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Advanced Air Mobility: Opportunities, Challenges, and Research needsfor the State of California (2023-2030)

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Advanced Air Mobility: Opportunities, Challenges, and Research Needs for the State of California (2023-2030)

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California Resilient and Innovative Mobility Initiative

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16. Abstract

Advanced air mobility (AAM) is a broad concept that enables consumers access to air mobility, goods delivery, and emergency services through an integrated and connected multimodal transportation network. AAM can provide short-range urban, suburban, and rural flights of about 50-miles and mid-range regional flights up to a several hundred miles. State law delegates responsibility for oversight in aviation primarily to the California Department of Transportation (Caltrans). This white paper presents an overview of the state of the market, such as the aircraft under development and forecast market growth and discusses factors that could facilitate the development of AAM or pose risks to its deployment or to the public, including the safety and the regulatory environment, airspace and air traffic management, security, environmental impacts, weather, infrastructure and multimodal integration, workforce and economic development, social equity, and community engagement and social acceptance. It concludes by recommending actions that Caltrans and other state agencies can take to facilitate the development of AAM.

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The University of California Institute of Transportation Studies (UC ITS) is a network of faculty, research and administrative staff, and students dedicated to advancing the state of the art in transportation engineering, planning, and policy for the people of California. Established by the Legislature in 1947, ITS has branches at UC Berkeley, UC Davis, UC Irvine, and UCLA.

The California Resilient and Innovative Mobility Initiative

The California Resilient and Innovative Mobility Initiative (RIMI) serves as a living laboratory bringing together university experts from across the four UC ITS campuses—policymakers, public agencies, industry stakeholders, and community leaders—to inform the state transportation system's immediate COVID-19 response and recovery needs, while establishing a long-term vision and pathway for directing innovative mobility to develop sustainable and resilient transportation in California. RIMI is organized around three core research pillars: Carbon Neutral Transportation, Emerging Transportation Technology, and Public Transit and Shared Mobility. Equity and high-road jobs serve as cross-cutting themes that are integrated across the three pillars.

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List of Terms and Acronyms

AAM – Advanced Air Mobility

ACRP – Airport Cooperative Research Program

CALTRANS – California Department of Transportation

CEQA – California Environmental Quality Act

CFR – Code of Federal Regulations

DOT – Department of Transportation

eVTOL – Electric Vertical Takeoff and Land

IFR – Instrument Flight Rules

FAA – Federal Aviation Administration

MPOs – Metropolitan Planning Organizations

NAS – National Airspace System

NASA – National Aeronautics and Space Administration

OEMs – Original Equipment Manufacturers

PSUs – Providers of Services for Urban Air Mobility

RAM – Regional Air Mobility

STOL – Short Takeoff and Land

TRB – Transportation Research Board

UAM – Urban Air Mobility

sUAS – small Uncrewed/Unmanned Aircraft Systems

UAS – Uncrewed/Unmanned Aircraft Systems

USDOT – United States Department of Transportation

UTM – Uncrewed/Unmanned Aircraft System Traffic Management

VTOL – Vertical Takeoff and Land

Executive Summary

Executive Summary

Advanced air mobility (AAM) is a broad concept that integrates new, advanced aircraft designs and emerging flight technologies into lower altitude airspace operations, as part of an integrated and connected multimodal transportation network, including first- and last-mile connections to airports. AAM services are focused on aviation and can accommodate urban, suburban, and rural flights of about 50 miles and regional flights up to a several hundred miles. AAM operations serve passengers, logistics and goods delivery, aeromedical transportation and treatment, emergency response, disaster relief operations, and other professional and industrial activities. AAM incorporates several converging innovations, such as vertical takeoff/landing, electrification, automation, and the growth of app-based on-demand mobility services. Urban Air Mobility and Regional Air Mobility are subsets of AAM.

California's Aeronautics Act (Public Utilities Code Section 21001 et seq.) broadly establishes and clarifies the roles and responsibilities of state agencies with respect to aviation. The law delegates responsibility for oversight in aviation primarily to the California Department of Transportation (Caltrans). Caltrans and other state agencies must defer to the Federal Aviation Administration (FAA) and other federal agencies on all matters preempted by federal law (e.g., aircraft, airworthiness, and pilot certification, management of the National Airspace System (NAS), etc.).

This white paper presents an overview of the state of the market, such as the aircraft under development and forecast market growth and discusses factors that could facilitate the development of AAM or pose risks to its deployment or to the public, including the safety and the regulatory environment, airspace and air traffic management, security, environmental impacts, weather, infrastructure and multimodal integration, workforce and economic development, social equity, and community engagement and social acceptance.

While the roles and responsibilities of state agencies in aviation regulation are largely defined in the State Aeronautics Act, California could also play a key role in AAM in several additional ways, such as:

- Supporting stakeholder and community engagement on AAM issues, such as vertiport siting and community impacts,
- Providing resources to educate local and regional entities on their roles and responsibilities with respect to AAM and aviation-related issues,
- Conducting an environmental justice analysis of proposed vertiports when Caltrans reviews permit applications for new takeoff and landing facilities,
- Adopting state and local social equity and justice policies to help mitigate potential effects of gentrification and displacement in the vicinity of vertiports,
- Establishing state grant programs to support electrification, hydrogen, and other infrastructure consistent with safety and other requirements established by federal partners,
- Adopting state tax credits, incentives, and other policies to support AAM activities (e.g., aircraft manufacturing, infrastructure development, etc.), and
- Supporting the development of training/retraining programs that provide the job skills and technical expertise to enter AAM career fields.

Contents

Introduction

Advanced air mobility (AAM) is a broad concept that integrates new, advanced aircraft designs and emerging flight technologies into lower altitude airspace operations, as part of an integrated and connected multimodal transportation network, including first- and last-mile connections to airports.[1] AAM services are focused on aviation and can accommodate urban, suburban, and rural trips up to about 50 miles (known as Urban Air Mobility) and regional trips up to a several hundred miles (known as Regional Air Mobility (RAM)) (Cohen, Shaheen, and Farrar 2021). Urban Air Mobility (UAM) and RAM are a subset of AAM.

AAM operations can serve passengers, logistics and goods delivery, aeromedical transportation and treatment, emergency response, disaster relief operations, and other professional and industrial activities. AAM encompasses a number of converging innovations, such as vertical takeoff/landing, electrification, automation, and the growth of app-based on-demand mobility services.

Background

The concept of urban aviation is not new. Beginning in the early 1900s, inventors began developing "flying car" concepts and by the mid-20th century early operators began offering scheduled flights using helicopters. Between the 1950s and 1980s, several operators began providing early passenger helicopter services in Los Angeles, New York City, San Francisco, and other cities. In the U.S., these services were typically supported by a combination of helicopter subsidies (discontinued in 1966) and airmail revenue (Cohen, Shaheen, and Farrar 2021). Between 1965 and 1968 (resuming in 1977), Pan Am offered hourly connections between Midtown and JFK's WorldPort, allowing passengers to check in at the Pan American building in Midtown 40 minutes prior to their flight departure at JFK. Over the years, the service offered various promotions, such as "buy one, get one free" that offered international business travelers a free helicopter connection to their flight. The service was discontinued in 1977 when an incident involving metal fatigue of the landing gear caused a rooftop crash killing five people (four people on the roof and one person 59 stories below on the ground) (Cohen, Shaheen, and Farrar 2021). Helicopter services began to slowly re-emerge in Manhattan in the 1980s. Trump Air offered scheduled service using Sikorsky S-61 helicopters between Wall Street and LaGuardia airport connecting to Trump Shuttle flights. The service was discontinued in the early 1990s when Trump Shuttle was acquired by US Airways (Cohen, Shaheen, and Farrar 2021).

California's Aeronautics Act (Public Utilities Code Section 21001 et seq.) broadly establishes and clarifies the roles and responsibilities of state agencies with respect to aviation. The law delegates responsibility for oversight in aviation primarily to the California Department of Transportation (Caltrans).[2] The law specifically grants Caltrans the following roles and responsibilities:

- Encouraging the establishment of airports and air navigation facilities
- Cooperating with and assisting the federal government, political subdivisions of California, and others

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[1] The California State Transportation Agency (CalSTA) is embarking on a study to identify policies which could ensure that AAM provides broad societal benefits to Californians.

[2] The State Aeronautics Law also addresses civil liability issues and rules against the operation of aircraft while under the influence of drugs and alcohol. The law also provides people or entities aggrieved by any procedure or aeronautical action of Caltrans the opportunity to seek redress before the California Transportation Commission.

in aeronautical activities

- Drafting and recommending necessary legislation to advance California’s interest in aeronautics
- Representing California in all aeronautical matters before federal and other agencies
- Participating as plaintiff, defendant, or intervenor on behalf of the state or any

political subdivision or citizen in any controversy that involves California’s interest in aeronautics

- Assisting political subdivisions and their law enforcement agencies in becoming acquainted with and enforcing civil air regulations
- Entering into agreements with other states and federal agencies to receive, share, and exchange data and reports, and
- Accepting, receiving, disbursing, and expending federal and other funds.

Report Overview

This white paper is organized into four sections. The first section provides an overview of the state of the market, such as the aircraft under development and forecasted market growth. The second section discusses factors that could facilitate the development of AAM or pose risks to its deployment or to the public, including the safety and regulatory environment, airspace and air traffic management, security, environmental impacts, weather, infrastructure and multimodal integration, workforce and economic development, social equity, and community engagement and social acceptance. The final section discusses potential actions California could take over the next two to five years to plan and prepare for AAM over the next decade. The appendix includes a discussion of the role of research and presents an AAM research roadmap for the State of California, of which this study is a part.

Section 1. State of the Market

Recent developments in electric propulsion, automation, and other technologies are contributing to the development of emerging aircraft designs. AAM includes an array of novel aircraft types with various propulsion technologies (e.g., battery electric, hydrogen electric, hybrid, or gas-powered); design; and flight capabilities (e.g., conventional, short distance, and vertical takeoff and landing); aircraft capacity (i.e., payload or passengers); aircraft range; and degrees of autonomy (e.g., piloted, remotely piloted, and autonomous). While AAM does not have a distinct regulatory category at this time; it is an area of regulatory and policy development that is still emerging. Common aircraft types include:

- Short Takeoff and Land (STOL) aircraft that require a short runway for takeoff and landing.
- Small Uncrewed Aircraft Systems (sUAS, also referred to as “drones”) that weigh less than 55 pounds on takeoff, including everything that is on board or otherwise attached.
- Uncrewed Aircraft that operate without the possibility of direct human intervention from within or on the aircraft (i.e., no on-board pilot).
- Vertical Takeoff and Land (VTOL) aircraft that can take off, hover, and land vertically. The term electric VTOL, or eVTOL, is also commonly used to refer to such aircraft that are powered by electric engines.

As with any emerging technology, it is important to note that AAM is an evolving field encompassing a variety of definitions, including aircraft types. Nearly 300 innovative aircraft concepts are currently under development by traditional manufacturers such as Airbus, Bell, and Embraer and new market entrants such as Archer, Ehang, EVE, Joby, Lilium, Vertical Aerospace, and Wisk. Additionally, a number of automotive manufacturers have announced investments in AAM including Aston Martin, Audi, Daimler, Geely, General Motors, Hyundai, Porsche, Stellantis, and Toyota (Cohen, Shaheen, and Farrar 2021). Many of these aircraft under development will accommodate two to seven passengers (or equivalent weight in cargo). While a few petroleum and hydrogen powered aircraft are under development, the vast majority are electric VTOL (eVTOLs) with a power requirement typically ranging between 300 to 600 kW (Cohen, Shaheen, and Farrar 2021).

Several pre-pandemic market studies forecast the total passenger mobility market potential for AAM over the next decade at between $2.8 to $4 billion USD and a goods delivery market projected between $3.1 and $8 billion USD in 2030. Global market studies forecast a market potential ranging from $74 to $641 billion USD, with the wide variation attributable to different study assumptions such as including or excluding various submarkets (e.g., military applications) (Reiche, Goyal, et al. 2018; Hasan 2019; Porsche Consulting 2018; Jonas 2019). Variations in geography, timeline, methodologies, and scenarios examined can notably influence market forecasts. However, Johnston et al. (2020) and Lineberger et al. (2019) find that limited infrastructure globally has the potential to constrain AAM growth (Lineberger, et al. 2019; Johnston, Riedel and Sahdev 2020).

A market study examining 74 existing studies from cities around the globe coupled with an analytical forecasting model that included demographics; infrastructure costs; aircraft and supply chains, demand assumptions; and community and regulatory constraints estimated a market potential of $318 billion USD across the cities in 2040 (Herman 2019). Other studies have estimated a global demand for 23,000 eVTOL aircraft in 2035 (Porsche Consulting 2018) and regional air taxis (up to 300 km) in 2042 (Becker et al. 2018)

One AAM market study commissioned by the National Aeronautics and Space Administration (NASA) estimates that an air taxi and airport shuttle operations could capture a 0.5% mode share in the U.S. upon market maturity. This study concludes that daily demand for AAM passenger services could reach 82,000 passengers (nearly 30 million trips annually) served by approximately 4,000 four- to five-seat aircraft in the U.S. under the most conservative scenario (Reiche, Goyal, et al. 2018). Another AAM market study commissioned by NASA estimated that by 2030, drone deliveries using 40,000 small unmanned aircraft could reach 0.5 billion annual deliveries by 2030 (Hasan 2019). However, Johnston et al. (2020) and Lineberger et al. (2019) found that a variety of factors such as limited takeoff and landing and energy infrastructure could constrain AAM growth.

Section 2. Enabling and Risk Factors

AAM could benefit from existing conditions in the aviation industry but also face a number of potential barriers from factors such as: 1) the safety and regulatory environment; 2) airspace and air traffic management; 3) security; 4) environmental impacts (e.g., noise, visual pollution, and privacy); 5) weather; 6) infrastructure and multimodal integration; 7) workforce and economic development; 8) social equity; and 9) community engagement and social acceptance. This section discusses these potential enabling and risk factors that could support or impede AAM growth, as well as the potential role for the State of California, where applicable.

2.1 Safety and Regulatory Environment

Aviation safety is supported by a robust federal policy and regulatory environment governing aircraft and airworthiness; operations (including crew requirements); and access to airspace (Graydon, Neogi, and Wasson 2020; Thipphavong, et al. 2018). Civil aviation authorities have several tools, such as certification, operational approvals, airspace access, and others to promote safety. This broad regulatory scope provides a toolbox of approaches that the FAA can use to manage and promote safety. Additionally, California and local governments can promote aviation safety through land use and zoning, building and fire codes, and law enforcement operations (Cohen, Shaheen, and Farrar 2021).

Valid concerns about the safety of AAM users, other airspace users, and those on the ground could present barriers to adoption (Cohen, Shaheen, and Farrar 2021; Graydon, Neogi, and Wasson 2020; Thipphavong, et al. 2018). Seven system-wide, safety-critical risks related to aircraft and their operating environment (Connors 2020) that will need to be addressed include:

- Flight outside approved airspace
- Unsafe proximity to people and/or property
- Critical system failure and loss of control (e.g., degraded or loss of command and control, GPS; engine failure; etc.)
- Cybersecurity risks
- Hull loss (i.e., an aviation accident that catastrophically damages the aircraft beyond economical repair, resulting in a total loss), and
- Other potential hazards such as weather, bird strikes, air and ground crew errors (e.g., loss of situational awareness, task saturation, etc.), passenger interference (e.g., disruptions, hijacking, sabotage, etc.).

Flight safety is evaluated by the interaction of three characteristics or conditions: 1) criticality of the function; 2) severity of a failure; and 3) probability of an event, with criticality of the function and severity of a failure overlapping concepts (Connors 2020). Each of these concepts are summarized in Table 1.

Table 1. Flight Safety Evaluation Characteristics

Criticality	**Non-essential**. Non-essential functions are those functions that do not contribute to or cause a failure condition that would significantly impact the safety of the airplane or the ability of the flight crew to cope with adverse operating conditions.
	Essential. Essential functions are those that could contribute to or cause a failure condition that would significantly impact the safety of the airplane or the ability of the flight crew to cope with adverse conditions.
	Critical. Critical functions are those whose failure would cause a condition that would prevent the continued safe flight and landing of the airplane.
Severity	Failure with **no safety effects**
	Minor failure conditions
	Major failure conditions
	Hazardous failure conditions
	Catastrophic failure conditions
Probability	**Extremely improbable.** Failure would be expected to occur no more than once in a billion hours of flight.
	Improbable or remote. Failure would be expected to occur ***no more than*** once in 100,000 hours of flight.
	Probable. Failure would be expected to occur ***more than*** once in 100,000 hours of flight.

Adapted and reprinted from: Connors (2020)

Connors (2020) explains that assessing the severity and probability of an individual failure is relatively straightforward; however, the emergence of complex and autonomous systems is resulting in the need for more advanced risk assessment techniques. Connors further notes that quantitative safety measures are increasingly being complemented with qualitative measures, which include:

- **Extremely improbable**. A failure condition is not expected to occur during the entire operational life of all airplanes of this type.
- **Improbable or remote**. A failure condition is not anticipated to occur during the entire life of a single random airplane. However, a failure may occur occasionally during the entire operational life of all airplanes of one type.
- **Probable**. A failure condition is anticipated to occur one or more times during the operational lifetime of each aircraft.

According to Connors (p.6) “An acceptable safety level for equipment and systems is based on an inverse relationship between average probability of failure per flight hour and the severity of the failure condition being considered. Critical aircraft functions are required to be Extremely Improbable. Essential functions are required to be Improbable; while non-essential functions have no specific probability requirements."

The current regulatory regime only sets standards for on-board piloted operations. This may present challenges for certifying and authorizing the use of some novel technologies and combinations of features that could be found in AAM aircraft (Coudert, et al. 2019; Reiche, Goyal, et al. 2018; Connors 2020). While not an exhaustive list, some of the novel AAM technologies that may pose risks include distributed electric propulsion/tilt-wing propulsion, VTOL, autonomy hardware and software, optionally piloted configurations, electric energy storage, and others (Reiche, Goyal, et al. 2018; Coudert, et al. 2019). Additional safety challenges for emerging aviation technologies can include:

- Autonomy and Highly Complex Software: Machine learning and other algorithms are not always predictable, which means that even for the same input, the algorithm may exhibit different behaviors on different runs (Reiche, Goyal, et al. 2018)
- Electric Propulsion and Energy Storage: Both propulsion and energy storage may pose a variety of challenges. More research is needed to understand the variety of risks associated with aircraft electrification (Reiche, Goyal, et al. 2018)
- Unmanned and Optionally Piloted Aircraft: For AAM aircraft to operate autonomously, there are a number of operational risks, such as physical security, operational procedures, cybersecurity and unmanned traffic management that will need to be considered as part of certifying airworthiness (Reiche, Goyal, et al. 2018), and
- More Aircraft than Operators: Several AAM business models involve a transition period to full autonomy that may include operations centers with remote operators controlling multiple aircraft. The associated operational risks will need to be considered as part of airworthiness certification; airspace access; crew training; certifications (e.g., airworthiness, aircrew, training, air carrier, air agency); and operational approvals (Reiche, Goyal, et al. 2018).

Safety data from the FAA shows that over time commercial airlines (operating under 14 CFR 121) have the fewest number of accidents and fatalities, followed by commuter and on-demand operations (operating under 14 CFR 135), with the highest number of accidents and fatalities reported for general aviation.[3] In 2020, *scheduled* and *non-scheduled* commercial airlines reported 0.132 and 0.529 accidents per 100,000 flight hours, respectively. In comparison commuter and on-demand air carriers reported 2.223 and 1.317 accidents per 100,000 flight hours, respectively. In contrast, general aviation had 5.572 accidents per 100,000 flight hours. Thus, while aviation has historically had a relatively good safety record compared to other modes, aviation's safety record varies considerably when comparing specific categories of operations. There are likely many factors for this such as regulatory, policies/procedures, aircrew training, aircraft types, etc. Because AAM is an emerging technology, the regulatory environment and how AAM aircraft, personnel, and air carriers are certified and regulated is likely to evolve over time.

[3] The operating regulations refer to the U.S. Federal Aviation Regulations (FARs) that govern all aviation activities in the U.S (Title 14 of the Code of Federal Regulations (CFR)). Part 107 regulates a broad spectrum of commercial and government uses of small Uncrewed Aircraft Systems (sUAS). Part 121 regulates scheduled air carriers (i.e., commercial airlines). Part 135 primarily oversees commuter and on-demand operations. Generally, each of these parts has requirements for pilot licensing, aircraft maintenance, crew duties, insurance, and other requirements that must be met to legally operate in the National Airspace System.

California and federal agencies could consider tracking safety incidents involving specific aircraft designs and technologies to aid in early identification of emerging safety risks and trends. Examples of categories that Caltrans (and other agencies) may consider tracking include AAM safety incidents involving:

- Piloted, remotely piloted, and autonomous AAM aircraft
- Vertical, short, and conventional takeoff and land aircraft (VTOL, STOL, and CTOL, respectively)
- Aircraft configuration (e.g., multicopter, lift+cruise, vectored thrust, augmented lift, and other design categories)
- Propulsion type (e.g., gas-powered, electric, hydrogen, etc.), and
- Use case (e.g., passenger services, cargo delivery, emergency response, etc.)
- Type of service (e.g., passenger services, cargo delivery, emergency response, etc.)

California Department of Transportation (Caltrans) Role

While the FAA will remain the primary regulatory authority for aircraft and airworthiness, operations, and airspace, the California Department of Transportation (Caltrans) can play an important role in several key areas. For example, Caltrans administers state and federal funds for airport development, maintenance, and operation. They also regulate, inspect, and license aviation operations. They also could support safe flight through radio and visual navigation aids; electrical and lighting systems; and collect and disseminate weather information to aircrews. A few key areas in which Caltrans could support AAM safety include:

Educational and research safety programs;

Grants and funding of airport and other AAM infrastructure improvements intended to enhance safety;

Registration of aircraft and aircrew in accordance with state laws and regulations;

Inspections and permitting of public- and private- use facilities to ensure compliance with state and federal regulations;

Wildlife management and security at and near airfields;

Facilitating search, rescue, and recovery operations when safety incidents occur; and

Partnering with the NTSB, FAA, and Transportation Security Administration (TSA) on safety related roles (e.g., holding investigations, inquiries, and hearings concerning accidents in aeronautics in California).

2.2 Airspace and Air Traffic Management

AAM operations are expected to take place at relatively low altitudes and in dense urban environments (Cohen, Shaheen, and Farrar 2021). One of the principal challenges facing AAM is that it will likely have to interact with existing commercial aviation and uncrewed/unmanned aircraft systems in a variety of contexts. FAA considers AAM separate from uncrewed/unmanned aircraft systems (or UAS) due to their separate concept of operations. Commercial air carriers operate with experienced pilots in controlled airspace where air traffic controllers have the authority to direct air traffic. In contrast, unmanned aircraft and drones have generally evolved in low-level and uncontrolled airspace using a different set of regulations, often with relatively inexperienced operators. AAM services operating in urban areas (and particularly to and from large and medium airports) will have to interact with both operational environments and likely fly in both controlled and uncontrolled airspace. Controlled airspace encompasses different classifications of airspace and defined areas where air traffic control services are provided to pilots. To enter controlled airspace, an aircraft must first gain clearance from air traffic control. In controlled airspace all aircraft must maintain continual radio contact with air traffic control and submit a flight plan detailing the route and height they will fly. In uncontrolled airspace, clearance is not required to operate and there is no supervision by air traffic control. Additionally, AAM will also need to ensure safe takeoff, approach, and landing alongside drones that typically operate below 400 feet (Federal Aviation Administration 2018). These interactions present a number of interrelated air traffic management related safety risks including collision avoidance, managing shared airspace, and greater air traffic congestion as the tempo of AAM activity increases.

The ability for AAM to move from either uncontrolled airspace (Class G) and/or designated AAM airspace corridors to busy controlled airspace[4] (Class B) without overwhelming air traffic control is one key risk. Additionally, procedures will need to be established for resolving collision avoidance alerts, particularly between AAM and commercial aircraft. As the number of operations increase, collision avoidance, communication, and management systems of both AAM and non-AAM airspace users may need to adapt (Graydon, Neogi, and Wasson 2020; Neogi and Sen 2017).

The risks AAM presents to air traffic management may vary based on a variety of external factors such as the size and growth of the industry; composition of piloted, remotely piloted, and autonomous flight operations (including whether these operations can co-exist within the same airspace); and enabling air traffic technologies such as unmanned aircraft systems traffic management (UTM)[5] (Graydon, Neogi, and Wasson 2020; Neogi and Sen 2017). Due to the complexity of flying in low altitude urban airspace, urban air mobility will likely present a greater degree of risk associated with air traffic management than rural operations. However, even in urban areas air traffic management risks will likely vary based on a variety of local and

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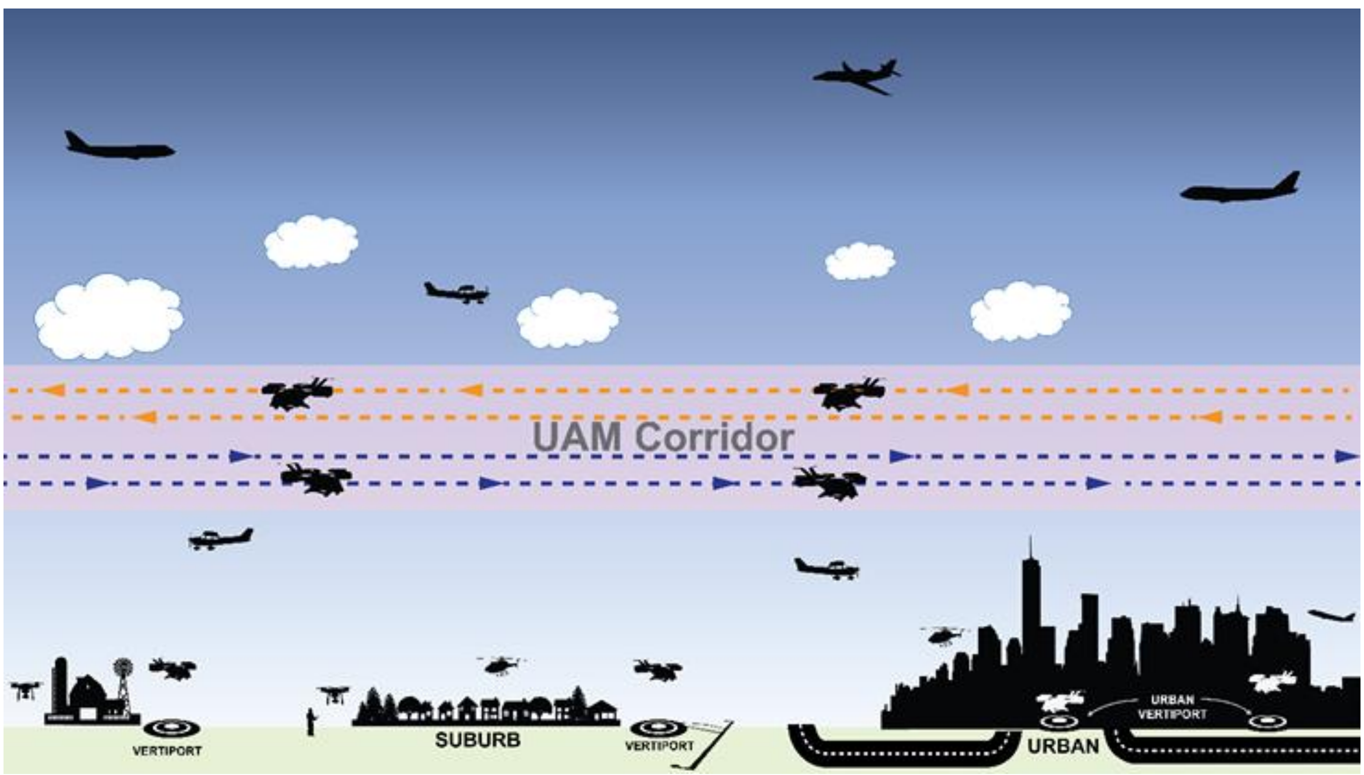
[4] Controlled airspace is a generic term that covers the different classifications of airspace and defined dimensions within which air traffic control service is provided in accordance with the airspace classification. In the U.S., controlled airspace consists of Classes A through E. Class B airspace is employed around airports with a high traffic volume. Class C airspace is used around airports with a moderate traffic level. Class D is used for smaller airports that have a control tower. Class E is a type of controlled airspace that often is controlled by air traffic control via radar coverage rather than by a local control tower. Class G airspace (uncontrolled) is that portion of airspace that has not been designated as Class A, Class B, Class C, Class D, or Class E airspace.

[5] Uncrewed aircraft system traffic management (UTM) is a traffic management system that establishes airspace integration requirements enabling safe low-altitude operations. UTM provides services such as: airspace design, corridors, dynamic geofencing, weather avoidance, and route planning. UTM systems will not require human operators to monitor every aircraft continuously; rather, the system will provide data to human managers for making strategic decisions.

regional factors such as existing airspace classes and congestion, location and proximity of major airports to AAM operations, and other factors. As such, it is not possible to forecast the level or likelihood of air traffic management risk.

The 1958 Federal Aviation Act delegated responsibility for the safe and efficient use of the airspace to the FAA, requiring it to create and enforce federal regulations (Serrao, Nilsson, and Kimmel 2018). Under existing laws and regulations, the FAA has exclusive authority over the national airspace. In recent years, the FAA has taken a number of steps to manage risks related to AAM air traffic. In March 2020, the FAA released the UTM Concept of Operations 2.0 that seeks to address more complex airspace operations for unmanned aircraft operating at or below 400 feet above ground level and increasingly more complex operations within and across controlled and uncontrolled airspace (Federal Aviation Administration 2020). Additionally, the FAA has published Urban Air Mobility Concept of Operations (ConOps) 2.0 describing the operational environment needed to support the anticipated growth of flight operations in and around these urban areas (Federal Aviation Administration 2023). ConOps 2.0 presents the FAA's air traffic management vision to support initial AAM operations in urban and suburban environments. The agency envisions that initial AAM operations will consist of a small number of low complexity operations and will evolve to more numerous and complex mature state operations. As the operational tempo of AAM increases, the FAA envisions the establishment of "Urban Air Mobility/UAM Corridors" where piloted aircraft will have the capability to exchange information with other corridor users in order to safely separate air traffic without relying on air traffic control (Federal Aviation Administration 2023). Figure 1 illustrates the envisioned UAM corridors (Federal Aviation Administration 2023). The State of California can support safe early deployments of AAM by establishing UAM corridors for demonstration flights.



The FAA also envisions the establishment of "Providers of Services for Urban Air Mobility" (PSUs) to support operations planning, operational intent (e.g., flight plans), airspace management, and information exchange during operations (e.g., notifications, weather information, etc.). The PSUs would process flight requests;

evaluate the operational intent for air traffic, space availability, and adverse conditions; and if approved, facilitate information sharing with a network of other PSU providers (Federal Aviation Administration 2023). The PSU could negotiate airport access through an airport's sponsor. PSUs could also support the management of Urban Air Mobility operations without direct FAA involvement on an individual flight basis (Federal Aviation Administration 2023). PSUs would be able to support local governments to gather, incorporate, and maintain information that may be accessed by AAM service providers. Although ConOps 2.0 does not specify how many PSUs there could be and whether or not PSUs would be public or private entities, the services offered by PSUs could theoretically be offered by a state agency such as Caltrans.

The ability for AAM aircraft and PSUs to communicate with both commercial and general aviation aircraft (which have a range of sophisticated to basic avionics and communication capabilities, respectively) is also an unknown and unresolved risk. In the future, remotely piloted and autonomous aircraft could allow for increasingly complex and higher volume operations; however, the development of new regulations, policies, procedures, guidance materials, and training requirements are needed to enable these operations (Cohen, Shaheen, and Farrar 2021). Due to federal preemption in airspace management, metropolitan planning organizations and Caltrans should monitor the growth and complexity of AAM operations and work with the FAA on strategies to manage air traffic management, as appropriate.

2.3 Security

Ensuring personal, personnel, physical, and cyber security of all aspects of AAM will be critical to maintaining safety and building public confidence. In a 2018 focus group study, participants in Los Angeles and Washington DC. raised numerous concerns about passenger security during booking, boarding, and on-board the aircraft from departure to arrival (Shaheen, Cohen, and Farrar 2018). Key security concerns included hijacking, terrorism and aircraft sabotage, people pointing lasers at passengers and aircrew on takeoff and final approach, and unruly passengers and incidents involving passenger violence (particularly in an autonomous flight scenario without any aircrew on-board). Data on security incidents involving general aviation (Part 91) and charter services (Part 135) are more limited than incidents involving commercial aviation (Part 121). Fortunately, the most serious incidents have declined in recent decades and remain relatively rare particularly given the total number of flights and flight hours. Since 2002, there have been 57 aircraft hijackings globally, although none in the U.S. since 9/11 (Mazareanu 2021). Sabotage, terrorism, and other intentional acts are not always included in aviation safety statistics. The Aviation Safety Network has identified five intentional incidents impacting commercial aviation globally between 2013 and 2017 (Flight Safety Foundation n.d.). In 2020, the FAA reported 6,852 incidents involving lasers pointed at aircraft (Federal Aviation Administration n.d.). Finally, as of January 2023, the FAA reported that incidents involving unruly passengers occurred 2.1 times per every 10,000 commercial aviation flights (Federal Aviation Administration 2023).

While terrorism, hijacking, aircraft sabotage, lasing, unruly passengers, and violence against passengers represent security risks, limited data and information on how AAM may operate make it difficult to assess the potential likelihood of these security issues. For example, the risk of an AAM hijacking may be highly dependent on whether AAM passengers and personnel go through security screening, and if so, how extensive those screening procedures may be. There could also be scenarios where some AAM services or routes screen passengers and personnel while others do not, for example, trips to or from an airport versus a route between two intracity non-airport locations.

Strategies such as passenger background checks, no-fly lists for people convicted of certain criminal offenses, passenger rating systems (similar to passenger and driver ratings used by transportation network companies/TNCs, also known as ridehailing and ridesourcing), as well as and trusted traveler programs (similar to the Transportation Security Administration's PreCheck that offers expedited security screening for passengers that have completed a vetting process) are a few strategies that could be employed to enhance AAM security. In addition, technologies such as biometric screening, emergency dispatch buttons, and individual passenger compartments within an aircraft could also be employed to enhance personal safety.

Regulators, air carriers, and ancillary service providers will likely need a system of policies and procedures to mitigate the risk of insiders (e.g., workers, contractors, vendors, etc.) exploiting their legitimate access to AAM infrastructure and services for unauthorized purposes. Moreover, the physical security of vertiports (areas that can support the takeoff and landing of VTOL aircraft), aircraft, charging/refueling, other physical infrastructure, and cargo will also need to be ensured. Finally, cybersecurity of all the enabling IT systems, including but not limited to ticketing/booking, air traffic management, communications, navigation, surveillance, and autonomous aircraft systems will be critical. In the future, close coordination among private sector stakeholders, local and state law enforcement, airports/vertiports, Caltrans, and national security agencies will be necessary to establish security standards and emergency plans for an array of possible scenarios.

2.4 Environmental Impacts

AAM could have several environmental impacts, such as noise, visual pollution, and privacy. The subsections below review each of these potential impacts in greater detail.

Noise

Aircraft and helicopter noise are a frequently cited nuisance in neighborhoods around airports and heliports (Federal Aviation Administration 2021). In the near future, the high level of rotorcraft noise will likely limit the use of helicopters in urban areas. A general population survey across four locations—Los Angeles, Mexico City, Switzerland, and New Zealand—found that the second and third highest factors impacting the public perception of AAM was the type of sound generated by eVTOL aircraft, followed by the volume of sound generated from an aircraft (Yedavalli and Mooberry 2019). An exploratory study which included a general population survey in five U.S. cities combined with focus groups in Los Angeles and Washington, D.C., found that noise levels could impact public support for AAM (Shaheen, Cohen, and Farrar 2018). According to a study by Holden and Goel (2016), eVTOL aircraft should be one-half as loud as a medium-sized truck passing a house (75 to 80 decibels at 50 feet; approximately 62 decibels at 500 feet altitude)—approximately one-fourth as loud as the smallest four-seat helicopter on the market (Holden and Goel 2016). Please note this has yet to be regulated, and aircraft noise can vary widely based on aircraft design and propulsion type.

As the AAM market grows, noise concerns could be mitigated through technological improvements (e.g., aircraft design and electrification) or persist as the market matures into larger-scale operations (due to the total ambient aircraft noise from multiple aircraft operating in close proximity). Plainly stated, increased demand for AAM poses potentially greater risk that noise will be a concern for communities impacted by AAM. Additionally, as surface transportation electrifies, a potential reduction in overall ambient urban noise could make aircraft noise more perceptible in the future than it is today.

Unfortunately, it is difficult to estimate the precise likelihood or magnitude of AAM noise because public tolerance of AAM noise may vary considerably based on a variety of factors such as aircraft and propulsion type; noise characteristics; flight operation type; time of day; and specific conditions. For example, the public may perceive noise from air ambulances to be highly disruptive but willing to accept the noise because the activity is occasional and serves a public good.

In the future, nine AAM noise considerations that will need to be addressed include:

- Volume of AAM noise (e.g., dB level)
- Length of time AAM noise occurs
- Time of day AAM noise occurs
- Type or frequency of AAM noise
- Number of people affected by AAM noise
- Location of AAM noise and proximity to sensitive land uses
- Number and location of takeoff and landing facilities
- Comparison of AAM noise to other ambient noise
- Differences in noise associated with varying types of AAM operations
- Differences between individual AAM aircraft noise compared to noise from large-scale AAM operations.

Under existing law, local governments can plan for and mitigate aviation noise primarily by promoting compatible land uses, requiring real estate disclosures, and including noise data in municipal codes. With respect to larger aircraft (e.g., commercial aviation operations), the Airport Noise and Capacity Act (ANCA) of 1990 prohibits local governments from implementing aircraft noise restrictions after October 1990. Although airports can apply to the FAA to impose additional noise restrictions, such as curfews under FAR Part 161, airports almost never receive approval (Castagna 2020). In some cases, communities have closed smaller airports in response to community complaints about noise and quality of life (e.g., Santa Monica airport is now scheduled to close in 2028). The State Aeronautics Act grants Caltrans the ability to adopt noise standards governing the operation of aircraft and aircraft engines for airports operating under a valid permit issued by Caltrans to an extent not prohibited by federal law. State law also establishes misdemeanor offenses and fines for the violation of noise standards by aircraft. Finally, state law allows property owners to enter into avigation easements whereby a property owner allows another entity to subject that property to noise, vibration, and other impacts commonly associated with airport (and presumably also vertiport) activity.

Although the FAA and other regulatory bodies have set thresholds for aviation noise around airports, AAM may need to meet stricter noise standards due to the nature of low-level flights over highly populated urban areas, coupled with large-scale operations (Holden and Goel 2016). At present, the primary mechanism for local, regional, and California agencies to influence noise may be through land use planning, and more specifically the location and approval of takeoff and landing infrastructure such as vertiports. In some cases, noise risk could be mitigated by prohibiting vertiports near sensitive land uses (or not allowing sensitive land uses near vertiports). Additionally, during the vertiport planning process, a public agency may conditionally approve a vertiport but prohibit flight operations during late night and early morning hours. Public agencies may own, operate, and/or fund vertiports to retain greater influence over AAM operations. In other cases, local agencies may be able to reduce the impacts of AAM noise through building codes, grants, and other practices that require or incentivize the use of sound deadening material in structures near vertiports and along key flight paths (Volpe

Center 2017). Other noise mitigation measures may be more appropriate for the FAA and the private industry such as reducing noise through aircraft and flight operation design. In the future, legislative and regulatory reform could expand policy mechanisms for noise abatement by local communities, metropolitan planning organizations (MPOs), and Caltrans.

Visual Pollution

An excessive number of low-altitude aircraft flights in urbanized areas, particularly for non-essential activities that can be completed using ground transportation, could create unwanted visual disturbances (Cohen and Shaheen 2021). However, the environmental impacts from AAM visual pollution are difficult to ascertain because aesthetic impacts can vary based on several qualitative factors such as frequency of operations, location of operations relative to surrounding land uses, aircraft size, and other characteristics. For example, the public may be more annoyed by the presence of an air taxi flying over a historic neighborhood or greenspace than over the parking lot of a shopping mall. Similarly, the public may be more annoyed by multiple aircraft near one another (e.g., near a vertiport with a high volume of air traffic). The public also could be concerned by the size of an aircraft in the sky or by its color or materials (e.g., if the aircraft has a reflective surface). For all these reasons, the risks associated with visual pollution are diverse and difficult to quantify.

A few studies have attempted to understand the potential aesthetic impacts of Urban Air Mobility operations and the proliferation of uncrewed aircraft through public surveys; however, limited experience observing AAM in the built environment can make it difficult for survey respondents to accurately respond to these types of survey questions. Although studies on the impacts of AAM visual pollution on society are limited, some emerging research on the impacts of visual pollution from uncrewed aircraft/drones as well as other sources may be able to provide some insight. A survey (n=3,690) by the European Union Aviation Safety Agency (EASA) on the potential societal barriers associated with AAM found that 19 percent of survey respondents raised concerns about visual pollution from drones and 16 percent were concerned about air taxis (European Union Aviation Safety Agency 2021). A survey (n=1,465) on the use of drones conducted by the United States Postal Service found that approximately one in five respondents raised concerns about visual pollution associated with drone use. Interestingly, the findings were consistent among respondents in urban, suburban, and rural communities (United States Postal Service Office of the Inspector General 2016). A number of studies on visual pollution in other contexts such as outdoor advertising (Portella 2014; Abaya Gomez Jr. 2012; Chmielewski, Lee, et al. 2016; Chmielewski, Samulowska, et al. 2018; Wakil, et al. 2021), cellular towers (Nagle 2009), and wind turbines (Jensen, Panduro, and Lundhede 2014) suggest that AAM could also present concerns about visual pollution, however, more research is needed (Jacksonville Community Council, Inc. 1985).

Privacy

Another concern about AAM is both physical and data privacy. For example, residential communities may be concerned with low-altitude aircraft flying over homes and yards (as well as other impacts). While studies are limited, some emerging studies on uncrewed aircraft/drone privacy may provide some insight. Broadly, drones are capable of highly advanced surveillance and are already used by law enforcement. They may be equipped with various types of devices, such as live-feed video cameras, infrared cameras, heat sensors, and radar, potentially raising privacy and civil liberties concerns. Several qualitative and quantitative studies examining bystanders' perception of drones have found that the public has notable concerns relating to stalking, photo/video recording, the sharing of recorded information, and the use of drones near residential land uses (Wang, et al. 2016; Rice, et al. 2018;

Winter, et al. 2016; Uchidiuno, Manweiler, and Weisz 2018; Bajde, et al. 2017). In contrast, a study of uncrewed aircraft/drone controllers found that many drone operators believed that privacy concerns were exaggerated and that drone operators have the constitutional right to fly drones in public spaces (Yao, et al. 2017).

Other studies suggest regulation has not kept pace with the potential technological and privacy concerns associated with drones (Winkler, Zeadally, and Evans 2018; Jenkins 2013-2014; Popescu Ljungholm 2019). Some states have begun to pass legislation intended to protect individuals from aerial surveillance. For example, California's Assembly Bill 856 (2015), makes individuals liable for the physical invasion of privacy when a person knowingly enters the land or airspace above the land of another person without permission to capture a visual image or sound recording. California Assembly Bill 2655 (2020), prohibits first responders from taking pictures (including pictures by drone) of a crime scene without a valid reason. The likelihood and severity of physical privacy risks will likely vary based on a variety of factors such as aircraft configuration (e.g., the ability for owners to outfit their aircraft with equipment that can collect sensitive information), operational characteristics (e.g., the altitude and flight paths of AAM operations), and operational tempo (i.e., overall volume and intensity of AAM operations over a particular area).

Additionally, there are multiple privacy concerns associated with data collection, sharing and management (e.g., user, financial, location, trip data, etc.). Broadly these issues center on traveler or user privacy. California's Consumer Privacy Act (CCPA) gives consumers more control over the personal information that businesses collect such as: 1) the right to know about the personal information collected about them and how it is used and shared; 2) the right to delete personal information collected from them (with some exceptions); 3) the right to opt-out of the sale of their personal information; and 4) right to non-discrimination for exercising their CCPA rights (California Office of the Attorney General 2023). AAM businesses operating in California may be required to give consumers certain notices explaining their privacy practices. However, there could also be privacy concerns from the private sector perspective associated with the sharing and storage of data and its potential impacts on proprietary trade secrets. California may want to work closely with the FAA to ensure the state protects controlled, privacy, sensitive, and unclassified critical infrastructure data and information pertaining to AAM. The FAA has established a Data and Information Management Policy intended to protect sensitive data while simultaneously ensuring awareness and compliance with the federal Open, Public, Electronic, and Necessary (OPEN) Government Data Act to support evidence-based policymaking (Dickson 2021).

2.5 Weather

Weather could pose a number of safety risks and operational challenges for AAM. Smaller aircraft and their passengers are more sensitivity to weather hazards (Reiche, Cohen, and Fernando 2021). Additionally, weather conditions such as low visibility, icing (snow/ice that accumulates on flight surfaces), wind shear, and precipitation (rain, thunderstorms) could present several weather-related challenges for AAM. Table 2 describes some of the common atmospheric conditions that could impact AAM. Some of these weather conditions could pose greater risks to AAM due to their low-altitude operations over urbanized areas, and for VTOL operations during the transition from vertical to horizontal flight. Strategies that are typically used in commercial aviation to overcome adverse weather conditions, such as delaying and rerouting flights to alternate airports are not particularly viable strategies for AAM because its value is premised on convenience and time savings over other transportation modes. Additionally, several proposed technologies for autonomous flight operations (e.g., lidar) may be degraded in low visibility conditions.

Table 2. Common Types of Atmospheric Conditions that May Impact AAM

Weather Condition	Description
High Winds	High winds and wind gusts can create several challenges for AAM operating at low altitude and in high-density built environments. High-rise buildings can also create canyon effects that produce unpredictable wind environments in urban centers.
Ice	Snow and ice can stick to critical surfaces (e.g., wings and rotors). De-icing systems and icephobic surfaces (currently under development) may be able to help mitigate some of these risks.
Precipitation	Rain, thunderstorms, snow, sleet, and hail can create a variety of flight hazards for aircraft which can include turbulence, tornados, icing, lighting, and downdrafts/microbursts.
Turbulence	Turbulence is an irregular motion of the air resulting from air currents. Smaller aircraft are typically more susceptible to turbulence.
Visibility	Low visibility can limit a pilot's ability to safely fly, particularly during critical phases of flight such as takeoff and landing. For most piloted aircraft under instrument flight rules (IFR) conditions, pilots are still required to visually observe the landing environment. In the future, autonomous aircraft may be able to land in a greater variety of low visibility conditions, however, minimums may still be required given potential technological limitations of the landing systems
Wind Shear	The sudden change in wind speed and/or direction which can cause a loss of airspeed and/or altitude. Wind shear can be particularly hazardous during critical phases of flight such as takeoff and landing.

One exploratory study of AAM found that no more than 16 percent of aggregate operational time will be impacted by weather. However, the study also notes that certain areas could have greater weather constraints (Holden and Goel 2016). A key limitation of this study is that it focuses on case studies of particular markets rather than large multi-city analyses. Another study conducting an exploratory AAM climatology analysis of ten U.S. cities with a variety of typologies and weather patterns, found the most favorable weather in the Pacific region (Reiche, Cohen, and Fernando 2021). A key limitation of this study, though, is the difficulty of precisely estimating the impacts of weather on AAM operations due to the variety of weather conditions and aircraft under development (each with different design characteristics and performance limitations). Additionally, the proprietary nature of these aircraft concepts results in limited publicly available information about their design capability in terms of airspeed, weight, cruise altitude, density altitude, etc. While aircraft design and technology may be able to expand the performance limits, some weather challenges are likely to remain (Reiche, Cohen, and Fernando 2021). One way the State of California could support AAM is through the deployment of a network of high-fidelity weather sensors. California also could establish a weather data clearinghouse that collects, aggregates, and disseminates weather data collected on automated vehicles, drones, and VTOLs equipped with meteorological sensors.

The ability for AAM businesses to grow their operations may depend on the ability to provide dependable and consistent service with minimal delays. The integration of AAM into mobility platforms (e.g., mobility-as-a-service) could help improve traveler reliability and minimize delays by automatically routing a traveler's journey around travel disruptions, such as weather (Shaheen, Cohen, and Broader, et al. 2020). This could include shifting trips from AAM to other modes at the onset of adverse weather. Additionally, AAM service providers and aircraft manufacturers may be able to consider mixed fleets of aircraft with different performance capabilities suited for a variety of weather conditions and climates. Thus, weather could present a variety of operational and safety risks to California agencies and be an important factor for why AAM may succeed in some parts of the state and not others.

2.6 Infrastructure and Multimodal Integration

AAM will require an extensive network of infrastructure, such as takeoff and landing facilities and energy infrastructure (e.g., charging and fueling stations). While AAM businesses may be able to use existing aviation facilities such as airports and heliports, as they grow a variety of different sized facilities could evolve. Several studies have attempted to develop a standardized classification for vertical takeoff and landing infrastructure. Generally, these studies classify three types of facilities, from smallest to largest: 1) vertipads; 2) vertiports; and 3) vertihubs. Vertipads are single landing pads and parking stalls intended to accommodate one or two parked aircraft. Johnston et al. (2020) estimated that vertipads would be approximately 6,000 square feet and cost between $200,000 and $400,000 USD to construct. A vertiport is a medium-sized facility intended to accommodate up to three landing pads and up to six parked aircraft. Johnston et al. estimated vertiports would be approximately 23,000 square feet and cost between $500,000 and $800,000 USD to construct. Vertihubs are larger facilities (possibly with multiple floors) to accommodate numerous landing pads with parking for multiple aircraft. Johnston et al. estimate vertihubs would be approximately 70,000 square feet, spread across multiple floors, and cost between $6 and $7 million USD to build. Given that many vertiports will require substantial electric infrastructure for charging, some experts envision vertiports and vertihubs will also serve as multimodal facilities that could integrate electric vehicle charging and serve as a depot for shared automated vehicles. The FAA has an Airport Zero Emissions Vehicle (ZEV) and Infrastructure Pilot Program that allows airport sponsors to use Airport Improvement Program (AIP) funds to purchase ZEVs and to construct or modify infrastructure needed to use ZEVs.

Caltrans or other state agencies could offer similar grant programs to encourage the development of electric infrastructure and the use of zero emission vehicles and equipment at AAM facilities. State agencies would need to coordinate closely with the FAA to ensure potential grant programs fund infrastructure that meets FAA safety standards, as appropriate. Mixed-use development around intermodal passenger facilities could create synergies with public transportation and provide transportation alternatives in the event of inclement weather, maintenance, or other operational delays impacting AAM. California's Senate Bill 375 permits California Environmental Quality Act (CEQA) exemptions for transit priority projects within a ½ mile radius of high-quality transit corridors. Similar policies could be applied in the vicinity of intermodal passenger facilities with AAM, being mindful of AAM land use compatibility concerns (e.g., noise impacts on sensitive land uses).

California's Aeronautics Law requires the construction of new airports to be approved by the county board of supervisors or city council where a proposed facility will be located. The law also allows boards of supervisors and city councils to delegate the authority to approve new helicopter takeoff and landing areas to their respective planning departments. The law also prohibits the takeoff and landing of helicopters within 1,000 feet of a public or private K-12 school. Caltrans requires a permit to establish and operate takeoff and landing facilities (Meyers 2022). Caltrans may review and assess vertiport permit applications; assist current and prospective vertiport owners, managers, and consultants with permitting, regulatory, and other aviation issues and facilitate coordination between local governments, state agencies, and the FAA.

In California, Airport Land Use Commissions (ALUCs) have also been established for all counties with public use airports within the state to implement state law regarding airports and surrounding land use compatibility (Los Angeles County 2009). ALUCs coordinate planning efforts at the state, regional and local levels; prepare and adopt an Airport Land Use Compatibility Plan for each public-use airport in its jurisdiction; and review plans, regulations and other actions of local agencies and airport operators (to promote and ensure compatibility between each airport in the county and surrounding land uses (Los Angeles County 2009). With legislative and regulatory reform, California may be able to leverage ALUCs to support compatible land uses around vertiports as well as private use facilities.

Finally, trip planning, booking, fare payment, and ticketing integration with other modes of transportation through programs such as the California Integrated Travel Project (CalITP) could allow for seamless modal connections and enable the public and private sectors to price trips efficiently with respect to existing surface modes of transportation (Cohen, Shaheen and Wulff 2023).

2.7 Workforce and Economic Development

Although a California-specific economic analysis of AAM has not been conducted, anecdotal evidence suggests that AAM could represent an important economic cluster given the high number of California-based manufacturers.

To capitalize on these potential opportunities, California could consider tax credits, incentives, and other policies to support AAM activities in the state (e.g., aircraft manufacturing, infrastructure development, etc.). For example, California works with local governments to help identify census tracts which meet the definition of "low-income community" under Internal Revenue Code Section 45(e). Census tracts meeting this definition can qualify as "Opportunity Zones." California has the potential to incentivize AAM investment and economic development (e.g., aircraft design, manufacturing, and assembly) in distressed communities by establishing state tax benefits for AAM. At the federal level, opportunity zones enable businesses to obtain a temporary deferral on capital gains for qualified investments through a Qualified Opportunity Fund established with the Internal Revenue Service.

California may also be able to apply and/or expand a number of business incentives and tax credits to AAM, such as:

- *California Competes Tax Credit*: This is an income tax credit available to businesses that want to relocate, stay, or grow in California.
- *Advanced Transportation and Manufacturing Sales and Use Tax Exemption*: This tax exemption provides a full sale and use tax exclusion to manufacturers that promote alternative energy and advanced transportation.
- *Research & Development Tax Credit*: This tax credit offers businesses an income tax credit if it paid for or incurred qualified research expenses (including wages, supplies, and contract research costs) while conducting qualified research activity in California.
- *ZEV Funding Opportunities:* California and many local governments offer a variety of incentives, financing options, and grants to help property owners, businesses, and California residents to acquire zero-emission vehicles (ZEVs) and infrastructure. Although most of these are currently limited to light-

duty ground vehicles, California could consider extending these programs to light and general aviation and/or establishing similar programs to encourage the growth of electric aviation.

- *Economic Development Rate Program*: This program gives special utility discounts for businesses that require high-energy loads to operate or continue operating in California. The state could extend this program or establish a new program to provide utility discounts for airside charging at California airports, heliports, and vertiports.

The state could also consider supporting the development of training/retraining programs that provide the job skills and technical expertise to enter AAM career fields. California has the Employment Training Panel (ETP) which provides funding to employers for training that upgrades the skills of their workers. Some counties (e.g., Santa Cruz) have established accelerator programs designed to foster entrepreneurship, mentorship, and strategic business support. These accelerators can also provide financial backing, legal support, marketing, and help connecting entrepreneurs to venture capital. To foster diversity and inclusion, many of these programs are available free of charge to participants. Other programs are designed to provide training and certifications.

California could consider establishing workforce development grants modeled after similar FAA programs. These grants could support the development and expansion of aviation programs across the state to expand the number of pilots, ground crew, maintenance technicians, and other specialties required to support the growth of AAM.

2.8 Social Equity

While limited published research exists on the potential equity impacts of AAM, the effect of AAM on vulnerable populations and historically disadvantaged communities present notable challenges. Broadly, fair treatment of all people regardless of race, color, national origin, or income with respect to the planning and implementation of AAM services, policies, and regulations means no group should bear a disproportionate share of the negative environmental consequences resulting from public or private sector operations or policies (Environmental Protection Agency n.d.).

With respect to potential AAM passenger services, current services using helicopters are premium offerings that have, in recent years, typically averaged $149–300 US per seat. eVTOLs could reduce total operating cost per seat mile by about 26 percent compared to helicopters currently in use (Duffy, Wakayama, and Hupp 2017). On-demand air taxis could cost from $8 to $18 USD per minute (Porsche Consulting 2018). McKinsey and Company estimate that an “air metro” type service will cost $30 USD per trip in 2030, while air taxis will remain pricier, ranging from $131 to $1,912 USD per trip (depending on vertiport density) (Hasan 2019). There are concerns that AAM may not be an affordable transportation option for lower- and middle-income households, and that AAM may be used by upper income households to avoid traffic congestion. While proponents compare AAM to early commercial aviation and foresee the eventual democratization of air travel, it took decades for commercial aviation to achieve mass market affordability (Cohen, Shaheen, and Farrar 2021). Additionally, the business models of intraurban, small aircraft operations are quite different. While electrification and automation have the potential to reduce costs, it is unclear if AAM can be affordable for a mass market. Similar affordability concerns could also be raised with regard to some emergency response services, such as medical transport for —people without any or sufficient levels of medical insurance coverage who may not be able to afford aeromedical transport and/or be left with unaffordable medical transportation bills after using the service (Goyal and Cohen 2022).

There are also concerns that low-income, minority, and other vulnerable populations may bear a disproportionate share of the negative environmental impacts of AAM (Cohen and Shaheen 2021). While not an exhaustive list, examples include noise impacts on low-income and minority neighborhoods, and concerns about gentrification and displacement around vertiports. State agencies and local governments may consider adopting anti-gentrification and anti-displacement policies to help mitigate these potential effects in the vicinity of vertiports. Caltrans could also consider conducting an environmental justice analysis of proposed vertiports when reviewing permit applications for new facilities. Caltrans and local agencies may also consider whether public sector investments in AAM may be diverting funding from other services with broader availability (e.g., public transportation).

Caltrans can play a key role guiding equitable outcomes by ensuring full and fair participation in AAM decisions by protected groups that may be impacted, and by applying environmental justice principles to the review and approval of vertiport locations. State agencies should also consult with the FAA on how to mitigate the impacts of AAM flight paths and corridors on vulnerable communities. California could also support equitable outcomes through subsidies and programs that expand AAM access to low-income communities. Ensuring accessibility for people with disabilities is also another important social equity concern.

In summary, there is much uncertainty about how much AAM will ultimately cost, how long it will take to become affordable (if ever), what type of public investment (if any) should support AAM, and what will be the impacts of AAM users on non-users (e.g., noise, aesthetics, vertiport siting, foregone public sector resources that could be spent on other initiatives, etc.). Ensuring meaningful involvement and fair treatment of all people in AAM planning and implementation will be critical.

2.9 Community Engagement and Social Acceptance

AAM presents many new challenges that could affect the public. Historically, aviation planning has focused on aviation stakeholders and the communities around airports. Since AAM could potentially affect areas beyond the immediate vicinity of airport facilities, AAM will require a greater degree of engagement with community and aviation stakeholders that may have limited experience working together (Cohen, Shaheen, and Wulff 2024). While environmental processes, such as the California Environmental Quality Act (CEQA) could provide tools for assessing the technical viability of vertiport and operational concepts, early engagement is important to understanding and addressing potential community concerns. Community engagement will be an essential part of understanding and mitigating the adverse impacts of AAM on underrepresented populations and communities (Cohen, Shaheen, and Wulff 2024).

Additionally, negative community perceptions could pose challenges to the adoption of AAM, as well as presenting a variety of institutional, public relations, and political risks for California agencies (Cohen, Shaheen, and Farrar 2021). As previously noted, a few notable concerns that will likely contribute to public acceptance include safety, security, noise, visual pollution, privacy, equity, and other social and environmental impacts. While a number of exploratory surveys have attempted to understand barriers to community acceptance, the lack of public experience with AAM aircraft and operations represents notable limitations of these studies as it is difficult for respondents to accurately comment on something they have no direct experience with (Yedavalli and Mooberry 2019; Shaheen, Cohen, and Farrar 2018; Holden and Goel 2016; Fu, Rothfeld and Antoniou 2019). In November 2019, the non-profit Community Air Mobility Initiative (CAMI) was established to educate and provide resources to the public and local and state decisionmakers. Ongoing education, outreach, community engagement, and research are needed to advance understanding of potential barriers to community acceptance and policies that will be able to guide safe, sustainable, and equitable outcomes.

Section 3: Potential State Role in AAM

While the roles and responsibilities of state agencies in aviation issues are largely defined in the State Aeronautics Act, California could also play a key role in AAM in four key areas: 1) institutional readiness; 2) funding and infrastructure readiness; 3) workforce readiness; and 4) equity and vertiport planning. Each of these are summarized in the subsections below.

Institutional Readiness: Capacity Building and Engagement on AAM Issues

Caltrans should consider developing resources to educate local and regional entities on their roles and responsibilities with respect to AAM and aviation-related issues. To this end, the California State Transportation Agency and Caltrans should consider convening state and local stakeholders as part of working groups and other outreach efforts to engage and provide stakeholders with AAM information. SB800 (2023) requires the state's transportation agencies in coordination with the Governor's Office of Planning and Research and the Air Resources Board establish an Advanced Air Mobility, Zero-Emission, and Electrification Aviation Advisory Panel. This committee will be developing a report for the Legislature to examine issues such as electrification goals in the aviation industry, consideration of aircraft fuel into the Low Carbon Fuel Standard, potential legislation and regulatory changes needed to support the development of AAM, and equitable access to AAM infrastructure. The California State Transportation Agency and Caltrans could also consider additional outreach and engagement efforts to solicit public and private sector input, and develop a statewide AAM strategic plan that addresses emerging issues and assess the strengths, weaknesses, opportunities, and threats. These agencies should also consider scenario planning to help inform the planned deployment and evolution of AAM in California.

In addition to state-level engagement on AAM issues, Caltrans should consider developing tools that provide local and regional governments resource materials to engage community stakeholders and the public on issues related to AAM. These resource materials could include a "quick-start" guide to provide early foundational resource material to local/regional governments and airports on AAM and a toolkit for local and regional governments and recommend steps to successfully engage communities on AAM-related topics.

Funding and Infrastructure Readiness: State Tax Credits and Incentives to Support AAM Energy, Take-off and Landing, and Digital Infrastructure

The Governor's Office of Business and Economic Development (GO-Biz) could consider tax credits, incentives, and other policies to support AAM economic development in the state (e.g., aircraft manufacturing job creation, infrastructure development, etc.). California may also be able to expand a number of business incentives and tax credits to AAM, such as California Competes Tax Credit, Advanced Transportation and Manufacturing Sales and Use Tax Exemption, Research & Development Tax Credit, ZEV Funding Opportunities, and the Economic Development Rate Program. Broadly, many these existing initiatives are intended to support the research and development of clean transportation options but have historically focused on surface modes. Because of the recent loss of multiple AAM manufacturing initiatives to other states, GO-Biz should quickly review potential economic development incentives required to attract and retain AAM original equipment manufacturers (OEMs) and ancillary industries in the state.

Caltrans, the California Public Utilities Commission, and the California Air Resources Board should consider conducing a gap analysis of hydrogen, grid and charging Infrastructure for AAM to produce a base level understanding of the energy needs to operationalize AAM in California and to identify what infrastructure upgrades and potential funding sources are available to meet these needs. This gap analysis should be completed over the next one to two years to guide AAM energy investments over the next decade. Additionally, these agencies could consider establishing new grant programs to support AAM electrification, hydrogen, and other infrastructure, consistent with safety and other requirements established by federal partners.

Workforce Readiness: Training and Retraining Programs

California can play a critical role supporting the development of training and retraining programs that provide the job skills and technical expertise to enter AAM career fields. To ensure a ready workforce by the end of the decade, the Employment Development Department (EDD) should work with trade schools, colleges, and universities today to develop curriculums that help prepare students for careers in AAM. Additionally, EDD should develop training programs for AAM career paths for unemployed and early career personnel and members of underserved communities. Additionally, GO-Biz and EDD could consider establishing workforce development grants modeled after similar FAA programs. These grants could support the development and expansion of aviation programs across the state to expand the number of pilots, ground crew, maintenance technicians, and other specialties required to support the growth of AAM as well as other aviation careers in California.

Equity and Vertiport Planning: Land Use Compatibility and the Environmental Justice Analysis of Proposed Vertiports

Caltrans can play a key role guiding equitable outcomes by ensuring full and fair participation in AAM decisions by protected groups that may be impacted, and by applying environmental justice principles to the review and approval of vertiport locations. To aid local governments on AAM vertiport planning, Caltrans should consider developing a toolkit to support compatible land use planning in the vicinity of existing and new vertiports for AAM (e.g., an assessment of various types of land uses that would be supportive or hazardous surrounding vertiports in urban areas). This toolkit should be ready for local agencies within the next two years to aid in the planning of vertiports over the next decade.

As new vertiport permit requests are submitted to the state, Caltrans should consider conducting an environmental justice analysis of proposed vertiports when the state reviews permit applications for new vertiports. State agencies should also consult with the FAA on how to mitigate the impacts of AAM flight paths and corridors on vulnerable communities. California could also support equitable outcomes through subsidies and programs that expand AAM access to low-income communities.

Over the next decade, the California Department of Housing and Community Development (HCD) may consider developing model anti-gentrification and anti-displacement policies that could be implemented at the local level to help mitigate the potential effects of gentrification and displacement in the vicinity of vertiports. While not an exhaustive list, potential policies could include requiring outreach with community groups to identify concerns; conducting technical analyzes to help identify locations at-risk of gentrification and displacement; developing funding programs and policies that help prevent and mitigate gentrification and displacement around vertiports. (e.g., inclusionary zoning which requires a share of residential and commercial development to be dedicated to low-to-moderate income households and small businesses, respectively).

Glossary

Advanced Air Mobility (AAM) - A broad concept focusing on emerging aviation markets and activities for on-demand aviation in urban, suburban, and rural communities. AAM includes local use cases of about a 50-mile radius in rural or urban areas and intraregional use cases of up to a few hundred miles that occur within or between urban and rural areas.

National Airspace System (NAS) - A network of both controlled and uncontrolled airspace, both domestic and oceanic. The NAS includes air navigation facilities, equipment, and services; airports and landing areas; aeronautical charts, information and services; rules and regulations; procedures and technical information; and manpower and material.

Regional Air Mobility (RAM) - Envisions a safe, sustainable, affordable, and accessible air transportation system for passenger mobility, goods delivery, and emergency services for intra- and interregional trips of about 50–500 miles (e.g., from one metropolitan region or urban area to another). RAM includes scheduled and on-demand flights, typically between smaller airports, using small aircraft with less than 20 passengers (or an equivalent weight in cargo).

Rural Air Mobility - Envisions a safe, sustainable, affordable, and accessible air transportation system for passenger mobility, goods delivery, emergency services, and other applications within or traversing rural and exurban areas (e.g., delivery of healthcare and other critical services in rural communities, agriculture crop dusting using unmanned aircraft, etc.). Rural air mobility may overlap with Urban Air Mobility (below) in cases where a flight traverses an urban area and at an altitude low enough to impact communities on the ground.

Short Takeoff and Land (STOL) – An aircraft that can use a short runway for takeoff and landing.

Small Uncrewed/Unmanned Aircraft Systems (sUAS) – A drone that weighs less than 55 pounds on takeoff, including everything that is on board or otherwise attached.

Uncrewed/Unmanned Aircraft (UAS) – An aircraft that operates without the possibility of direct human intervention from within or on the aircraft (i.e., no on-board pilot).

Urban Air Mobility (UAM) - Envisions a safe, sustainable, affordable, and accessible air transportation system for passenger mobility, goods delivery, and emergency services within or traversing metropolitan areas. UAM typically includes services within or between edge cities and urban, suburban, and exurban areas.

Vertical Takeoff and Land (VTOL) – An aircraft that can take off, hover, and land vertically. The terms electric VTOL or eVTOL are also commonly used to refer to electric aircraft that can take off and land vertically.

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Appendix: AAM Research Roadmap

This appendix presents California's AAM research roadmap. The first section discusses some of the research currently underway and similar AAM research roadmap efforts recently completed. The next section discusses the methodology used to develop the state's AAM research roadmap. The following section presents AAM research needs and gaps for the State of California. The fourth section discusses the role of demonstrations. The final section concludes with key takeaways.

A1. Key Current and Pending AAM Research Efforts

Several public and private entities are engaged in AAM research. Although not an exhaustive list, this section describes some notable research efforts underway as well as research needs identified by the Transportation Research Board (TRB), NASA, and the FAA.

TRB's Cooperative Research Programs have funded ongoing research and recently completed a number of AAM studies. A few notable studies include:

- *Airport Cooperative Research Program (ACRP) 03-50 An Airport-Centric Study of the Urban Air Mobility Market* (Research Complete) – This study assessed the potential impacts of AAM on airports of different sizes and discussed planning considerations for airports to prepare for AAM.
- *ACRP Synthesis 11-03/S03-17 - Airport Centric Advanced Air Mobility Market Study* (Research Complete) – This research summarizes, compares, and contrasts existing AAM market studies.
- *ACRP 03-51 Electric Aircraft on the Horizon - An Airport Planning Perspective* (Research Complete) – This study developed a guidebook to help airports prepare for airside electrification. The study includes methods to help practitioners estimate costs, determine facility requirements, and consider environmental and land use impacts.
- *ACRP 03-71 - Growth of Airport Electrification: Vehicles, Mobile Equipment, and Aircraft* (Research Underway) – This research will develop a guidebook that helps airports inventory and assess the anticipated growth in electrification needs for aircraft, vehicles, and mobile equipment.
- *ACRP 11-02/Task 43 - Successful Community Inclusion in Advanced Air Mobility* (Research Underway) – This research will develop a primer for engaging airport and community stakeholders on AAM.
- *National Cooperative Highway Research Program (NCHRP) 23-15 Guidance on Risks Related to Emerging and Disruptive Transportation Technologies* (Research Underway) – This study will develop a risk register for AAM, electric vehicles, automated vehicles, and mobility on demand for local, regional, and state governments. The study will also recommend approaches agencies can use to prioritize those risks and identify policies and actions to address the risks.
- *Transit Cooperative Research Program (TCRP) D-21 Planning for the Future of Intermodal Passenger Facilities: Guide and Decision-Making Framework* (Research Underway) – This project is jointly funded with NCHRP and ACRP. The research will develop a planning guide for future intermodal passenger facilities which incorporate emerging transportation technologies, such as AAM and automated vehicles.
- *Urban Air Mobility Airspace Research Roadmap Rev. 2.0 (NASA)* (Research Complete) – This document

provides a basis for prioritizing and coordinating research efforts, and for integrating results that build towards NASA's UAM research. The project is ongoing, and the document is updated periodically.

- *Advancing Aerial Mobility: A National Blueprint* *(National Academy of Sciences, Aeronautics and Space Engineering Board)* (Research Complete) – This document outlines essential characteristics of Urban Air Mobility systems and key barriers to achieving a national vision for UAM. It includes recommendations on research projects that NASA, other government agencies, industry, and academia could employ to overcome the barriers.

In addition to this research, NASA and the FAA have also identified several AAM research needs and priorities. Broadly, NASA has identified research across four "capability cornerstones" (Cooperative and Highly Automated Operations; Integrated, Distributed Information Infrastructure; Automation and Ecosystem Performance; Integrated Safety Assurance) and five stages of development (architect and improve (2025 to 2030); connect and integrate (2030 to 2035); inform and empower (2035 to 2040); optimize and learn (2040 to 2045), achieve Sky for All (2045 to 2050)).

NASA has also developed and continues to update a research roadmap to identify Urban Air Mobility (UAM) research needs. NASA recently completed UAM Airspace Research Roadmap (rev 2.0) which identifies airspace research that NASA can pursue over the next decade to achieve intermediate level/maturity level 4 where the AAM ecosystem consists of medium-density and medium-complexity operations with collaborative and automated systems. This includes research needed to support airspace management systems and services architecture; airspace and procedure design; airspace system regulations and policies; communications, navigation, and surveillance services and systems; airspace security; separation services and standards; vertiport operations; and weather.

Additionally, the FAA's FY2022-26 National Aviation Research Plan recommends that the FAA invest in human factors research associated with increasingly automated operations, including human-machine systems integration, pilot/operator training and certification, and airspace interoperability between traditional and AAM operations. The FAA conducted human factors research in FY 2020 looking at human impacts from new operations and new uses of autonomy. The FAA continues to engage NASA and industry partners on this and other AAM research topics

A2. Research Roadmap

The researchers employed a multi-method approach to developing the research roadmap. To begin, the authors conducted a review of the literature to understand what research has been completed, ongoing and planned research studies, and research gaps. This review was supplemented with exploratory interviews with representatives from the FAA, NASA, ACRP, Caltrans, and several academic institutions. In addition, the researchers also identified five topics (airspace, aircraft, operations, community and infrastructure) and six cross-cutting themes (public acceptance and equity, workforce and economic development, sustainability, safety, governance, and planning). Using these topics and cross-cutting themes, the researchers engaged experts in five virtual workshops. Each virtual workshop was organized around a different theme:

- Local and Regional Governance, Planning, Community Engagement, Societal Adoption, and Equity
- Local and Regional Benefits and Impacts of AAM
- Workforce and Economic Development
- Airspace, Aircraft, and Operations (Governance and Planning)
- Airspace, Aircraft, and Operations (Safety and Sustainability)

During the virtual workshops, participants were led through a guided protocol where they were able to share information on AAM research needs from a state perspective. Based on these workshops and feedback from participants, the researchers determined that most aircraft, airspace, operational, and safety research should be led by the FAA and NASA. They further determined that California should focus its research efforts on equity; stakeholder and community engagement; public perception; local, regional, and state governance; understanding social and environmental impacts; and workforce and economic development. Although important, research topics that fell outside of the local, regional, and state roles of government were not included as part of this AAM research roadmap (e.g., research needed to support airspace management, aircraft and aircrew safety and certification, etc.). Individual interviews with subject matter experts were also conducted to help inform identified research needs and potential research topics.

A3. Research Needs and Gaps

The research roadmap process identified 16 research topics across five thematic areas: 1) Equity, Community Engagement, and Societal Adoption; 2) Governance, Planning, and Infrastructure; 3) Safety; 4) Sustainability and Environmental Impacts; and 5) Workforce and Economic Development. Figure 2 summarizes the number of projects identified in each thematic area. Table 3 summarizes each of the research needs identified including a title and description, key research questions, and desired project outcomes.

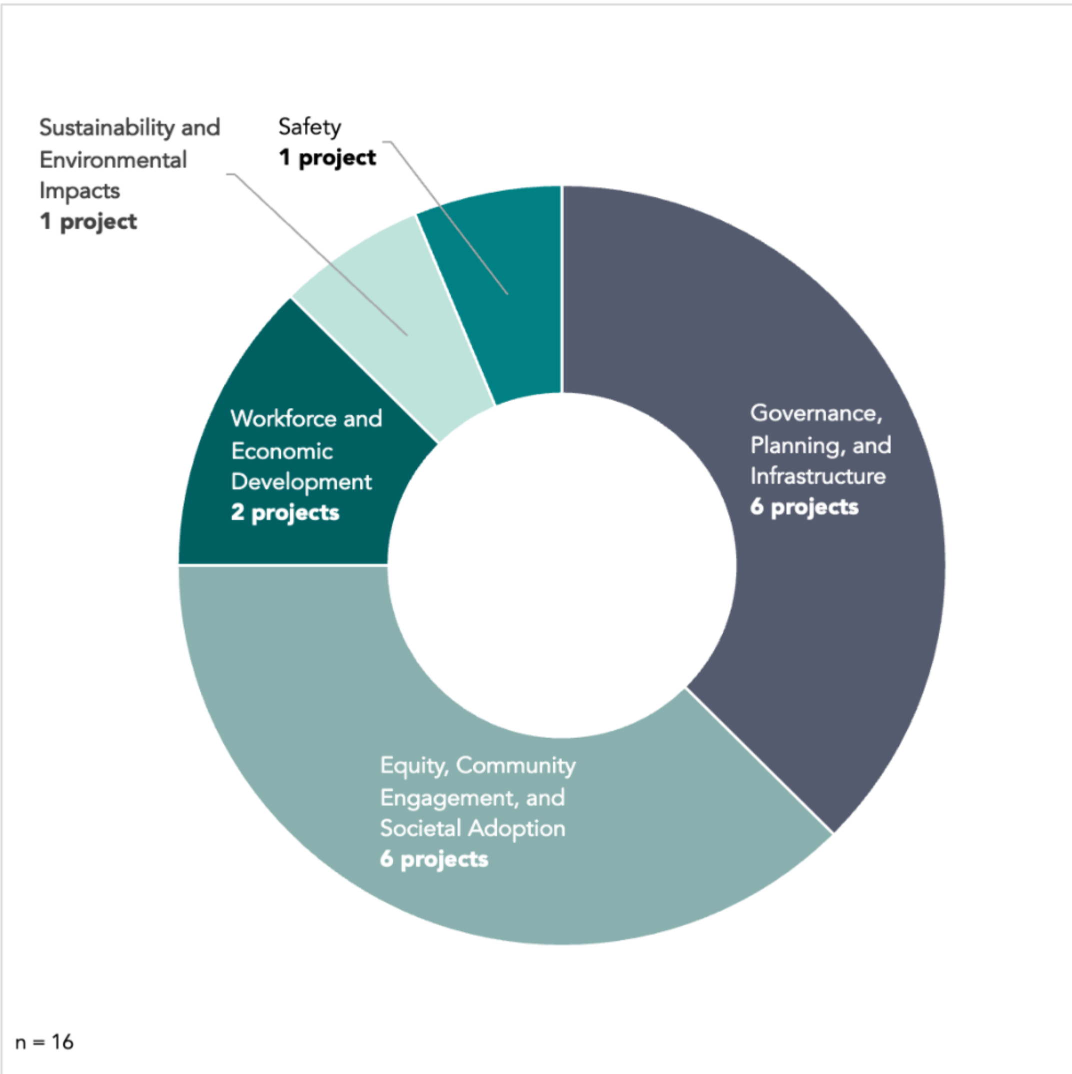


Table 3. Advanced Air Mobility Research Needs by Thematic Area

Research Needs	Title	Description	Research Questions	Research Outcomes
1. Equity, Community Engagement, and Societal Adoption (6 projects)				
1.1 AAM Stakeholder & Community Engagement Resources	*Early Resource Materials for Engaging Stakeholders and the Public on AAM*	This research will provide California local and regional governments early resource materials to engage stakeholders and the public on issues related to AAM.	1. Which stakeholders and community-based organizations should be engaging on AAM related issues at the local and regional levels of government? 2. What strategies are needed to bring together traditional and non-traditional aviation and community stakeholders together on AAM related issues? 3. What emerging engagement strategies are being employed within and outside California on AAM (e.g., focus groups, virtual meetings, town halls, etc.)?	This research will develop a community engagement toolkit for local and regional governments and recommend steps to successfully engage communities on AAM-related topics.
1.2 AAM in California: Early Understanding of Environmental, Social, and Behavior Impacts (Part 1)	*Public Perceptions about AAM Deployments in California Part 1*	This study will evaluate early understanding of public perceptions of potential AAM deployments in California, and potential concerns from the user and non-user perspectives through immersive technologies and experiential study, such as virtual reality, flight simulation, and demonstrations.	1. How do potential users and non-users perceive AAM? (e.g., safety, equity, etc.) 2. What concerns do users/non-users have (e.g., safety, equity, etc.)? 3. How are the perceptions and concerns of users/non-users similar and different?	This study will produce a research report and policy brief summarizing key findings.

Research Needs	Title	Description	Research Questions	Research Outcomes
1.3 AAM in California: Early Understanding of Environmental, Social, and Behavior Impacts (Part 2)	*Public Perceptions about AAM Deployments in California Part 2*	This study will evaluate early understanding of public perceptions of AAM deployments in California, and their impacts from the user and non-user perspectives.	1. What are the impacts of initial AAM deployments in California? 2. How do impacts vary for users and non-users? 3. What policies and/or practices are needed to guide safe, sustainable, and equitable outcomes?	The goal of this request is to study user and community impacts of early AAM deployments. The proposed funding will help California communities and public agencies prepare for emerging innovations in aviation. This study will produce a research report and policy brief summarizing key findings.
1.4 AAM Routing and Vulnerable Communities	*Ensuring Equitable AAM Routing: Developing Policy Strategies to Mitigate Impacts on Vulnerable Communities in California*	This project seeks to understand the least harmful way to approach AAM routing decisions in California to establish policy strategies to ensure that vulnerable communities are not overburdened with the impacts of AAM flight paths.	1. How are the benefits and burdens allocated across different communities in CA as part AAM deployment (e.g., impacts of flight paths on vulnerable communities)? 2. What policy strategies could help protect vulnerable communities from the burdens associated with AAM flight paths?	This research will develop a report and policy brief that define the disparate benefits and burdens of the AAM industry in CA and help the state begin to implement policies to protect vulnerable populations from negative externalities of AAM operations.

Research Needs	Title	Description	Research Questions	Research Outcomes
1.5 Impacts of Vertiports on Neighboring Communities	*Potential Impacts of Vertiports on Gentrification and Displacement in California: Examining Anti-Displacement Policies for Equitable AAM Infrastructure Development*	Vertiport location decisions will inevitably impact communities in CA as AAM infrastructure is developed across the state. This project seeks to examine the potential gentrification and displacement impacts associated with vertiports and anti-displacement policies that could protect against these forces.	1. What are the impacts of AAM vertiport locations on gentrification and displacement? 2. What locations in CA are most likely to be affected by these impacts and are there any targeted anti-displacement policies that could protect against displacement?	This project seeks to provide a preliminary understanding of the relationship between displacement and AAM vertiports while also beginning to examine possible policy strategies to protect against the displacement effects of vertiport construction. Key outcomes will include a report and policy brief.
1.6 Community Benefits of AAM	*Access and Societal Benefits of AAM in California: Understanding Early Adopters and Excluded Populations, and Identifying Benefits for Non-Users*	As an emerging industry, there will inevitably be a period of time where AAM is not accessible to everyone in California. This project seeks to define the populations that will use AAM in the early stages of the industry and those who will be left out. Second, in light of the inaccessibility to all in the early stages of the industry, this project looks to examine potential societal benefits of AAM to non-users in California.	1. What demographics are going to be early adopters of AAM? What communities will be left out? 2. What other societal/community benefits will AAM provide to those who can't afford to use AAM?	This research will help understand the demographics of those who will utilize AAM in the early phases of deployment and define the wider community benefits of AAM. Key outcomes will be documented in a research report and policy brief.
2. Governance, Planning, and Infrastructure (6 projects)				
2.1 Preparing	*Preparing for Safe*	This research will enhance	1. What is the level of readiness of California	This research will develop

Research Needs	Title	Description	Research Questions	Research Outcomes
Local and Regional Governments for AAM: Understanding Institutional Readiness	*and Sustainable Air Mobility: Enhancing Public Sector Understanding and Planning Initiatives for AAM in Urban, Rural, and Regional Contexts*	understanding of public sector perceptions of AAM and identify ongoing planning initiatives and policies needed to guide safe, sustainable, equitable, and multimodal outcomes. A key goal of this study will be to aid local and regional governments, often with limited experience or no involvement in aviation issues, in preparing for urban, rural, and regional air mobility.	local/regional governments and airports for AAM? 2. What tools and/or resources are needed to help California local/regional governments and airports prepare for AAM and build institutional capacity on AAM-related issues.	a "quick-start" guide to provide early foundational resource material to local/regional governments and airports on AAM.
2.2 Vertiport/ AAM Land Use Compatibility Resources	*Enhancing Land Use Planning for Vertiports in Urban Areas: A Guide for Local Governments and Neighborhood-level Planning*	Although Caltrans has a California Airport Land Use Planning Handbook which provides guidance for conducting airport land use compatibility planning, this guide is principally intended for airport facilities. Additionally, land use planning will likely be conducted by local governments and not by county-level airport land use commissions (ALUCs). The purpose of this project is to provide supplemental information on vertiport land	1. What types of considerations do local governments need to consider to ensure land use compatibility around vertiports? 2. What practices and/or policies are needed, and how do these differ across a variety of planning contexts (e.g., high vs. low volume of activity; urban vs. rural; greenfield vs. grayfield vertiport development; etc.)? 3. What types of land uses would be hazards in the vicinity of vertiports?	This research will develop a toolkit to support compatible land use planning in the vicinity of existing and new vertiports for AAM. Additionally, this project will provide an assessment of various types of land uses that would be supportive or hazardous surrounding vertiports in urban areas. Finally, this project will examine what role the state and regional MPOs can play in providing guidance for local

Research Needs	Title	Description	Research Questions	Research Outcomes
		use planning and compatibility that is more suitable for urban areas and neighborhood-level planning.		municipalities in regard to land use around vertiports.
2.3 Gap Analysis of Grid Infrastructure and Charging Infrastructure for AAM	*Powering the Future of Air Mobility in California: Assessing*[redacted] *Electric Infrastructure Needs for AAM Operations and Aircraft*	This project aims to understand the electric infrastructure needed at the state and local level in California to support AAM operations and aircraft.	1. How much energy and what types of energy sources will be needed to operate AAM in California? 2. What grid infrastructure needs to be adapted and developed to eVTOL/eSTOL operations in California? 3. Are there ways to tap into grid projects that are already underway (e.g., microgrids) and partner with other states and/or local authorities on these projects? 1. What are the funding sources for these types of grid infrastructure upgrades and enhancements? 2. What are the charging needs for AAM at the airport and vertiport level? 3. What policies need to be in place at the state level in California to support the generation and sale of electrification for AAM? 4. How can California support safe charging for eVTOLs and eSTOL operations?	The goal of this project is to produce a base level understanding of the energy needs to operationalize AAM in California and to identify what infrastructure upgrades and potential funding sources are available to meet these needs. Key outcomes will be documented in a research report and policy brief.
2.4 Gap Analysis of Hydrogen Infrastructure for AAM	*Powering the Future of Air Mobility in California: Assessing Hydrogen Infrastructure Needs*	This project aims to understand the hydrogen infrastructure needed at the state and local level in California to support AAM	1. How much hydrogen and other fuel alternatives will be needed to operate AAM in California? 2. What are the funding sources for hydrogen infrastructure upgrades?	The goal of this project is to produce a base level understanding of the hydrogen and alternative fuel needs to

Research Needs	Title	Description	Research Questions	Research Outcomes
	for AAM Operations and Aircraft	operations and aircraft.	3. What are the hydrogen and alternative fueling needs for AAM at the airport and vertiport level? 4. What policies need to be in place at the state level in California to support the generation and sale of hydrogen and other alternative fuels for AAM? 5. How can California support safe hydrogen fueling and operations for AAM?	operationalize AAM in California and to identify what infrastructure upgrades and potential funding sources are available to meet these needs. Key outcomes will be documented in a research report and policy brief.
2.5 Scenario Planning for AAM	*Scenario Planning to Shape the Future of AAM in California*	Scenario planning can be used as a tool to better understand potential AAM deployment and use cases. This project will use scenario planning to help inform the planned deployment and evolution of AAM in California.	1. What should be included in AAM scenario planning (e.g., AAM demand, use cases)? 2. How will regulations at different levels (e.g., local, state) factor into different scenarios?	This research will create multiple AAM deployment scenarios, summary of strengths, weaknesses, opportunities, and threats across a range of AAM scenarios.

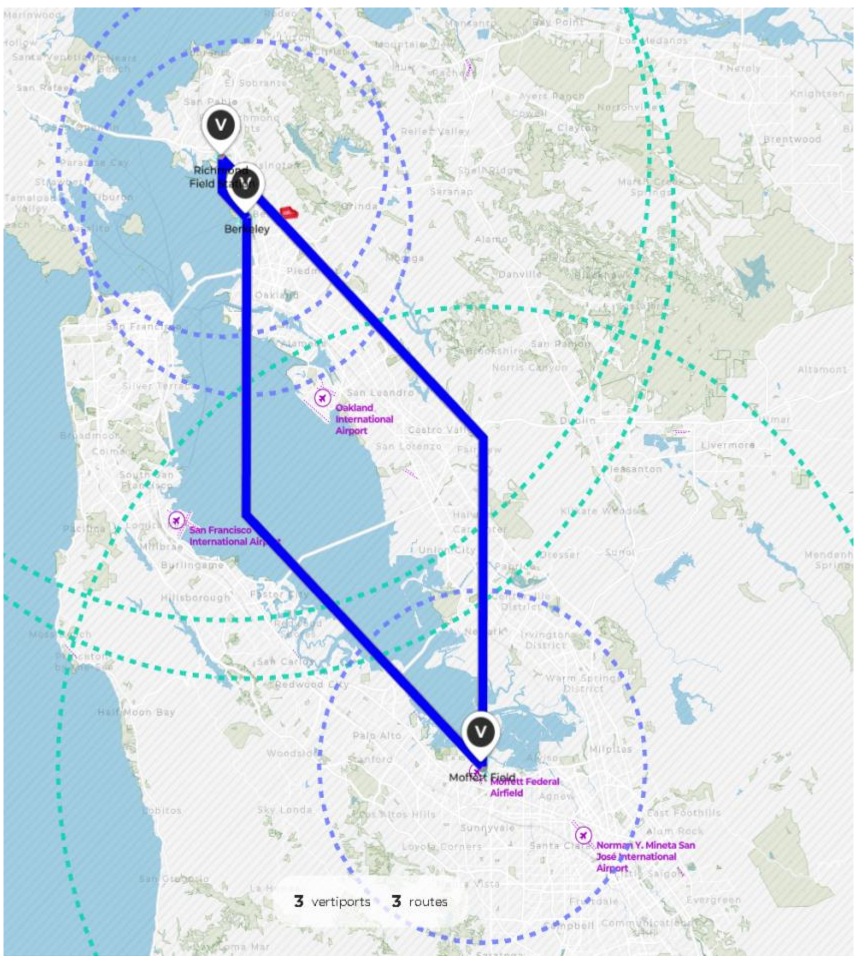
Research Needs	Title	Description	Research Questions	Research Outcomes
2.6 The Role of AAM in California's Multimodal Transportation System	*Understanding the Role of AAM in the Transportation System and its Impact on Other Modes*	This project seeks to understand the role of AAM in California's transportation system, with a focus on both the potential synergies between AAM and surface transportation and the impact AAM will have on other modes.	1. Will AAM complement existing surface transportation? a. Is AAM anticipated to reduce congestion? b. How will AAM connect with other modes to offer multimodal trips (e.g., first/last mile connections to veriports)? 2. Will AAM displace other modes (i.e., where will the mode shift come from)? a. Will the mode displacement be different for different AAM use cases? b. Are there equity impacts of the mode shift? c. Are there impacts on car use and car ownership? d. What will the impacts of AAM be on commercial air operations? 3. Would the proliferation of AAM defer new surface transportation infrastructure?	The goal of this project is to understand how AAM will impact other modes of surface transportation in California. Specifically, the project will examine the role that AAM can play in complementing other existing modes and how the addition of AAM will impact mode choices and resulting infrastructure investment needs. Key outcomes will be documented in a research report and policy brief.
3. Safety (1 project)				
3.1 AAM Safety Infrastructure and Emergency Response	*Preparing for Emergencies Involving AAM Vehicles: Investigating Emergency Response and Infrastructure Needs*	There are various research questions surrounding the emergency response and infrastructure needs to prepare for emergencies involving AAM vehicles.	1. Where can emergency landing sites for AAM be located in urban settings? Can existing vertiports be used for emergency situations? 2. What emergency response procedures need to be in place at the local level to support response to emergencies involving AAM vehicles (e.g., fire codes, etc.)?	This project seeks to answer some of the preliminary safety and emergency response questions that local jurisdictions need answered in terms of preparedness for safe AAM operations. Key outcomes will be documented in a

Research Needs	Title	Description	Research Questions	Research Outcomes
				research report and policy brief.
4. Sustainability and Environmental Impacts (1 project)				
4.1 AAM Energy Supply and Life Cycle Emissions	*Estimating Energy and GHG Impacts of AAM Operations: Assessing the Environmental Footprint of Different Energy Sources*	This project seeks to estimate/forecast the range of energy and GHG impacts of planned AAM operations associated with different energy sources.	1. What are the direct and cumulative impacts of different AAM energy supply/fuel choices? 2. From energy generation to batteries, what are the life cycle impacts of zero emission AAM aircraft? 3. How will environmental assessments need to be changed or adapted for AAM?	The goal of this project is to quantify and measure the life cycle impacts of AAM operations with varying fuel/propulsion choices and begin to understand the policies needed to address the environmental impacts of AAM. Key outcomes will be documented in a research report and policy brief.
5. Workforce and Economic Development (2 projects)				
5.1 Defining and Diversifying AAM Employment	*Building an Inclusive Workforce for AAM: Understanding Job Creation and Identifying Policies to Promote Diversity, Equity, and Inclusion in AAM*	This project seeks to develop an understanding of the types of jobs that will be created and impacted by AAM. Second, identifying policies that support diversity, equity, and inclusion in the AAM workforce.	1. What existing jobs and industries will be impacted by AAM? 2. Are these existing jobs high quality? 3. What kinds of jobs are needed in the AAM industry (e.g., building infrastructure, manufacturing vehicles, etc.)? 4. What are the skills needed to support these jobs? 5. What are the pipelines (training and education and access to the jobs themselves) and skills needed for these jobs? 2. Who needs to be engaged across the State of California in order to begin exploring	This project will provide a base level understanding of the types of jobs that will exist within the AAM industry (including the pipelines to access these jobs) and begins to build capacity towards creating a workforce development strategy that reaches diverse groups. Key outcomes will be documented in a research report and policy brief.

Research Needs	Title	Description	Research Questions	Research Outcomes
			how to develop a workforce development strategy that reaches groups underrepresented in the aviation industry?	
5.2 AAM Economic Opportunities and Impact Analysis for California	*Securing California's Position in the Global AAM Market: Examining Strategies for Continued Leadership in AAM*	California is already home to many of the emerging AAM manufacturers. This project seeks to examine strategies to continue to ensure California represents a large share of the AAM global market as the industry continues to grow.	1. How can California be more economically competitive in the AAM industry? 2. What policy actions can different levels of government in California play in encouraging the AAM industry to continue to take root in California? 3. What strategies can help overcome structural challenges, such as the high cost of housing and environmental and planning process delays, that will inevitably impact the AAM industry in California?	The goal of this project is to identify policy strategies for continuing to build the AAM industry within California, thus furthering the opportunity to grow an AAM industry in California. Key outcomes will be documented in a research report and policy brief.

A4. Role of Demonstrations

During the AAM research roadmap stakeholder workshops, the participants discussed need to construct prototype vertiports and AAM corridors to support early demonstrations and research. For example, the University of California, Berkeley has proposed a concept for a living lab for advanced air mobility research, known as Airlink. Airlink will enable a range of technical and socio-behavioral research using drones, STOLs, and VTOLs along AAM corridors. Using both Moffett Field and the Richmond Field Station, which has a helipad plus other landing points, UC Berkeley and NASA could pioneer one of the first AAM demonstration corridors to operate short-haul flights, thereby demonstrating the technical and institutional feasibility of this new approach. Figure 3 depicts the envisioned Airlink system. Blue and green lines represent 10- and 26- mile ranges around hypothetical vertiports.



A5. Key Takeaways

The research roadmap process identified 16 research topics across five thematic areas: 1) Equity, Community Engagement, and Societal Adoption; 2) Governance, Planning, and Infrastructure; 3) Safety; 4) Sustainability and Environmental Impacts; and 5) Workforce and Economic. In light of California's role with respect to AAM and aviation issues, the roadmap identified a number of research needs to:

- Engage the public and community stakeholders on an array of AAM issues
- Conduct scenario planning and support institutional readiness to help prepare local and regional governments for AAM and related aviation innovations that could impact communities
- Understand the equity impacts of vertiport placement and AAM routing on neighborhoods and vulnerable populations
- Develop vertiport and AAM land use compatibility resources
- Identify energy, takeoff/landing, and emergency response infrastructure needed to support AAM
- Understand environmental, social, and behavior impacts of AAM
- Measure the lifecycle GHG impacts of AAM activities, and
- Identify the economic opportunities and impacts of AAM.

The roadmap identified 16 recommended research topics for the State of California to consider to help fill these gaps in knowledge.