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October 22nd, 2018

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

RE: *RNAV Presentation Provided to the Massport CAC on October 18th, 2018*

Dear Chairman Carlon:

As requested, please see the attached presentation deck. This presentation provided by MIT (Massport and the FAA's lead technical consultant) at the October 18th Massport CAC 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

# Procedure Design Concepts for Logan Airport Community Noise Reduction

R. John Hansman
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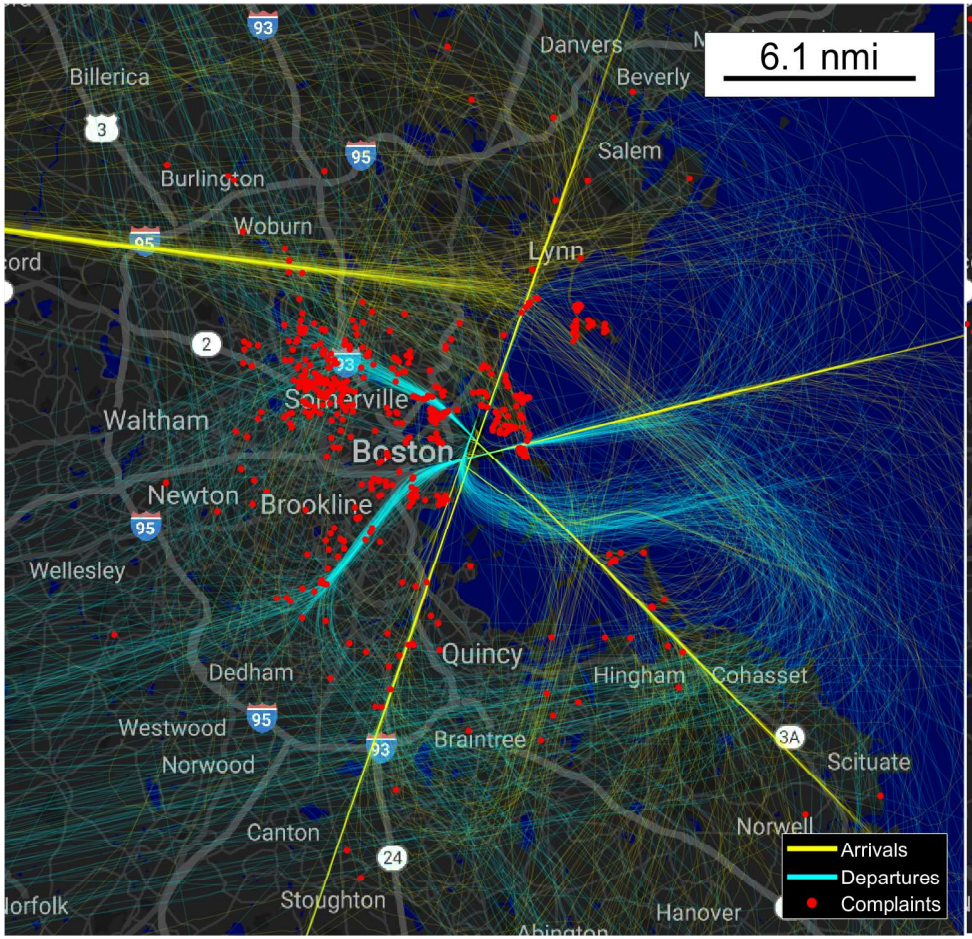
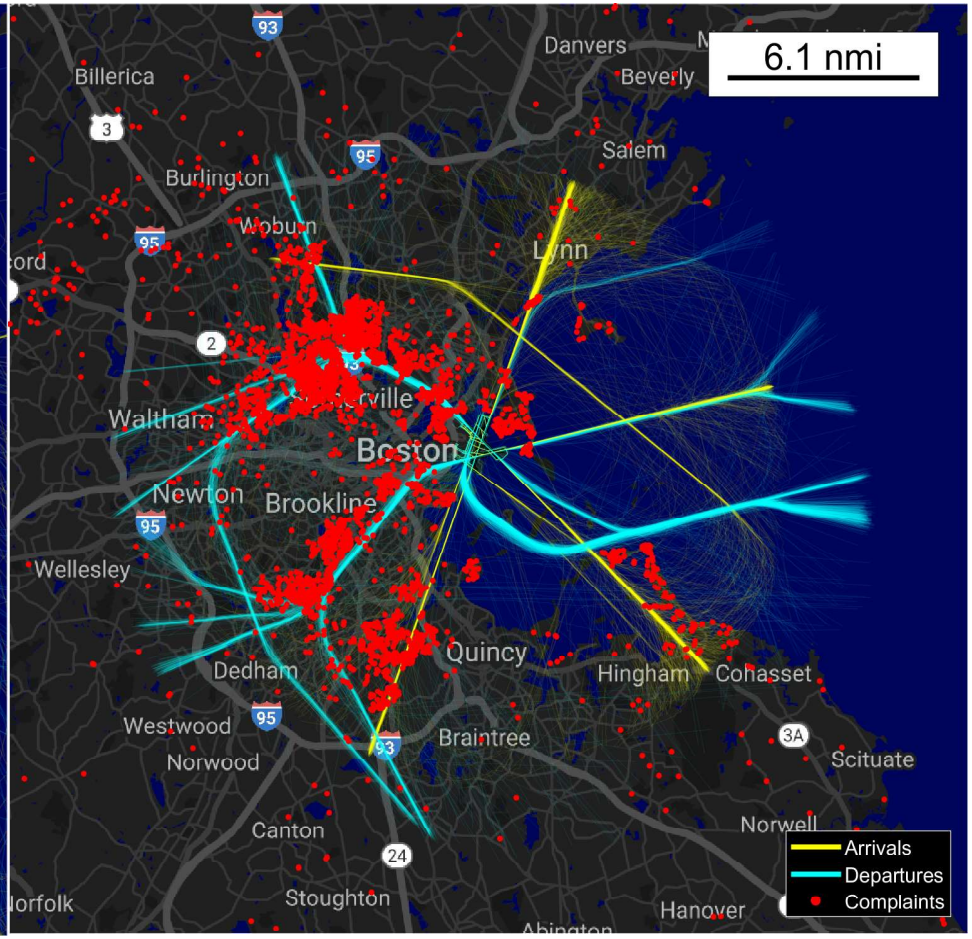
Technical support from MIT ICAT students, HMMH, and Massport

# RNAV Track Concentration

2010




2017



# 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

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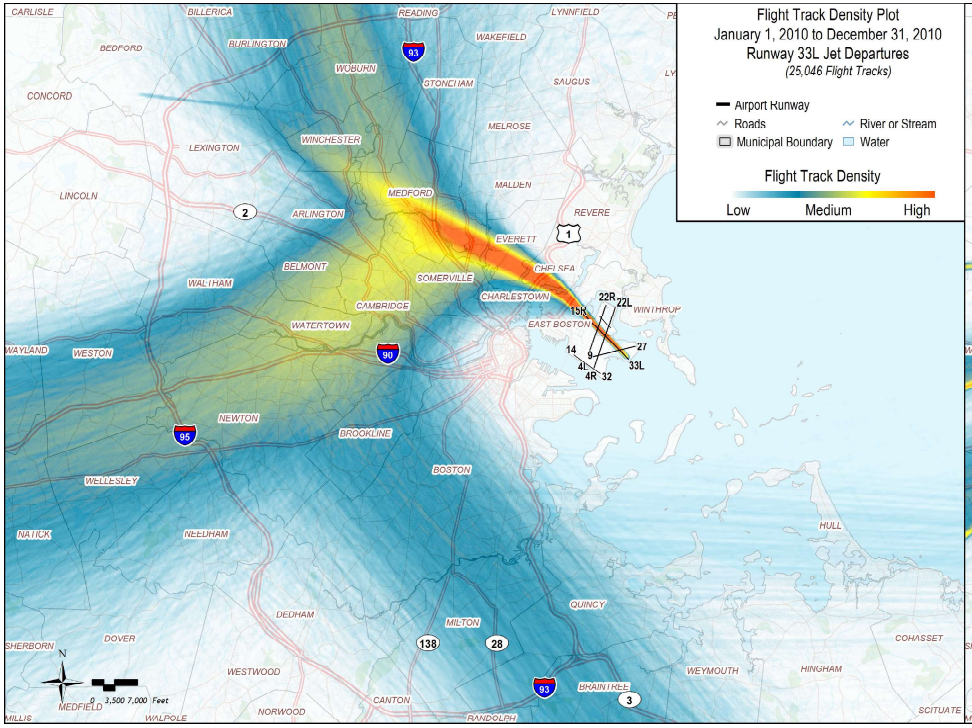
# Block 2

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

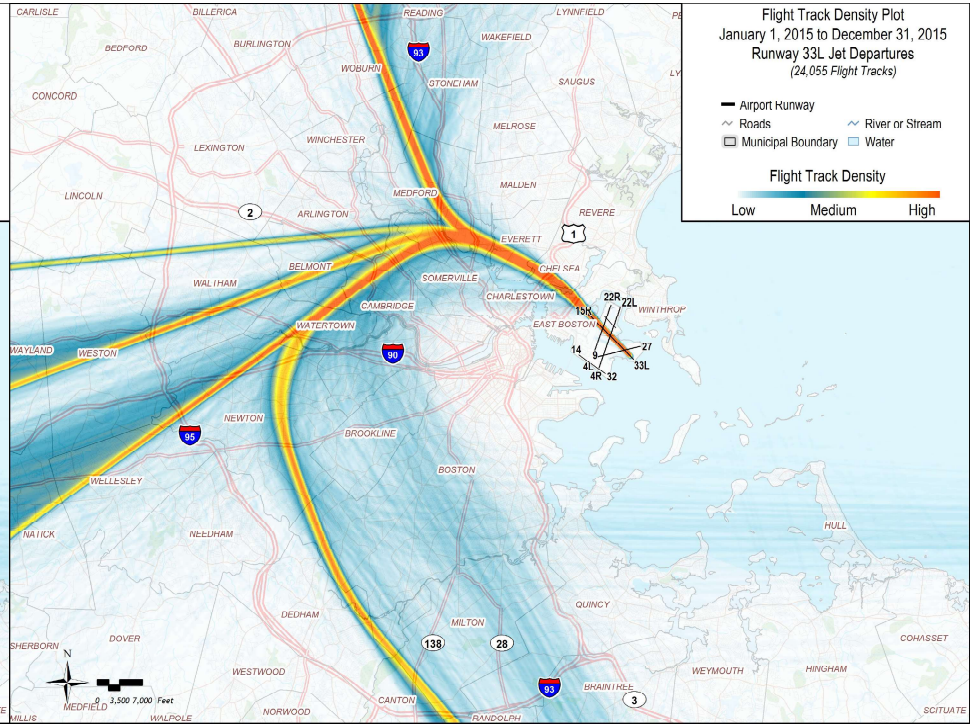
# Need for Integrated Exposure Metrics

In order to study impact of flight track concentration, need integrated exposure metrics and analysis which consider cumulative effects of multiple overflights

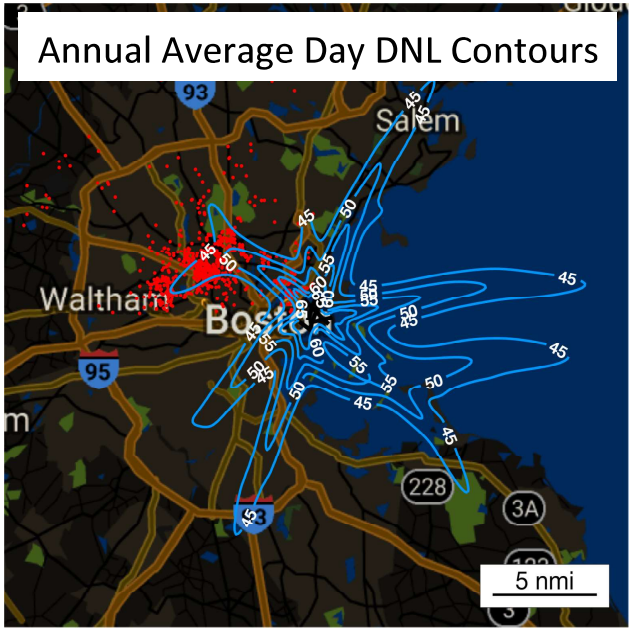
2010

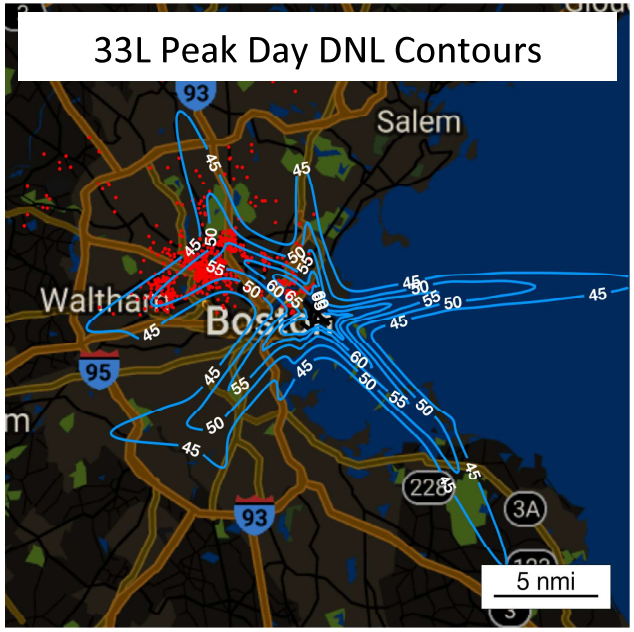


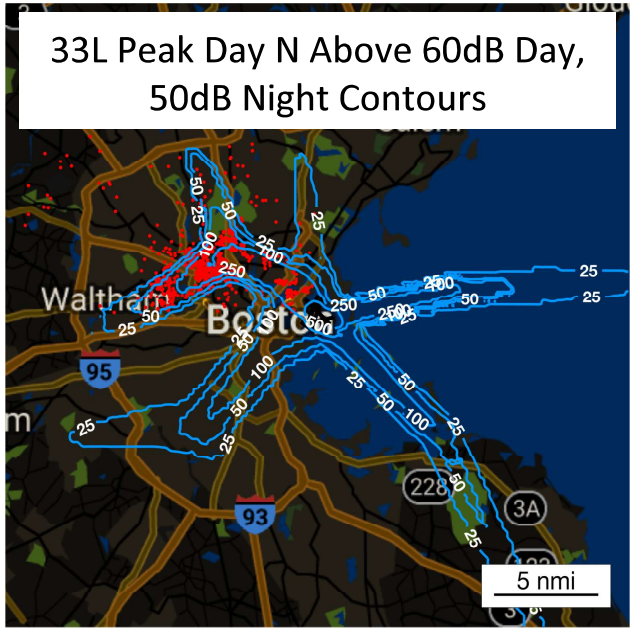

2015



# Metrics Based on Peak Day Runway Use




- Peak Day $N_{Above}$ of 50 flights at the 60dB $L_{A,max}$ day, 50dB $L_{A,max}$ night appears to capture over 80 % of complaints
  - $N_{above}$ analysis was performed on multiple runway ends at BOS, MSP, and CLT

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

| Peak Day N Above | Complaints Captured |
|---|---|
| 25x | 90.0% |
| 50x | 83.8% |
| 100x | 59.9% |

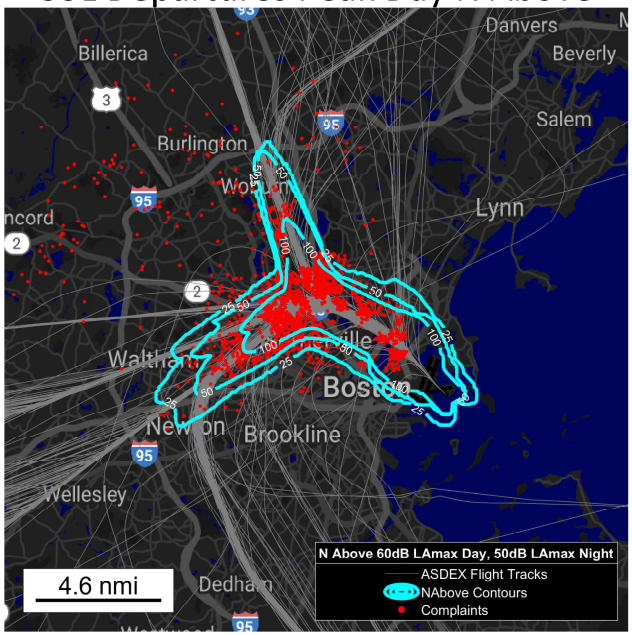
2017 Data

Source: Brenner 2017

# BOS N Above Thresholds

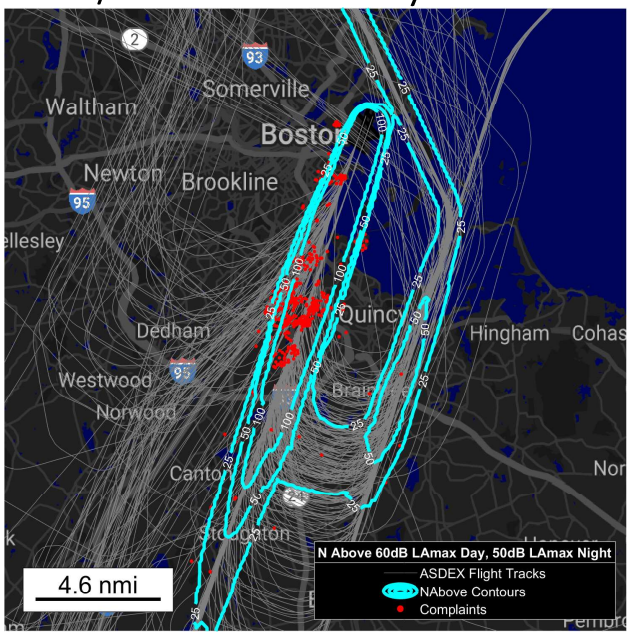
- 50 $N_{Above}$ 60dB $L_{A,max}$ day, 50dB $L_{A,max}$ night on a peak day appears to capture complaint threshold in dispersion analysis

33L Departures Peak Day N Above



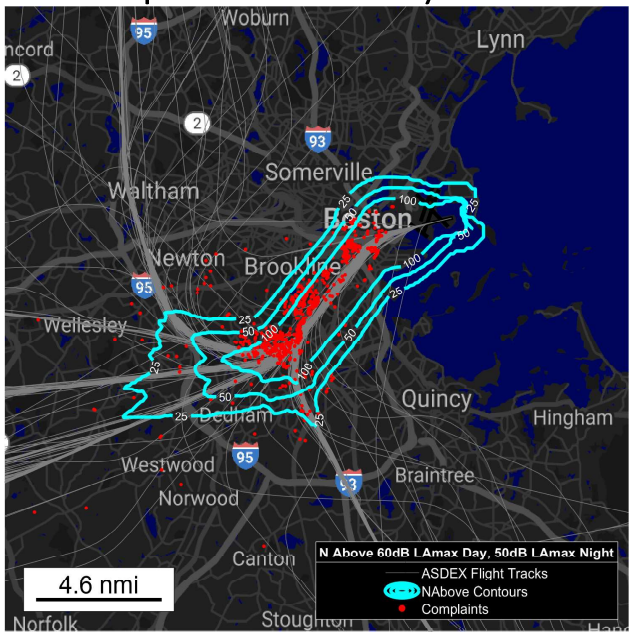

| Peak Day N Above | Complaints Captured |
|---|---|
| 25x | 90.0% |
| 50x | 83.8% |
| 100x | 59.9% |

4L/R Arrivals Peak Day N Above




| Peak Day N Above | Complaints Captured |
|---|---|
| 25x | 91.3% |
| 50x | 81.3% |
| 100x | 70.6% |

27 Departures Peak Day N Above




| Peak Day N Above | Complaints Captured |
|---|---|
| 25x | 94.6% |
| 50x | 90.2% |
| 100x | 76.8% |

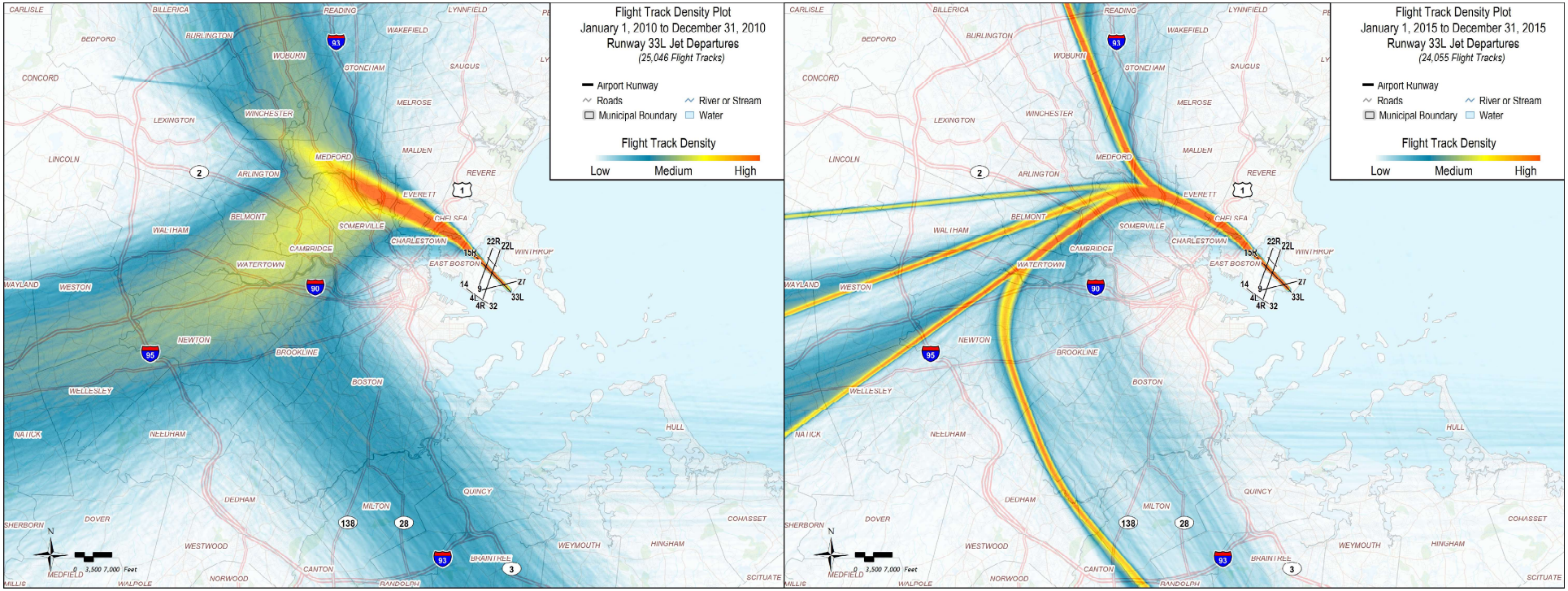
2017 Data

# Comparative Noise Levels


https://www.faa.gov/regulations_policies/policy_guidance/noise/basics/

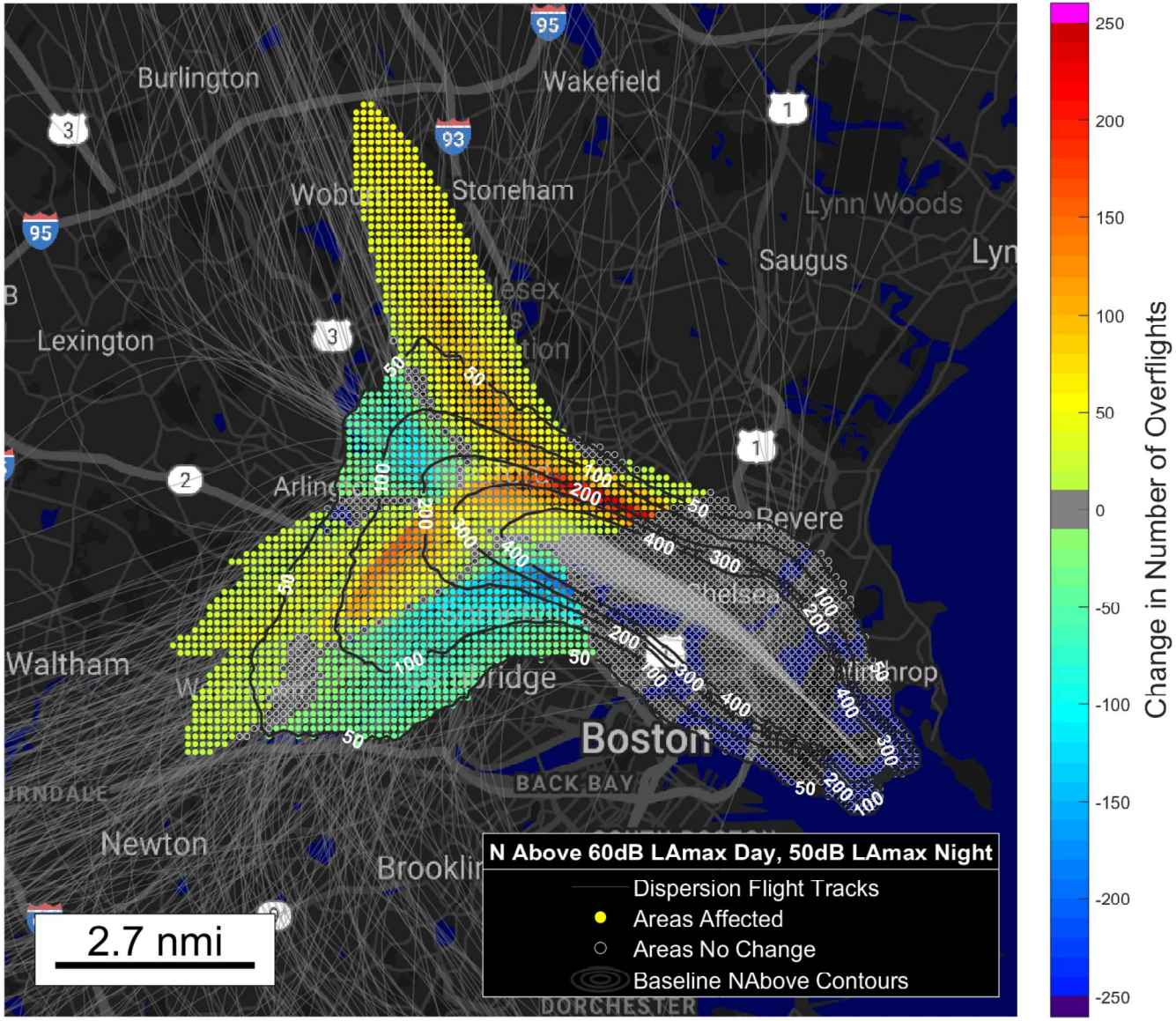
# Impact of RNAV Concentration

2010




2017

# Effect of RNAV on 33 Departures
## 2010 to 2017







**Population Exposure**

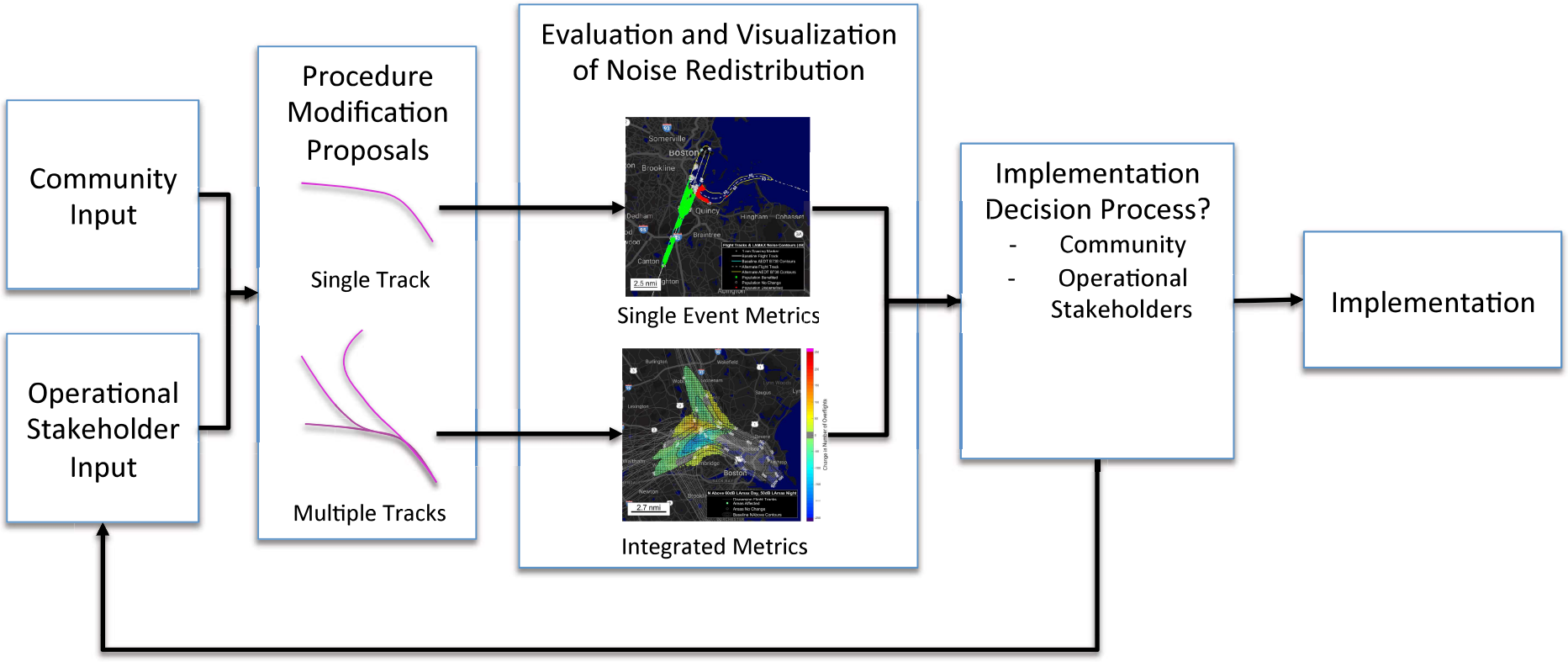
| N Above | 50x |
|---|---|
| Dispersion | 356,960 |
| RNAV | 336,643 |
| RNAV Benefit | 20,317 |

| Change In N Above | Population |
|---|---|
| +200x | 1,844 |
| +100x | 19,167 |
| +50x | 65,338 |
| -50x | 77,428 |
| -100x | 20,566 |
| -200x | 290 |

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

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

# Community Involvement in Procedures with Noise Redistribution



# Block 2 Procedures Under Consideration

**Block 2 Departure Mods**

- Dispersion
  - Runway 33L and 27
  - Open SID or direct-to flexibility for ATC on RNAV procedures
  - Altitude-based dispersion
  - Controller-based dispersion
  - Divergent heading dispersion
- RNP SID
  - Runway 22
    - Recent addition base on Block 1 status

**Block 2 Arrival Mods**

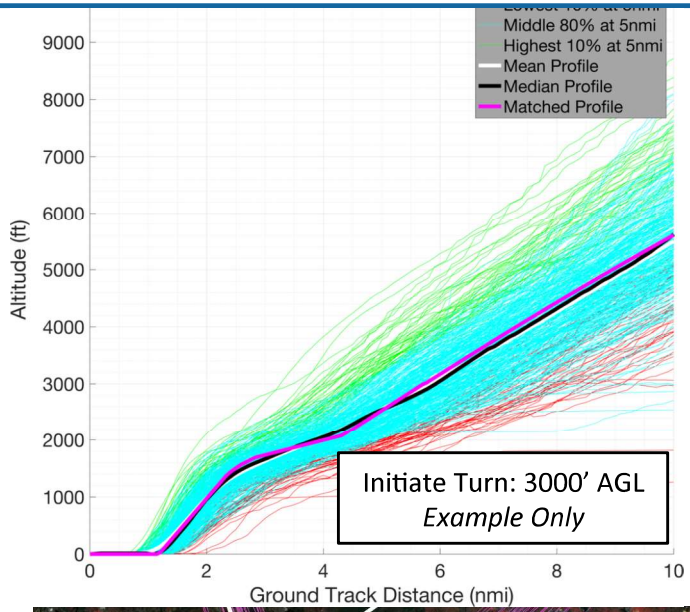
- Low-noise overwater approach procedures
  - Runway 22L
    - RNAV approach with RNP Overlay
  - Runway 4L and/or 4R
    - RNAV approach with RNP Overlay
    - RNP approach
- Vertical Path Changes
  - Steep Approaches
  - Delayed Landing Gear Extension
  - Continuous Descent Profiles
    - RNP arrivals that would allow continuous descent procedures from the north

**Preliminary/Subject to Change**

# Departure Dispersion: Runway 33L and 27

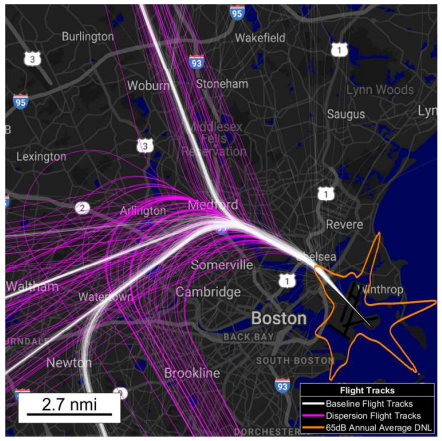
# Dispersion Concepts

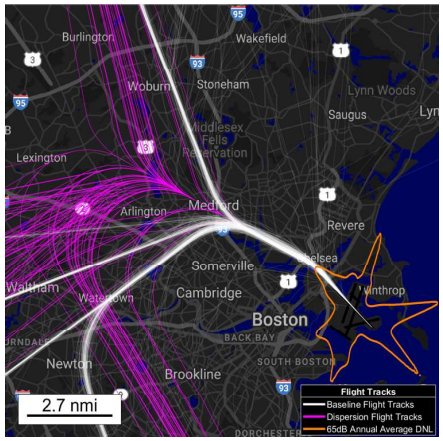
- Altitude-based dispersion
  - Direct routing to transition waypoint upon reaching specific altitude
- Controller-based dispersion
  - Dispersion arising from radar vectoring
  - 2010 flight track data normalized for comparison with 2017 data
  - Comparison between pre-RNAV and RNAV flight tracks
- Divergent heading dispersion
  - $15^0$ divergent headings then direct routing to transition waypoint upon reaching 3000ft
  - Increases throughput capacity

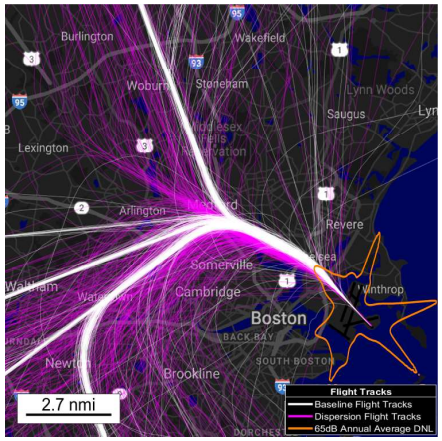


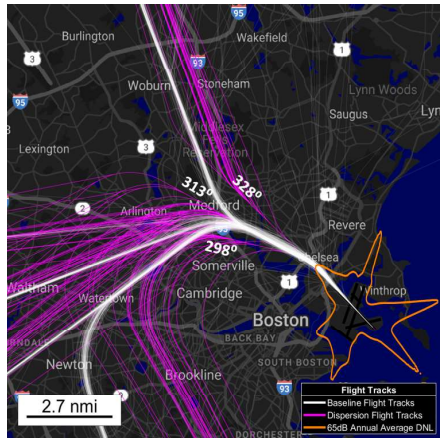

# Dispersion Concepts

33L Departures

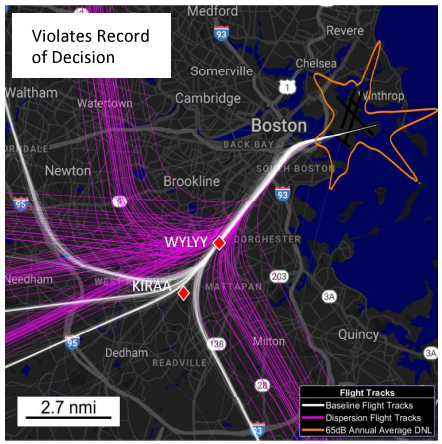


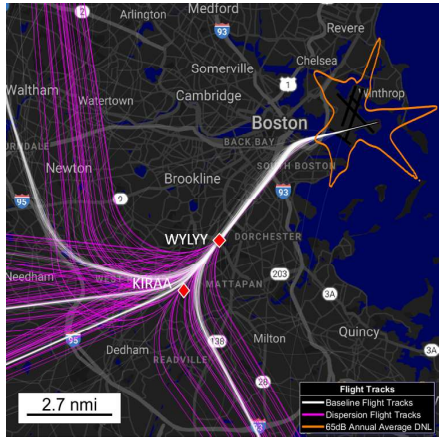



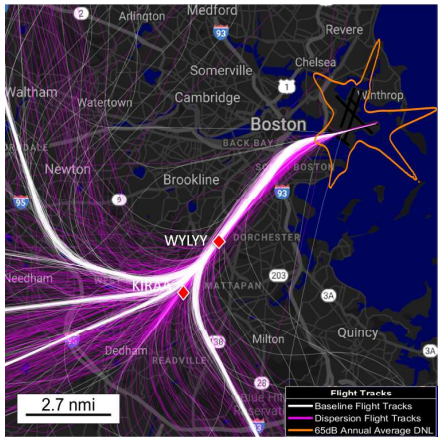



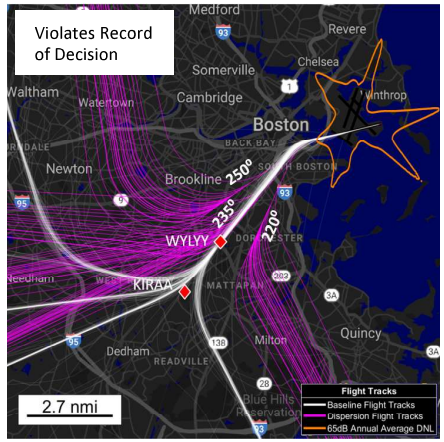




27 Departures



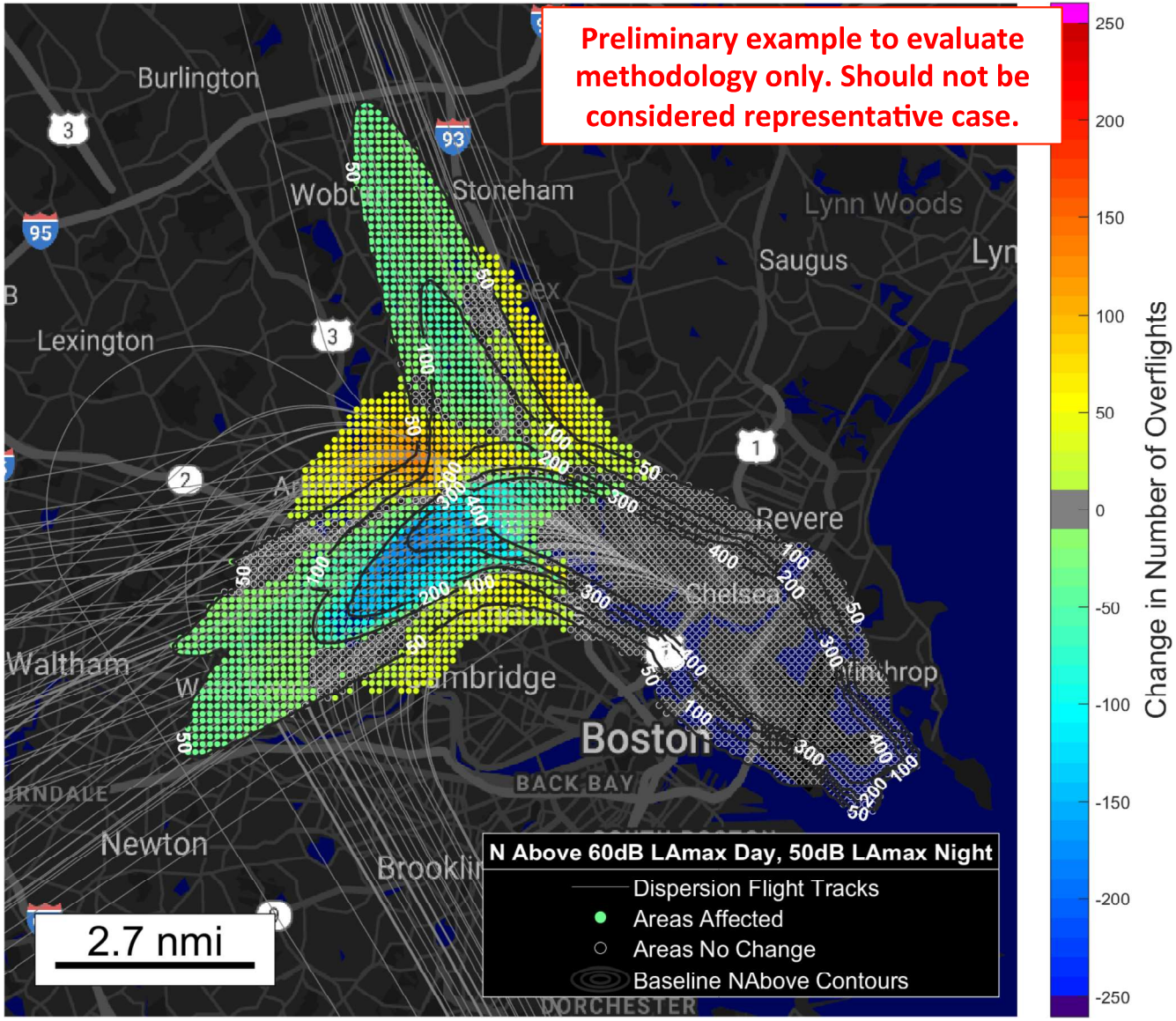




Altitude-Based 3000ft | Altitude-Based 4000ft | Controller-Based | Divergent Headings

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

# 33L Departures Dispersion Analysis

# 33L Departures Altitude-Based Dispersion at 3000ft Change in $N_{Above}$




**Population Exposure**

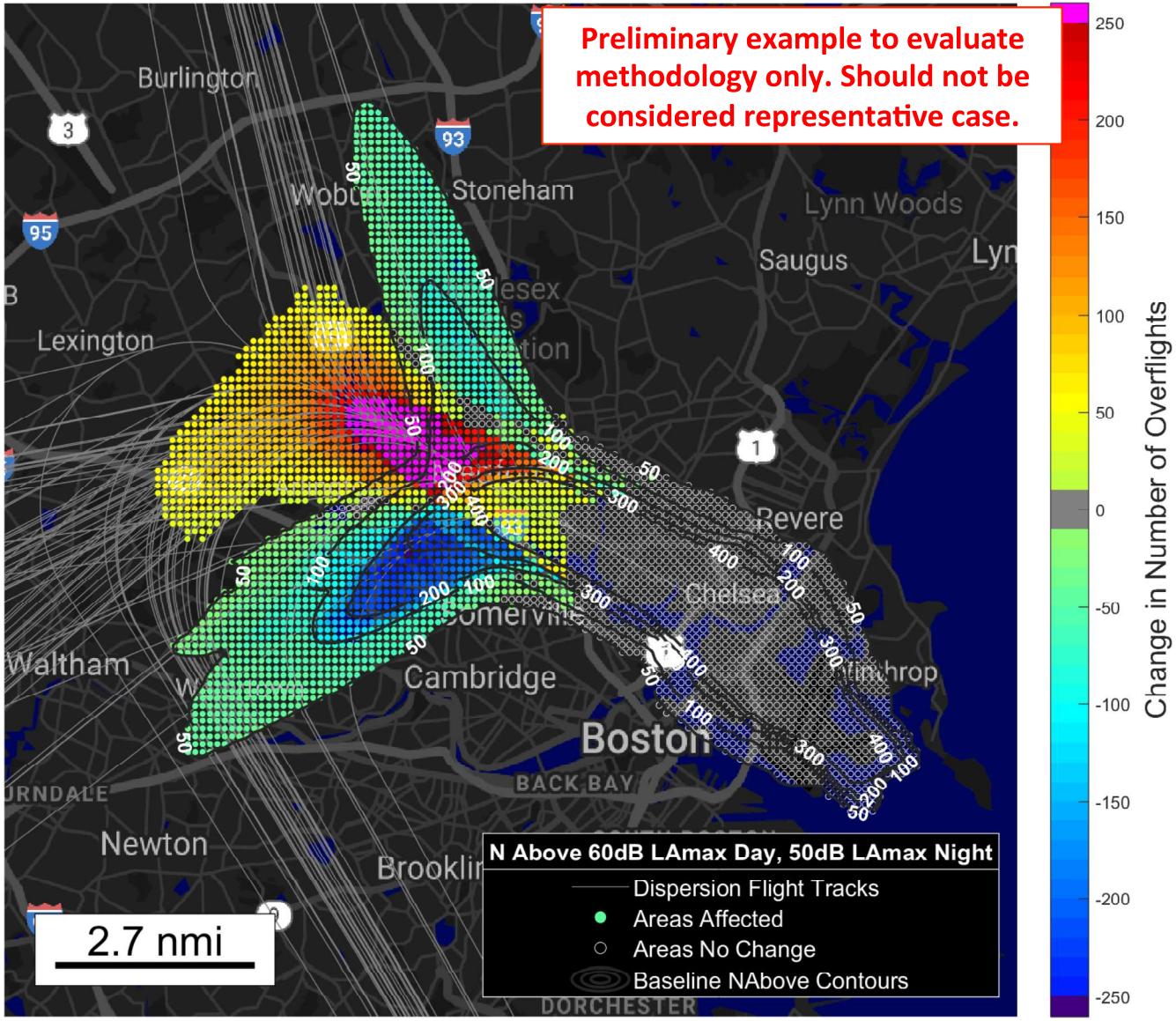
| N Above | 50x |
|---|---|
| Baseline | 336,643 |
| Dispersion | 338,951 |
| Baseline - Dispersion | -2,308 |

| Change In N Above | Population |
|---|---|
| +200x | 0 |
| +100x | 3,870 |
| +50x | 22,300 |
| -50x | 51,577 |
| -100x | 31,561 |
| -200x | 0 |

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

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

# 33L Departures Altitude-Based Dispersion at 4000ft Change in $N_{Above}$




**Population Exposure**

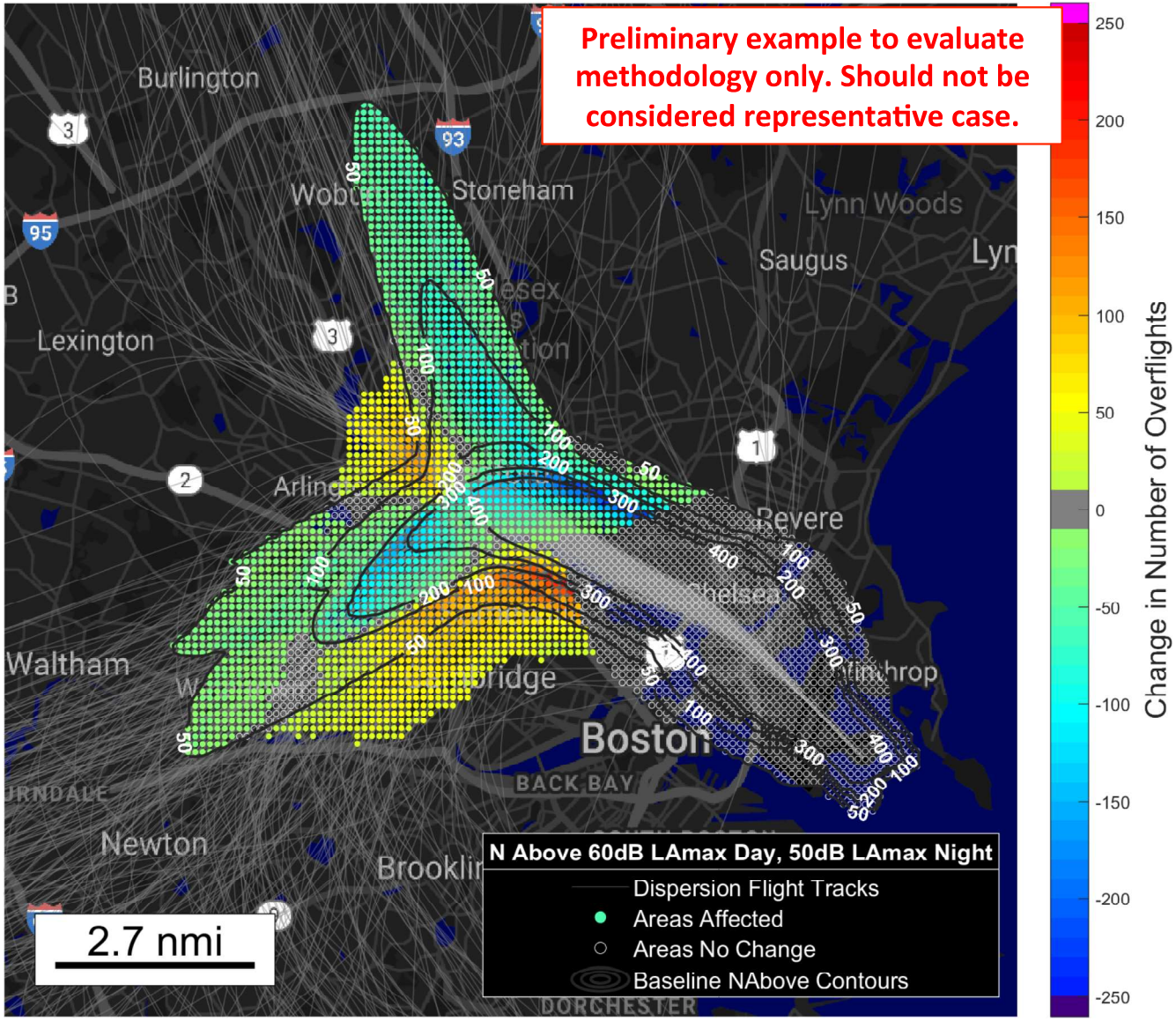
| N Above | 50x |
|---|---|
| Baseline | 336,643 |
| Dispersion | 268,231 |
| Baseline - Dispersion | 68,412 |

| Change In N Above | Population |
|---|---|
| +200x | 14,621 |
| +100x | 29,097 |
| +50x | 63,377 |
| -50x | 108,207 |
| -100x | 46,702 |
| -200x | 24,427 |

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

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

# 33L Departures Controller-Based Dispersion Change in $N_{Above}$




**Population Exposure**

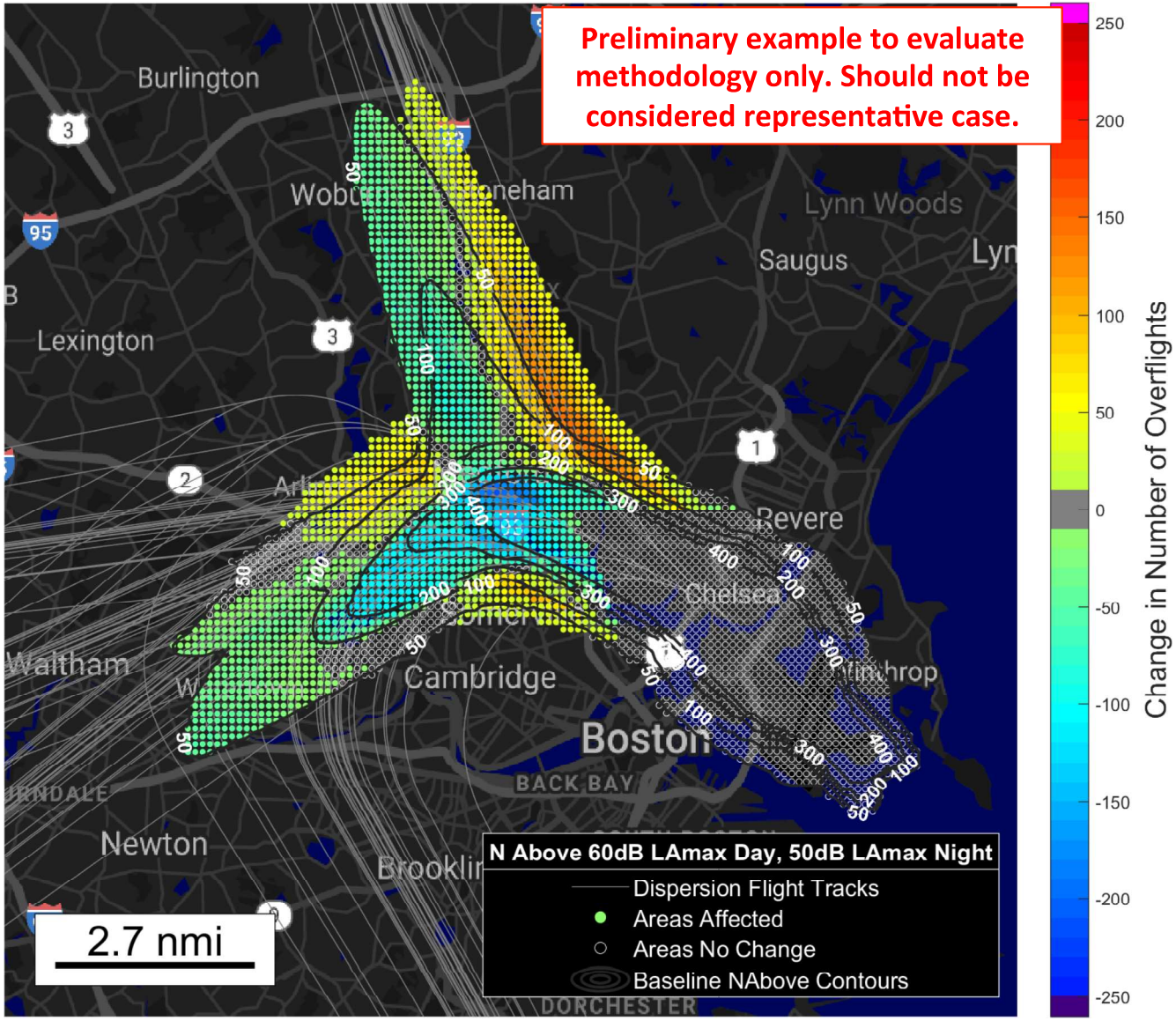
| N Above | 50x |
|---|---|
| Baseline | 336,643 |
| Dispersion | 356,960 |
| Baseline - Dispersion | -20,317 |

| Change In N Above | Population |
|---|---|
| +200x | 290 |
| +100x | 20,566 |
| +50x | 77,428 |
| -50x | 65,338 |
| -100x | 19,167 |
| -200x | 1,844 |

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

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

# 33L Departures Divergent Headings Dispersion Change in $N_{Above}$




**Population Exposure**

| N Above | 50x |
|---|---|
| Baseline | 336,643 |
| Dispersion | 335,602 |
| Baseline - Dispersion | 1,041 |

| Change In N Above | Population |
|---|---|
| +200x | 0 |
| +100x | 13,651 |
| +50x | 47,885 |
| -50x | 62,772 |
| -100x | 31,545 |
| -200x | 0 |

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

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

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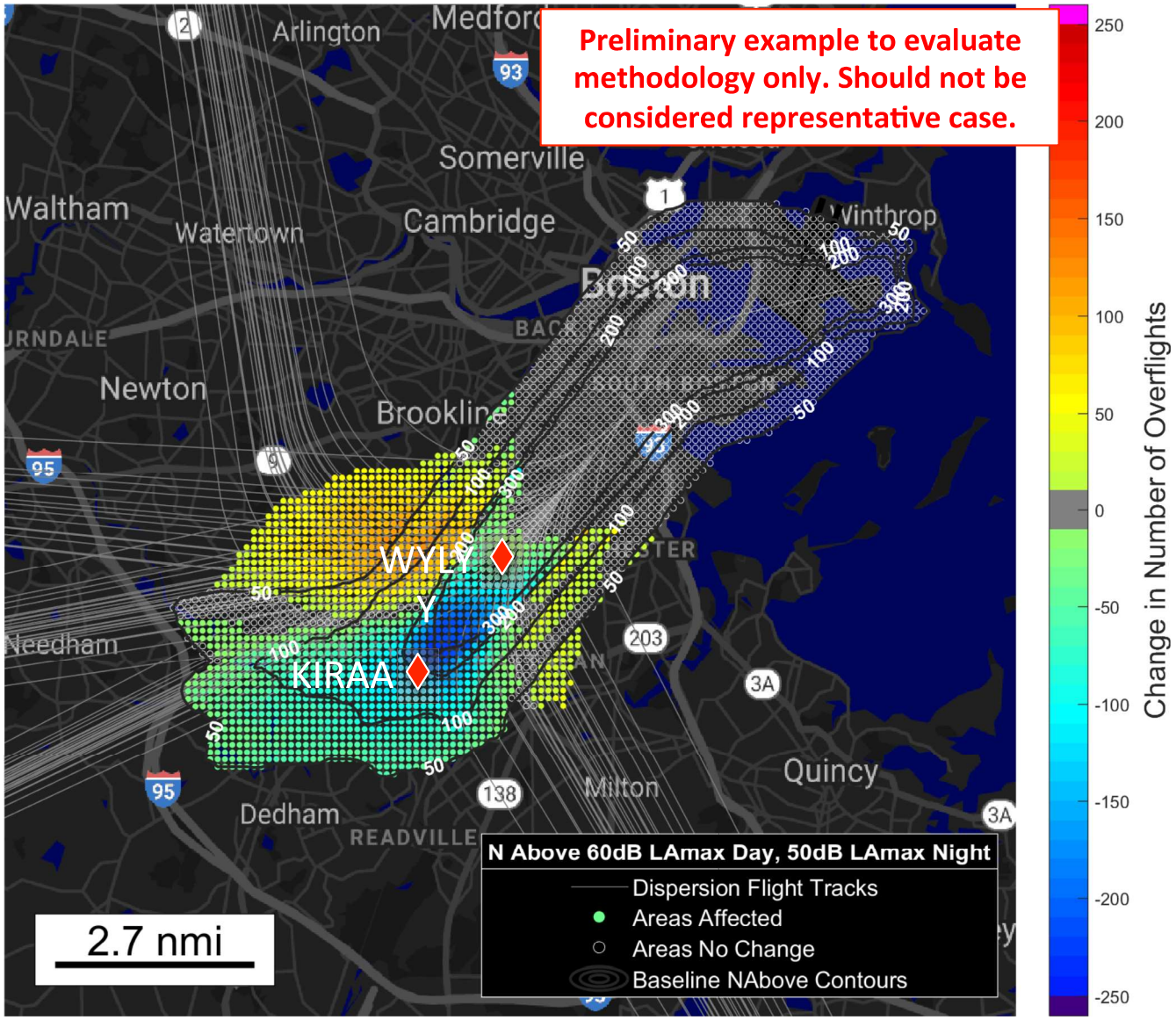
# 27 Departures Dispersion Analysis

# 27 Departures Altitude-Based Dispersion at 3000ft
## Violates Record of Decision
### Change in $N_{Above}$




**Population Exposure**

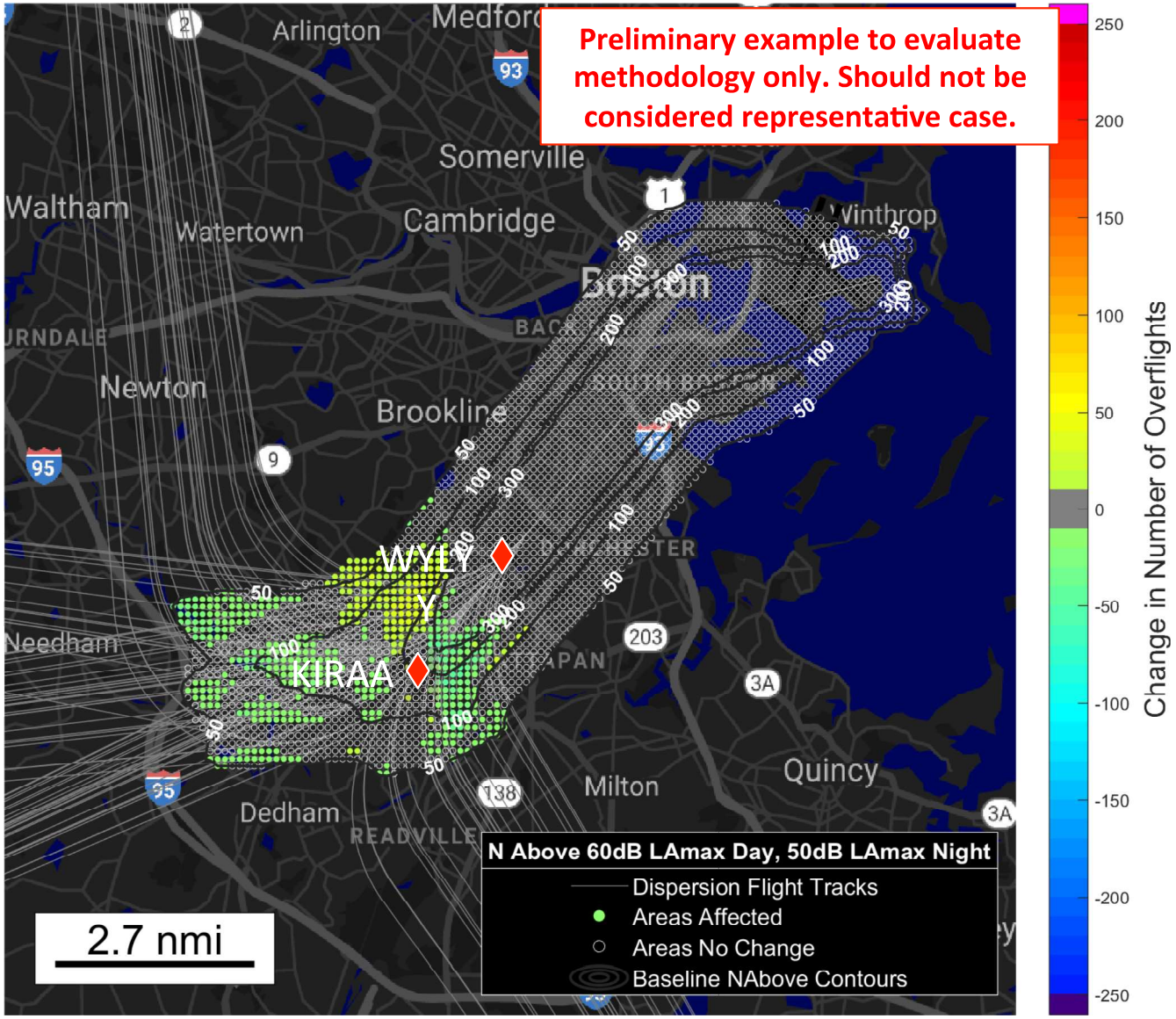
| N Above | 50x |
|---|---|
| Baseline | 407,357 |
| Dispersion | 373,940 |
| Baseline - Dispersion | 33,417 |

| Change In N Above | Population |
|---|---|
| +200x | 0 |
| +100x | 2,232 |
| +50x | 22,084 |
| -50x | 56,292 |
| -100x | 22,475 |
| -200x | 4,368 |

Analysis based on peak day operations; only includes 27 departures

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

# 27 Departures Altitude-Based Dispersion at 4000ft Change in $N_{Above}$




**Population Exposure**

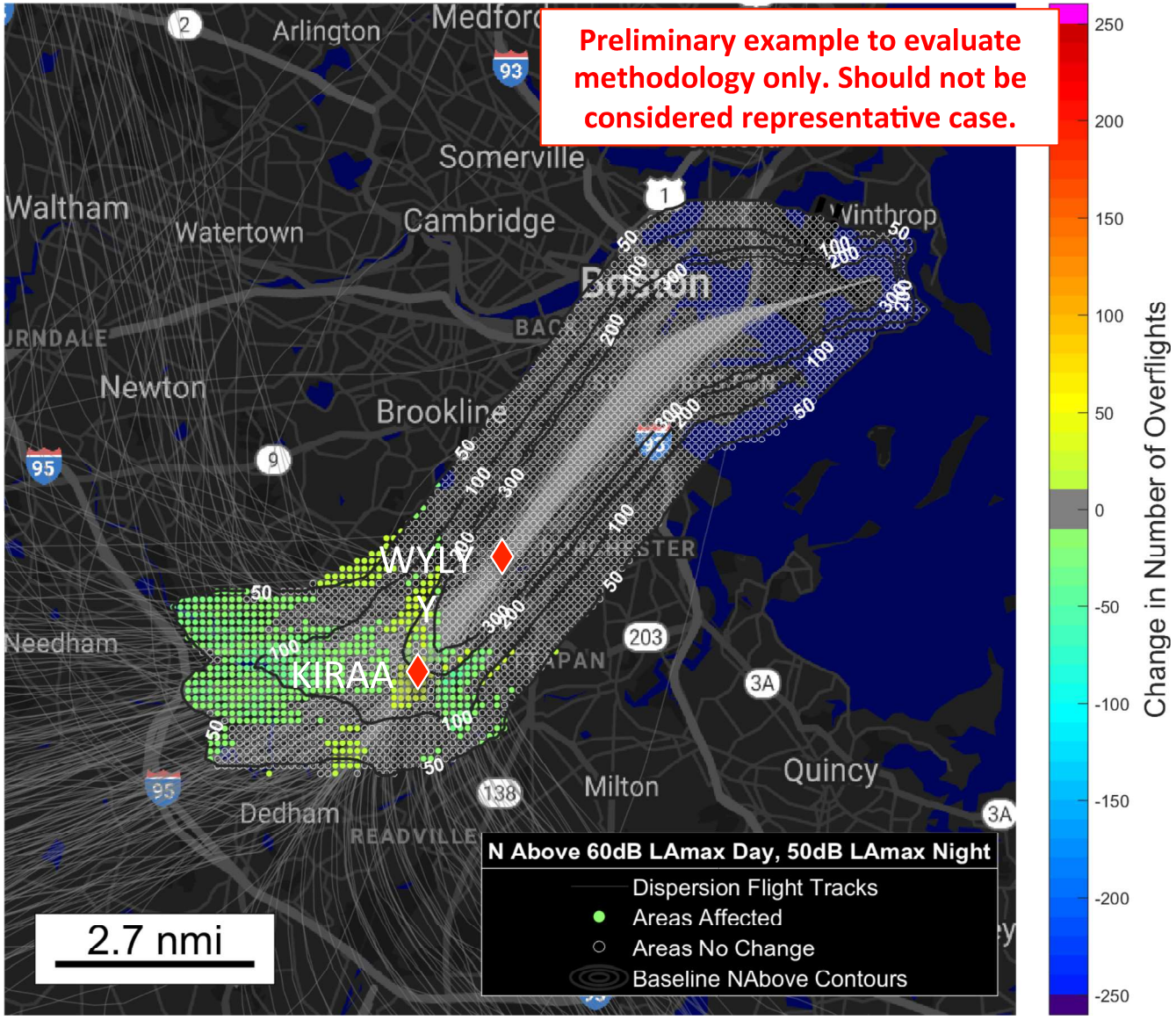
| N Above | 50x |
|---|---|
| Baseline | 407,357 |
| Dispersion | 393,053 |
| Baseline - Dispersion | 14,304 |

| Change In N Above | Population |
|---|---|
| +200x | 0 |
| +100x | 0 |
| +50x | 0 |
| +25x | 5,708 |
| -25x | 6,876 |
| -50x | 0 |
| -100x | 0 |
| -200x | 0 |

Analysis based on peak day operations; only includes 27 departures

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

# 27 Departures Controller-Based Dispersion Change in $N_{Above}$




**Population Exposure**

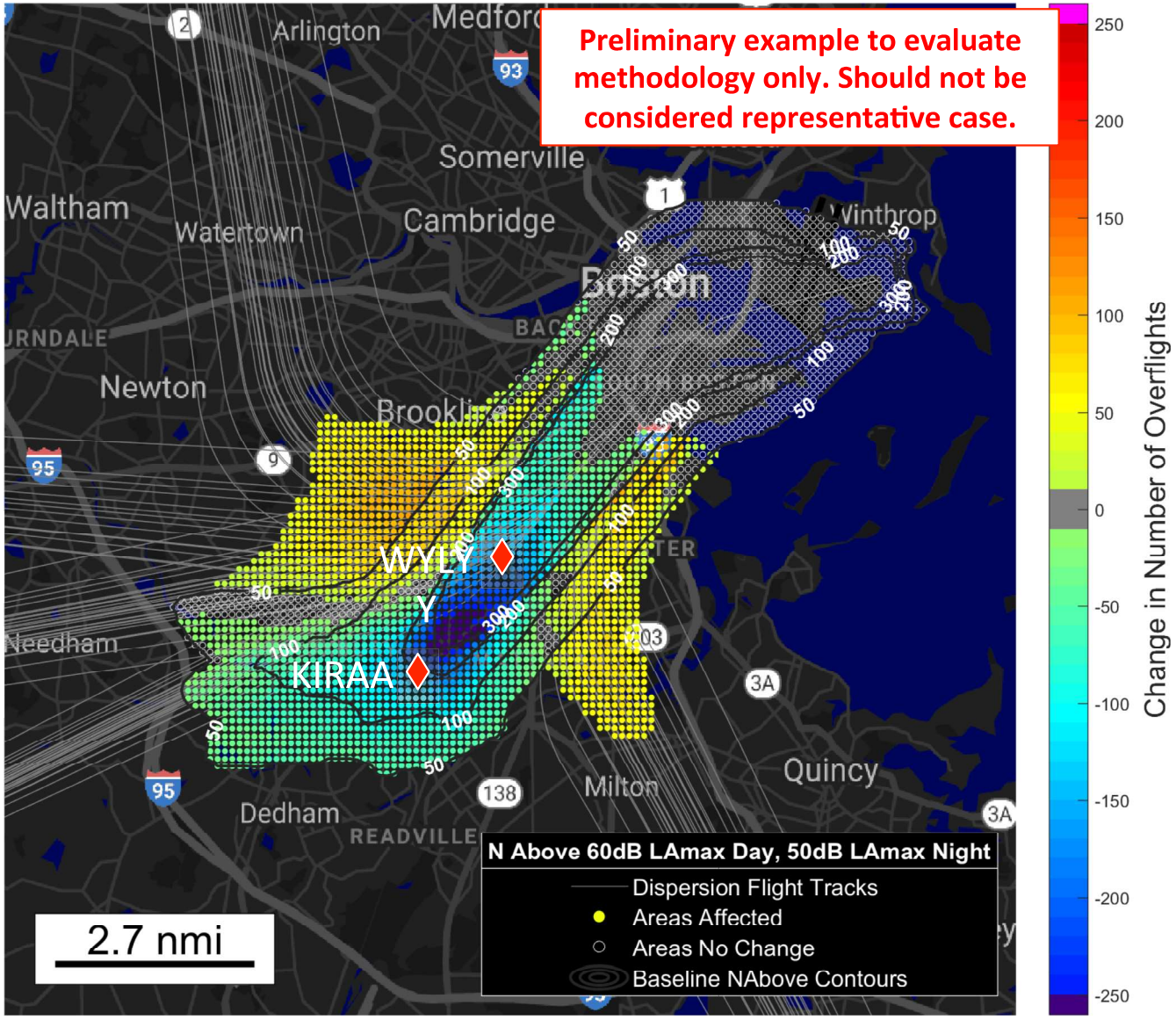
| N Above | 50x |
|---|---|
| Baseline | 407,357 |
| Dispersion | 396,394 |
| Baseline - Dispersion | 10,963 |

| Change In N Above | Population |
|---|---|
| +200x | 0 |
| +100x | 0 |
| +50x | 109 |
| -50x | 0 |
| -100x | 0 |
| -200x | 0 |

Analysis based on peak day operations; only includes 27 departures

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

# 27 Departures Divergent Headings Dispersion
## Violates Record of Decision
### Change in $N_{Above}$




**Population Exposure**

| N Above | 50x |
|---|---|
| Baseline | 407,357 |
| Dispersion | 399,229 |
| Baseline - Dispersion | 8,128 |

| Change In N Above | Population |
|---|---|
| +200x | 0 |
| +100x | 1,562 |
| +50x | 73,563 |
| -50x | 113,007 |
| -100x | 39,790 |
| -200x | 9,047 |

Analysis based on peak day operations; only includes 27 departures

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

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# Low-Noise Overwater Approach Procedure

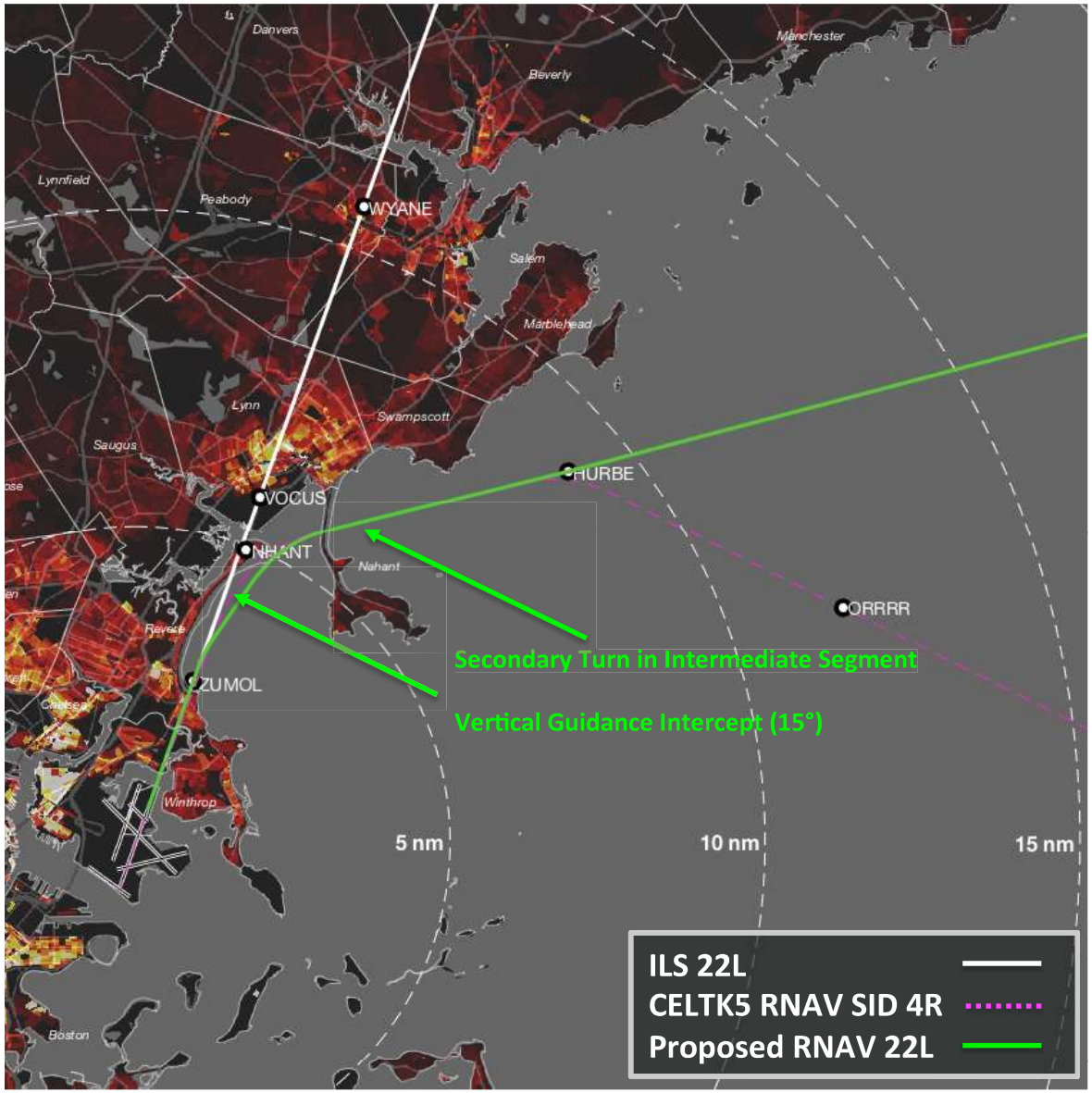
22L Arrival

# 22L Low-Noise Offset RNAV Approach with RNP Overlay

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

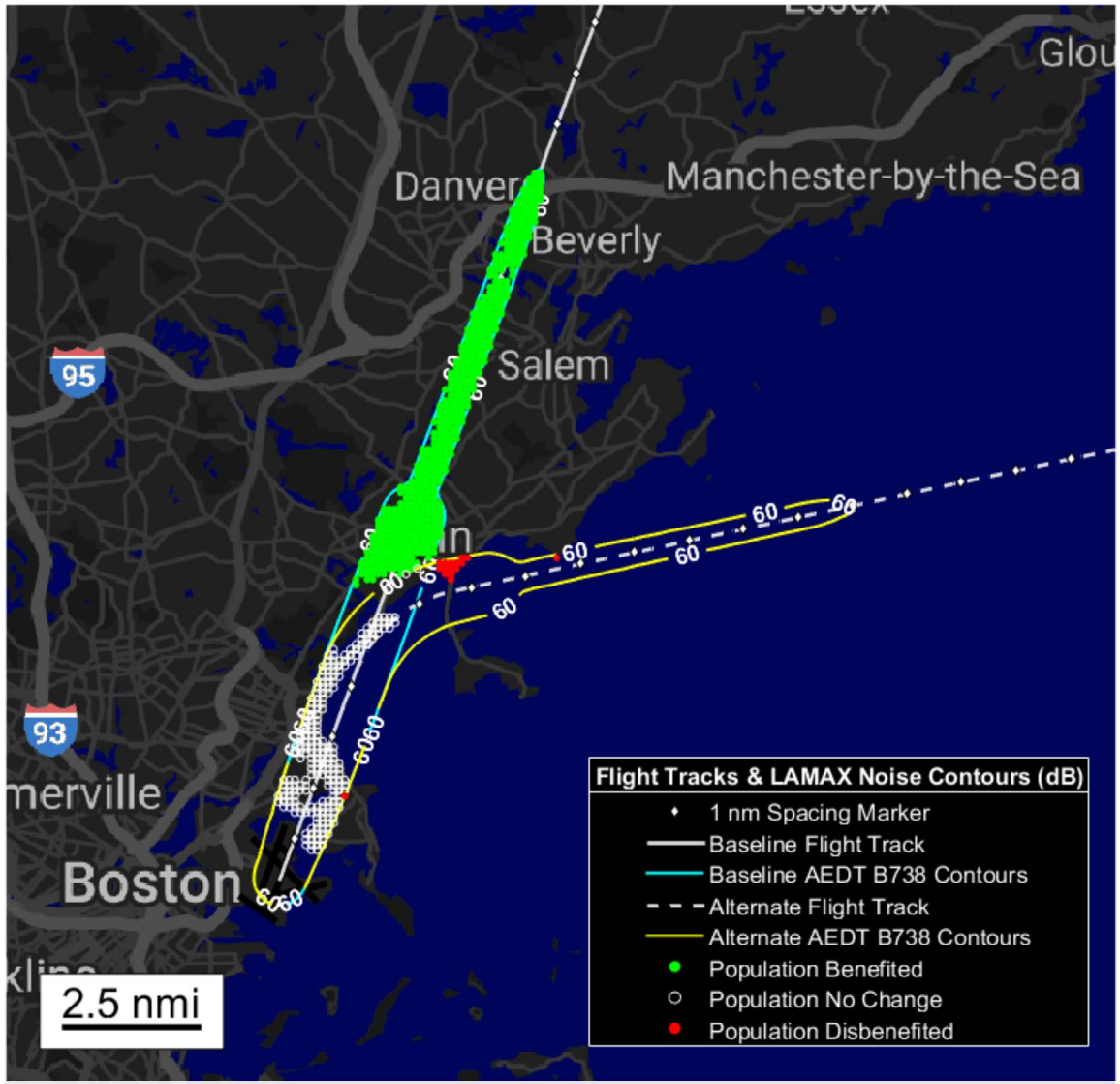
Notes:

- 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

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




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

| | 60dB |
|---|---|
| Straight In | 82,162 |
| RNP | 29,561 |
| Difference (Straight In – RNP) | 52,601 |

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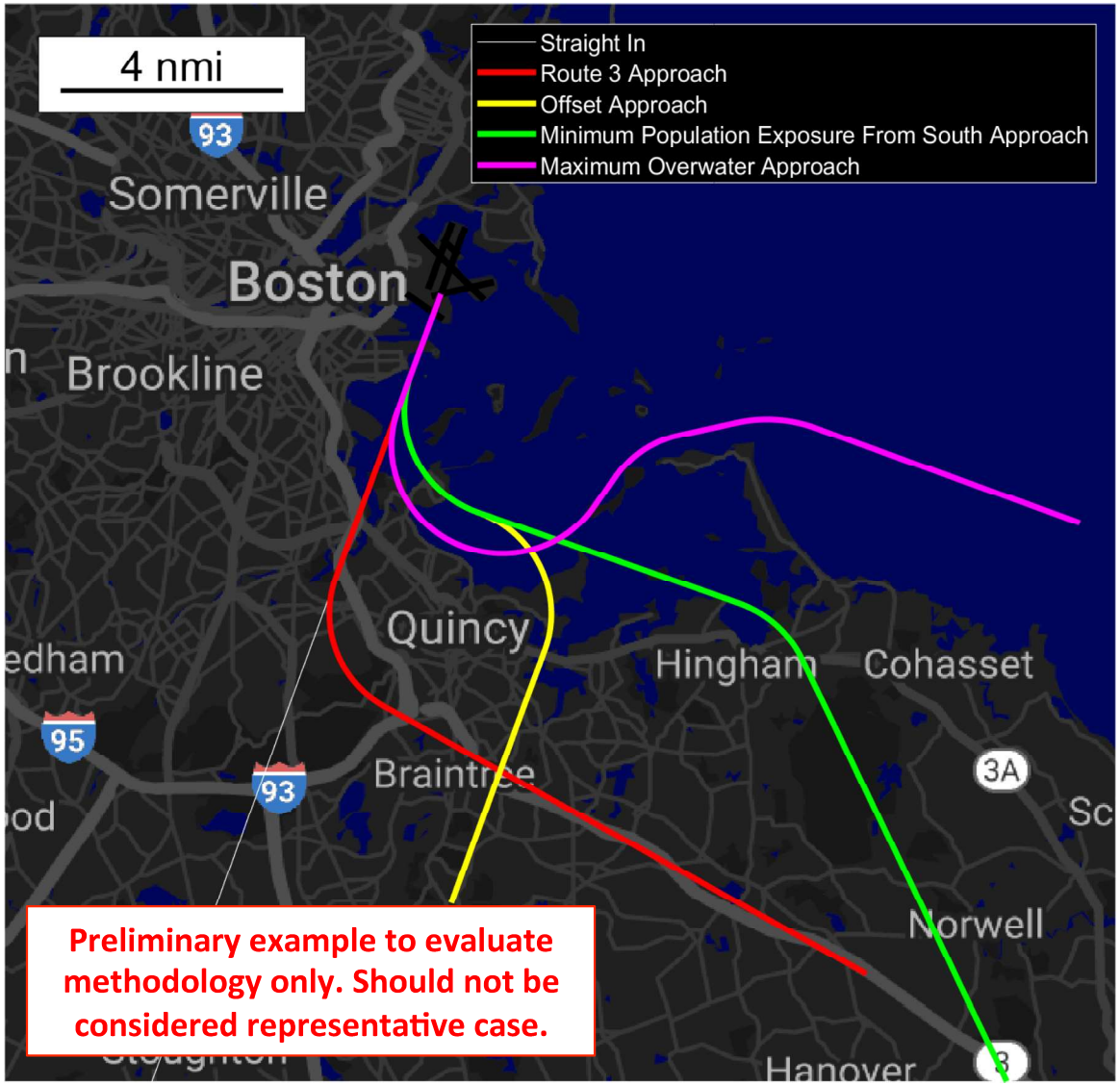
International Center for
Air Transportation

# Low-Noise Overwater Approach Procedure

4R Arrival

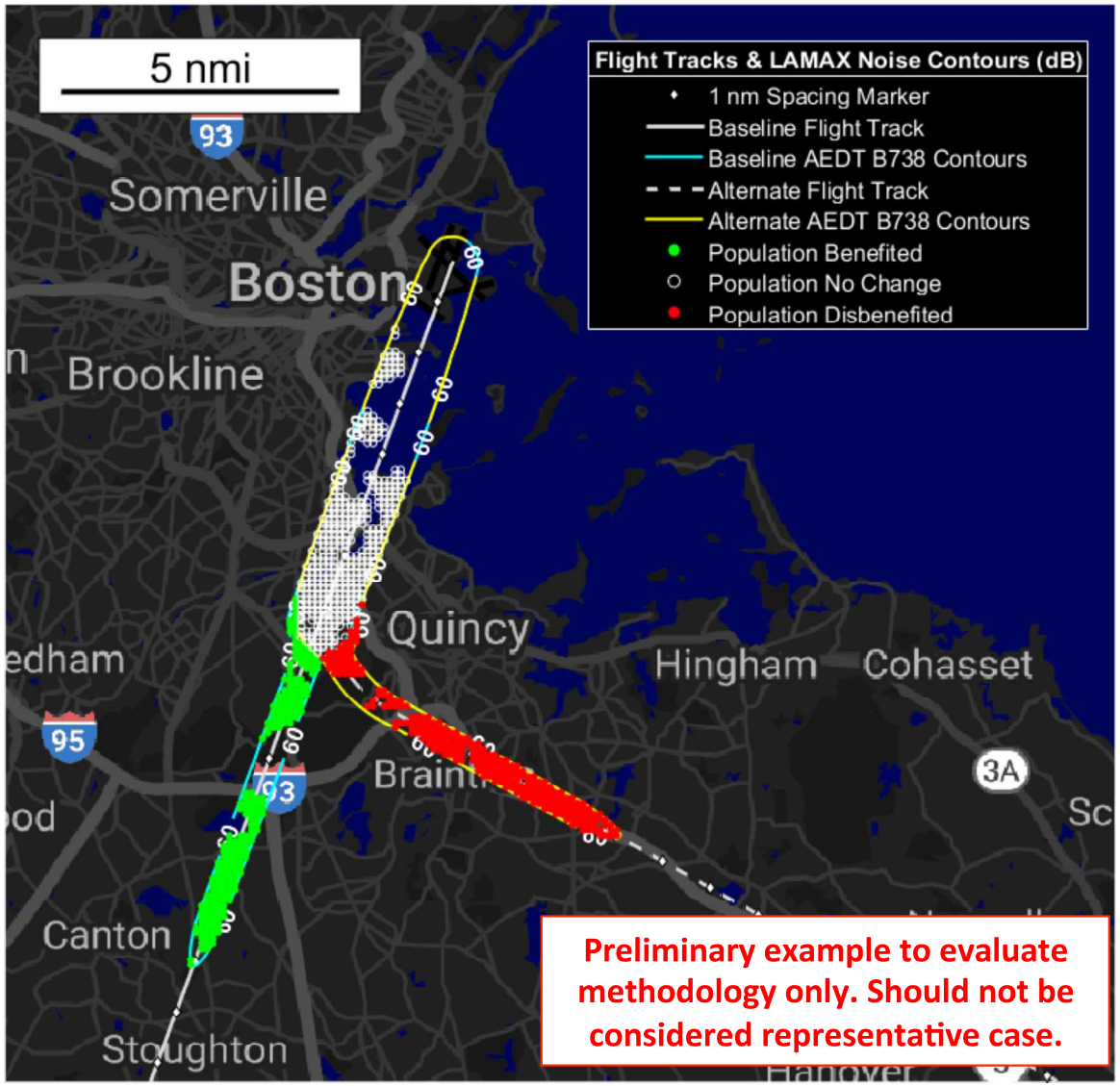
# Example 4R RNP Approach




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

# 4R RNP Approach – Route 3 Initial

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



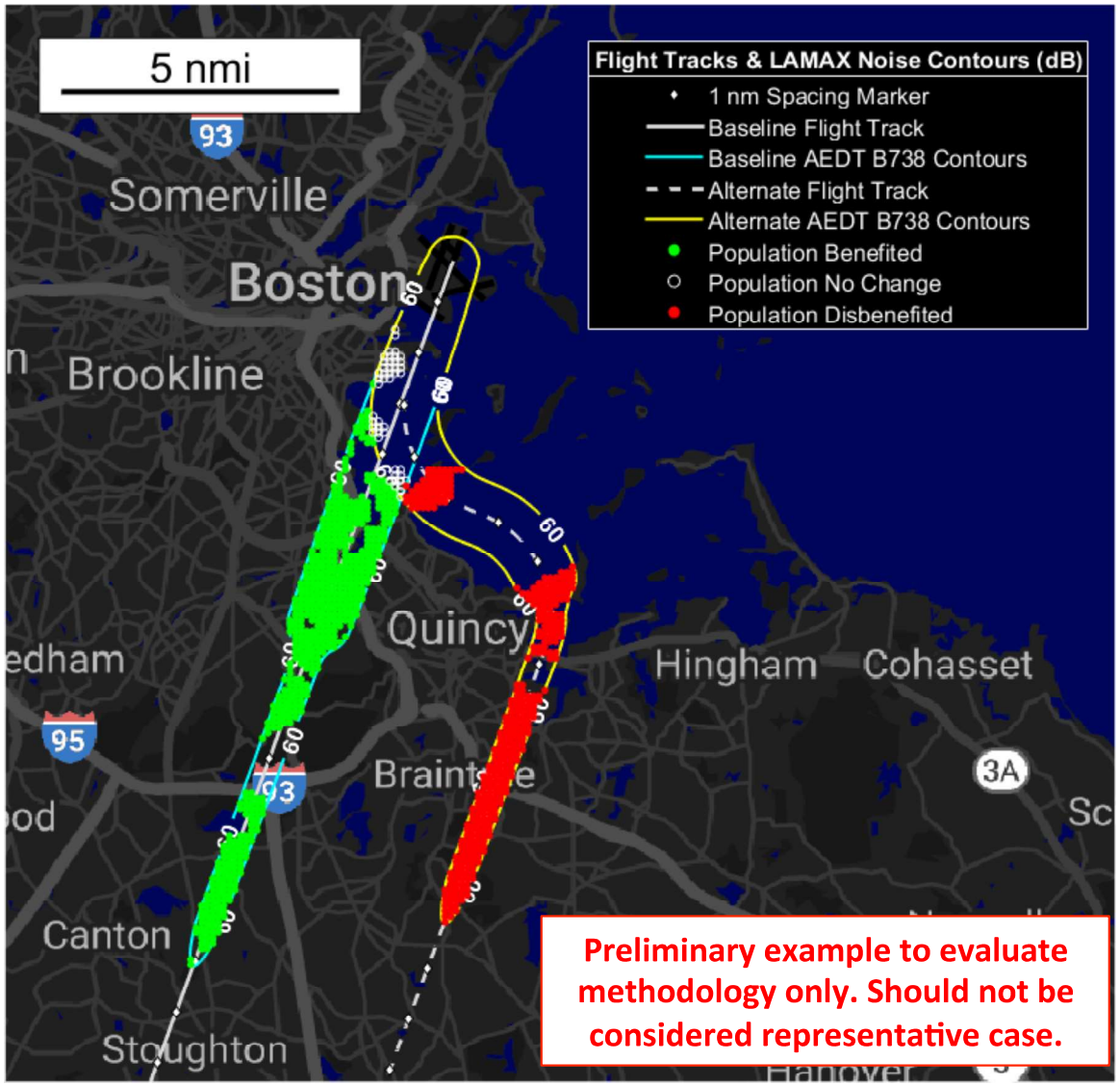

**B737-800**
**Population Exposure ($L_{A,MAX}$)**

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

5.5nmi final segment
$80^{o}$ 2nmi radius-to-fix turn

# 4R RNP Approach – Offset Initial

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



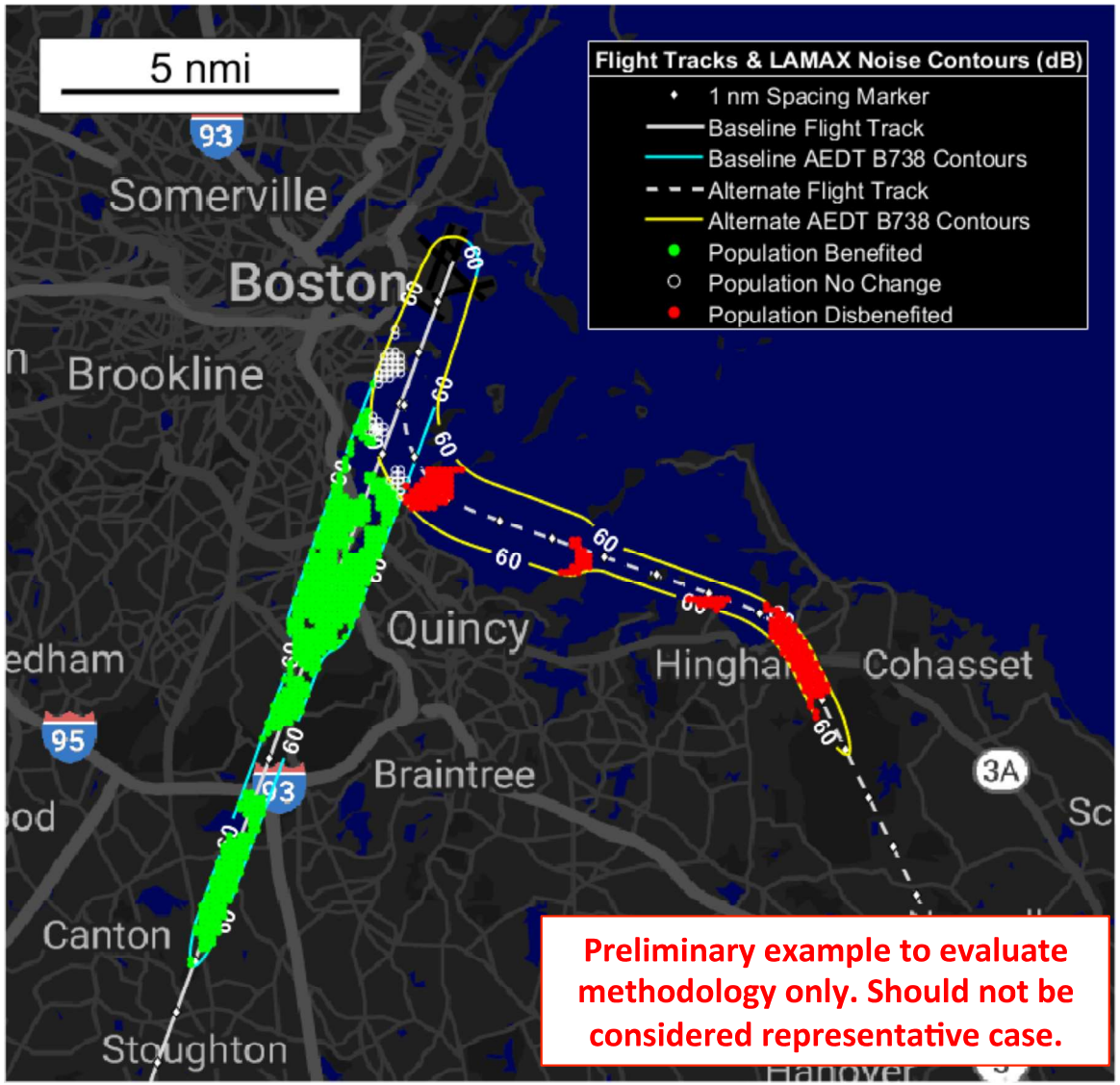

**B737-800**
**Population Exposure ($L_{A,MAX}$)**

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

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

# 4R RNP Approach – Min Population Exposure from South

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



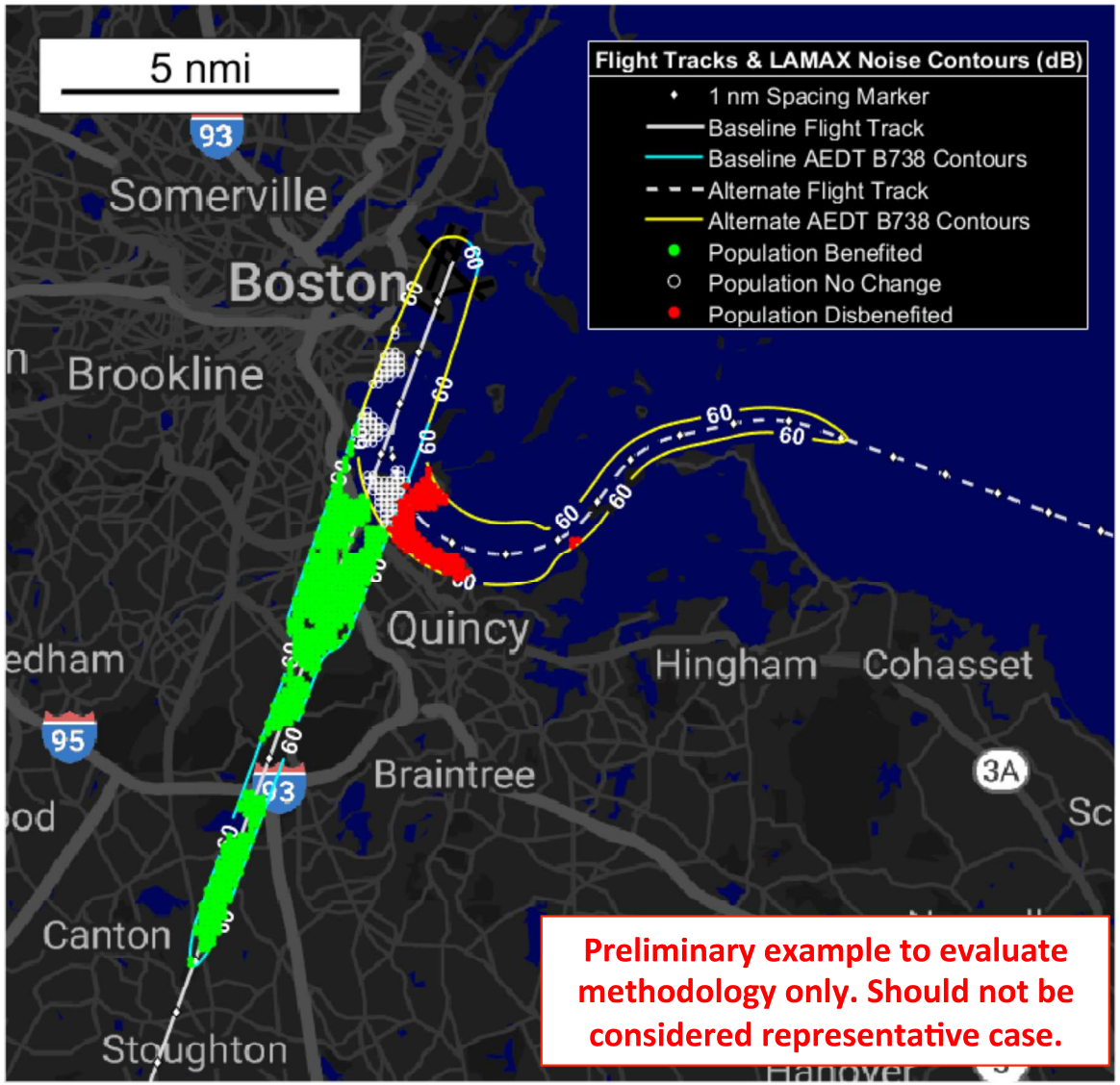

**B737-800**
**Population Exposure ($L_{A,MAX}$)**

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

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

# 4R Arrival RNP – Maximum Overwater

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




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

| | 60dB |
|---|---|
| Straight In | 32,144 |
| RNP | 20,754 |
| Difference (Straight In – RNP) | 11,390 |

Different routes for 4R arrivals still under analysis

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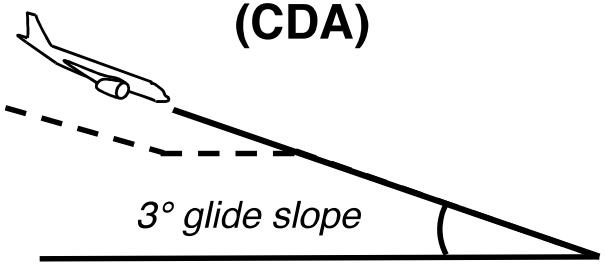
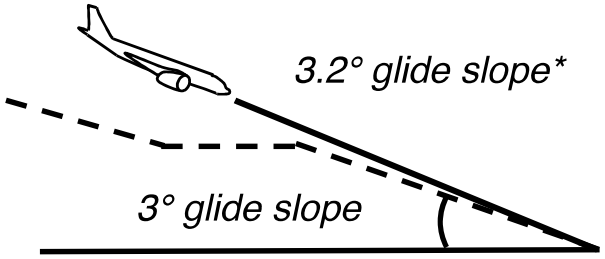
# Vertical Path Changes
# Runway 4R

# Vertical Path Change Options Evaluated

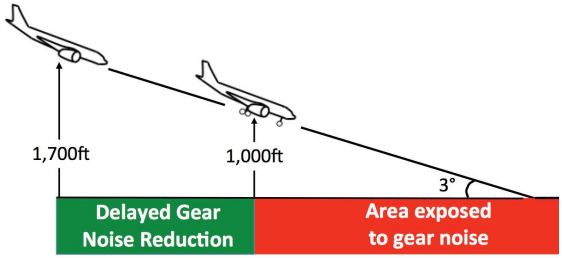
## Continuous Descent (CDA)

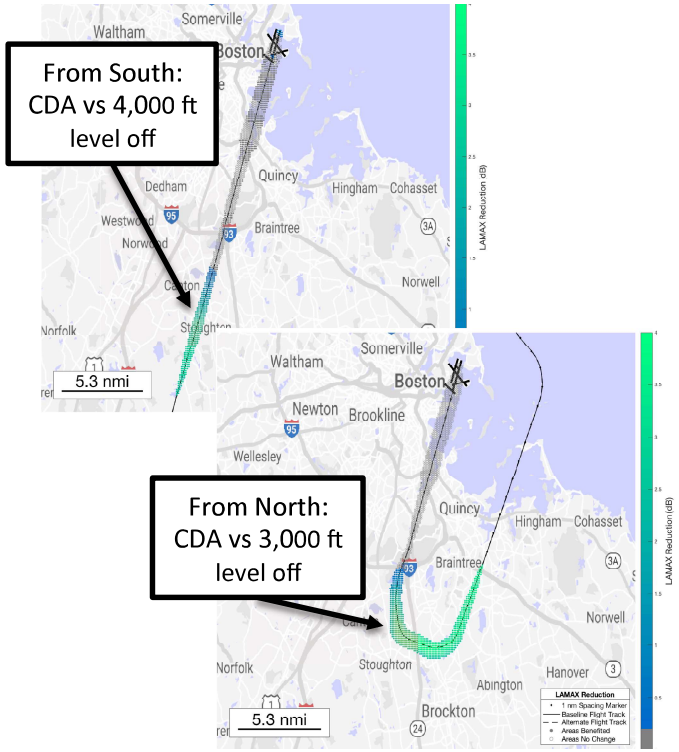


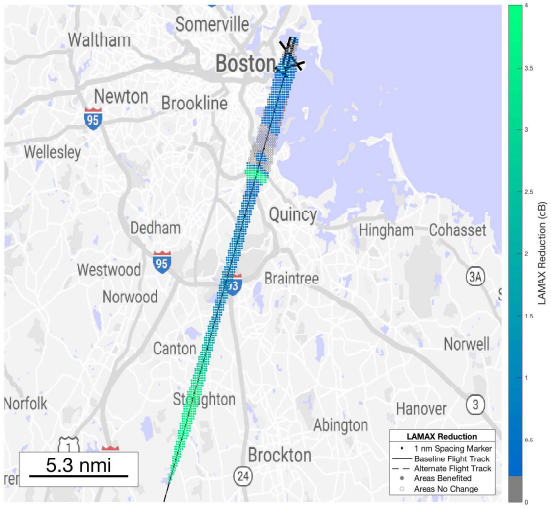

## Steeper Descent

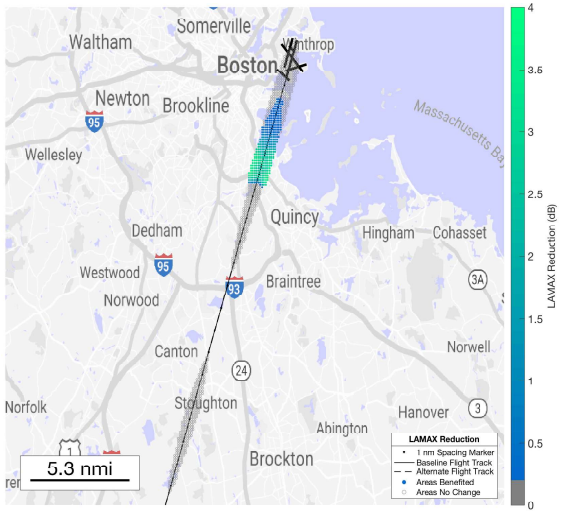



## Delayed Gear



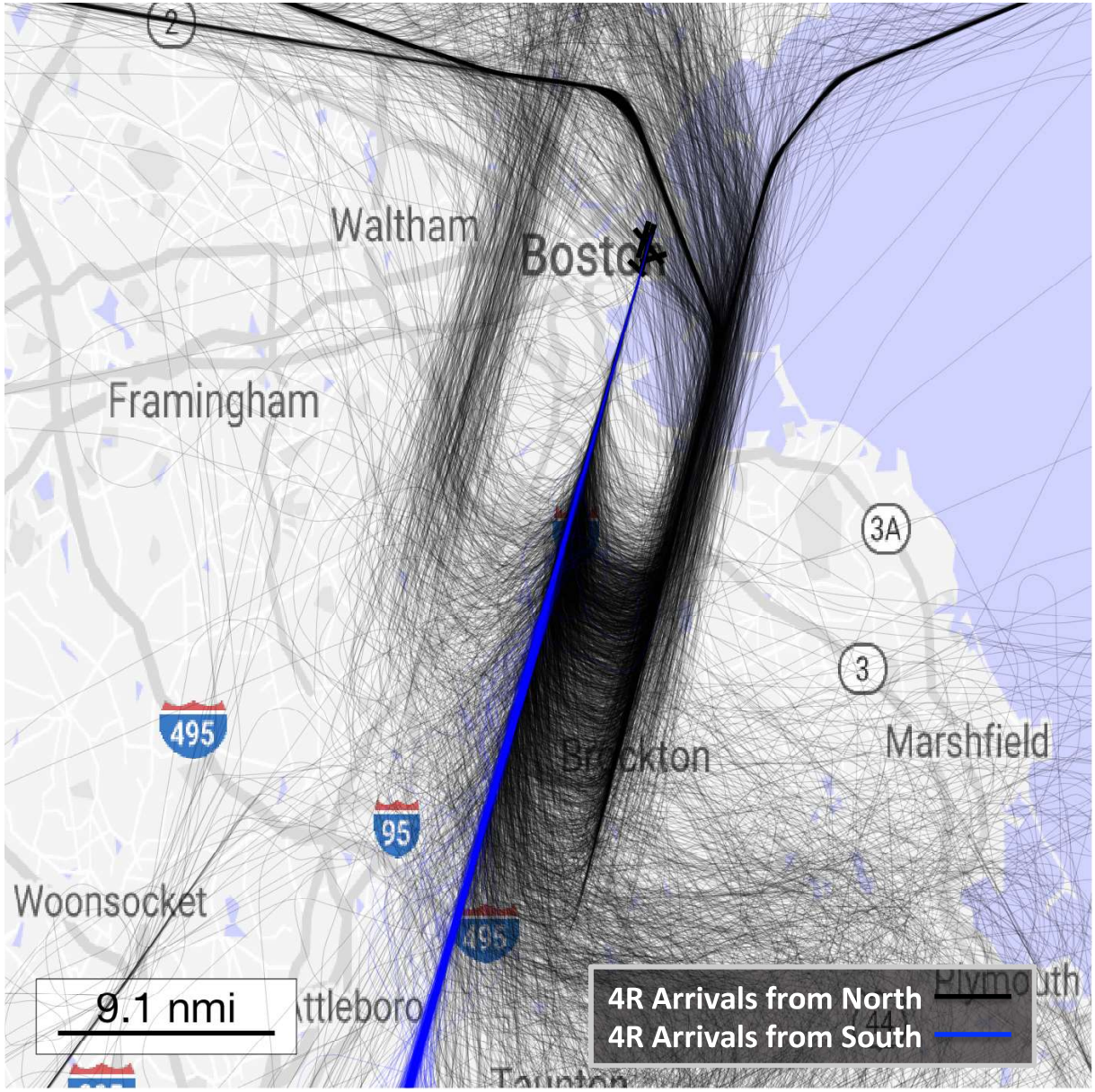




Preliminary examples to evaluate methodology only.
Should not be considered representative case.

*Approval required to establish a glide path angle higher than 0.2° of VGSI (greater than 3.2° at BOS) (TERPS criteria page 2-47)

# Baseline: 2017 Arrivals to Runway 4R



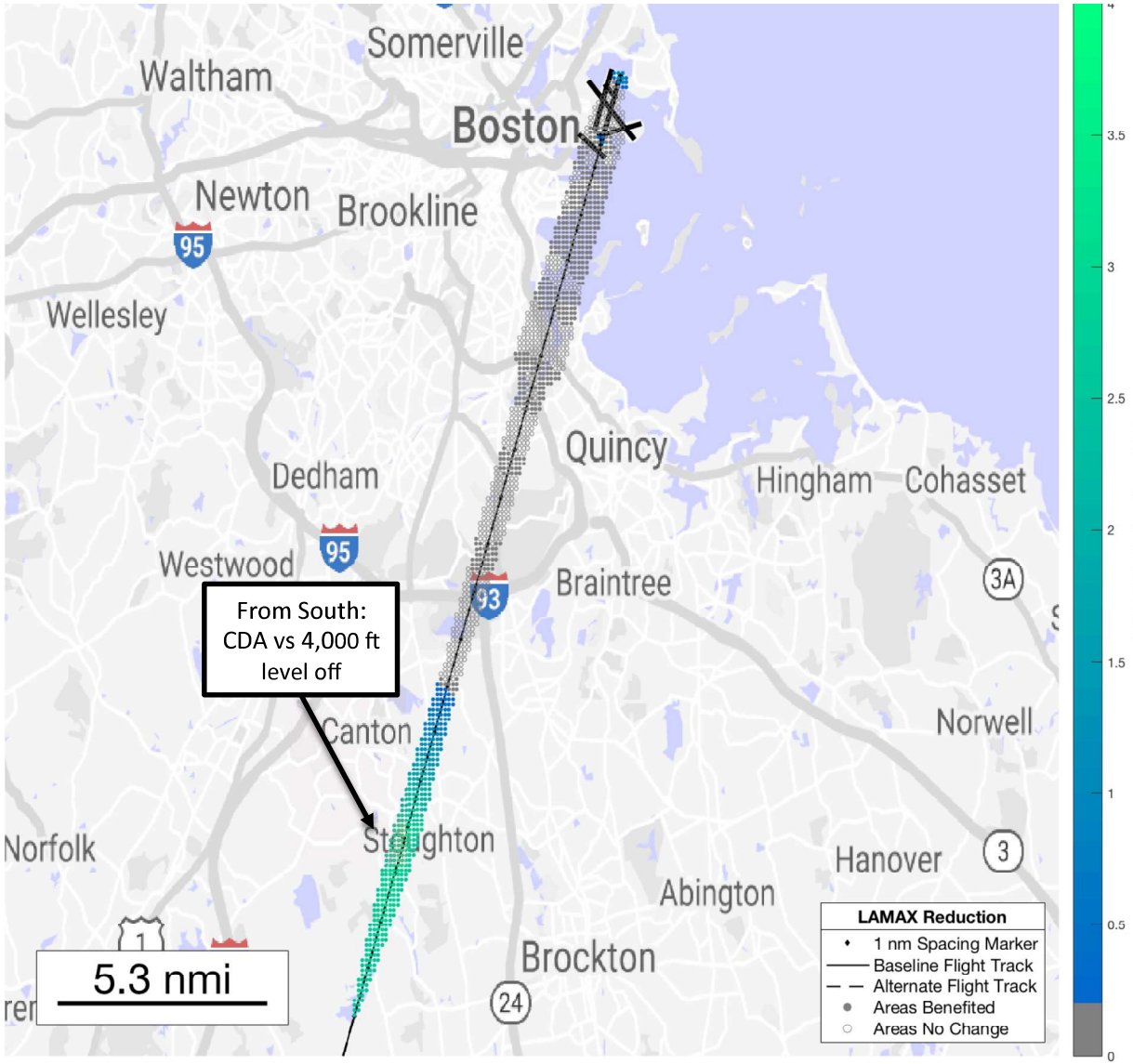

**Notes:**

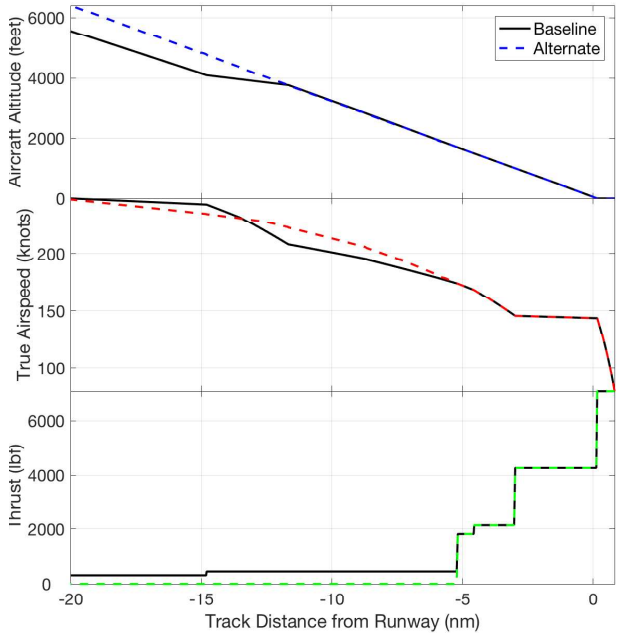
- 39,615 Arrivals to Rwy 4R in 2017 (jet & prop):
- Figure shows 10% of all 2017 arrivals selected at random
- Data Source: Flight Tracks, Massport Noise and Operations Management System (NOMS)

- **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 |

# 3.0° Continuous Descent from the South vs Baseline Stepped Descent LAMAX Reduction



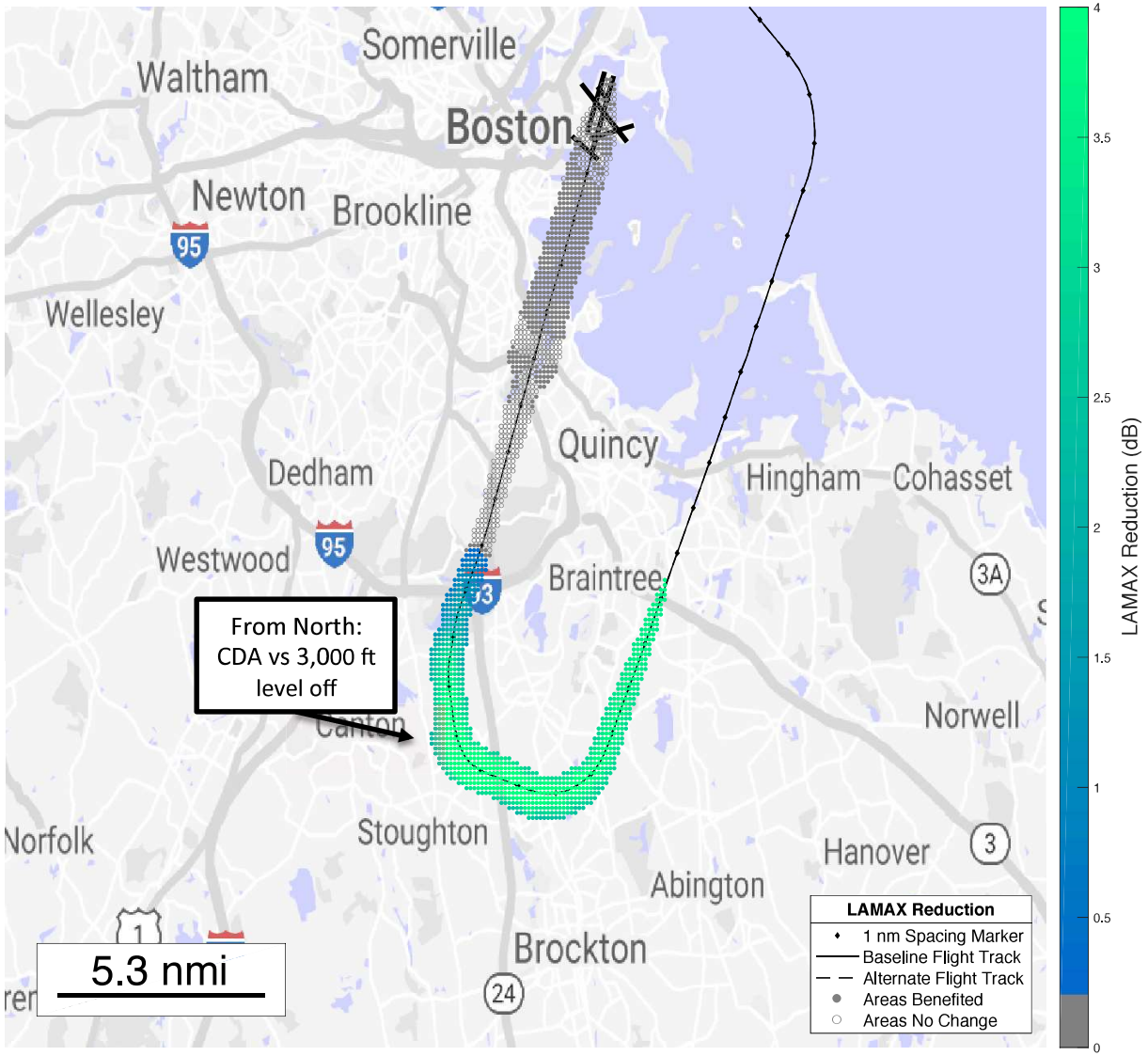



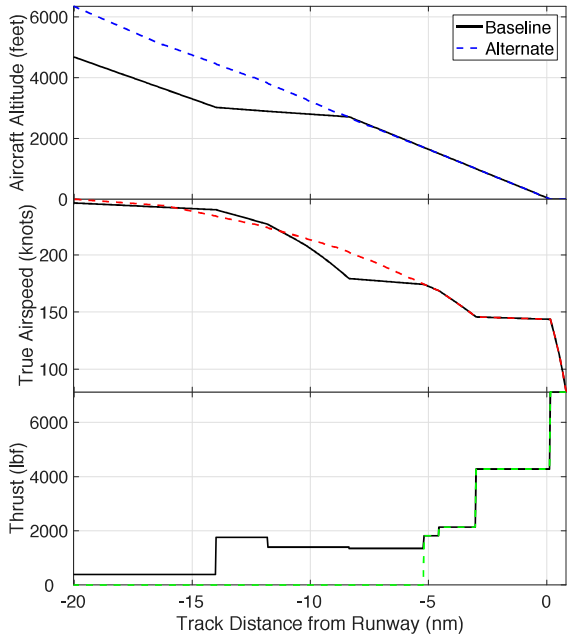

**Population Exposure**

| LAMAX Reduction | Population Exposure |
|---|---|
| 4dB | 1,014 |
| 3dB | 1,057 |
| 2dB | 7,525 |
| 1dB | 21,152 |

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

# 3.0° Continuous Descent from the North vs Baseline Stepped Descent LAMAX Reduction



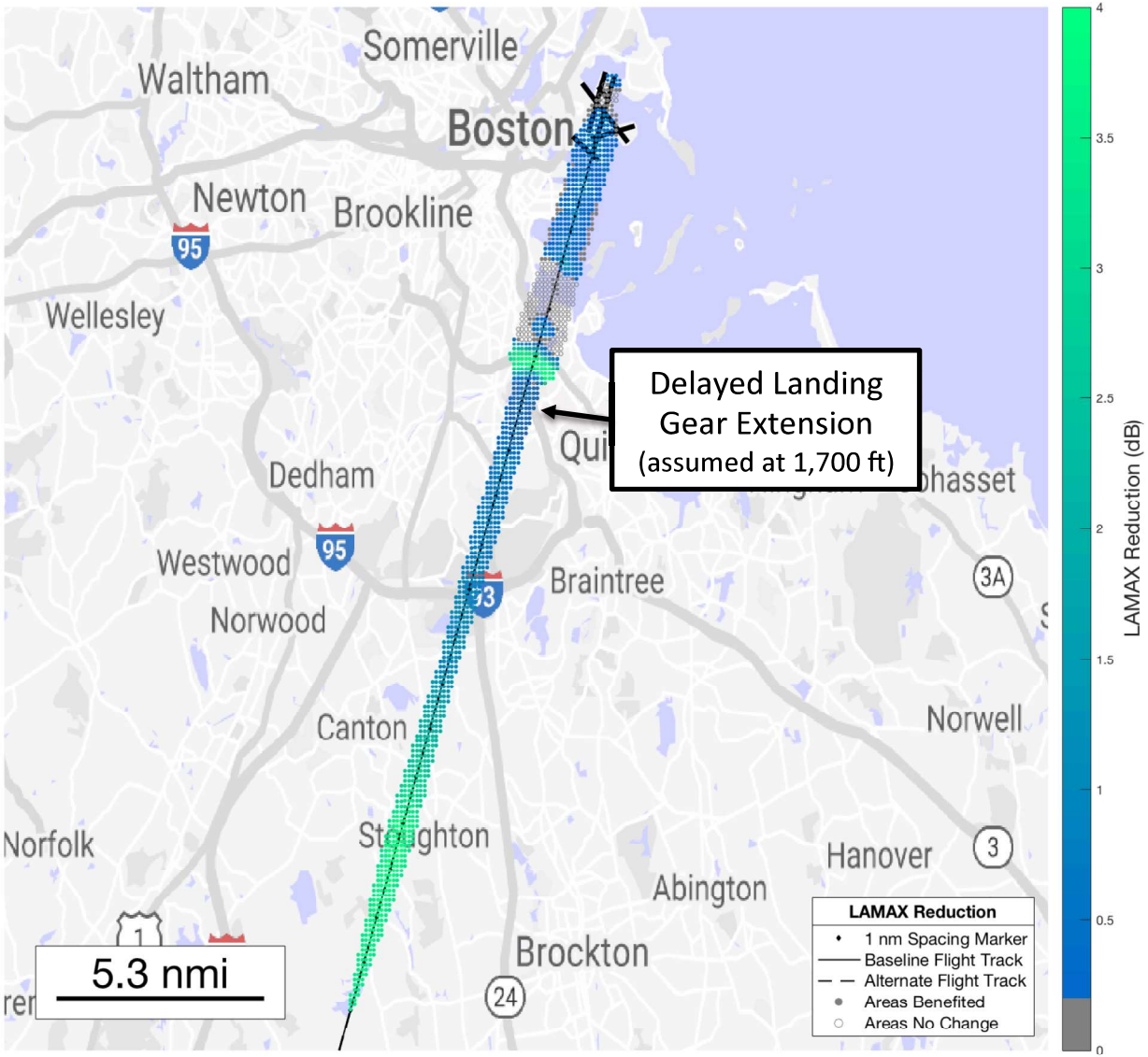



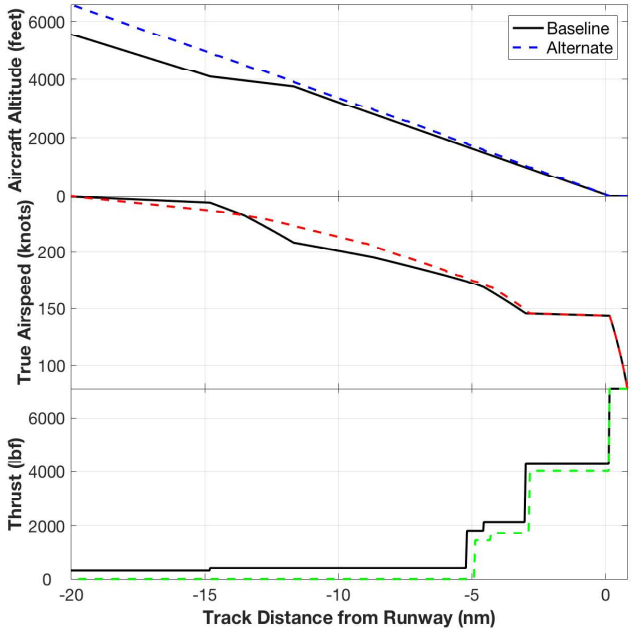

**Population Exposure**

| LAMAX Reduction | Population Exposure |
|---|---|
| 4dB | 2,104 |
| 3dB | 10,772 |
| 2dB | 12,921 |
| 1dB | 13,282 |

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

# 3.2$^0$ Continuous Descent vs Baseline Stepped Descent LAMAX Reduction



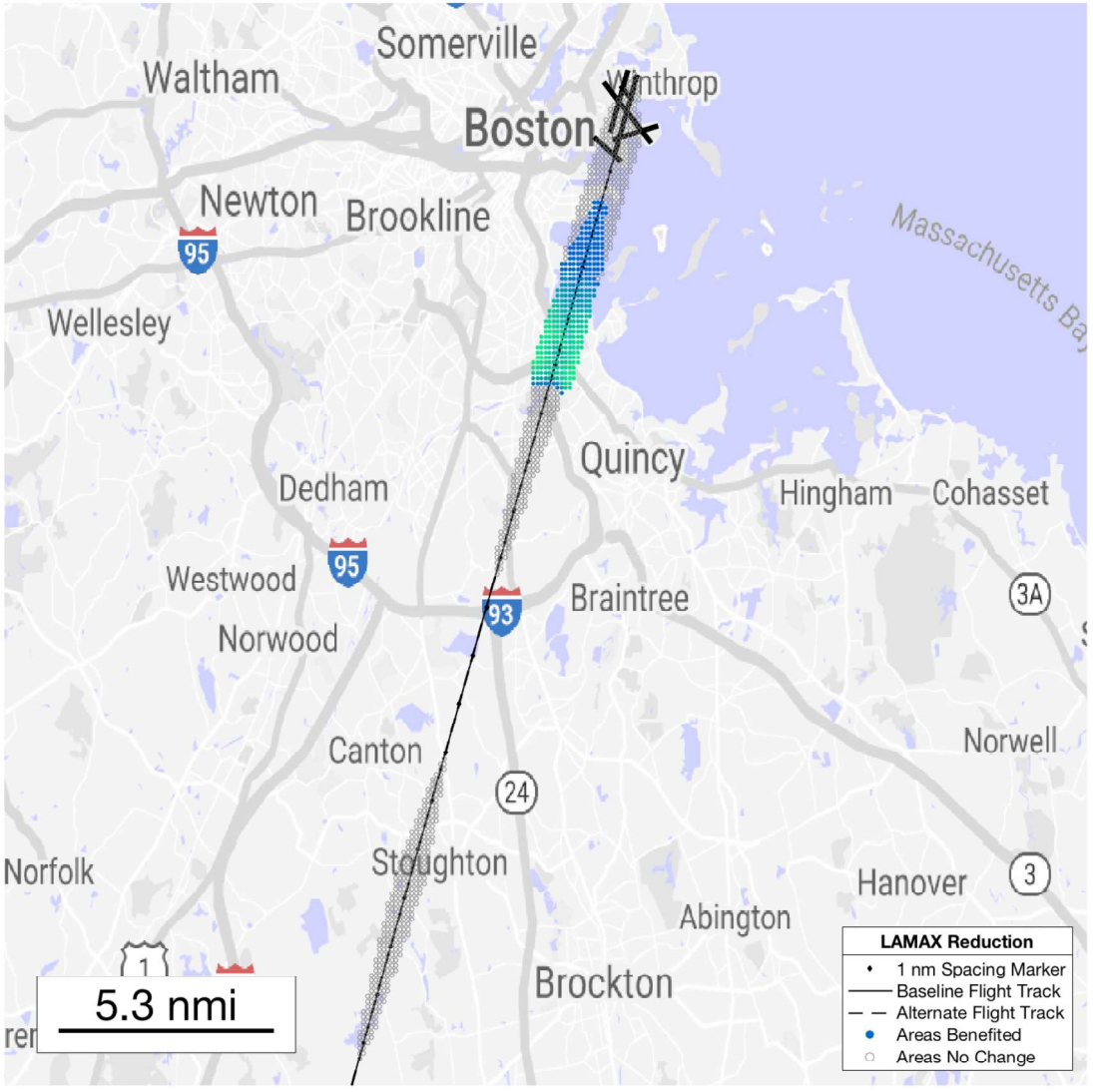



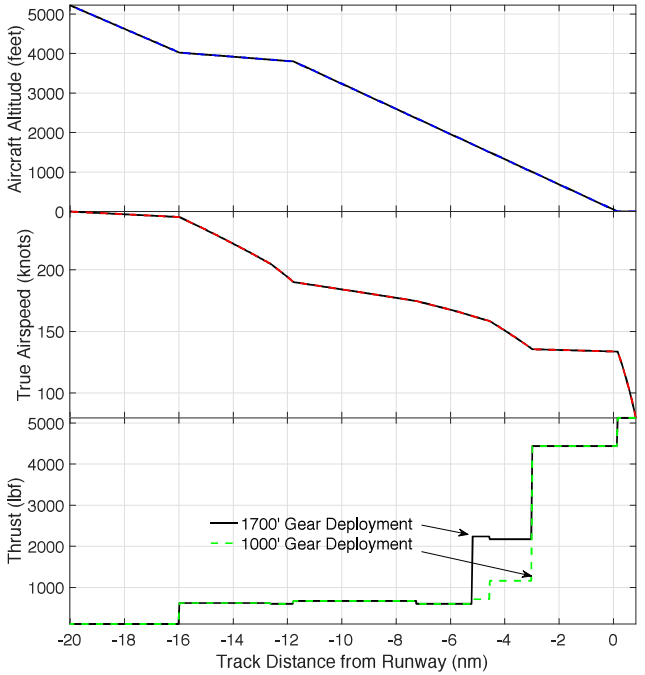

**Population Exposure**

| LAMAX Reduction | Population Exposure |
|---|---|
| 4dB | 1,445 |
| 3dB | 9,801 |
| 2dB | 23,738 |
| 1dB | 44,057 |

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

# 1000’ vs. 1700’ Gear Deployment Stepped Descent LAMAX Reduction




**Population Exposure**

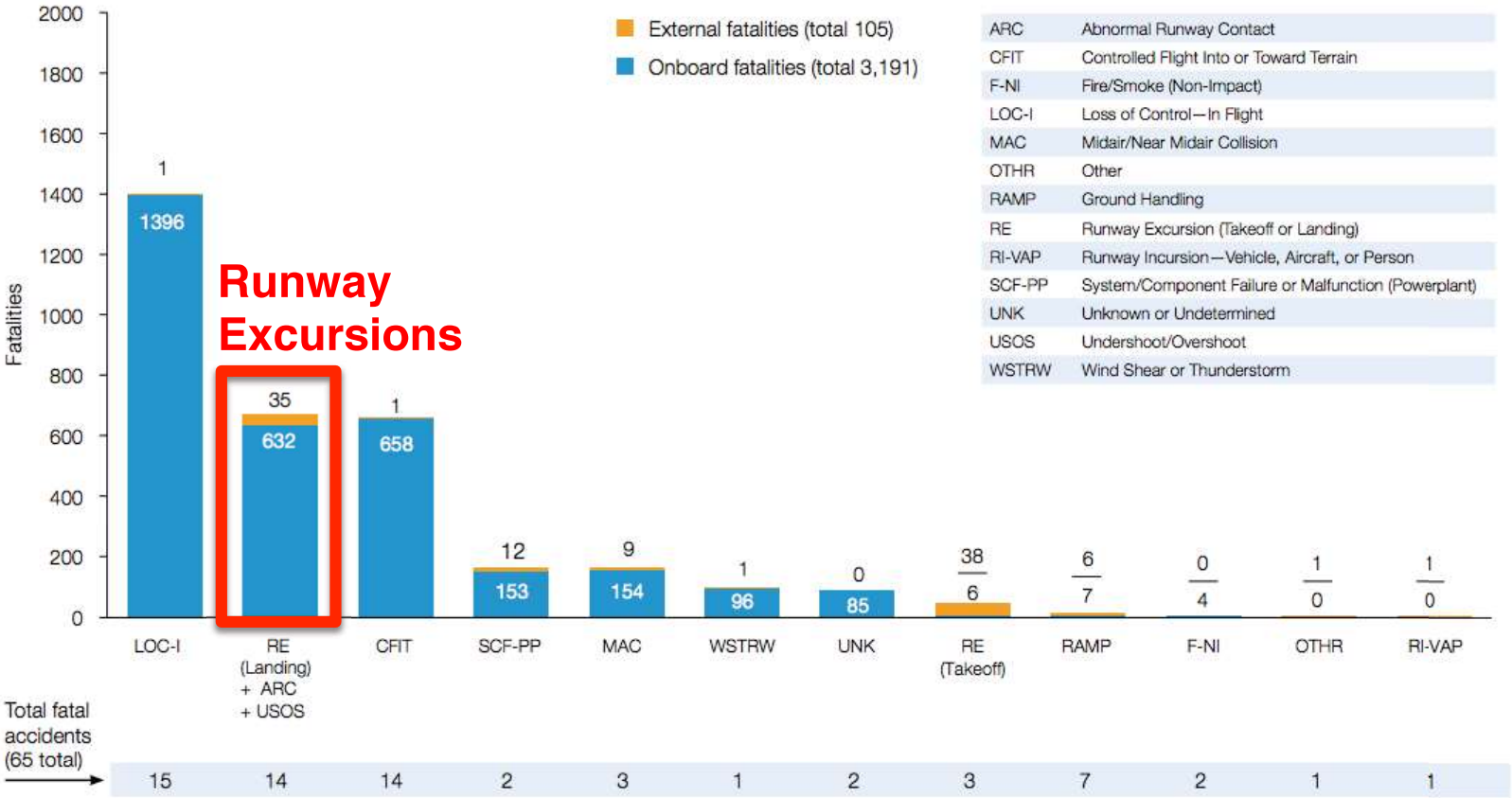
| LAMAX Reduction | Population Exposure |
|---|---|
| 4dB | 14,468 |
| 3dB | 38,841 |
| 2dB | 46,777 |
| 1dB | 48,626 |

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

# Significant Resistance from Pilot Unions on Steep or High Energy Procedures

## Fatalities by CICTT Aviation Occurrence Categories

Fatal Accidents | Worldwide Commercial Jet Fleet | 2006 through 2015




| | |
|---|---|
| ARC | Abnormal Runway Contact |
| CFIT | Controlled Flight Into or Toward Terrain |
| F-NI | Fire/Smoke (Non-Impact) |
| LOC-I | Loss of Control—In Flight |
| MAC | Midair/Near Midair Collision |
| OTHR | Other |
| RAMP | Ground Handling |
| RE | Runway Excursion (Takeoff or Landing) |
| RI-VAP | Runway Incursion—Vehicle, Aircraft, or Person |
| SCF-PP | System/Component Failure or Malfunction (Powerplant) |
| UNK | Unknown or Undetermined |
| USOS | Undershoot/Overshoot |
| WSTRW | Wind Shear or Thunderstorm |

Note: Principal categories as assigned by CAST.

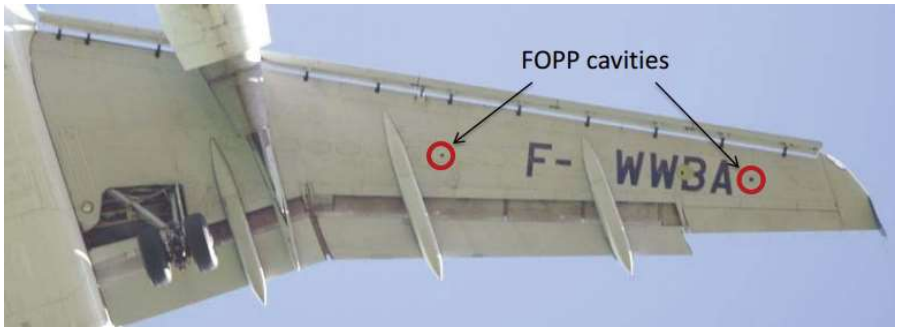
For a complete description of CAST/ICAO Common Taxonomy Team (CICTT) Aviation Occurrence Categories, go to www.intlaviationstandards.org.

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

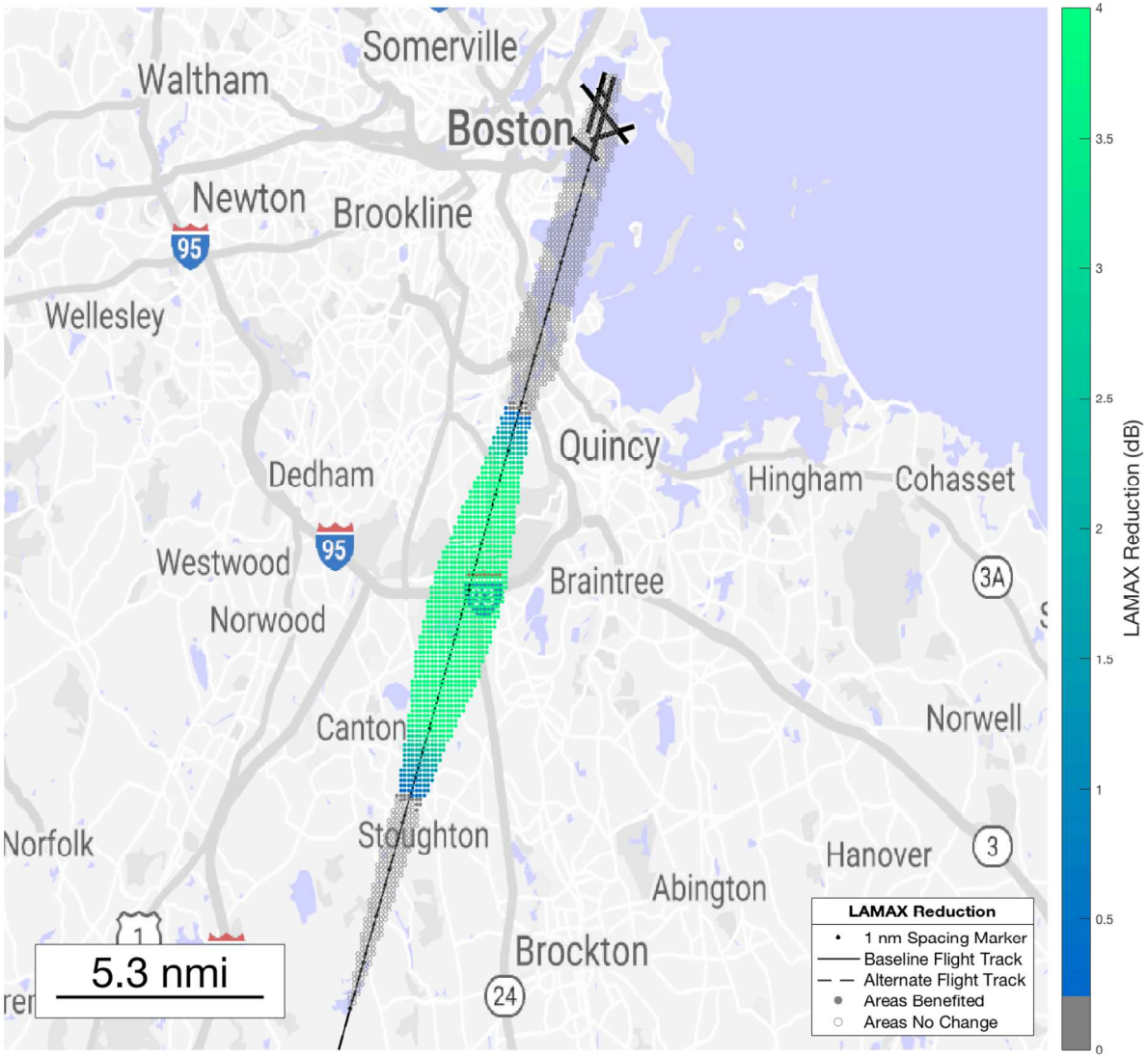
# Vortex Generators

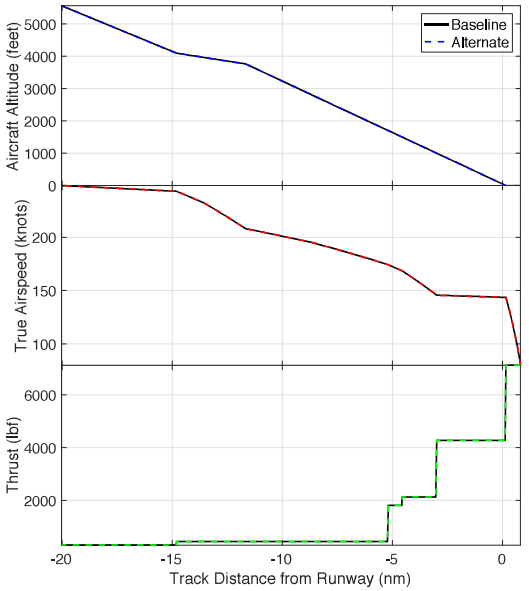
# Vortex Generators Introduction

- Fuel Over-Pressure Ports (3.5” diameter) cause strong tonal noise peaks at 573 Hz
  - Perceived as a “whistling” tone louder than all other noise sources
- Tone only appears at specific speeds (180-220kts) and aircraft configurations
  - Strongest in clean configuration




# Example Impact of Vortex Generators for A320s on 4R




**Population Exposure**

| LAMAX Reduction | Population Exposure |
|---|---|
| 4dB | 6,916 |
| 3dB | 8,482 |
| 2dB | 9,964 |
| 1dB | 11,723 |

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

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# Discussion