Simulating Fleet Noise for Notional UAM Vehicles and Operations in New York

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Abstract — **This paper presents the results of systems-level simulations using Metrosim that were conducted for notional Urban Air Mobility (UAM)-style vehicles analyzed for two different scenarios for New York (NY). UAM is an aviation industry term for passenger or cargo-carrying air transportation services, which are often automated, operating in an urban/city environment. UAM-style vehicles are expected to use vertical takeoff and landing with fixed wing cruise flight. Metrosim is a metroplex-wide route and airport planning tool that can also be used in standalone mode as a simulation tool. The scenarios described and reported in this paper were used to evaluate a fleet noise prediction capability for this tool. The work was a collaborative effort between the National Aeronautics and Space Administration (NASA), Intelligent Automation, Inc (IAI), and the Port Authority of New York and New Jersey (PANYNJ). One scenario was designed to represent an expanded air-taxi operation from existing helipads around Manhattan to the major New York airports. The other case represented a farther term vision case with commuters using personal air vehicles to hub locations just outside New York, with an air-taxi service running frequent connector trips to a few key locations inside Manhattan. For both scenarios, the trajectories created for the entire fleet were passed to the Aircraft Environmental Design Tool (AEDT) to generate Day-Night Level (DNL) noise contours for inspection. Without data for actual UAM vehicles available, surrogate AEDT empirical Noise-Power-Distance (NPD) tables used a similar sized current day helicopter as the Baseline, and a version of that same data linearly scaled as a first guess at possible UAM noise data. Details are provided for each of the two scenario configurations, and the output noise contours are presented for the Baseline and reduced noise DNL cases.**

I. INTRODUCTION

The National Aeronautics and Space Administration (NASA) Integrated Demand Management (IDM) sub-project under the Air Traffic Management-eXploration (ATM-X) Project has been collaborating with the Port Authority of New York and New Jersey (PANYNJ) since 2015 to quantify costs and benefits of NASA Next Generation Air Transportation System (NextGen) technologies when applied to New York airspace operations. Work prior to 2018 focused on conventional commercial transport operations with both current day and notional routing options[1]. Some of the studies produced ground noise contours for notional scenarios using results from the Aviation Environmental Design Tool (AEDT)[2], developed for the Federal Aviation Administration (FAA).

In 2018, the simulation supporting the conventional air transport studies was adapted to include Urban Air Mobility (UAM)-style vehicles. New York currently has a helicopter-based air-taxi service to the major airports, which potentially makes it an attractive market for commercial UAM-based air-taxi operators. Understanding the impact of UAM fleet operations is of interest to both the Port Authority and NASA as an early step toward the assessment of the suitability of these operations in a busy metroplex that is already sensitive to community noise. Potential introduction of new UAM vehicle types into the NY area will require collaborative support from all stakeholders and careful consideration of community concerns.

The new version of the Metroplex simulation allows concurrent staging of commercial transport and UAM vehicle fleets with hundreds or thousands of vehicles in a given run. Physics-based trajectories are generated for all aircraft, and the tool automatically interfaces the output to AEDT at the user's option. An animation of the trajectories flown is also available for inspection. For the scenarios presented in this paper, the UAM aircraft use predicted performance data for concept vehicles generated with the NASA Design and Analysis of Rotor Craft (NDARC) vehicle design and sizing tool. The vehicles are resized versions of concept vehicles developed and reported in [3], delivered for this task by the NASA Ames NDARC team.

The work summarized in this paper used two scenarios simulated under several conditions to demonstrate the new tool capability using scenarios of interest to NASA and the Port Authority collaborator. It is important to note that while the simulation capability is fairly mature, the supporting data for UAM vehicle noise is not well known yet. Some prototype vehicles exist in private industry, but data associated with the vehicle (including noise data) is proprietary. Noise prediction of UAM vehicles is in progress by NASA and others, but not yet mature enough to offer certainty in the data models. This is expected to improve significantly in the future, but for this initial study to demonstrate the tool capability a work-around was needed for the noise characterization for AEDT, which relies on empirical data in the form of Noise-Power-Distance (NPD) tables.

Technology in rotor development, shielding techniques, and phasing design are expected to reduce the noise decibel level (and possibly the annoyance level) of new UAM vehicles. Small multi-rotors are predicted to be quieter than single large rotors, and electric motors are quieter than turbines. For vehicles that transition to winged flight there would be much less rotor noise in cruise. The level of noise reduction is still unknown, with some more optimistic than others. For the UAM noise characterizations for the scenarios reported here, a two-fold process was used to first create a "Baseline" noise analysis for the scenarios using a suitable current day helicopter noise data set (to represent as a worst-case result if no noise improvement were to occur). The helicopter used was the Aerospatiale SA-350D Astar (also known as the H125)[4]. This helicopter is a single engine light utility helicopter with cabin configurations that can accommodate 4 to 6 passengers. The SA-350D also provided a tool interface benefit because the 4-dimensional trajectories needed for the UAM vehicles were supported by AEDT for this helicopter. NPD data was then linearly scaled to be 20% lower (i.e., 80% of the original value) to represent reduced noise UAM data. While this is undoubtedly an oversimplification, it offered a starting point without making overly optimistic assumptions. Once more reliable data is available for UAM noise characterizations, the flown trajectory sets can be rerun with the updated AEDT UAM noise NPD tables as a more accurate update.

II. TOOLS

A. *Trajectory Simulation with Metrosim*

Metrosim is a metroplex-wide route and airport planning tool that can be also used in standalone mode as a simulation tool [5]. Intelligent Automation, Inc. (IAI) originally developed it as an air traffic controller (ATC) support tool to optimize arrival and departure scheduling to a multiple airport system, or "metroplex". The multi-airport interaction capability made the tool valuable for airspace concept work, and NASA supported the adaptation of the tool to run simulations for fleets of vehicles.

In 2018, IAI adapted the Metrosim tool to include the capability to model transitional flight trajectories needed for UAM vehicles. This required extension of the trajectory performance capability to include vertical and near-vertical takeoff and landing and hover capability for spacing along routes. A new trajectory configuration option was also added for UAM vehicles that allows takeoff and landing from any configured location (i.e., not restricted to airports). In 2019, IAI extended the tool again to seamlessly integrate the UAM trajectories with AEDT to provide noise contour results from the flown paths. Conventional aircraft simulation was preserved during the modification stage of Metrosim to allow both UAM and conventional aircraft to be modeled in the same run with concurrent noise generation and interactions captured. Proximity metrics can be generated between UAM and large transport vehicles, and noise contours generated from the combined runs capture the noise characteristics of the combined traffic.

For each of the scenarios modeled in the work presented in this paper, routes were created and configured to provide the basis for flown UAM routes. The Metrosim vehicle spacing enforcement relies on vehicle adherence to prescribed routes, which is a nearer term use case and well-suited to the scenarios of interest to the collaborators.

B. *Notional UAM Vehicles*

The two vehicles used in the scenarios modeled represent small UAM-style vehicles capable of carrying two to four passengers. The vehicles are resized versions of the dual rotor six-passenger side-by-side helicopter presented in [3]. The resized models were chosen to meet cruise characteristics and vehicle carrying capacity more consistent with the UAM commuter scenarios being modeled. Note that while these vehicles differ from the long-term target for some air-taxi visions, the models provided defensible vehicle performance characteristics and so were ideal for testing the new trajectory algorithms within the tool. These performance characteristics provided by NDARC for the resized vehicles were the basis for performance datasets generated for Metrosim.

C. Noise Analysis with AEDT

AEDT is a software tool developed and maintained by Volpe and is the FAA's primary tool for community noise assessment. AEDT handles fixed wing aircraft and helicopters and is capable of estimating noise, fuel consumption, and air quality consequences for aircraft trajectories in 4-dimensional space and time. Only the noise analysis capability of AEDT was used for this work.

AEDT contains a "Fleet" (vehicle specific) database with approximately 4600 airframe/engine combinations[1]. This Fleet database uses NPD empirical data tables to characterize the acoustic data for each vehicle, which allows AEDT to succinctly represent predicted noise for complicated configurations. The NPD data includes the airframe and engine noise for all configurations plus the rotor noise for helicopters. The user also has the option to provide custom data to replace or supplement AEDT's native Fleet database elements.

Notably absent from the AEDT vehicle type definitions for this study, though, are UAM-style transitional flight vehicles (vertical or near-vertical takeoff and landing with fixed wing cruise) which share trajectory characteristics with both helicopter and fixed wing aircraft for different phases of flight. There are efforts in progress at NASA and by industry and academia to advance noise prediction for UAM-style vehicles. Though the NPD tables used by AEDT are compact, the science that goes into generating that data is complex and requires considerable effort since the NPD tables bundle the vehicle's noise characteristics with the operational use cases. The generation of those tables is beyond the scope of the work presented here since the primary goal of this work was to test the new simulation-with-noise tool capability. Once new predictions are available, these will be leveraged for follow-on work. That being said, some reasonable representation of NPD data was needed to test the tool capability. As previously stated, a representative helicopter was the surrogate for AEDT as the Baseline (worst-case) run, and a scaled version of this same helicopter was used to represent an optimistic guess at future UAM noise reduction over current day helicopters.

III. NOISE OUTPUT

For each of the two scenarios modeled, the Day-Night Level (DNL) for the region in decibels was chosen for output. Noise experts will point out that the decibel level of the noise is not the only relevant information, and other characteristics can be significant contributors to the level of annoyance [6]. The Federal Aviation Administration (FAA) Code of Federal Regulations (CFR) Title 14 Part 36 describes the noise regulations associated with air vehicles [7], including helicopters and tilt rotors. However, the areas potentially having the highest noise impact from proposed UAM air-taxi services and personal air vehicles differ from the traditional airport centers that have been the reference locations for high noise.

New York has a relatively high number of helicopter operations for tourism, emergency support, and police oversight, but the scenarios modeled were designed to exceed current day usage and in some cases to overfly areas without current helicopter traffic. Without clear regulatory guidance for UAM vehicle noise, reference data was useful for a comparative context. In their publication "A Guide to New York City's Noise Code; Understanding the Most Common Sources of Noise in the City"[8], the City of New York office of Environmental Protection states:

> *"Street-level noise measures were obtained at 99 street sites located throughout New York City (NYC), along with data on time, location, and sources of environmental noise. The mean street noise level was 73.4 dBA, with substantial spatial variation (range 55.8-95.0 dBA). Density of vehicular (road) traffic was significantly associated with excessive street level noise levels"*

In this context, proposed new UAM air operations will be introducing new types of noise into already noisy environments. While the resulting noise levels from the air vehicle traffic may be below both the ground vehicular noise levels in some regions and the FAA's air noise maximum regulations for airport areas, the acceptability of this new noise in new areas is yet to be determined. For this reason, this paper presents the output noise levels of the analysis but cannot conclude whether they would ultimately be acceptable. Table 1 presents a comparative noise assessment from the same publication [8] for reference[2]:

Whisper	30 dB(A)
Normal Conversation/Laughter	50 – 65 dB(A)
Vacuum Cleaner at 10 feet	70 dB(A)
Washing Machine/Dishwasher	78 dB(A)
Midtown Manhattan Traffic Noise	70 – 85 dB(A)
Motorcycle	88 dB(A)
Lawnmower	85 – 90 dB(A)
Train	100 dB(A)
Jackhammer/Power Saw	110 dB(A)
Thunderclap	120 dB(A)
Stereo/Boom Box	110 – 120 dB(A)
Nearby Jet Takeoff	130 dB(A)

Table 1: Street Noise Sources and Levels

IV. SCENARIO 1: UAM AIR-TAXI OPERATIONS TO MAJOR AIRPORTS

The first scenario modeled represents possible nearer-term UAM operations that expand on the existing helicopter-based air-taxi services in New York using UAM-style vehicles and

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[1] Aviation Environmental Design Tool (AEDT) Technical Manual, Version 2d, Federal Aviation Administration September 2017, Page 22.

Funded by the Federal Aviation Administration.

[2] Reference [8], page 2

with some route modification. This scenario demonstrates the simultaneous simulation of current day commercial transport aircraft and UAM vehicles and the ability to generate proximity metrics for aircraft on different routes.

In Metrosim, the routes are specified in a configuration file in eXtended Markup Language (XML) format and can either be created by hand or auto-generated using the Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS) tool [9]. Token values in the individual route definitions identify which category of aircraft are allowed to use that route (UAM, light, heavy, etc.). This allows the routes to restrict aircraft by type, or to allow multiple types to share a route. The simulation scheduler enforces spacing on the route by vehicle type in both cases. Vehicle following constraints are configured for leader/follower pair types in a wake spacing configuration file, which can be modified with custom values by default or at runtime. Wakes are not expected to be an issue for UAM vehicles unless very close, but safe separation is still required to avoid potential collisions.

A. *Vertiport Locations*

For Scenario 1, the vertiport locations at the major airports were modified to include new locations of interest specified by PANYNJ. Note that these were proposed sites for the research and were used for modeling purposes only. (Review and approval for actual sites would require extensive official review and community involvement.) The new vertiport locations for Kennedy, LaGuardia and Newark Airports are shown in Figs. 1, 2, and 3 respectively. The UAM routes to the vertiports were generated using the current day helicopter routes with the final segments adjusted to connect to the new vertiport locations. In this scenario, UAM flights depart and return to three existing heliports in Manhattan – the West 30th Street Heliport on the Hudson River, the 34th Street Heliport on the East River, and the Downtown Manhattan Heliport on the lower East River near Broad Street.

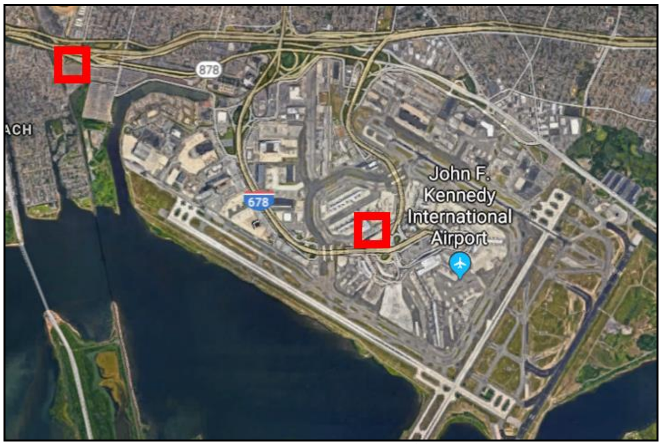

Fig. 1: Modeled Vertiports for Kennedy Airport[3]

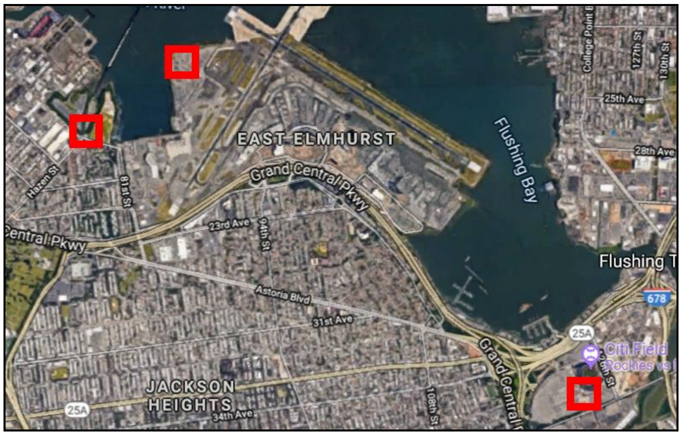

Fig. 2: Modeled Vertiports for LaGuardia Airport[4]

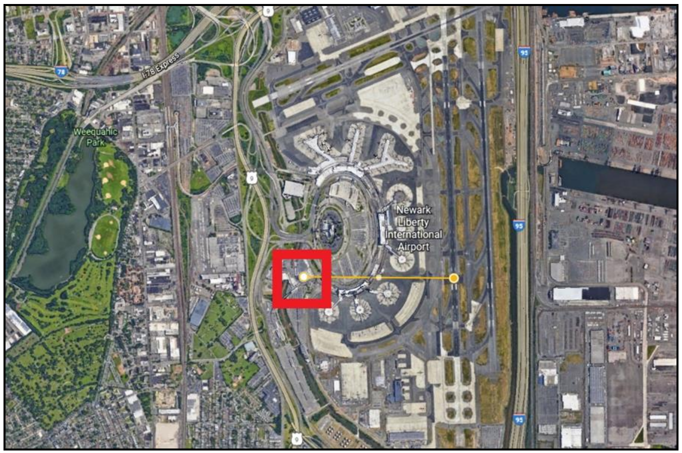

Fig. 3: Modeled Vertiports for Newark Airport[5]

Once the routes were established, the air vehicle traffic was configured. For the current day air transport aircraft, a set of historic traffic from July 2015 was selected because it provides very high volume from a fair weather day during the busy summer travel season. The UAM traffic was varied to use 8, 16, 32, 64, and 128 vehicle operations per hour as a near-term operational case in an effort to capture noise levels below and above potentially acceptable values and to present an overall picture of the impact of increasing numbers of vehicles on the noise footprint. For each UAM case, the same historic 2015 air transport set was used for consistency.

Fig. 4 shows the current day routes around New York City for helicopters, which were the basis for the UAM routes for this scenario.

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[3] Proposed vertiport site for modeling purposes only

[4] Proposed vertiport site for modeling purposes only

[5] Proposed vertiport site for modeling purposes only

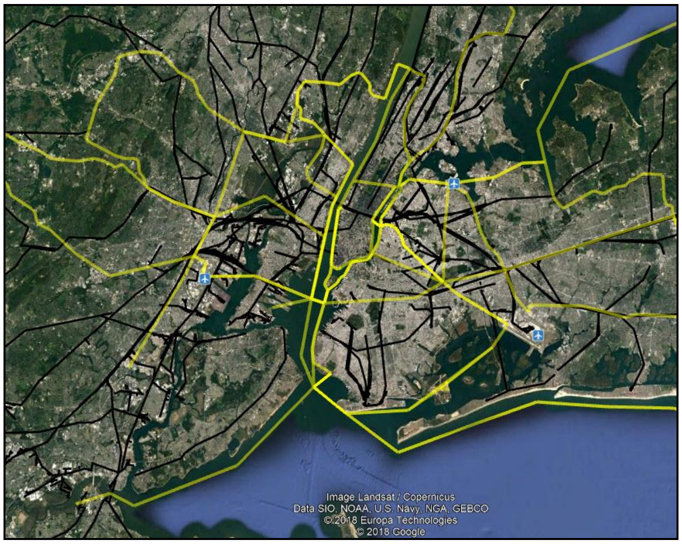

Fig. 4: UAM and conventional air transport routes for Scenario 1

B. *Noise Baseline Case – Current Day Helicopter Equivalent*

To model noise for a set of supplied trajectories, AEDT computes individual vehicle noise outputs and then performs averaging over time to create the overall system metric. Different metrics are available in AEDT. The Day-Night Level (DNL) metric was used for these runs. Additionally, the flight times were selected to keep the entire scenario within the "Day" window to avoid noise penalties for night operations. Figs. 5, 6, and 7 present the DNL curves that resulted from the 8, 32, and 128 UAM operations per hour cases using the NPD data for the Baseline (current day helicopter level) noise case.

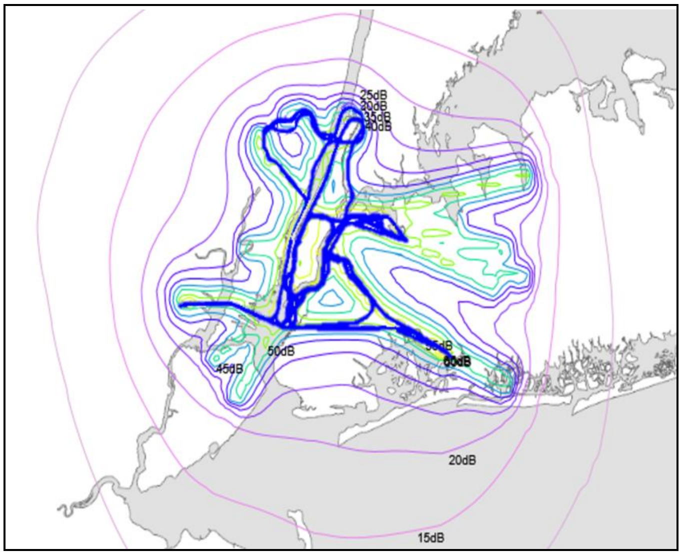

Fig. 5: DNL for Baseline NPD data for conventional air transport and UAM at 8 operations per hour

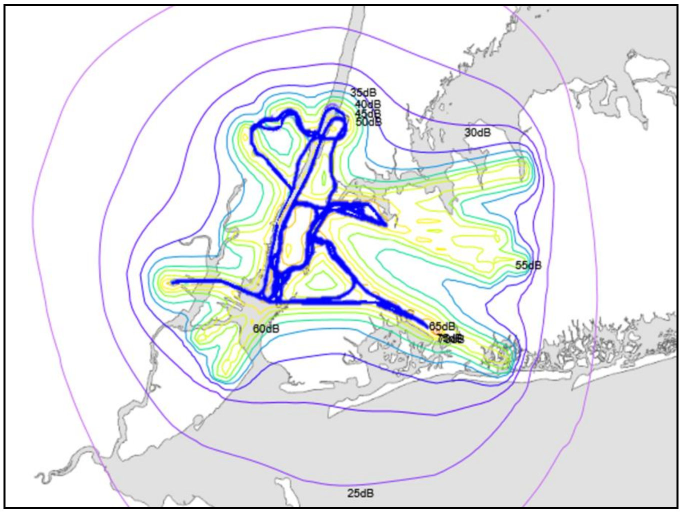

Fig. 6: DNL for Baseline NPD data for conventional air transport and UAM at 32 operations per hour

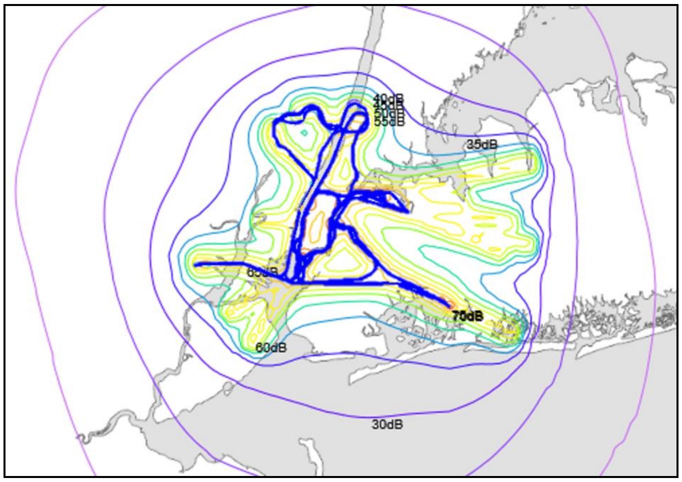

Fig. 7: DNL for Baseline NPD data for conventional air transport and UAM at 128 operations per hour

C. *20% Noise Reduction Case*

A second noise analysis was performed for the same trajectories, but with the NPD data for the UAM vehicles modified to be 20% lower than the helicopter noise data used for the Baseline case runs. While the choice of 20% was somewhat subjective, it is consistent with target noise reduction for some quiet rotor technologies, and has been suggested as a possible target for advanced rotorcraft and UAM (with varying levels of optimism by supporters and detractors). Figs. 8 and 9 present the results for 32 and 128 UAM per hour using the reduced noise level NPD tables.

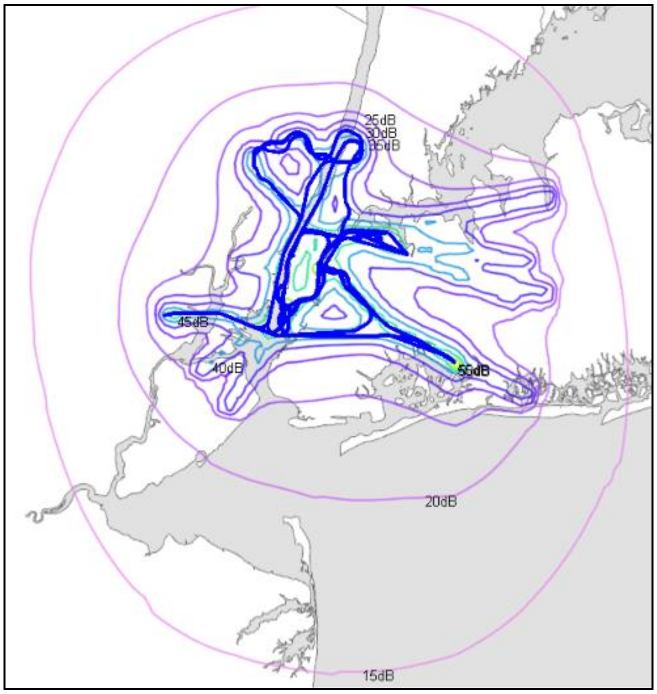

Fig. 8: DNL for 20% reduced NPD data, conventional air transport and UAM at 32 operations per hour

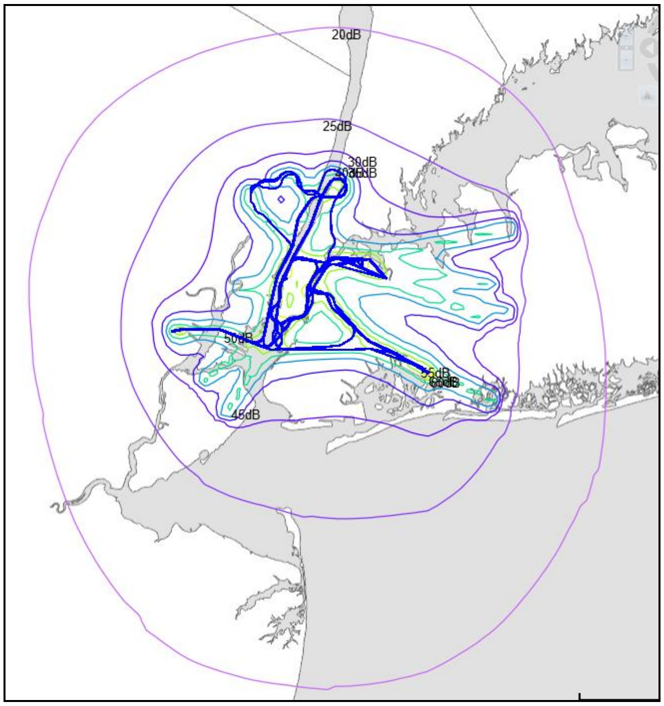

Fig. 9: DNL for 20% reduced NPD data, conventional air transport and UAM at 128 operations per hour

V. SCENARIO 2: REGIONAL COMMUTERS TO AIR-TAXI HUBS

This scenario models a farther term use case with commuters using personal air vehicles (PAVs) from outlying areas to the periphery of the NY metropolitan area connecting to air-taxis to deliver them into key locations within Manhattan. These commuter vehicle and air taxi connection vertiports are called “hubs” in this scenario. Inside Manhattan, only air taxis are operating. The commuter origin locations were selected based on very simple demographics assumed for “early adopters” – the origin points are beyond ground vehicle commuter range and are known to be weekend or vacation home areas for New York professionals. The selected locations include the eastern end of Long Island, seaside towns on the southern New Jersey shore, the Pocono Mountains, and the upper Hudson River region. The scenario stages the commuter traffic from the origin locations to the connecting hubs. Notional commercial air-taxis running frequent connector trips to key locations in Manhattan then allow air transit without the need for vehicle storage in Manhattan, and presumably with stricter operator regulations in proximity of the highest density population.

A. *Air-Taxi Route Design*

To estimate viable air-taxi frequencies for this scenario, a preliminary analysis was performed to assess the volume of UAM flights that could be scheduled on a given air-taxi route with varied leader/follower spacing for the minimum cruise speed (as a most-constraining case) for this study. This was done for runtime efficiency to inform the volume of traffic that would overload the routes, which would significantly extend the simulation run times (since the scheduler will investigate alternate route and delay options for flights that cannot be granted their requested flight plans due to spacing violation). Table 2 lists the results of that analysis.

Speed (Kts)	Spacing (NMi)	Max Flights Per Hour	Per Route	
			Passengers per Hour	Interval (Minutes)
100	0.100	1000	4000	0.06
100	0.250	400	1600	0.15
100	0.500	200	800	0.30
100	1.000	100	400	0.60
100	1.667	60	240	1.00
100	3.333	30	120	2.00

Table 2: Analysis Results

The required spacing between UAM vehicles is still in debate since these regulations do not yet exist, but a spacing requirement that is less than the conventional aircraft spacing of 3 NMi inside the Terminal region may be justified since UAM could hover in place if needed. A six-minute departure interval was selected between air-taxis to each Manhattan destination for Scenario 2. With three Manhattan destinations, this resulted in a 2-minute interval between departures from each hub and a 30 vehicle per hour rate for the route, which is feasible without reducing the UAM-to-UAM spacing requirement, as shown in Table 2. The return flights to the hubs used different routes on the opposite sides of the Hudson and flights were run at the same rate to capture the noise of the full route loops.

NY already has some helipads staged on both the East and Hudson River. The existing helipad location on the lower East Side was used as one air-taxi vertiport because of its proximity to the Financial District. The other two vertiports were added inside the city and were selected for their proximity to ground transportation. One vertiport was placed at the Port Authority Bus Terminal near 41st Street and 8th Avenue. The other was placed at Penn Station, near 7th Avenue and 32nd Street.

Note that the inner-Manhattan air-taxi vertiports are purely notional and have no basis in any current plan. The locations selected are near existing ground transportation hubs and have fewer obstructions than many inner-city locations, and so offered some realism for a scenario that is one possible future vision. Routes to and from the Manhattan air-taxi vertiports were designed to fly over the rivers to concentrate noise away from the city and to minimize fly-over of populated areas. Fig. 10 shows the air-taxi routes from the outer commuter/air-taxi hubs into the three air-taxi vertiports created in Manhattan. PAV air routes notionally carry commuters in privately owned air vehicles from outlying areas to the air-taxi hubs at the periphery of the city. Two hubs were configured for this scenario -- one in Fort Lee, NJ near the George Washington Bridge and one on Staten Island in NJ.

Fig. 10: Air-Taxi Routes from Hubs to City

B. *Commuter Route Design*

Routes to the Fort Lee hub arrive from northwestern New Jersey, the upper Hudson, and from routes along the north shore of Long Island. The Staten Island hub is the destination for routes from the southern shore routes of Long Island and from the New Jersey southern shore. (The Newark Amtrak station was considered as an alternative option and would likely provide similar analysis results, but would require more overflight of land and populated areas than the Staten Island location.)

Air routes to the hubs were staged over water when possible to minimize overflight of population and noise, and were also designed to avoid existing air routes to the major airports. Routes from the upper Hudson region were staged over the Hudson River (Fig. 11). Routes from eastern Long Island overlay existing helicopter routes over the Long Island Sound to the north and over the Atlantic Ocean to the south. Routes from the southern New Jersey shore fly several miles off the beach (Fig. 12). Routes from northwestern New Jersey had no water routing option, but primarily traverse rural areas. These routes also were staged to avoid existing Newark and Teterboro air traffic routes.

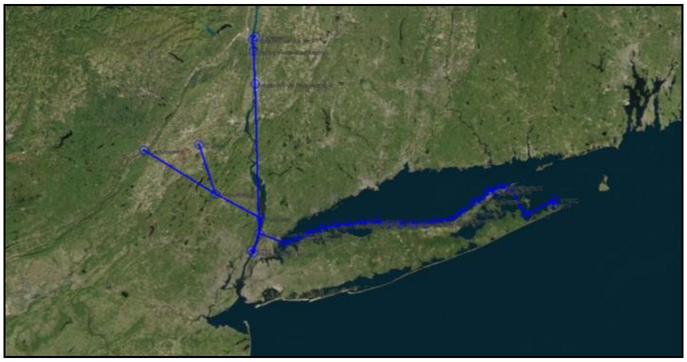

Fig. 11: Routes to Fort Lee Air-Taxi Hub

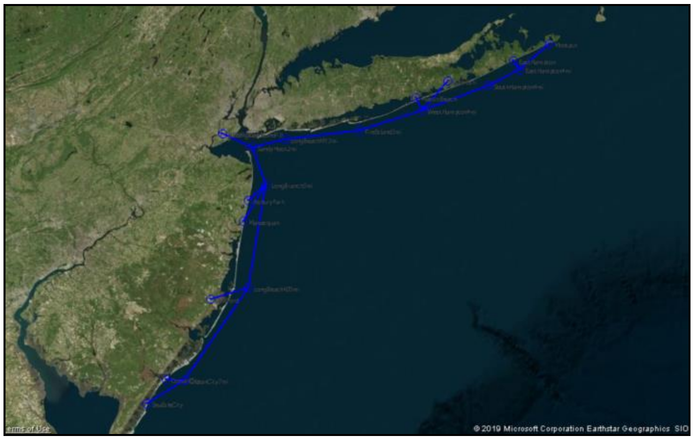

Fig. 12: Routes to Staten Island Hub

All of the origin points for this scenario used existing airfields in the FAA's airport database. These are small executive airports, private airstrips, or small regional airports. Use of FAA facilities is not expected to be a requirement for UAM vehicles, but this made the simulation setup easier with equally plausible departure locations.

C. *Baseline Noise Case - Current Day Helicopter Equivalent*

Two configurations were tested for this scenario. As with Scenario 1, the Baseline case was first produced using UAM vehicle DNL data for AEDT to be equivalent to a modern day helicopter. Fig. 13 presents the resulting AEDT noise DNL contours for this configuration.

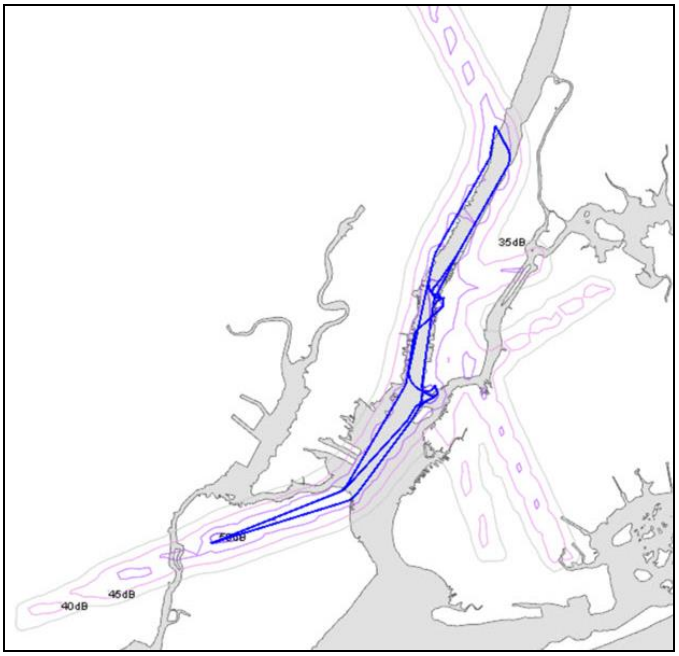

Fig. 13: AEDT DNL Result for Air-Taxi Baseline Case

Next, the air-taxi trajectories were analyzed with AEDT using the notional 20% reduction NPD tables. Fig. 14 presents the result of that case.

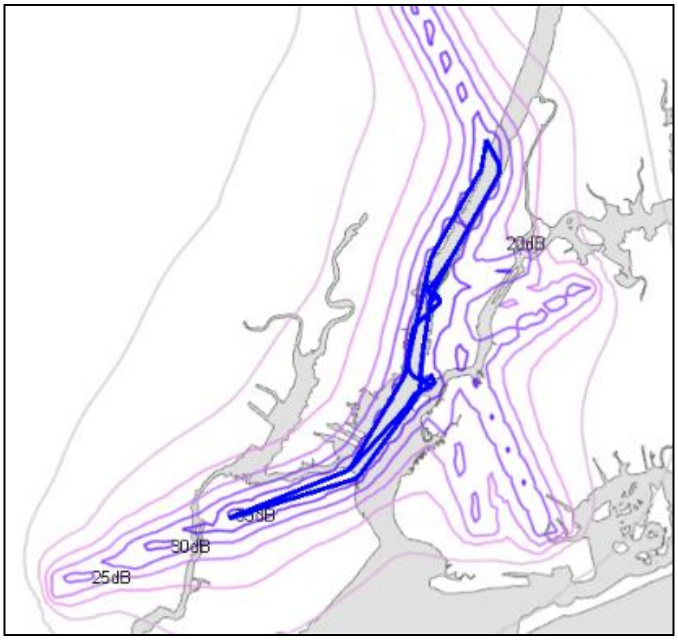

Fig. 14: AEDT DNL Result for Air-Taxi 20% Reduced Noise Case

Finally, the full set of traffic was analyzed with AEDT to generate DNL contours for all commuters to the hubs and air-taxis together using the baseline and 20% reduced noise NPD tables. Related to noise, the traffic to and from the hubs is the primary impact because the commuters to the hubs effectively double the amount of inbound traffic. Fig. 15 shows the result of the Baseline noise analysis, and Fig. 16 shows the 20% reduced NPD case.

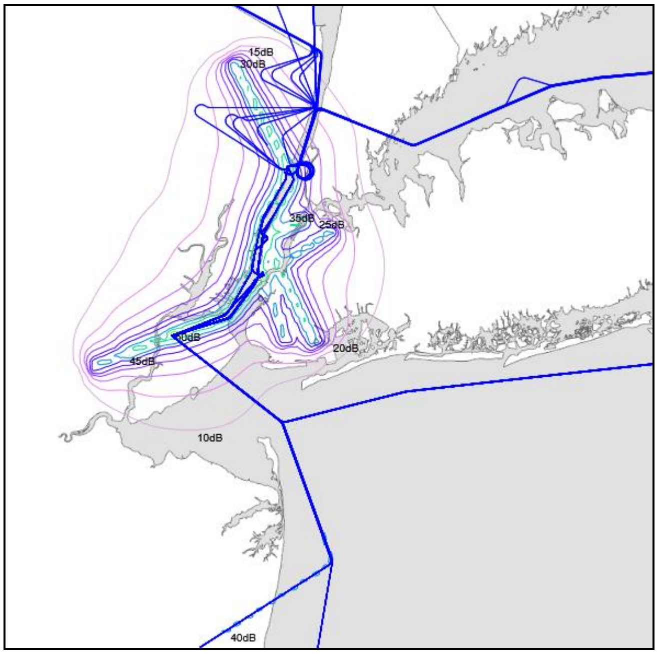

Fig. 15: AEDT DNL Result for Full Traffic Set, Baseline Noise Case

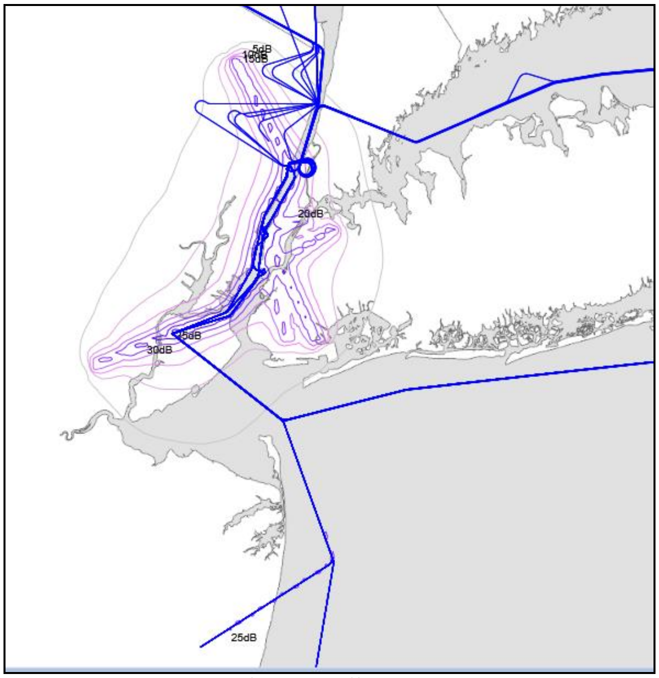

Fig. 16: AEDT DNL Result for Full Traffic Set, 20% Reduced Noise Case

VI. RESULTS

With a large degree of uncertainty in how communities will respond to an increased presence of air vehicles of any sort (especially vehicles with a potentially very different sound characteristic than that of a helicopter) a notional target decibel level was used for this paper of 50 dB, which is below

FAA maximum values. Note that this value was selected to facilitate comparison between generated noise outputs in this work. Final noise targets for New York or any community of operation for UAM will be determined by those communities in conjunction with FAA regulators, and is beyond the scope of this paper.

We emphasize again that a very simplistic representation of UAM noise was used in this tool demonstration using NPD curves as linearly-scaled versions of conventional helicopter data. Once better predictions for NPD-style data are available for UAM concepts, these noise contours can be regenerated to reflect the updated predictions, but for now these results must rely on a simplified surrogate noise characterization. Therefore, the results presented here are intended only to demonstrate tool capability for trajectory/noise interaction and could serve as a starting point for future investigation.

A. Scenario 1 Results

Scenario 1 modeled a possible near-term case with expanded air-taxi service from the perimeter of Manhattan to the major New York airports using UAM vehicles. The scenarios used increasing numbers of flights per hour with the resulting DNL contours presented for each.

The AEDT DNL contour plots for the 8 operations per hour case in Fig. 5 indicates that the southern half of Manhattan experiences over 50 dB, and the northern half is mostly over 45 dB. Portions of Queens and Brooklyn exceed 55 dB.

For the 32 operations per hour scenario, almost all of Manhattan is exposed to levels over 60 dB. Portions of Queens and Brooklyn also exceed 60 dB. Most of Queens, Brooklyn, and Bronx also exceed 30 dB.

For the 128 operations per hour case, AEDT predicts most of Manhattan to levels over 65 dB, with the some pockets of 70 dB. Portions of Queens and Brooklyn also exceed 60 dB. Most of Queens, Brooklyn, Bronx, and eastern NJ also exceed 30 dB.

For Scenario 1 using the Baseline NPD noise data values, only the 8 flights per hour case met the target criteria of 50 dB or less for populated areas outside the immediate vertiport vicinity.

When the runs were repeated for the 20% reduced noise data case, the scenario using 32 vehicles per hour did not exceed the target value of 50 dB for populated areas outside the vertiport vicinity (with 60 dB in the area near the vertiport). Results for the 128 vehicle per hour run are also included as a comparison. Note that while the 128 vehicle per hour case exceeded the 50 dB target for the work shown here, the noise level results are within FAA regulations. This case resulted in noise levels of 55 dB in the interior of Manhattan and 65 dB in the vicinity of the vertiports.

B. Scenario 2 Results

Scenario 2 modeled a farther-term use case with PAVs to hub vertiport locations outside New York City traveling to commercial air-taxi services for the final leg of the trip into Manhattan. This provides an air-commuter use case which removes the burden of parked air-vehicles within Manhattan where space is extremely limited. It also restricts PAV operators from overflight of the highest population density areas, which may be a future constraint, and suggests a higher level of pilot training and qualification for commercial operations.

The noise contours for the Baseline Scenario 1 case using helicopter-level NPD data predicted the highest noise levels of 50 dB only in the vicinity of the vertiports. The interior of Manhattan experienced a maximum 45 dBA exposure for the Baseline case. The staging of the routes primarily over the river helps confine the highest noise away from populated land areas.

For the 20% reduced NPD level case, the interior of Manhattan saw a maximum of 35 dB of noise, with 40 dB at the vertiports. Both the Baseline and the reduced noise cases met the notional target 50 dB noise levels.

There are some noise artifacts that appear in the Scenario 2 AEDT contours that are still being investigated. Specifically, Figs. 13 through 16 show noise propagating more than 5 miles down range of the landing sites. One possibility is that these represent a real effect and are valid outputs. Another possibility is that the non-conventional use of AEDT (using helicopter noise data, sometimes scaled, in conjunction with trajectories that sometimes better resemble aircraft performance characteristics) exaggerates the downrange noise footprints. This is a subject of continuing investigation, and illustrates one of the challenges in adapting or integrating analysis tools to UAM vehicles with non-traditional flight characteristics.

VII. FUTURE WORK

As previously mentioned, surrogate NPD tables were used to represent a simplistic guess at possible future UAM noise data. The authors investigated other options, but none could be defended as more accurate, so simplicity was chosen for this research. Efforts are underway at NASA to advance predictive tool capabilities to improve future UAM noise characterization, with NPD-style data as one of the target outputs. Once this data is available, follow-on comparison is planned to re-evaluate noise for these trajectory sets. It is also possible that actual empirical data may emerge to inform the creation of UAM vehicle NPD tables. Either of these options will be valuable for revisiting the scenario analyses.

Defensible performance predictions (based on NDARC analysis) were used to model and constrain the UAM vehicle flight envelope, but assumptions were required in choosing the trajectory profiles in absence of UAM operational regulations. These included takeoff and landing angles and rates, cruise altitudes, and spacing constraints. As UAM flight profile regulations or recommendations emerge, the trajectory configurations can be updated and the simulation re-executed as a basis for an updated analysis of the noise contours.

Though the Metrosim tool is capable of managing transport and UAM vehicles on a shared route, this capability was not used for the scenarios modeled. The predicted cruise speed of some UAM could potentially allow shared route segments within the Terminal Air Space, and a scenario demonstrating this for New York could be relevant as a first look at this use case for future work.

Constraints in AEDT related to the use of existing heliports in the reference database also limited the ability to conduct noise analysis with entirely new heliports for these studies. Configuration of new heliport locations as trajectory destination and origin points is possible with AEDT, but requires a tailored database buildup and was not possible within the time available. If follow-on funding or more flexible heliport modeling for AEDT becomes available in the future, Metrosim could support trajectory and noise analysis of small delivery drones. This could be a valuable analysis tool to inform best practices and offer insight for regulatory constraints.

Finally, a new development for the simulation tool includes the application of trajectory uncertainty. The uncertainty modeling could be used to evaluate proximity metrics between vehicles, and could also impact the overall noise contours.

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