AEROSPACE INDUSTRIES ASSOCIATION

METROPOLITAN AIRSPACE STRATEGY:

Initial Advanced Air Mobility Operations

May 2023

Prepared by the Aerospace Industries Association (AIA)

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Executive Summary

New experimental aircraft types are currently undergoing flight testing and are expected to begin commercial aviation operations within the next five years. The aircraft introduce innovations with the potential to greatly expand the envelope of aviation capabilities and operations beyond what is available today. One result of those innovations is that they may require changes to the way the National Airspace System (NAS) works today, whether as a result of novel performance characteristics, scale and tempo of operations, or increased levels of automation. In order to identify where changes do and do not need to occur, this document describes key operational details of three use cases. The use cases were selected because they are proposed to be carried out by experimental aircraft flying today and because they exercise different facets of the changes that may be needed in the airspace. The use cases are independent of each other, and each will follow its own implementation timeline. The first use case is performed by an onboard piloted electric vertical takeoff and landing aircraft that is operated in Visual Meteorological Conditions (VMC) under Visual Flight Rules (VFR) and transports passengers in the vicinity of metropolitan areas. The second use case is performed by an optionally piloted conventional takeoff and landing aircraft with higher levels of automation that is operated in VMC and Instrument Meteorological Condition (IMC) under Instrument Flight Rule (IFR) and transports cargo between urban and rural areas. The third use case is a remotely supervised electric vertical takeoff and landing aircraft that is operated in VMC and IMC under IFR and transports passengers in the vicinity of metropolitan areas.

AIA's Emerging Technologies Committee, Airspace Working Group has identified next steps to assist stakeholders in enabling this emerging aviation segment, including creating a roadmap that will assist in identifying gaps. This roadmap will be guided by the general target timeline associated with each of the three scenarios and will be published in a separate document. AIA is committed to engaging and enabling Advanced Air Mobility (AAM) through direct interaction with relevant stakeholders and providing industry perspectives to assist in the successful maturation of AAM operations. Industry leaders working actively to advance AAM operations who are interested in joining the Working Group are encouraged to reach out to AIA.

Acronyms

AAM = Advanced Air Mobility
ADS-B = Automatic Dependent Surveillance-Broadcast
ADS-R = Automatic Dependent Surveillance-Rebroadcast
AGL = Above Ground Level
ANSP = Air Navigation Service Provider
APNT = Alternate Positioning Navigation and Timing
ARTCC = Air Route Traffic Control Center
ATAR = Air-to-Air Radar
ATAS = Airspace and Traffic Advisory Service
ATC = Air Traffic Control
ATD = Airspace Technology Demonstrator
ATIS = Automated Terminal Information Service
ATM = Air Traffic Management
ATS = Air Traffic Service
BVLOS = Beyond Visual Line of Sight
C2 = Command and Control
CFR = Code of Federal Regulations
CNS = Communication, Navigation, and Surveillance
CPDLC = Controller-Pilot Data Link Capability
CTAF = Common Traffic Advisory Frequency
CTOL = Conventional Take-off and Landing
DAA = Detect and Avoid
DME = Distance Measuring Equipment
eVTOL = Electrical Vertical Takeoff and Landing
FATO = Final Approach and Takeoff Area
GOM = General Operations Manual
GPS = Global Positioning System
HOTL = Human on the Loop
HOVTL = Human over the Loop
HWTL = Human within the Loop

IFP = Instrument Flight Procedure
IFR = Instrument Flight Rule
IMC = Instrument Meteorological Condition
LOA = Letters of Agreement
NAS = National Airspace System
NOTAM = Notices to Air Missions
PIC = Pilot in Command
PPR = Prior Permission Required
RNP = Required Navigation Performance
RPIC = Remote Pilot in Command
SID = Standard Instrument Departure
STOL = Short Take-off and Landing
SWIM = System Wide Information Management
TAWS = Terrain Awareness and Warning System
TIS-B = Traffic Information System – Broadcast
TOD = Top of Descent
TRACON = Terminal Radar Approach Control
UAM = Urban Air Mobility
UNICOM = Universal Communications
VFR = Visual Flight Rules
VHF = Very High Frequency
VMC = Visual Meteorological Conditions
VOR = Very High Frequency Omni Directional Range
VTOL = Vertical Take-off and Landing
WAAS = Wide Area Augmentation System

Taxonomy

Automatic Systems: Automatic systems will follow pre-defined, finite, and thus predictable, deterministic sequences of tasks. Automatic systems will require operator initiation and may be interrupted by operators.

Autonomic Systems: Autonomic systems will select from a pre-defined, finite set of tasks to achieve a given objective or regulate subsystems conditionally, but without the need for operator initiation. Autonomic systems may involve operator intervention.

Autonomous Systems: Autonomous systems will independently decide their own course of tasks to achieve a given objective without the possibility of operator intervention.

Beyond visual line of sight (BVLOS): Aircraft remotely piloted and operates beyond visual line of sight.

Electronic Pilot: A system of hardware, firmware, and software that controls the trajectory of an aircraft without constant "hands-on" control by a human pilot. Electronic pilots also autonomically provide decision-making flight functions, operational path management, and communication.

Fleet Manager: A person who manages internal fleet resources, plans and replans flights with traffic awareness, and files aircraft intent (e.g. IFR flight plan submission and vertiport slot reservations). The fleet manager uses a system of hardware, firmware, and software, collectively known as the fleet management system.

Human-within-the-loop (HWTL): The human is always in direct control of the automation.

Human-on-the-loop (HOTL): The human is supervising and actively monitoring the automation and can take full control when desired.

Human-over-the-loop (HOVTL): The human is passively monitoring the automation and can be informed or engaged by the automation to step in if necessary.

Operator: The entity exercising operational control over an aircraft operation (e.g. Part 135 operator).

Pilot: The term "pilot" refers to the pilot in command (PIC) as defined in 14 CFR Section 1.1. That is, the pilot is the person in command of an aircraft who is directly responsible for and is the final authority as to the operation of the aircraft. The pilot may be onboard the aircraft or remote, but if a distinction is not explicitly used in this document, it should be assumed the PIC is onboard the aircraft.

Remote Supervisor: A person who can override the automatic and autonomic behavior of the electronic pilot while the aircraft has an active C2 link. For a given flight, the remote flight supervisor is also the primary point of contact for Air Traffic Control. The remote supervisor uses a system of hardware, firmware, and software, collectively known as the remote supervisor system.

Timeframes

Day 1: The first day for a given scenario to be fully operational and revenue making. Day 1 can differ for each of the three use cases described in this document.

Near Term: Represents the time frame within the next five years.

Mid Term: Represents the time frame from five to ten years.

Far Term: Represents the time frame beyond ten years.

INTRODUCTION

This document contains descriptions of aviation operations that are coming in the next several years and that may evolve in ways that necessitate changes to certain aspects of the NAS. The case studies of operations are focused on how they will be conducted in today's NAS, including in some cases near-term changes to it. The three different scenarios were chosen because they represent the intended operations of industry members actively building and flying next-generation aircraft, and because they exercise different facets of the changes expected from the operations: novel performance characteristics, increasing scale and density of operations, and higher levels of automation.

This document is intended for an audience of direct and active NAS stakeholders. Such stakeholders are those that are concerned with operating, regulating, or enhancing the NAS, and details are provided at a depth consistent with entities performing those functions. The scenarios are intended to illustrate what operations are feasible and trigger the identification of areas in which stakeholders must collaborate to enable the introduction of these applications. The three scenarios are distinct from one another, and no implication should be made that a progression exists from one to the next. Each will follow its own implementation timeline.

It is envisioned that readers of this document will come away with three things. First, they should have a clear understanding of the use cases that these new aircraft are designed to perform. Each of the use cases may be performed by aircraft already flying experimentally today, with the intention of flying commercially in the next five years (i.e. the "near term"). Second, readers should be able to identify aspects of operations that fit well into the existing NAS and the areas where more investigation may be required, either to increase the scale of operations, add automation, or understand the novel performance characteristics of these aircraft. In many cases, what is necessary is not a new technology, but instead a new procedure, process, study, or engagement. Finally, the reader should understand that these new types of operations will coexist with traditional aviation operations, expand aviation's scope, add a transportation modality, and improve opportunities across the industry.

Challenges to Airspace Integration

The integration of AAM and Urban Air Mobility (UAM) operations has the potential to present several challenges due to the novel nature of the aircraft, their flight characteristics, differing levels of automation, and higher anticipated operational tempos in urban metropolitan airspaces. A brief description of some of these challenges is described in the sub-sections below.

Flight Characteristics

Some of the new aircraft types being proposed for introduction have different combinations of performance and operating characteristics than traditional aircraft. Electric vertical take-off and landing (eVTOL) aircraft may be powered entirely by batteries or have a hybrid battery-combustion powertrain and are capable of VTOL flight like helicopters. Designs vary among different manufacturers and include models with tilting propellors that are used both in vertical flight and forward wing-borne flight, models with separate sets of propellors for lift versus cruise flight, and models with fixed vertical propellors that can provide horizontal thrust by pitching and rolling the entire aircraft. There are also new types of short takeoff and landing (STOL) and conventional takeoff and landing (CTOL) models that will have performance characteristics like traditional fixed-wing aircraft in these categories today.

Levels of Automation

Operations that are remotely piloted and operate beyond visual line of sight (BVLOS) introduce new challenges for interactions between the remote pilot/operator, traditional piloted aircraft, and air traffic controllers. Automation, as described in the FAA Urban Air Mobility Concept of Operations (CONOPS) v1.0 [1}, is categorized into three levels:

- Human-within-the-loop (HWTL) — The human is always in direct control of the automation.
- Human-on-the-loop (HOTL) — The human is supervising and actively monitoring the automation and can take full control when desired; and
- Human-over-the-loop (HOVTL) — The human is passively monitoring the automation and can be informed or engaged by the automation to step in if necessary.

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[1] https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf

Early operations are expected to include a combination of these levels of automation — some with a pilot in command (PIC) on board (HWTL) with a remote pilot monitoring on the loop as a step towards reducing risk and increasing safety in a future evolution. Other operations may have a remote PIC on the loop (HOTL) with a safety pilot in the cockpit (HOTL) shadowing the remote PIC. A third variation is to have a remote PIC supervising (HOVTL) the automation with no pilot onboard the aircraft. Some of these variations may impose new requirements for communication, navigation, and surveillance technologies.

Operational Tempo

Early operations are expected to include a variety of operational characteristics, with some operators intending to fly only in VMC under VFR and others in any weather conditions under IFR. Initial operations are expected to be low tempo, fewer than 10 operations per hour per operating location and expanding well beyond that in the mid-term. Near term operations, those occurring in the next five years, are anticipated to use existing communication, navigation and surveillance infrastructure, airspace structure, and air traffic services. Changes to these functions are anticipated only in the mid-term and beyond, more than five years in the future.

Airspace Regulatory & Operations Environment

A combination of airspace structure, policies, guidance, and regulation provide the framework under which mixed operations ranging from balloons and gliders to fixed wing and helicopter are safely conducted in the NAS. Airspace design and procedures are governed by 14 Code of Federal Regulations (CFR) Part 71, for the designation of class of airspace, air traffic service routes, and reporting points; 14 CFR Part 73, for special use airspace designations; 14 CFR Part 77, for safe, efficient use and preservation of navigable airspace; and 14 CFR Part 157 for construction or alteration of airports. The procedures to implement these rules are captured in orders 8260.19 and 7400.2 that specify the required analyses and design processes for metro airspace design. The national airspace review handbook translated those orders into a waterfall design process for significant changes to a metro area.

The summary of these regulations and practices that govern the airspace and operations environment are presented here, so that as issues are uncovered through discussions and roadmap development, the specific areas to be addressed in the orders can be referenced. Any nuances or changes necessary to accomplish operations on day 1 that mimic, but do not specifically meet the requirements of current orders or rules will touch the regulatory landscape. These may be waived, exempted, or otherwise approved, but it is important to know where the gaps will need to be addressed.

Scenarios

Three scenarios describing different day 1 operations are presented below. Each is first discussed in terms of the following key aspects of operations and airspace:

- The **aircraft capability and operational characteristics** such as aircraft class, weight, engine type, speed, and other design characteristics relevant for aircraft certification. Airspace may be organized to create flows of homogenous populations with similar performance requirements and limitations that can easily operate in close proximity under existing rules. This includes the communication, navigation, and surveillance (CNS) capabilities required by the operation type and airspace where the operation is conducted.

- The **airspace features and structures** define the procedures and determine specific operating requirements and limitations based on congestion and complexity of an airspace.

- The **airports and infrastructure** in terms of numbers, type, geometry, and standard approach or departure for each airport provide the needs for structure and priorities of flows. In some cases, the expansion of some infrastructure will impact the operations of other sites. This can include coupled procedures connecting one airport operation to another airport.

- The **flight operations and conditions** are key assumptions in the roles of the pilot, operator, and ATC, including providing services for advising and safely separating aircraft.

- The **community impact and acceptance** are largely about the environmental (noise, visual, and pollution) review and community engagement and comment on the acceptability of the review.

- The **constraints and contingencies** are about the events management for any likely off-nominal conditions.

Scenario 1: Onboard Piloted eVTOL VFR Operations in Metropolitan Airspace

This scenario describes details of initial operations that may be conducted by onboard piloted eVTOL aircraft, largely under VFR, in metropolitan airspace. The first sections describe common elements of this scenario, while the final two sections describe two versions of this scenario with different levels of interaction with ATC. The first version consists of minimal ATC interactions because it is conducted in airspace classes G and E. The second includes ATC interactions that could occur during entry into and operations in class B airspace.

Overview

Initial revenue eVTOL operations will have an onboard PIC and generally be conducted in VMC under VFR, although high priority flights might occasionally necessitate special VFR, VFR on top, and IFR operations. These flights, conducted by a non-scheduled Part 135 operator, will use a type-certified aircraft to transport people and cargo in the vicinity of a metropolitan area. The scale of operations anticipated in early years is consistent with the tempos of operations conducted by light aircraft observed in cities today, though they may be more concentrated along specific routes to and from specific operating locations.

Aircraft Capability and Operational Characteristics

The eVTOLs are type-certified as 21.17(b) special class powered-lift aircraft. In low-speed configurations, the flight characteristics will be consistent with typical helicopter approach speeds and flight path angles. In the wing-borne lift configuration the aircraft will operate like a high-performing general aviation aircraft, though with the maneuverability of a rotorcraft and the ability to quickly revert to a low-speed configuration. The terminal area procedures used by eVTOL aircraft will also resemble those of rotorcraft.

The aircraft are configured with the CNS required by the airspace where the operation is conducted. This includes a Mode S transponder, Automatic Dependence Surveillance Broadcast (ADS-B) In and Out, Very High Frequency (VHF) voice radios, and Wide Area Augmentation System (WAAS) Global Positioning System (GPS) navigation capabilities. Some eVTOL aircraft may also be equipped with terrain awareness and warning systems (TAWS), the ADS-B traffic advisory system (ATAS), and radar altimeters to increase safety.

Airspace Features and Structures

During the planning phase, the operator will work with local airspace authorities to select routes and operating locations that are compatible with existing operations and take into account any unique characteristics and constraints of each region. If necessary or of benefit, the routes and procedures for operations could be codified in a letter of agreement (LOA) between the local ATC facilities and the operator. Under no circumstances would operators seek or be granted exclusive use airspace volumes or corridors.

Airports and Infrastructure

Heliports, vertiports, and both towered and non-towered airports will be part of the intra-city network for eVTOL passenger and cargo traffic. Aircraft will use existing procedures at most airports and will only seek changes or new procedures if existing ones are incompatible with aircraft performance or would negatively affect existing operations. In those cases, the operator would work with the airport to develop procedures that serve all stakeholder needs. These new procedures are not anticipated to result in safety impacts to the NAS. Similar to today's rotorcraft operations, eVTOLs could be operated to and from non-movement areas of towered airports.

The initial operations will use existing airports and the CNS products and services necessary to conduct the operations. Existing navigation aids like VHF omni-direction ranges (VORs) and distance measuring equipment (DMEs) may be used along certain routes. The pilot may rely on WAAS GPS, or they may simply navigate via pilotage (navigation by reference to landmarks or checkpoints). The VHF voice communications infrastructure will also continue to be used, with no new communications requirements between the pilot and ATC.

Modifications should not be necessary to existing heliports and airports, though some facilities may elect to convert to vertiports [2]. Existing services provide weather and obstacle information for these heliport and airport facilities. Infrastructure other than that dedicated for aviation, for example data communications, may be used for functions not related to air traffic management or safety-critical functions. Examples of these functions include vehicle health monitoring for maintenance purposes, company communications, or operator-to-operator coordination of access to shared facilities.

[2] See the draft engineering brief no. 105:
https://www.faa.gov/airports/engineering/engineering_briefs/drafts/media/eb-105-vertiport-design-industry-draft.pdf

Flight Operations and Conditions

Operations will be conducted under VFR in VMC during the day and at night. The pilot is responsible for maintaining well clear from obstacles and other air traffic. At uncontrolled facilities, the pilot will coordinate with other aircraft using standard procedures over a common traffic advisory frequency (CTAF) or universal communications (UNICOM) for air-ground communications.

Some operators may have personnel other than the pilot serving in the role of a dispatcher or flight follower. Those personnel will evaluate weather conditions, review notices to air missions (NOTAMs), review flight conditions, and conduct other activities in accordance with the operator's Part 135 general operations manual (GOM).

Existing airspace structure will ensure minimal interactions with other flow-managed traffic for the origin or destination heliport during initial operations, for example by keeping the vehicle outside Class B, C, or D airspace whenever possible. The aircraft will maintain speeds and altitudes compatible with other aircraft operating in the vicinity of the route. The flight will adhere to typical helicopter approach speeds and flight path angles. Enroute, the pilot will communicate with ATC as required by airspace class via voice radio. Under normal circumstances, the pilot will not request flight following services from ATC.

Community Impact and Acceptance

The initial operations will fit within the current traffic patterns used in the applicable environmental impact assessments. Requirements for noise abatement procedures will apply to eVTOL aircraft, though in some cases the lower levels of noise that these aircraft may generate could allow them to operate at times and locations in which noisier aircraft are prohibited from operating.

Constraints and Contingencies

The pilot will monitor usable energy information. The pilot will ensure adequate charge is available to meet all flight plan requirements. In some circumstances, an operator's dispatch or flight follower personnel will assist with or prepare energy and performance calculations. Procedures to handle contingencies, urgent situations, or emergencies will be like other single pilot aviation operations. However, special awareness and training for first responders to handle technology specific factors (e.g., battery related dangers) will be essential.

Scenario 1a: Operation Between Non-Towered Heliports in Classes G & E

The aircraft in this scenario flies between two non-towered heliports, both located in Class G airspace, and flying enroute through Class E airspace at 1500 ft AGL. An illustration of the route is shown in Figure 1a, and the core assumptions are provided in Figure 1b with the key ones highlighted. Conditions are VMC at both heliports and in between. In the preflight phase, operations personnel create an operation plan that includes a departure time, destination, route of flight, weather and performance information, and other relevant details. This information is communicated to the pilot via an application on their electronic flight bag. The pilot completes a preflight checklist, tunes to the heliport frequency (UNICOM), and announces their intent to depart to the southeast. The heliport operator responds on the heliport frequency that the final approach and takeoff area (FATO) is available, and no aircraft are known to be inbound. The pilot taxis on the ground to the FATO and lifts off. The role of the heliport operator is assumed to be similar to current day operations. Any take-off and landing clearance requirements at public or private heliports will be like current day operations (e.g., private prior permission required (PPR) heliports).

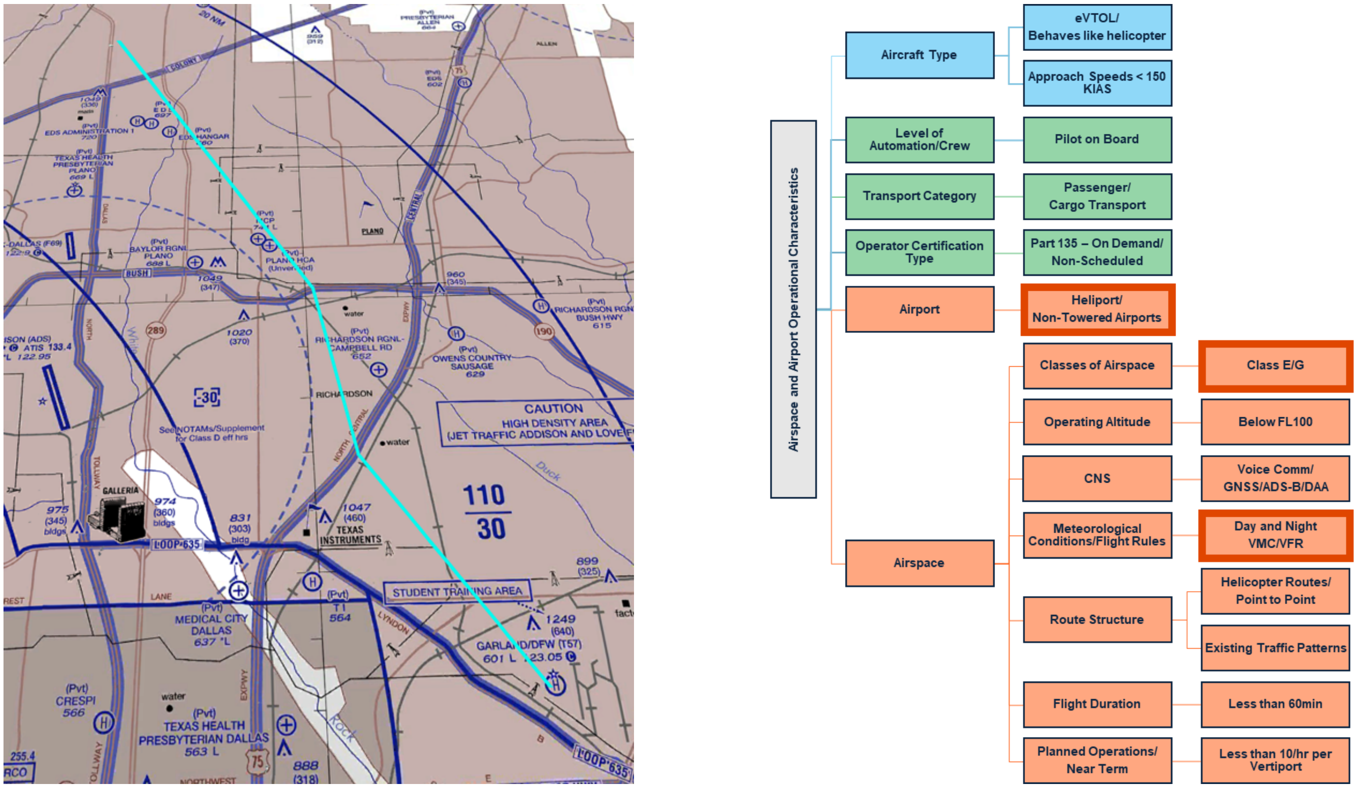

Figure 1. (A) Route for Scenario 1a, (B) Assumptions in the Near Term

During the departure, enroute, and approach phases of flight the operator monitors the progress of the aircraft using existing surveillance sources. The pilot tunes to the UNICOM frequency as they approach the destination heliport to announce their location and intention to land at the heliport. The heliport operator radios back that there is one helicopter landing ahead of the eVTOL and that the pilot should expect to taxi to parking pad two after touchdown. After touching down and taxiing to the pad the pilot completes the post-landing checklist. At no point during the flight does the pilot talk to ATC or request flight following services.

Scenario 1b: Operation from Heliport in Class G to Airport in Class B

This scenario expands on the previous scenario and explores access into Class B airspace. The starting conditions of this scenario are identical to those in Scenario 1a except that in the pre-flight phase the pilot enters a transponder code from a block of codes that have been assigned to the operator. The destination is a towered airport in Class B airspace. The route of flight is shown in Figure 2 along with key assumptions for the scenario. The pilot climbs the aircraft at 1000 fpm in the wing-borne flight configuration and levels off at 1500 ft AGL. As the pilot nears the Class B airport the pilot tunes to the ATIS frequency and notes the conditions at the destination, version "whiskey."

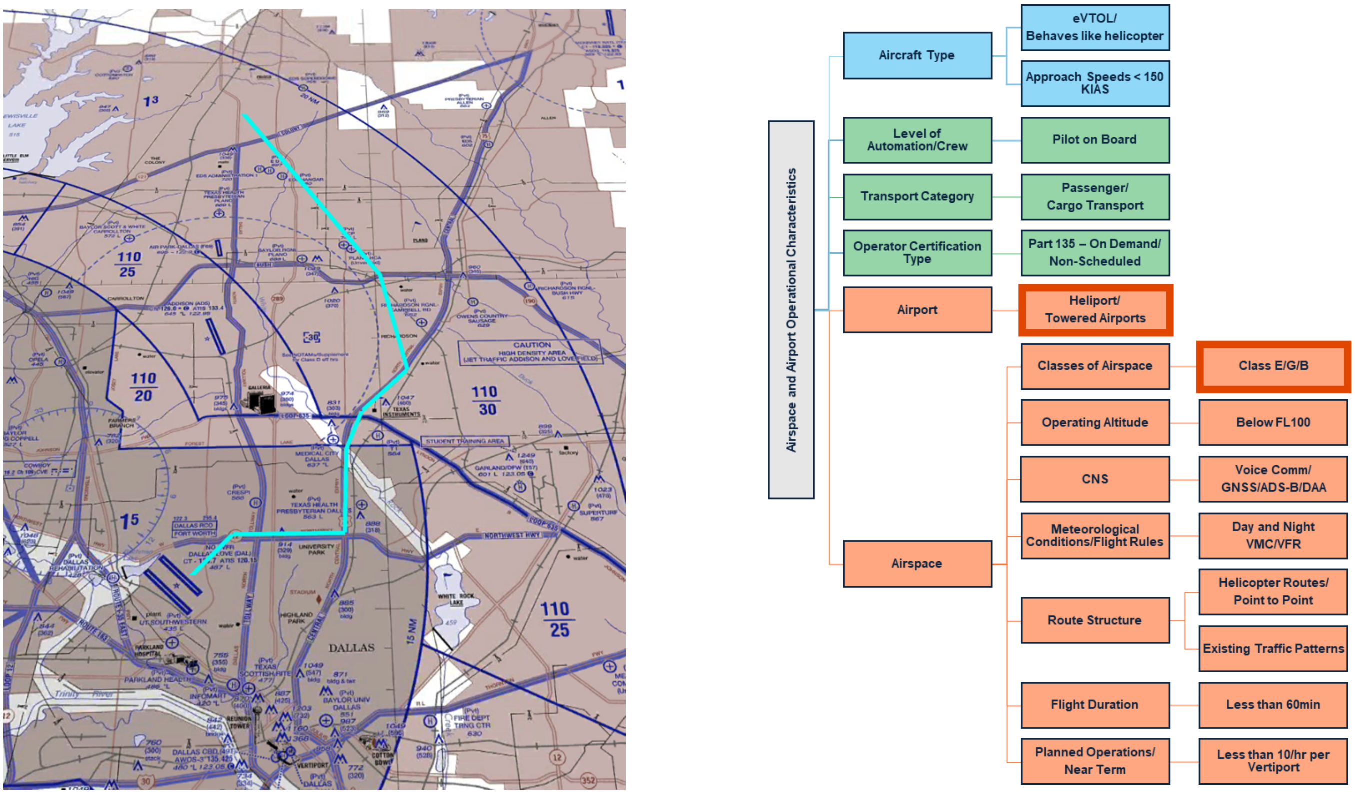

Figure 2. (A) Route for Scenario 1b, (B) Assumptions in the Near Term

When the pilot has intercepted the helicopter route approximately three miles north of the Class B boundary the pilot tunes to the helicopter frequency of the destination airport's tower. Following procedures specified in the LOA between the operator and tower, the pilot reports their identity, present position, altitude, desired route, and ATIS version:

"Love tower, air one niner, two northeast of Texas Instruments, one thousand five hundred, lover's lane, whiskey"

The ATC sees the aircraft with the right transponder code in the location and at the altitude indicated by the pilot and clears the aircraft into Class B airspace, noting that another aircraft from the same operator is inbound on the same route ("lover's lane arrival") and approximately one mile ahead.

"Air one niner, love tower, radar contact, cleared lover's arrival. Do you have company in front of you?"

The pilot acknowledges the clearance and that they have "company" traffic in sight, another eVTOL that is part of the operator's fleet and flying the same procedure:

"Cleared lover's arrival, company traffic in sight, one niner"

The LOA specifies that eVTOLs using the lover's lane arrival procedure may proceed to land at a non-movement area of the airport if they stay at least 700 feet from the centerline of the runway. They require no additional communication with the tower unless traffic advisories or other advisories are pertinent. The pilot follows the leading aircraft down to the helipad on the non-movement area, maintaining responsibility for appropriate separation. Once on the ground the pilot switches to the fixed based operator (FBO) frequency and requests parking instructions. The pilot taxis to the parking pad to disembark passengers and completes the post-flight checklist.

The example communication provided above only considers communication with a single controller. Depending on the geographical location, the route of the flight and the airspace being transitioned, interaction with multiple controllers might be necessary for some LOAs.

Scenario 2: Optionally Piloted Fixed Wing Operations Between Towered Airports

This scenario describes details of initial operations that may be conducted by optionally piloted, modified fixed wing aircraft (CTOL) that are highly automated, such that in one mode a remote pilot can safely operate the aircraft without anyone onboard, and in another mode an onboard pilot can operate the system. Each section describes elements of this scenario as relevant for aircraft, airspace, infrastructure, operations, and community pertaining to operations conducted in controlled airspace and all-weather conditions for cargo transport operations.

Overview

Both towered and non-towered airports are essential to inter-city cargo operations. Some operators will begin revenue operations involving towered airports under IFR as a non-scheduled part 135 operator. These operations will use certified fixed wing aircraft to transit Class B, C, D, E, and G airspace and will engage ATC through normal clearance and communication channels. The operations begin as replacement flights for similar existing operations, and so will not affect the scale of operations at these towered airports. Initial operations will have an onboard pilot to mitigate airspace integration challenges such as see and avoid. The day 1 operation is illustrated on the far left of Figure 3 as Block 1.

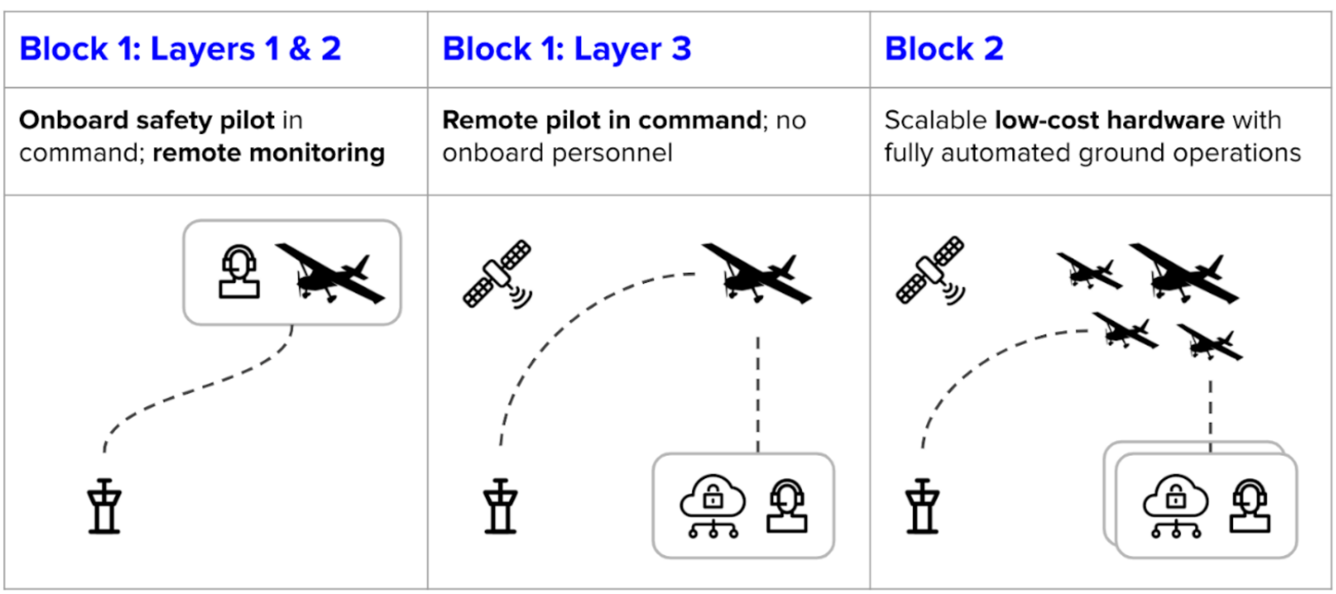

Figure 3. Evolution Path for Operations from Piloted to Remotely Piloted to m:N Flights

Aircraft Capability and Operational Characteristics

The fixed-wing aircraft are existing type-certified aircraft that have been modified to enable a remote pilot operation. The flight characteristics will be consistent with existing operations. The aircraft are configured with CNS capabilities required for the airspace, route, and procedures being flown. Voice communication between the remote pilot and ATC will be though standard VHF radios onboard the aircraft. WAAS augmented GPS navigation capabilities will enable RNAV routes and procedures to be used. The aircraft will be equipped with ADS-B Out and a Mode S transponder. The C2 Link will consist of Satcomm and Radio Line of Sight datalinks as necessary to meet the C2 Link performance necessary for the airspace, route, and procedures being flown.

Airspace Features and Structure

The aircraft arrive and depart from controlled airports similar to existing piloted aircraft operations. The flights will fly enroute in both Class E and Class A airspace, depending on the weather and winds. The flights will be IFR, satisfying all the necessary communication requirements with ATC by using existing Very High Frequency (VHF) radios. In IMC, aircraft will proceed similar to any other traditionally piloted operation flying IFR.

Flight Operations and Conditions

Operations are enabled in IMC by having flights receive air traffic services and follow IFR clearances. The pilots have the means to detect and avoid other air traffic, including both remain well clear and collision avoidance functions against both cooperative and non-cooperative aircraft. These flights will be dispatched with a flight plan, just as traditionally piloted aircraft predecessors were, but with an indication that the aircraft is remotely piloted. ATC communications will also have this indication (e.g., “Robot one two three remote, proceed to taxiway alpha and hold short of runway three”).

If there is a traffic conflict, regardless of IMC, the remote pilot will be able to broadcast over local CTAF, and they will be able to initiate a heading and/or altitude change maneuver to avoid the traffic, without the need for ATC. If in controlled supported airspace, aircraft will also be able to follow ATC instruction. Not only will it have the maneuvering capability, as described above, but will also be able to modify flight plan utilizing new waypoints, holding patterns, etc. Aircraft will also have missed approach capability that will follow existing instrument approach procedures.

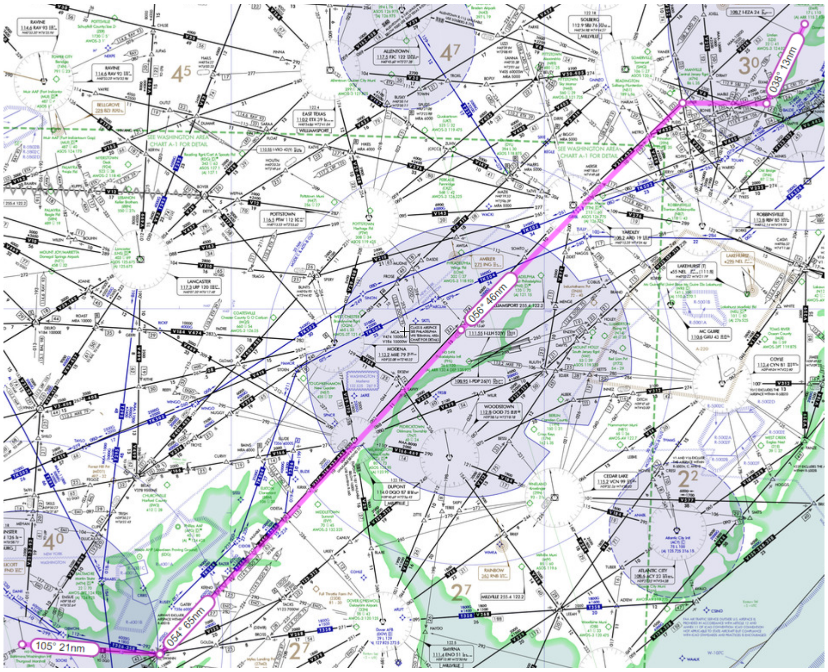

Figure 4. Example Flight from BWI to EWR

Airport and Infrastructure

The initial operations involve legacy infrastructure in terms of both the airports and the CNS products / services necessary to conduct the operations. A notable exception is one operator assumes the use of pilot-controller data communications even in the terminal environment.

The CTOL aircraft will taxi as any other aircraft would, receiving direction from the control tower if present. If no control tower, all movements will be communicated on Common Traffic Advisory Frequency (CTAF) by the Remote Pilot in Command (RPIC), who will have the ability to stop at any point if necessary. Ground observers will assist RPIC to ensure no incursions or risk of collision (including with wildlife) occur.

Community Impact and Acceptance

The day 1 operations fit within the current traffic patterns used in the most recent environmental reviews. Operations will comply with local noise abatement procedures, so initial operations are not expected to impact communities around airports in any way beyond today's aircraft operations. Operations will be seamlessly integrated into airport operations, so no impact to existing airport surface movements is expected beyond what would occur when adding another traditional aircraft to the airport.

Constraints and Contingencies

The pilot will ensure they are responsive to ATC clearances and instructions so that the remote-pilot operation is transparent to the controller.

Should the aircraft experience a mechanical emergency, the remote pilot will engage ATC like any contingency event on a piloted aircraft, including coordinating alternate landing sites.

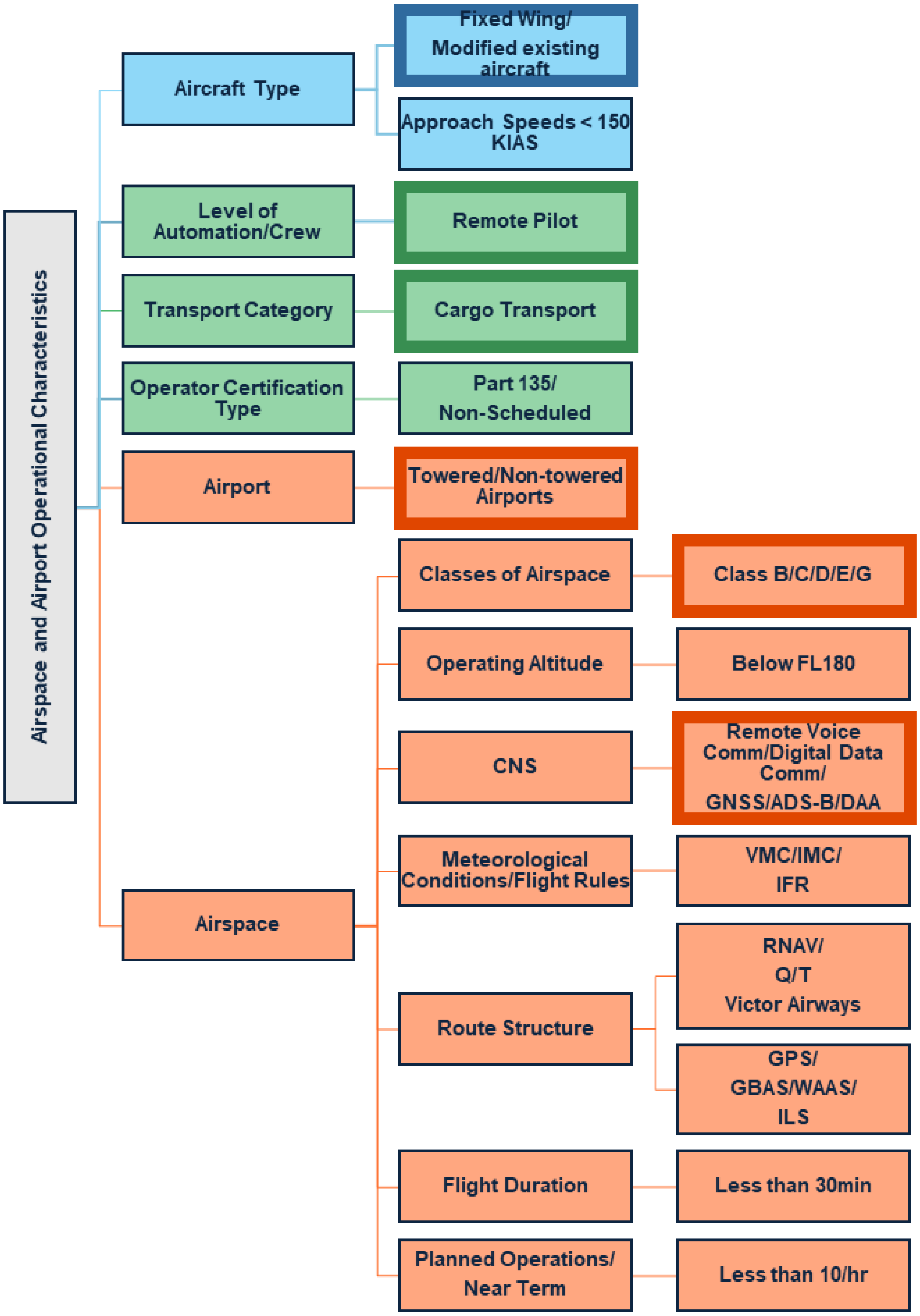

Figure 5. Assumptions for the Near Term - Towered Airports in Class B, C, and D.

Scenario 3: Remotely Supervised eVTOL IFR Operations in Metropolitan Airspace

This scenario describes details of initial operations that will be conducted by remotely supervised eVTOL aircraft under IFR. The first sections describe common elements of this scenario, while the final three sections describe three versions with different levels of interaction with air traffic controllers (ATC). The first sub-scenario consists of minimal ATC interactions because it is conducted in airspace Classes G and E. The second sub-scenario includes flight entry into and transitions through Class B airspace. The third sub-scenario includes flight departures and approaches at Towered Airports.

Note 1: The term "remotely supervised" is used instead of "remotely piloted" in this scenario to avoid the connotation of remote stick and rudder control that frequently comes with the term "remotely piloted." In this scenario, the eVTOL aircraft will execute aviation behavior in a responsible manner (autonomous aviation) and will execute navigation behavior, as well as communication behavior, in an assistive manner (autonomic navigation and communication). The individual that retains the overall responsibility for the safety of flight via navigation/separation and communication authority, is known as the "flight supervisor." This terminology shift, aligned with the overall paradigm shift associated with autonomous aviation, supports a new mentality that will allow the industry to more seamlessly scale and evolve from Scenario 3 day 1 operations.

Overview

Initial revenue-generating eVTOL operations for Scenario 3 (which will be beyond day 1 scenarios 1 and 2) will be conducted under a tailored form of IFR. These operations will use a type-certified aircraft and transport people or cargo in the vicinity of a metropolitan area. The aircraft will operate using flight profiles that are similar to today's helicopter and fixed wing aircraft profiles. The procedures used by eVTOL aircraft, where applicable, will also resemble those of rotorcraft but with key advancements, discussed below. The scale of operations anticipated in early years of Scenario 3 (toward the end of the near-term) is consistent with the tempos of operations conducted by light aircraft observed in cities today, though they will be more concentrated along specific routes to and from specific operating locations (as indicated in Figure 5, throughout will be initially low per vertiport with less than 10 operations per hour per vertiport).

Aircraft Capability and Operational Characteristics

The eVTOL aircraft are type-certified under 15 CFR 21.17(b), as a hybrid with flight characteristics that are a unique mix of those belonging to typical helicopters and fixed wing aircraft. Unique flight characteristics will define specific approach speeds, hover capability, and flight path angles for the aircraft. Of note is that the hover capability of eVTOL will be limited, thus path stretching, or small holding patterns, are preferred for delay absorption. In cruise, the aircraft will fly like a traditional fixed wing aircraft.

The aircraft will have a detect-and-avoid (DAA) capability to stay well clear of other aircraft, and will also have the capability to avoid terrain, obstacles, and other airspace hazards (e.g., hazardous weather). It is important to note that the flight supervisor will still be able to issue high-level commands to aircraft in order to comply with ATC instructions. The aircraft will have the standard surveillance equipment to be visible to ATC and other aircraft in the airspace. With ADS-B In (including ADS-B Out Automatic Dependent Surveillance - Rebroadcast (ADS-R), and Traffic Information Services – Broadcast (TIS-B) information) along with Air-to-Air Radar (ATAR), the aircraft will rely on others being detected to support DAA capabilities.

The aircraft will have the instrument navigation equipment for end-to-end instrument flight in metroplex environments. This includes being equipped for a special/private terminal Instrument Flight Procedure (IFPs) from the departure vertiport to the arrival vertiport. This includes aircraft equipage and vertiport infrastructure for Auto-Landing and Auto-Takeoff.

The aircraft will be equipped with standard communication equipment for respective aviation communication channels, including those used to communicate with ATC. The BVLOS component will also require a certified over-the-air command and control (C2) Link to enable communication between the flight supervisor and the aircraft. Communication between the flight supervisor and ATC will be via a ground-to-ground communication channel(s), ideally supporting both voice and DataComm.

Airspace Features and Structure

As mentioned above, the aircraft will leverage a special/private terminal IFPs from the departure vertiport to the arrival vertiport. From an IFR perspective, a single 4DT authorization over DataComm will be used to implicitly clear the aircraft for the entire length of the mission (which will be 15 – 30 mins). In other words, clearance will be implied in the absences of tactical ATC intervention. This kind of 4DT authorization will be similar to an arrival clearance over DataComm, which is being developed to provide airliners clearance from top-of-descent (TOD) to a runway landing, based on an assured 4D trajectory over a 15–30-minute window. The assurance of the 4D trajectory over the 15–30-minute window is the core capability to be applied.

Note 2: DataComm to support pre-departure clearances/departure clearances, that in this case will run origin to destination, is assumed to be available at most ATC towers of interest. DataComm should also be available in the applicable ATC facility (a TRACON in this instance) that covers the metroplex of interest. It is important to acknowledge that this preference for DataComm clearance would therefore come from the applicable ATC tower or the overarching ATC facility.

To enable the scaling of BVLOS UAM operations, while reducing the burden on ATC, a combination of sufficient containment (related to Required Navigation Performance (RNP) NavSpecs) along the terminal IFP, as well as self-provisioned spacing services, is desired for BVLOS UAM operations.

It is acknowledged that DataComm can place a burden on controllers, but DataComm is an important feature for the flight supervisor and the respective flight supervisor system. Therefore, an integrated 4DT authorization mentioned earlier is the only DataComm capability envisioned. Under IFR, approach control and local controllers will need to talk to the flight supervisor if there is a tactical need.

The operator will seek new procedures that support end-to-end missions between FATOs in a metroplex. Most other existing terminal instrument flight procedures serve runways at major airports and are not end-to-end. As such, the operator's commercial procedure design contractor will work with the airport to develop procedures that serve all stakeholder needs. Similar to today's rotorcraft operations, eVTOLs will be operated to and from non-movement areas of towered airports, which further mitigates the need for ATC interaction. Vertiport resources will be guaranteed for day 1 operations. The operators will reach an agreement with vertiport owners to establish designated zones (e.g., FATOs) initially.

It is important to note that these aircraft will share the same missions as helicopter and manned eVTOLs, namely the transport of passengers to/from heliport/vertiport/airport facilities (e.g., UAM). As such, a goal for the UAM community should be that these private end-to-end Terminal IFPs become shared, public procedures that all qualified aircraft can use (they must meet the respective generally applicable RNP NavSpecs).

Note 3: For both manned and unmanned eVTOLs that seek to conduct IFR UAM missions, along Terminal IFPs, the ability of controllers to accommodate both helicopters and eVTOLs (that cruise on the wing) on terminal IFP needs to be assessed with respect to scanning workload and rare intervention by exception.

Note 4: It is important to note that while these aircraft (that have VTOL capability and cruise on the wing) will share the flight characteristics of fixed wing aircraft in cruise, they will have a differing mission in the sense that normal fixed wing aircraft will fly to/from runways. It is also important to acknowledge flight supervisor fixed wing aircraft on day 1 are existing in parallel. These will be type-certified aircraft and will maintain the same performance characteristics. It is important to recognize the notion that these fixed wing aircraft will fly along more traditional air traffic service (ATS) routes (e.g., VOR radials, T-routes)

To ease the burden on ATC, self-provisioned spacing services will occur within the containment of the terminal IFP, although ATC will remain responsible for separation assurance for IFR flights. The concepts will be similar in nature to two concepts from NASA's Airspace Technology Demonstrator (ATD) Program, both of which are being used in the airliner industry today:

- **Speed Adjustments (Interval Management):** Based on operator traffic awareness, programmed speed adjustment will maintain along-track spacing for the internal fleet flying along the network of terminal IFPs.
- **Path Adjustments (Traffic Aware Rerouting):** Also based on operator traffic awareness, programmed path adjustments (path stretching) will be done within the containment bounds when the speed adjustment mechanisms are insufficient.

Airport and Infrastructure

With these concepts in mind, the operation will still be conducted in accordance with FAA IFR protocols, which will involve low controller scanning workload (given predictability of the operation) as well as very rare ATC intervention by exception (done over voice to the flight supervisor). These air traffic management (ATM) actions will be done by ATC tower or terminal radar approach control (TRACON) facilities depending on where the flight is. The initial operations involve designated surface resources (e.g., FATOs) that are located on existing heliports and non-towered airports. The products andservices necessary to conduct detect and avoid operation rely on ADS-B, air to air radar, and government radars for the TIS-B Message (as well private radars for information akin to TIS-B messages). Cruise navigation depends on Global Positioning System (GPS), Wide Area Augmentation System (WAAS) satellite navigation, and other legacy navigation infrastructure. As indicated above, there is a reliance on DataComm infrastructure in the areas of interest. As indicated earlier, additional surveillance infrastructure may be privately provisioned where there are gaps (e.g., private ground radar for non-cooperative surveillance, ADS-B Xtend for cooperative.)

Flight Operations and Conditions

All flights will be conducted IFR to make the operation as safe as possible. The fleet manager will file an IFR flight plan for these flights, checking all hazards, flight conditions and requirements. Pre-defined terminal IFPs will account for safe minimum altitudes for obstacle clearance and wake avoidance for airliners flying along other procedures (e.g., standard instrument departures (SIDs) from runways).

Note 5: The term “fleet manager” is used here in place of the more traditional “dispatcher” term in order to reflect a more advanced capability set. This advanced capability set will be embedded in the fleet manager’s fleet management system. This system will have key advancements over modern dispatcher/electronic flight bag (EFB) systems, such as traffic awareness features demonstrated in NASA’s Airspace Technology Demonstrator (ATD) Program.

Departure will be authorized by an integrated 4D trajectory sent over DataComm, and during the flight the operator will self-provision spacing services. Whether in VMC or IMC, the detect and avoid capability enables the aircraft to remain well clear of other aircraft and obstacles. The flight supervisor or autonomous response will coordinate with other aircraft and when approaching uncontrolled facilities, such as a Class G heliport. For example, the aircraft may automatically broadcast voice recordings of intentions over a common advisory frequency. Additionally, as mentioned before, increased awareness of the BVLOS activity may be facilitated by respective NOTAMs.

Community Impact and Acceptance

The expansion of the terminal IFPs can be added to the FAA’s helicopter modernization effort or exercised as a private effort (baseline) and will go through the appropriate environmental review.

For the baseline effort, the operator will work with a private company, that is certified for instrument flight procedure design, to define private/special terminal IFPs to andfrom FATOs that may be located on legacy heliports, non-towered airports, or novel vertiports. These will go through the appropriate environmental review. Unlike in Scenarios 1 and 2, traffic using these new IFPs may not fit the traffic patterns assumed for previous environmental reviews.

Constraints and Contingencies

High density GA VFR traffic in Class E and separation requirements for eVTOL IFR flight will need consideration. The baseline stances, to be validated/verified, is that DAA capabilities (supported by remote flight supervision) can safely handle GA VFR traffic and that the containment bounds of the terminal IFPs, including contingency terminal IFPs to alternatives, can be integrated into the metroplex.

In the event of an emergency or diversion to a non-towered airport, high-volume pattern traffic using radios might present challenges for the flight supervisor to communicate on CTAF. The mitigation is that all diversion sites will be predefined and have established private or special terminal IFPs that safely guide the BVLOS eVTOL through that environment to the designated FATO on the surface. These will be designed to avoid the previously established traffic patterns. Additionally, as mentioned before, increased awareness for the BVLOS eVTOL operation can also be established by NOTAMS.

Scenario 3a: Operations To/From Heliport and Non-Towered Airport

The eVTOL aircraft in this scenario plans to operate IFR between heliports or to non-towered airports from day 1. The operations will transit only Class G and E airspace and the operator will file IFR flight plans, but engagement with ATC should usually be limited to the issuance of an end-to-end 4D trajectory authorization, aligned with what was previously filed. These operations will use a certified aircraft with a flight supervisor in a scheduled and/or non-scheduled part 135 operations. During the airspace planning phase of these initial passenger carrying BVLOS operations, the operator will work with local airspace authorities to establish the best methods for airspace access based on the unique characteristics and constraints of each region.

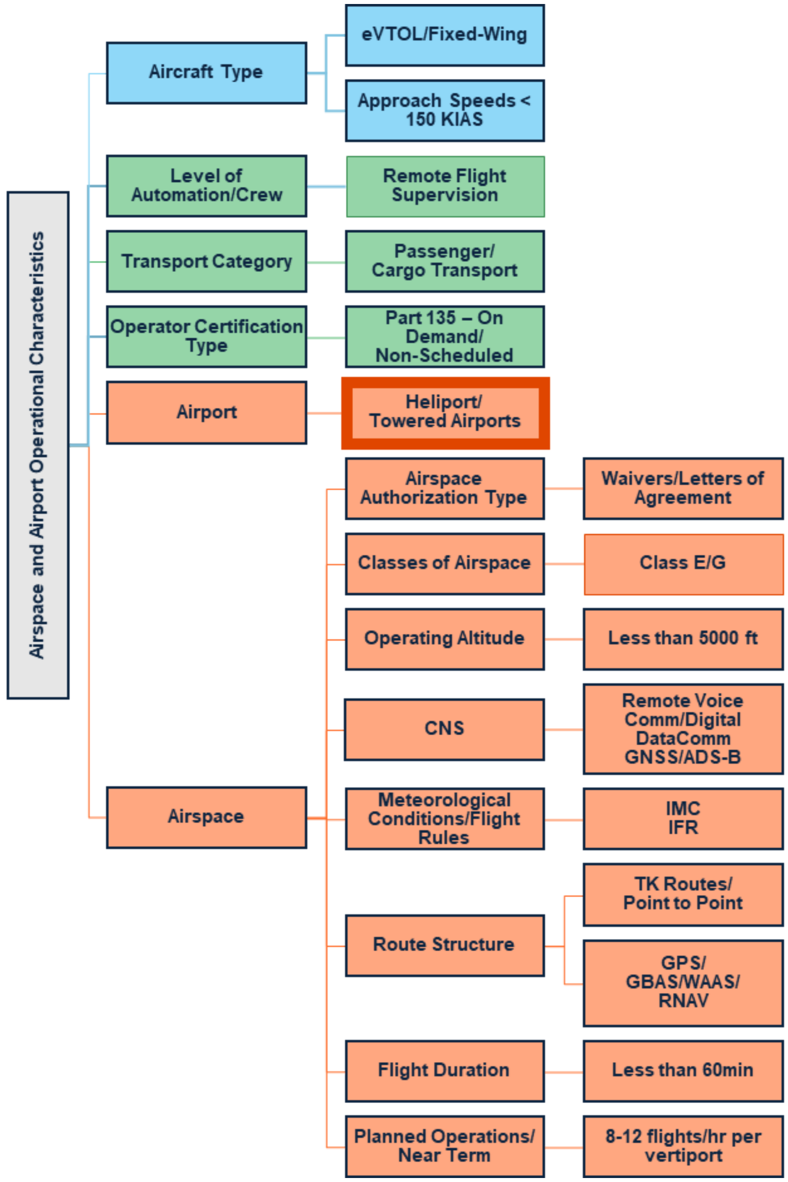

Figure 6. Assumptions in the Near Term for Day 1 Operations from Non-Towered Airports/Heliports in Class E/G

Scenario 3b: Operations To/From Heliport and Towered Airport

This scenario is akin to 2a, but a portion of the mission will go through an ATC tower's-controlled airspace.

- Designated FATOs will likely be placed near General Aviation (GA) terminals, outside of the ATC authorized movement area (where helicopter operations takeoff and land today).
- This requires handoff of control from a TRACON controller to an ATC tower controller.
- Private or Special Terminal IFPs to a designated FATO located near the GA terminal eliminates the need to enter a traffic pattern for a runway.

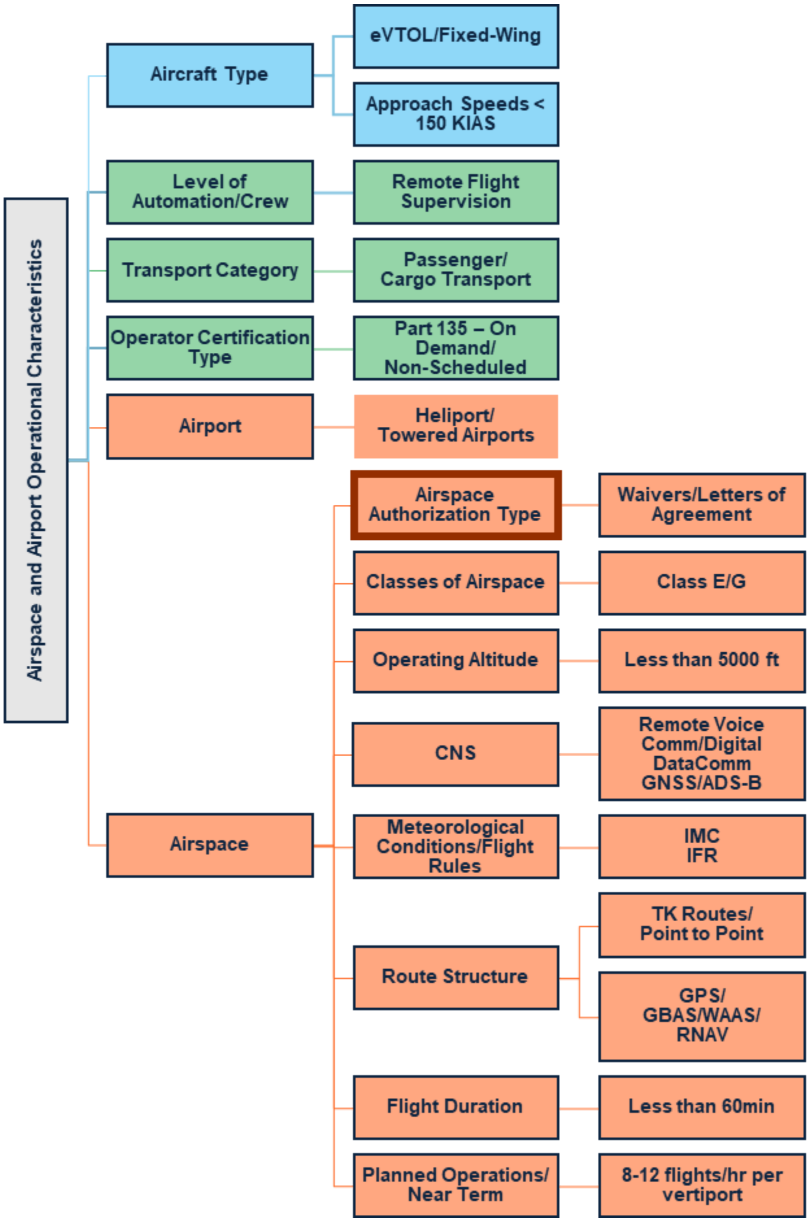

Figure 7. Assumptions in the Near Term for Day 1 Operatio*ns During IMC from Heliports/Towered Airports*

Scenario 3c: Operations To/From Towered Airports

This scenario is akin to 2b, but both the departure and approach portions of the mission (at a minimum) will go through ATC tower-controlled airspace.

- Designated FATOs will likely be placed near GA Terminals, outside of the ATC authorized movement area (where helicopter operations takeoff and land today).
- This requires handoff of control between TRACON controller and ATC tower controllers.
- Private or Special Terminal IFPs to a designated FATO located near the GA terminal eliminates the need to enter a traffic pattern for a runway.

CONCLUSION

Each of the three scenarios presented in this paper represents a category of AAM operations and describes how respective operations will interact with the existing NAS. They reflect an AIA perspective on considerations relevant to a range of operations envisioned within complex airspace surrounding metropolitan areas. These operational scenarios are intended to provide a starting point for defining the path to enabling mature AAM operations in the future. AIA intends to complement these descriptions of "day one" operations with descriptions of "mature state" operations. Following these state definitions, a roadmap will be developed to define the path for airspace integration between the states, including policy, regulatory, and technology gaps. In some cases, gaps exist even for day one operations and so AIA intends to develop roadmaps to enabling those scenarios as well, which will be published under a separate cover.

The scenarios in this document illustrate aspects of AAM operations that are novel: aircraft performance, level of automation, and scale or tempo of operations. Some, though by no means all, AAM aircraft will have novel performance characteristics, including electric vertical takeoff and landing aircraft (eVTOLs). To be safely integrated, air traffic controllers must be trained in their novel performance characteristics including any potential limitations. The aircraft must also demonstrate an ability to interoperate with existing users of the airspace.

AAM aircraft may possess an increased level of aircraft automation compared with typical commercial aircraft today, including the capability to be remotely piloted or supervised. Highly automated aircraft will require new capabilities to be certified, such as certified Detect-and-Avoid (DAA), as well as full Autoland and Autotakeoff capabilities. Furthermore, remote supervision will require increased reliance on ATC Automation Systems and associated DataComm messages instead of traditional, more tactical instructions relayed by voice. It should be emphasized that not all AAM aircraft will be highly automated or remotely piloted, many will have onboard pilots (Scenario 1) or safety pilots (Scenario 2, Block 1).

AAM operations may increase in scale and tempo compared with traditional aviation operations and be introduced in certain locations in which they are less common today. Initial operations will be at low tempos and be conducted under VFR or IFR, with growth proceeding at a pace that is dependent on many factors including demand, infrastructure, and airspace considerations. The airspace community should work together to understand potential limitations and the contributions of specific solutions to enabling increases in scale.

Road mapping activities to advance from day one to mature state operations will be guided by the general target timeline associated with each of the three scenarios. Scenarios 1 and 2 are expected to occur first (within the next five years), prioritizing activities aimed at integrating powered lift aircraft into the NAS for Scenario 1 and activities that ensure optionally piloted cargo aircraft have certified DAA capabilities for Scenario 2. Scenario 3 will require expanded use of DataComm and other capabilities, and so are expected to occur later in the decade. The activities required to enable the scenarios should, therefore, be pursued as parallel tasks. A high-level definition of the cross-scenario roadmap will follow the publication of this document.

AIA Emerging Technologies Committee, Airspace Working Group has identified next steps to assist stakeholders in enabling this emerging aviation segment. The Working Group is committed to engaging and enabling AAM through direct interaction with relevant stakeholders and providing industry perspectives to assist in the successful maturation of AAM operations. Industry leaders working actively to advance AAM operations who are interested in joining the Working Group are encouraged to reach out to AIA.

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