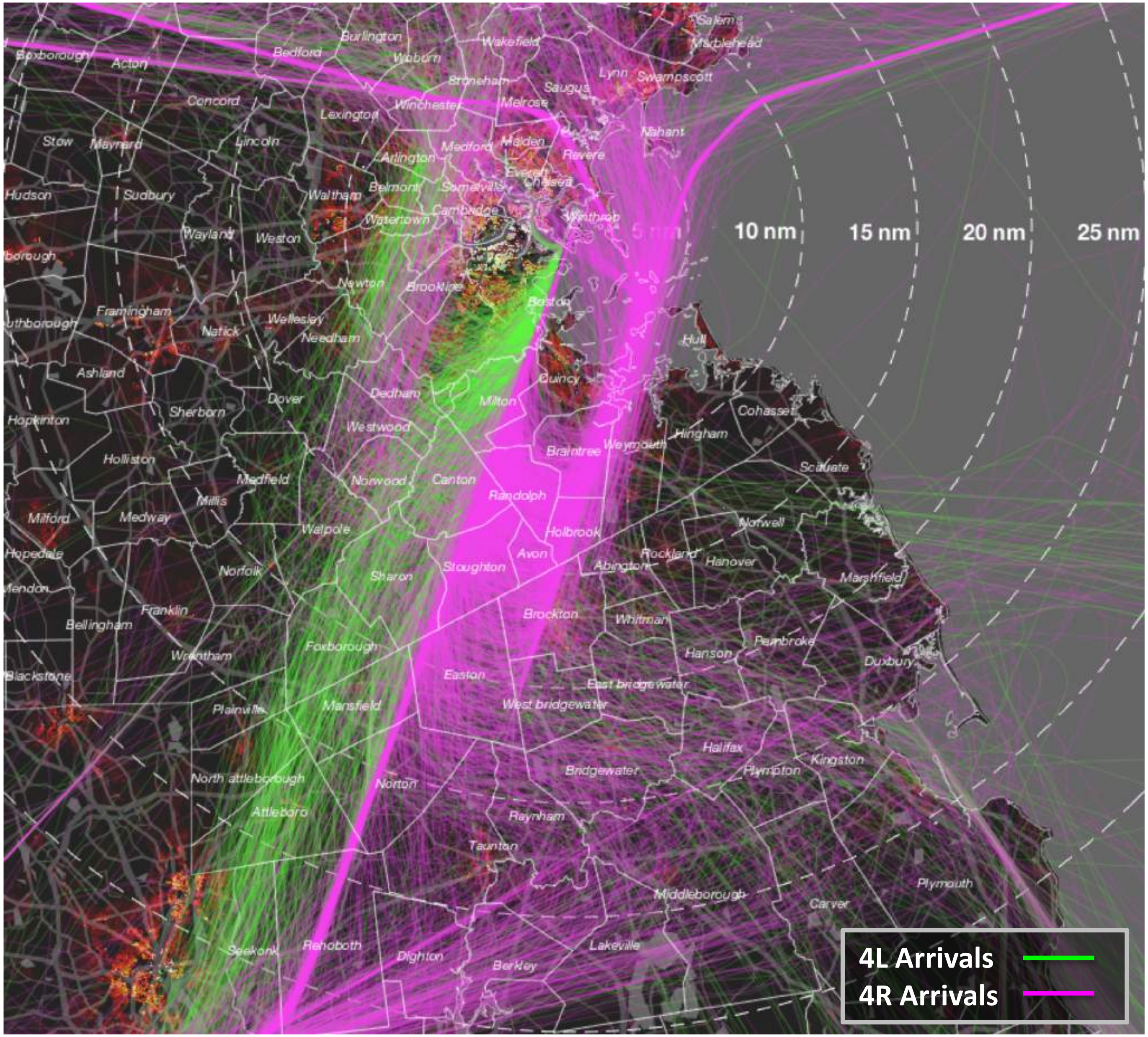


Illustration example only to evaluate methodology. Should not be considered representative case.

Arrival Dispersion: Runway 4L and 4R

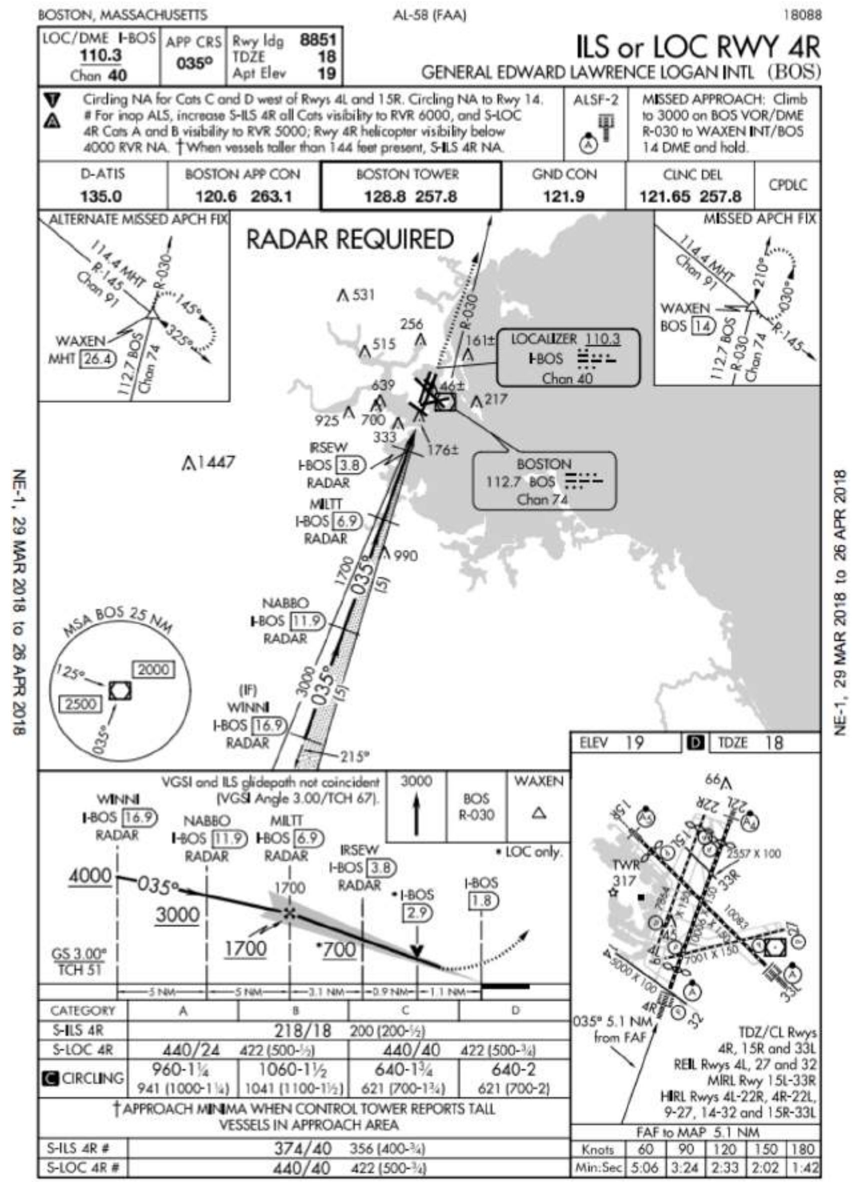
Baseline: 2017 Arrivals to Runway 4L and 4R

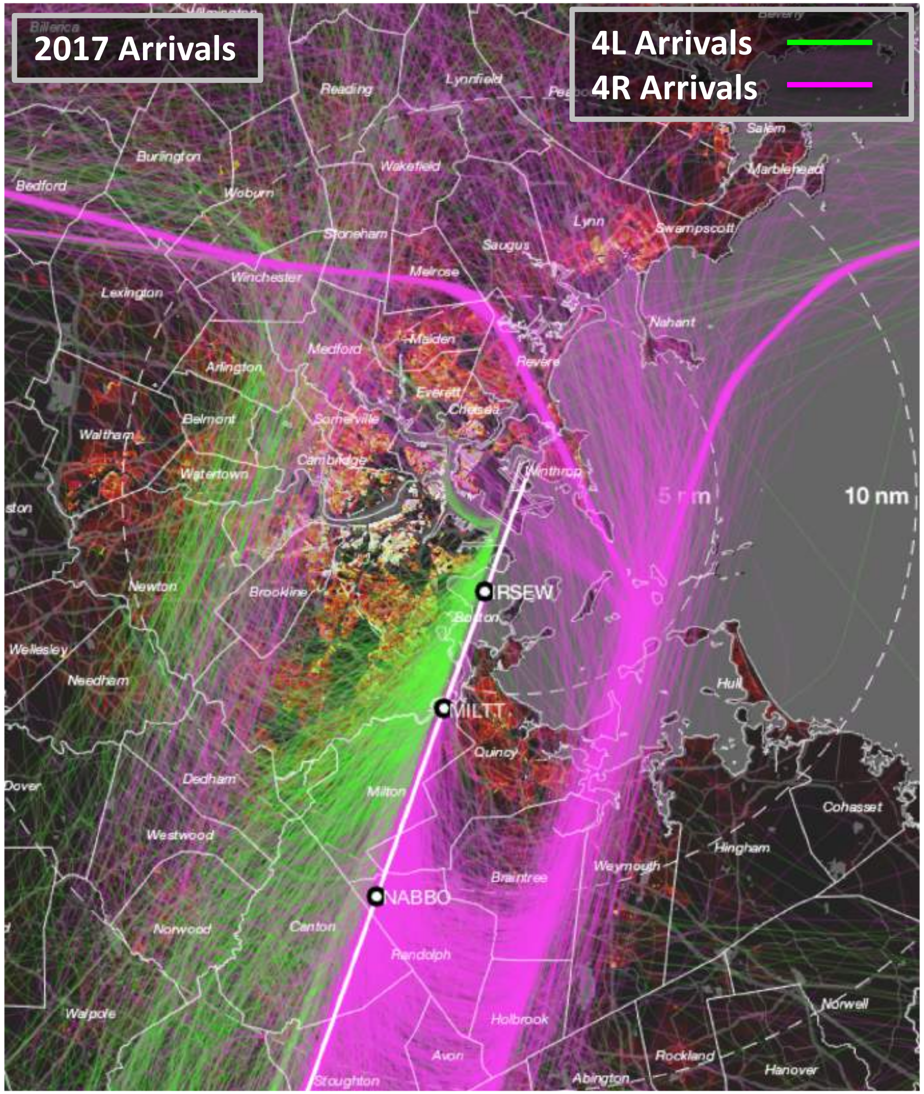


Notes:

- 2017 Arrival Counts (jet & prop):
  - Rwy 4R: 39,615
  - Rwy 4L: 12,311
- Figure shows 10% of all 2017 arrivals selected at random
- Data Source: Flight Tracks, Massport Noise and Operations Management System (NOMS)

ILS Runway 4R





Notes:

- 2017 Arrival Counts (jet & prop): Rwy 4R: 39,615 Rwy 4L: 12,311
- Figure shows 10% of all 2017 arrivals selected at random
- Data Source: Flight Tracks, Massport Noise and Operations Management System (NOMS)

Example of 4R Arrival Dispersion:
RNAV Tracks with Vertical Guidance (Southerly Arrivals)

- Equal distribution of arrivals across five ground tracks

2 example options:

1. Equal distribution
2. Rotating time periods

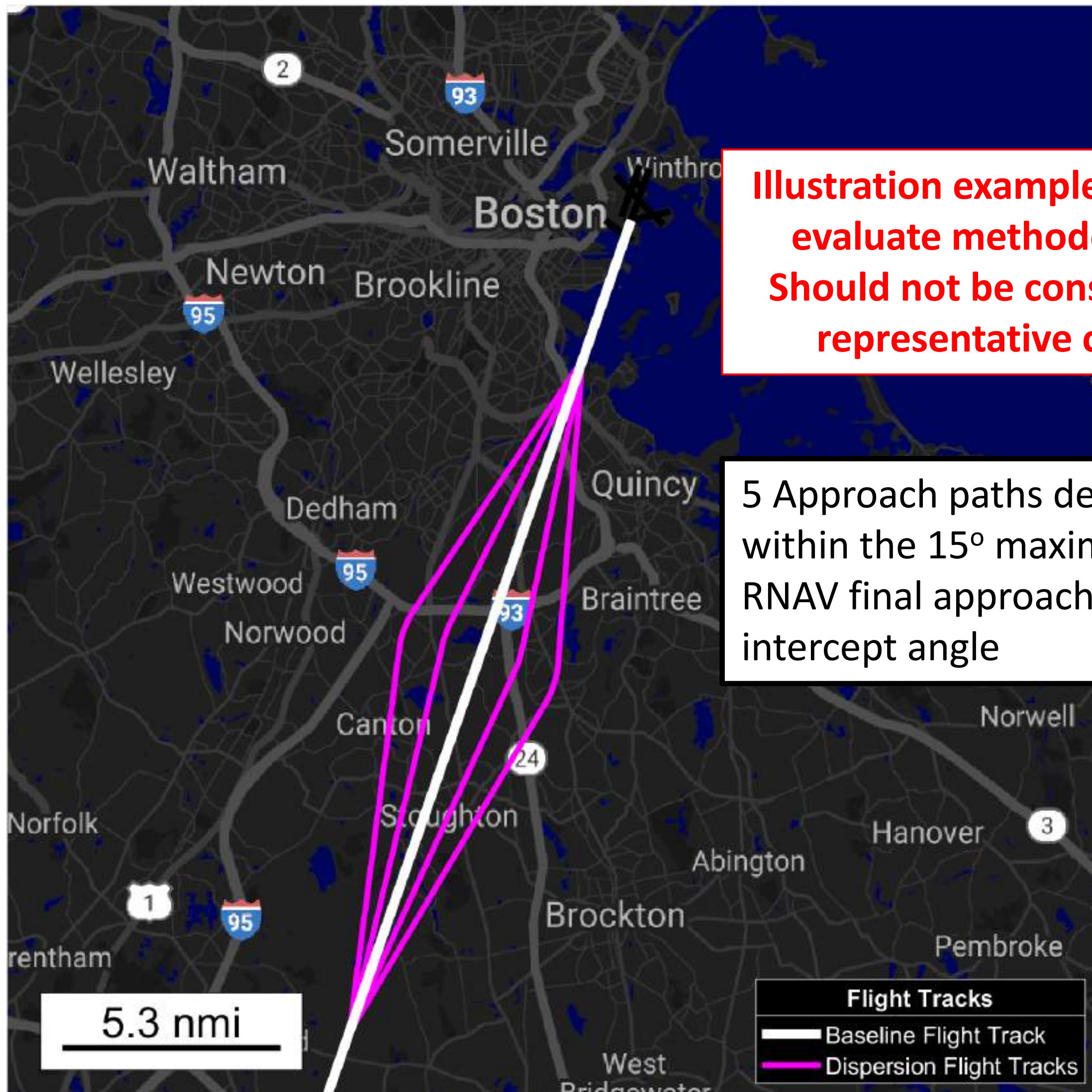
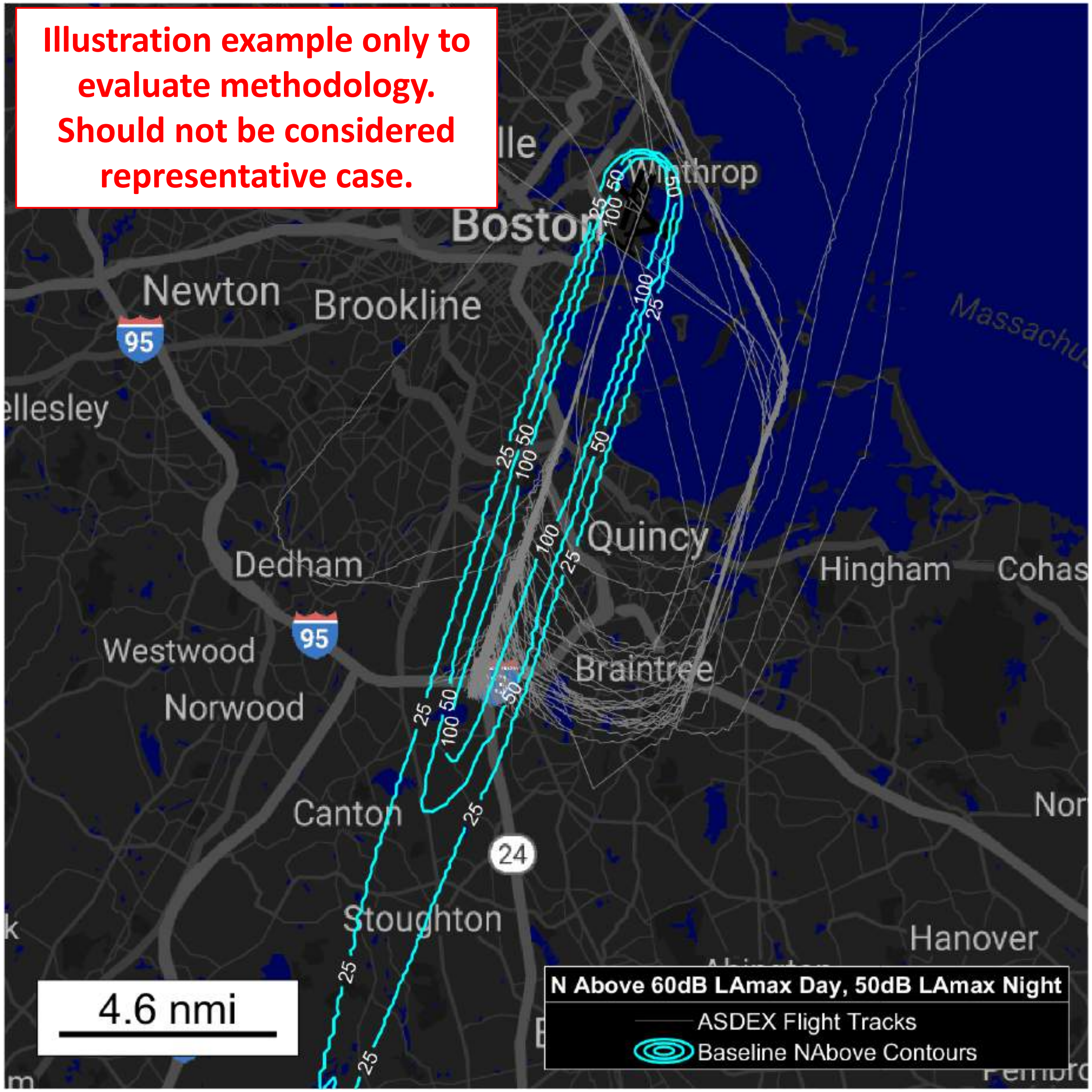


Illustration example only to evaluate methodology. Should not be considered representative case.

5 Approach paths defined within the 15° maximum RNAV final approach intercept angle

4R Arrival Baseline Peak Day N Above

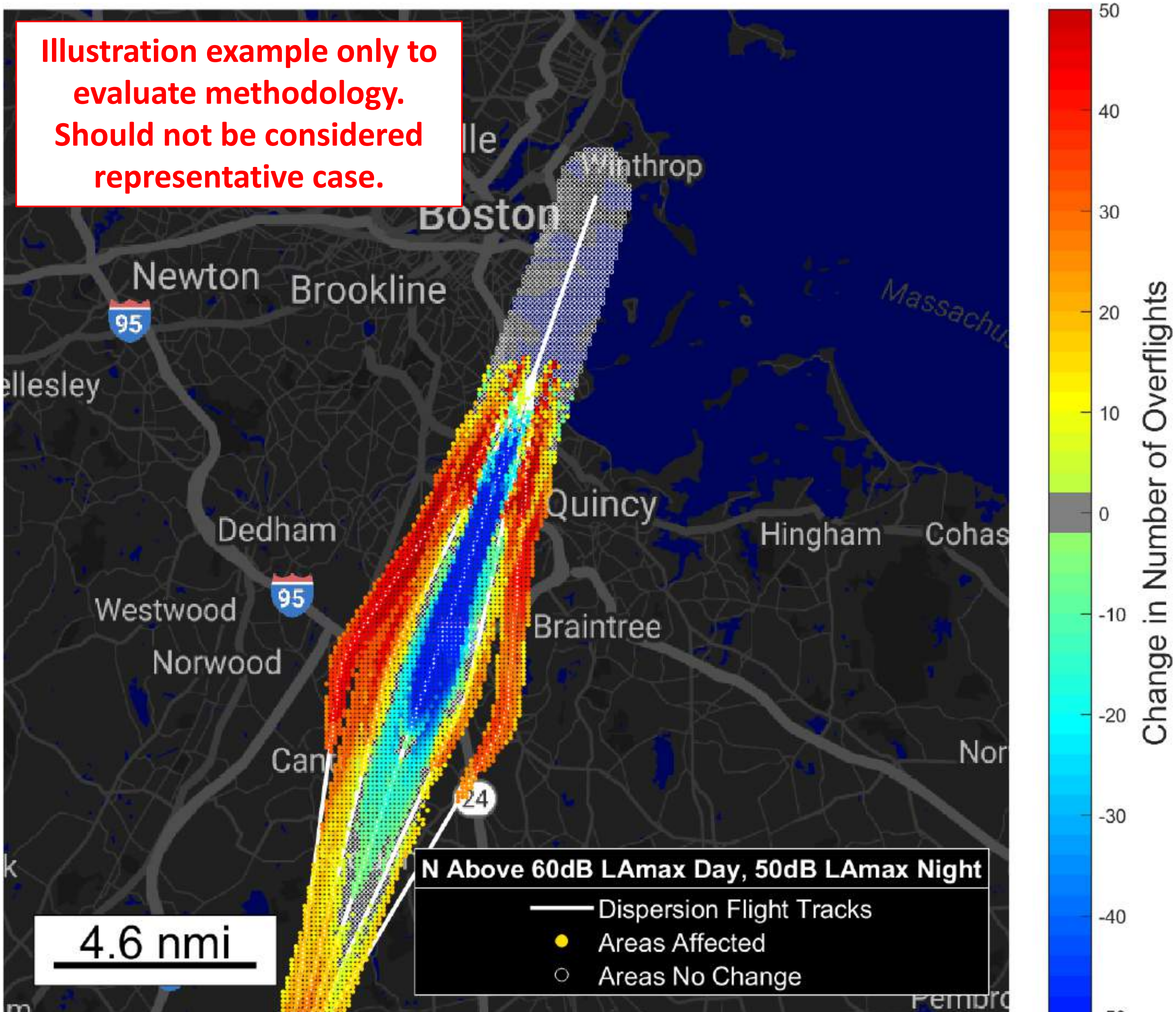


N Above Levels:
60dB $L_{A,max}$ Day
50dB $L_{A,max}$ Night

Population Exposure

N Above	25x	50x	100x
Baseline	104,460	56,419	30,665

Example of Equal Distribution over 5 RNAV Arrival Paths



N Above Levels:

60dB $L_{A,max}$ Day

50dB $L_{A,max}$ Night

Population Exposure

Change In N Above	Population Exposure
+50x	5,567
+25x	38,958
-25x	11,258
-50x	5,777

Example of Deterministic 4R Arrival Dispersion N Above Exposure

Population Exposure

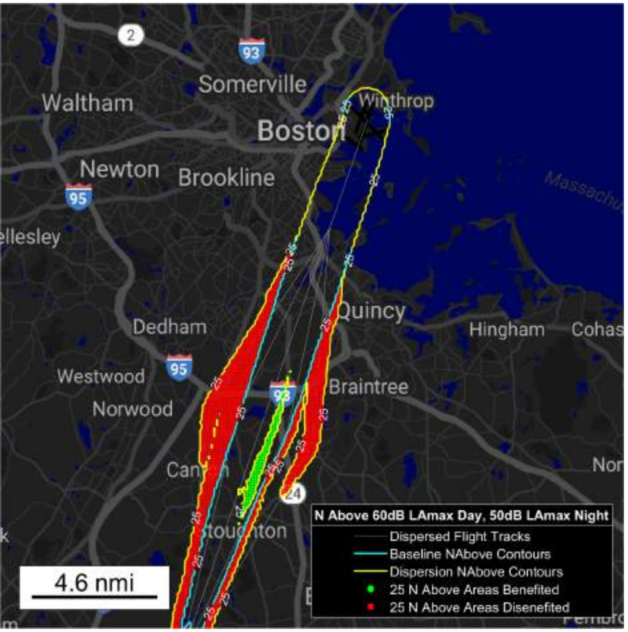
N Above	25x	50x	100x
Baseline	104,460	56,419	30,665
Dispersion	143,018	72,656	35,136
Baseline - Dispersion	-38,558	-16,237	-4,471

N Above Levels:

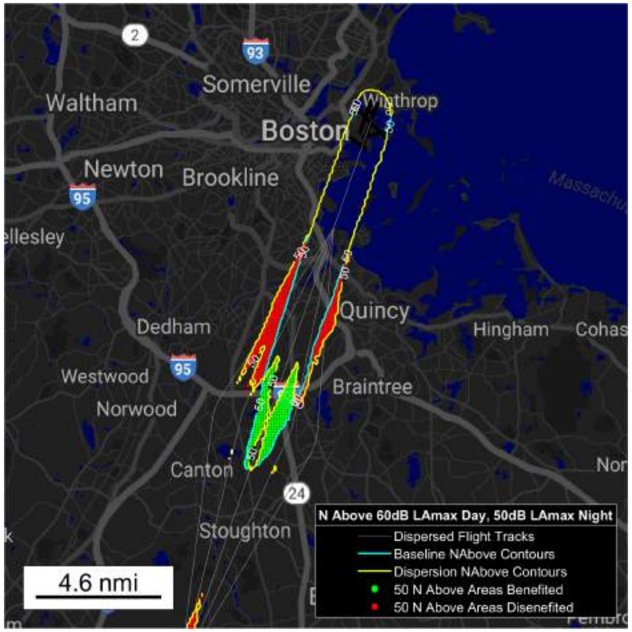
60dB $L_{A,max}$ Day

50dB $L_{A,max}$ Night

25 N Above



50 N Above



100 N Above

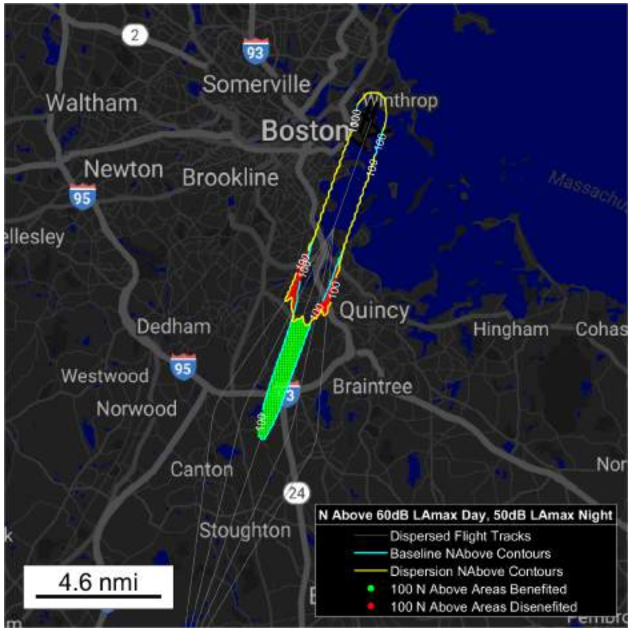
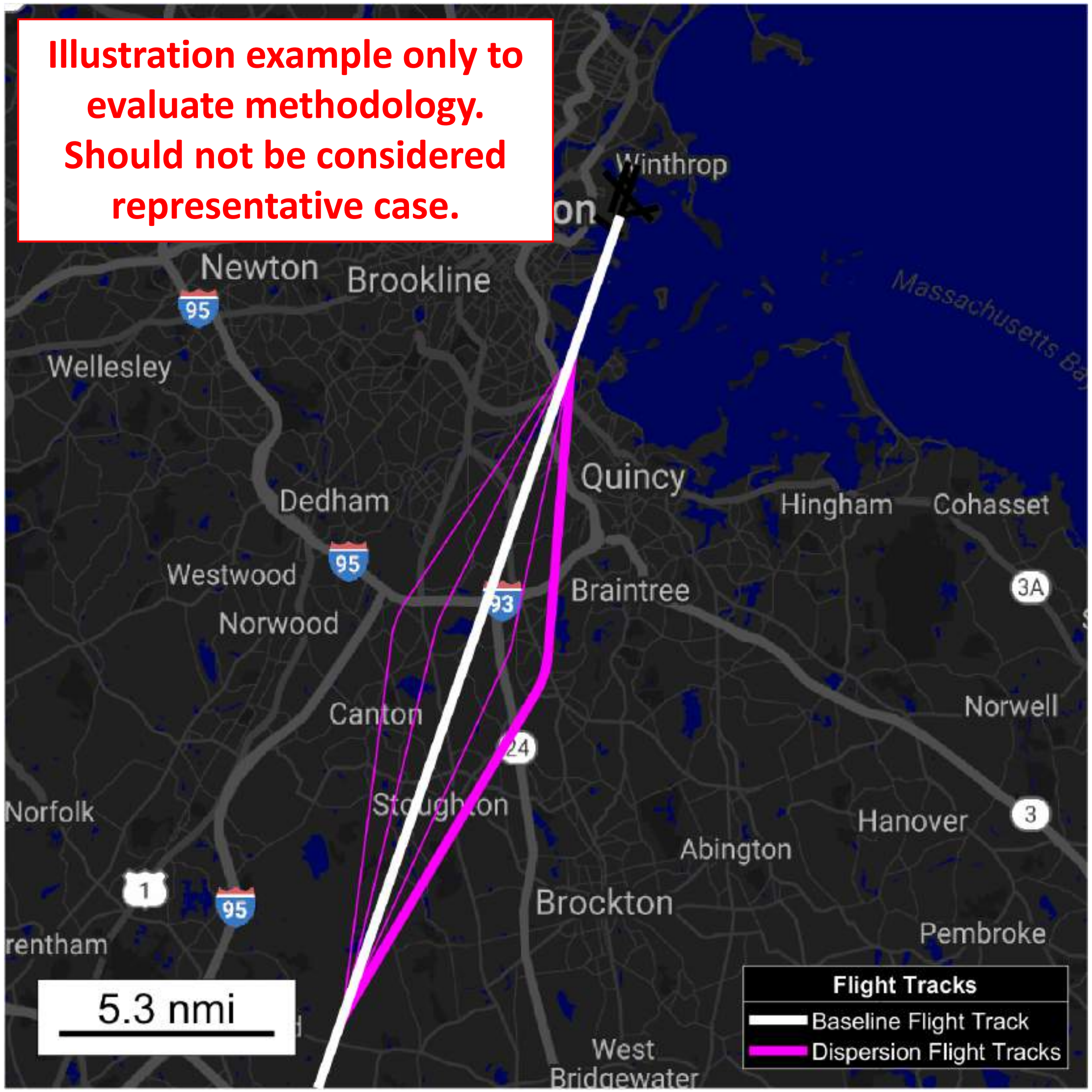


Illustration example only to evaluate methodology. Should not be considered representative case.

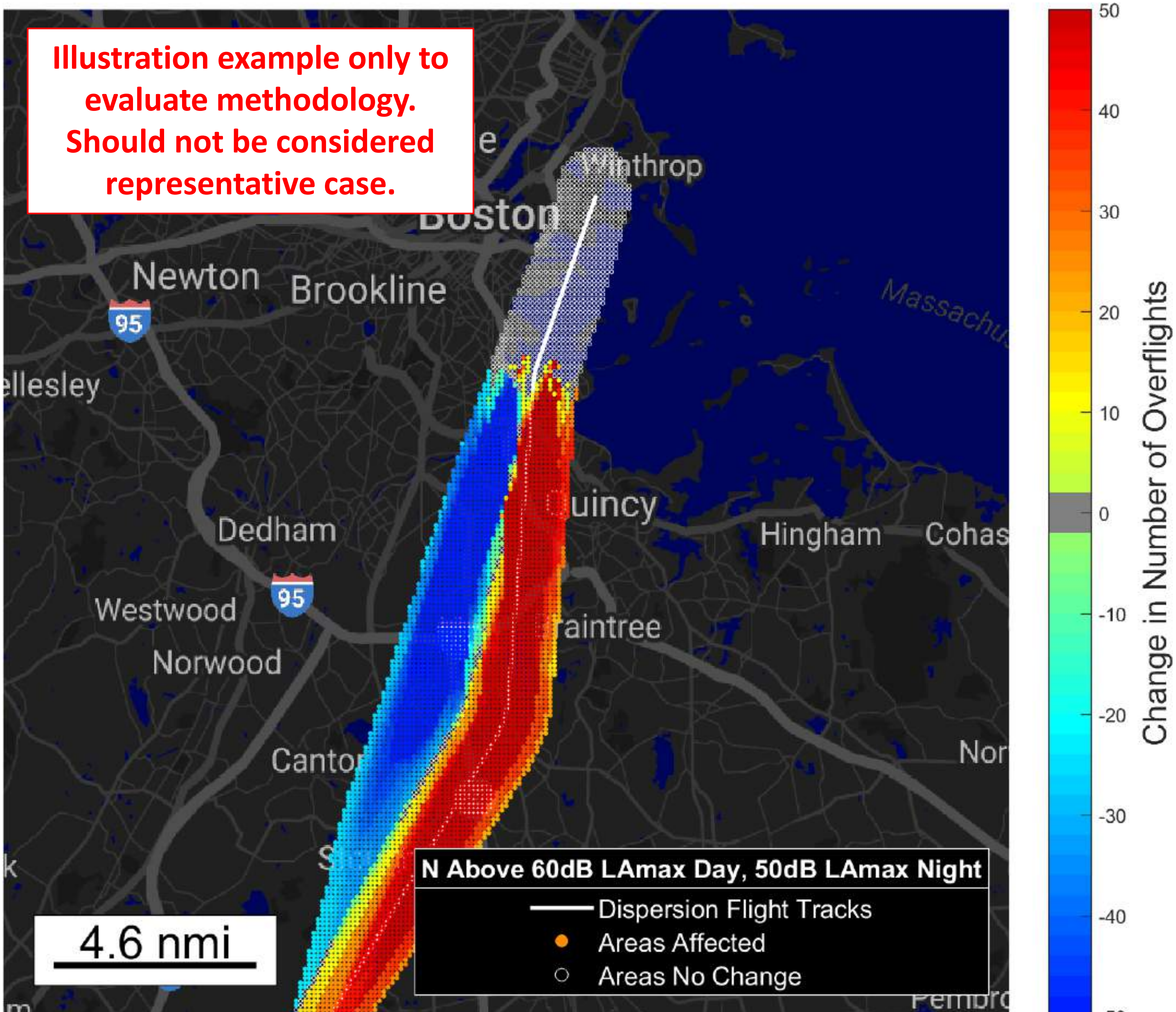
Example of Deterministic 4R Arrival Dispersion

- Select track depending on day



MIT ICAT

Example of Deterministic 4R Arrival Dispersion Change in N Above



N Above Levels:
60dB $L_{A,max}$ Day
50dB $L_{A,max}$ Night

Population Exposure

Change In N Above	Population Exposure
+50x	46,562
+25x	79,528
-25x	47,964
-50x	20,180

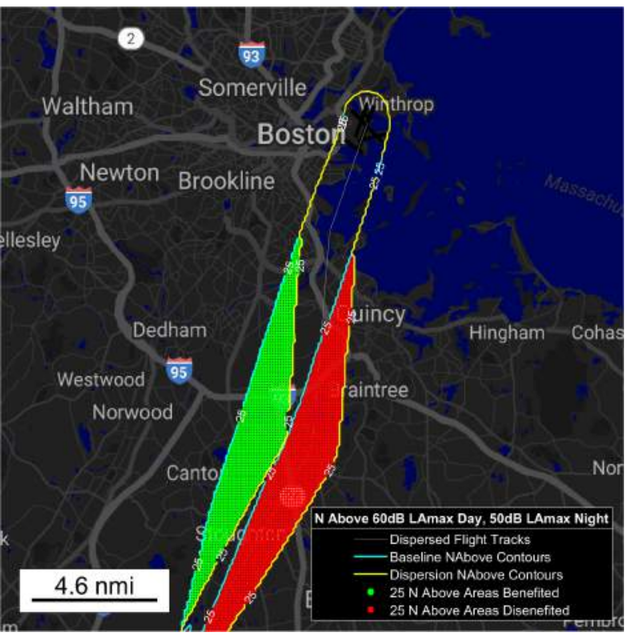
Example of Deterministic 4R Arrival Dispersion N Above Exposure

Population Exposure

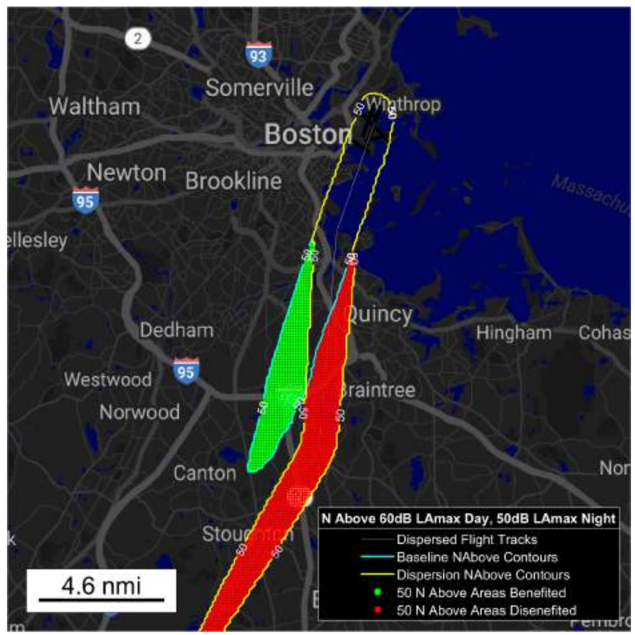
N Above	25x	50x	100x
Baseline	104,460	56,419	30,665
Dispersion	138,826	91,372	44,803
Baseline - Dispersion	-34,366	-34,953	-14,138

N Above Levels:
60dB $L_{A,max}$ Day
50dB $L_{A,max}$ Night

25 N Above



50 N Above



100 N Above

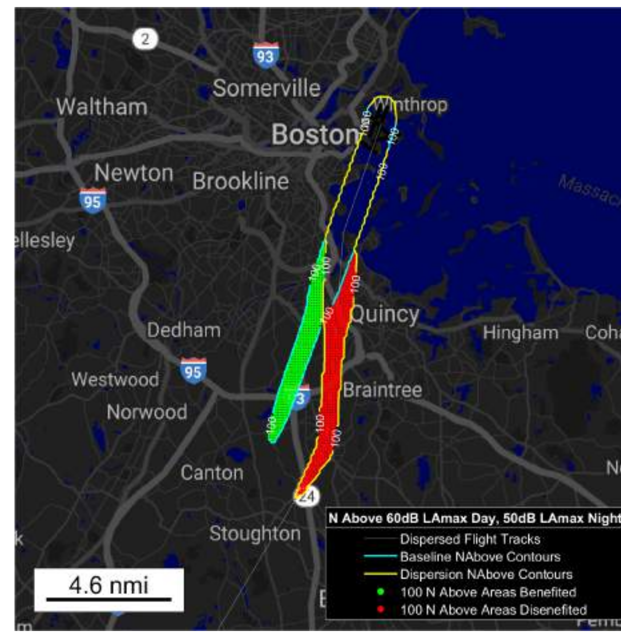


Illustration example only to evaluate methodology. Should not be considered representative case.

Discussion