ASCENT Project 23

Analytical Approach for Quantifying Noise from Advanced Operational Procedures

Massachusetts Institute of Technology

PI: John Hansman

PMs: Christopher Dorbian & Joe Dipardo

Cost Share Partner: Massachusetts Port Authority

Objective:

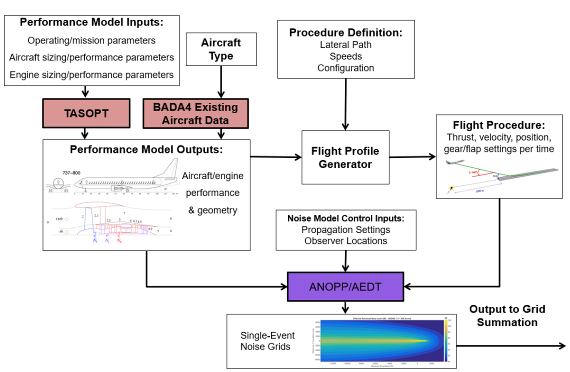
The objective of the research is to continue development of a noise analysis method with improved fidelity, accuracy, and utility for evaluation of advanced operational procedures.

Project Benefits:

The current phase of the project is focused on continued refinement of the analysis tools and application to a broad set of sample problems to demonstrate noise reduction opportunities leveraging Performance Based Navigation in the National Airspace System (NAS).

Research Approach:

This project involves development of a noise modeling framework to be used to evaluate candidate advanced operational procedures for community noise reduction, with additional focus on identifying operational repercussions and implementation barriers.



Major Accomplishments (to date):

- Developed recommendations for new operational procedures as well as modifications to current procedures for Boston Logan Airport (BOS). Depending on the context, proposed procedures offer:
  - Reduction in net population exposure, or;
  - Re-distribution of noise targeting higher equity.
- Developed new metrics and means of communicating effects of noise re-distribution caused by modifications to procedures.
- Documented the set of procedure design constraints that restrict how noise-abating procedures can be designed and implemented in today's NAS.
- Published the Block 2 Report (https://dspace.mit.edu/handle/1721.1/131242) and presented recommendations to communities.

Future Work / Schedule:

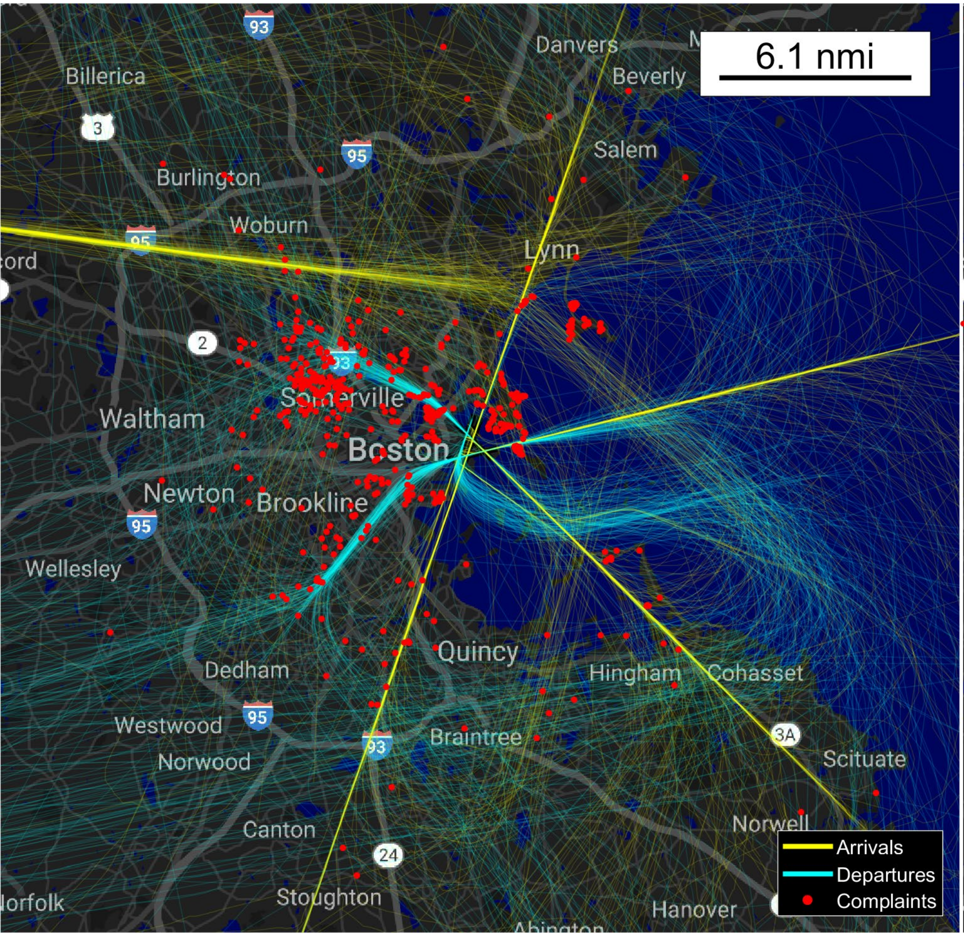
- Identify and disseminate lessons learned from the project.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 31 through FAA Award Number 13-C-AJFE-MIT-031 under the supervision of Christopher Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

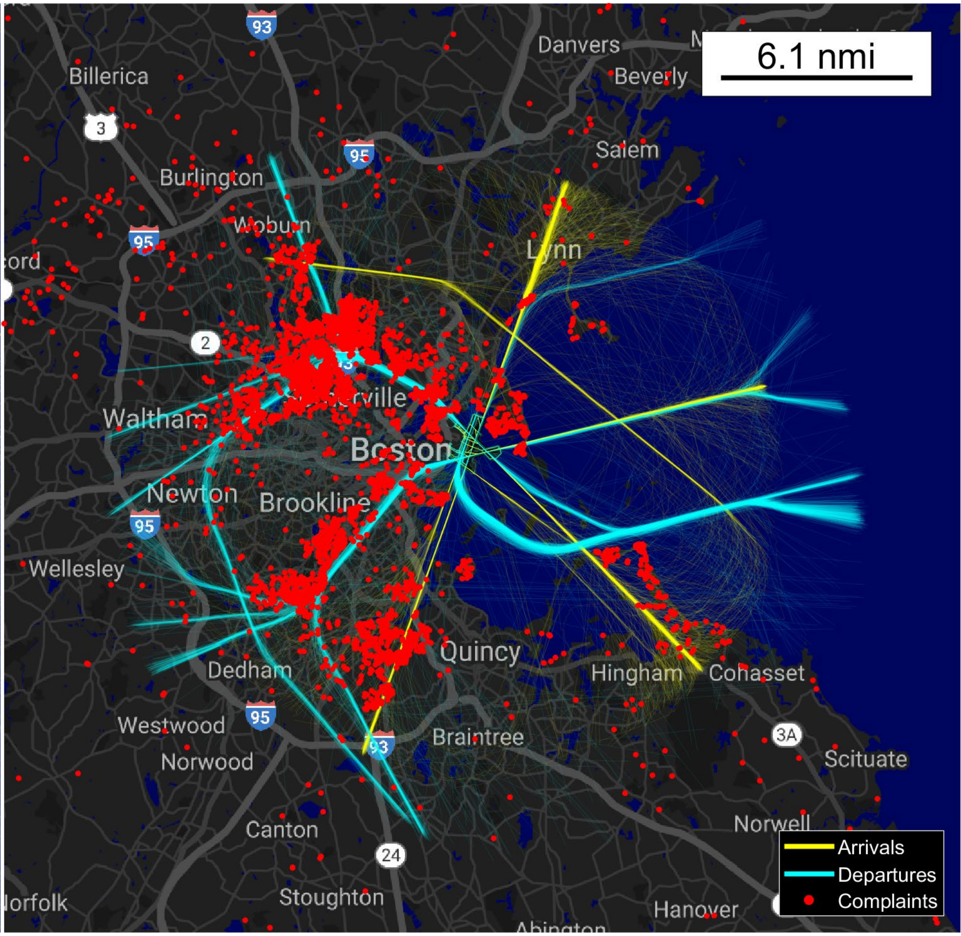
RNAV Track Concentration

ASCENT
AVIATION SUSTAINABILITY CENTER

2010: pre-RNAV



2017: post-RNAV



Goal of the work at BOS:
To identify concepts of air traffic procedures that could mitigate the perceived noise burden caused by RNAV flight track concentration.

Massport/FAA/MIT MOU 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 MCAC, Massport and FAA

Noise Analysis Framework

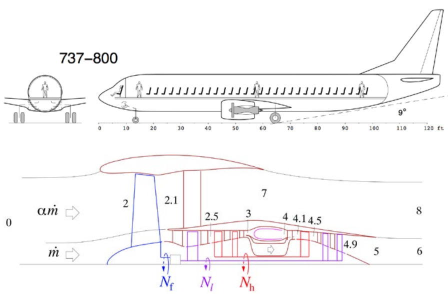
Performance Model Inputs:
Operating/mission parameters
Aircraft sizing/performance parameters
Engine sizing/performance parameters

Aircraft Type

TASOPT

BADA4 Existing Aircraft Data

Performance Model Outputs:

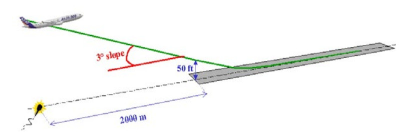


Aircraft/engine performance & geometry

Procedure Definition:
Lateral Path
Speeds
Configuration

Flight Profile Generator

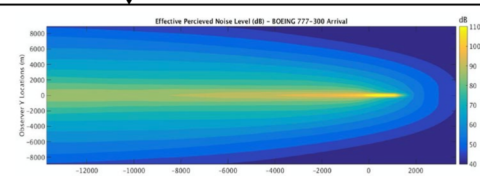
Flight Procedure:
Thrust, velocity, position, gear/flap settings per time



Noise Model Control Inputs:
Propagation Settings
Observer Locations

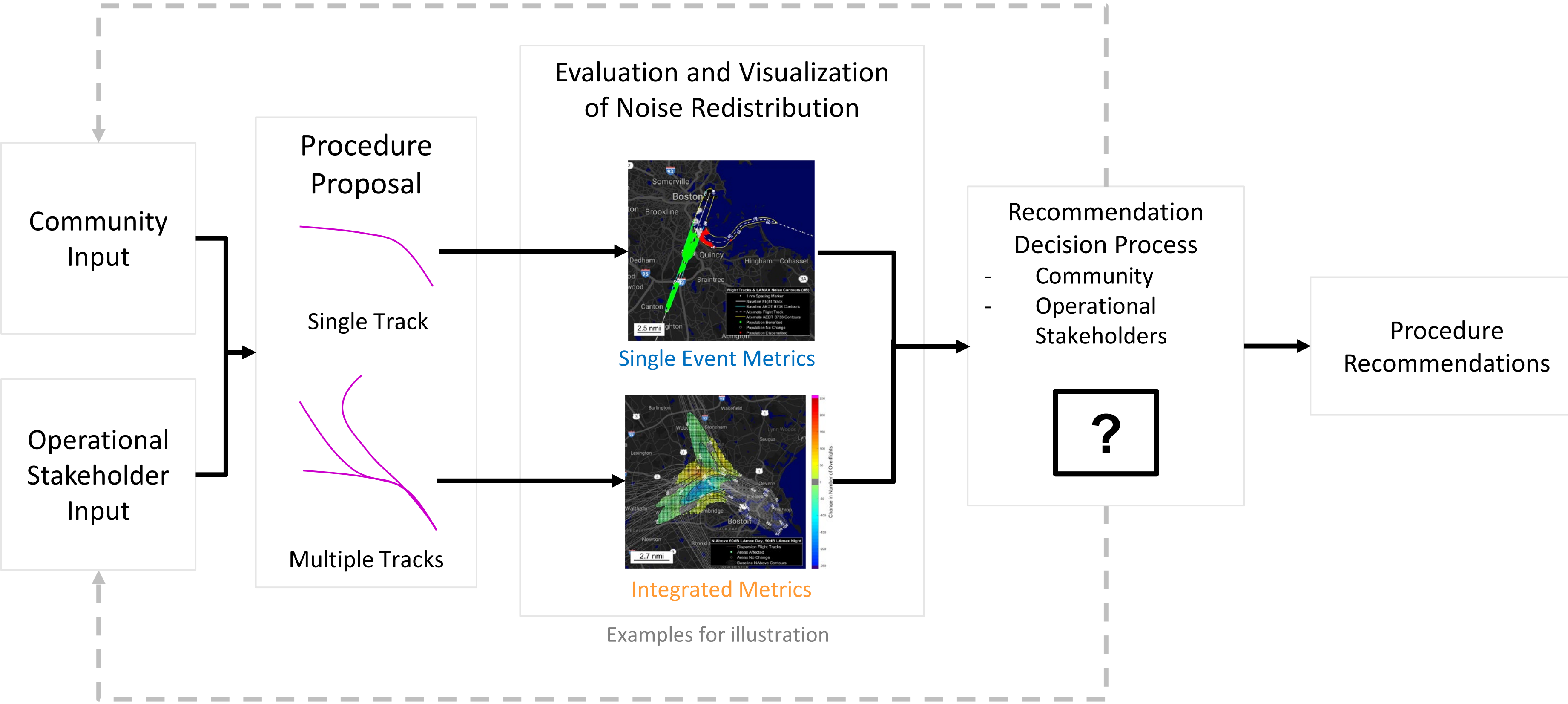
ANOPP/AEDT

Single-Event Noise Grids



Output to Grid Summation

Noise Modeling Framework for Operational Procedure Evaluation



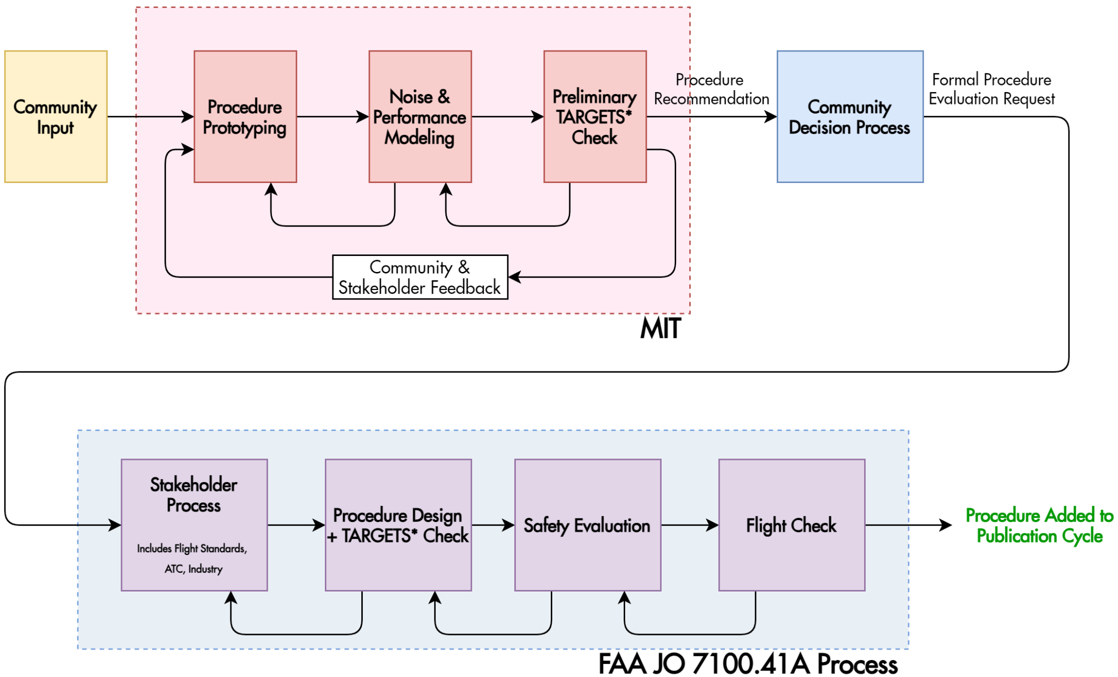
Examples for illustration

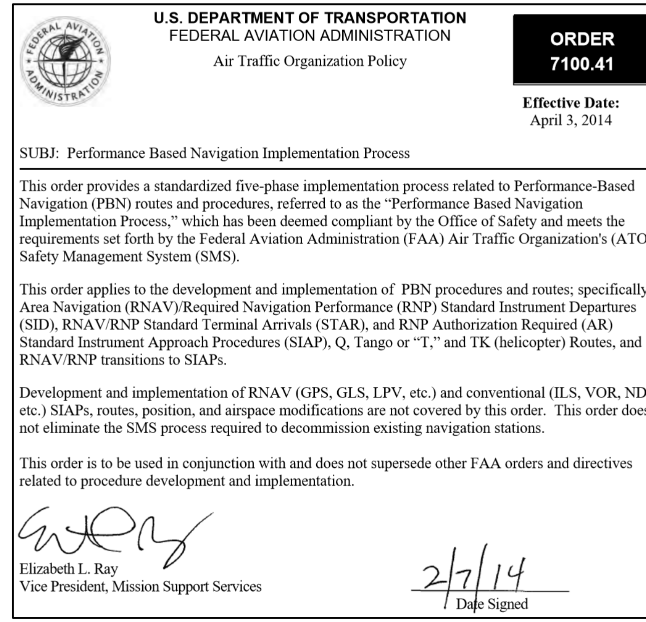
Analysis Metrics

- 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

Overall Process Flow and FAA 7100.41 Process

- 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.





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).

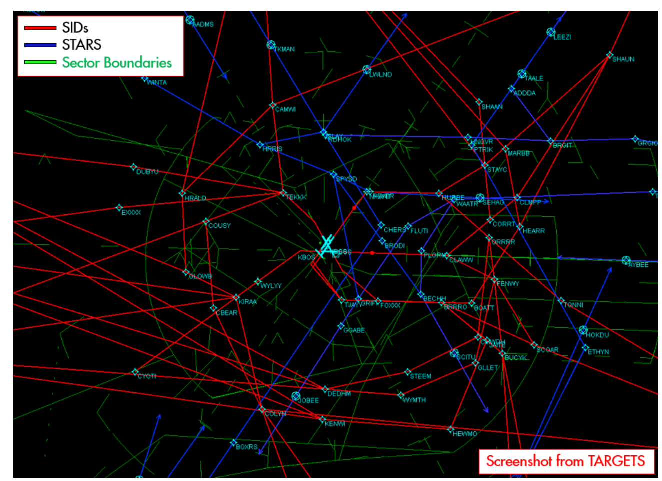
This order applies to the development and implementation of PBN procedures and routes; specifically, Area Navigation (RNAV)/Required Navigation Performance (RNP) Standard Instrument Departures (SID), RNAV/RNP Standard Terminal Arrivals (STAR), and RNP Authorization Required (AR) Standard Instrument Approach 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



*TARGETS is the FAA's official software for procedure design and verification of criteria compliance. The addition of TARGETS to MIT's workflow is new to Block 2.

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

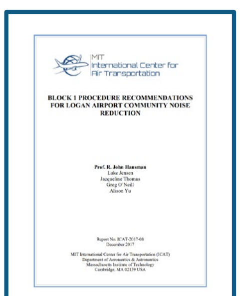
Block 1/Block 2 Timeline

2016 · 2017 · 2018 · 2019 · 2020 · 2021

October 7, 2016
MOU Signed

February 22, 2017
Block 1 Public Hearing

October 2017
Block 1 recommendations presented to the MCAC*.



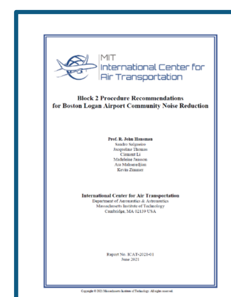
December 2017
Block 1 Report published

December 20, 2017
Block 1 procedures that passed .41 process recommended to FAA for implementation.

October 18, 2018
.41 Full Working Group response to Block 1 recommendations.
Two procedures forwarded to implementation (in progress as of Oct 2021).

May 21, 2020
Meeting with operational stakeholder group to discuss preliminary feasibility of Block 2 concepts.

June 2021
Block 2 recommendations presented to the MCAC*.



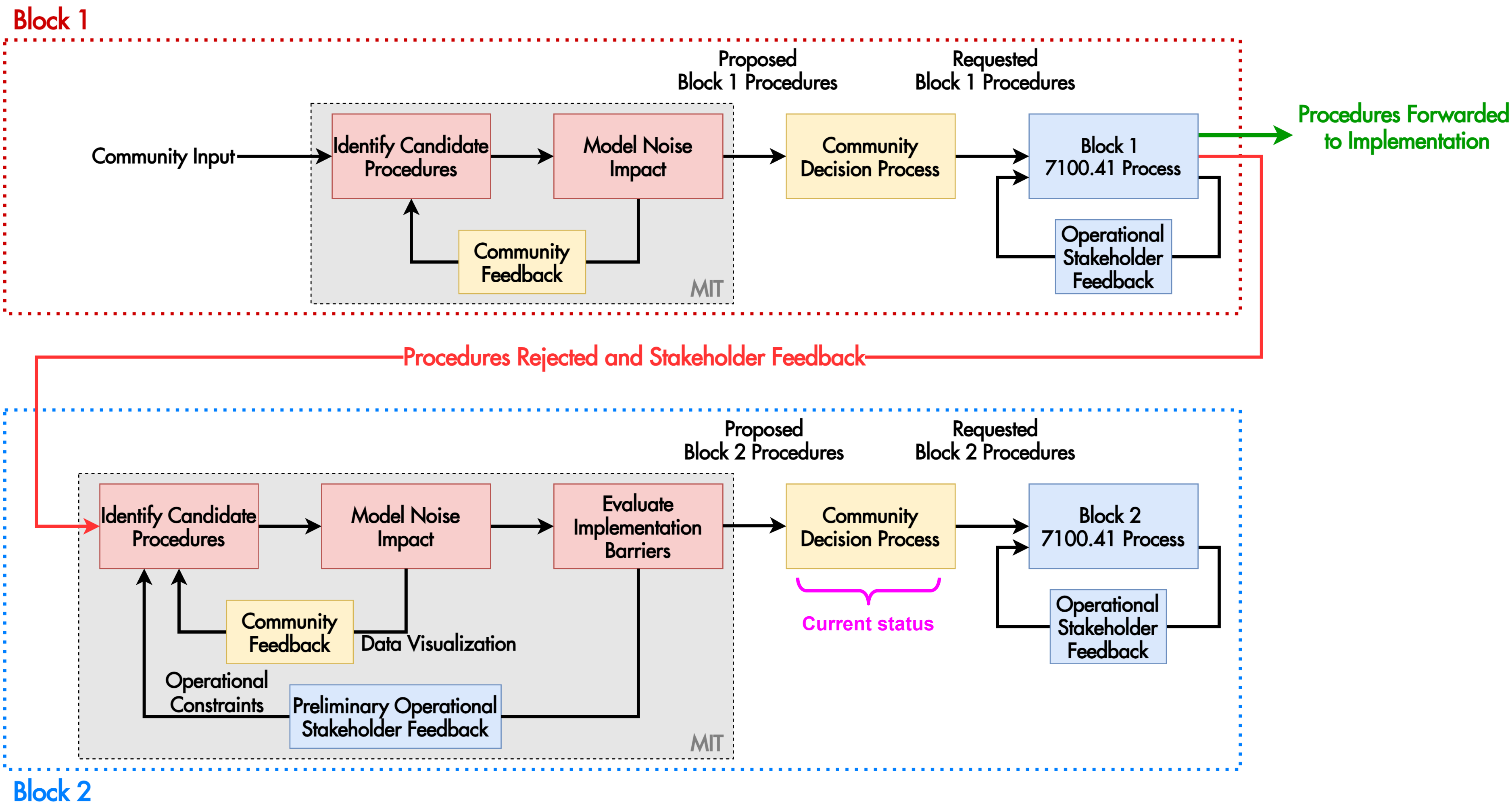
June 2021
Block 2 Report published

September 23, 2021
Block 2 Public Hearing

Current status:
Providing support to community decision process by responding to questions and requests for data.

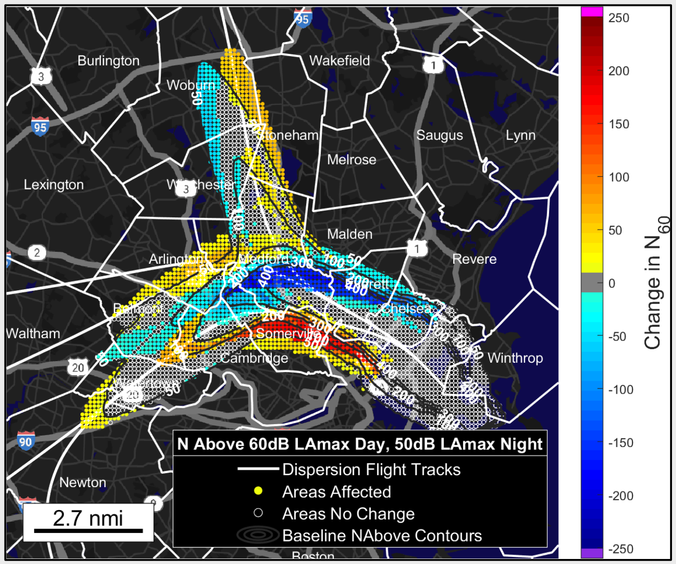
*The Massport Community Advisory Committee (MCAC) is composed of community representatives.

Block 1/Block 2 Process



Areas of Lessons Learned

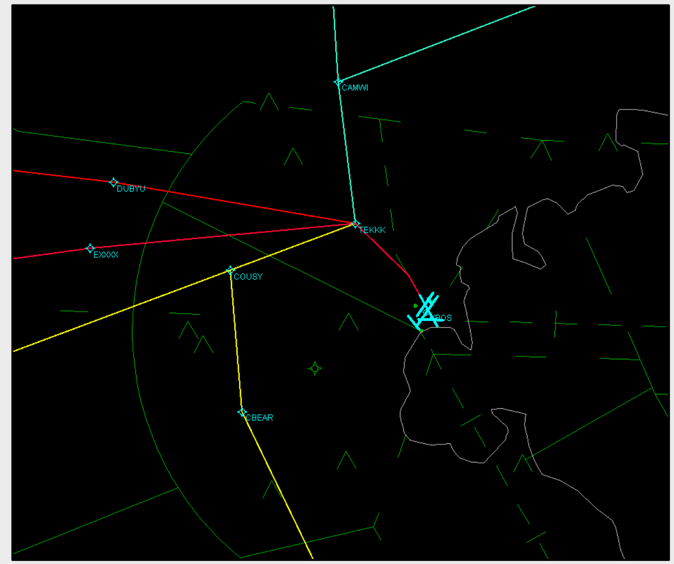
Lessons Learned on Data Visualization for Communities



Community feedback indicated:

- Effectiveness of N_{60} metric.
- Interest in aggregate metrics.
- Interest in expected aircraft altitude values.
- Interest in expected frequency of procedure use.

Lessons Learned on Procedure Operational Constraints



The following categories of implementation constraints were identified through discussions with operational stakeholders:

- Flight Standards Design Criteria.
- Air Traffic Control Rules and Procedures.
- Aircraft Limitations and Standard Operator Practices.

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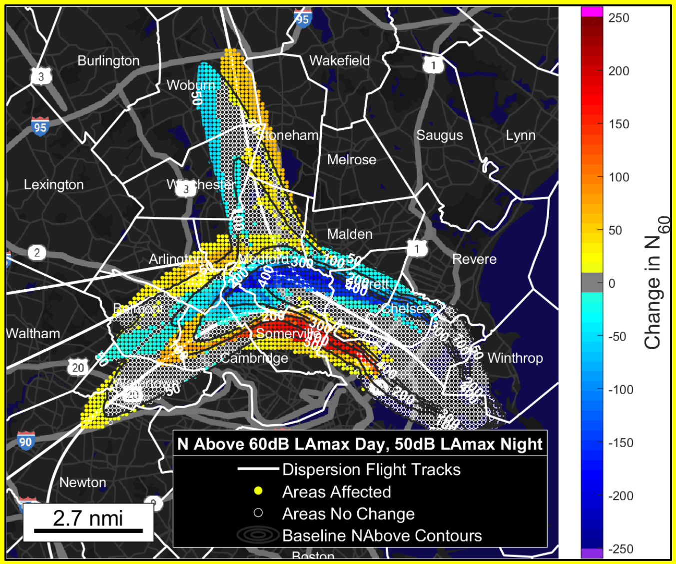

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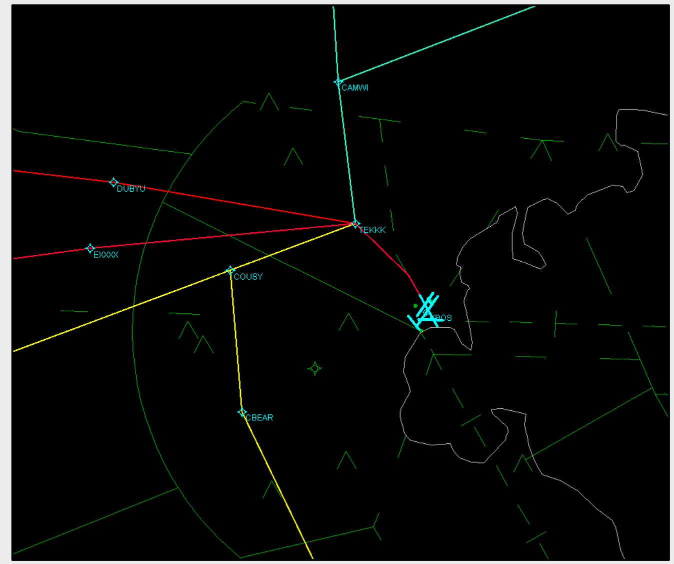

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- Flight Standards Design Criteria.
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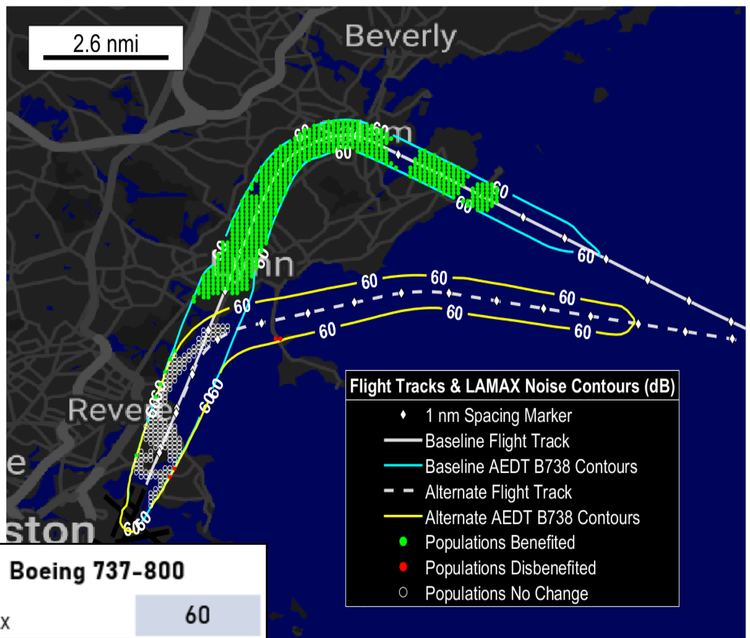
Data Visualization for Communities

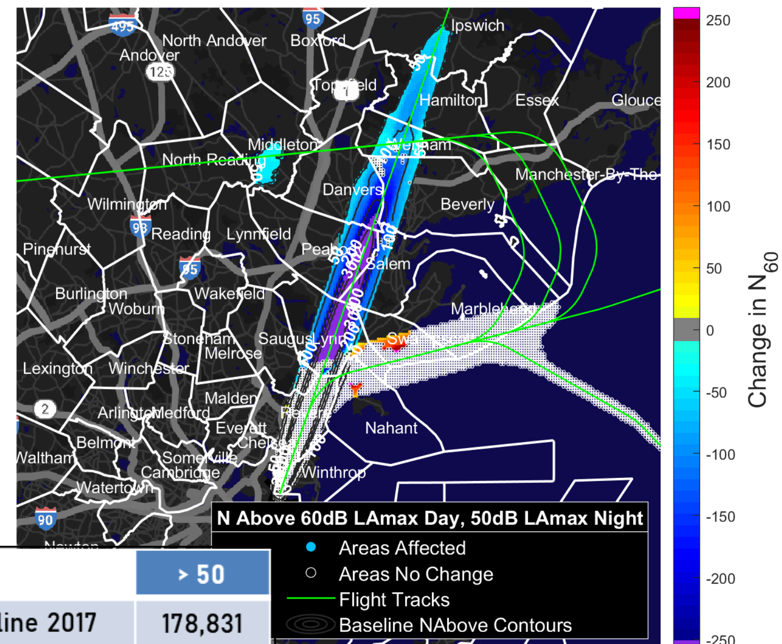
- N_{60} metric was effective for communication
- Aggregate visualizations were preferred over single-track $L_{A,MAX}$.
  - However, analysis requires assumptions on which aircraft can fly the procedure

Single-track $L_{A,MAX}$ impacts



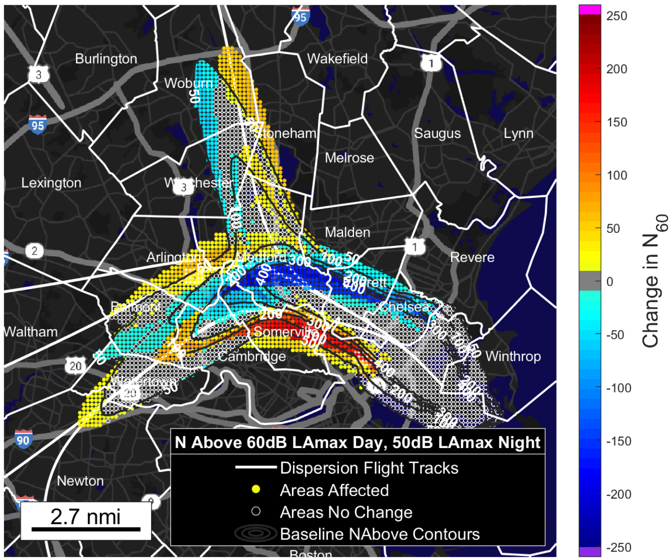
Boeing 737-800	
$L_{A,MAX}$	60
Observed	84,640
Proposed	19,934
Difference	64,706

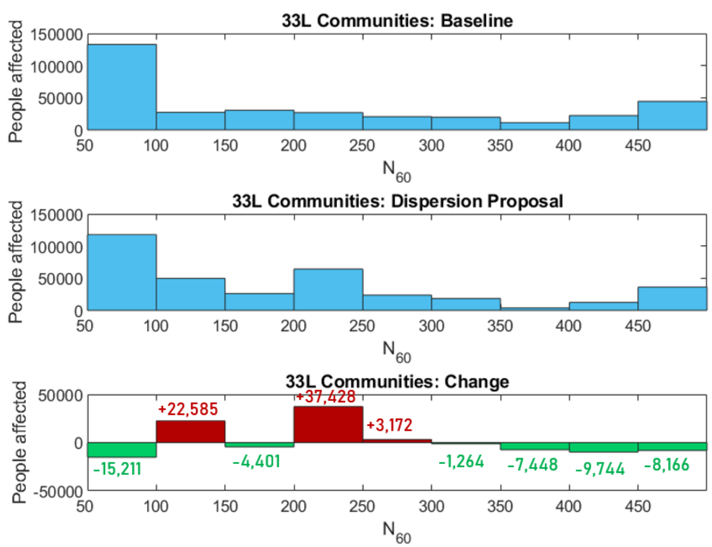
Aggregate N_{60} impacts



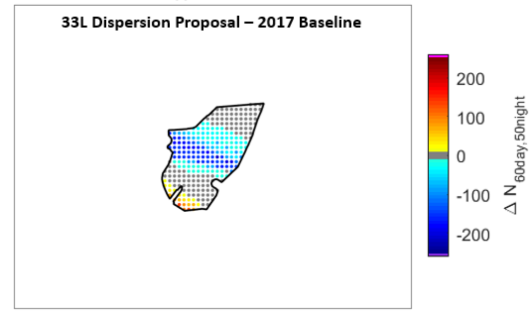
N_{60}	> 50
Baseline 2017	178,831
Recommended Procedure	46,939
Difference	131,892

Data Visualization for Individual Communities

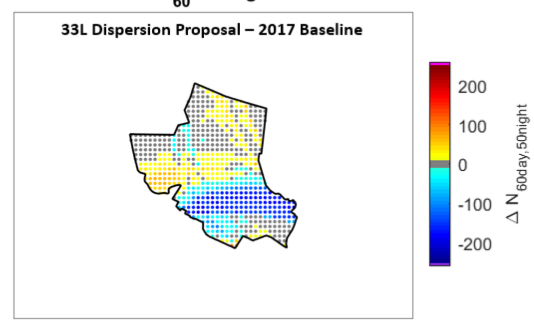




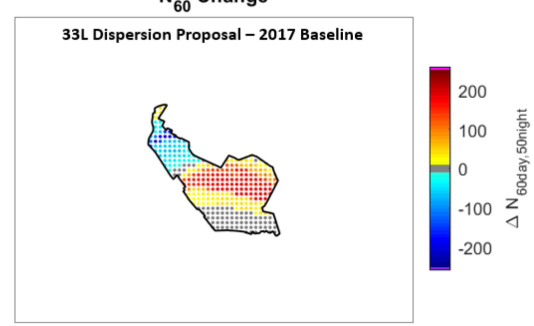
Everett
N_{60} Change



Medford
N_{60} Change

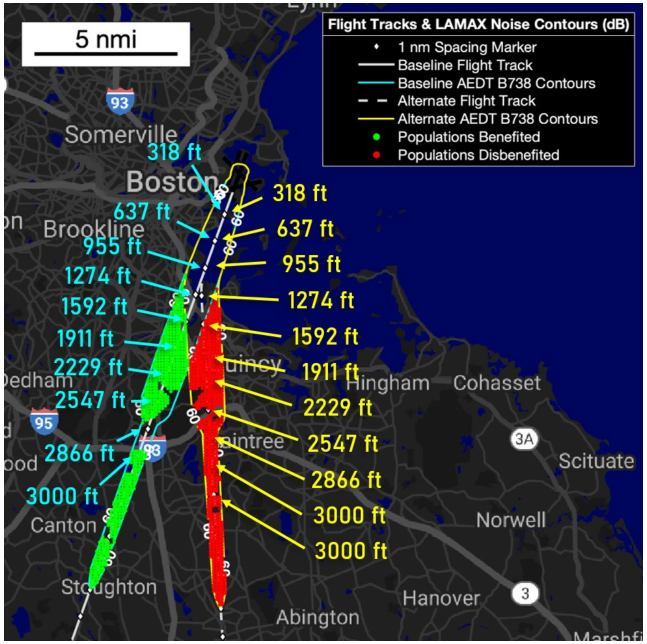


Somerville
N_{60} Change

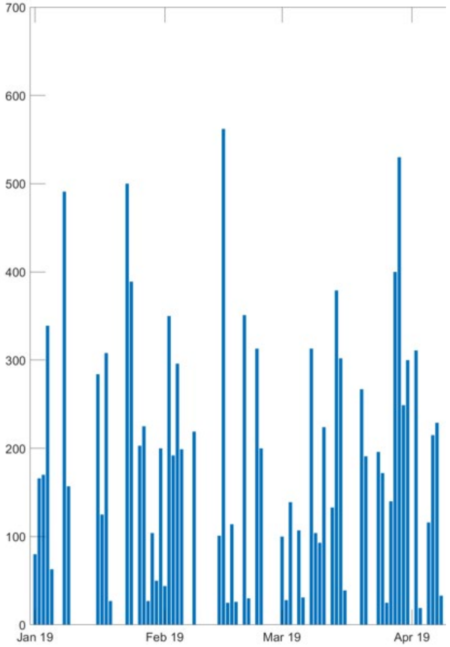


Data Visualization for Communities

- Communities often requested expected aircraft altitudes along proposed procedures in addition to noise metrics.
  - For approaches, altitudes were estimated based on a 3º glidepath on final approach.
  - For departures, altitudes were estimated based on a median B737-800 climb profile.
- Communities where the noise exposure was expected to increase due to re-distribution requested more data on when the proposed procedure would be used.
  - Data for runway use and airport runway configuration were sourced from the FAA ASPM database to answer these questions.



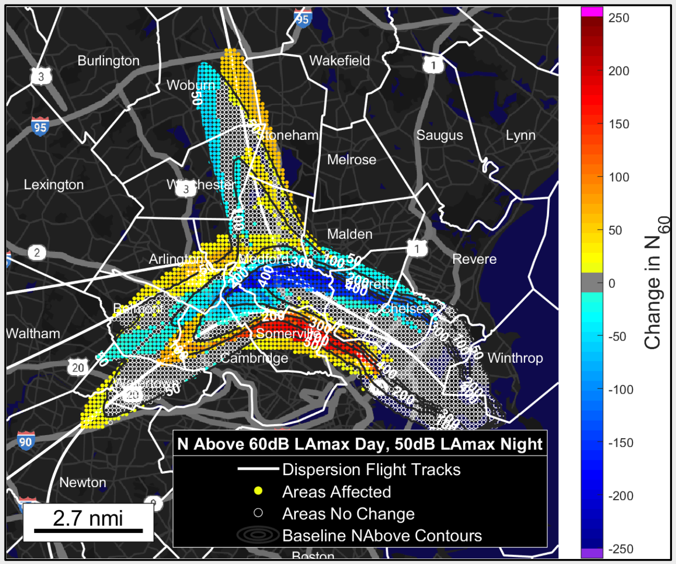
Concept of RNAV approach to RWY 4R, with expected altitude values shown.



FAA ASPM data showing number of daily landings on Runway 22L in 2019.

Areas of Lessons Learned

Lessons Learned on Data Visualization for Communities



Community feedback indicated:

- Effectiveness of N_{60} metric.
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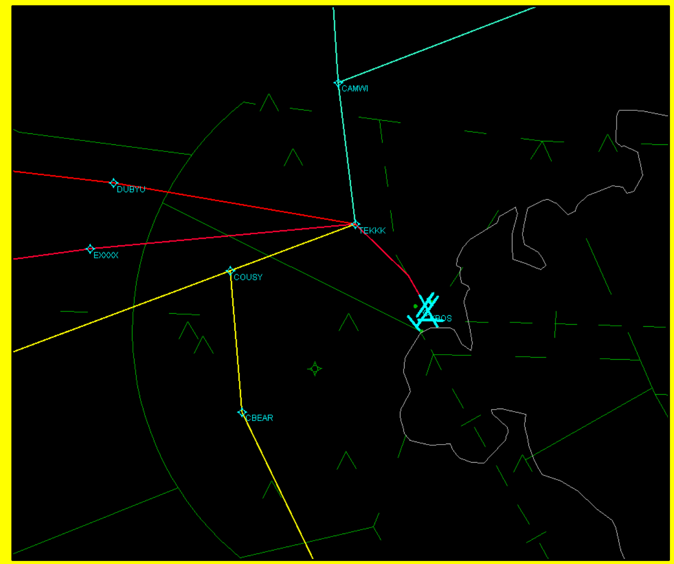
Lessons Learned on Procedure Operational Constraints

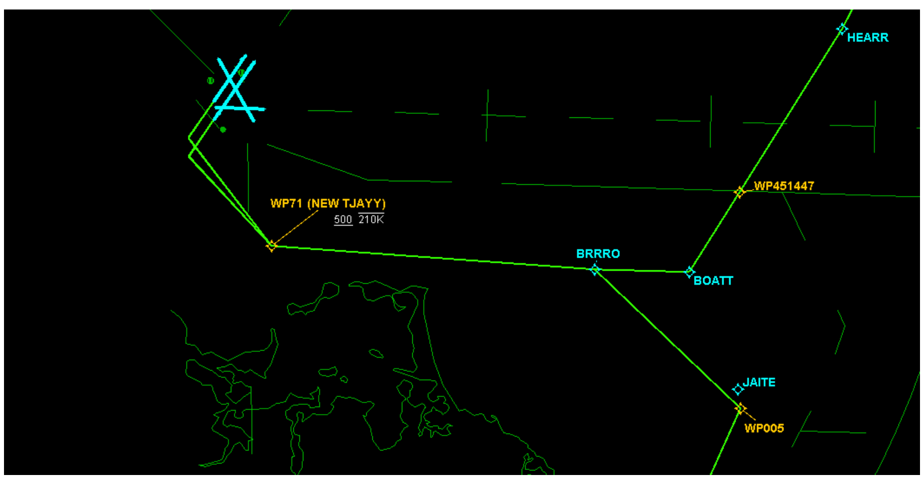


The following categories of implementation constraints were identified through discussions with operational stakeholders:

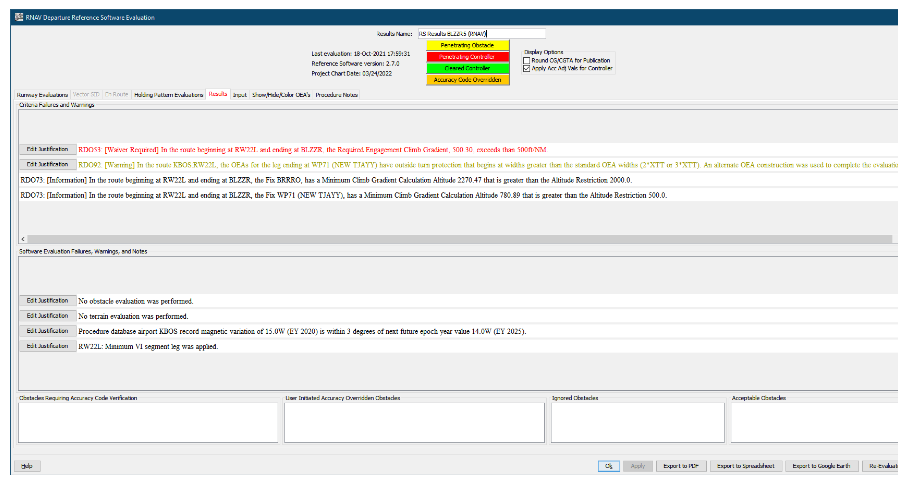
- Flight Standards Design Criteria.
- Air Traffic Control Rules and Procedures.
- Aircraft Limitations and Standard Operator Practices.

Flight Standards Design Criteria

- Design criteria are rules imposed on the construction of an instrument flight procedure. Criteria include:
  - Minimum leg lengths.
  - Maximum turn angles.
  - Terrain and obstacle clearance.
- Block 2, proposed procedures were constructed in TARGETS* and checked for design criteria compliance.
- The use of TARGETS* files was an effective way of communicating with operational stakeholders.
- Opening a procedure for modification imposed updated criteria often outside noise impact area.
  - *"Grandfather"* clause issue.



Example TARGETS screen during procedure design

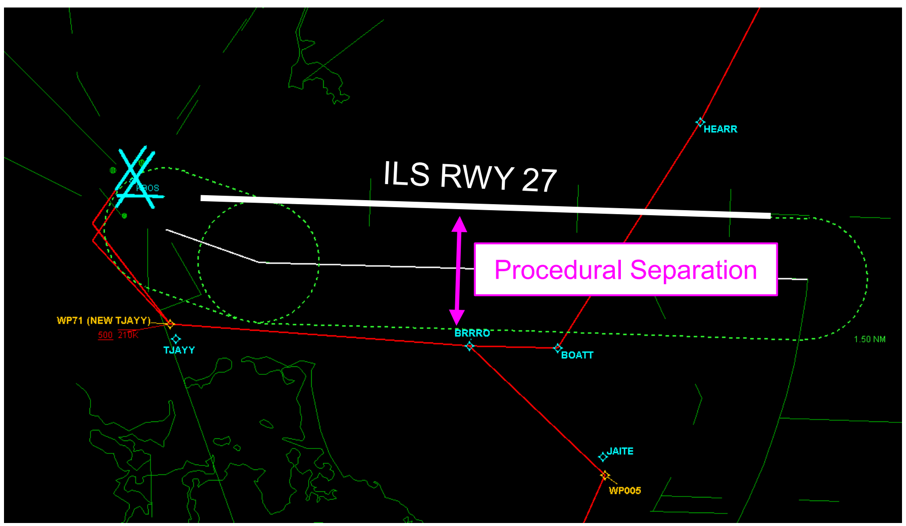


TARGETS screen during design criteria check

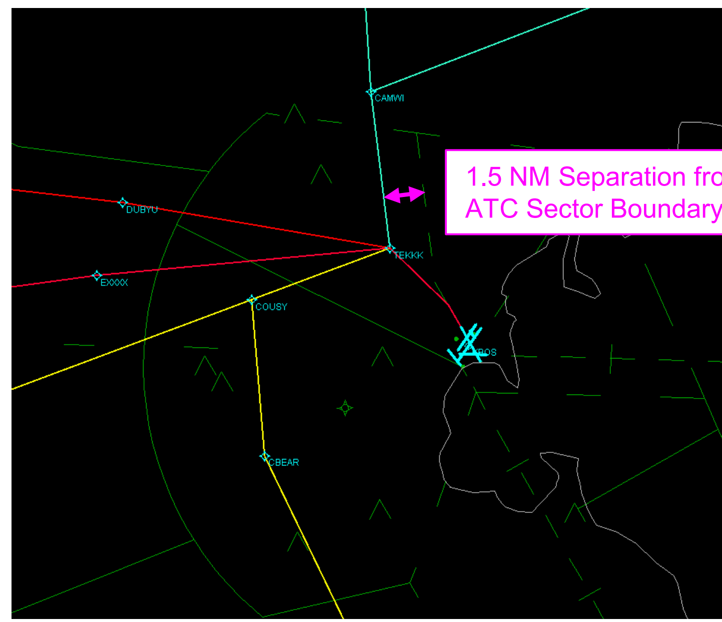
*TARGETS is the FAA's official software for procedure design and verification of criteria compliance.

ATC Considerations

- Procedural separation requirements
  - ATC required procedures that would be in use simultaneously to be procedurally separated.
  - Limited credit for vertical separation.
- Airspace sectorization impacts
  - Air traffic rules require aircraft to remain more than 1.5 NM from ATC sector boundaries that they won’t cross.
  - Facility Standard Operating Procedures (SOPs) may reserve certain airspace sectors for specific operations (e.g. slower propeller aircraft).



Proposed RWY 22L/R Departure



Current RWY 33L Departure

ATC Considerations

- SOP and Letter of Agreement (LOAs) impacts
  - LOAs between TRACON and Center define specific locations/waypoints where handoffs must occur.
  - Changing these waypoints requires changes to not only the LOAs, but also to ERAM (En Route Automation Modernization).
  - LOAs and SOPs are facility-specific and are not published in public domain.

BOSTON AIR ROUTE TRAFFIC CONTROL CENTER AND BOSTON CONSOLIDATED TERMINAL RADAR APPROACH CONTROL

LETTER OF AGREEMENT

EFFECTIVE: February 11, 2018

SUBJECT: APPROACH CONTROL SERVICE AND INTERFACILITY COORDINATION PROCEDURES

1. PURPOSE: To define responsibility and coordination requirements for approach control services in the Terminal Control Airspace and to outline interfacility procedures supplemental to JO 7110.65, Air Traffic Control Handbook.

TERMINAL CONTROL UNCONDITIONAL USE AIRSPACE

A	000 - 100	E	000 - 040	F	000 - 050
I	000 - 140	M	060 - 100	L	000 - 090
N	080 - 100	O	080 - 110	K	000 - 100
S	000 - 100				

BOSTON AREA AIRPORTS

BOS - Logan Intl Boston, MA

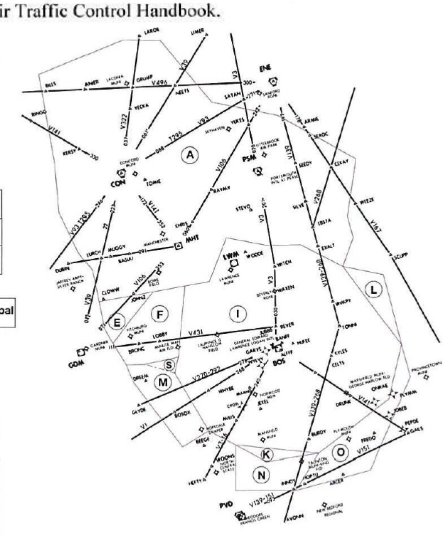
BEDFORD SECTOR	
BED - Hanscom Field Bedford, MA	LWM - Lawrence Municipal Lawrence, MA
BVY - Beverly Municipal Beverly, MA	9B1 - Marlboro Airport Marlboro, MA
FIT - Fitchburg Municipal Fitchburg, MA	6B6 - Minute Man Stow, MA

LYNCH SECTOR	
OWD - Norwood Memorial Norwood, MA	1B9 - Mansfield Municipal Mansfield, MA
GHG - Marshfield Municipal Marshfield, MA	

MANCHESTER AREA AIRPORTS

MHT - ManchesterAirport, Manchester, NH

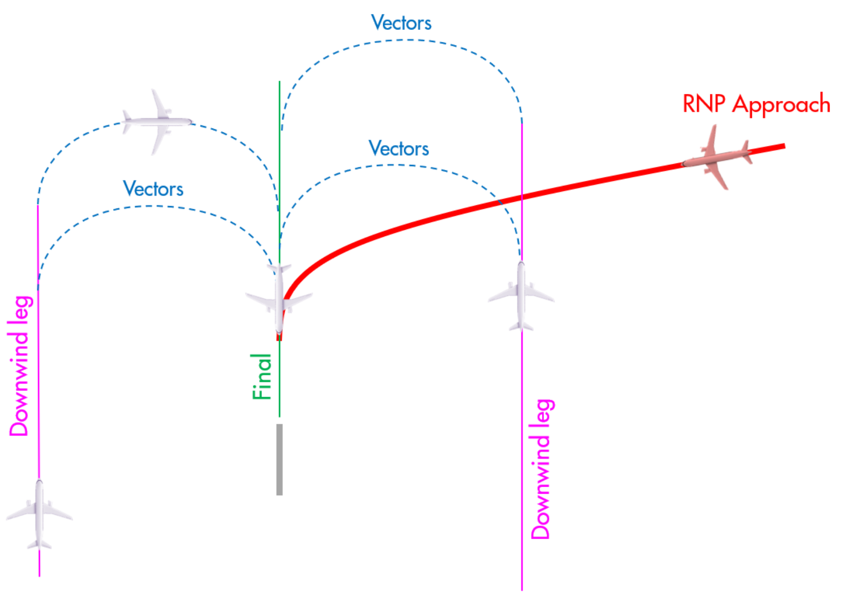
WEST SECTOR	EAST SECTOR
ASH - Boire Field Nashua, NH	PSM - Portsmouth Intl at Pease, Portsmouth, NH
CON - Concord Municipal Concord, NH	DAW - Skyhaven Airport Rochester, NH
LCI - Laconia Municipal Laconia, NH	3B4 - Littlebrook Air Park Eliot, ME
8B1 - Hawthorne-Feather Airpark, Hillsboro, NH	7B3 - Hampton Airfield Hampton, NH



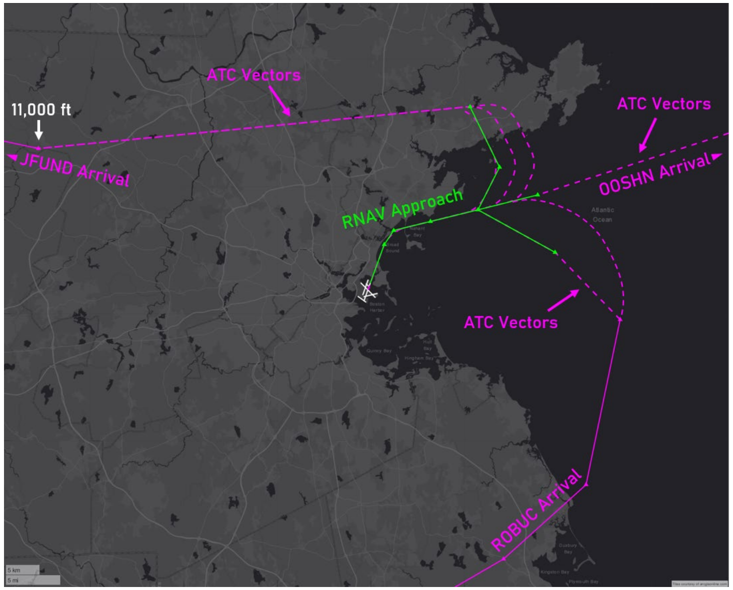
BOSTON ARTCC/ BOSTON TRACON LETTER OF AGREEMENT

ATC Considerations

- Workload
  - Merging and spacing
    - Mixed equipage (e.g. RNAV) introduced a merging challenge on final approach.
      - In mixed equipage scenario, ATC reverts to baseline procedure
    - The RNAV approach proposed for RWY 22L (right image) with offset initial and intermediate segments was supported by ATC based on the premise that it could be used by all aircraft.



Example of mixed equipage leading to late final merging

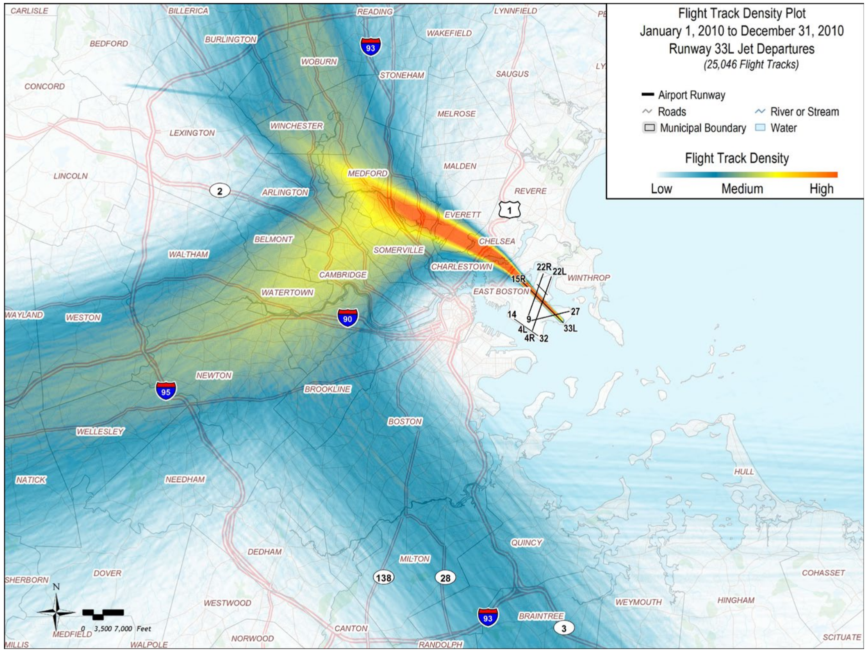


Proposed 22L Overwater RNAV Procedure

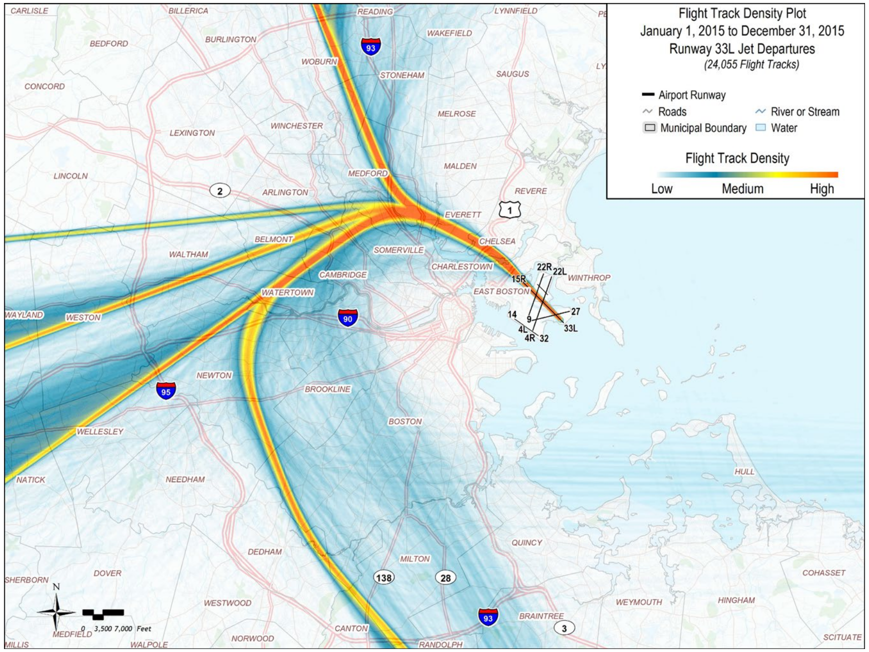
ATC Considerations

- Controller training and workload
  - ATC generally opposed procedures that would require additional aircraft vectoring.
  - Vectoring was generally perceived as a potential source of error
    - Higher controller workload
    - More radio exchanges.
  - Training and Experience
    - TRACON controllers have limited experience with high-intensity use of vectoring procedures.

RWY 33L Departures (2010, vector-based)

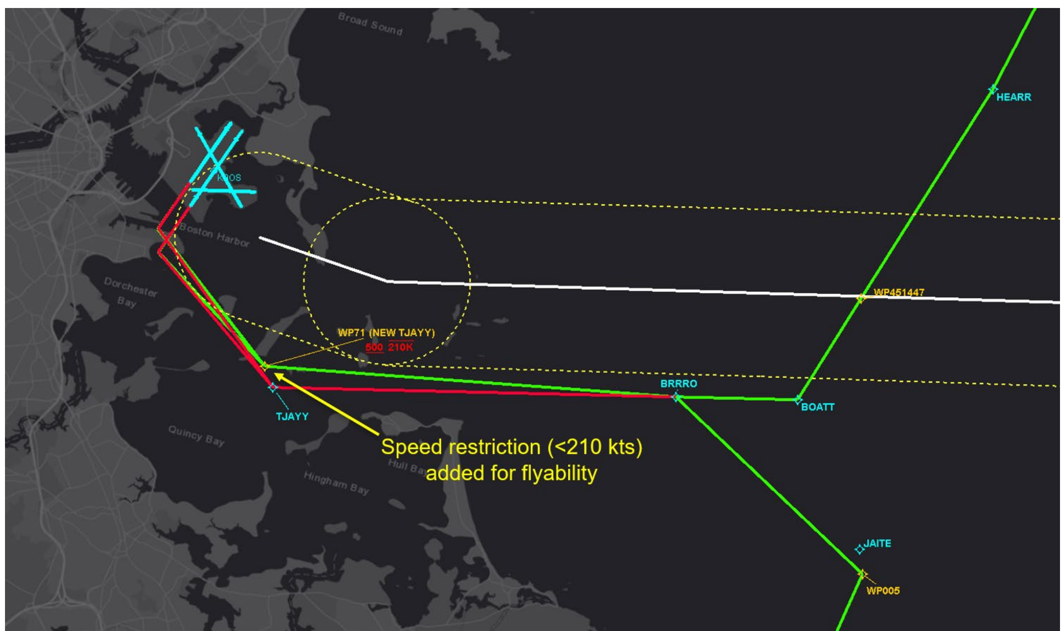


RWY 33L Departures (2015, RNAV)



Operator Considerations

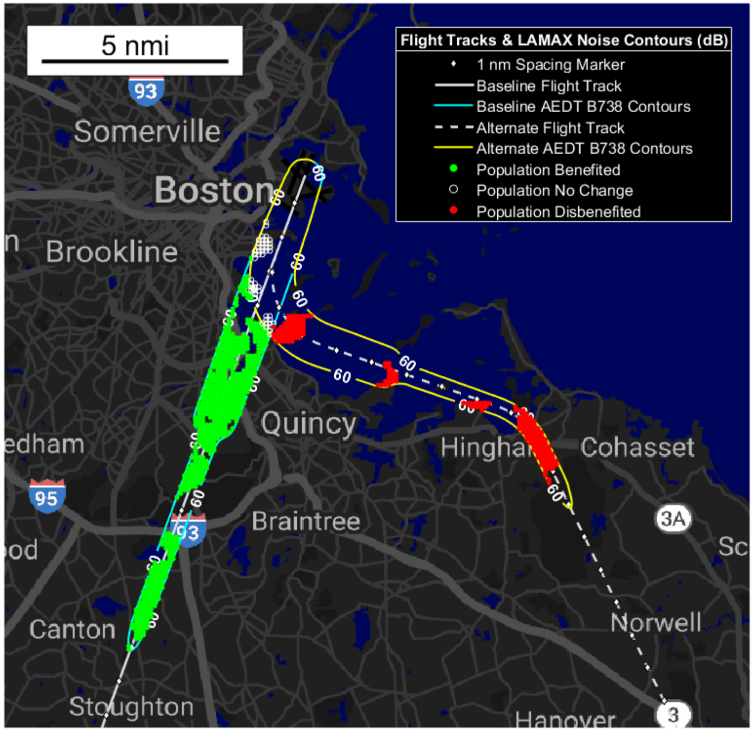
- Flyability
  - Airlines reported that procedures that pass FAA design criteria may occasionally present flyability issues.
    - Late turn to final.
    - Impact of strong tailwind conditions.
      - These conditions may cause turn overshoots and a disengagement of the aircraft's autopilot.
  - Speed restrictions may be added to waypoints to mitigate flyability concerns.



RWY 22L/R Departure. Current in red, proposed in green.
The proposed procedure uses a speed restriction at the initial waypoint.

Operator Considerations

- Adherence to SOPs
  - Airlines disfavored procedures that would require special pilot procedures.
  - One operator stated that they would not fly any procedure that had a final approach shorter than 4 NM due to concerns with approach stabilization (left image).
  - Operators also rejected the idea of a mid-procedure *voluntary* thrust cutback, which would be manually initiated by the pilots at a specified position or altitude (right image).
  - Non-standard dispatch concerns.

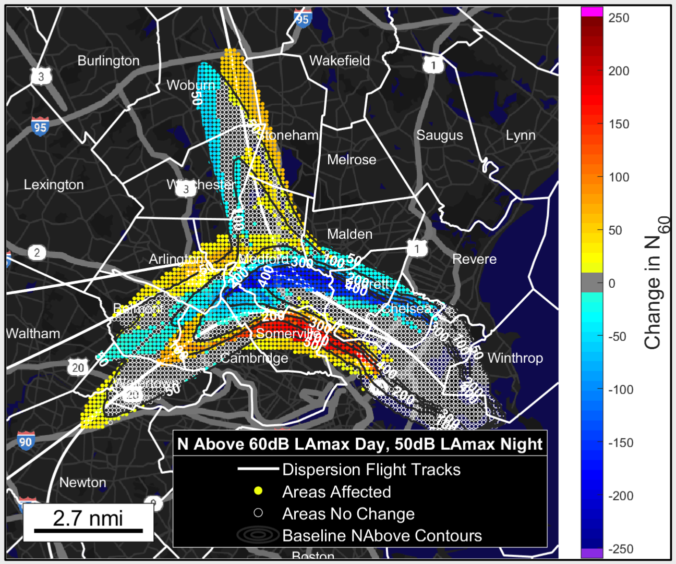


Concept of RNP approach to RWY 4R.
Not supported by operators due to short final segment.

Concept of voluntary thrust cutback for RWY 22L/R departures.
Not supported by operators due to non-standard procedure.

Areas of Lessons Learned

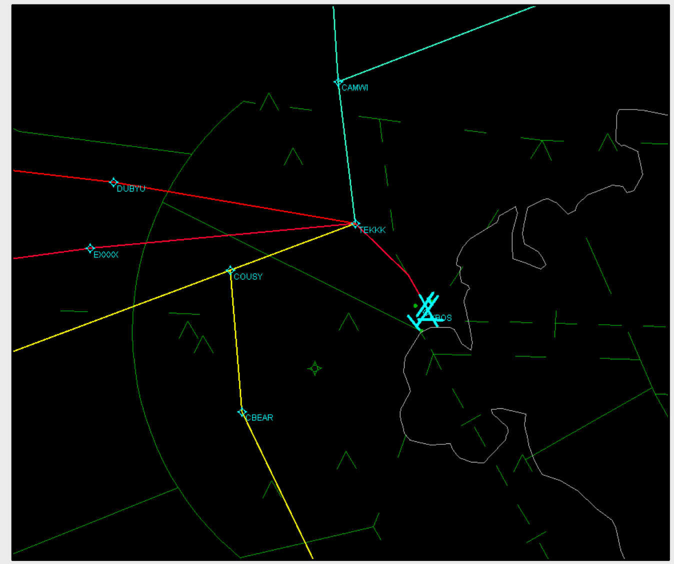
Lessons Learned on Data Visualization for Communities



Community feedback indicated:

- Effectiveness of N_{60} metric.
- Interest in aggregate metrics.
- Interest in expected aircraft altitude values.
- Interest in expected frequency of procedure use.

Lessons Learned on Procedure Operational Constraints



The following categories of implementation constraints were identified through discussions with operational stakeholders:

- Flight Standards Design Criteria.
- Air Traffic Control Rules and Procedures.
- Aircraft Limitations and Standard Operator Practices.