Validating Encounter Model Assumptions and Representativeness for the Class B Environment

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RTCA SC-228

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Correlated Encounters between Aircraft in Terminal Airspace

- **Revision A of the DAA MOPS by RTCA SC-228 permits UAS terminal operations in Class C, D, E and G airspaces**

- **To support MOPS certification, MIT LL developing a statistical model of how aircraft behave near or within terminal airspace, traffic patterns, and runway operations**
  - **Class C, D, E, G aerodromes with single or multiple runways**
  - **Ownship assumed to be a fixed-wing landing straight-in or taking off straight-out**
  - **Intruder can land or takeoff by any means and also merely transit through the airspace**
  - **Intruder classified as either fixed-wing or rotorcraft**
  - **Prototype unvalidated model available for Class B airports**
  - **Out of scope was vertiports and aircraft operating from nearby airports**

- **An encounter was defined based on the geometry between aircraft and a runway**
  - **Aircraft within 4 nautical miles laterally and 2000 feet vertically of each other**
  - **Encounter must be at least 30 seconds in duration (both aircraft tracks exist)***
  - **Both aircraft must be within 8 nautical miles laterally and 5000 feet vertically of a runway**

*** Thirty second requirement designed to have sufficient data for model training and not based on RTCA SC-228 guidance**
UAS – Unmanned Aerial System
MOPS – Minimum Operational Performance Standards
IAP – Instrument Approach Procedure

Correlated Terminal Model History

Attribute	Feature	V1 (06/2020)	V2 (03/2021)	V3 (10/2021†)
Ownship Intent	Landings – Straight In	○	○	✓
	Take offs – Straight Out	✗	○	✓
Intruder Intent	Landings – Any	○	○	✓
	Take offs – Any	○	○	✓
	Transit – Any (General)	✗	○	○
	Transit - Published Routes	✗	✗	✗
Airspace Class	B	✗	✗	○
	C	✗	○	✓
	D	✓	✓	✓
	Other (E/G)	✗	✓	✓
Aerodrome Design	Single Runway	✓	✓	✓
	Multiple Runways	✗	✗	✓
	Heliports / Vertiports	✗	✗	✗
Technology Transfer	Publicly Available Models‡	✗	✗	✓

† *As of October 1, 2021*
‡ *em-model-manned-bayes on GitHub*

✗ No Support ○ Prototype feature with update in a future version ✓ Full Support

Proposed High Level Workplan

1. *Operational Suitability Analysis: validating and informing DO-365 alerting thresholds*
   - A. Leverage existing surveillance data sources—TRAMS, RADES, ADS-B—in the Class B terminal environments to generate representative Class B operational suitability encounter set(s)
   - B. Assess alerting performance in Class B using existing alerting requirements/implementations (DAIDALUS), and assess alternatives if needed

2. *Safety Analysis: validating and informing surveillance performance requirements and safety analysis (e.g., to support TSO/SRM)*
   1. Validate encounter model assumptions and representativeness for Class B environment
   2. Modify encounter model structure and relearn model based on identified extensions (in 2.1.)
   3. Perform initial simulation analysis to validate the model use and provide preliminary indication of safety performance

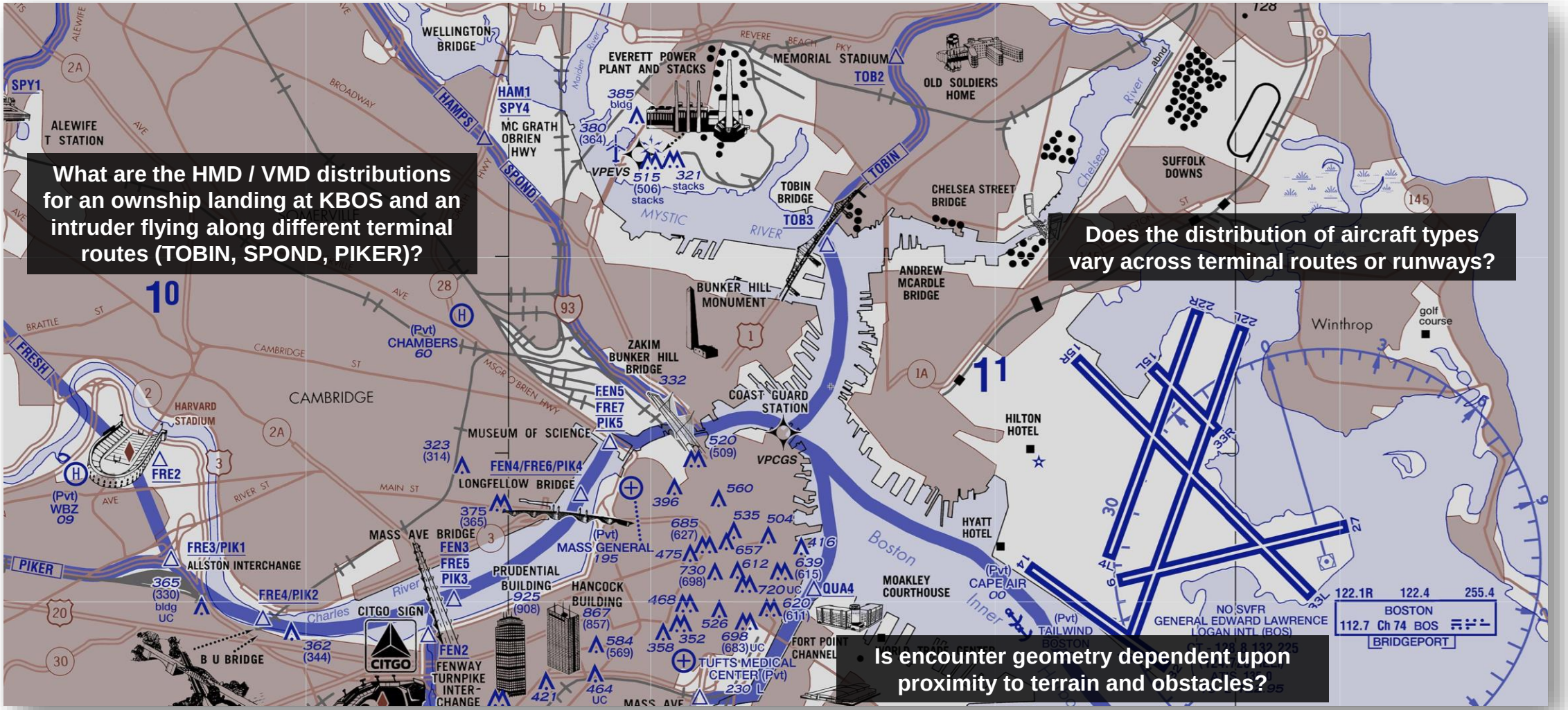
***Not formally encounter model/set development or needed to directly support the MOPS (could be separate effort).**
†Represents latest deliverable date; should be accomplished earlier if possible to reduce risk.
Note: estimates do not fully consider multi-threat encounters.

Focus of initial funded tasking from October 2021 – February 2022

Motivating Questions

- **Does an encounter between a large aircraft landing at a Class B runway and a helicopter flying within a VFR route differ from an encounter between two large aircraft landing at the same airport but different runways?**
- **What is the likelihood of an encounter with 3 or more aircraft? Is it significantly more likely to occur in Class B airspace than Class D?**
- **What airspace structures exist besides runway approach and departure corridors?**
- **Should the model be dependent upon time of day or location (i.e. JFK vs LAX)?**

Motivating Questions



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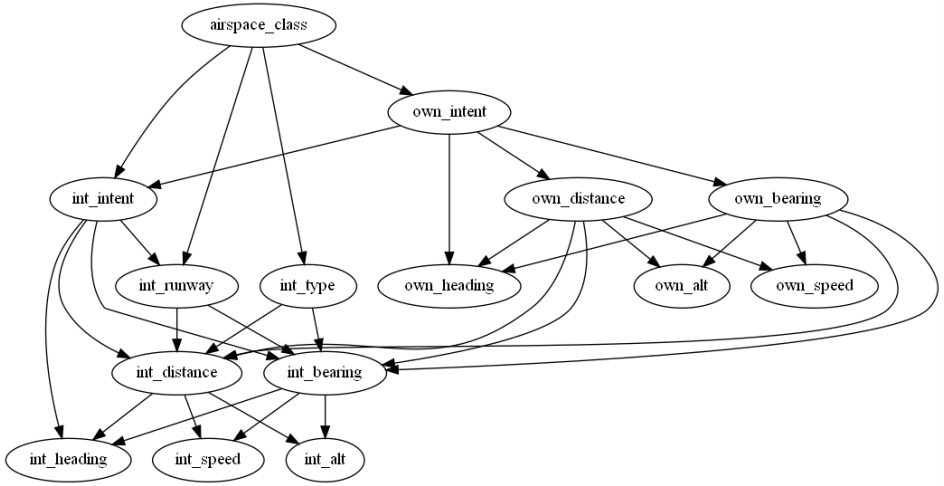
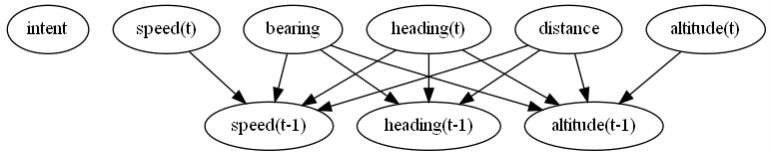
HMD – horizontal miss distance
VMD – vertical miss distance
VFR – visual flight rules

Current Correlated Terminal Model Structure
October 2021

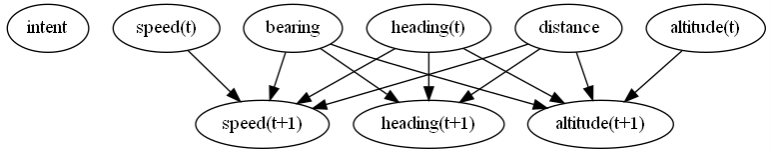
- **Correlated terminal model consists of multiple distinct Bayesian Networks**
  - **Geometry model is a static Bayesian Network that represents the relative geometry of the aircraft with the respect to the runway at CPA**
  - **Ownship and intruder each have a trajectory model, a dynamic Bayesian network, for the aircraft kinematics**
- **Rejection sampling of the models used to model ownship to behave similar to UAS defined by RTCA SC-228**
- **Sampled sets of encounters generated to support RTCA SC-228 SRMD**



Geometry Model



Backward Propagation Trajectory Model

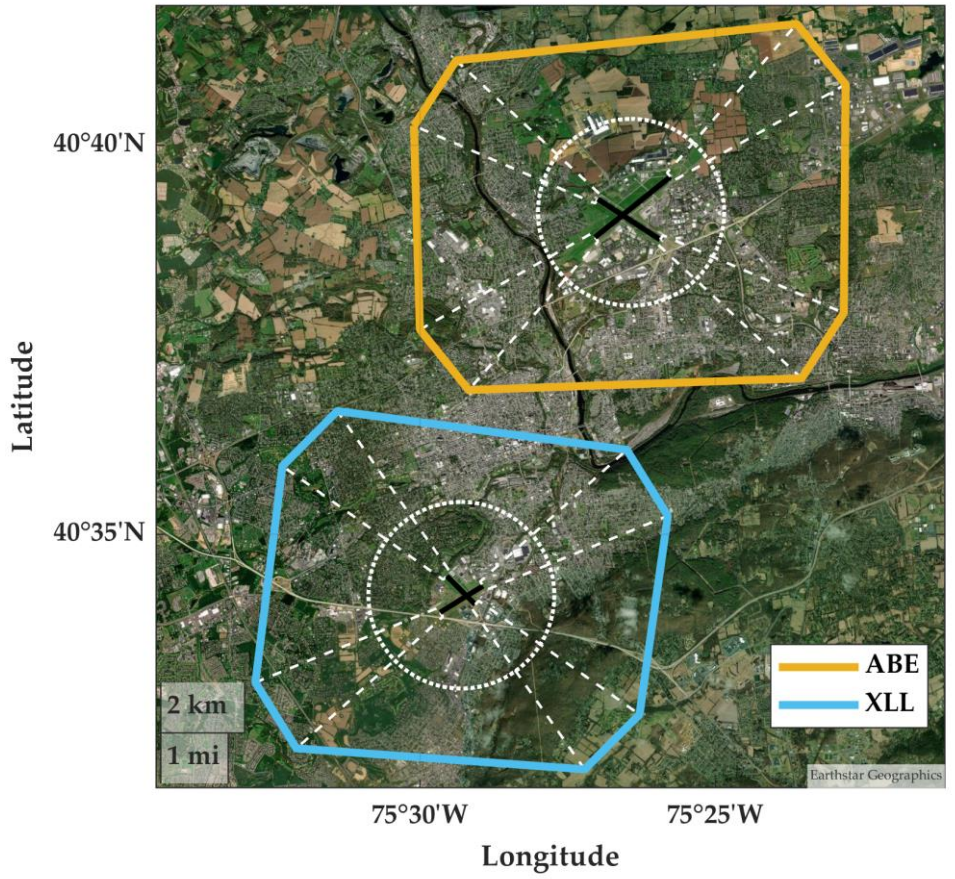


Forward Propagation Trajectory Model

https://github.com/airspace-Encounter-Models/em-model-manned-bayes/tree/v2.1.0
CPA – Closest Point of Approach
SRMD – Safety Risk Management Document
UAS – Unmanned Aerial System

Classifying Track Intent

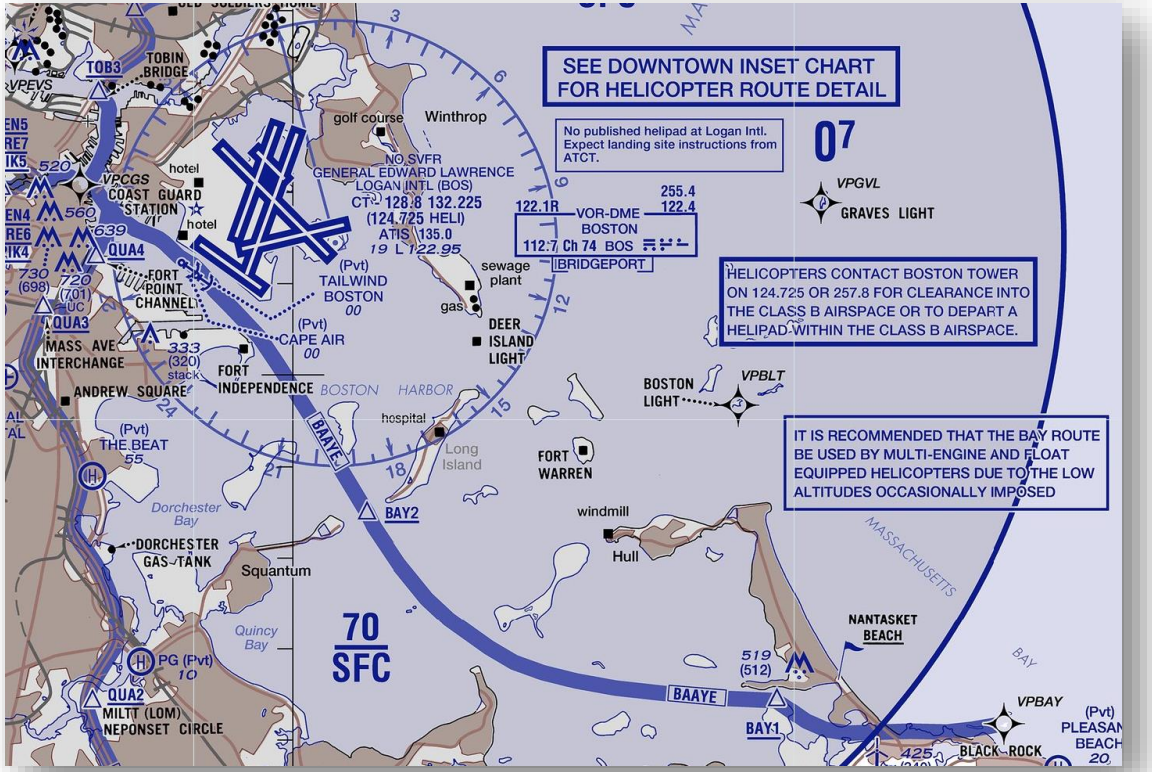
- **Track intent determined based on aerodrome bounding polygons and notional approach and departure corridors**
- **To be classified as taking off or landing, tracks must satisfy duration, vertical rate, and relative heading criteria while in a runway corridor**
- **Classification algorithm leverages general assumptions about aerodrome and runway design to enable a scalable and efficient means to classify intent**
- **Algorithm can be extended to consider terminal routes and other well structured navigation corridors**



Runways colored in black and the approach trepezoids and traffic patterns colored in white

ABE – Lehigh Valley International Airport
XLL – Allentown Queen City Municipal Airport

Terminal Routes: Published Guidance



BOSTON TERMINAL AREA
ROUTE DESCRIPTIONS AND COORDINATES

Bay Route (BAAYE)

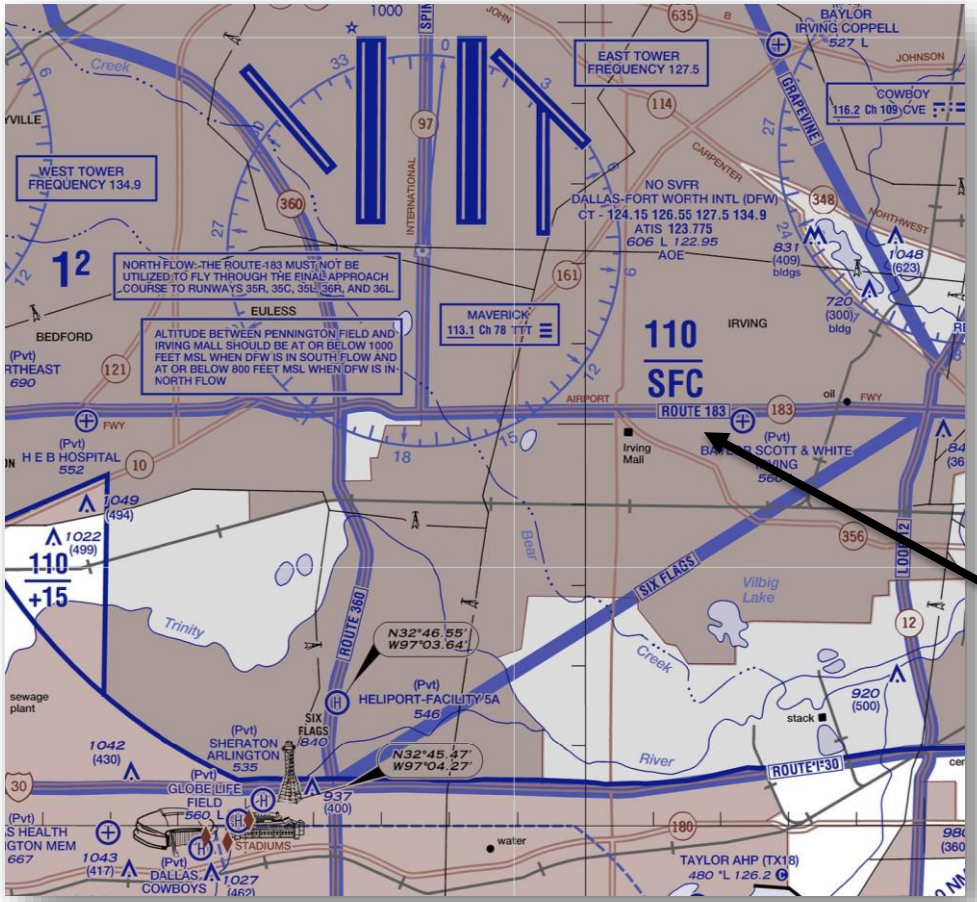
Southern end of Nantasket Beach at offshore rocks, cross inlet to Worlds End, via the coastline to the west of Long Island then to the channel to the Coast Guard Station. Note: It is recommended that the Bay Route be used by multi-engine and float equipped helicopters due to the low altitudes occasionally imposed.

VPBAY	Black Rock	N42°16.17′	W70°49.48′
Bay1	Worlds End	N42°16.43′	W70°52.87′
Bay2	Long Island	N42°18.50′	W70°58.90′
VPCGS	Coast Guard Station	N42°22.08′	W71°03.13′

Terminal route information can be sourced from aeronautical charts or the 28 Day National Airspace System Resource (NASR) System Subscription

https://skyvector.com/?ll=42.37990830005483,-71.05046523957584&chart=205&zoom=2
https://www.faa.gov/air_traffic/flight_info/aeronav/Aero_Data/NASR_Subscription/

Terminal Routes: Features of Interest
Identifying Ad-Hoc Routes and Supplementing FAA Guidance



DESCRIPTION OF DFW METROPLEX HELICOPTER ROUTES

EAST-WEST ROUTES

BUSH: FROM THE INTERSECTION OF HIGHWAY 78 AND HIGHWAY 190, WEST ON HIGHWAY 190 TO THE INTERSECTION OF I-35 EAST.

COLONY: FROM THE INTERSECTION OF I-35 EAST AND HIGHWAY 121, NORTHEAST ALONG HIGHWAY 121 TO THE INTERSECTION WITH HIGHWAY 75.

I-20: BEGINNING AT WEST EDGE OF CHART AND I-20, PROCEED EAST ON I-20 TO THE EAST EDGE OF CHART AND I-20.

I-30: BEGINNING AT THE I-20/I-30 INTERSECTION WEST OF FORT WORTH, PROCEED EAST ON I-30 TO THE EAST EDGE OF CHART NEAR ROCKWALL.

NORTHWEST HWY: FROM LOOP 635 PROCEED WEST ALONG NORTHWEST HIGHWAY TO MIDWAY ROAD.

ROUTE-183: BEGINNING AT THE I-35 WEST AND NORTH LOOP- 820, PROCEED EAST ON HIGHWAY 183 (AIRPORT FREEWAY) TO THE INTERSECTION OF LOOP-12 AND HIGHWAY 183, THEN ALONG THE FREEWAY DIRECT TO THE INTERCHANGE AT I-35 EAST. [NOTE: ALTITUDE BETWEEN PENNIGTON FIELD AND IRVING MALL (BELT LINE ROAD) SHOULD BE AT OR BELOW 1000 FEET MSL WHEN DFW IS IN SOUTH FLOW AND AT OR BELOW 800 FEET MSL WHEN DFW IS IN NORTH FLOW.

VISTA RIDGE: FROM ROANOKE PROCEED TO THE NORTHWEST CORNER OF GRAPEVINE LAKE. PROCEED ALONG THE NORTH SHORE OF GRAPEVINE LAKE TO A POINT NORTH OF THE GRAPEVINE GOLF COURSE (NORTH END OF GRAPEVINE RESERVOIR DAM), THEN DIRECT TO VISTA RIDGE MALL. PROCEED SOUTH TO THE NORTH LAKE. [NOTE: EASTBOUND ODD ALTITUDES, WESTBOUND EVEN ALTITUDES.

Terminal routes also based on long linear infrastructure, whose information can be sourced from general open source maps, such as OpenStreetMap or Natural Earth Data

Encounter Rate and Time of Day

- The Class B terminal environment consists of a wide variety of different operations
  - Large passenger transport
  - General aviation VFR
  - Local commercial / business (i.e. helicopter tours)
  - On-demand (i.e. private jets)
- The frequency of operations will vary temporally
  - General aviation primarily flies during the day
  - Air shuttle services operate hourly
- Need to characterize encounter rate given intent and time of day. Hypothesize that it is more likely for two passenger transports to encounter each other at 23:00 local than a passenger transport and general aviation


https://flic.kr/p/9QpUjo

https://commons.wikimedia.org/wiki/File:American_Airlines,_Boeing_737-823(WL),_N969AN_-_LAX_(22300501588).jpg

Technical Approach

Oct. 2021 – Feb. 2022

- In addition to the existing approach and departure corridors, define terminal routes based on published guidance and features of interest
- Using existing training data, characterize the frequency that each route is utilized and the potential operation frequency within each route

Spring 2022

- Update model structure to include additional intents, such as “VFR route”
- Update model structure to include time of day and evaluate if inclusion sufficiently influences the observed distributions
- Train independent models for different Class B airspaces and determine if location should be a model dependency

Summer - Fall 2022

- Prototype encounters with 3 or more aircraft by potentially updating model structure or sampling trajectories based on route frequency
- Investigate support for vertiports and heliports
- Release updated model and determine if additional model iteration required

Focus of initial funded tasking from October 2021 – February 2022

Thank You!

Questions?

Feedback?

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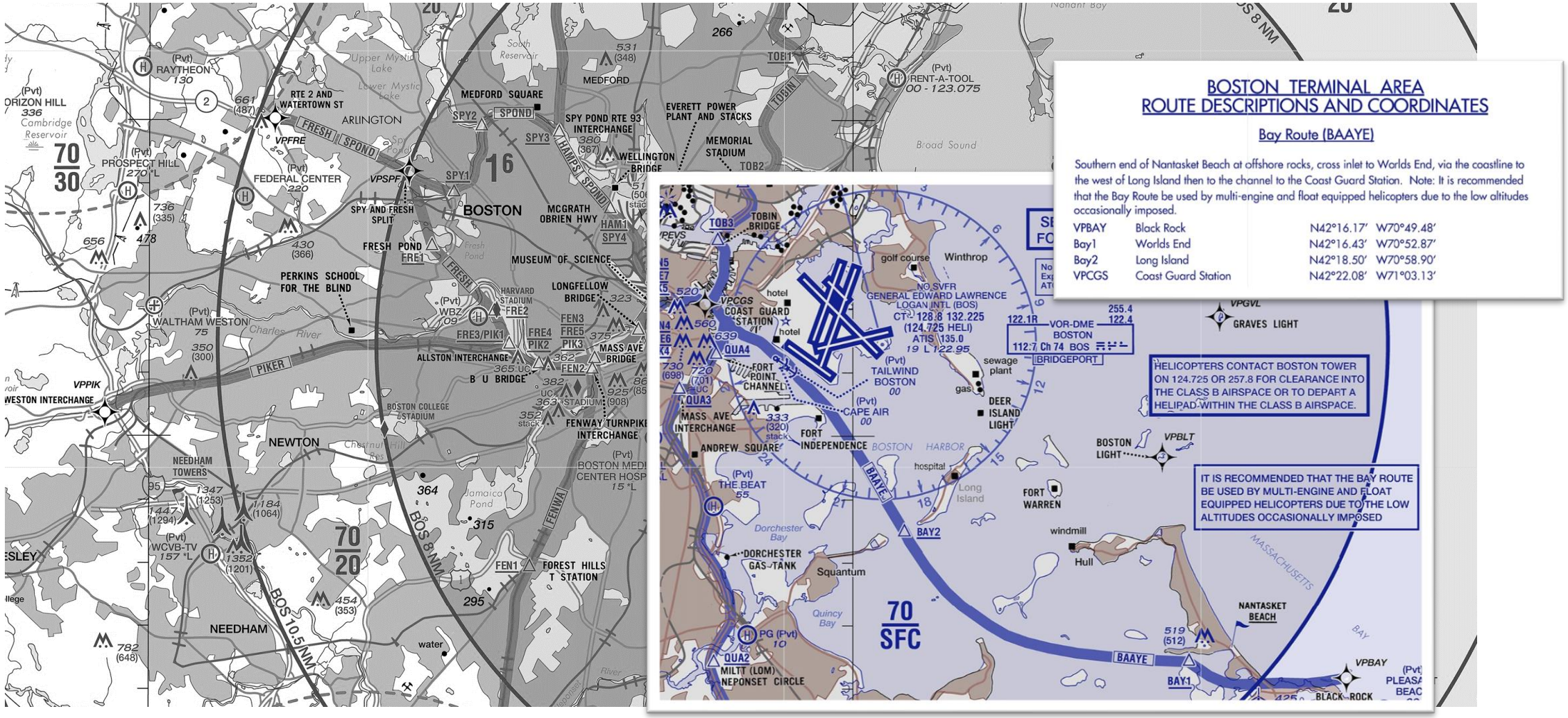
Boston Downtown Helicopter Insert

Scale 1:50,000



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