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MTI MINETA TRANSPORTATION INSTITUTE

Feasibility Study of Regional Air Mobility Services for High Priority Transportation in the San Joaquin Valley

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CSUTC California State University Transportation Consortium

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16. Abstract
Regional Air Mobility (RAM) focuses on building upon existing airport infrastructure to transport people and goods using innovative aircraft that offer a huge improvement in efficiency, affordability, and community-friendly integration over existing regional transportation options. These aircraft, which typically carry less than 20 passengers or an equivalent weight in cargo, are flexible in terms of where they can take off and land, even using existing runways and infrastructure to maximize compatibility with today's airports. This project examines the feasibility of RAM supporting high-speed transportation for high-priority passenger and cargo movement within Fresno County and connection to coastal urban centers. Some examples of high-priority passengers and cargo could include, but would not be limited to, medical patients needing specialized and/or emergency treatment, organ transport, and critical medical supply deliveries. Electrification of aviation is happening, and Fresno County has the potential to combine our existing closely spaced underutilized airport infrastructure, early demonstration, and experience with electric aircraft, renewable energy opportunities, central location within the state, and the need to open the door for new industry opportunities for youth to take advantage of this "Third Revolution" in aviation.

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Any opinion, findings, and conclusion or recommendations presented herein are those of the authors.

CONTENTS

List of Figures

List of Tables

Executive Summary

The objective of this project [A1] seeks to determine how Regional Air Mobility (RAM) using electric/hybrid electric aircraft can provide new high-speed transportation for high priority passenger and cargo movement within Fresno County and connections to coastal urban centers. It is achieved by researching the demand for regional air travel generating an inventory of existing infrastructure, studying new technology available, studying infrastructure requirements from the landside and the airside, and evaluating the potential for integration with, and enhancement of, current and planned ground transportation services.

Regional Air Mobility (RAM) using electric aircraft will become a reality within the next 10 years and transform both and air and ground transportation by offering a new service using existing, underutilized airports that will change them in vibrant hubs for zero emission transportation for the communities they serve. Using small 5-20 passenger all electric or electric-hybrid aircraft, RAM services will provide connectivity for both passengers and freight to communities where ground transportation currently provides the bulk for goods and people movement.

The San Joaquin Valley is an area of California that could benefit greatly from RAM services due to the large land area of the region, the presence of over 30 general use airports from Bakersfield to Stockton, and the need for improved connectivity for communities within the region with the urban centers in the north and south. In spite of having many small airports near cities in the region, there is currently only limited commercial air service available, leaving most of the region reliant on ground transportation. Understanding the potential of RAM to become an economic engine for communities with these underutilized airport assets was an important outcome for this research.

1. Introduction

Regional Air Mobility (RAM) using advanced electric and hybrid-electric aircraft provides a cost-effective solution to connect communities that have been underserved by current aviation norms, while also providing needed relief to capacity-constrained aviation hubs and regional highways. As this new generation of aircraft enters the market, communities will have the opportunity to receive the benefits of using their local airport infrastructure to provide a conduit for new opportunities in their region.

RAM focuses on building upon existing airport infrastructure to transport people and goods using innovative aircraft that offer huge improvements in efficiency, affordability, and community-friendly integration over existing regional transportation options. These aircraft, that typically carry less than 20 passengers or an equivalent weight in cargo, are flexible in terms of where they can take off and land, even using existing runways and infrastructure to maximize compatibility with current airports.

If an affordable, efficient, robust, and environmentally friendly aircraft network were implemented across the more than 5,000 public use airports in the United States, more people would be able to choose convenient air travel over cars for mid-distance trips, around 50–500 miles. RAM's vision is to transform these local airports into multi-modal zero-emission transportation and innovation hubs.

RAM aircraft are able to operate physically close to communities due to characteristics such as low emissions, low noise, and steep climb/descent profiles which reduce nuisance factors and environmental impacts. Their ability to operate from short runways at smaller local airports located closer to the populations they serve, reduces vehicle miles traveled (VMT), and lowers costs for both passenger and freight movement.

Because electric aircraft require charging support and thus bring a large consumer of electrical energy to the airport, airport renewable energy solar projects will see a larger return of investment and may further support the electrification of ground transportation at these sites. Regional airports typically sit on hundreds of acres of public-use land, which is well-suited for renewable energy production such as solar power generation; this energy can be used to charge the batteries of electric RAM aircraft, ground transportation, or sequester carbon as part of a fuel offset.

As more electric/hybrid electric aircraft are revealed to the public and begin to enter service, state and local governments around the country are beginning to evaluate the potential of this technology to improve connectivity, reduce greenhouse gas emissions, and generate new economic activity.

2. Project Objective and Motivation

Advances in electric aircraft development are providing opportunities for new Regional Air Mobility services that can enhance connectivity of regions by using underutilized existing airport infrastructure and integrating use of electrified ground transportation. This research project seeks to determine how RAM using electric/hybrid electric aircraft can provide new high-speed transportation for high priority passenger and cargo movement within Fresno County and connections to coastal urban centers. This project also seeks to study the potential opportunities and challenges to effectively implement (electric/hybrid) RAM in the San Joaquin Valley

This study covers a range of topics to help clarify what RAM is and why it matters. It should not be construed as the final, defining source of all knowledge when it comes to possibilities and best ways forward as they relate to RAM initiatives. Rather, this study is intended to start a conversation with the communities that will be participants in what is an evolving RAM deployment process.

The focus of this study is what is needed in terms of RAM development in order to effectively implement RAM for high-priority cargo and passengers.

3. Project Background

The California High-Speed Rail system is not planned to become the connector to the Bay Area and Los Angeles for several years, with initial operations limited to the section from Merced to Bakersfield starting in 2025. This plan for operations of the system means that passengers wanting to use the service to connect with these urban centers will still have to find other ways of connecting to their final destinations. In order to make this connectivity possible and not over burden the highway systems, there is a need for high-speed connections between the ends that does not use ground transportation, is environmentally friendly, and can scale the mountain barriers that separate the San Joaquin Valley from the coastal urban economic centers.

Efficient connections are needed from initial high-speed rail section to the final destination points it was originally planned to reach. Fortunately, recent advances in electric propulsion in aviation can provide a solution. RAM using electric aircraft is one way to reach these destinations efficiently in terms of time and cost while taking advantage of existing infrastructure. In a pending white paper publication from NASA titled "Regional Air Mobility, Reenergizing and Reimagining Local Airports for Increased Convenience and Safety in Mid-Distance Air Travel", the potential of RAM to increase connectivity options for traveling from 50–500 miles is discussed and reported. RAM provides the possibility of transitioning from a 220 miles per hour high speed train in Merced to a 220+ miles per hour electric commuter aircraft that will take passengers directly to smaller regional airports close to the final destination, while avoiding urban ground congestion.

This project proposes to discover the feasibility of RAM in supporting high-speed transportation for high priority passenger and cargo movement within Fresno County and connection to coastal urban centers. Some examples of high priority passengers and cargo could include, but is not limited to, medical patients needing specialized and/or emergency treatment, organ transport, and critical medical supply deliveries.

The study will also compare RAM to existing charter flight operations under the FAA Title 14 of the Code of Federal Regulations (14 CFR) part 135 to see if RAM could substantially lower costs for business travel. To date, no such study has been done in California and, thus this project has the potential to add greatly to the knowledge of how RAM can be added to existing efforts to electrify ground transportation, reduce VMT, and improve connectivity in the San Joaquin Valley.

4. Methodology

The objective of this project is achieved by assessing the demand for this kind of travel, generating an inventory of existing infrastructure, determining new technology available, examining infrastructure requirements from the landside and the airside, and evaluating the potential for integration with, and enhancement of, current and planned ground transportation services.

5. Assessment of RAM Feasibility

This study evaluates existing airport infrastructure in Fresno County and strategic airports in the area, studies aircraft that will be available, examines infrastructure requirements from the landside and the airside, and evaluates the potential for integration with, and enhancement of, current and planned ground transportation services.

The aircraft envisioned as serving within the regional air mobility network will need to address several barriers to accomplish adoption feasibility. These barriers are grouped into five categories: technology, operational, infrastructure, development, and market, which are discussed in the following sections.

5.1 Technology Landscape

This phase is focused on the identifying potential electric aircraft that could serve the required routes and study their performance, estimated cost of acquisition, operation, and maintenance. The list below is not intended to be the full list of aircraft that could be used in RAM operations in the San Joaquin Valley; they only represent some of the first aircraft that could enter the market to provide RAM services.

Potential aircraft (aircraft that could be available in within the next 5 years)

- Eviation Alice, both cargo and passenger, battery electric
  - 440 nautical mile range at 220 kts
  - 9 passenger or 2,500 lbs of cargo
- Ampaire EEL, cargo and passenger, hybrid
  - 200 nautical mile range at 140 kts
  - 3 passengers or 450 lbs of cargo
- Ampaire Cessna Caravan, cargo and passenger, hybrid
  - 250 nautical miles at 185 kts
  - 9 passengers or 2,500 lbs cargo

- Magni X Cessna Caravan, cargo and passenger, battery electric
    - 100 miles at 185 kts
    - 6–9 passengers or approximately 1,500 lbs cargo

Aircraft needs for charging

- Eviation Alice has not disclosed charger sizes, but it is estimated that they will require at least 480 volt, 3-phase power at 1,000+ amps.
- Ampaire EEL is reported to use 60 kW chargers using 480 volt, 3 phase power.
- Ampaire Cessna Caravan is not reported to need plug-in charging.
- MagniX Cessna Caravan does not have a disclosed charger size yet, but it will likely need 480 volt, 3-phase power at 500 amps.

Aircraft needs for infrastructure

All the aircraft listed will be able to use existing airport terminal infrastructure for passenger and freight loading.

Time savings compared with ground options

Comparing airtime vs ground time required to get from Fresno Chandler Executive Airport in Fresno to the following airports in California shows air transport takes between 1/3 to 1/6 the amount of time as driving as can be seen in Table 1.

Table 1. Airtime vs Ground Time from Fresno Chandler Airport to Selected Destinations

Destination Airport	Distance	Time by Air (at 220 kt airspeed)	Time by Ground	Time Savings
Redding Municipal	254.5 nm	1.4 hrs	5.1 hrs	3.7 hrs
Palo Alto	118.5 nm	0.7 hrs	2.8 hrs	2.1 hrs
Henderson, NV	231.6 nm	1.3 hrs	6.1 hrs	4.8 hrs
Fullerton	193.7 nm	1.2 hrs	4.9 hrs	3.7 hrs
Sacramento Executive	133.2 nm	0.8 hrs	2.7 hrs	1.9 hrs
Reno, NV	165.9 nm	0.9 hrs	4.8 hrs	3.9 hrs
Lake Tahoe Airport	129.8 nm	0.7 hrs	4.4 hrs	3.7 hrs

Operating cost comparison between electric aircraft and ground options

Table 2 presents travel economics from work done in the UK (Rama, 2021).

Table 2. Travel Economics

$0.50 – $0.75/ Pax Mile	Regional turboprop aircraft, less than 100 seats
$0.30 – $0.40/ Pax Mile	Electric aircraft, 9 pax short haul
$0.30 – $0.45/ Pax Mile	Driving (2 passengers assumed)
$0.15 – $0.25/ Pax Mile	Rail travel

Assumptions: Aircraft assumed to operate at 50% average load factor. Benchmark outliers excluded and simplifying assumptions applied. Source: ICF analysis

Fuel Supply Security and Emergency Operations

Currently liquid aviation fuels have to be produced at a refinery site remote from the airports and then trucked to airports for use. Recent jet fuel shortages in Fresno caused by lack of available tanker truck drivers (The Associated Press, 2021) is just one example of how vulnerable the current supply network is to disruption and the impacts such disruptions can cause on mobility. Because electricity can be produced from renewable sources, such as solar, which can be sited at the airports, the potential exists for airports that operate RAM services to be independent of both traditional trucked fuel supply limitations and challenges with the electric grid. RAM airports could deploy solar panels with battery storage and advanced energy management systems that allow “islanding” of the site from the electric grid in the event of power shutdowns due to wildfires, earthquakes, or other natural disasters that are being exacerbated by climate change. This “islanding” capacity would ensure continued operations of RAM services and would allow the airports to act as bases for relief operations to the surrounding areas impacted by whatever emergency restricted fuel supply deliveries or electric grid operations. If these RAM airports also included ground electric vehicle charging infrastructure connected to “the micro-grid” (Markind, 2021) that supported air operations, these airports could operate RAM services, aerial reconnaissance, aerial drone supply deliveries, emergency medical evacuations, ground support and rescue vehicles, and food deliveries to people in need. An electric air ambulance from AMSL Aero in Australia is shown in Figure 1.

Figure 1. Electric Air Ambulance from AMSL Australia

5.1.1 Vehicle Landscape

One of the benefits of electric motors over contemporary internal combustion engine (ICE) is efficiency. On a piston or turbine-powered aircraft, anywhere from one half to two-thirds of the energy stored in the fuel goes directly out the tailpipe in the form of waste heat.

An electric motor is capable of converting more than 90% of electricity provided to it into mechanical power. This efficiency benefit is especially important in RAM operations since fuel is a large portion of an aircraft's total operating cost. In addition, the lower efficiency of IC engines is directly linked to the environmental impact of aircraft operations.

Electric motors use far less energy than their ICE counterparts and allow for unique and more efficient aircraft designs for improved performance. IC engines have approximately 25% efficiency in converting fuel to mechanical power, with most of the energy being wasted as heat. Electric motors have an efficiency of 90% or better, converting energy to mechanical power and with considerably less energy wasted as heat. Electric motors have only one moving part, while IC engines have dozens of moving parts, so reliability is greatly improved and the size and weight of an electric motor is a fraction of a comparable IC engine. Because of the efficiency and reduced size and weight, electric aircraft are being designed with the innovative placement of the electric motors to improve lift, provide aerodynamic and propulsive benefits, and create new categories of aircraft such as eVTOL (electric Vertical Take-Off and Landing) configurations as shown in Figure 2.

Figure 2. eVTOL Prototypes

Source: NASA at https://www.nasa.gov/ames/aeronautics/vertical-lift

Electric motors can produce the same amount of power regardless of altitude or air temperature, which enables the aircraft to climb faster and higher, even from hot and high locations which adds another positive aspect to electric propulsion in aviation.

The current downside with electric aircraft is that a modern battery suitable for aviation applications contains less than 1/50th of the energy stored in gasoline or jet fuel for a given weight, limiting the range of electric aircraft. Despite the increased weight of the batteries, the lightweight, powerful electric motors have proven to be far more reliable and simpler to operate in comparison to IC engines. In combination with new innovative designs, these electric aircraft are being developed to fill gaps in the aviation market, such as regional air services for small airports that once existed but have vanished in the current market due to the high cost of operation for ICE-based aircraft.

5.1.2 Maintenance and Operational Cost Reduction

Electric propulsion systems have fewer moving parts and lower part counts than conventional IC propulsion systems and are therefore much easier to manufacture and maintain. Based on an early electric propulsion demonstration project in California, a two-seat training aircraft's energy costs were reduced by 85%, and annual inspection costs were reduced by 50% compared to the traditional piston engine variant of the same aircraft. Similarly, a plug-in hybrid version of a six-seat aircraft exhibited a close to 50% reduction in energy costs compared to the base aircraft, while covering the same distance in the same amount of time.

Table 3 shows a cost comparison is between a Beechcraft King Air C-90 and the new Eviation Alice battery-electric aircraft. Both aircraft have similar size, passenger capacity, and cruising speeds. The differences are that the King Air is slightly faster at 226 kts vs. 220 kts for the Alice and has a longer range at 1,127 nm compared to the Alice's 440 nm. However, the King Air has less payload at 2,108 lbs (FlyRadius, 2016) compared with the Alice at 2,600 lbs (Weintraub, 2021).

Table 3. Cost Comparison Calculations for Beech King Air C-90 to Eviation Alice Electric

Trip Length	440		
Passenger Load	5		
Operating Costs	King Air Turbine	Eviation Alice Electric	Electric Difference
Trip time (hrs)	1.95	2.00	-0.05
Over-all cost per trip	$2,510	$1,004	$1,506
Fuel cost for trip	$351	$109	$242
Cost per passenger	$502	$201	$301

The costs listed for the Eviation Alice are estimates based on information published about the size of the battery pack, calculated battery recharge power requirements, and average cost of $0.21 per kWh for electricity from Pacific Gas and Electric Company E-19 rate (PGE, 2021). The overall cost per trip for the Eviation Alice is very conservatively estimated to be 40% of the cost of the King Air turbine aircraft, though the manufacturer suggests that the savings may be up to 90%. Actual cost of operation for an electric aircraft the size of the Eviation Alice remain unknown until these aircraft are available in the market, so this report has developed estimates based on actual data from smaller aircraft such as the Pipstrel Alpha Electro and Velis Electro. One such cost is that of insurance, and it is likely this cost will be higher than current aircraft such as the King Air C-90 because insurance underwriters do not have data on the safety of new electric aircraft. This situation actually occurred when the first production electric aircraft, the Pipistrel Alpha Electro, came to the U.S. in 2018. The owners of the aircraft had difficulties getting insured and were turned down by many carriers until finally working with the Experimental Air Association, they were able to get coverage. However, that coverage was very expensive compared with the insurance for a comparable piston engine aircraft and this situation is likely to plague all the new electric aircraft entering the market until substantial operational history is achieved.

Future transport aircraft will continue to push the boundaries for increased efficiency and safety. Manufacturers are investing in electric and hybrid-electric technology and associated integration of propulsion into the airframe for more efficiency improvements. According to the Advanced Air Mobility (AAM) Reality Index developed by SMG Consulting, over twenty of the estimated 475 companies working on advanced aerial mobility designs are already developing and flying early vehicle prototypes (SMG Consulting, 2021).

5.2 Operational Landscape

This step identifies potential operational scenarios identifying specific origin and destination airports and the connections between these airports and high priority destinations such as medical facilities and major business centers.

The recommended airports in Fresno County to support early deployment and operations are:

- Fresno Chandler Executive (KFCH)

Has existing electric aircraft operations and charging for both ground vehicles and aircraft.

Is 2 miles from downtown Fresno and Community Regional Medical Center

Has FAA Code of Federal Regulations Part 135 air charter operations to destinations identified in this report

Has land area available for solar and energy storage

- Reedley Municipal (O32)

Has existing electric aircraft operations and charging for both ground vehicles and aircraft

Located furthest east in Fresno County to serve rural and mountain area residents

Has Reedley College Aviation Maintenance Technician training program

Has land area available for solar and energy storage

- Coalinga Municipal (C80) / Harris Ranch (3O8)

Coalinga is the airport furthest west in Fresno County, to serve residents in the Coast Range mountains and west-side rural communities such as Huron

Harris Ranch currently has a very large bank of Tesla super chargers for ground vehicles and a small hydrogen fueling station near the airport

Both airports have land available for solar and energy storage

Harris Ranch is adjacent to the I-5 and can provide support for emergency air lifts of accident victims along that freeway

Coalinga Airport could provide emergency evacuation or support services in the event of an earthquake along the San Andres Fault located just west of Coalinga

Range from those airports to destinations with a high priority value

- San Carlos (KSQL) (SFO and Silicon Valley)

FCH to SQL = 126 nautical miles, 43 mins

O32 to SQL = 143 nautical miles, 48 mins

C80 to SQL = 124 nautical miles, 42 mins

Palo Alto (KPAO) (Stanford Medical Center and Silicon Valley)

FCH to PAO = 118 nautical miles, 45 mins

O32 to PAO = 136 nautical miles, 50 mins

C80 to PAO = 117 nautical miles, 44 mins

Sacramento (KSAC) (Capitol and State agencies)

FCH to SAC = 133 nautical miles, 45 mins

O32 to SAC = 147 nautical miles, 49 mins

C80 to SAC = 152 nautical miles, 50 mins

Fullerton (Western LA basin area for business and connection to LAX)

FCH to FUL = 194 nautical miles, 60 mins

O32 to FUL = 183 nautical miles, 57 mins

C80 to FUL = 178 nautical miles, 55 mins

- El Monte (Eastern LA basin area for business)

FCH to EMT = 180 nautical miles, 56 mins

O32 to EMT = 170 nautical miles, 53 mins

C80 to EMT = 167 nautical miles, 52 mins

Aircraft Range and Operation

Commercial air-taxi services in the U.S. are regulated under FAA Code of Federal Regulations Part 135 which allows scheduled commuter and non-scheduled, on-demand flights. An interview with a Part 135 air charter operator at Fresno Chandler Executive Airport revealed that the most popular destinations for their clients are at a maximum 260 nm from Fresno one way. This means that RAM services with electric aircraft such as the Eviation Alice with a 440 nm range would be able to serve these destinations without issue, provided that adequate charging infrastructure was available. Table 4 presents those destinations and their distance from Fresno.

Table 4. Distance from Fresno Chandler Airport to Selected Destinations

Destination Airport	Distance
Redding Municipal	254.5 nm
Palo Alto	118.5 nm
Henderson, NV	231.6 nm
Fullerton	193.7 nm
Sacramento Executive	133.2 nm
Reno, NV	165.9 nm
Lake Tahoe Airport	129.8 nm

Pilot and Technician Training

FAA Code of Federal Regulations Part 135 operations today require a commercial pilot's certificate with a minimum pilot in-command experience of 500 hours for visual flight rules operations, and 1,200 hours for instrument flight rules (FAA, DOT, 2021). RAM operations will not change the requirements for pilots in command of these aircraft except that they will be required to obtain the appropriate training in the new aircraft they are expected to fly, which may require a type rating depending on the aircraft; weight and category as certified by the FAA.

The new aircraft technologies being developed to support RAM operations are designed to make aircraft easier and safer to operate, reduce pilot task-loading, and the scope of tasks for which the pilot is responsible. As these technologies are proven to be successful and more data is collected, the requirements for pilot experience in these advanced aircraft could be reduced with RAM service operations becoming an earlier steppingstone for pilot careers.

Autonomous Operations

While many of the new electric/hybrid aircraft being developed will have the capability for autonomous or near autonomous operations, most of them coming into service within the next 5–10 years are planned to be piloted. This is because the pace for development of fully autonomous flight operation regulations is slow and public acceptance of automated vehicles is also slow. Regulators have introduced new rules for autonomous aircraft systems, ranging from how they are identified and integrated into the national airspace system to how these aircraft are tested. As regulators become more comfortable with the validation and results from autonomous systems testing and see the benefits in terms of safety, some RAM operations in the San Joaquin Valley may prototype autonomous operations for freight because of the large number of warehouse complexes in the Valley and the relatively flat open terrain.

5.3 Infrastructure

Certain infrastructure is essential for the implementation of RAM services including: charging stations; proper runway length for the aircraft used in the RAM service; and adequate facilities for aircraft maintenance and passenger and/or freight handling. This section of the report will look at these essential infrastructure components of RAM services in the San Joaquin Valley.

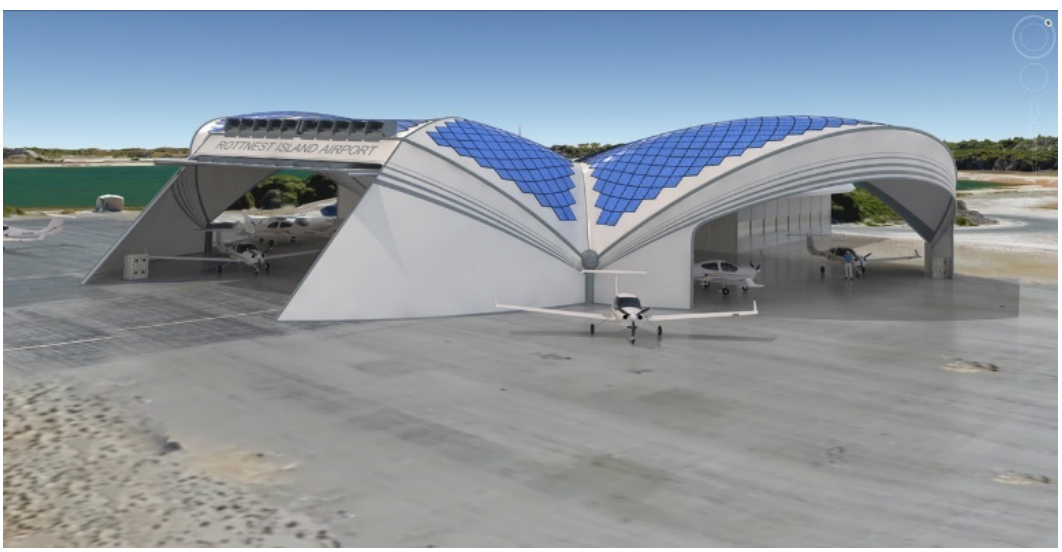
Regional Operational Infrastructure

The short takeoff and landing (STOL) or vertical takeoff and landing (VTOL) capability enabled by electrified aircraft propulsion will spur future growth of RAM markets by connecting communities that currently don't have commercial air service but do have functioning airports for general aviation use. The potential to add new "vertiports" for eVTOL operations is also feasible and has already been started by companies such as Beta Technologies for operations of their ALIA eVTOL designed for the transport of medical supplies and human organ deliveries (BETA, 2021). The self-contained vertiports being deployed by Beta Technologies are designed to be multi-modal charging locations for both ground vehicles and aircraft as well as providing other services for travelers. Another option for expanding RAM services is the construction of new short takeoff/landing air strips at key facility locations. Traditional STOL aircraft can require up to 2,000 ft. of runway but Extreme STOL aircraft with electrified propulsion may require as little as 200 ft., so new purpose-built strips at warehouse or other facilities could require relatively little space to be effective in promoting RAM services.

Most of the 32 regional airports in the San Joaquin Valley have some existing facilities to support aircraft operations beyond fuel, with restrooms, pilot lounges, and hangars. As RAM services are developed from these airports to support passenger and freight movement, additional facilities will need to be constructed at many of the sites. Some modular facilities are now being designed by several companies such a Beta Technologies (Figure 3) and Electro Aero (Figure 4).

Figure 3. Modular Facility Beta Technology

Figure 4. Modular Facility Electro Aero



Modular designs, such as the ones represented here, can be installed quickly, provide renewable energy to support both air and ground vehicle operations, and be expanded as the demand for service increases.

Airports sometimes attract negative attention from local residents, generally due to noise and emission concerns. However increasing operations at local airports with electric aircraft, with low noise and emissions, may shift the negative perception of living close to an airport to a positive, due to the added benefit of transportation mobility access and the economic benefits that comes from that increased connectivity.

Charging Infrastructure

Billions of dollars, from both the public and private sectors are already being invested into electric grid upgrades to support the electrification of transportation. RAM can integrate into the electric infrastructure not just for the aircraft but also to allow for innovative first and last-mile zero-emission transportation options, such as "vertiports", that allow for eVTOL passenger and freight operations from neighborhood locations to downtown areas or larger transportation hubs such as regional airports.

Figure 5. Beam EV ARC Charging Electric Aircraft and Car at Reedley, CA

Source: https://sustainableskies.org/beam-me-up-flying-on-sunshine/

Airports are logical hubs for the generation and storage of sustainable energy because of the amount of land area associated with them. Solar and hydrogen energy generation deployed on-site can be used for ground vehicles, community users, and RAM aircraft. This shared-use allows for the initial infrastructure cost and regular maintenance to be shared into a larger pool of users making the business case for deployment more attractive. Figure 5 shows a public demonstration of a Beam Global charger at Reedley Municipal Airport in Fresno County, California.

5.4 Development Pathways

The most likely developmental pathway for RAM services in the San Joaquin Valley will be with companies like Surf Air bringing hybrid Cessna Caravan aircraft to locations such as Fresno and Merced (Gerardi, 2021) to haul both passengers and freight. The Caravan has already been demonstrated with electric propulsion in 2020 and Surf Air has announced plans to purchase one hundred (100) new Cessna 208 Caravans for conversion to hybrid electric propulsion using a system developed by Ampaire, which is owned by Surf Air (Thurber, 2021). Surf Air currently provides both scheduled and on-demand air services using FAA Code of Federal Regulation Part 135 operators and adding hybrid Caravans would be an easy, low risk first step into RAM services (Surf Air, 2021). Routes connecting Merced and Fresno to L.A. and the Bay Area are likely to be first to use the hybrid electric aircraft once they enter service. The projected 25% reduction in direct operating costs for the hybrid Caravans could result in lower ticket prices and increase demand for service (Horne, 2021). Just as hybrid electric cars paved the way for all-electric vehicles, the hybrid electric aircraft will likely pave the way to gain public acceptance and demand for RAM services using all-electric aircraft.

Policy

Because RAM services will use existing FAA Code of Federal Regulation Part 135 operators and existing airport infrastructure initially, there will not need to be any new policies at the State or Federal level developed. Some local policy changes may be needed in terms of local zoning for businesses to support RAM operations, but those would be on a case-by-case basis.

5.5 Market Landscape

The data listed below represents a snapshot from 2018/19 passenger and freight movement through the San Joaquin Valley prior to COVID-19 impacts.

- Current air carrier demand
- Passengers per year from FAT = 1.96 million passengers in 2019 (Fresno Yosemite International Airport, 2020)
- Amtrak
- Amtrak passenger volume 2018/19 = 1.1 million passengers
- High-speed rail potential

An analysis of air service and airport expansion costs as compared with high-speed rail was done in 2019 (WSP, 2019), but was only focused on the costs to expand service around the primary commercial airports in California and did not evaluate the potential for RAM to use existing small airports and operate using electric aircraft with minimal noise and no emission impacts.

Passenger Travel

RAM hybrid and all-electric aircraft have the ability to serve mid-range travel in a quiet, fast, clean, efficient, and safe manner. This is expected to increase the demand for this type of travel. In the past year, the impacts of COVID-19 on conventional commercial air travel have driven many business people to seek alternatives such as fractional ownership of aircraft, membership programs, and FAA Code of Federal Regulation Part 135 air charter operations (Hodge, 2020). As the total number of users increases, the utilization of the aircraft increases, resulting in higher load factors and lowering the cost/ price for the service, which feeds back to drive more demand. RAM services are coming at a time when there is a strong move toward smaller, more agile air transport services which will likely be the first adopters of the new electric aircraft being designed for regional air travel. This demand increase could impact the volume of aircraft required, which in turn drives manufacturing costs down.

Could RAM aircraft, especially eVTOL aircraft, displace traditional transit services? The answer to this question depends on the context and ridership levels for the existing transit service, but for long distance rural transit (> 30 miles) where typical passenger loads are 10–15% the capacity of the bus, the answer could be "yes", especially if the RAM aircraft was autonomous. Comparing projected costs per passenger for RAM service of $0.40 per mile from the UK study referenced previously using data from 2018 (Rama, 2021) to Fresno County Rural Transit (FCRTA) showing on operating cost per passenger per mile for rural bus service of $13.10, it is clear that there is a potential to replace ground transit service with aerial transit service provided that the actual operating costs for the aircraft meet or are close to the current projections. In addition to the potential for operating cost savings, the time savings for passengers is significant. Comparing driving from Coalinga to Fresno with the same trip in a 150 mph eVTOL, the time savings is 66 minutes one-way using the aircraft vs. ground transportation.

In the long-term, using electric/hybrid aircraft for trips between 50 to 300 miles could be an affordable form of daily transportation for the masses, even less expensive and more convenient than driving a ground vehicle.

Cargo

Regional aircraft have transported air cargo for decades. The ability for aircraft such as the Cessna 208 Caravan to land at small, unimproved airstrips gives them unique access and range, particularly when the alternative is ground travel that may not be practical, feasible, or possible. Bringing hybrid and all-electric aircraft into service transporting cargo will open new opportunities to expand air freight operations into close proximity to users by taking advantage of the low noise, zero-emission, and eVTOL/STOL attributes of electric propulsion.

RAM systems may be the only means for high-priority delivery to remote locations. Technologies, such as autonomy and electric propulsion, can drive down the price of transporting cargo and provide a low-risk, revenue-producing test case to ensure reliability of these technologies before transporting passengers.

The use of RAM aircraft to perform cargo flights in addition to passenger flights will help improve the RAM business case because cargo transport enables an airplane to be flown both day and night, not just during peak passenger priority hours. Also, passenger demand will vary, so flexibility of use will help maximize the utility of the aircraft, reducing the impact of fixed costs on total operating costs.

High Priority Passenger and Cargo

Some of the earliest use cases for RAM aircraft will be for high-priority cargo and passenger movement. It has been well-publicized that eVTOL aircraft are being developed specifically for use in dense urban settings where ground transportation is highly congested; markets such as Los Angeles, San Francisco, Dallas, and numerous international cities are already moving to be prepared for the new services with the primary focus being on moving passengers more quickly than ground options (Dimitrova, 2021). Several companies such as Joby Aviation and Archer are looking at this model as their primary business.

Other companies such as Beta Technologies, in partnership with United Therapeutics (Kumar, 2021), are looking at high-priority cargo such as organ transport to medical facilities as an early business case for their ALIA eVTOL design as well as UPS for transporting parcels. In the eVTOL space, DHL has placed tentative orders for the Eviation Alice aircraft to use for parcel delivery as a replacement for the Cessna Caravan (Weintraub, 2021). In this role, the Alice will likely not have specific cargo designated for it but will be used to transport any parcel cargo that would otherwise be sent using short-haul aircraft. Tecnam Aircraft in Italy, in partnership with Rolls-Royce, is progressing rapidly to electrify their P2012 regional airliner with an all-electric version called the P-Volt for certification and deployment in 2026 (Pallini, 2021). Cape Air already operates the P2012 and could be an early adopter of the new P-Volt.

6. Conclusion

Regional Air Mobility using electric aircraft is coming and will transform transportation by reducing the cost of operation for small 5–20 passenger aircraft to a point that they can compete with ground transportation options in cost and surpass ground transportation in speed and efficiency. Using existing underutilized airports initially, this new service offers the potential to bring new economic vitality and connectivity to communities currently not receiving air transport services. These airports have the potential to become economic engines for the communities that have them as support businesses such as restaurants, maintenance facilities, ground transport services, and logistics services are added to meet the demand generated by RAM operations.

RAM services in the San Joaquin Valley also offer the potential to transform these airports in zero-emission, multi-modal transportation hubs to greatly increase the use of electric vehicles in communities currently not adopting this technology quickly because of the perception electric vehicles don't have the range to travel the long distances between these communities and larger economic centers. Because the airports have large land areas that could support solar and battery storage, they can be new transportation hubs that support cars, delivery trucks, buses, and electric aircraft with renewable electricity to further reduce carbon emissions and leverage the Valley's solar power potential. The ability for these airports to support multiple modes of electric vehicle operations with on-site power allows them to operate in emergencies independent of the electric grid and support community transportation needs.

A good next step for Fresno County to prepare and plan for RAM service deployment would be a site-by-site evaluation in detail of the existing electric infrastructure and capacity for electric service expansion at Fresno Chandler Executive Airport, Reedley Municipal Airport, and Coalinga Airport/Harris Ranch Airport. This study should also include the potential for renewable energy and battery storage, connections with existing transit, and population growth projections within 10 miles of each location over the next 10 years.

When the American Society of Civil Engineers looked at the costs for highway and air service expansion in 2019 to compare with the California investment in High-speed rail, RAM services were not evaluated which may have been due to the stealth mode that most of the electric aircraft companies were in at that time. However, following the release of the NASA white paper in April 2021 about the potential for RAM services to transform and democratize air travel regionally (NASA, 2021), many of the aircraft developers have come out of their stealth mode and the public has become increasingly aware of this new technology and opportunity. To be prepared for this new technology to serve the residents and businesses of Fresno County and the San Joaquin Valley, more detailed studies by county need to be completed and opportunities to leverage State and Federal funding for infrastructure pursued.

Electrification of aviation is happening, and Fresno County has the potential to combine our existing closely spaced underutilized airport infrastructure, early demonstration and experience with electric aircraft, renewable energy opportunities, central location within the state, and the need to open the door for new industry opportunities for our youth to take advantage of this "Third Revolution" in aviation.

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Julio Roa, PhD, PMP is currently an Assistant Professor at California State University, Fresno. The aim of Dr. Roa's research is to make air transportation sustainable. This includes researching renewable energy supplies to support the aviation industry's transition to renewable energy systems, as well evaluating required modifications and additions to airport infrastructure to accommodate for new technologies and logistics.

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A native of the San Joaquin Valley and a private pilot since 1974, Mr. Oldham has had a passion for aviation since early childhood. A graduate of California State University, Fresno, Mr. Oldham has spent most of his professional life working to improve air quality in the region through deployment of clean energy and clean vehicle technology. Mr. Oldham is the President and CEO of New Vision Aviation, Inc., a 501c3 non-profit charitable organization focused on providing aviation education for youth and residents of communities of color and low-income neighborhoods in the San Joaquin Valley. Mr. Oldham is the lead pilot and project manager for the Sustainable Aviation Project designed to validate operations of electric aircraft and has over 230 hours of flight in Pipistrel Alpha Electro aircraft, the first production electric aircraft in the world. The project is beginning the process of getting the public familiar and comfortable with electric propulsion in aircraft as a step toward the advanced electric powered aerial sky taxi vehicles of the future and larger commercial electrically powered aircraft. Mr. Oldham is a contributor to the NASA white paper published in 2021 on the potential for Regional Air Mobility using advanced electric aircraft to change how underutilized regional airports can bring enhanced mobility to the communities they serve.

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