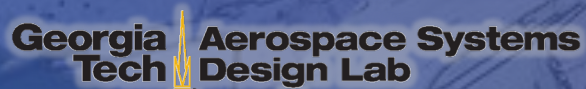


NASA
Urban Air
Mobility

November 2018

URBAN AIR MOBILITY (UAM) MARKET STUDY



Contents

- Introduction and summary by Crown Consulting, Inc.
- Market analysis by McKinsey & Company
- Public acceptance by McKinsey & Company
- UAM regulatory environment by Ascension Global
- Potential barriers by Georgia Tech Aerospace Systems Design Lab and Crown Consulting, Inc.
- Moving forward by Crown Consulting, Inc.

This report assesses UAM viability and potential barriers and solutions

Report Inputs

(Deliverable 1)

- **Interviews with >100 experts** across the Unmanned Aircraft Systems (UAS), eVTOL, regulatory, and relevant technology fields
- **Detailed assumptions and inputs** for >50 variables (such as wind shear and battery storage efficiency) for each use case model
- **Aggregated insights** from large consumer and business-to-business surveys with >2,000 respondents across 5 representative metropolitan areas

Living Econometric Model / User Interface (UI)

(Deliverable 2)

- **Detailed econometric model**
 - Living model that the Aeronautics Research Mission Directorate (ARMD) can update as variables change in the future
 - Complete documentation that the ARMD team can update to align with model changes
- **Executive user interface**
 - Tool that ARMD can use to explore the 10 most significant variables in each use case

UAM Market Study

(Deliverable 3 - Focus of this document)

- **Holistic assessment** of use case profitability by 2030
- **Review of technology, regulatory, and infrastructure** changes likely needed to achieve UAM operations
- **Overview of potential public acceptance landscape** and possible solutions and barriers to widespread UAM adoption

Five principles guided the development of this report

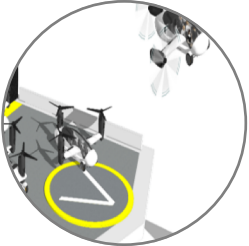
- 1 **Flexible:** Since UAM is quickly evolving, ARMD will likely require a *rigorous and dynamic model* that can evolve as technology changes, not a static report that will quickly become obsolete
- 2 **Challenging:** The assessment should evaluate the most challenging use cases to *push the boundaries of technology and regulatory constraints*
- 3 **Unbiased:** To avoid a biased answer, the UAM assessment should draw on a *diverse set of stakeholders* (e.g., original equipment manufacturers [OEMs], component manufacturers, infrastructure providers, operators, regulators, special interest groups)
- 4 **Exhaustive:** *The full system of costs* (across OEMs, operators, and infrastructure providers) should be included, not just the vehicles and supporting equipment
- 5 **Consumer-backed:** UAM models should incorporate *consumer and business willingness to pay*, since price may be a major barrier to widespread adoption

Analysis focused on the three most challenging (and different) UAM use cases



Use case 1 – Last-mile delivery

Rapid delivery of packages (less than 5 lb.) from local distribution hubs to a dedicated receiving vessel. Deliveries are unscheduled and routed as online orders are placed



Use case 2 – Air metro

Resembles current public transit options such as subways and buses, with pre-determined routes, regular schedules, and set stops in high traffic areas throughout each city. Vehicles are autonomously operated and can accommodate 2 to 5 passengers at a time, with an average load of 3 passengers per trip



Use case 3 – Air taxi

The air taxi use case is a near-ubiquitous (or door-to-door) ridesharing operation that allows consumers to call vertical takeoff and landing aircraft (VTOLs) to their desired pickup locations and specify drop-off destinations at rooftops throughout a given city. Rides are unscheduled and on demand like ridesharing applications today. Like the air metro case, vehicles are autonomously operated and can accommodate 2 to 5 passengers at a time, with an average load of 1 passenger per trip

Study findings

- **Near-market segments:** A commercially viable market for last-mile parcel delivery and air metro could be in place by 2030
- **Likely market constraint:** There is likely a limited potential market for air taxis in concentrated areas of high net worth individuals and businesses in 2030
- **Key challenges:** For UAM to be viable, it is necessary to address the technical, physical, operational, and integration challenges of a highly interdependent system-of-systems
- **Dependencies for the market to become viable:**
 - Safety and security
 - Economics
 - Transportation demand
 - Regulation
 - Market substitutes (e.g., autonomous delivery and transportation)
 - Public acceptance

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Findings are informed by interviews, surveys and research

Econometric model

- Algorithm to test economic viability of UAM (3 separate use cases), incorporate consumer (and business) demand and willingness to pay; UAM industry costs (including over 50 variables); weather and technical constraints; and evolution of costs over time
- Adaptable and 'living' parametric model that allows ARMD to continually update key data items as the market evolves

Over 200 expert/executive interviews, including with:

Director of Product, Aircraft company	Former General Manager, Aircraft company
Former Sr. Manufacturing Engineer, Automotive company	Former Technical Operations Manager, Retailer
Former Field Operations Manager, UAS company	Current Chairman of UAS association
Former CEO, Global Freight Forwarding, Logistics company	Head of Business Development, Logistics company
Former Sr. Manager, Retail company	Manager, C-UAV company
Former President and CEO, Helipad company	VP of Sales, UAS company
Chief Marketing Officer, UAS company	COO, Aircraft company
Former Group Leader, Aircraft company	Program Manager, Defense company
Founder, Aircraft company	Director of Technology, Logistics company
Former Regional Operations Manager, Logistics company	Former Managing Director, Automotive company
Former VP of Engineering, and Systems, UAS company	Former Head of Operations, Ground robotics company
Former Director of Global Bus. Dev., Logistics company	Former Head of ADAS, Automotive company
Former Executive VP, Automotive company	Former Vice President, Delivery logistics company
Founder/Managing Member, UAS company	Former Autonomous Vehicle Instructor, Automotive company
Former Vice President of Operations, Sensor company	Director, UAS university research program
Former Project Manager, Aircraft company	Director, UAS university program
Former VP of Operations and Strategy, UAS company	Former Vice President, EU delivery logistics company
Founder, UAS company	Executive Director, UAS test site
Co-Founder, Aircraft operations company	Former Chairman, UAS association
Former Civil Certification Manager, Helicopter company	7+ additional topical experts (e.g., warehousing)

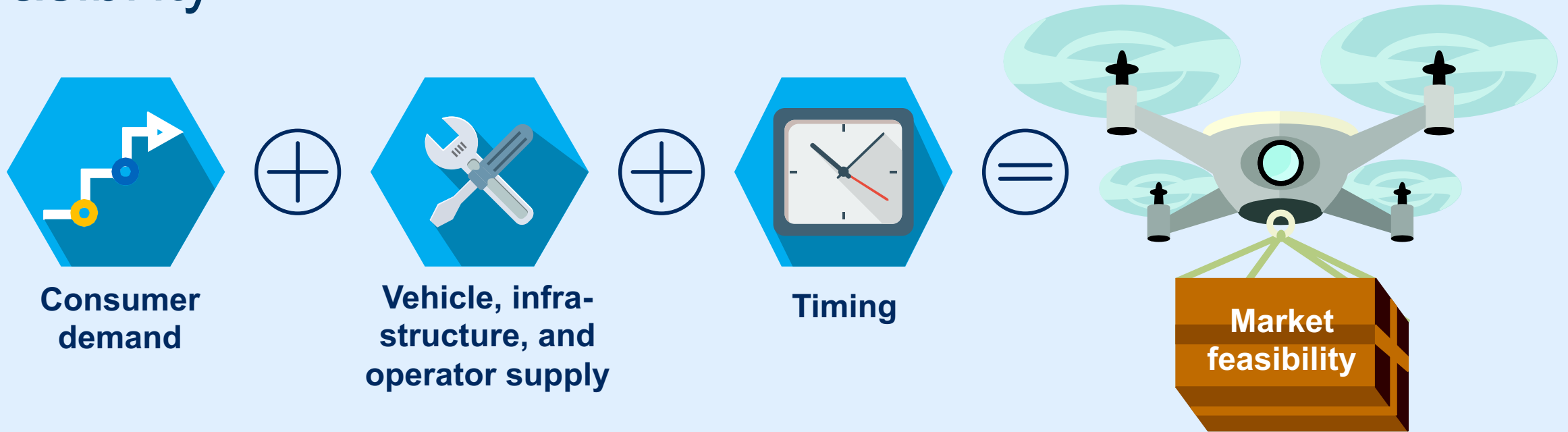
Survey with 2,000+ consumer/business respondents

- Current transportation and delivery spend by consumer income and age
 - Consumer willingness to pay for increased speed across both transportation and delivery use cases by income, age, and average trip duration
 - Public acceptance of UAS technology, broadly, and transportation and delivery UAM options, specifically
-
- Current B2B delivery spend by company size and speed preferences
 - Business willingness to pay for increased delivery speed

Data and research

- Frost & Sullivan, "Future of Flying Cars 2017-2035"
- Teal Group, "World Civil Unmanned Aerial Systems: Market Profile and Forecast 2017"
- Frost and Sullivan, "Global Commercial Mapping and Surveying Unmanned Aerial Systems Services Market," 2016
- Uber Elevate White Paper
- Resilient Ops, Inc., "Traffic Flow Management in the Presence of Unmanned Aircraft"
- University of Massachusetts Amherst, "Unmanned Aircraft System traffic management: Concept of operation and system architecture"
- US Postal Service (USPS) report, "Public Perception of UAS Delivery in the US"
- US Department of Transportation (DOT) report, "Exploring the Relationship between Travel Demand and Economic Growth," 2012

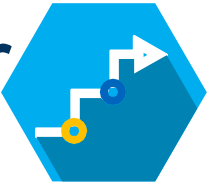
Econometric models were structured around supply, demand, and time to develop a perspective on market feasibility



[Market feasibility uses net market profitability across the value chain as a proxy for viability¹]

¹ The net profitability across the value chain is used as an assumption for market viability, but there may be cases (e.g., well funded actors investing ahead of market profitability or market subsidies) that drive investment in the market well ahead of the assumed 3- to 5-year market ramp up time.

Demand was driven by the target market, consumer willingness to pay, and technology availability



What is the target market(s)?

Consumers living within the 15 largest metropolitan areas in the US (by 2030 population)

- Total population of 15 target metropolitan areas
- Population segmentations by age, income, and length (in time) of travel

How much will the target market grow?

The population is projected to grow in targeted metropolitan areas in the US; the projected segment growth was determined for each sub-segment (e.g., by age and income for delivery)

How much does the target market spend?

Defined current transportation and delivery spend within target markets, including current transportation and delivery options and costs

How much more is the target market willing to spend?

Determined the willingness to pay for increased transportation and delivery speed

- Customer key buying factors (e.g., speed, price, comfort)
- Willingness to pay for increased speed

What competing technologies may the target market choose in the future?

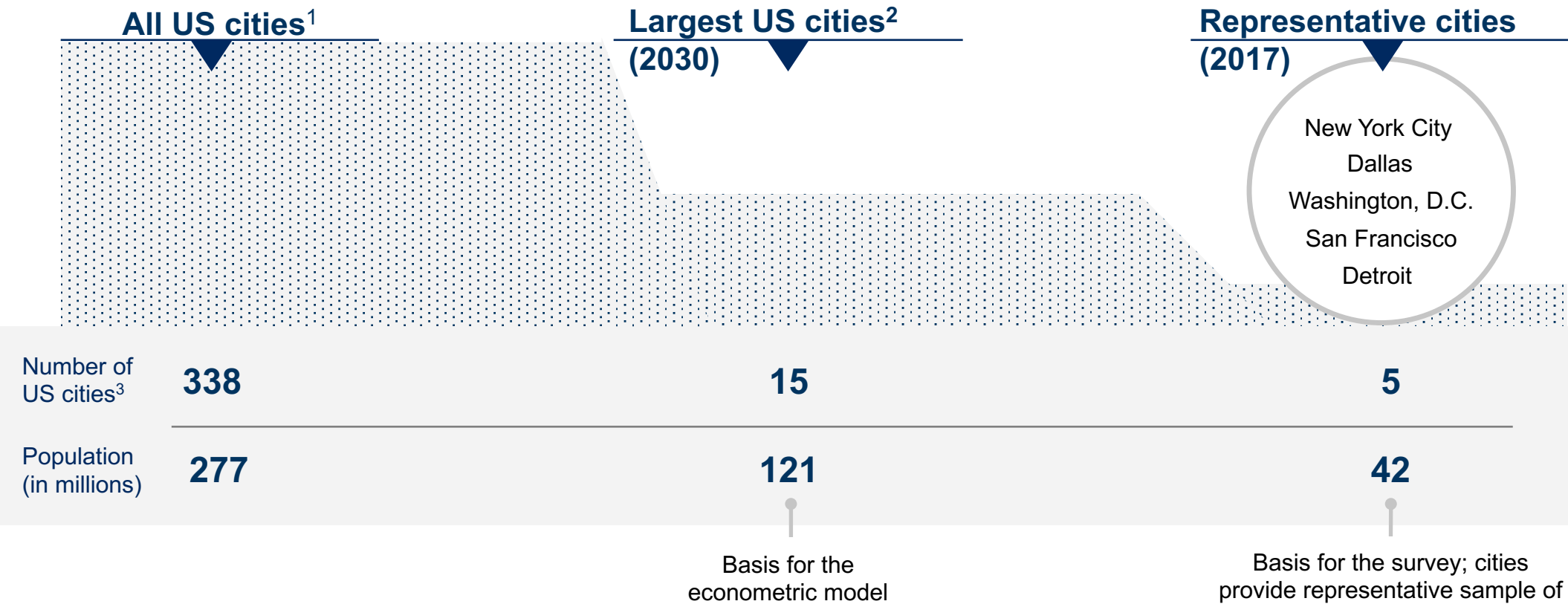
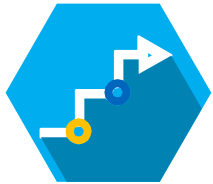
Driverless cars, driverless car rideshares, robo taxis, AGV lockers and other technologies that are likely to provide the same service in the future

- Projected adoption rate for future technologies
- Projected costs for future technologies

What portion of the market will adopt new UAM technologies?

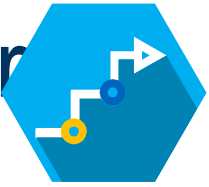
Defined percentage of consumers willing to pay for improved speed who are open to autonomous air taxis, air metros, and UAS, including projected public acceptance by income segment, age, and average trip duration

Demand was modeled for the 15 largest US cities, and 5 representative cities were surveyed



1 As defined by the US Office of Management and Budget (OMB).
2 15 largest metropolitan areas (by city name): New York City, Los Angeles, Chicago, Dallas, Houston, Miami, Atlanta, Washington DC, Phoenix, Philadelphia, San Francisco, Boston, Riverside, Seattle, Detroit.
3 Defined as the metropolitan statistical area.
Source: United States Census, BOC, Moody's Analytics.

Willingness to pay and adoption rates were derived from surveys with over 2,500 respondents

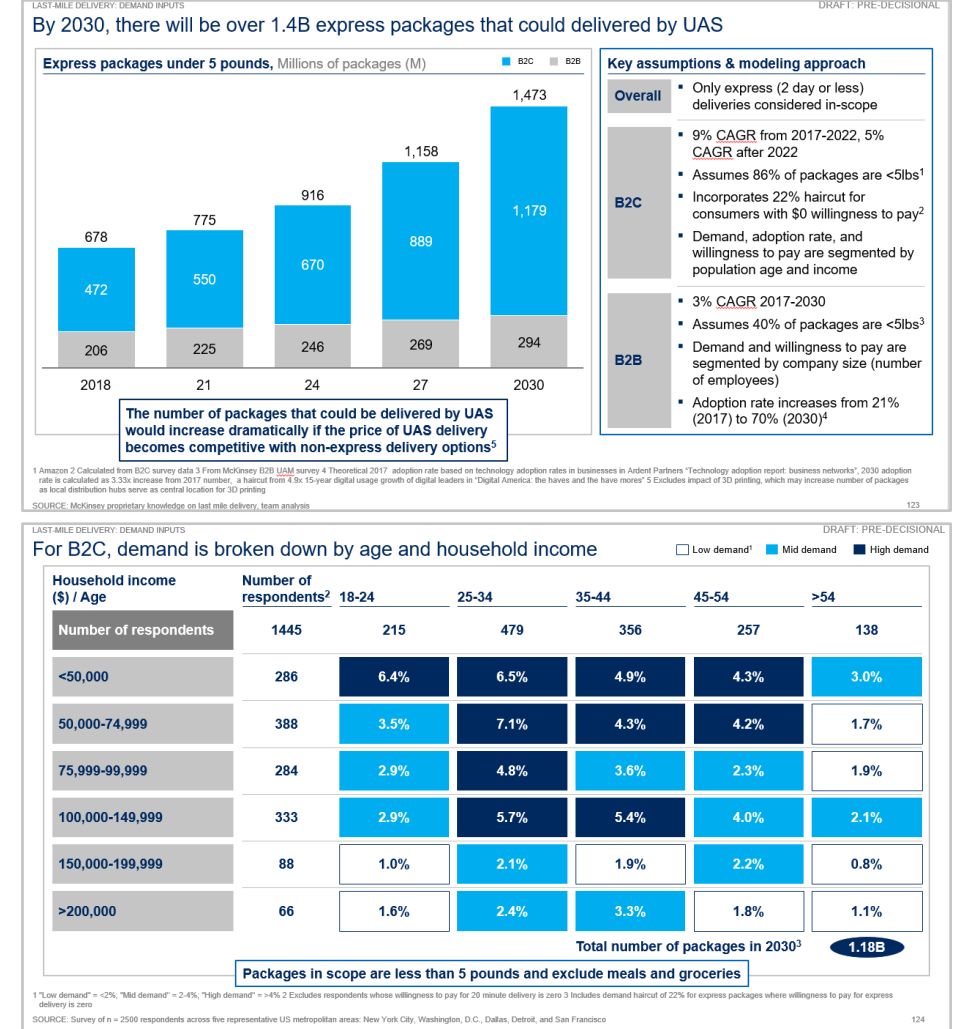


ILLUSTRATIVE

Methodology for determining consumer demand

- Representative cities (New York City, Dallas, Washington, DC, San Francisco, and Detroit) were selected for survey distribution based on their market characteristics
- Surveys included >2,500 consumers and >200 shipping and logistics coordinators in businesses, and were weighted to reflect the demographic characteristics (e.g., age, income) of the 15 MSAs
- Respondents were asked about current package delivery and travel preferences, their willingness to pay for immediate delivery (<20 minutes) and rapid travel times (<20 minutes and <10 minutes), and their willingness to adopt autonomous delivery and transportation technology
- Responses were examined across multiple demographic characteristics, including age, income, and current commute length, to determine the best predictors of willingness to pay and adoption rates
- The last-mile delivery model was segmented into business-to-consumer (B2C) and business-to-business (B2B) categories; willingness to pay and adoption rates were sub-segmented by age and income of the consumer (B2C) and number of employees (B2B)
- The air metro and air taxi models were segmented into commuter and non-commuter categories; willingness to pay and adoption were sub-segmented by average trip time and income
- Model sub-segments (e.g., number of individuals age 25 to 34 making \$75,000-\$100,000) and their willingness to pay and adoption rates were used to determine demand for the econometric models

Illustrative outputs of demand sub-segments



UAM supply is a function of OEM, infrastructure provider, and operator cost structures



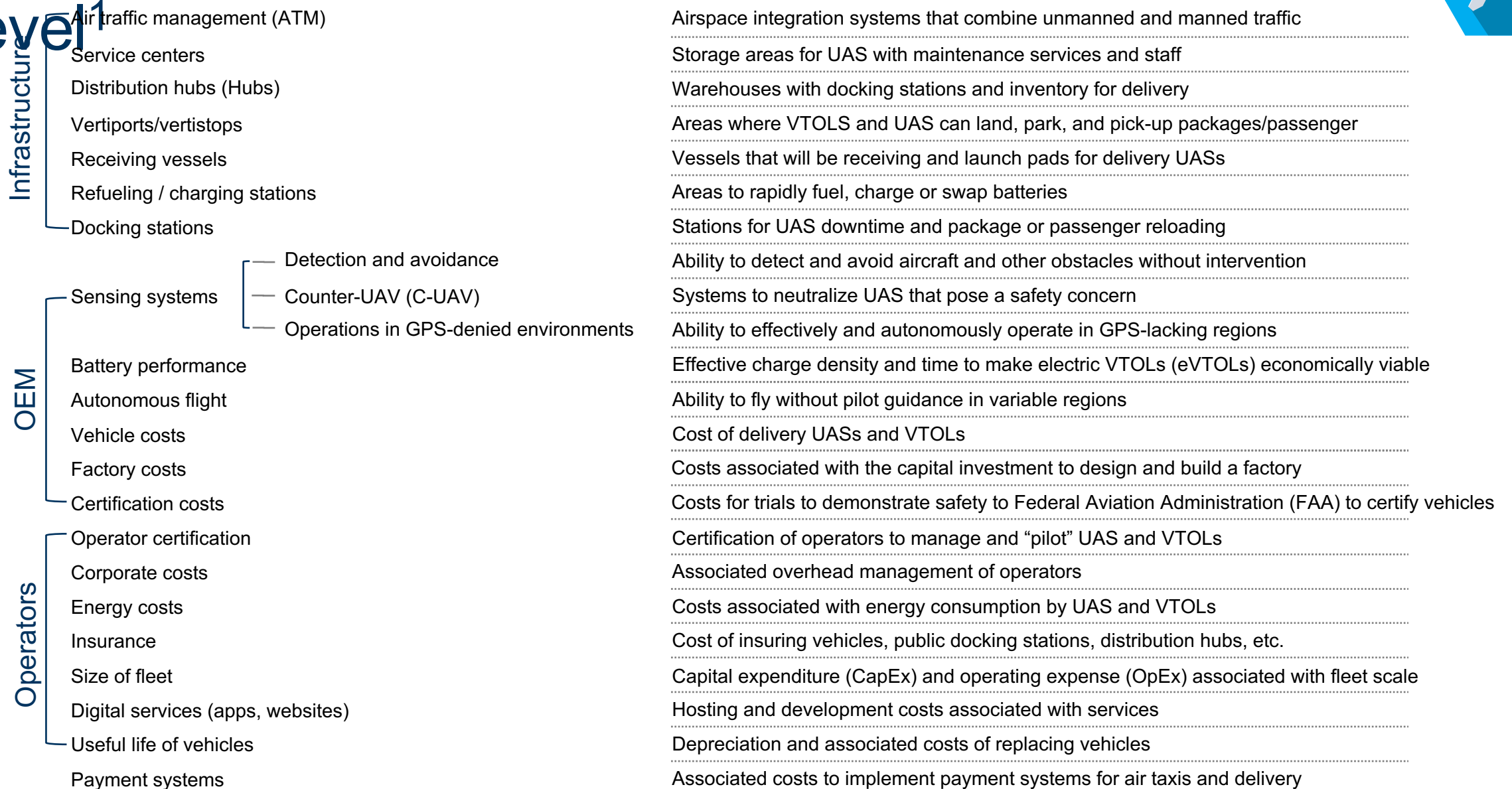
What is the cost structure for infrastructure providers?

What is the cost structure for UAM operators and service providers?

What is the cost structure for OEMs?

Sensitivity curve of volume supplied by cost point

The cost structures were modeled at a detailed level¹



¹ Analysis relates solely to cost structures for supply; regulatory aspects are excluded as they will be used separately to develop timing and sequencing of market events.

Beyond the demand and supply variables, econometric models made several critical assumptions

Use case-specific assumptions

- Receiving vessels for last-mile delivery are positioned to allow for (average) door-to-door 20-minute delivery
- Vertiports for the air metro case are positioned to enable 20 minute door-to-door trips¹
- Vertiports and vertistops in the air taxi case are positioned to enable 10-minute door-to-door trips²
- Air metro assumes 3 passengers per ride while air taxi assumes 1 passenger per ride

Vehicle assumptions

- Delivery UAS are highly modular, which increases useful life and the number of purchased components
- Transportation UAS have modular batteries; other components are replaced with the vehicle
- Delivery UAS are assumed to have 0.5 days per week of potential maintenance time and operational downtime while transportation vehicles have 1.5 days per week. Additional haircuts on operational time are incorporated for loading, unloading, battery swapping, and weather

Technology, infrastructure, and regulatory assumptions

- Technology in key areas, such as Unmanned Traffic Management (UTM), detect-and-avoid, noise management, operations in GPS-denied environments, and automation, will have step-change advances
- Costs of key technologies currently on the market (e.g., LiDAR, battery storage, sensing and navigation systems) will decline significantly
- Private and public entities will be willing to invest in and build key infrastructure requirements (e.g., receiving vessels, vertiports) to provide the necessary coverage for UAM operations
- Regulations will be in place that allow UAM operations to occur (such as airworthiness standards for vehicles to be created), and regulations and local ordinances will not block UAM, including no local ordinances that limit the construction or placement of key enabling infrastructure elements (i.e., receiving vessels, distribution hubs, vertiports, or other infrastructure)
- Certification processes will take into account the rapidly changing technology in the space and the models will incorporate year-by-year cost curves for each of the components (e.g., battery cost, airframe costs); it is also assumed that regulation will allow manufacturers to rapidly move down cost curves

¹ Commute times are an average and will vary by location and distance traveled.

² To enable 10-minute door-to-door commute times (on average), vertiport and vertistop infrastructure must be ubiquitous.

UAM is likely to be a commercially viable market with both parcel delivery and air metro use cases

Last-mile parcel delivery

- Projecting a potentially profitable market by 2030
- A significant ramp-up of UAS delivery in the years prior to profitability is likely as e-commerce players “lean in” to the market

Air metro

- Could potentially be profitable by 2030 assuming that regulations are in place to accommodate this market
- In anticipation of profitability by 2030, larger-scale “entry into service” may occur in prior years
- Piloted air metro services may be a stepping stone to large-scale autonomous operations

Air taxi (limited)

- High investment costs make a widespread air taxi market with ubiquitous vertiports unlikely in 2030
- There may be concentrated areas of high net worth individuals and businesses served by an air taxi solution (e.g., Manhattan to suburbs)

1 | Last-mile delivery

Last-mile delivery is rapid package delivery from local distribution hubs to a receiving vessel. Deliveries are unscheduled and flight times are determined as orders are placed

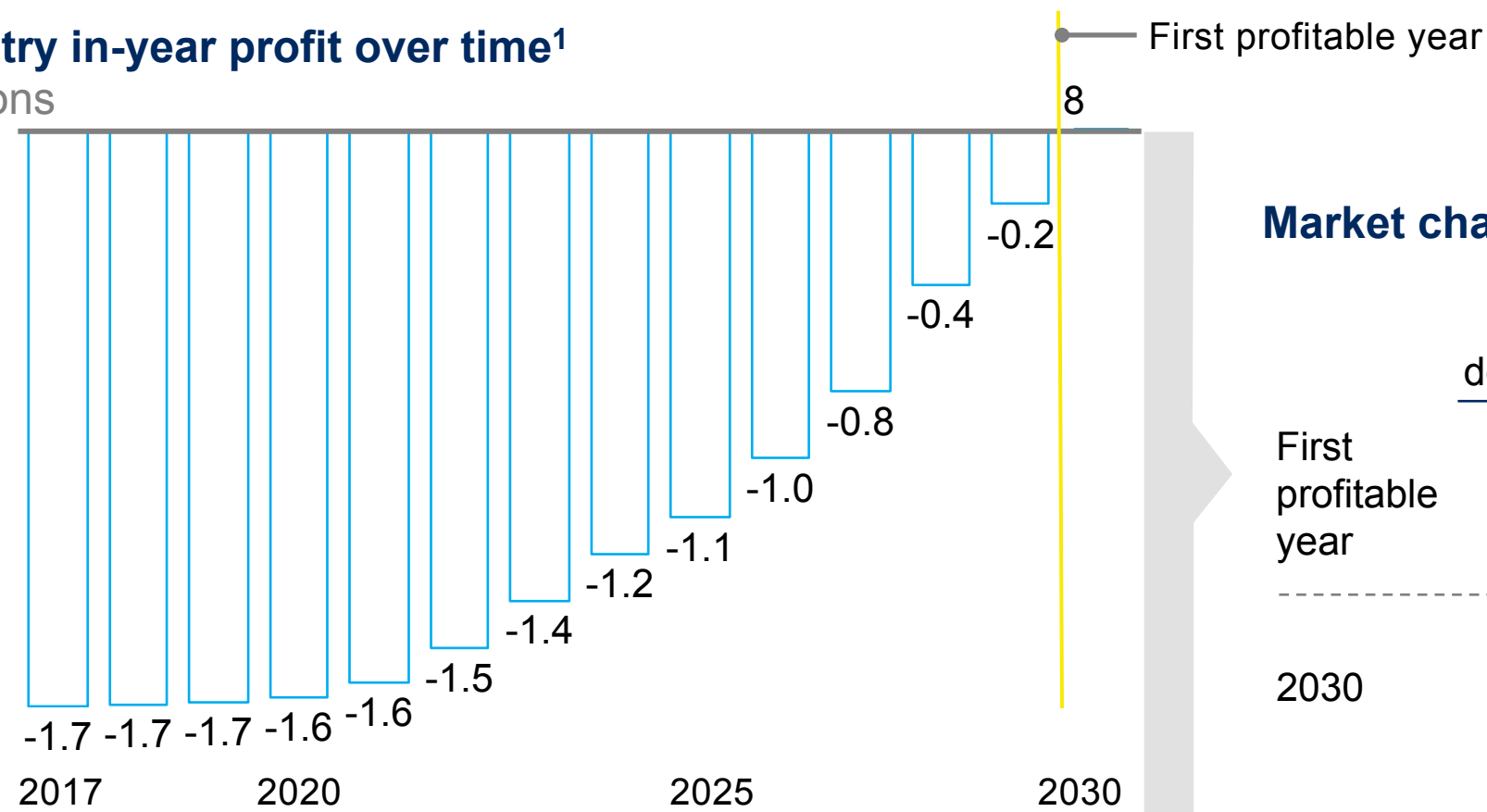
Use case attribute	Characteristics
Vehicle	Small UAS
Payload	5 pounds
Distance	Within ~10 miles roundtrip
Scheduling and routes	Deliveries are unscheduled and routes are determined as orders are received
Infrastructure	Receiving vessels, distribution hubs, docking/charging stations, UTM
Technology	Improvements in battery technology, autonomous flight technology, detect-and-avoid (e.g., LiDAR, camera vision), electric propulsion, GPS-denied technology
Potential regulatory requirements ¹	BVLOS (Beyond Visual Line of Sight), air worthiness, UTM, flight above people, altitude restrictions, operator certification, identification, environmental restrictions
Competing technology	Autonomous and human driven ground delivery services (e.g., FedEx, UPS, Amazon Prime), courier services, AGV lockers, droids



¹ Regulatory requirements are likely to range across use cases depending on risks (for example, delivery case may have less stringent airworthiness requirements than air taxis).

UAS last-mile delivery may have a viable market in 2030

Industry in-year profit over time¹
\$ billions



Market characteristics

	No. deliveries	No. vehicles	Price (\$/delivery)
First profitable year	0.5B	40k	\$4.20
2030	0.5B	40k	\$4.20

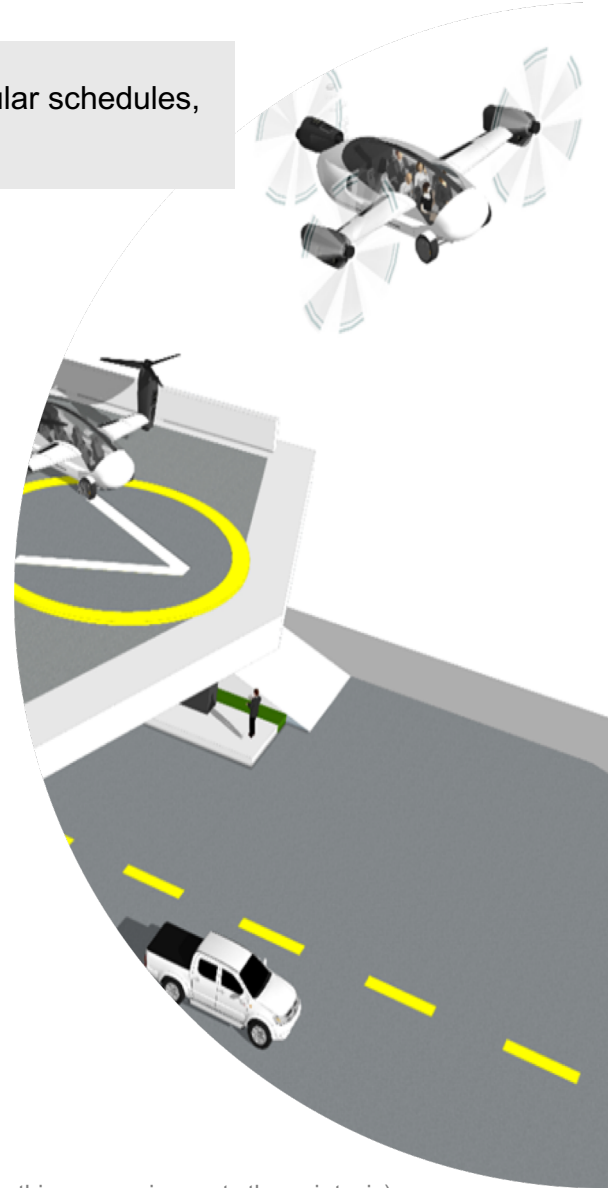
Last-mile delivery may become more profitable post-2030 as the number of deliveries increases

¹ Industry in-year profit implies net in-year profitability across the entire value chain if the market existed (including OEMs, operators, and infrastructure providers), not projected investment losses. It assumes that all regulatory challenges are overcome.

2 | Air metro

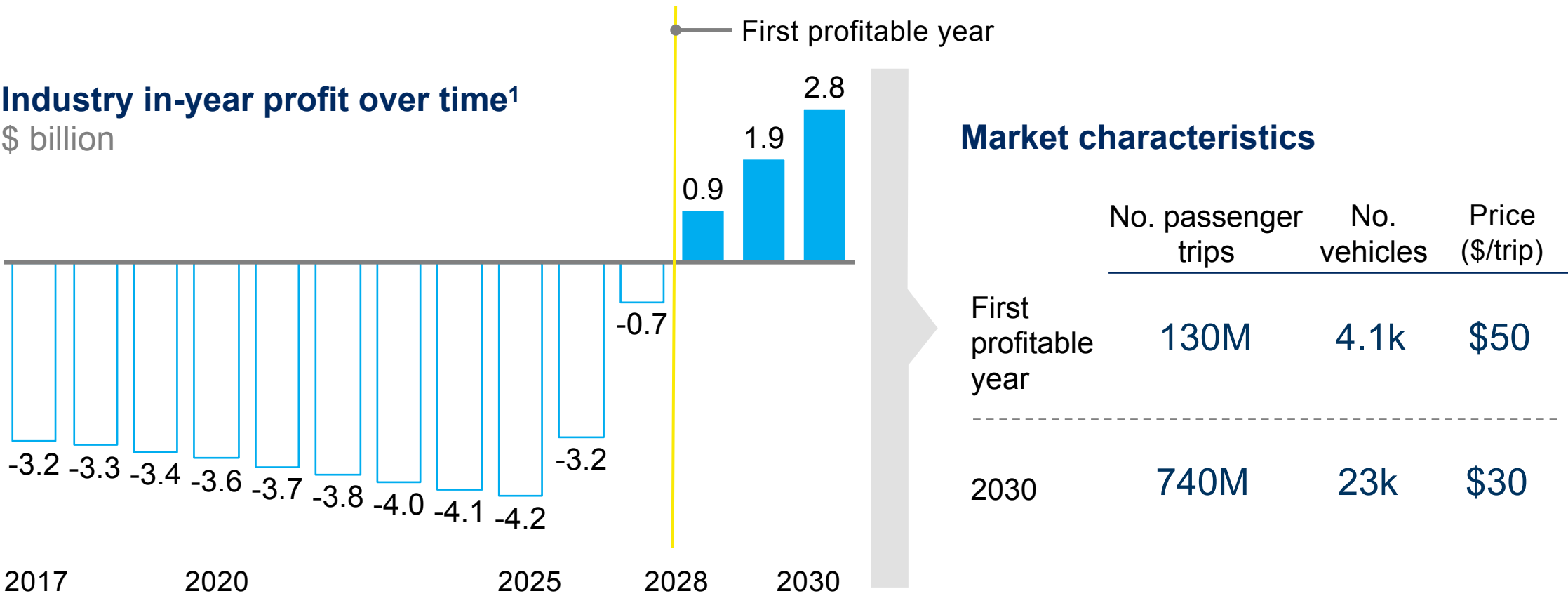
The air metro use case resembles current public transit options such as subways and buses, with pre-determined routes, regular schedules, and set stops in high-traffic areas throughout each city

Use case attribute	Description at end state
Vehicle	2-5-passenger autonomous (unpiloted) VTOLs ¹
Payload	~1,000 pounds
Distance	~10-70 miles per trip
Scheduling and routes	Routes are predetermined and scheduled well in advance of flight time
Infrastructure	~100-300 vertiports per MSA located in high-traffic areas capable and of handling ~3-6 VTOLs at once (on average); charging stations; service stations; UTM
Technology	Improvements in battery technology, autonomous flight technology, detect-and-avoid (e.g., LiDAR, camera vision), electric propulsion, GPS-denied technology
Potential regulatory requirements ²	Development of air worthiness standards, UTM, flight above people, weight and altitude restrictions, BVLOS, operator certification, identification, environmental restrictions
Competing technology	Subway, bus, bike, rideshare, driverless cars (personal vehicle, ride-hail, or rideshare)



¹ Vertical Takeoff and Landing ² Regulatory requirements are likely to range across use cases depending on risks (for example, delivery case may have less-stringent air worthiness requirements than air taxis).

Air metro may have a viable market in 2028



¹ Industry in-year profit implies net in-year profitability across the entire value chain if the market existed (including OEMs, operators, and infrastructure providers), not projected investment losses. It assumes that all regulatory challenges are overcome.

Vertiport operations in 2030 could follow a distributed hub and spoke model

Distributed hubs would likely be located in heavily trafficked areas. To accommodate high volumes, a cluster of rooftops in the area may have vertiports and could together serve as the “hub”

Suburban areas may be serviced by 1 to 2 vertiports – “the spokes”

Each vertiport may service a limited number of routes. Routes will be demand-driven and may be modified or updated as demand shifts. Passengers may reserve seats in advance to allow for route optimization

As the business case for air metro services becomes firmly established, structures specifically built to accommodate VTOLs may emerge



3 | Air taxis

The air taxi use case is a door-to-door ride-sharing or ride-hailing operation that allows consumers to call VTOLs to their desired pick-up locations and specify drop-off destinations at rooftops throughout a given city. With air taxis, the destinations are chosen by the passengers

Use case attribute	Characteristics
Vehicle	2- to -5-passenger autonomous (unpiloted) VTOLs ¹
Payload	~1,000 pounds
Distance	~10-70 miles per trip
Scheduling and routes	Routes are unscheduled and unplanned and are likely different each time
Infrastructure	Very large density of vertistops on or near buildings to create a “door-to-door” service; charging stations; service stations; UTM (unmanned traffic management)
Technology	Requires improved battery technology, autonomous flight, detect-and-avoid (e.g., LiDAR, camera vision), electric propulsion, and GPS-denied technology
Potential regulatory requirements ²	Significant OEM requirements for air worthiness, BVLOS, UTM, flight above people, weight and altitude restrictions, operator certification, identification, environmental restrictions
Competing technology	Human-driven cars (personal vehicle, ride-hail/taxi, rideshare), driverless cars (personal vehicle, ride-hail, rideshare), commuter rail, subway, bus



¹ Vertical takeoff and landing ² Regulatory requirements are likely to range across use cases depending on risks (i.e., delivery case may have less-stringent air worthiness requirements than air taxis).

The cost of ubiquitous vertistops may make the air taxi model prohibitive in 2030

Annual cost per vertistop (\$k)	Max walk time to vertistop (min) ¹ , based on distance between vertistops (miles)				
	Air taxi cost per trip (\$/trip)				
	2.5 min (0.3 mi)	6 mins (0.7 mi)	8.5 mins (1 mi)	13 mins (1.5 mi)	17 mins (2 mi)
10k	\$150	\$101	\$95	\$92	\$91
50k	\$393	\$145	\$117	\$102	\$96
100k	\$697	\$201	\$144	\$114	\$103
300k	\$1,912	\$424	\$254	\$162	\$131
500k	\$3,126	\$647	\$363	\$211	\$158

“Ubiquitous” vertiport assumption

Best cost estimate

- The primary barriers to the air taxi model with ubiquitous vertistops:
- Infrastructure required is dense to accommodate truly “door-to-door” on-demand service
 - The model assumes one passenger per trip, whereas there are three passengers per trip in the metro case

¹ Based on an average walking time of 17 minutes/mile.

While air taxis are unlikely to be ubiquitous and profitable in 2030, some localized or niche market scenarios could run profitably

- Although under current constraints the model suggests that air taxis are unprofitable for widespread consumption, there are a few possible scenarios wherein an air taxi business may be viable that could be considered
- Additionally, although it may be unprofitable in 2030, the synergies between delivery and air metro infrastructure investments (i.e., UTM, vertiports), as well as investment in technologies leading to cost declines (i.e., batteries, sensing systems) may lead to a post-2030 follow-on market

The air taxi vision proposed in this model requires nearly ubiquitous infrastructure that is unlikely to be achieved in 2030

- To satisfy the vision of creating a taxi system (i.e., door to door, unscheduled) the model assumes there is a walking time of less than 3 minutes to a stop at any time, which makes widespread infrastructure costs across all MSAs unlikely by 2030
- Technology and infrastructure required is nearly identical to the air metro use case, though the air taxi model requires a greater density of vertistops to satisfy people's need for nearly door-to-door service

Although this market may not be ubiquitous in 2030 there is the possibility for localized profitability:

- In some highly-dense areas (i.e., Manhattan, Boston, SF, Miami, Philadelphia) there may be an opportunity for profitability where a limited number of vertistops would be able to effectively serve certain populations
- There may also be an initial market that primarily serves businesses and wealthy individuals (similar to today's helicopter services between NYC and the Hamptons), that may act as a catalyst for a future market that can serve the broader population

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Public acceptance

- Overall, **25% of the >2,500 consumers surveyed** report they are comfortable with unmanned aerial technology; approximately 25% of consumers report they will not use UAS or eVTOLs when services become widely available. This means that nearly half of all consumers surveyed are potentially comfortable with delivery and UAM use cases
- Across all unmanned aerial use cases, concerns from consumers fall into 5 major categories: safety, privacy, job security, environmental threats, and noise and visual disruption
 - When it comes to UAS last-mile delivery, consumers are specifically concerned about safety (e.g., vehicles malfunctioning and damaging people and property), theft of packages, and invasion of privacy from vehicle camera systems
 - In UAM transport cases, consumers are most concerned about the safety of both passengers and bystanders and prohibitively high costs associated with operations
- Consumers cite proven safety records and demonstrations as factors that would most increase their level of comfort with UAM
- A comprehensive strategy to address public concerns may include targeted technology R&D, unified messaging to counteract misinformation, proactive engagement with interest groups, and large-scale demonstrations of use case capabilities

Public concerns generally fall into five categories



Consumers distrust autonomous technology and are not aware of safety systems in place



Privacy

Civil liberties groups have privacy concerns with widespread UAM adoption but may misunderstand how camera equipment is used in sensing system technology



Jobs

There is concern that autonomous technology will render jobs obsolete across multiple industries



Environment

Waste buildup from batteries, impact on wildlife, and energy usage concern younger consumers

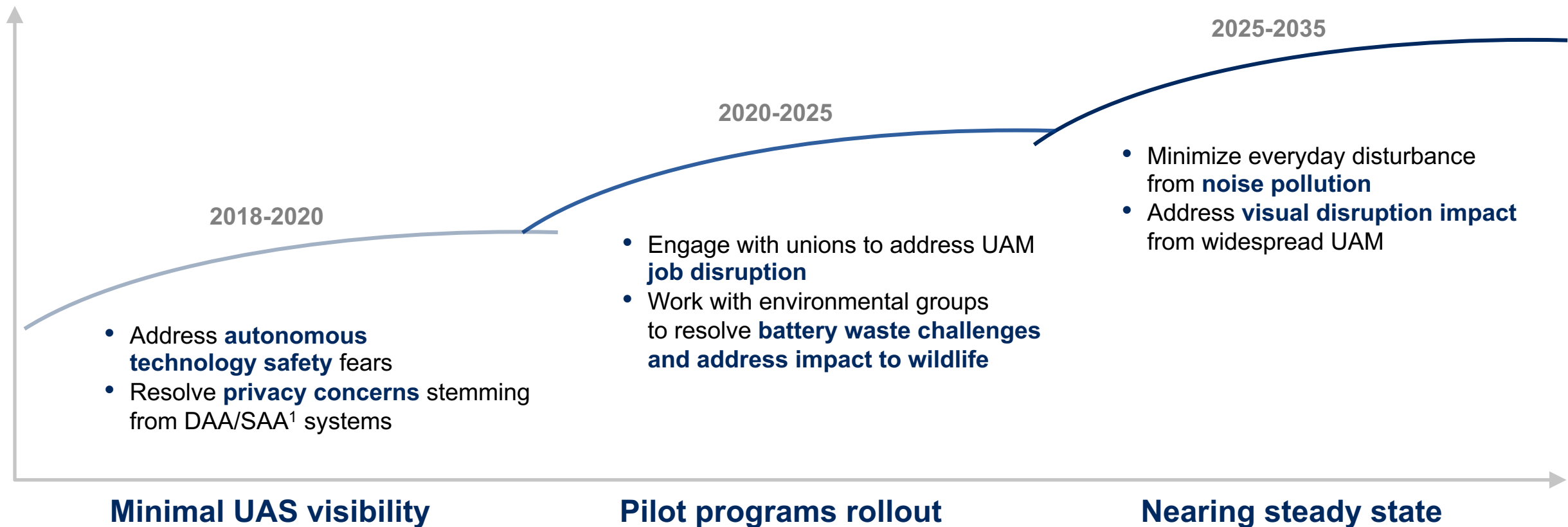


Noise and visual disruption

Auditory and visual disturbances in residential neighborhoods are likely to create strong, localized pushback as the market expands

Concerns may evolve as UAS become more prevalent

In addressing public concerns with UAM, early efforts could consider utilizing a phased approach



¹ Detect-and-avoid (DAA) or sense-and-avoid (SAA) systems..

Three strategies could help address public acceptance concerns

Mitigation strategy	Description
1 Technology R&D	<ul style="list-style-type: none">• Invest in key technologies to improve UAM adoption• Focus on noise abatement and safety systems• Establish safety standards (for instance, through FAA coordination)
2 Unified messaging campaign	<ul style="list-style-type: none">• Leverage UAM partnerships to coordinate messaging campaign between UAM stakeholders• Address public concerns and emphasize benefits
3 Proactive engagement with concerned groups	<ul style="list-style-type: none">• Identify groups that may organize resistance to UAM• Hold forums and co-create solutions to address these concerns

Effective large UAM demonstrations could draw on these three strategies

- Pilot programs may provide a demonstrated safety case to alleviate consumer concerns
- Large-scale demonstrations could provide an avenue for both government and industry to test use case visions and new technologies
- Prior to piloting, stakeholders should consider working to create a unified messaging campaign that preemptively addresses public acceptance challenges
- By engaging activist and interest groups early, pilot programs could test methods for addressing feedback

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Study findings: overview of the regulatory environment

- Today, **the regulatory environment does not permit the types of vehicles and operations that scalable UAM** would entail
 - **Last-mile delivery** is **heavily restricted** and **permitted only through the use of waivers and COAs**
 - **Air metro and air taxi regimes are permitted only as traditional manned helicopter services**, which leave out critical components of their business cases (e.g., autonomy, eVTOL design)
- However, the **DOT Integration Pilot Program (IPP)** is **opening up opportunities for expanding last-mile delivery** pilots
- In order to enable last-mile delivery, air metros, and air taxis, there are **five major categories of regulation** that need to be addressed: air traffic & fleet operations management, vehicle development & production, airspace design & implementation, individual vehicle management & operations, and community integration
 - The **majority of regulatory requirements reside at the Federal level** under the jurisdiction of the FAA, DOT, and DHS; however, there is likely to be **significant state and local involvement in certain areas** in the form of registration requirements for operators and vehicles, zoning and infrastructure requirements, and local ordinances
- Absent significant changes, the timeline for the regulatory climate to be in place for **scalable operations is in the near-term (~2-5 years) for last-mile delivery** and **mid- to long-term (~10+ years) for air metro and air taxi**
- Leveraging innovative risk management approaches, such as **safety management systems (SMS) and selected industry self-regulation, can help accelerate these timelines**, but the **rulemaking process itself remains a substantial hurdle** for getting the required regulation in place

Although last-mile delivery operations are limited and permitted primarily through waivers and pilots, industry is working closely with the FAA to forge regulatory pathways to enable testing

Current commercial small UAS (sUAS) operations are governed under Part 107...

- **Vehicles:** Aircraft <55 lbs
- **Pilots:** require Part 107 certification for commercial operations
 - Must be 16 years old and pass an in-person knowledge exam and TSA background check
- **Operations:**
 - Aircraft must remain within visual line of sight
 - Fly at or below 400 feet
 - No flights over people
 - Flights only permitted during daylight or civil twilight
 - Must yield right of way to manned aircraft
 - Fly at or below 100 mph
 - Fly only in Class G airspace without authorization¹
 - Cannot operate from a moving aircraft
 - Cannot operate from a moving ground vehicle, unless in sparsely populated areas
- Last-mile delivery **operations may soon be governed by an exemption to Part 135** through the IPP²



... However, expanded operations are permitted on a case-by-case basis with waivers and COAs

- **Part 107 waivers** are available to organizations for expanded operations (e.g., Enhanced Visual Line of Sight (EVLOS), nighttime operations, etc.)
 - In order to obtain a waiver, organizations must develop a credible safety case that is reviewed and accepted by the FAA
 - To date, there have been over 1,815 waivers granted to organizations around the U.S. for expanded operations³
- Public **Certificates or Waivers of Authorization (COA)s** are another avenue for expanded operations available to public sector entities
 - To date, over 70 COAs have been issued to public entities around the U.S.³
 - Public agencies are allowed to operate either under blanket COAs or under Part 107 depending on their operations and preference

Part 107 will likely not be suitable for enabling scalable last-mile delivery operations; industry is working closely with the FAA through the IPP and other initiatives to chart effective regulatory pathways for last-mile delivery testing and eventual commercial operations

¹ The Low Altitude Authorization and Notification Capability (LAANC) program is starting to facilitate operations in controlled airspace (Airspace B, C, D, and E)

² Integration Pilot Program; ³ As of May 22, 2018

Last-mile delivery activity is picking up pace internationally as many companies have launched pilots and have begun initial operations

NON-EXHAUSTIVE



X – Project Wing piloting food delivery in Canberra, Australia

Amazon piloting package delivery in the United Kingdom

Zipline piloting medical supply delivery in Rwanda

Dominos piloting pizza delivery in New Zealand

DHL piloting package delivery in Germany

Unicef standing up the humanitarian UAS corridor pilot in Malawi



However, the DOT Integration Pilot Program (IPP) has opened more opportunities to bolster last-mile delivery operations and testing in the U.S.

NON-EXHAUSTIVE

At a glance: DOT IPP

- Program developed by DOT and FAA to **partner with local communities and businesses** to **pilot UAS technologies** and operations
 - The IPP is set to run for 3 years
- **10 awards were granted** to pilot programs around the U.S. covering a range of communities and use cases
- **Last-mile delivery is seen as one of the big winners**, being the focus of half of the pilots

Select last-mile delivery applications from the IPP



The city of Reno is teamed up with Flirtey to expand its **medical supply delivery program**

Memphis-Shelby airport is teamed up with FedEx to **pilot last-mile parcel delivery, beginning with aircraft parts delivery in airports**, with the potential to expand to other delivery applications



North Carolina DOT is partnered with Flytrex to pilot **food delivery applications**

The City of San Diego and North Carolina DOT are partnered with Matternet to pilot **food delivery and medical delivery applications** in both urban and rural environments



MATTERNET

Going forward, last-mile delivery operations will require evolutions across five key categories of regulation

Air Traffic & Fleet Operations Management	Vehicle Development & Production	Airspace System Design & Implementation	Individual Vehicle Management & Operations	
Operator certification	sUAS vehicle certification	Airspace integration	Registration	Flight above people
Operator licensing	Continuing airworthiness	Zoning restrictions	Identification	BVLOS operation
UTM requirements		Altitude restriction	Weight restriction	Autonomous flight
Community integration		Cybersecurity	Pilot certification	
Noise requirements		Infrastructure requirements		

- Today, last-mile delivery is operating on **an exception basis through waivers and pilot programs**
- These early operations are **charting pathways through Part 107 and Part 135 for future operations**
- However, **scalable last-mile delivery will require further clarity and standards** across these five categories

Traffic & Fleet Operations Management and Vehicle Development & Production

Regulatory need		Why it is required for last-mile delivery	Where the regulation stands today	Jurisdiction
Air Traffic & Fleet Operations Management	Operator certification	Although there currently is no requirement for operator certification for last-mile delivery, it is possible that operator requirements will be placed on organizations that conduct high frequency/volume operations	There is no operator certification required today; individual pilots must be certified Part 107 pilots, but last-mile delivery operators flying under Part 107 have no certification requirement at this time	Federal (FAA)
	Operator licensing	State and local authorities will likely put up operator/business licensing requirements for last-mile delivery operators	There is no operator licensing requirement today	State & Local
	UTM requirements	UTM technical requirements and operating protocols, authority for system-level control, and potential delegation for operations of UTM system(s) are all required for an effective system of traffic management to be in place to deconflict autonomous operations below 400 ft AGL	UTM technology is being developed and tested at test sites around the country; major jurisdictional, regulatory, and CONOPS questions on UTM remain unanswered	Federal (FAA, DOT, Congress)
Vehicle Development & Production	sUAS vehicle certification	It is still not determined whether vehicle airworthiness standards will be required for sUAS undertaking last-mile delivery operations	Currently, there is no specific Airworthiness Certification standard for sUAS, but aircraft could potentially be certified under existing standards for airplanes or rotorcraft	Federal (FAA)
	Continuing Airworthiness	Similar to sUAS vehicle certification, it is unclear what will be required in terms of continuing airworthiness requirements	There are no specific continuing airworthiness standards for sUAS at this time	Federal (FAA)

Airspace System Design & Implementation and Community Integration

Regulatory need		Why it is required for last-mile delivery	Where the regulation stands today	Jurisdiction
Airspace Design & Implementation	Airspace integration	Enables sUAS operations in the NAS and ensures separation and obstacle avoidance; may be required in some urban environments where operations will need to extend above 400 ft AGL or into airspaces other than Class G	Additional rules and systems to govern how UAS are integrated into the NAS are required before scalable operations above 400 ft AGL can be enabled. The FAA has convened an Access to Airspace ARC to make recommendations on this issue	Federal (FAA)
	Zoning restrictions	Existing access and operational regulations may need to be adapted; many state and local entities may use their zoning authority over take-off and landing to restrict operations	De facto applicable protocols are those governing manned aircraft operations and other time, place, and manner restrictions	State & Local
	Altitude restriction	A lot can be accomplished below 400 ft AGL, but many operations will require access to higher altitudes	Commercial UAS operations above 400 ft AGL are prohibited without a Part 107 waiver or COA, Part 107 operations in controlled airspace require authorization	Federal (FAA)
	Cybersecurity	Cybersecurity standards to protect vehicles and overall systems against jamming, spoofing, and other forms of interference are necessary for safe and reliable operations	Currently, there are no comprehensive cybersecurity standards for UAS and their supporting systems; more attention will need to be paid to this issue going forward to develop the appropriate standards and technologies	Federal (FAA, DOT, DHS, DOD)
	Infrastructure requirements	Needed to create sUAS infrastructure standards for key last-mile delivery operations (e.g., receiving vessels)	There are currently no standards for key last-mile delivery infrastructure; industry remains unaligned on the technical visions and needs for receiving vessels	Federal (FAA)
Community	Noise requirements	Acceptable noise levels, and resulting noise abatement procedures must be developed for community health and safety	Current de facto applicable protocols are those governing manned aircraft noise requirements	Federal (FAA), State & Local

Individual Vehicle Management & Operations

Regulatory need		Why it is required for last-mile delivery	Where the regulation stands today	Jurisdiction
Individual Vehicle Management & Operations	Registration	Aircraft registration is required for all sUAS over 0.55 lbs; it is likely that State and Local authorities will create additional registration requirements in certain jurisdictions as well	There is a Federal registry for both sUAS and an aircraft registry for traditional manned aircraft	Federal (FAA), State & Local
	Identification	Required for law enforcement and Air Traffic Control (ATC) to remotely track and identify aircraft in order to ensure accountability and enable enforcement where required	Unmanned Aircraft Systems (UAS) Identification and Tracking Aviation Rulemaking Committee (ARC) released their guidance in December 2017; the FAA will consider their recommendations in promulgating a rule	Federal (FAA)
	Weight restriction	In order to operate under Part 107 the total aircraft weight, including payload, must be less than 55 lbs; this is likely sufficient for most last-mile delivery operations, but there may be some instances where a larger aircraft and payload may be desired	sUAS must be under 55 lbs to operate under Part 107; operations requiring greater payload capacity must pursue other regulatory pathways or certifications	Federal (FAA)
	Pilot certification	Pilot certification ensures pilots are capable of conducting safe sUAS operations in the NAS	Pilot must have a remote pilot airman certificate for commercial operations; cert is currently a written test	Federal (FAA)
	Autonomous flight	Required to reduce operator to aircraft ratio, and full integration into automated UTM system	Under Part 107, all operations must be within visual line of sight and under the control of a remote pilot ¹	Federal (FAA)
	BVLOS ¹ operation	Delivery operations will require BVLOS operations in all scalable last-mile delivery models	BVLOS operations are currently prohibited without a Part 107 waiver or COA; some EVLOS ² waivers have been granted to certain organizations (e.g., PrecisionHawk, BNSF, and GE) but true BVLOS flights are heavily restricted	Federal (FAA)
	Flight above people	Enables operations in urban and suburban areas where demand is likely to be significant and flight routes will require operations above people	UAS operations over people are currently prohibited without a Part 107 waiver or COA; some flight above people testing has been done (e.g., CNN operations), and is expected to be further tested in the IPP	Federal (FAA)

1 Beyond Visual Line of Sight (BVLOS); 2 Extended Visual Line of Sight (EVLOS)

Today, the closest parallel to the air metro and air taxi markets are manned helicopter services

At a glance: *the helicopter service market in the US*

- There are currently **5,660 heliports in the U.S.** (most are not public-use) and **9,750 civil helicopters in the fleet**
- Today, the civil **helicopter transport market is growing, but remains relatively limited, expensive, and often seen as disruptive** by local communities
 - Many communities have **issued local ordinances to restrict these routes** in their jurisdiction to address community concerns
- The global commercial helicopter market is expected to continue to **grow steadily over the next 10 years, from \$8.2B in 2017 to \$11.6B by 2027**
- **The U.S. is expected to lead this market with ~\$38B in spending** over the ten year period
 - **This growth is driven by increasing adoption of helicopters for public and para-public missions** like Helicopter Emergency Medical Services (HEMS), law enforcement, and Search & Rescue
- Many current **helicopter services are planning to transition their operations to eVTOLs** in the future (e.g., Airbus VROOM)

The regulatory climate for helicopter services

- Today, these **helicopter services are governed primarily by Part 135**
- In order to achieve a more scalable and accessible Air Metro UAM market, **current operations will need to undergo several major innovations**, including:
 - Automation and development of associated safety systems
 - Distributed electric propulsion systems
 - Commercialization of tilt-rotor designs
 - Battery power improvements
 - New infrastructure designs and standards
- These evolutions will **require significant changes to the existing regulatory regime**, spanning everything from airworthiness to operator certification to infrastructure standards

Going forward, air metro and air taxi operations will require evolutions across five key categories of regulation

Air Traffic & Fleet Operations Management	Vehicle Development & Production	Airspace System Design & Implementation	Individual Vehicle Management & Operations	Community integration
Operator certification	Vehicle certification	Zoning restrictions	Registration	Noise requirements
Operator licensing	Continuing airworthiness	Cybersecurity	Surveillance	
Fleet management		Infrastructure requirements	Pilot certification	
UAM TM & airspace integration			Autonomous operations	

- Today, air metro and air taxi operations are **most closely paralleled by rules governing helicopter operations**
- Adding electrification and autonomy to the mix will **require a significant degree of maturation in the existing regulations and/or the introduction of new regulation** to govern these aircraft and operations
- **Integrated and automated UAM traffic management systems and associated protocols are in a nascent state, and pathways to vehicle certification** still need to be charted

Air Traffic & Fleet Operations Management and Community Integration

Regulatory need		Why it is required for air metro & air taxi	Where the regulation stands today	Jurisdiction
Air Traffic & Fleet Operations Management	Operator certification	AOC/Operator certification will be required for Air Metro and Air Taxi operators; these requirements will likely be an evolution of existing manned operator certifications	Under the current regulatory structure, there is only a standard for piloted operations, which operate under Part 135 in most cases; alterations and additional regulation may be needed for autonomous operations	Federal (FAA)
	Operator licensing	State and local authorities will likely implement operator/business licensing requirements for air metro & air taxi operations	Depending on the jurisdiction and operation type, additional licensing requirements exist for manned equivalents (e.g., medical operations licensing)	State & Local
	Fleet management	eVTOLs will require automated fleet management software and associated protocols to enable scalable autonomous use cases	There is no current regulatory baseline governing technical or protocol standards for autonomous fleet management	Federal (FAA)
	UAM traffic management & airspace integration	UAM Traffic Management (UTM) technical requirements, operating protocols, and supporting infrastructure and technologies are required for an effective system of traffic management for autonomous eVTOL operations. eVTOLs will need an integrated, automated system for UAM traffic management in order to operate in airspace with a range of cooperative, noncooperative, and autonomous traffic and to be able to safely deconflict eVTOLs from this traffic	Additional rules and systems to govern how autonomous eVTOLs are integrated into the NAS are required before scalable operations can be enabled	Federal (FAA, DOT, Congress)
Community	Noise requirements	Acceptable noise levels, and resulting noise abatement procedures will need to be developed for local community health	Current de facto applicable protocols are those governing manned aircraft noise restrictions	Federal (FAA), State & Local

Vehicle Development & Production and Airspace System Design and Implementation

Regulatory need		Why it is required for air metro & air taxi	Where the regulation stands today	Jurisdiction
Vehicle Development & Production	Vehicle certification	Vehicle airworthiness certification standards will need to be evolved to encompass electric propulsion, autonomy, and its related technologies and subsystems	Currently, there is no clear certification path for an autonomous eVTOL; Part 23 and Part 21 are seen as a starting point for the evolutions that will need to occur to enable vehicle certification, but a proven, viable path has yet to be established	Federal (FAA)
	Continuing Airworthiness	Continuing airworthiness standards will need to be developed to govern autonomous eVTOLs	There are currently no continuing airworthiness standards for autonomous eVTOLs; rotorcraft continuing airworthiness standards are the most likely baseline	Federal (FAA)
Airspace Design & Implementation	Zoning restrictions	Existing access and operational regulations may need to be adapted to accommodate LMD	De facto applicable protocols are those governing manned aircraft operations and other time, place and manner restrictions	State & Local
	Cybersecurity	Cybersecurity standards for the vehicles and the overall system to protect against jamming, spoofing, and other forms of interference are necessary for safe and reliable operations	Currently, there are no comprehensive cybersecurity standards for autonomous vehicles and their supporting systems (e.g., UTM); more attention will need to be paid to this issue going forward to develop the appropriate standards and technologies	Federal (FAA, DOT, DHS, DOD)
	Infrastructure requirements	Needed to create UAM infrastructure standards for key air metro and air taxi operations (e.g., vertiports)	There are currently no vertiport-specific standards and industry remains unaligned on the technical visions and needs for vertiports; currently all “vertiports” would likely comply with airport and/or heliport standards	Federal (FAA)

Individual Vehicle Management & Operations

Regulatory need		Why it is required for air metro & air taxi	Where the regulation stands today	Jurisdiction
Individual Vehicle Management & Operations	Registration	Aircraft registration is required for the majority of aircraft; it is likely that State and Local authorities will create additional registration requirements in certain jurisdictions as well	There is a Federal registry for traditional manned aircraft	Federal (FAA), State & Local
	Surveillance	Required for Air Traffic Control (ATC) and public safety officials to remotely track and identify aircraft in order to ensure separation standards, and accountability	There are currently no specific rules or requirements for autonomous eVTOLs, the closest parallel is equipage requirements for aircraft operating within the Mode C Veil	Federal (FAA)
	Pilot certification	Pilot certification will likely be required for potential interim use cases involving remote pilots for eVTOLs; these requirements will change as the platforms transition to full autonomy	Currently, there is no way to certify as a remote pilot of a remotely piloted eVTOL	Federal (FAA)
	Autonomous operations	Required for full-scale use case operations, which will entail repeated autonomous operations; regulation will need to be put in place to govern technical standards for autonomous mission management systems, as well as general standards and protocols for autonomous operations	Currently, regulation is in place to allow for piloted helicopter operation and VLOS operations for sUAS. There is no clear regulation in place to govern autonomous passenger-carrying operations or the systems that support them	Federal (FAA)

The future of UAM regulation will likely be a marriage between evolutions of sUAS and manned commercial rules

Part 107 (sUAS) evolution



Manned commercial evolution

Last-mile delivery

- **Last-mile delivery** applications will likely include **an evolution of Part 107** (sUAS) regulations
 - The vehicles, operations, and airspace standards that **regulators are currently tackling for sUAS more broadly are directly applicable to last-mile delivery**, and therefore will likely be addressed in large part by evolutions of Part 107

Air metro and air taxi

- Some of the standards and regulatory precedent will likely be borrowed from or based on **evolutions of Part 107 for key technologies, systems, and operations that are shared between sUAS** and Air Taxi or Air Metro regimes (e.g., UTM designs and standards, battery safety standards, DAA technology standards)

- Last-mile delivery will **likely entail revisions to Part 135**
 - Currently, last-mile delivery operations for the IPP are expected to operate under Part 135
- Many **components of last-mile delivery will borrow from evolutions of manned standards** (e.g, operator certification, should it be adopted, is likely to borrow from existing operator certification standards for commercial operations)

- Air Metro and Air Taxi use cases will likely borrow part of their **regulatory frameworks from existing manned commercial operations** (e.g., Parts 135, 91, etc.)
- Many of these **Parts already tackle the beginnings of automation**, but **none of them are a perfect fit for UAM operations**
 - e.g., even manned rotorcraft operations fail to address scalable UAM because they rely primarily on VFR¹

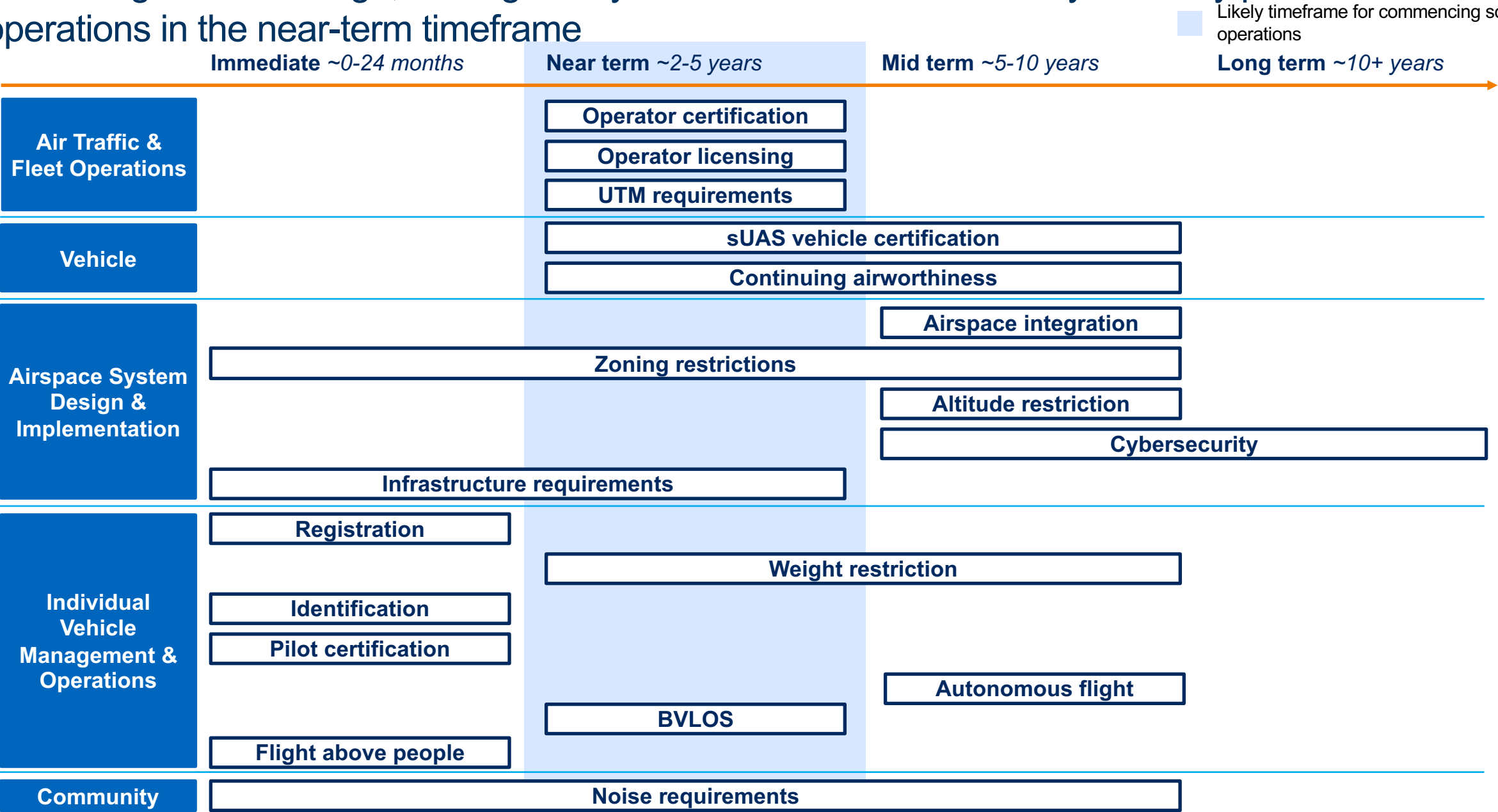
This process is likely to be time consuming and labor-intensive, and completed in a series of incremental steps. Both legs of this evolution will require significant updates to many existing Parts that interact with different components of UAM operations

¹ Visual Flight Rules

However, progress in this arena faces a series of challenges

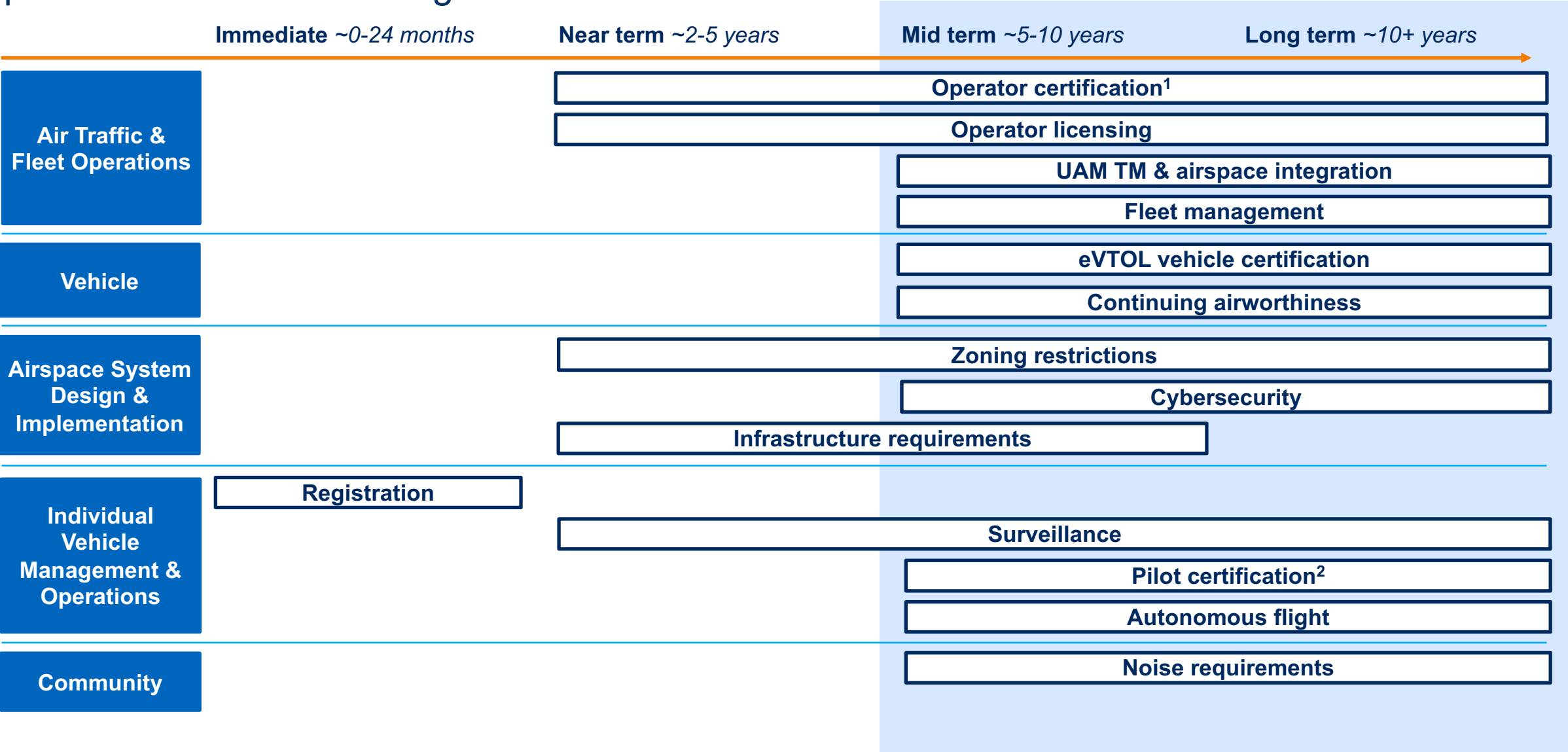
- **Time-consuming regulatory processes.** The regulatory process struggles to keep pace with the speed of innovation and demands from industry, many of whom are unfamiliar with aviation and the regulatory process associated with it. The rulemaking process is inherently collaborative, and requires community engagement and review as well as compliance with the Administrative Procedures Act. This creates a lengthy process for something like UAM, which is a complex and multifaceted issues requiring multiple rulemakings and Part updates.
- **Resource constraints for the regulators.** The regulatory process is labor-intensive, and regulators face tight resource constraints, large workloads, and multiple demands on their time.
- **Pressure to move more quickly.** Regulators are under significant pressure to move more quickly, but not at the cost of safety, given perceptions that the U.S. is being “outpaced” in this arena, and industry concerns around enabling commercial markets.
- **Open development needs for key technologies.** Many technologies are simply not there yet in terms of capabilities and performance to fill certain functions that are required for safe and reliable operations (e.g., DAA, navigation-denied environment technology, etc.). Absent reliable technologies for these functions, regulators cannot set reasonable or reliable safety standards for key UAM operations.
- **State and Local pre-emption.** In lieu of clear Federal rules and guidance, there is likely to be more unilateral action taken by State and Local authorities. This risks causing a more complex and fragmented regulatory landscape to manage and navigate in the future.

Absent significant change, the regulatory timeline for last-mile delivery will likely place scalable operations in the near-term timeframe



Absent significant change, the regulatory timeline for air metro and air taxi will likely place scalable operations in the mid- to long-term timeframe

Likely timeframe for scalable operations



1 Currently possible for traditional piloted operations under Parts 135 and 121; adaptations will likely occur for unmanned operations as needs arise
2 Currently possible to get pilot certification for traditional piloted helicopter operations, remote and autonomous “pilot” certification will develop in the long term

Adopting forward-leaning risk management approaches to UAM regulation will be critical in driving efficiency in the regulatory process

Enabling Safety Management Systems (SMS)

- Long lead times on adopting innovative technologies in innovation in many ways **has to do with risk and how risk is mitigated**
- The FAA is able to operate most efficiently when it can delegate the details of **safety and risk mitigation to operators who have approved Safety Management Systems (SMS)**
 - Building these **protocols for UAS and UAM operators allows for faster approvals for operations** and can accelerate expansion and scaling of UAM operations in the NAS

Facilitating selected industry self-regulation

- There are certain areas where regulators may be able to **leverage industry self-regulation to help accelerate the pace of adoption and implementation** of UAM technologies and operations
- **Industry is often able to move more quickly than regulators** in adopting consensus standards as opposed to putting standards through more complex internal processes
 - As a result, there are certain areas where **industry consensus standards or industry-driven self-regulation could help alleviate some of the burden of the regulatory process** and accelerate adoption and implementation, while maintaining the highest standard of safety
- For example, **insurance requirements** may provide an effective avenue for industry self-regulation
 - Should the FAA require operators to carry certain insurance limits, **insurance companies will help the industry self-regulate** as they will be unwilling to insure unsafe operators¹

¹ This avenue would require significant confidence in insurers' ability to accurately assess and quantify risk in UAM operations

However, the most significant hurdle for UAM regulation is the time-consuming regulatory process itself

The rulemaking process itself moves very slowly

- Aviation rulemaking will **typically take 38-42 months for a significant rule, and 30 months for a less significant rule**
- The process is governed by the **Administrative Procedures Act (APA)** and three associated executive orders (12866, 13563, and 13579)
- There are **three formal stages to rulemaking** (pre-rule, proposed rule, and final rule), but there are **nine distinct steps to the end-to-end process**
- This **process is very detailed and requires strict compliance with the requirements** under each stage, and is very **time- and labor-intensive**
- There are **some steps that have historically acted as chokepoints for rulemaking** (e.g., time-intensity for adjudicating comments, OST approval, OMB approval)
- As a result, the **rulemaking timelines for something as robust as UAM tend to be extended due to the requirements for compliance** with each stage of this process for each individual rule and rule update that is undertaken
- Rulemaking can take longer at FAA compared to other agencies/departments because **coordination is required with both DOT and the Office of Information and Regulatory Affairs (OIRA)**
- Some agencies tend to operate under **de-facto numerical limits on how many rules it can send each year to OIRA**
 - Even uncontroversial rules (e.g., Part 23 re-write) **suffer from the perception that rules are bad and we need less regulation. This leads to certain enabling regulation getting delayed in order to counter the perception of over-regulation**

Accelerating the regulatory timeline

- Going **through the traditional process will lead to long timelines** for UAM regulation to be in place
- Within the current process, there is room to reduce the time needed for rulemakings by **more closely involving DOT, OIRA, and other relevant government agencies** in the development and drafting of rules
 - **Concurrent agency review with abbreviated periods for comments** can also help accelerate timelines
- Some other potential avenues for acceleration, should legislators or regulators choose to pursue them, are:
 - **Congressional delegation of some airspace regulatory jurisdiction** to state and local authorities
 - **Regulator delegation of specific issues to industry consensus standards bodies** or to state and local authorities

There are a few principles regulators could consider adopting as they work to establish a progressive and effective UAM regulatory regime

Fostering cooperation between agencies. Many of these issues are inter-agency challenges (e.g., cybersecurity will require FAA, DHS, DOJ, and DOD cooperation at a minimum) and will require effective coordination and governance in order to be successful.

Developing innovative Public Private Partnerships. USDOT and FAA have already started this process by setting up a FACA in the form of the DAC and launching initiatives like Pathfinder, IPP, and LAANC. However, success in this arena may require more innovative PPP structures like these that allow for more agile co-development, testing, and standard-setting opportunities.

Adopting performance-based regulations. Given the pace of technological change likely to be seen in the UAM industry, building performance-based regulations are going to be critical to enabling innovation. The FAA has already begun the transition to this form of regulation with the 14 CFR Part 23 rewrite; this kind of approach will be critical to UAM.

Implementing forward-leaning risk management approaches. Regulators can operate more efficiently by delegating details of safety and risk mitigation to operators who have approved Safety Management Systems (SMS). SMS in conjunction with facilitating selected industry self-regulation can help improve efficiency of the regulatory process across the UAM ecosystem.

Acknowledging that politics are local. Although the regulatory authority is primarily Federal, local communities are going to be a major factor in the integration and adoption of UAM technologies and operations. Local sentiments will dictate the market adoption rates and what ordinances are created, and as a result, will heavily influence the ease of integration.

Developing new methods that match the new face of aviation. The UAM and UAS industries are much more vast and fragmented than the traditional manned aviation landscape. The ecosystem is larger and contains a much wider range of corporate sophistication and background than ever before. This means that some of the old ways of doing business may no longer be sustainable and new solutions will need to be developed to help the full ecosystem develop and operate unmanned aircraft safely in an urban environment.

Contents

- Introduction and summary by Crown Consulting, Inc.
- Market analysis by McKinsey & Company
- Public acceptance by McKinsey & Company
- UAM regulatory environment by Ascension Global
- **Potential barriers by Georgia Tech Aerospace Systems Design Lab and Crown Consulting, Inc.**
- Moving forward by Crown Consulting, Inc.

Prior assessment identified conditions needed for market viability

Conditions for a Viable Market

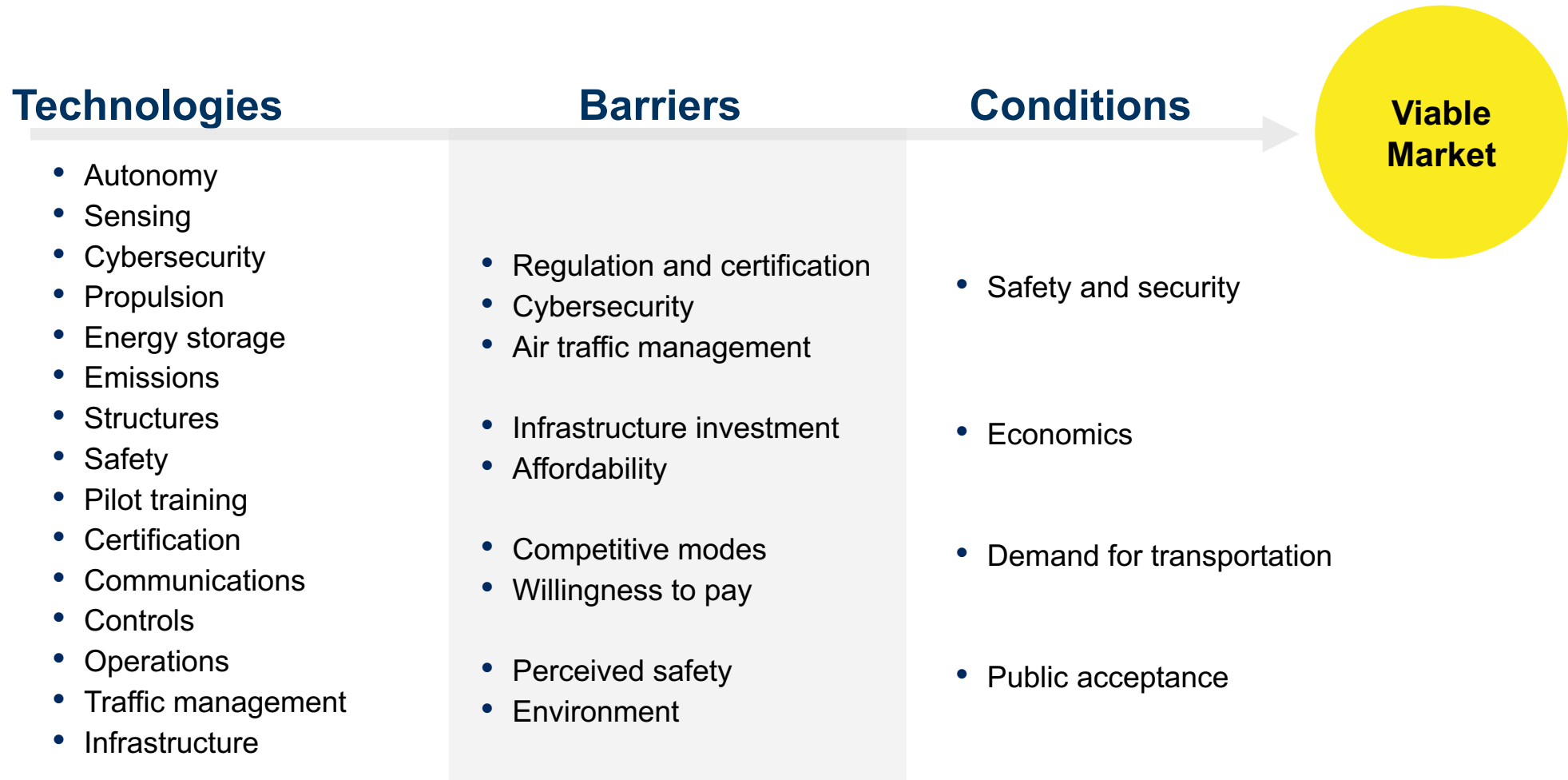
Last-mile parcel delivery Commercially viable market profitable around 2030

Air Metro Commercially viable market with in-year profitability in 2028

Air Taxi Possible market in 2030 in concentrated areas of high net-worth individuals and businesses

Safety and security	Detect-and-avoid, GPS-denied technology, weather mitigation, UTM technology Regulatory requirements for BVLOS, airworthiness, UTM certification, flight above people, altitude restrictions, operator certification, identification, environmental restrictions (e.g., noise, visual noise), emergency procedures, data security	Detect-and-avoid, GPS-denied technology, weather mitigation, UTM technology Regulatory requirements for airworthiness standards, UTM certification, flight above people, weight and altitude restrictions, BVLOS, operator certification, identification, environmental restrictions (e.g., noise, visual noise), emergency procedures, data security	Detect-and-avoid, GPS-denied technology, weather mitigation, UTM technology Regulatory requirements for airworthiness standards, BVLOS, UTM certification, flight above people, weight and altitude restrictions, operator certification, identification, environmental restrictions (e.g., noise, visual noise), emergency procedures, data security
Economics	Battery technology, autonomous flight technology, infrastructure (receiving vessels, distribution hubs, docking/charging stations, UTM)	Battery technology, autonomous flight technology, electric propulsion, infrastructure (~200 vertiports per MSA located in high-traffic areas capable and of handling ~3-6 VTOLs at once; charging stations; service stations; UTM)	Battery technology, autonomous flight technology, electric propulsion, infrastructure (very large density of vertistops on or near buildings to create a door-to-door service; charging stations; service stations; UTM)
Transportation demand	Competing modes (autonomous and human-driven ground delivery services (e.g., FedEx, UPS, Amazon Prime), courier services, autonomous ground vehicle (AGV) lockers, droids)	Competing modes (subway, bus, bike, ride-hail/taxi, or rideshare)	Competing modes (subway, bus, bike, ride-hail/taxi, or rideshare)
Public acceptance	Proven safety record, privacy, job security, environmental threats, and noise and visual disruption	Proven safety record, privacy, job security, environmental threats, and noise and visual disruption	Proven safety record, privacy, job security, environmental threats, and noise and visual disruption

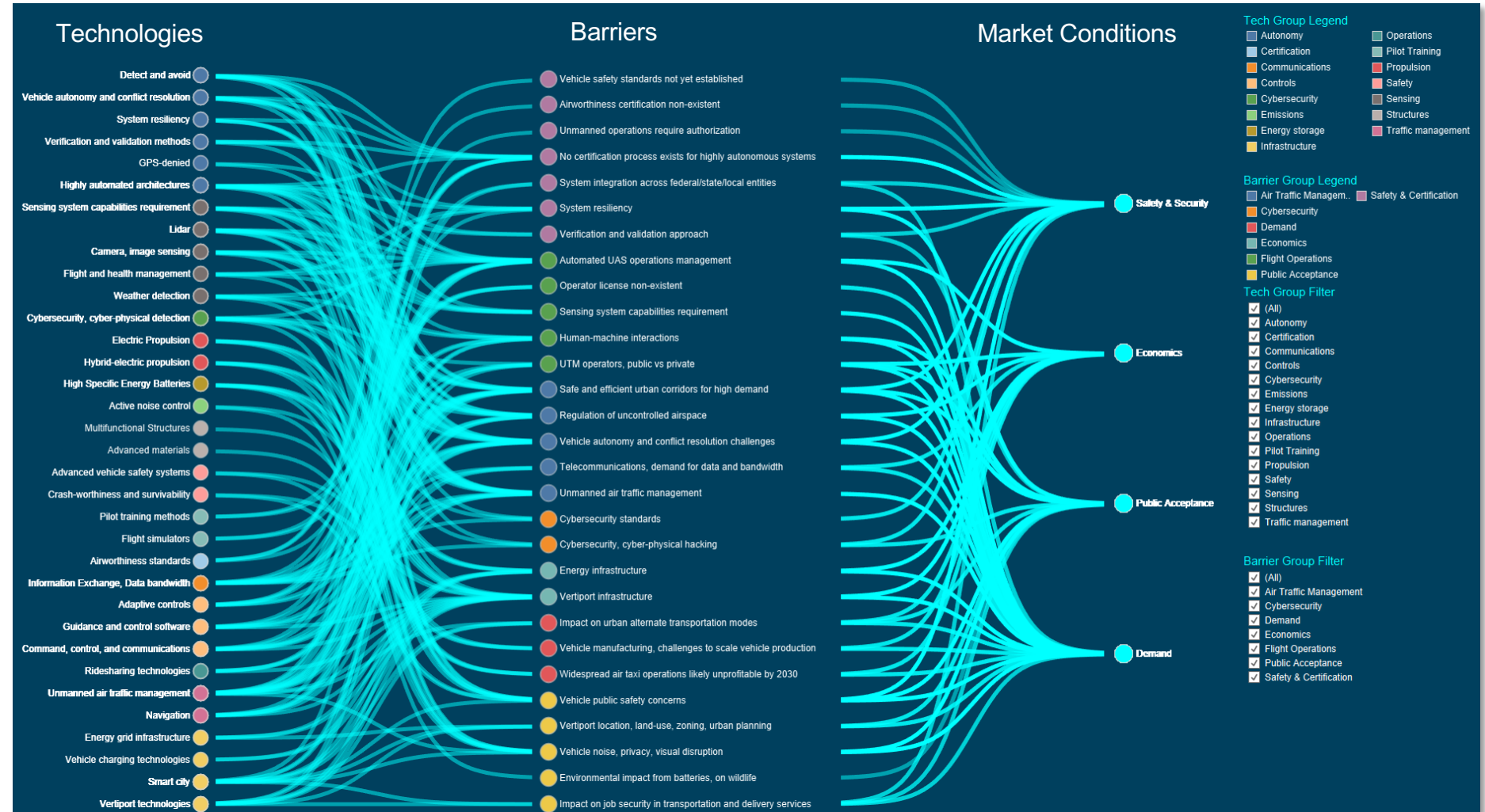
Possible Framework for Assessing Technology Contributions to UAM Viability



Detailed UAM Technology Assessment Framework

Tableau or similar software can trace connections or impacts across the framework

The framework can be portrayed at multiple levels of detail



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An aerial illustration of a city with a UAM flight path. The path starts from a city center, goes to a body of water, and then to an airport. Various aircraft are shown along the path, including a small propeller plane, a larger jet, and a helicopter. The city is depicted with buildings, roads, and green spaces.

Moving forward

- It is critical to evaluate UAM in terms of specific use cases (e.g., air metro) to produce meaningful results
- Determining the viability of specific UAM use cases requires a holistic approach that considers UAM's complex ecosystem
 - This study used over 100 discrete assumptions for the use cases (from the cost of sensing systems, to battery efficiency, to weather estimates in the 15 US cities studied)
 - Many of the most significant challenges to UAM are regulatory or policy-related across multiple governmental entities and would likely need to address evolving technologies
- There is an opportunity to coordinate planning for UAM research with industry needs
 - No single actor (public or private) has emerged yet as the UAM industry convener
 - Market participants do not yet agree on the vision for each UAM use case
- Public acceptance of UAM is likely to be more complicated than asking popular opinion; local policy, interest groups and research (for example, on noise) each play a major role