Rapid Fleet-wide Environmental Assessment Capability

ASCENT Project 11A

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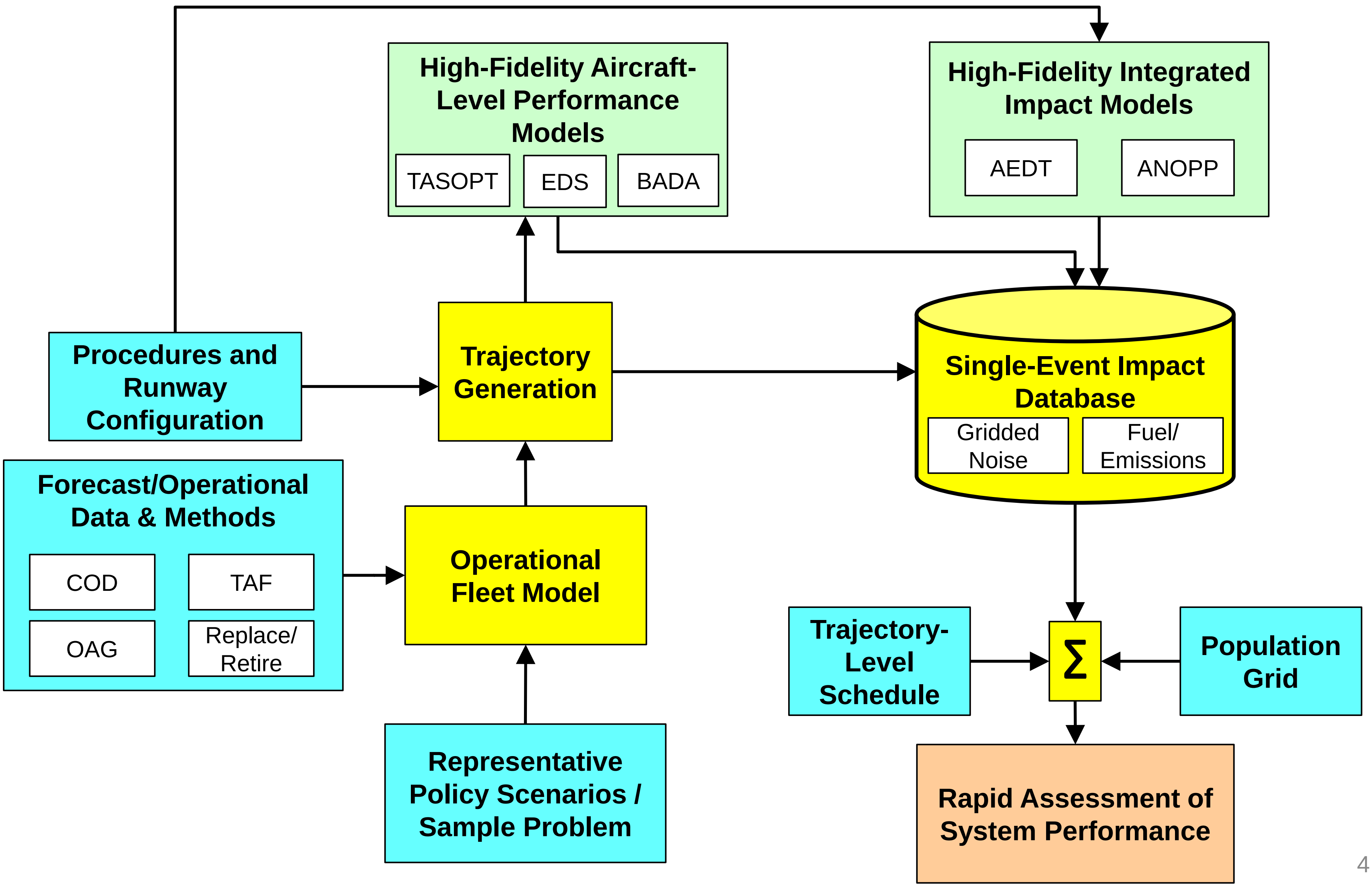
Motivation

- **Aviation environmental impact analysis involves flight-level and fleet-level:**
  - Fuel burn
  - Emissions
  - Noise
  - Population impact
- **Current aviation environmental impact analysis techniques (e.g. AEDT) are comprehensive but too slow for broad parametric analysis**
  - Do not enable analysis of future aircraft types/technologies
- **Need for rapid environmental assessment capability to inform and support policymaking and operational evaluation**

Objectives

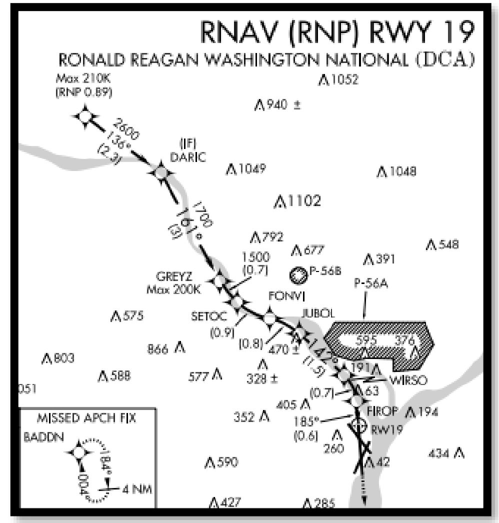
- **Develop rapid models for environmental studies**
  - Broad scenario explorations
  - Fast parametric analyses
- **Key environmental impact dimensions**
  - Noise
  - Fuel burn and emissions
- **Initial Phase: Develop modeling architecture (complete)**
  - Develop local noise modeling techniques
  - Integrate system-level impact models (i.e. DNL) with population impact models (i.e. population noise exposure) for policy evaluation
- **Current Phase: Application to sample problems**
  - Evaluate the impact of aircraft gauge change
  - Aircraft fleet substitution and modernization at specific airports
  - Extension to system-level analysis
- **Ongoing work: integration with advanced noise modeling capability developed under ASCENT Project 23**

Model Framework

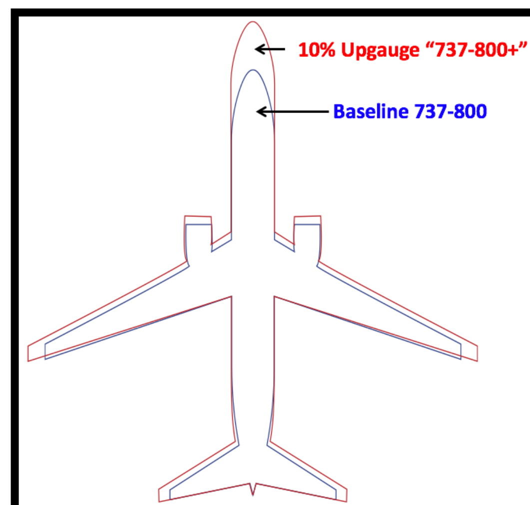


Environmental Analysis Reference Problem: Aircraft Gauge Policy at DCA

- Initial sample problem chosen based on following criteria:
  1. Generate results at airports with non-standard terminal procedures
  2. Demonstrate analysis capability for novel aircraft
- Aircraft gauge policy has potential impacts on:
  - Airport passenger capacity
  - Per-passenger environmental impact
- Rapid environmental analysis tool will be used to evaluate gauge-change scenarios
  - Noise
  - Fuel Burn
  - Emissions (e.g. CO_2, NO_X)
- DCA chosen as particularly challenging case due to nonstandard procedures
- Airport-level analysis, system-level impacts may be examined in follow-on



Complex, non-standard procedures at DCA

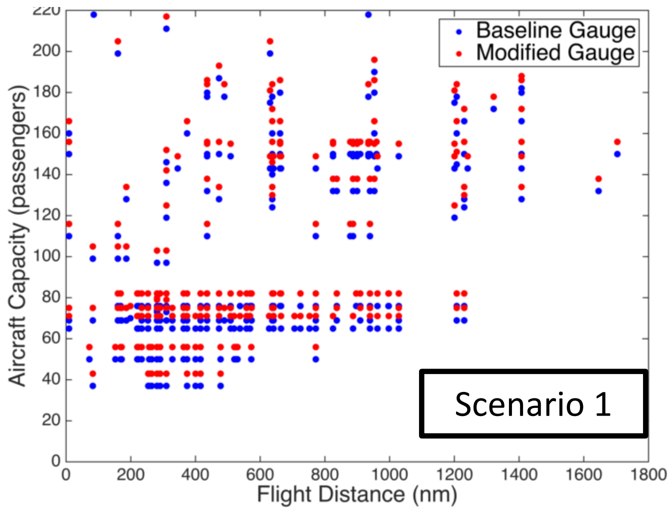


Demonstrates novel aircraft evaluation capability

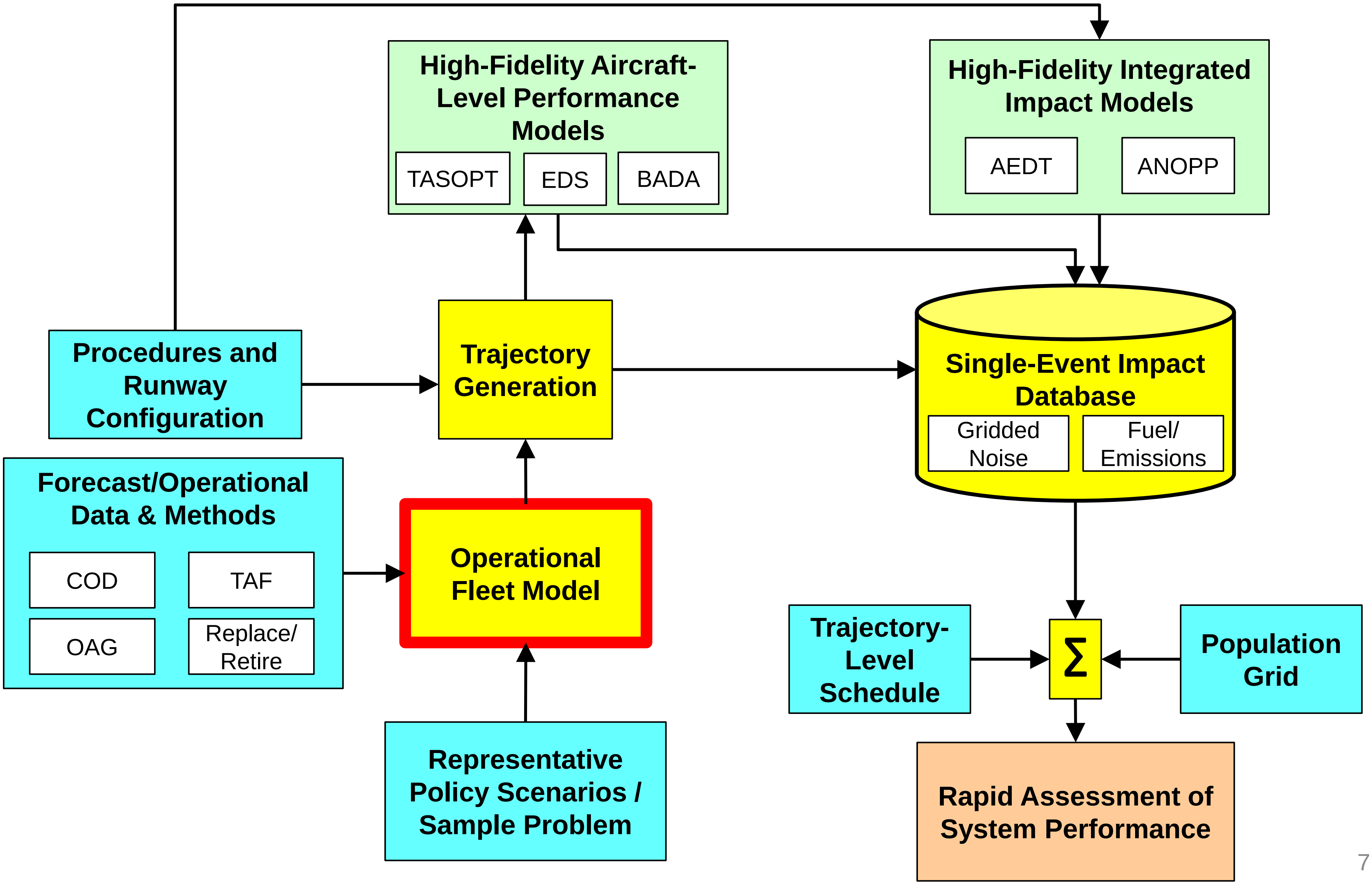
Aircraft Gauge Policy Scenarios

- Scenario 1: Fleet-wide Upgauge
  - Simple upgauge (by payload percentage) across all representative trajectories
  - Includes modeling of new representative upgauged aircraft types
- Scenario 2: Replace older aircraft types
  - MD-88 replaced one-for-one with 737-800

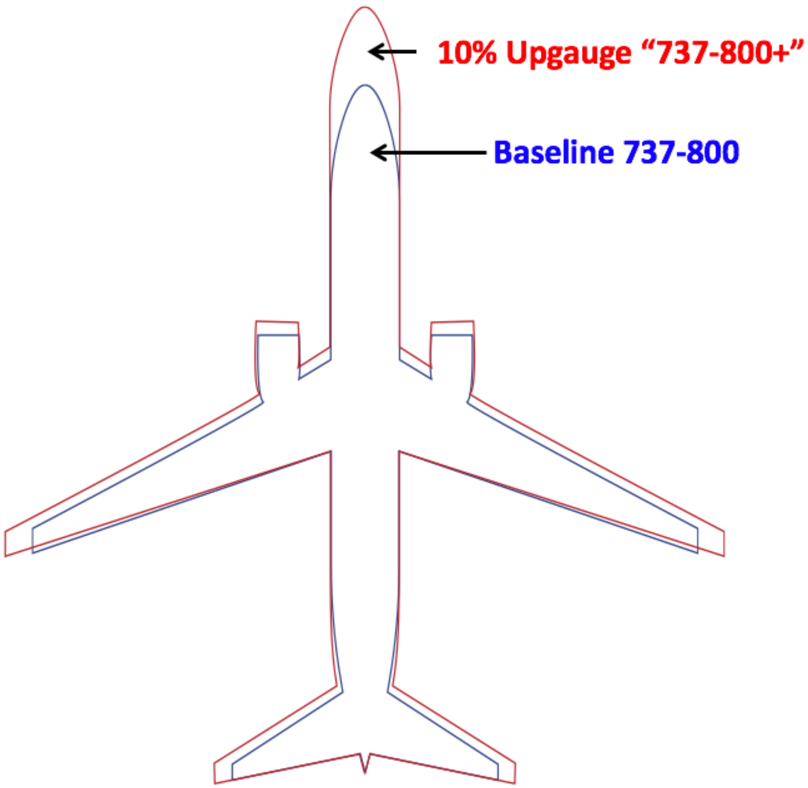
Mission Profiles at DCA
Week of August 2, 2015



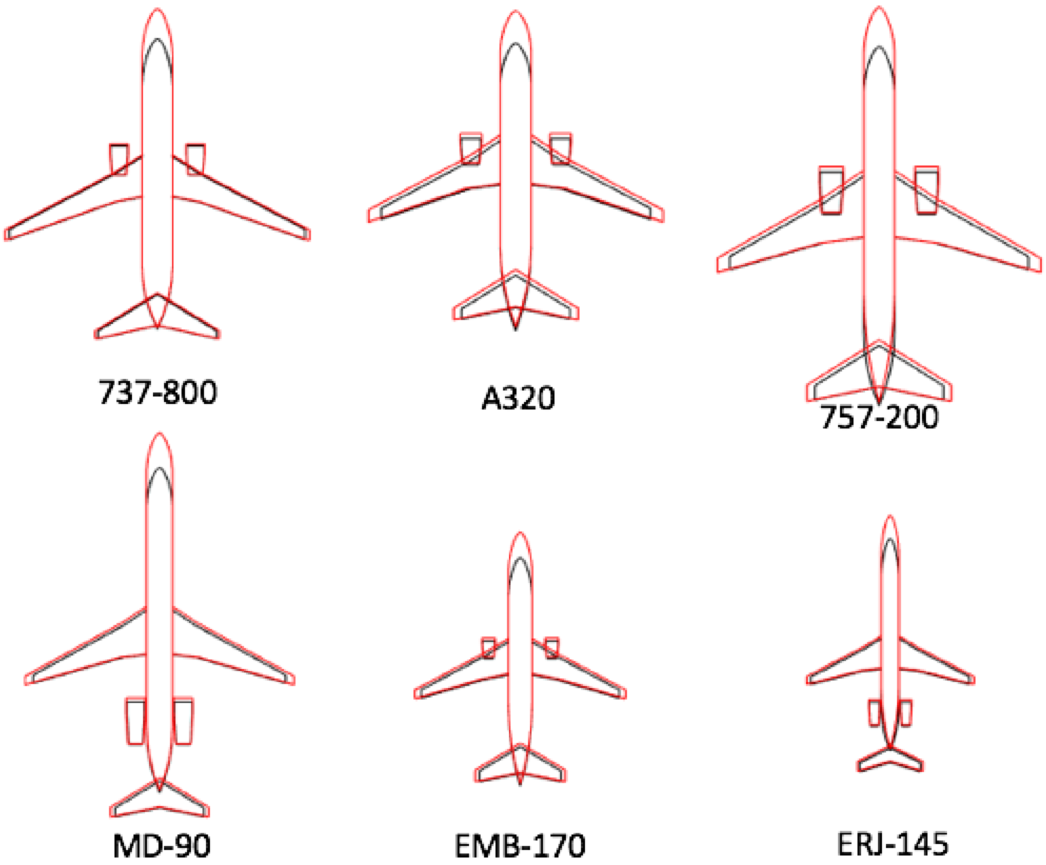
Model Framework



Fleet Modeled in TASOPT/ANOPP

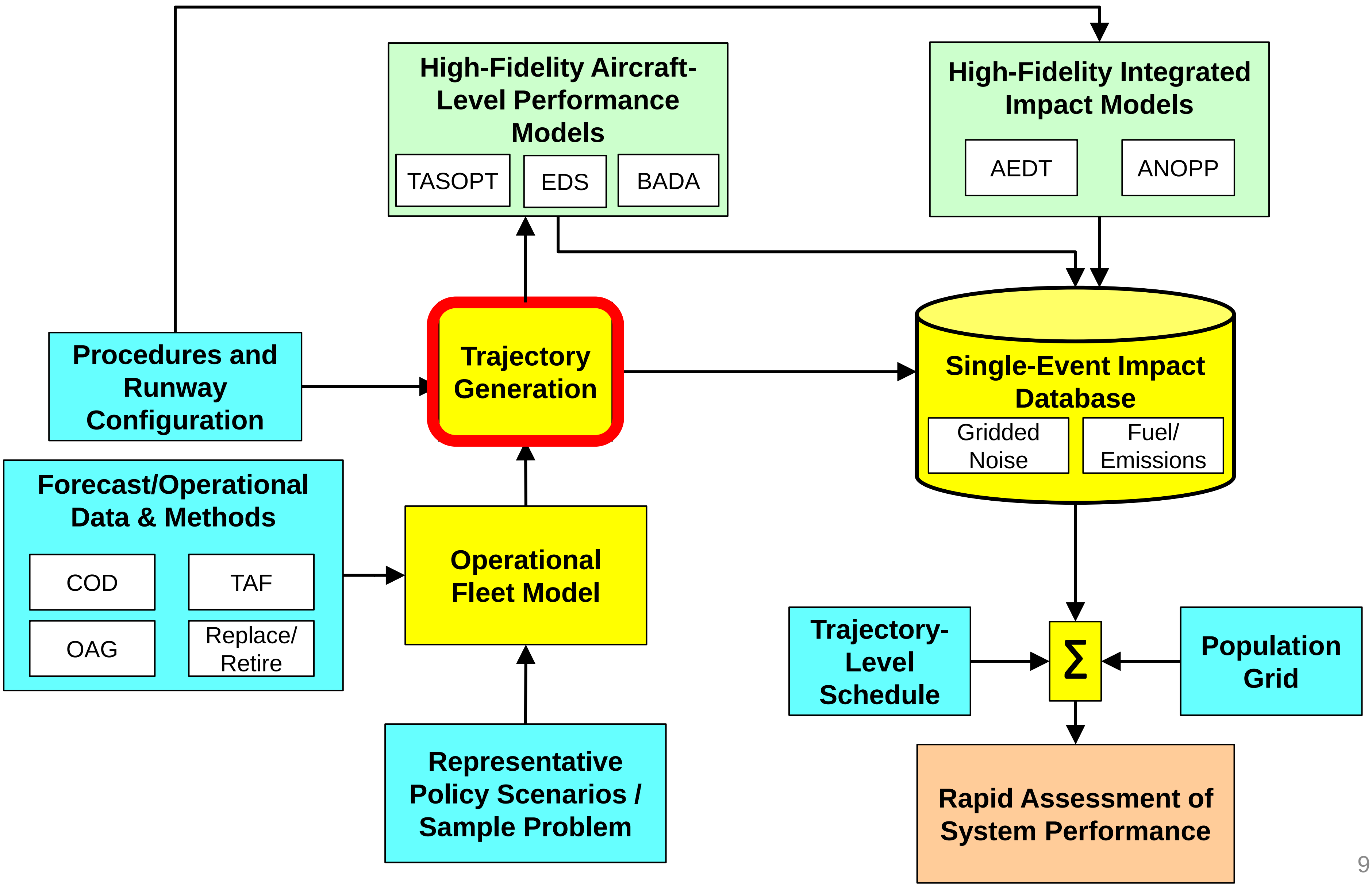


Example 737-800 10% Upgauge using TASOPT



Representative Fleet for DCA Sample Problem: Baseline and Upgauged

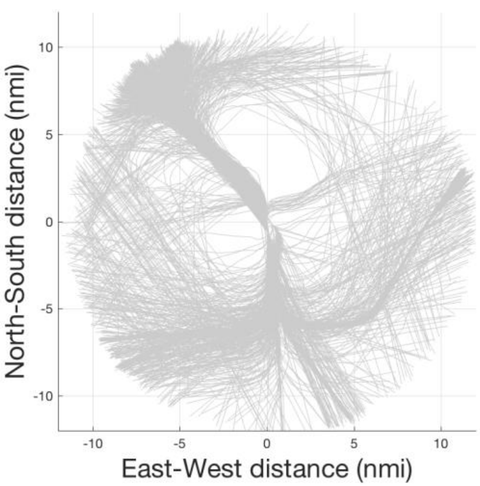
Model Framework



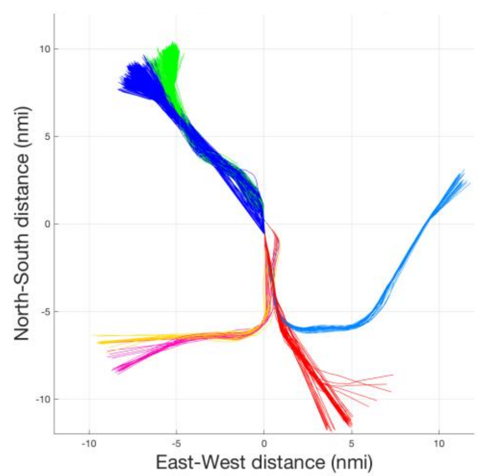
Defining Representative Trajectories

- Representative trajectories drastically reduce computation time but keep location-specific information
- Identify representative trajectories from RNAV routes
  - Filter ASDE-X historical radar track data data to find flights flying RNAV routes
  - Select flight closest to median
- Does not account for dispersion of flights
  - Noise impacts of flight track dispersion are currently under investigation

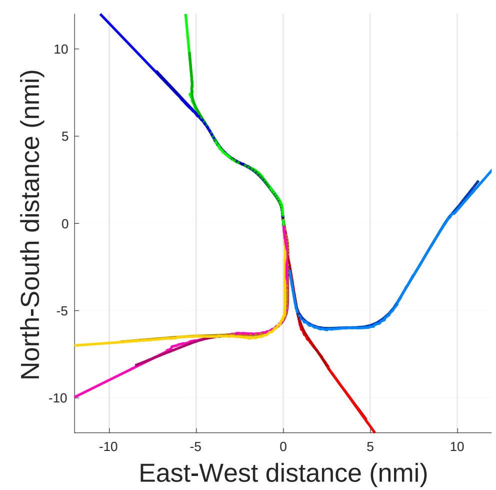
DCA Departures
(20 Days from 2015 and 2016)



RNAV Flights



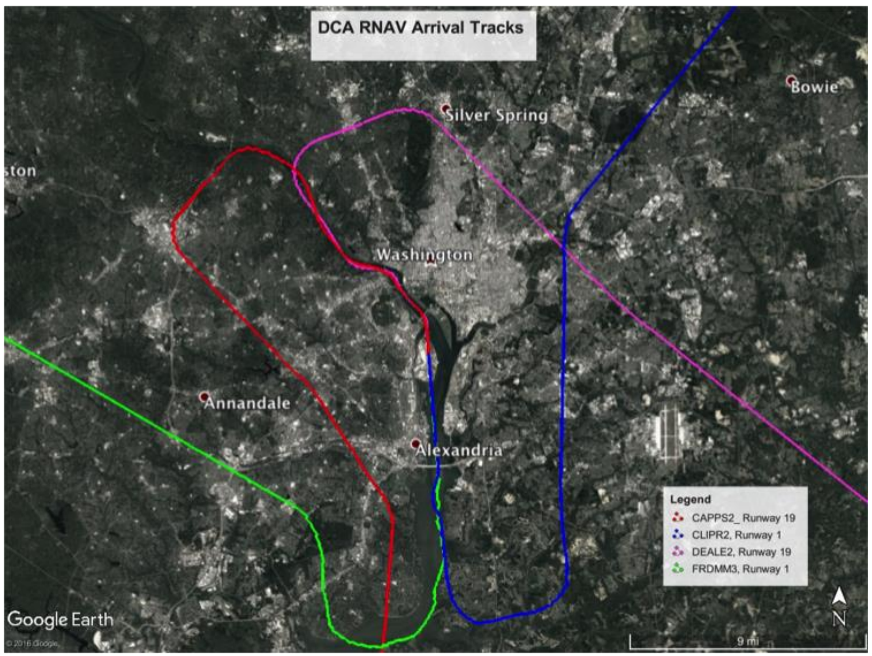
Representative Trajectories



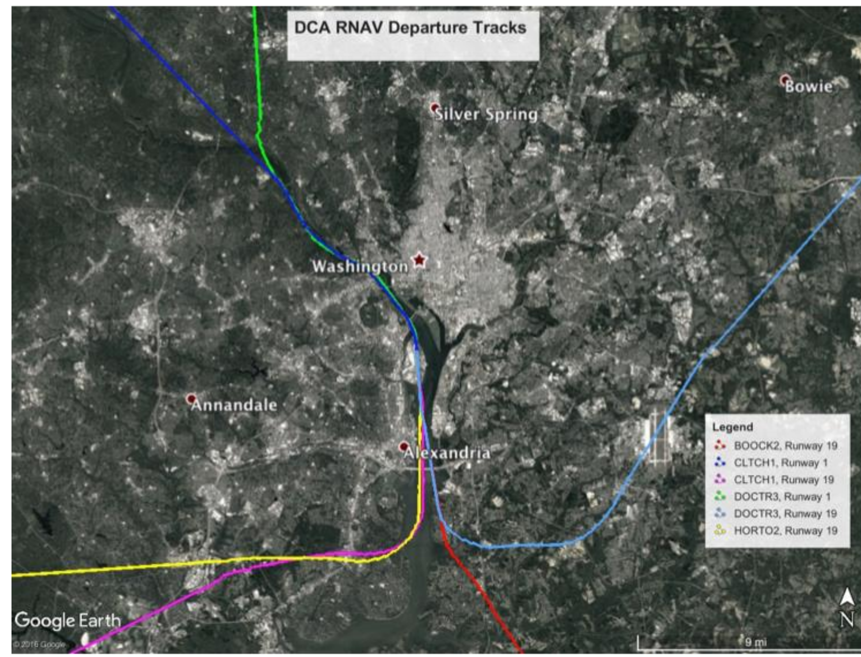
Representative Lateral Flight Tracks for DCA

Lateral trajectories derived from ASDE-X radar data and applied to all aircraft types:

4 Arrival Tracks



6 Departure Tracks

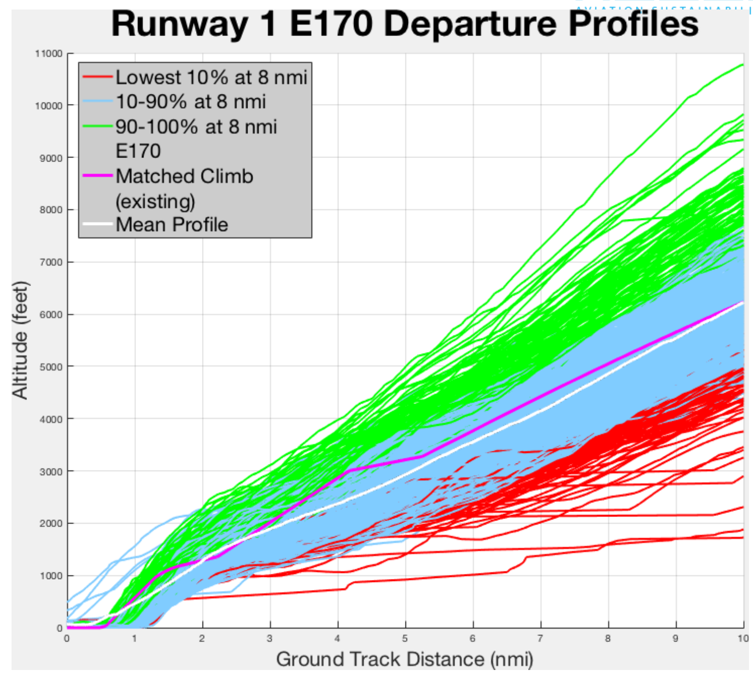


Vertical Profile Definition: Departure

Vertical profiles calculated based on radar data for each aircraft type

Departures:

- ICAO standard departure with thrust set to match median climb profile
  - Takeoff thrust and climb thrust set to match median radar-based initial climb rate
- Weight assumed to be 90% of MTOW
- Same percentage thrust and weight for upgauged aircraft



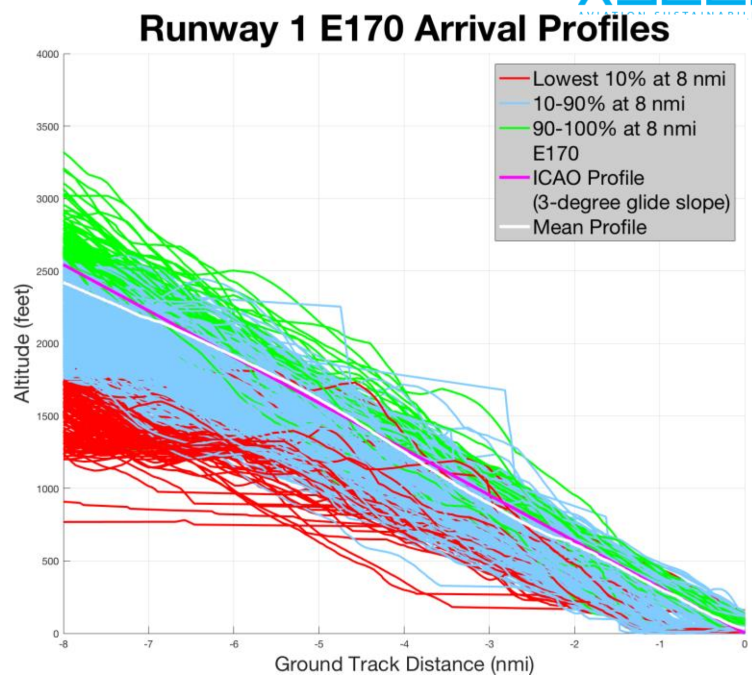
Attribute	Data Source
Drag	BADA 4
MTOW	TASOPT or BADA 4
Takeoff roll	ASDE-X data matching
Max thrust	Published data
V_2	TASOPT

Vertical Profile Definition: Arrival

Vertical profiles calculated based on radar data for each aircraft type

Arrivals:

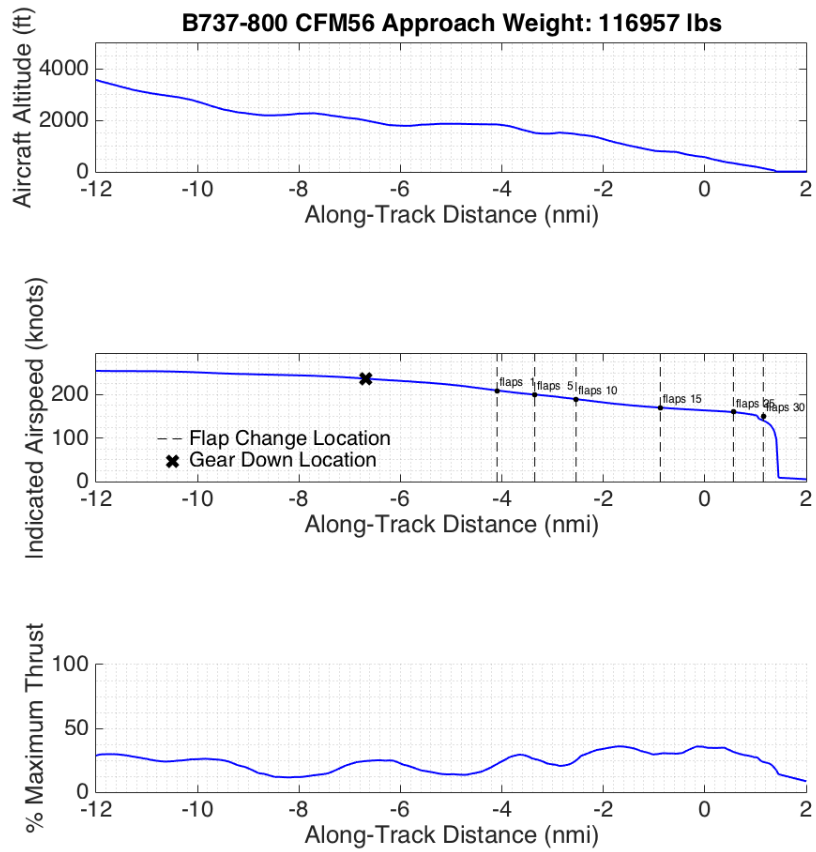
- Assume continuous 3-degree glide slope
  - Closely matches mean arrival profile
- Weight assumed to be 75% of MTOW
  - Consistent with most AEDT procedures
- Same percentage weight for upgauged aircraft



Attribute	Data Source
Drag	BADA 4
MTOW	TASOPT or BADA 4
Landing roll	ASDE-X data matching
Max thrust	Published data
$V_{approach}$	TASOPT

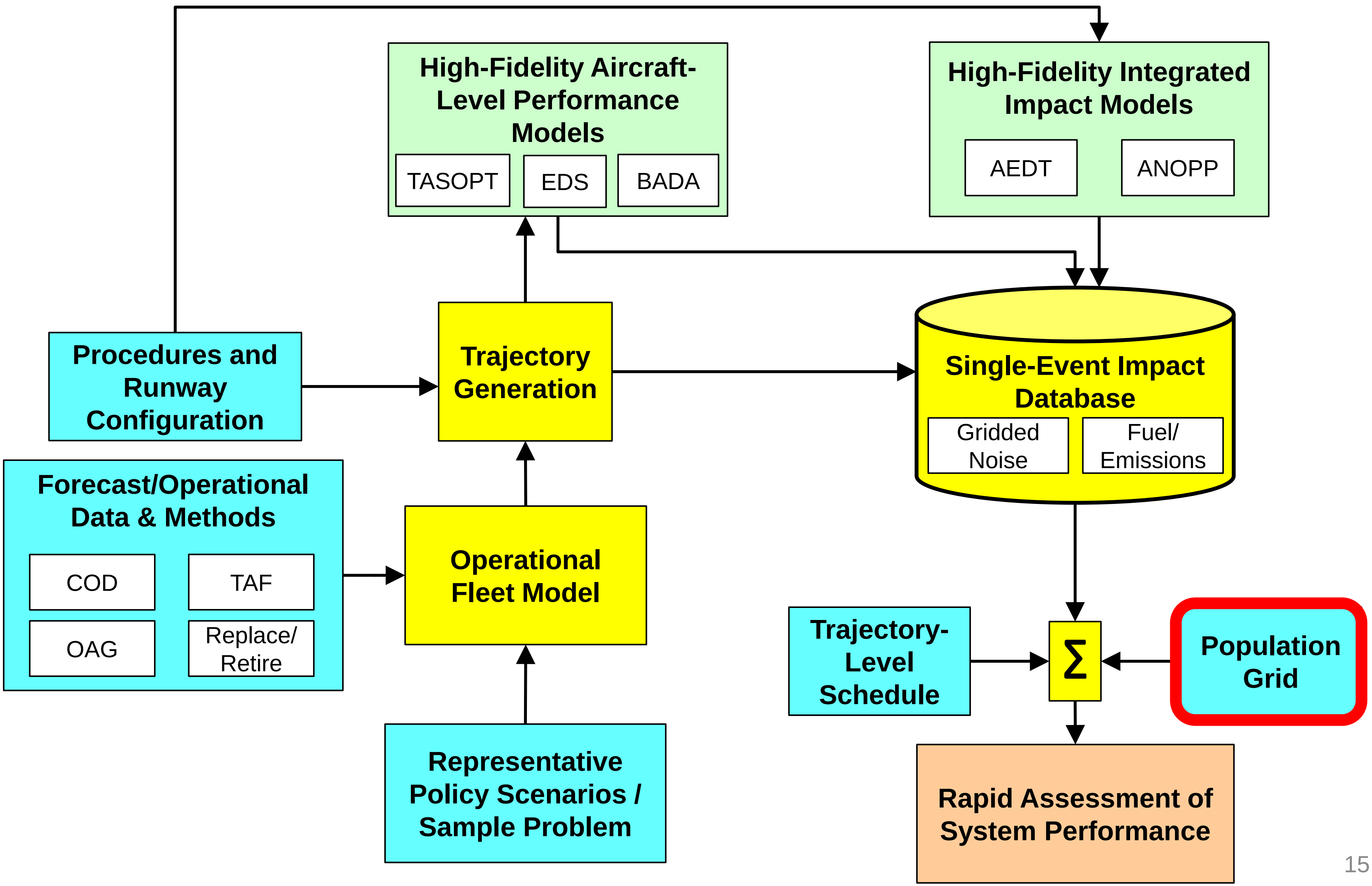
Thrust and Configuration Calculation

- Thrust and aircraft configuration required for noise and emissions analysis
- Radar records provide groundspeed only
  - Flap extension speeds obtained from BADA 4 performance files
  - Thrust calculated using kinematic approach and drag data from BADA or TASOPT
- Tool can also be used to design new trajectories and calculate thrust/performance



Example Trajectory
737-800, DCA Runway 1 RNAV Approach

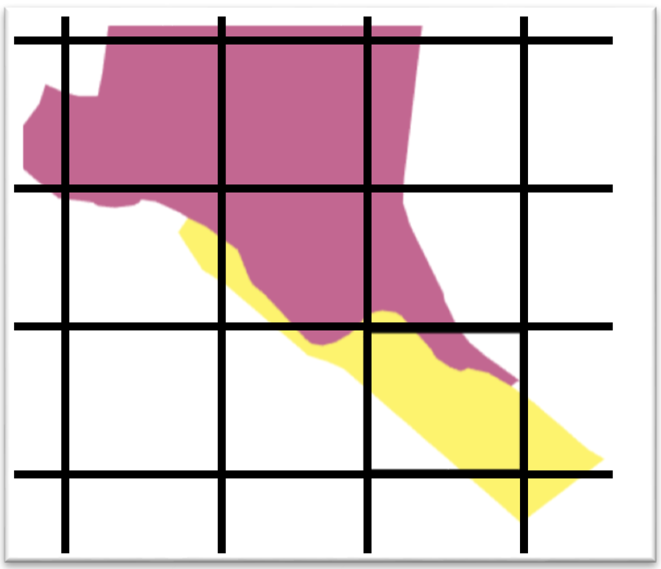
Model Framework



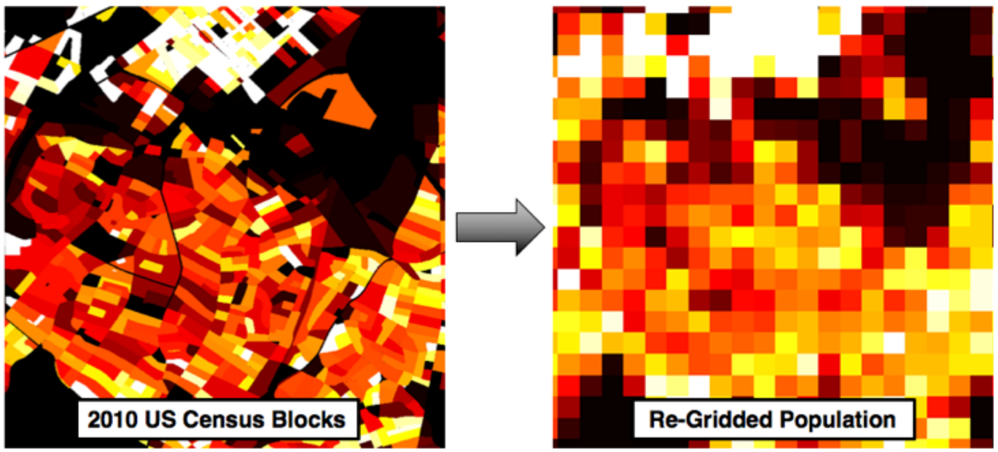
Population Impact Calculation

- Single-event noise results (SEL and L_{MAX}) calculated on a consistent grid at same resolution as population densities (2010 US Census)
- Database of single-event grids can be rotated and combined to quickly form integrated noise contours (DNL and N_{ABOVE})

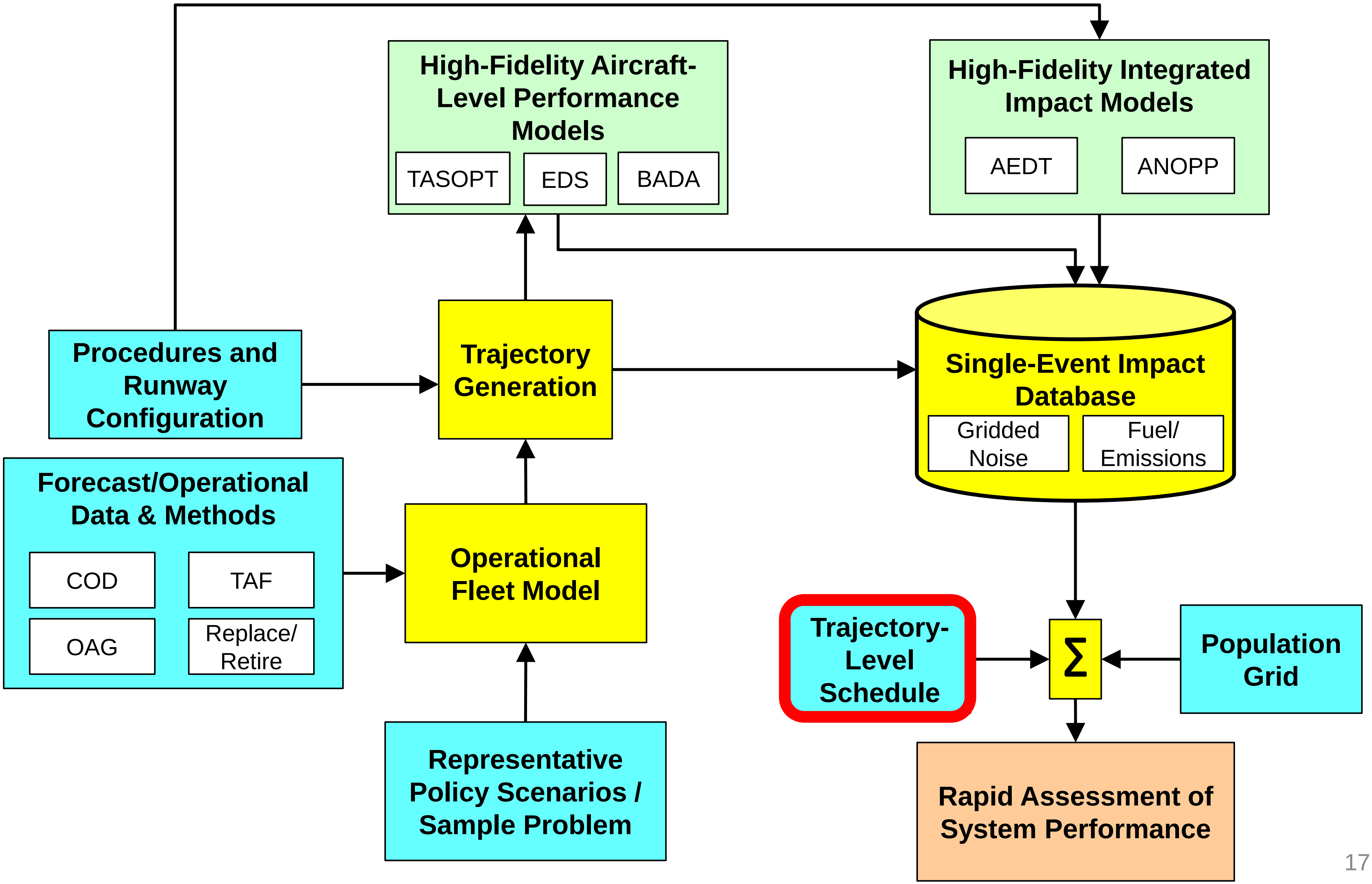
Census data re-gridded from irregular block form to regular 0.1nm square cells



Re-Gridded Population Density Map



Model Framework



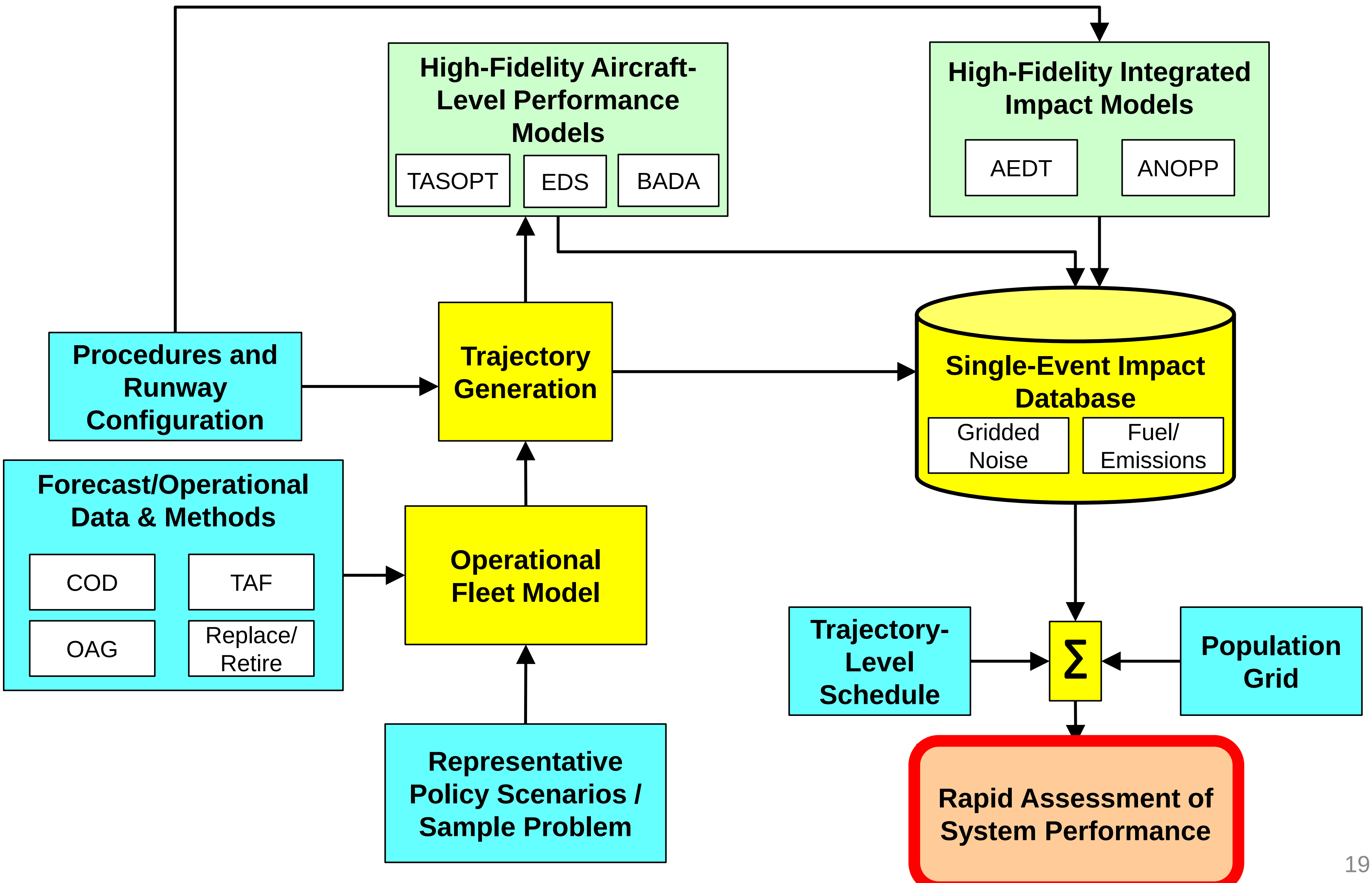
2015 Schedule and Fleet for DCA

- Aircraft types assigned to representative model families for analysis
  - Reduces number of required single-flight runs
- Schedule source: ASPM single-flight records
  - Jan 1, 2015 to Dec 31, 2015
- Flights distributed evenly across arrival and departure routes with type-specific vertical profiles

2015 DCA Average Daily Schedule and Fleet

Type Code	Annual Arrivals	Representative Type	Average Daily Arrivals
E170	28732	E170	132.4
E190	13399		
CRJ7	3734		
CRJ9	2455		
E135	222	E145	94.8
E145	2189		
E45X	1223		
CRJ2	28835		
DH8A	869		
DH8D	586		
GA T-Prop	370		
GA Turbine	290		
A319	16658	A320	65.9
A320	6419		
A321	985		
B733	193	B738	83.6
B737	15512		
B738	14684		
B739	117		
B752	814	B752	2.2
B712	378	MD88	16.6
MD82	22		
MD83	11		
MD88	2546		
MD90	3095		
Heli+Light GA	Omitted	Omitted	-
Total			**395.4**

Model Framework



Scenario 1: Fleet-wide Upgauge

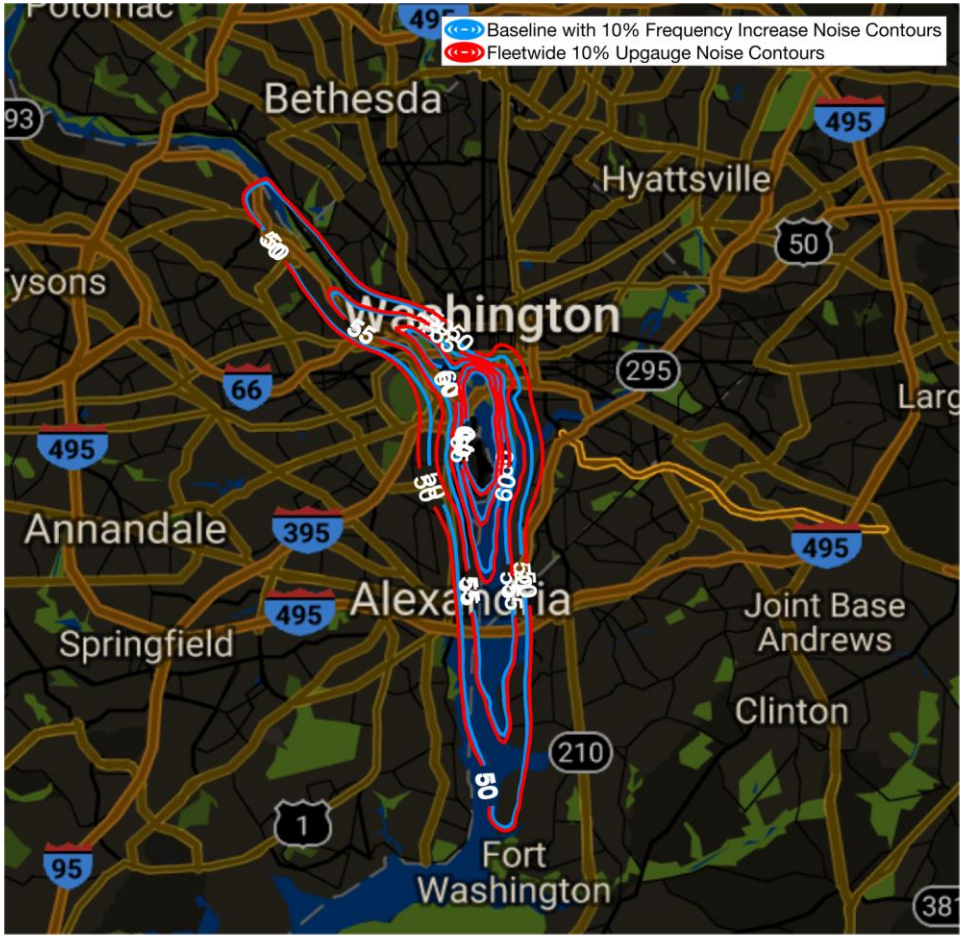
Metric	DNL
Noise Model	AEDT
Notes	Baseline Fleet with 10% Frequency Increase vs. 10% Aircraft Payload and Size Upgauge

10% Frequency Increase Schedule

Type	Daily Count*
E145	104.5
E170	145.2
A320	72.6
B738	92.4
MD88	18.7
B752	2.2

10% Gauge Increase Schedule

Type	Daily Count
E145+	95
E170+	132
A320+	66
B738+	84
MD88+	17
B752+	2



*Counts represent an average annual day, resulting in fractional operations

Scenario 1: Fleet-wide Upgauge LTO Emissions

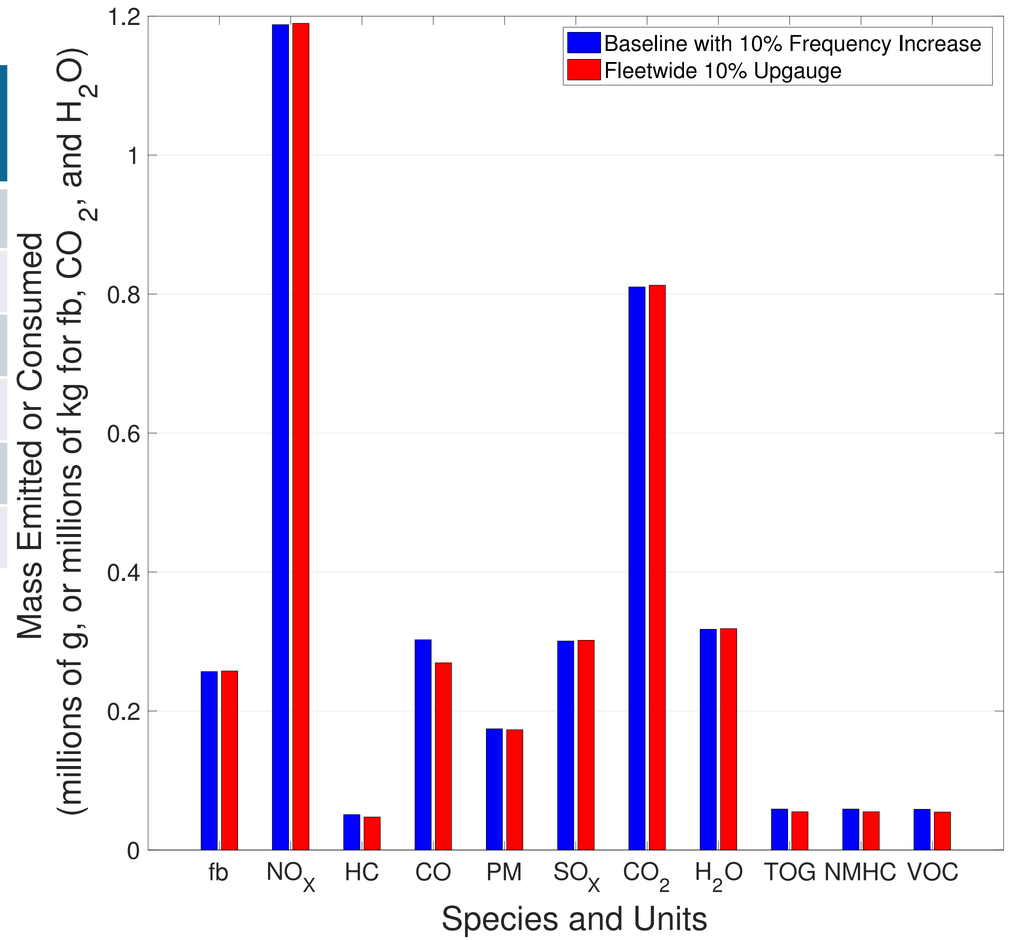
Metric	LTO Emissions, LTO <= 10,000'
Fuel Flow Model	TASOPT
Notes	Baseline Fleet with 10% Frequency Increase vs. 10% Aircraft Payload and Size Upgauge

10% Frequency Increase Schedule

Type	Daily Count*
E145	104.5
E170	145.2
A320	72.6
B738	92.4
MD88	18.7
B752	2.2

10% Gauge Increase Schedule

Type	Daily Count
E145+	95
E170+	132
A320+	66
B738+	84
MD88+	17
B752+	2

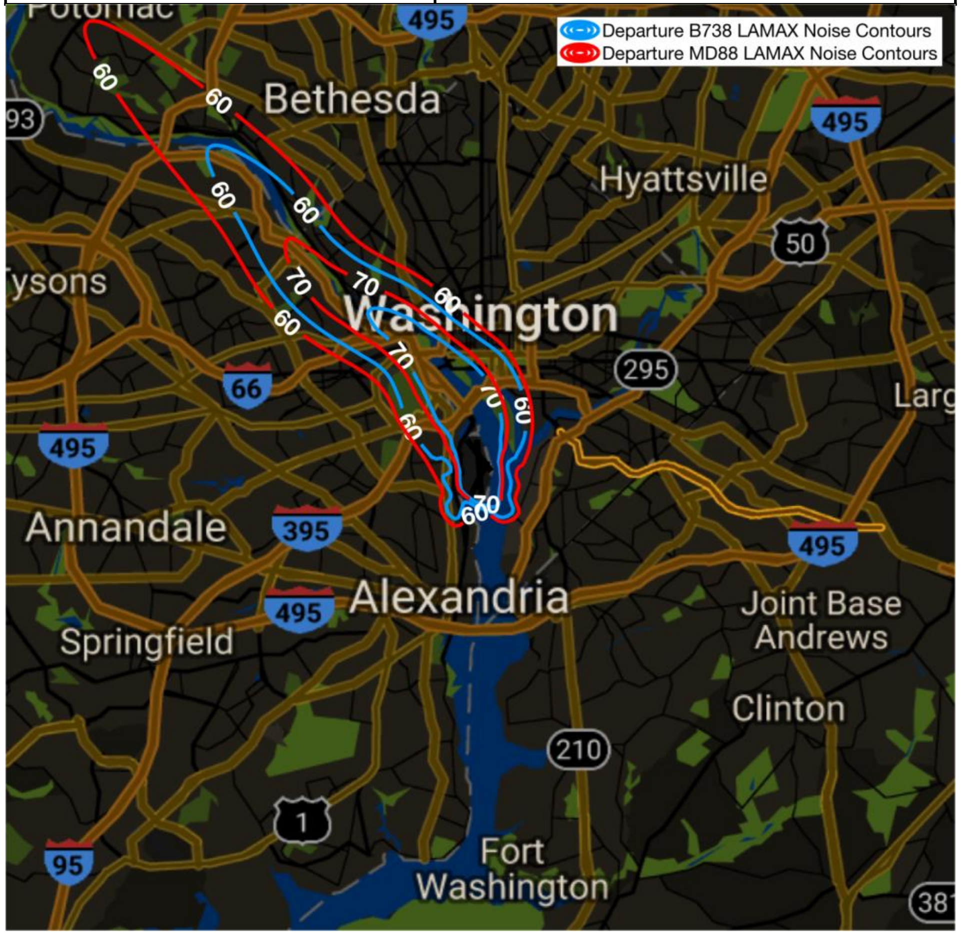


Example Single-Flight Departure: MD-80 vs. B738 L_{AMAX} Contours

Motivation for Scenario 3 (replacing older aircraft types):

- On single-flight basis, MD-88 significantly louder than B738

Metric	$L_{A,MAX}$
Noise Model	AEDT
Notes	MD-80 vs. B738



Scenario 2: Replace Older Aircraft Types DNL

MD80 flights shifted to B738 flights

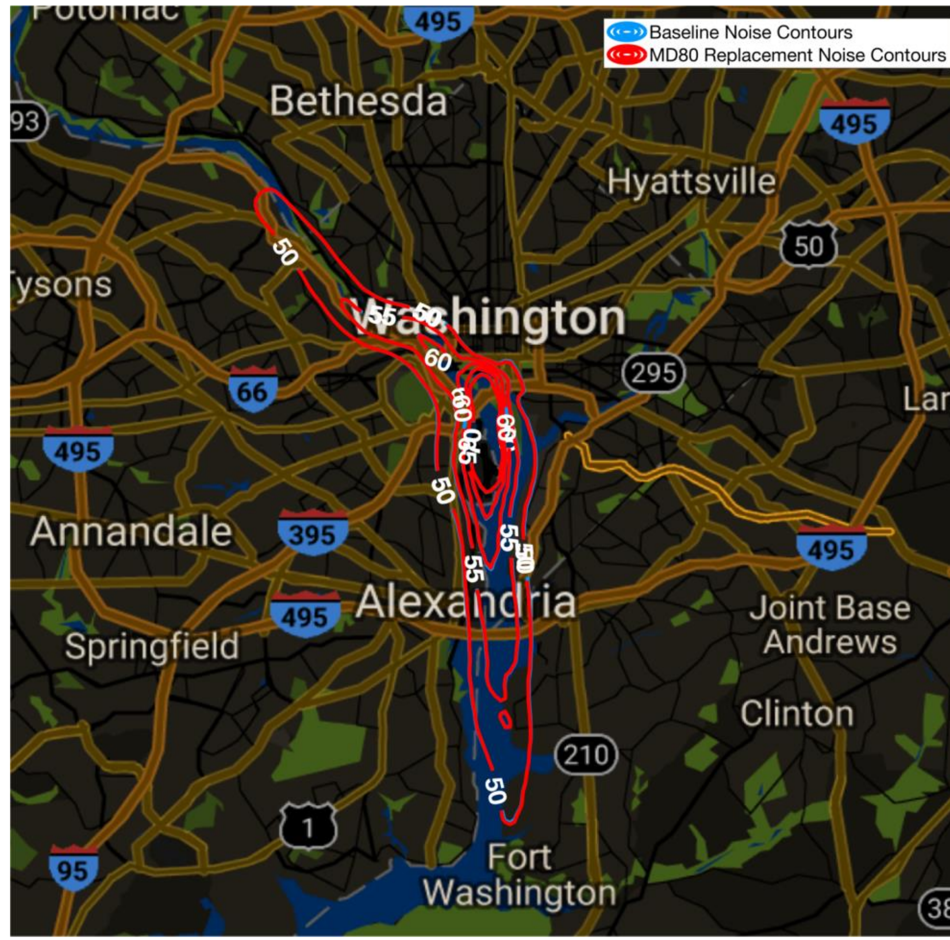
Metric	DNL
Noise Model	AEDT
Notes	Baseline Fleet vs. MD-80 Replacement Policy Passenger capacity larger for non-baseline

Baseline 2015 Schedule

Type	Daily Count
E145	95
E170	132
A320	66
B738	84
MD88	17
B752	2

MD-80 Replacement Schedule

Type	Daily Count
E145	95
E170	132
A320	66
B738	101
MD88	0
B752	2



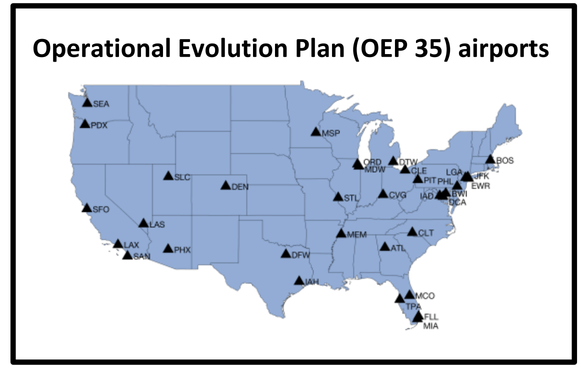
SYSTEM-LEVEL ANALYSIS

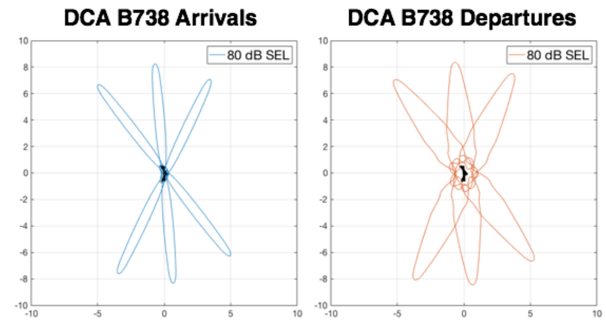
Simplified System Level Analysis: Method

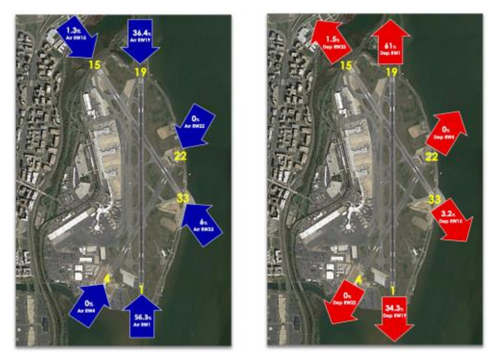
- Objective: rapidly calculate nationwide population exposure at 65dB DNL for OEP 35 airports
- Simplifying assumptions for computational efficiency
  - Straight-in arrivals, straight-out departures
  - 12 Representative Fleet Types:

A320	B77W	B738	B744	B752	B763
B788	CRJ2	DH8D	E145	E170	MD88

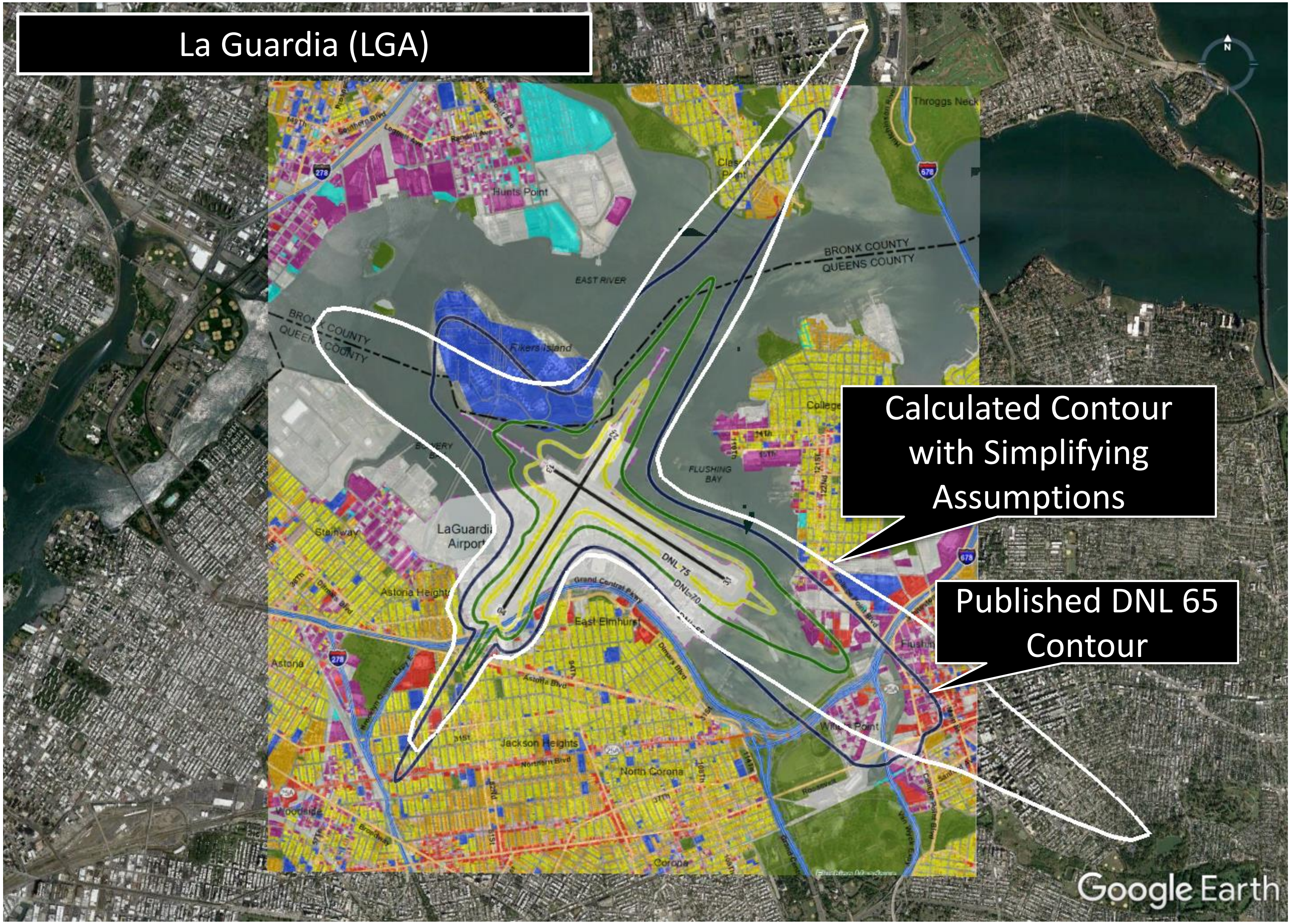
- 2015 fleet mix and runway utilization data from FAA Aviation System Performance Metrics (ASPM)
- Noise results generated on same grid as population data, enabling rapid exposure assessment





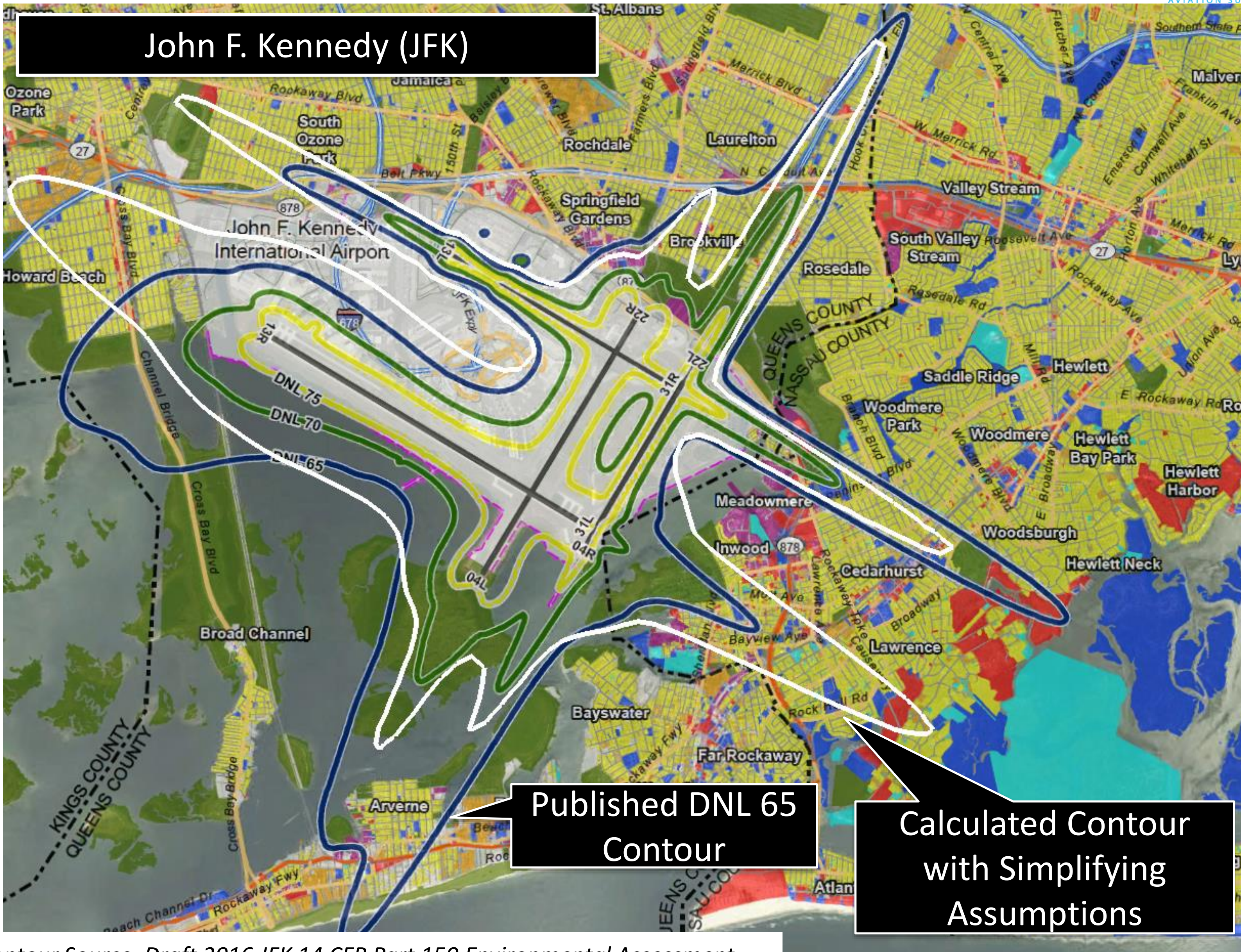


Comparison with Published 65 DNL Contours



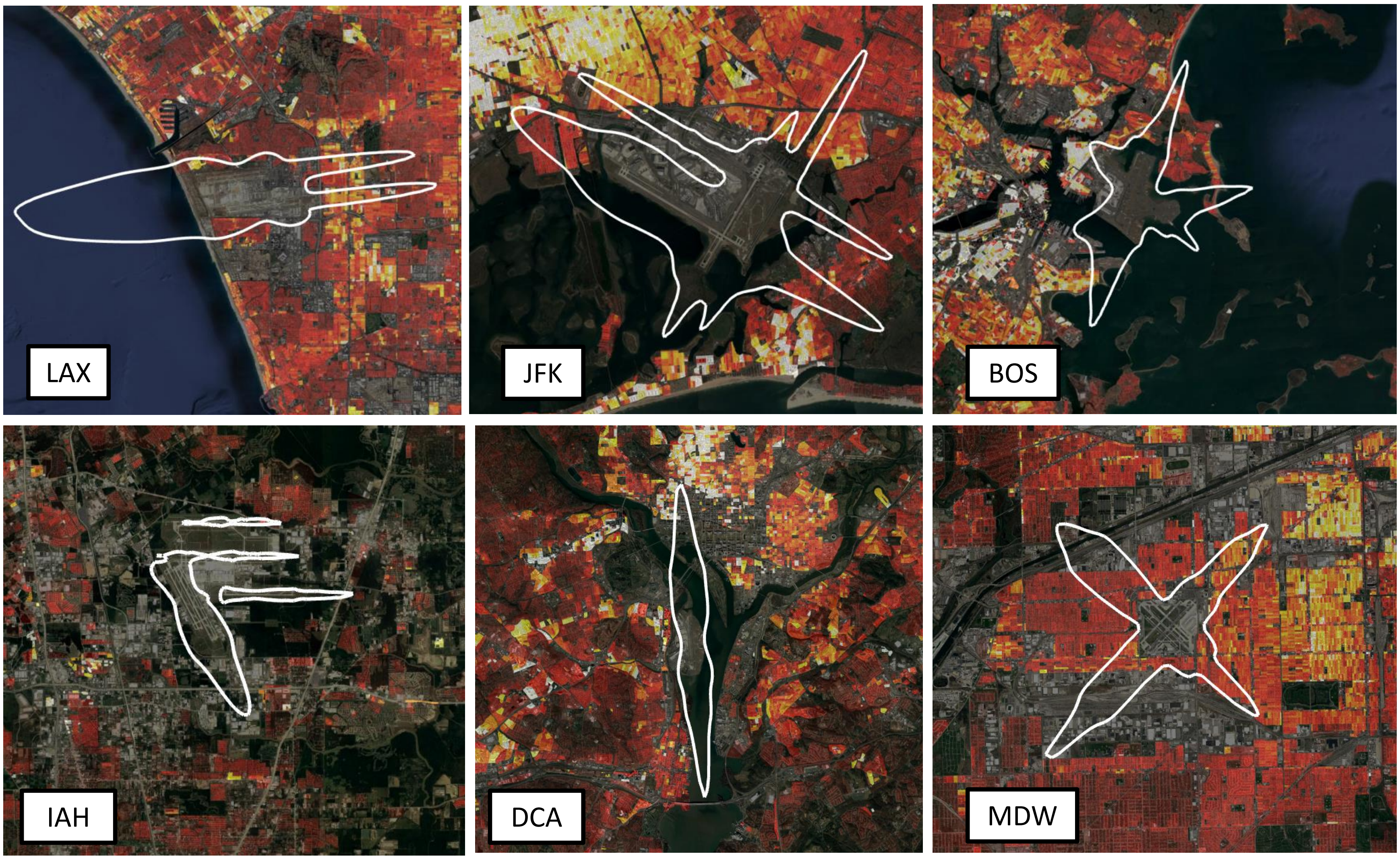
Contour Source: Draft 2016 LGA 14 CFR Part 150 Environmental Assessment

Comparison with Published 65 DNL Contours



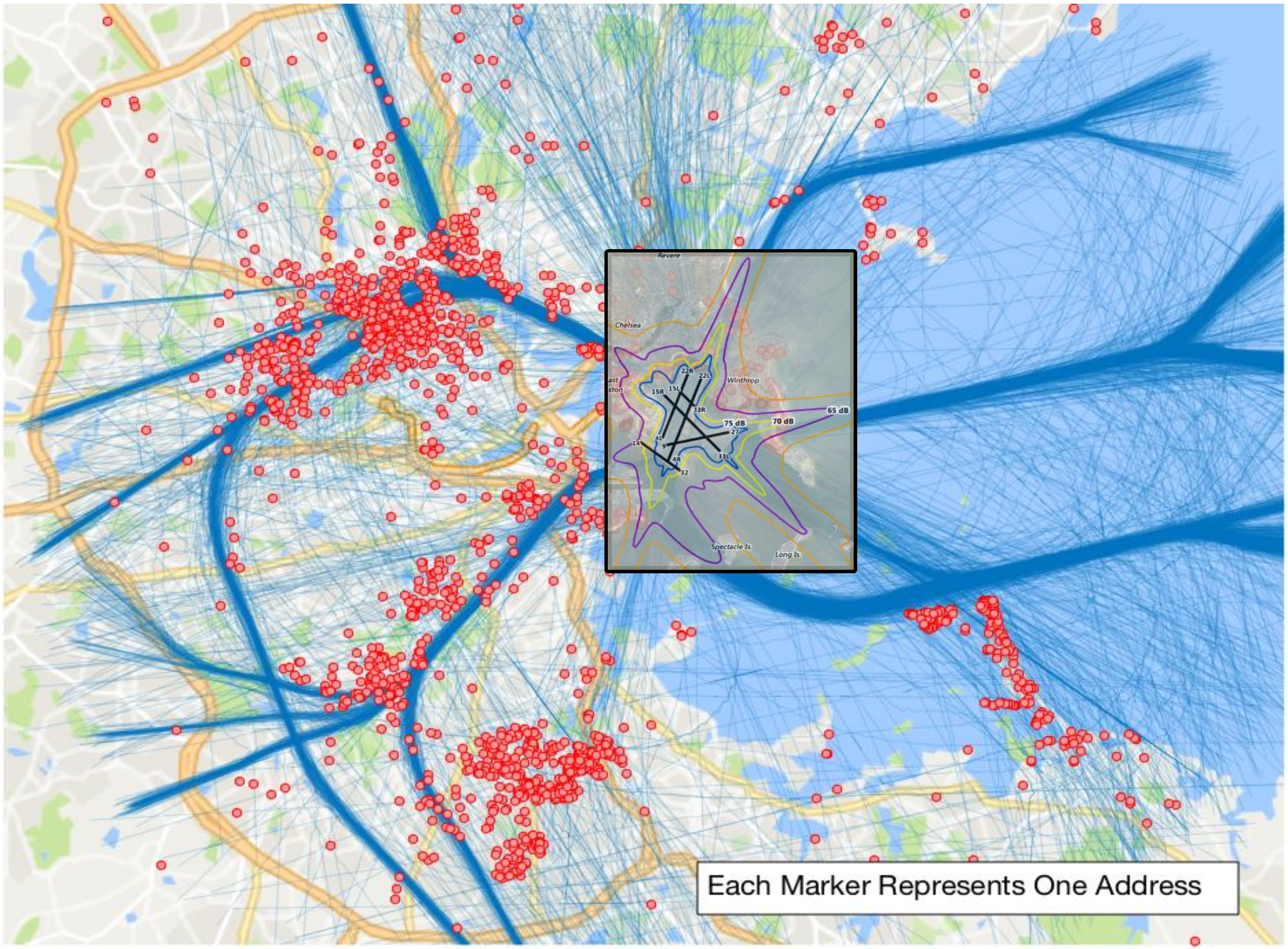
Contour Source: Draft 2016 JFK 14 CFR Part 150 Environmental Assessment

Simplified System Level Analysis:
Example Population Exposure Results (65 dB DNL)



65dB DNL Footprint vs. Geographic Extent of Noise Complaints

ASCENT
AVIATION SUSTAINABILITY CENTER

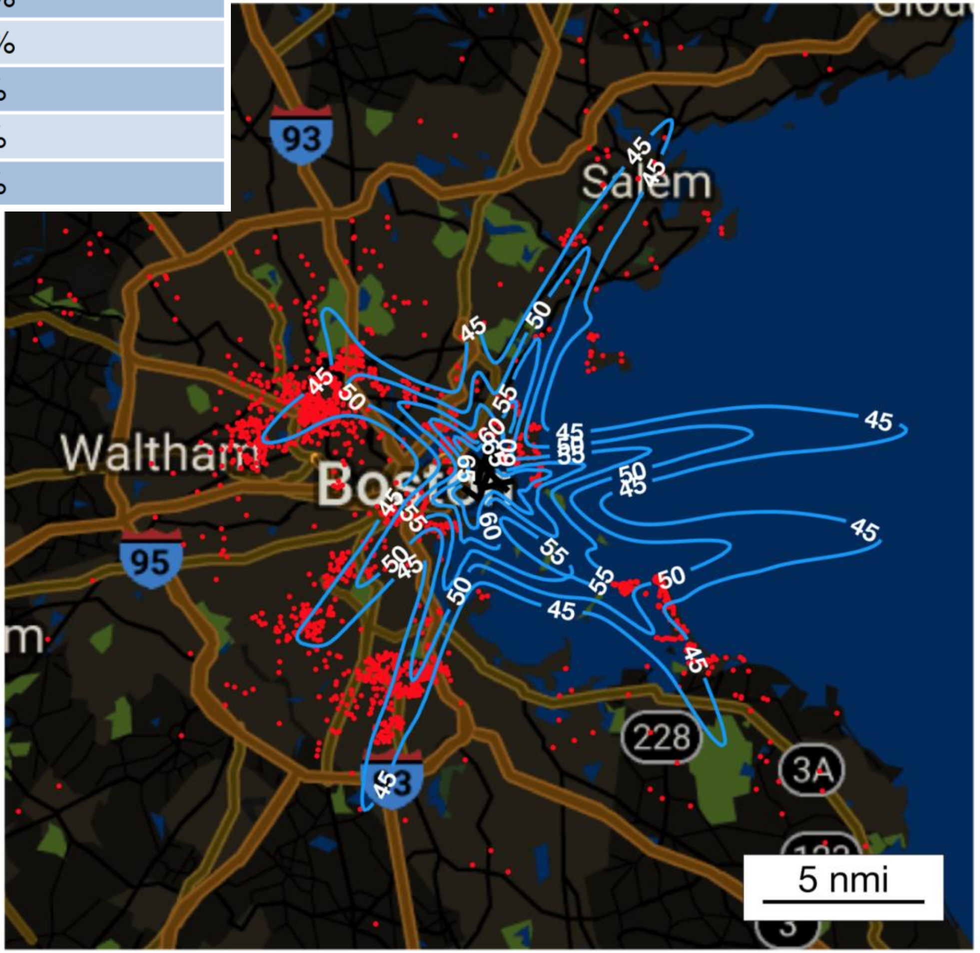


DNL Threshold Evaluation

Annual Average Day Complainant Coverage by DNL Contour Level

Contour Level	% Addresses Contained All Complainants	% Addresses Contained 33L Departure Complainants Only
45dB DNL	56.50%	54.21%
50dB DNL	18.58%	14.66%
55dB DNL	7.31%	8.05%
60dB DNL	3.40%	3.49%
65dB DNL	0.76%	0.12%

- 65dB DNL threshold captures almost no complainants
- In average day analysis, just over half of complainants are captured, which leaves a significant fraction of complainants unidentified



Annual Average Day DNL Contours

Comparison of Time Windows for DNL Computation

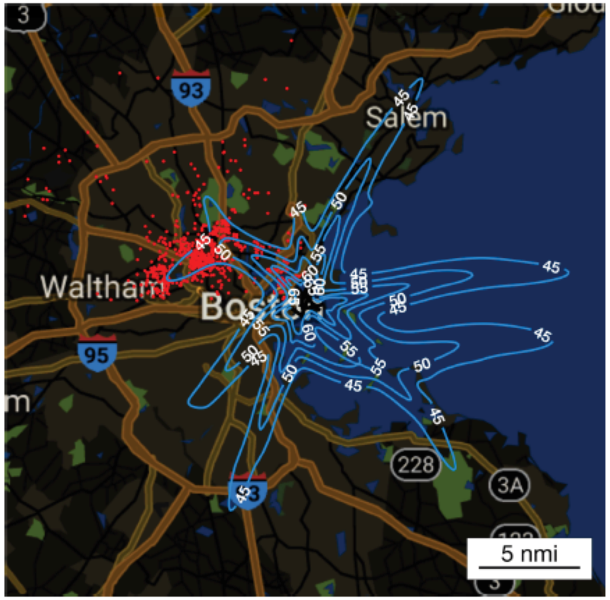


Figure 25: Annual Average Day DNL Contours

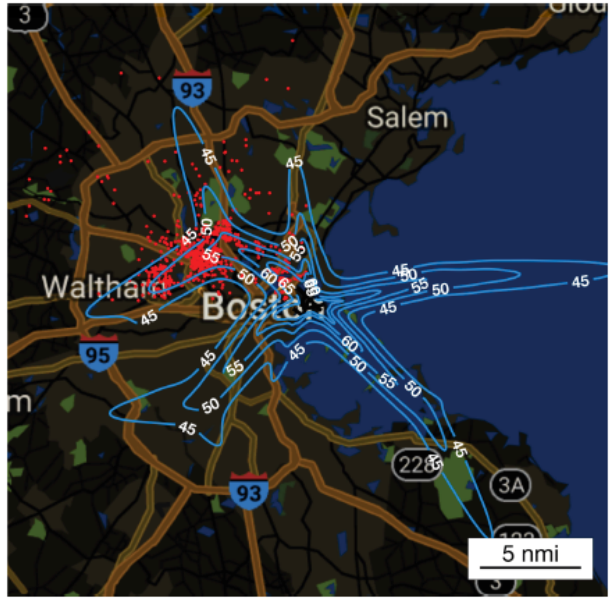


Figure 26: 33L Peak Day DNL Contours

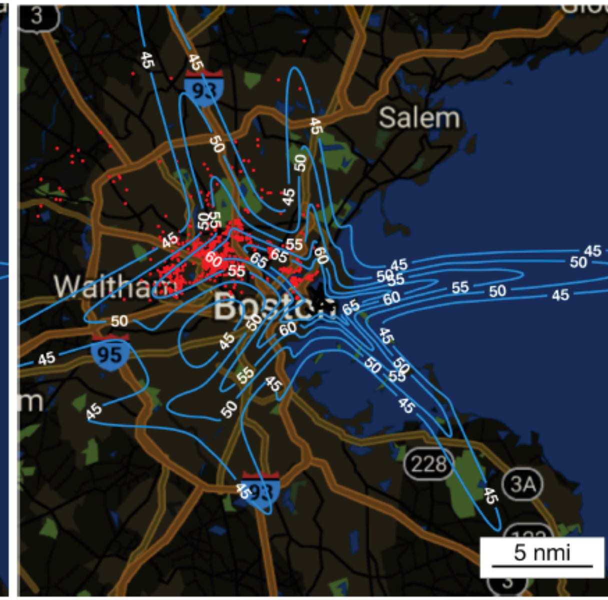


Figure 27: 33L Peak Hour DNL Contours

Table 19: 33L Departures Complainant Coverage for All Scenarios by DNL Contour Level

Contour Level	Annual Average Day	33L Peak Day	33L Peak Hour
45dB DNL	54.21%	87.26%	93.39%
50dB DNL	14.66%	66.11%	88.94%
55dB DNL	8.05%	21.27%	74.04%
60dB DNL	3.49%	8.53%	30.05%
65dB DNL	0.12%	5.17%	9.38%

Red: < 30% captured
Yellow: 30%-70% captured
Green: > 70% captured

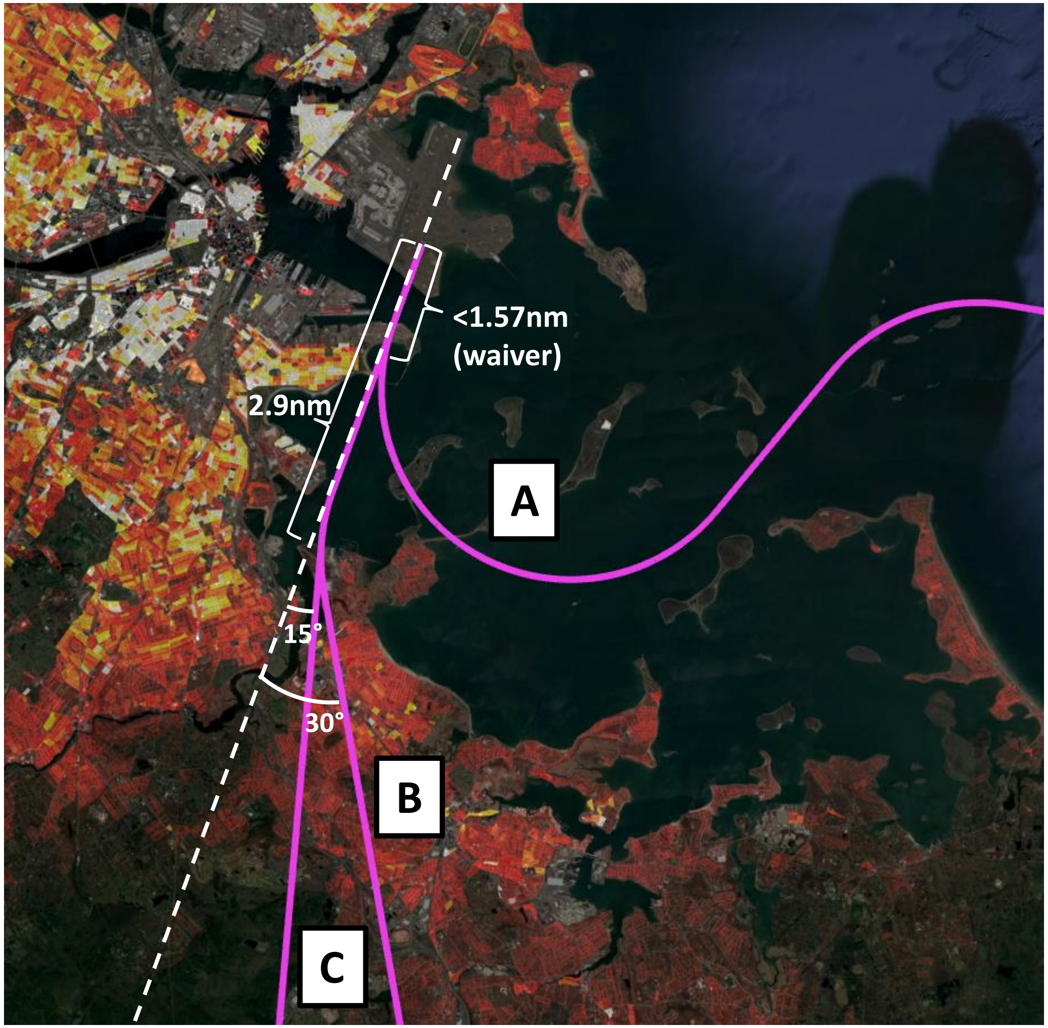
Table 20: Contour Area and Population Exposure for All Scenarios by DNL Contour Level

Contour Level	Annual Average Day		33L Peak Day		33L Peak Hour	
	Contour Area (nmi^2)	Pop Exposure	Contour Area (nmi^2)	Pop Exposure	Contour Area (nmi^2)	Pop Exposure
45dB DNL	107.43	554,679	114.80	879,087	236.90	1,345,823
50dB DNL	47.88	198,862	51.54	443,925	98.30	795,659
55dB DNL	20.28	61,017	21.86	153,988	43.44	384,738
60dB DNL	7.99	19,852	9.18	49,200	18.24	131,671
65dB DNL	3.38	1,568	3.76	17,640	7.94	50,955

Project Integration: ASCENT-11 and ASCENT-23

- Moving forward, Project 11 will merge with Project 23: *"Analytical Approach for Quantifying Noise from Advanced Operational Procedures"*
- Analysis architecture and tools will be integrated with those developed under Project 23
- System-level analysis framework will be applied to evaluate tradeoffs between noise reduction potential and procedure design criteria
  - Final approach segment length
  - Final approach intercept angle
  - Minimum leg length assumptions on arrivals and departures

PBN Criteria for RNAV and RNP Arrivals



Final approach TERPS criteria define final approach constraints

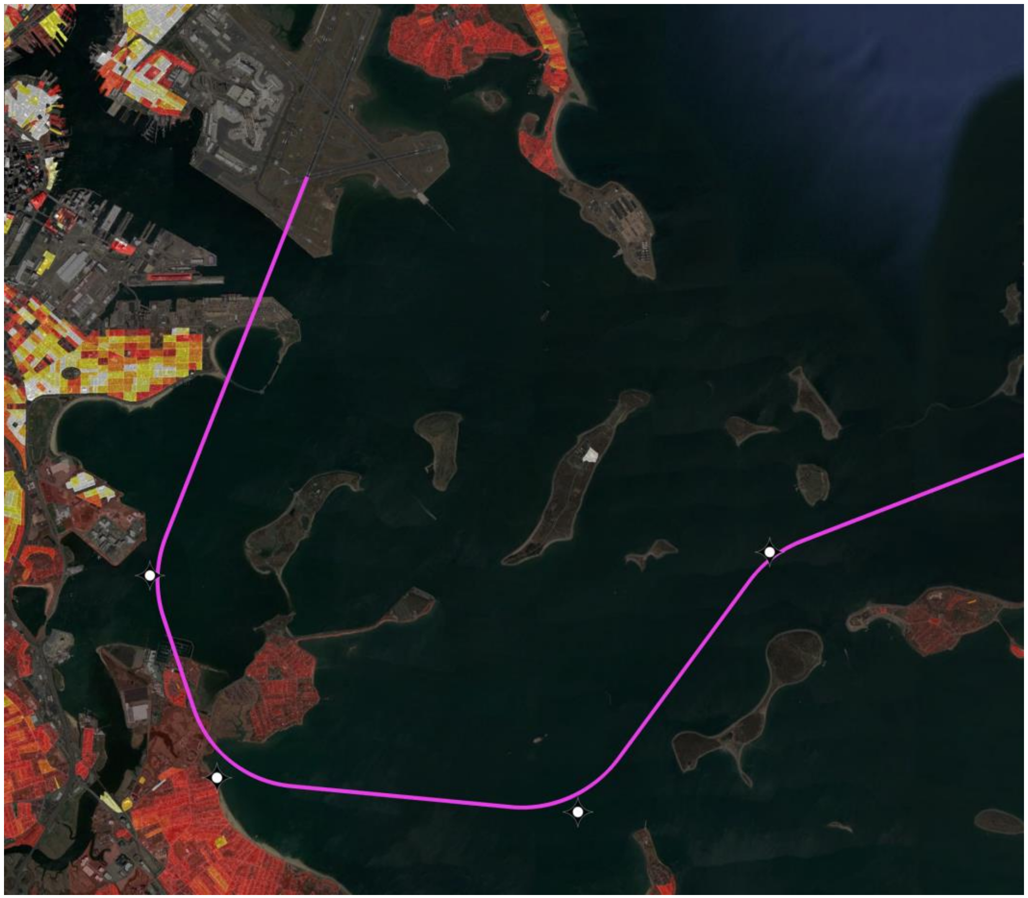
Assuming 3° glideslope

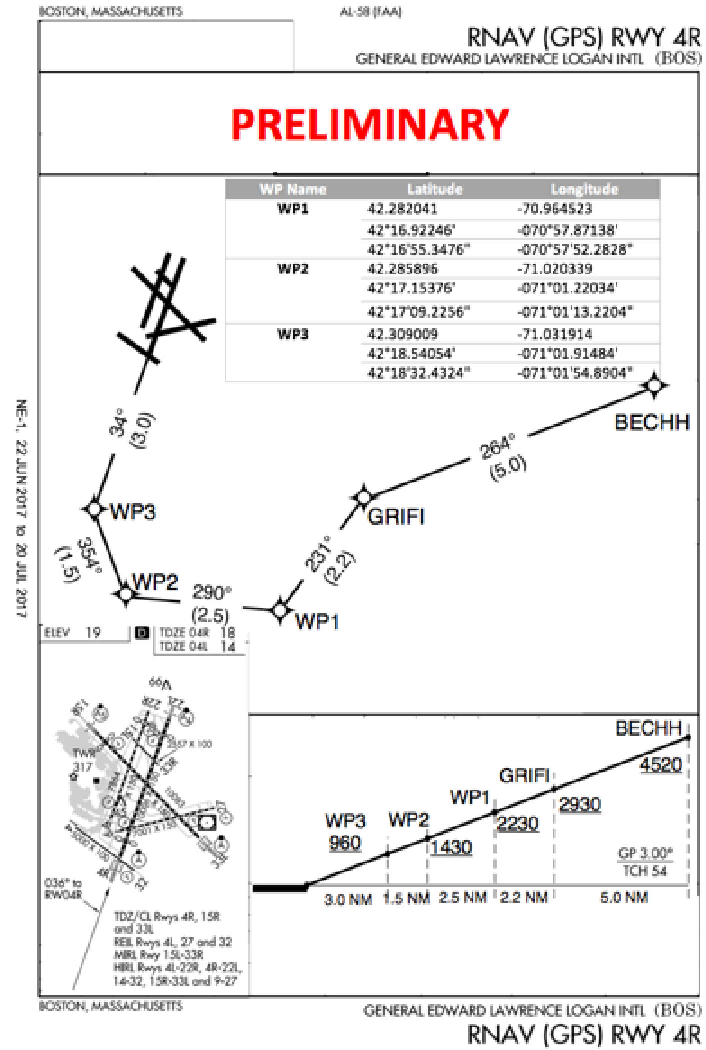
A. RNP Approach
   - Min. final approach length: 1.57nm

B. Nonprecision RNAV Approach
   - Min. final approach length: 2.9nm
   - Max intercept angle: 30°

C. Precision RNAV Approach
   - Min. final approach length: 2.9nm
   - Max intercept angle: 15°

RNAV (GPS) Approach Runway 4R

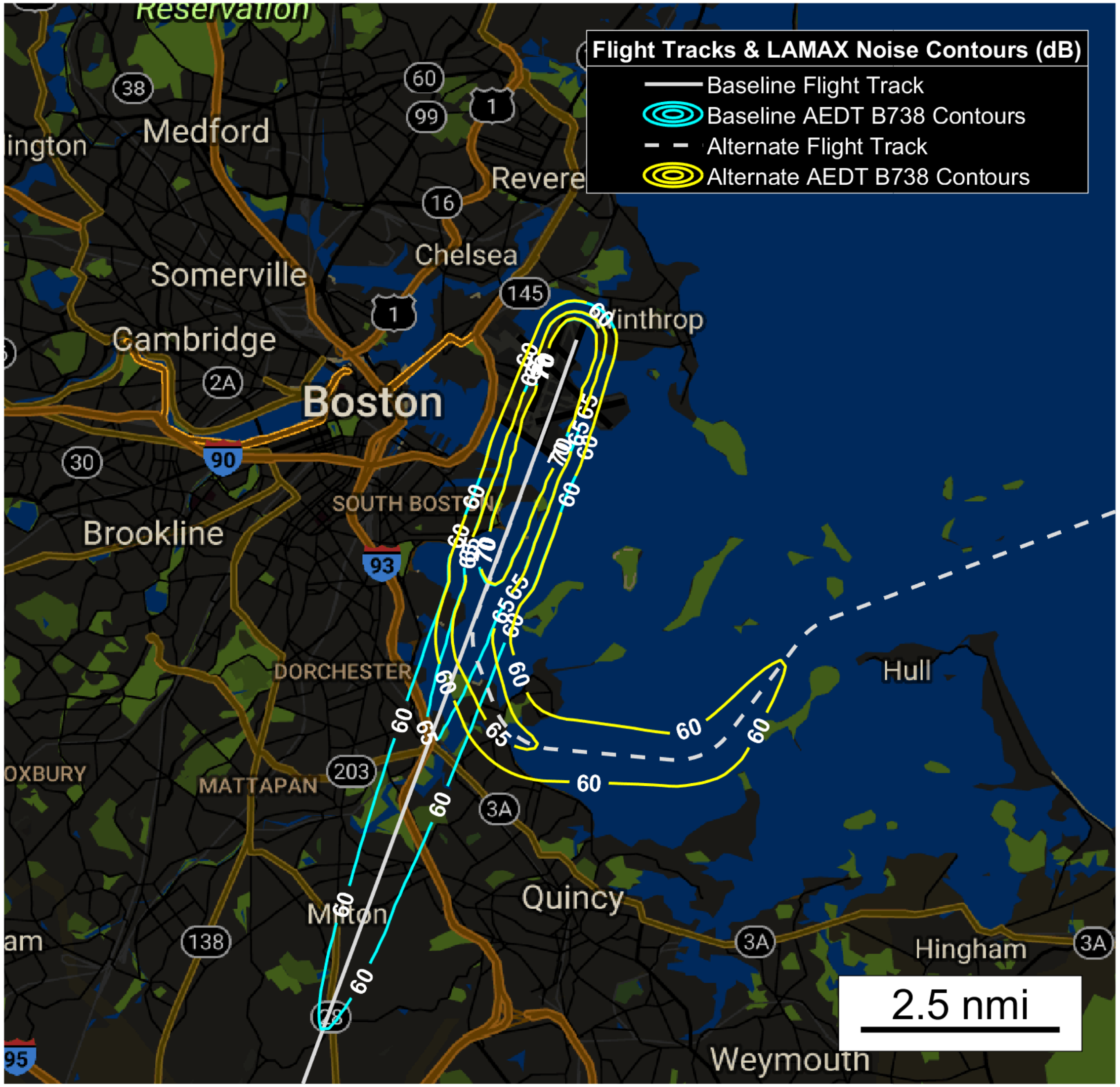




Simulator Tested for Flyability

RNAV (GPS) Approach Runway 4R: Noise Results

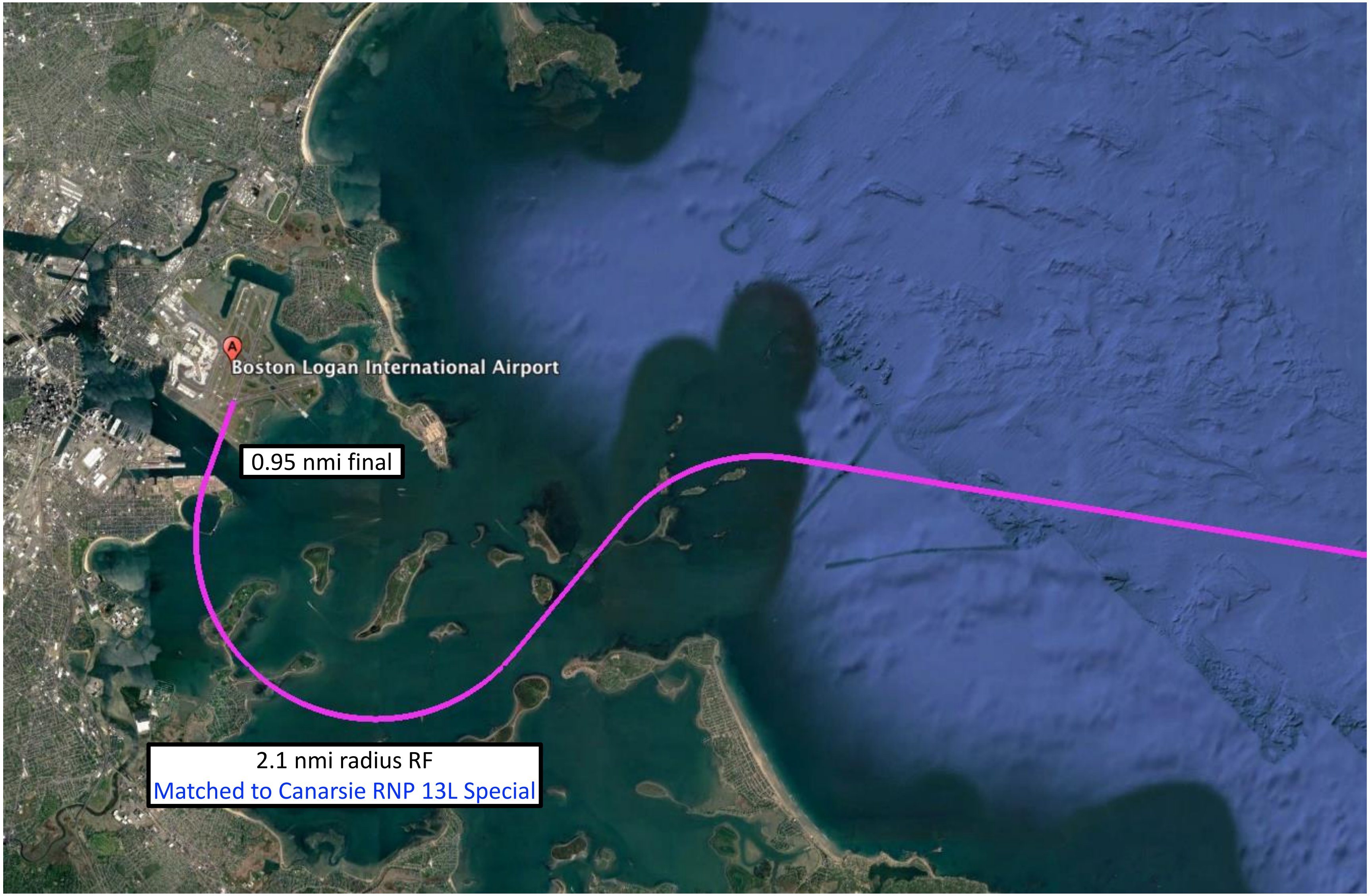
Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	AEDT
Notes	Continuous Descent Approach on 3° Glideslope



Population Exposure (L_{MAX})

	60dB	65dB	70dB
Straight In	21,008	4,263	1,043
Modified Procedure	12,658	3,868	236
Reduction	8,350	395	807

Notional Low-Noise Overwater RNP: BOS Rwy 4R



4R Low-Noise Overwater RNP Approach: Noise Exposure

Aircraft	B737-800
Metric	$L_{A,MAX}$
Noise Model	AEDT
Notes	Continuous Descent Approach on 3° Glideslope

Population Exposure (L_{MAX})

	60dB	65dB	70dB
Straight In	21,008	4,263	1,043
Modified Procedure	5,905	1,389	161
Reduction	15,103	2,874	882

Project Status

- Analysis framework demonstrated on sample problem at DCA airport
  - Novel aircraft modeling
  - Operational fleet model development (timetable and fleet mix)
  - Representative trajectory calculation using historical radar data
  - Population exposure calculation and contour generation
- Simplified system-level analysis technique developed and demonstrated for OEP 35 airports
  - Assuming straight-in arrivals an straight-out departures, representative fleet of 12 aircraft types
- Next Steps
  - Analyze trade space of PBN approach criteria and noise reduction potential
  - Develop efficient method to represent non-standard procedures
    - Avoid straight-in and straight-out assumption
    - Capture effects of flight track dispersion