Aero Medical Transportation:

Analysis of Fixed Wing Operations in the United States (2019-2020)

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Abstract:

Aero Medical Transportation (AMT) services provide transportation of patients, medical teams, and organs for the U.S. healthcare system. An estimated 67% of all AMT services are interfacility transfers, and delivering specialty care and organs. These flights are predominantly conducted using Fixed Wing aircraft operating from the nation's airports. This transportation service enables citizens living in rural areas to receive specialty care from the nation's Level 1 Hospitals that are located exclusively in large metropolitan areas. The number of Fixed Wing aircraft in the AMT fleet has grown 2.2% per year over the last decade along with a 3.6% per year expansion in the number of AMT base airports.

This paper provides a statistical analysis of flight operations of the AMT Fixed Wing aircraft over the period 2019 and 2020. There were approximately 64,000 flights per year uniformly distributed across seasons with an average of 180 flights per day (max 277). The average aircraft operates approximately once every two days on flights with average stage-length of 237 nautical miles and average flight duration of 64 minutes. The AMT fleet is made up of multi-engine turbo-props (45%), jets (32%) and single-engine turbo-props (19%). The average age of the fleet is 26 years. Although turbo-props are 64% of the fleet, they perform 81% of the operations. Fifty-two percent of the flights occurred at night. The average vehicle visited 49 unique airports, 42% of the flights were shuttle (i.e. origin-destination-origin), 58% included a dog-leg. The AMT aircraft preferred airports with RNAV and GPS approaches with Aircraft Approach Category B, and Airport Design Group Class II. Less than 3% of the flights used airports/runways with a lower ADG or AAC. The implications of these results, and future work are discussed.

INTRODUCTION

Aero Medical Transportation (AMT) services provide transportation of patients, medical teams, and organs for the U.S. healthcare system. Aeromedical services are also known as Helicopter Emergency Medical Services (HEMS), Helicopter Air Ambulance (HAA), and Medical Evacuation (Medivac). Aero Medical Transportation Service Providers (AMTSPs) are the entities that provide the transportation service.

Scene response, conducted using Rotary Wing aircraft, accounts for an estimated 33% of AMT (Loyd et.al. 2020). Inter-facility transfers (54%), delivering specialty care and organs (13%), and repatriation from outside the U.S. (statistics not recorded) are predominantly conducted using Fixed Wing vehicles that operate out of National Plan of Integrated Airport Systems (NPIAS) airports (Steenhoff, et.al. 2021).

Patient, medical team and organ transportation using Fixed Wing aircraft from NPIAS airport is a growing segment of the AMT services provided. Citizens living in rural areas, with level health care facilities (e.g.

Level 5, 4, 3 Hospitals, are increasingly transported to the higher level facilities (e.g. Level 1 Trauma Hospitals) for specialty care. Level 1 hospitals are located in major metropolitan areas. The majority of this transportation (97%) is performed using Ground Emergency Medical Services (GEMS) (Loyd & Swanson, 2020; Taylor, 2018). When appropriate, due to time, distance or remote location considerations, the remaining 3% are transported by AMT.

The number of Fixed Wing aircraft in the AMT fleet has grown 2.2% per year over the last decade along with a 3.6% per year expansion in the number of AMT bases.

The purpose of this analysis is to document the operations of the AMT Fixed Wing fleet to inform aircraft design (e.g. electric vehicles), airport design, Air Traffic Control infrastructure, and vehicle equipment needs of this growing segment of the aviation industry.

The main findings of this analysis:

- There are approximately 64,000 flights per year uniformly distributed across seasons with an average of 180 flights per day (max 277)
- The average aircraft operates approximately once every two days on flights with average stage-length of 237 nautical miles and average duration of 64 minutes
- The AMT fleet is made up of multi-engine turbo-props (45%), jets (32%) and single-engine turbo-props (19%)
- The average age of the fleet is 26 years with median age of 25 years
- Although turbo-props are 64% of the fleet, they perform 81% of the operations.
- Fifty-two percent of the flights occurred at night.
- The average vehicle visited 49 unique airports, 42% of the flights were shuttle (I.e. origin-destination-origin), 58% included a dog-leg.
- The AMT aircraft preferred airports with RNAV and GPS approaches with Aircraft Approach Category B, and ADG Class II. Less than 3% of the flights used airports/runways with a lower Aircraft Design Group (ADG) and Aircraft Approach Category (AAC) mismatch.

The paper is organized as follows: the next section provides a short overview of the AMT industrial sector. The following section describes the data used in the analysis and the analysis process. The next section describes the results. The final section provides a conclusion, limitations of the study and future work.

OVERVIEW OF AERO MEDICAL TRANSPORT (AMT) INDUSTRY

The availability of aero medical transportation services has significant societal, political, and economic impacts at the regional level. Several studies identified citizen decision criteria to live in rural regions (i.e. more than one hour from major metropolitan regions) based on the availability of air transportation for “health” services (e.g. Halpern et.al. 2011). The availability of AMT services in a region is considered a significant “catalytic effect” that accelerates the accumulation of factors that enables rural habitation.

This section provides an overview of the AMT industry: Regulations, AMSPs, Business Models, the Roles of Airports and Air Traffic Control.

Aeromedical Service Regulations

AMT services are regulated by a matrix of State and Federal regulations. States regulate the medical services related to patient safety. The Federal government - Department of Transportation/Federal Aviation Administration (FAA) - oversee the flight operations (e.g., Part 135) used in the conduct of aeromedical services. The FAA also provides Air Traffic Control and navigation services (e.g., GPS, ILS, and nav procedures). The FAA also supports the development of airport infrastructure through the Airport Improvement Program (AIP), and regulates airport operations, aircraft airworthiness, and aircraft manufacturing.

The rates (i.e., prices) for AMT services are primarily set by State health insurance regulations. The Federal government that establishes rates for Medicare patients (i.e., U.S. citizens over 65 years).

In the U.S., aero medical services providers (AMSPs) can achieve voluntary accreditation from the Commission on Accreditation for Medical Transport Systems (CAMTS - camts.org). One hundred fifty-three (153) aeromedical services hold CAMTS accreditation.

Aero Medical Service Providers (AMSPs)

AMT is provided by rotary wing and fixed wing aircraft. Rotary wing aircraft operate from helipads located at hospitals, at (NPIAS) airports, or stand-alone helipads. Fixed wing aircraft operate between NPIAS airports.

According to the most recent Atlas & Database of Air Medical Services (AAMS/CUBRIC, 2019), in the U.S. there are 303 AMSPs operating out of 1,114 bases (i.e., helipads and airports). One hundred and eighty-one (181) AMSPs (i.e. 60%) operate rotary-wing vehicles only, 37 (12%) fixed wing only, and 85 (28%) fixed-wing and rotary-wing.

There are 1,115 rotary-wing and 359 fixed-wing aircraft registered to AMSPs. Nine hundred and fifty-nine (959) bases support rotary-wing operations, 212 bases support fixed-wing operations. Fifty-seven (57) bases support both rotary-wing and fixed-wing aircraft. The fixed-wing bases are located at NPIAS airports.

Business Models

There are four basic AMSP business models: (1) Hospital-affiliated, (2) Independent operations, (3) Hybrid, and (4) Government.

Hospital-affiliated operators, generally not-for-profit, provide medical services, medical staff, and medical equipment using their own aviation services or contract for the aviation services from independents. Independent: operators, generally for-profit, employ the medical and flight crews to provide air ambulance services. Hybrid operators are a joint venture between a hospital and an independent provider where the hospital typically provides the medical crew but (unlike the hospital-affiliated model) does not make business decisions (e.g., process) setting prices. Government operator, typically in regions where dedicated aero medical services are not economically viable, provide crews and aircraft.

Prior to 2002, aeromedical services were predominantly owned and operated by hospitals. In 2002 Medicare officials created a national fee schedule for air ambulances based on a thorough investigation of the "reasonable cost" for emergency medical services (EMS). This schedule increased the Medicare reimbursement rate for AMT, in particular for rural transports. As a consequence the number of fixed wing aircraft used by AMT has increased 27% since 2007, and the number of rotary wing aircraft used by AMT has increased 69% since 2007.

Airport Roles in Supporting Aero Medical Services

To support AMT services, NPIAS airports provide hangar, ramp, helipads (for rotary wing), office space/sleeping quarters, fuel (by FBO), weather reporting services, de-icing services (if necessitated by prevailing weather conditions), snow removal (if necessitated by prevailing weather conditions,) and secure (i.e., gated) access and signage for ground ambulances. To ensure availability of transportation services, AMSPs prefer to operate out of airports with IFR services including instrument approaches and departure procedures.

NPIAS airports tend to pursue AMSPs as tenants, as they generate revenues from long-term (5-10 year) leases and from fuel sales. The also provide the airport the opportunity to show the benefits of the airport to the region by providing a "community service."

AMSPs, operating as for-profit enterprises, choose the location of their operational bases based on the potential for a financially viable operation. The catchment area is generated by the population, income and insurance coverage demographics, types of industry (e.g., manufacturing), transportation networks (e.g., highways), and the location and type of hospitals. AMSPs also consider the presence of competing AMSPs and market saturation.

Aircraft

Aircraft are operated under a Part 135 certificate must have equipment that meets the standards set out are required AC 135-14B. These regulations identify minimum performance standards such sealed, flame-retardant, moisture resistant panels, stretched standards, restraining devices, medical oxygen systems. Medical Portable Electronic Devices (MPEDs) such as Automated External Defibrillators (AED), airborne patient medical telemonitoring (APMT) equipment and portable oxygen concentrators (POC), supplemental lighting, and requirements for multiple electrically powered auxiliary systems. Aircraft used for aeromedical services are equipped with advanced life support equipment.

Pressurization and noise are two other considerations. Not all aircraft authorized for use for AMT purposes in all jurisdictions have pressurized cabins and those that do typically tend to be pressurized to only 10,000 feet above sea level. These pressure changes require advanced knowledge by flight staff with respect to the specifics of aviation medicine, including changes in physiology and the behavior of gases.

Part 135-14B stipulates aircraft be equipped with: (1) Radio Altimeter, (2) Terrain Awareness Warning Systems (TAWS), (3) FDM Recorder, and (4) Life-preservers and Emergency Location

Transmitter (ELT) for over-water operations. Equipment, such as Night Vision Imaging System (NVIS), satellite communication (SATCOM), position tracking and reporting systems and possibly equipment supporting instrument flight rules (IFR) are encouraged. Most states require aircraft to be equipped with an ILS receiver or IFR-approach-capable GPS receiver that is maintained to IFR standards (including a current IFR database).

Air Traffic Control Roles in Supporting Aero Medical Services

Fixed-wing AMT aircraft are domiciled and operate at NPIAS airports. These airports have RNAV and GPS approaches.

METHOD OF ANALYSIS AND DATA

This section describes the sources of data used and the process for analysis.

Data Sources

Twelve sources of data were required to perform the analysis (Table 1). Eleven of data sources are publicly available. Traffic Flow Management Systems (TFMS) data was provided by the Federal Aviation Administration (FAA) on request. The TFMS flight track data was de-identified. All flight track data is reported in aggregate statistics. The relationship between the databases is illustrated in Figure1.

TABLE 1: List of Data Sources used to perform the analysis

Database	Description	Source
Atlas & Database of Air Medical Services (ADAMS)	descriptive & geographic information on air medical service providers, their communication centers, base helipads, RW aircraft and receiving hospitals.	**https://aams.org/page/research**
FAA Aircraft Registration Releasable Aircraft Database	Aircraft N-Numbers, Owners, Aircraft Type, Engine Type/Count	https://www.faa.gov/licenses_certificates/aircraft_certification/aircraft_registry/releasable_aircraft_download/
FAA Aircraft Reference	Manufacturer name & code, Model #	FAA
Traffic Flow Management Systems (TFMS) data, CY 2019 20220 - TailNumber_RW_FW_030921	Flight track data (all flights, aggregate results, Tail Numbers de-identified	FAA
ADS-B Data	Flight track data (only transponding flights)	FlightAware
Airport Distances	Airport Lat/Long, Elevation	FAA
BTS Airport Latitude/Longitude	Airport Lat/Long	Bureau of Transportation Statistics

Airport Data	(Coordinates, Time zones)	https://raw.githubusercontent.com/jpatokal/openflights/master/data/airports.dat
FAA Airport Data & Contact Information (Facilities):	Used for checking if airports were towered.	https://www.faa.gov/airports/airport_safety/airportdata_5010/
FAA Airport Approach Data	Number of RNAV approaches, ILS and LPV/LP availability.	FAA
FAA Aircraft Characteristics Database	RDC categories for aircraft types (AAC, ADG)	FAA
RDC Database by Runway	AAC and ADG for Primary Airport Runways	FAA

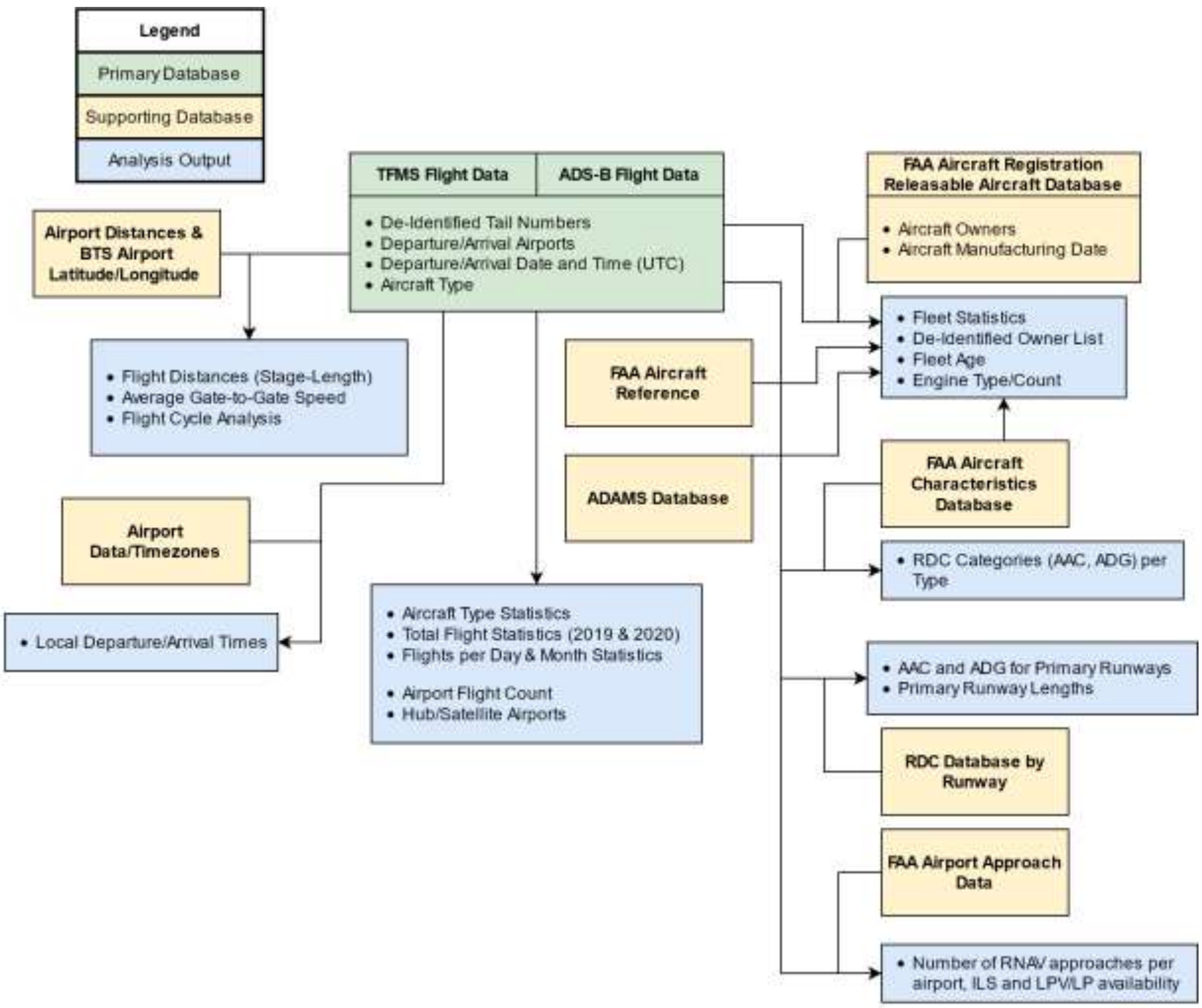

Figure 1: Data sources used in the analysis.

Analysis Process

The data was processed as follows (Figure 1):

1. AIRCRAFT OWNERSHIP: ADAMS Data-base 2019 (ref) identifies Aircraft Owners (i.e., AMSPs). The AMSP List was supplemented and checked using publicly available secondary and tertiary sources including company websites. The data was derived from the publicly available data from the AAMS database.
2. TAIL NUMBERS: Tail numbers in the AMT fleet were identified from FAA Aircraft Registry based on Aircraft Owners. Tail numbers were verified using publicly available secondary and tertiary sources including company websites.
3. AIRCRAFT CHARACETRISTICS: Aircraft characteristics (type, engine count) were identified by matching Tail Numbers to the publicly aircraft database provided the FAA.
4. OPERATIONAL FLIGHT STATISTICS: Tail Number were submitted in a query to the operational flight track- databases. The data-base returned flights with a unique identifier replacing the Tail number to keep the anonymity of the flights. The flight data included origin, destination, UTC departure time and UTC arrival time, physical class, and aircraft type. This data was reported in statistical aggregates only. No specific information on individual tail numbers was analyzed or reported.
    a. LOCAL TIMES: The flight operations data was processed to convert UTC time to local times and account for day-light savings.
    b. FLIGHT DURATION: The flight duration was calculated using UTC time. Special processing was required to account for flights from one day to the next (i.e. crossing midnight).
    c. FLIGHT STAGE-LENGTH: The flight distance was calculated in nautical miles using the Haversine formula which calculates the distance between two sets of latitude/longitude coordinates. Special attention should be paid to airports outside of the continental US (Alaska and Hawaii) as the codes may vary and require a modified search value criterion.
    d. DISCONTINUTIES: Discontinuities were identified by gaps in flights between the arrival and the next departure airport. For example, a flight SYR -> BUF, followed by the next flight between TEB-> SYR exhibited a gap between BUF and TEB. The gap is filled by adding a flight BUF -> TEB. Discontinuities in the flight-cycles, as described above, accounted for of 30% of the total flights. In this way, the flight counts reported represent a floor for total flights as there may be additional flights in between the discons that were not added.

       The flight duration for the added flight was estimated by using other flights between the same airport pairs. If the duration was not available, the duration was estimated using the duration of flights between city pairs with the same stage-length (+/- 10nm.). If estimation could not be derived from above methods, the flight duration was assigned the average duration (65 minutes).

5. FLEET STATISTICS: Flight operations per type were compared against fleet sizes (i.e. how many turboprops are in the AMT fleet vs how many flights turboprops perform). The TFMS data included 85% of the requested Tail Numbers. The missing flights were the result of eight (8) Tail Numbers that may have been in error or retired from the fleet.
6. AIRPORT STATISTICS: Airports were analyzed for count of AMT operations, number of hub and satellite airports, facilities available at airports (ILS, RNAV, LPV/LP, tower control). The data in the Airport data-base used for analysis of the type of approaches available (e.g. RNAV), did not have

data for 600 airports listed in the TFMS data. The results of the analysis is reported as percentages of the airports in the data-base.

RESULTS

This section provides the results of the analysis of AMT operations. The results are organized as follows:

1. Fleet Characteristics
2. Aircraft Ownership
3. Flight Operations (flights per day, flight duration, flight stage-length)
4. Asymmetry in Fleets vs Flight Operations
5. Flight-Cycles
6. Flight Time of Day
7. Air Traffic Control, Airports, Navigation Equipment, Airport Design

Fleet Characteristics

During the period 2019-2020, the AMT service was supported by a fleet of 283 vehicles (Table 2).

The fleet was predominantly turbo-prop aircraft (64%). Jet aircraft constituted 32% of the fleet. Piston powered aircraft constituted 3% of the fleet.

Forty-five percent (45%) of the fleet are multi-engine turboprops such as the Beechcraft King Air. Thirty-two percent (32%) of the fleet were multi-engine jets such as the Lear Jet and the Cessna Citation. Twenty percent (20% of the fleet were single engine turboprops such as the Pilatus PC12 and the Cessna 208 Caravan. The Cessna 210 Centurion, Cirrus SR22 are single engine pistons.

TABLE 2: AMT Fleet Statistics

Aircraft	Aircraft Type	Number of Engines	Example Aircraft
283 Aircraft (100%)	91 Jets (32%)	91 multi-engine (32%)	LJ35
			LJ31
			C550
			C560
			H25B
	183 Turboprops (64%)	56 Single-engine (20%)	PC12
			C208
		127 multi-engine (45%)	BE20
			BE9L
			AC90
	9 Piston (3%)	2 Single-engine (1%)	C210
		7 multi-engine (2%)	C414

Four aircraft models make up 78% of the AMT fleet (Figure 2). The Beech 200 Super King Air (BE20) makes up 21.6% of the fleet. This is followed by the Pilatus (PC12) at 18%, Beech 90 King Air (BE9L) 16.6%, and Lear Jet 35 (LJ35) at 12.4%.

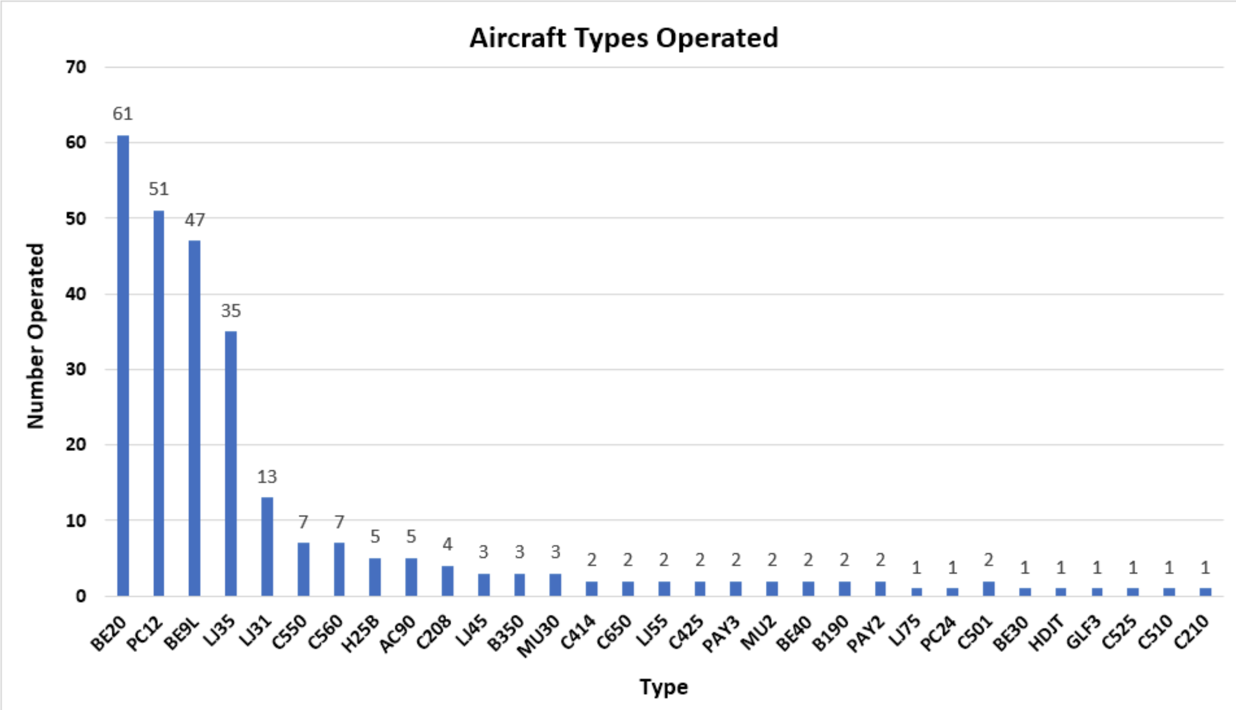

FIGURE 2: AMT Fleet composition by aircraft model

The average age of the fleet is 26 years with a median age of 25 years (Figure 3). The newest aircraft in the fleet is 2 years old. The oldest aircraft in the fleet is 48 years old.

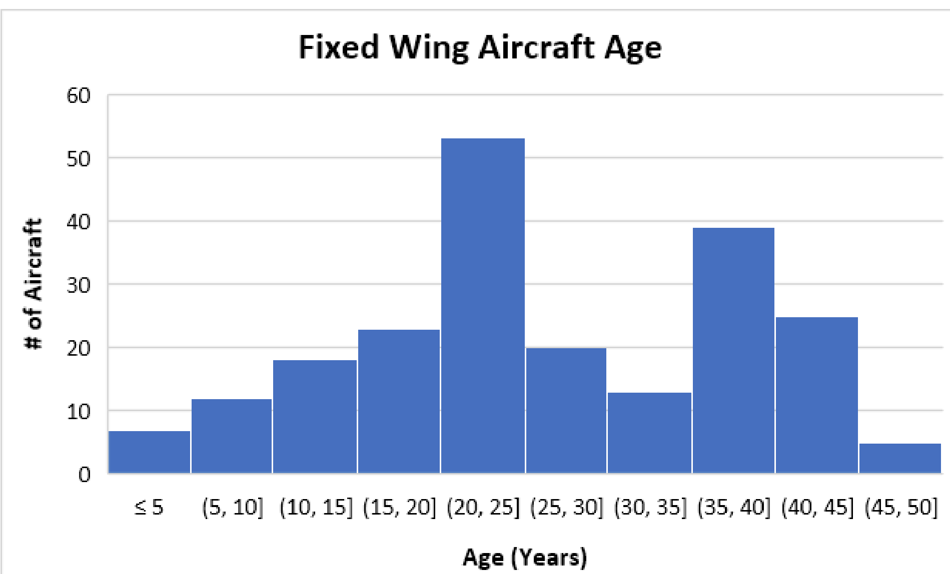

FIGURE 3: Histogram of age of Fixed Wing fleet

Aircraft Ownership

The analysis identified 109 owners (i.e., vehicle "registrants") of the 283 vehicles in the FAA Vehicle Registration Database (Table 2). The top 5 owners operate 25% of the fixed-wing fleet (70 out of 283 vehicles). Twelve owners have 4 or more aircraft. Ninety-seven (97) owners have 3 or less aircraft. It should be noted that several owners may be subsidiaries. Subsidiaries were not aggregated in this analysis.

Flight Operations

Total Annual Flights In 2019 was 65,994, and 62,063 in 2020 (Figure 4).

In 2019, the mean and median flights per day was 181 flights (see Figure 4). In 2019, the minimum number of flights per was 108 flights, the max was 245 flights (Table 3). In 2020, the mean and median flights per day was 169 flights. In 2020 the minimum number of flights per was 78 flights, the max was 277 flights (Table 3). The reduction in flight counts in 2020 can be accounted for by a slowdown at the start of the COVID-19 nation-wide lockdown in April and May 2020.

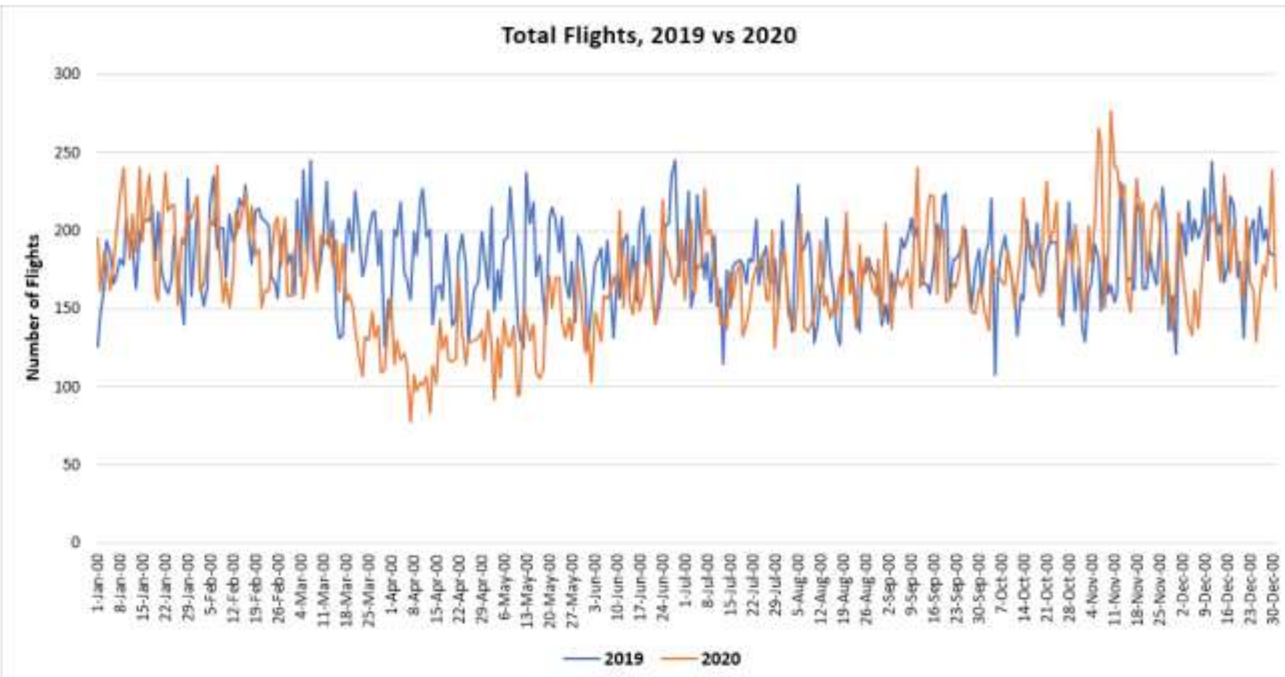

FIGURE 4: Daily Flight Counts for 2019 and 2020

TABLE 3: Flights Count per Day Statistics

2019 Stats per Day		2020 Stats per Day	
Min	108.00	Min	78.00
Median	181.00	Median	168.00
Mean	180.81	Mean	169.57
Max	245.00	Max	277.00
Stdev	26.27	Stdev	34.12
Total	65994	Total	62063

Monthly flight counts were steady throughput the time period (Table 4, Figure 5). In the year 2019 had a minimum of flights in November (5,246), and a maximum in December (5,980). In the year 2020 had a minimum of flights in April (3,592), and a maximum in January (6,185). April and May 2020 coincided with nation-wide lockdown for COVID-19. See Figure 5,

TABLE 4: Monthly Flight Count Statistics

Month	2019	2020
Min	**5246**	**3592**
Median	**5449**	**5276**
Mean	**5500**	**5172**
Max	**5980**	**6185**
Standard Deviation	**225**	**714**

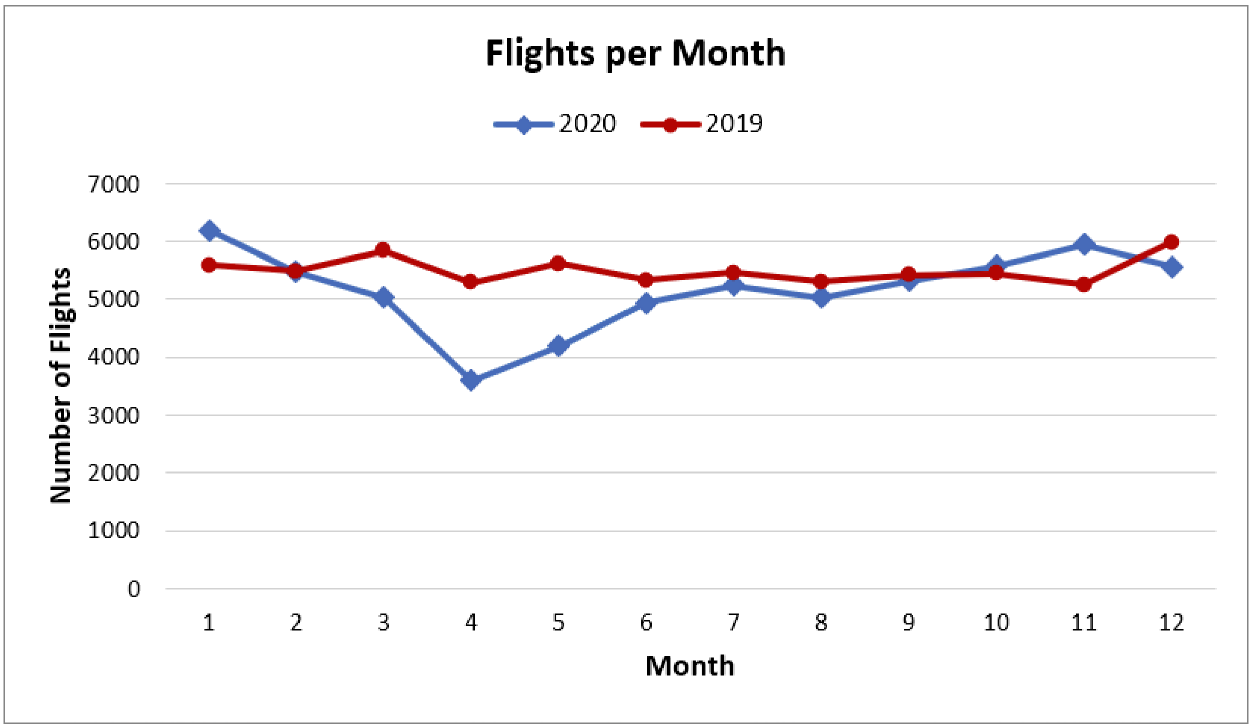

FIGURE 5: Flights per Month, 2019 & 2020

The average number of flights per day for aircraft in the fleet is 0.61 flights per day (Figure 6). Of the aircraft in the AMT fleet, 76% (218) performed 1 or less flights per day on average . Twenty percent (20%) performed between 1 or 2 flights per day on average, and 4% performed between 2 or 3 flights per day on average. One aircraft in the fleet average more than 3 flights per day.

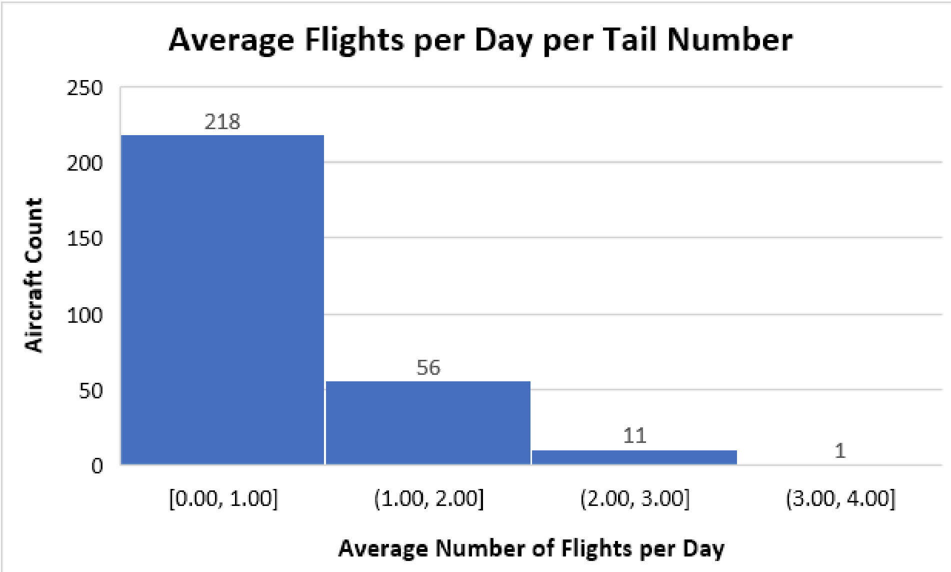

FIGURE 6: Average Flights per Day per Tail Number

The duration of AMT flights averages at 64 minutes with median of 52 minutes (Table 5). The distribution of the flight duration exhibits a long right tail with some flights between 2 and 6 hours (Figure 7).

TABLE 5: Flight Duration Statistics

Duration Stats	
Min	10
Median	52.36
Mean	64
Max	1438
Stdev	58.06

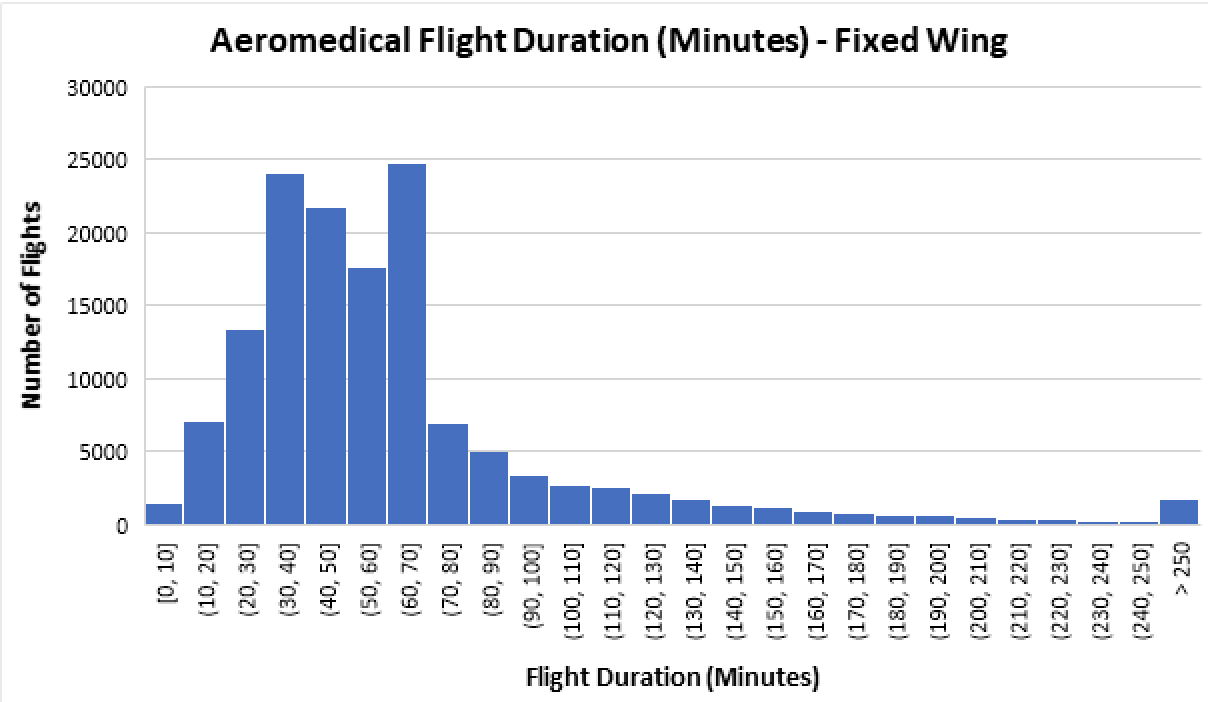

FIGURE 7: Flight Durations Histogram

The stage-length for the AMT fleet averaged 237 nm with a median of 165 nm (Table 6). The histogram shows a concentration (81%) of flights between 0 to 300 nm and long right tail from 300nm to over 1000nm flights (Figure 7). 19% of flights were > 300 nm.

TABLE 6: Flight Distance Statistics

Distance Stats	
Min	0
Median	165
Mean	237.74
Max	1997
Stdev	245.99

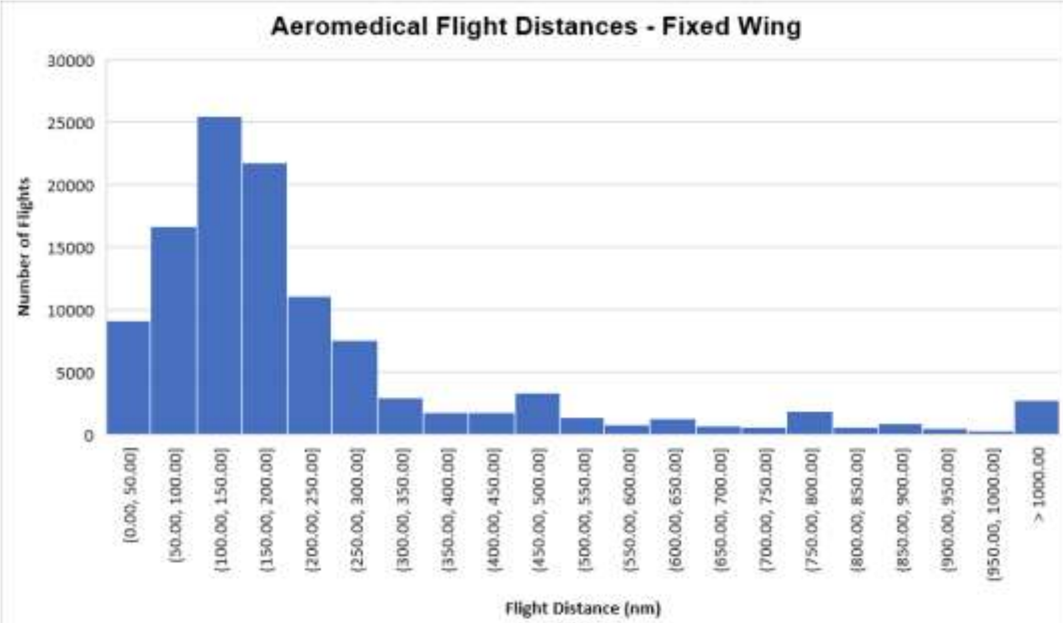

FIGURE 8: Total Flight Distances

Analysis of stage-length by aircraft type identified asymmetry (Figure 9). Eighty-three percent of the flights were less than 300nm. Seventeen percent (17%) of the flights were greater than 300 nm. Ninety percent (90%) of the 50 n.m. to 300 n.m. stage-lengths flights were conducted by turboprops. For flights with stage-length greater than 300 nm., the flights were evenly split between jets and turb-props.

Out of all turboprop operations, 88% of flights are less than 300 nm. A number of flights (9%) were less than 50 n.m. These flights departed a domicile airport to another airport (e.g., Fort Lauderdale Executive – FXE to Fort Lauderdale International – FLL) presumably to pick-up a transport before flying on to Orlando, Tampa or elsewhere.

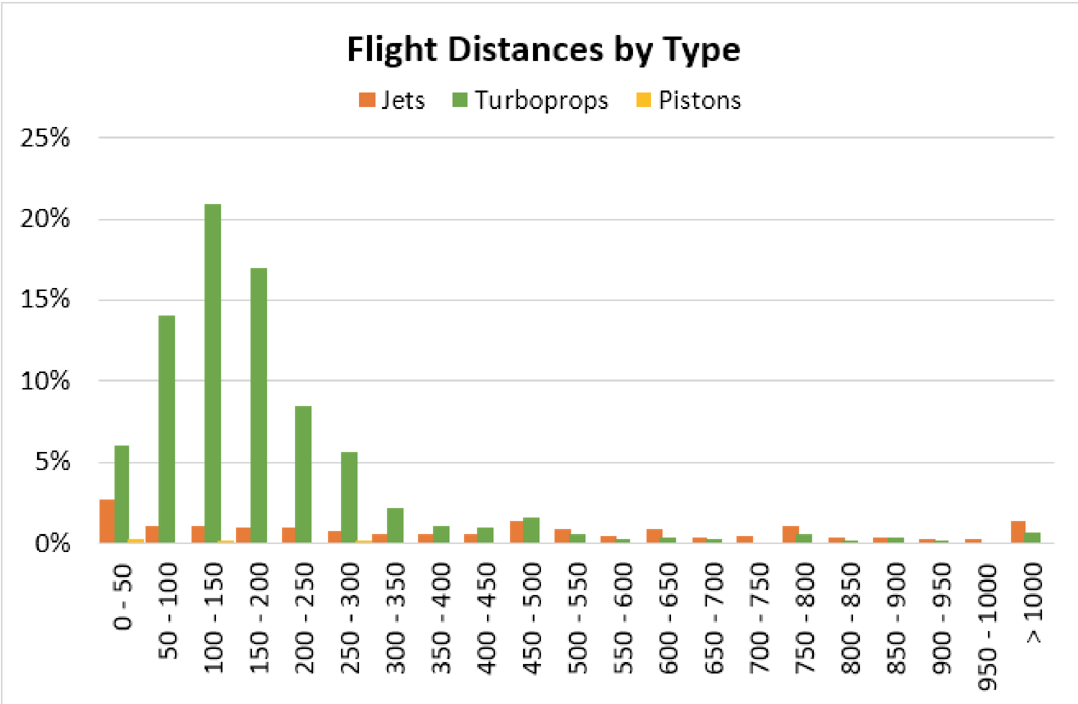

FIGURE 9: Flight Durations by Type

Asymmetry Between Fleet and Flight Operations

As described above, the AMT fleet is dominated by turboprops (64%) and jets (32%) such that there are roughly 2 turboprops for every jet. However, the turboprops perform 81% of the operations, while the jets perform 18% of the operations (Table 7). For every 4 turboprop operations there is one jet operation.

Pistons form only a fraction of the total fleet (3%) and operations. (0.6%)

TABLE 7: Fleet Type Counts vs Operations Count.

	Fleet Type Count	Fleet % out of Total	Operations per Type Count	Operations % out of Total
Jet	91	31.82%	23,467	18.0%
Turboprop	183	63.99%	106,330	81.4%
Piston	9	3.15%	757	0.6%

There also exists an asymmetry within the individual aircraft types (Figure 10 and Table 8). While the Pilatus (PC12) is only 18% of the AMT fleet, the PC12 performs 40% of the total operations (57,529).

The King Airs (BE20 and BE9L) constitute 38% of the fleet but only 31% of the operations (45,429). The Lear Jets (LJ35 and LJ31) make up 17% of the fleet, but only 10% of the operations (14,464).

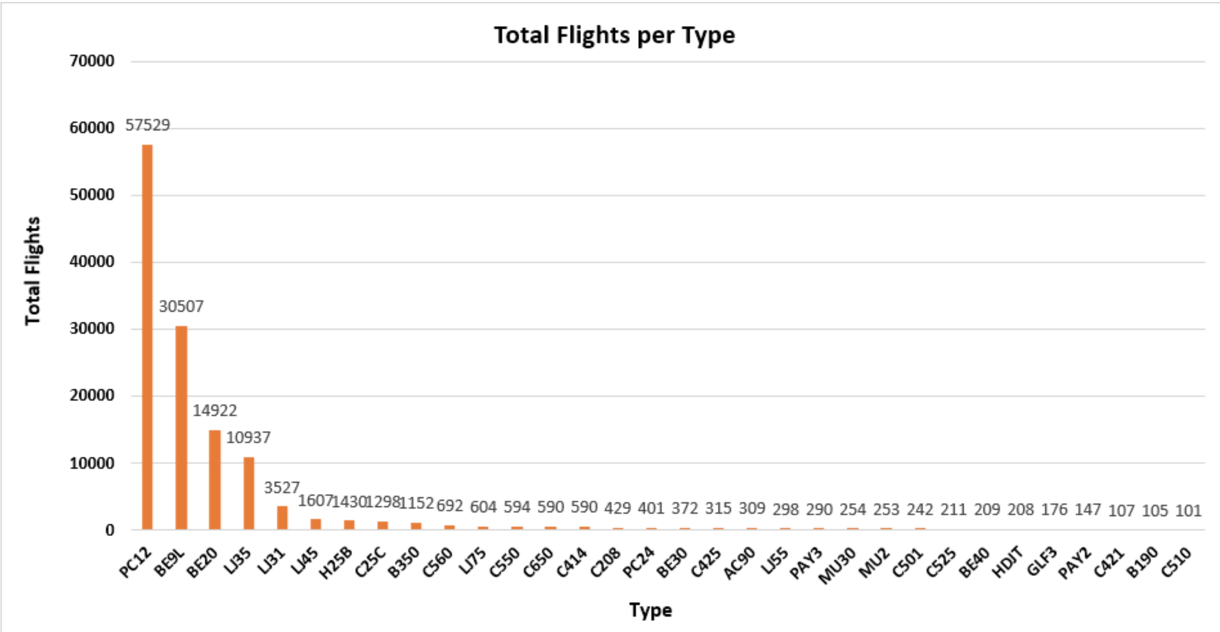

FIGURE 10: Total Flights per Type

TABLE 8: Total Flights per Type

Aircraft Type	Fleet Count	% Fleet	Number of Operations	% Operations
PC12	52	18%	57,529	40%
BE9L	47	17%	30,507	21%
BE20	61	22%	14,922	10%
LJ35	35	12%	10,937	8%
LJ31	13	5%	3,527	2%
LJ45	3	1%	1,607	1%
H25B	5	2%	1,430	1%

Flight Cycles

Flight cycle analysis indicates that 42% of aircraft fly Base – XXX – Base legs, meaning they fly from a base airport to a destination, then immediately back to the base (Table 8). The 58% remainder of the flights were multi-leg trips that did not immediately return to the base airport. Example flight cycles are shown in Table 9-a and 9-b.

TABLE 9: Flight Cycle Types

Type of Flight Cycle	Count (%)
Base – XXX – Base	42%
Base – XXX – YYY – Base	58%

TABLE 9-a: Example of Base – XXX – Base legs:

Made-up Tail Number	Departure Airport	Departure Date	Arrival Airport	Arrival Date
147	BUF	10-May-2019	ALB	10-May-19
147	ALB	10-May-2019	BUF	10-May-19
147	BUF	23-May-2019	ALB	23-May-19
147	ALB	23-May-2019	BUF	23-May-19

TABLE 9-b: Example of Base – XXX – YYY – Base legs:

Made-up Tail Number	Departure Airport	Departure Date	Arrival Airport	Arrival Date
3	LBL	18-Feb-2020	GCK	18-Feb-2020
3	GCK	18-Feb-2020	APA	18-Feb-2020
3	APA	18-Feb-2020	LBL	19-Feb-2020

Time of Day

Flight departure and arrival times (local) were calculated based on the provided UTC times adjusted for local Time Zones. The results showed that:

- 40.54% of flights had a daytime departure and daytime arrival.
- 4.63% of flights had a daytime departure that arrived during the night.
- 52.87% of flights had a nighttime departure that also arrived during the night.
- 1.97% of flights had a nighttime departure that arrived during the day.

There are approximately 10% more flights departing at night (55%) than during the day (45%).

Air Traffic Control, Airports, Navigation Equipment, Airport Design

Under the assumption that the flight legs included in the TFMS data were, by definition, operating under Instrument Flight Rules (IFR), 70% of the flights were IFR and 30% VFR.

The National Plan of Integrated Airport Systems (NPIAS) includes 3,310 U.S. airports. Aero Medical Transport operations used 55% of the airports (1,837 airports). Forty-three percent (43%) of the airports (785 of the 1,837 airport) had less than 5 AMT operations. The top 100 airports ranked by AMT flights accounted for 68% of the total flights. A list of the top 10 airports by AMT operation counts is shown in the Table 10. These airports are in the Inter- Mountain, and Pacific coast region, plus Alaska.

TABLE 10: Top ten airports by AMT operational count

Airport	Arrivals	Departures	Total Flights
ABQ	3784	3781	7565
BFI	3423	3415	6838
SLC	3172	3167	6339
HNL	3133	3131	6264
FSD	2757	2756	5513
GUP	2426	2429	4855
ANC	2374	2366	4740
APA	2360	2353	4713
BIL	1941	1941	3882
PHX	1941	1937	3878

AMTs operate from a "Base" airport flying out and back to the "satellite" airports. For example, flights based at Flying Cloud Airport (FCM) in Eden Prairie, MN served 155 satellite airports (Table 11). Of the 155 airports served, 78% of the airports had less than 5 flights during the analysis period, 22% had more than 5 flights.

The average airport with more than 1,000 AMT flights per year served on average 74 satellite airports. The average airport with more than 2,000 AMT flights per year served on average 95 satellite airports.

TABLE 11: Operations from Base Airports

Airport	City, State	# Of Airports Served	# Of Routes with < 5 Flights	% of < 5 Flight Routes out of Total Routes	Average Distance to Satellite Airports (nm)
FCM	Eden Prairie, MN	155	121	78%	673
SLC	Salt Lake City, UT	105	63	60%	764
ABQ	Albuquerque, NM	91	67	74%	704
BFI	King County, WA	86	55	64%	675
SFF	Spokane, WA	71	36	51%	512
FSD	Sioux Falls, SD	68	48	71%	560
ANC	Anchorage, AK	61	41	67%	907
RLD	Richland, WA	60	33	55%	596
GUP	Gallup, NM	43	29	67%	825
HNL	Honolulu, HI	20	10	50%	786

The average AMT vehicle visited 49 different airports at least once (Table 12). The distribution of unique airports visited has a long right tail (Figure 12). Sixty three percent (63%) of the vehicles visited less than the mean unique airports (48.85). The flight network from airports LZU, FCM, and BFI are shown in Figure 13.

TABLE 12: Unique Airports Visited Statistics

Min	1
Median	37
Mean	48.85
Max	296
Std Dev	47.91

(These numbers indicate the count of different airports visited by an aircraft)

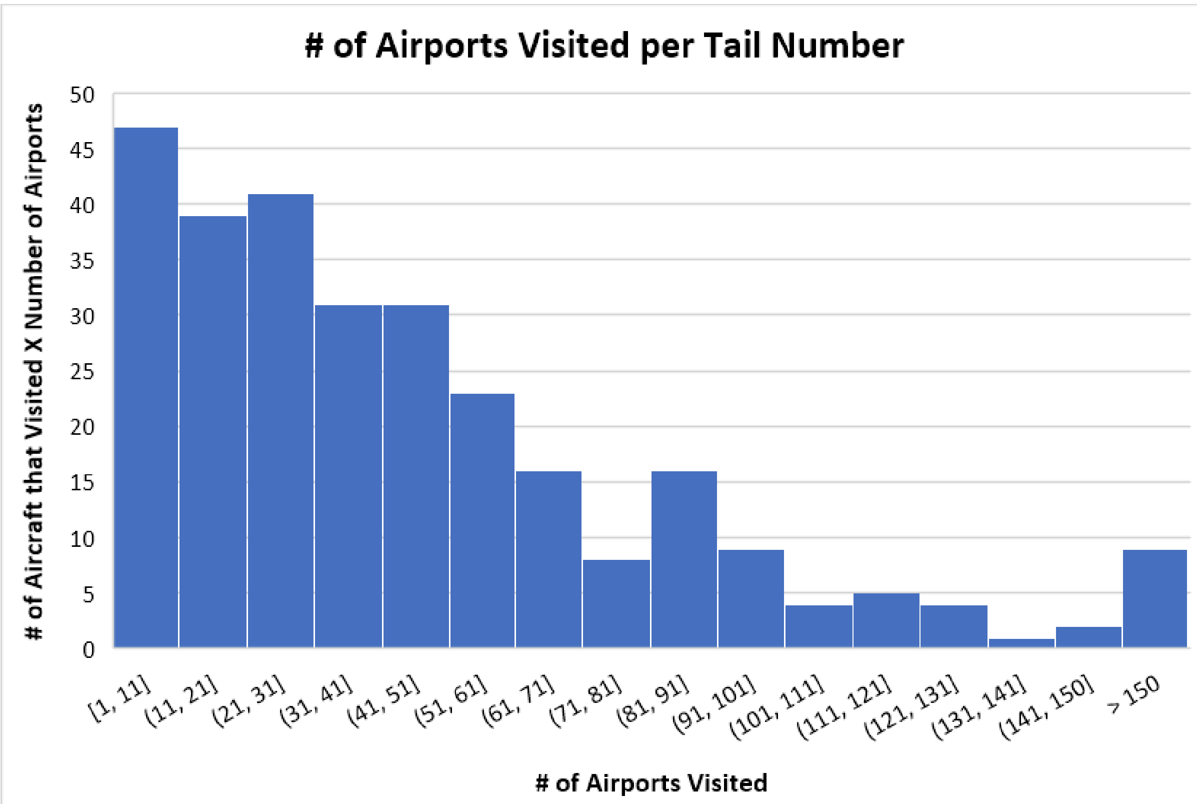

FIGURE 12: Number of Unique Airports Visited by Individual Tail Numbers

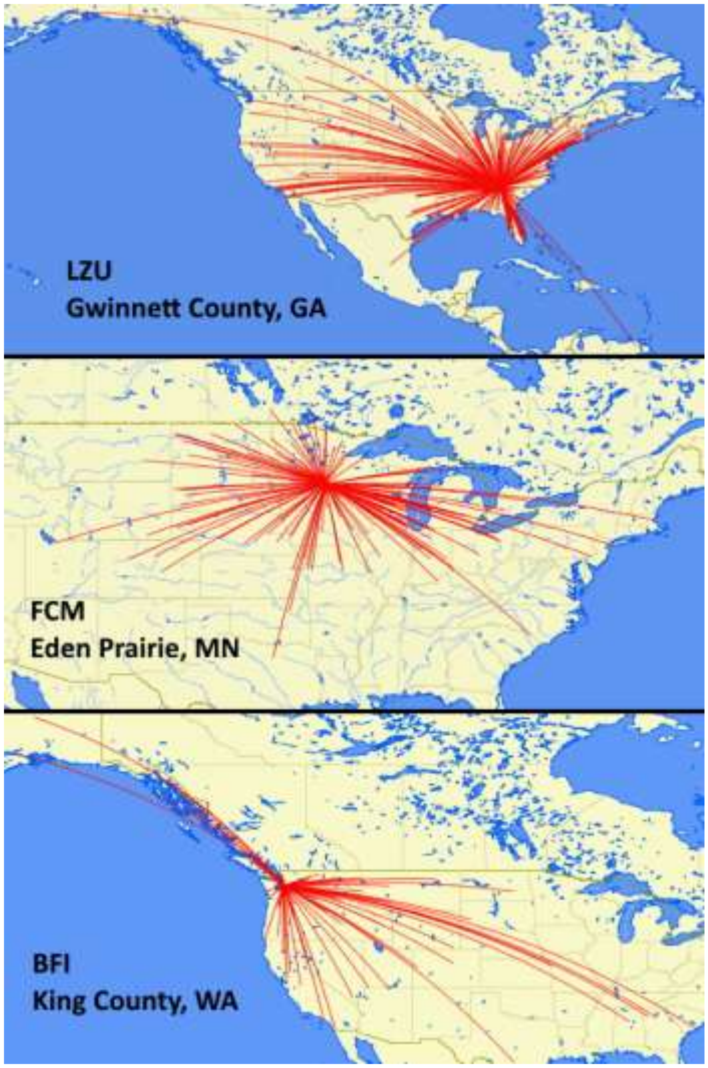

FIGURE 13: Visualization of ATM flights from three Base Airports

Air Traffic Control & Airport Navigation Equipment Used

Of the 1,837 airports that supported at least one AMT operation, 72% have ≥ 2 RNAV approaches (Figure 14). 28% have ≥ 3 RNAV approaches.

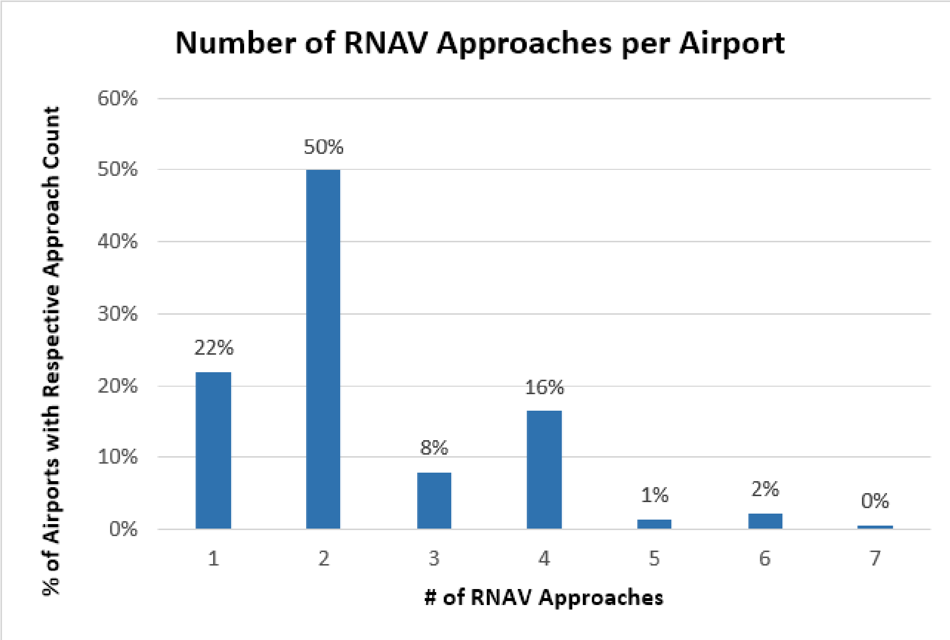

FIGURE 14: RNAV Approaches at the airports that supported AMT flights.

With regards to ILS and LPV/LP availability, out of the total 1,837 airports 670 (36.5%) are equipped with ILS, and 563 (30.7%) are not equipped with ILS. 994 (54.1%) have LPV approaches, 239 (13%) have LP approaches, and 604 (32.9%) did not have ILS or LPV/LP information available.

Out of the 785 that had < 5 aeromedical operations, 153 (8.3%) are equipped with ILS, and 310 (16.9%) are not equipped with ILS. 367 (20%) have LPV approaches, 96 (5.23%) have LP approaches, and 322 (17.53%) did not have ILS or LPV/LP information available.

The choice of airport used for fixed-wing operations is driven by runway length. Turbo-props in the AMT fleet require a minimum of 4000’ runway length. For jet operations, runway length is determined based on aircraft performance, flight plan (i.e., fuel requirements), and atmospheric conditions. Ninety-two percent (92%) of the airports used by AMT operations occur at airports with a primary runway length of more than 4,000 ft (Figure 15). 62% of the airports used had a primary runway between 4,000 – 7,000 ft long. Analysis of operational data shows that when two airports are equidistant from the transferring hospital, the airport with longer runways was always selected.

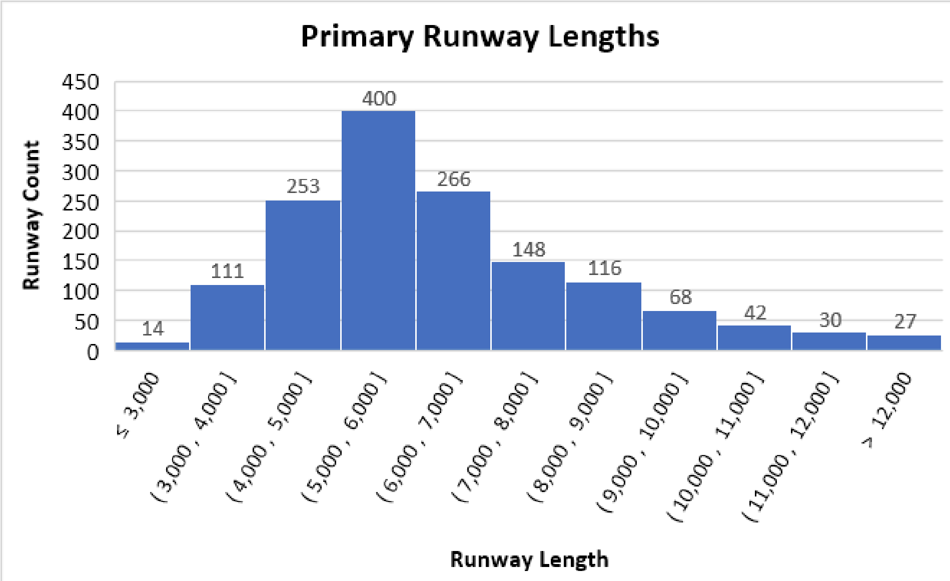

FIGURE 15: Primary Runway Lengths (feet) at Airports used by ATM

Jets tended to use airports with longer primary runway lengths (Figure 16). Ninety-eight percent (98%) of jets used runways > 5,000 feet. Seventy-three percent (73%) of turboprops used runways < 10,000 feet, and 27% of turboprops used runways > 10,000 feet.

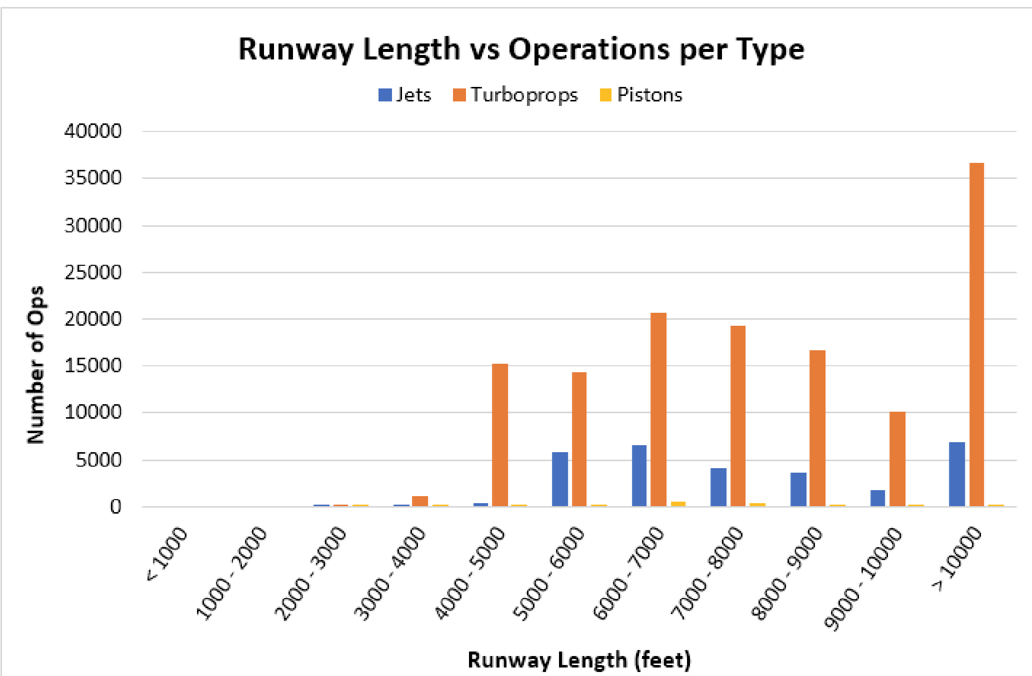

FIGURE 16: Primary Runway Length at Airports used by ATM vs Operations per Type

Runway Design Codes (RDCs) establish design standards for airports and aircraft compatibility. The Airport Approach Category (AAC) establishes the range of appropriate approach speed.

Aircraft Design Group (ADG) defines wingspan and tail height. The definitions of these classifications are as follows:

Aircraft Approach Speed (AAC)

- Category A: Speed 90 knots or less.
- Category B: Between 91 and 120 knots.
- Category C: Between 121 and 140 knots.
- Category D: Between 141 knots and 165 knots.
- Category E: Speed 166 knots or more

Airplane Design Group (ADG)

Group	Wingspan in feet (m)	Tail Height in feet (m)
I	< 49' (15m)	< 20' (6.1m)
II	49' (15m) - < 79' (24m)	20' (6.1m) - < 30' (9.1m)
III	79' (24m) - < 118' (36m)	30' (9.1m) - < 45' (13.7m)
IV	118' (36m) - < 171' (52m)	45' (13.7m) - < 60' (18.3m)
V	171' (52m) - < 214' (65m)	60' (18.3m) - < 66' (20.1m)
VI	214' (65m) - < 262' (80m)	66' (20.1m) - < 80' (24.4m)

The airports and fleet match in terms of AAC and ADG. Forty-six percent (46%) of the airports used by AMT had a primary runway AAC Type B, while 35% of the airports had a primary runway AAC Type C (Figure 17). In contrast the AMT fleet is composed of 68% Type B and 35% Type C. Only 5% of the AMT fleet are Type D.

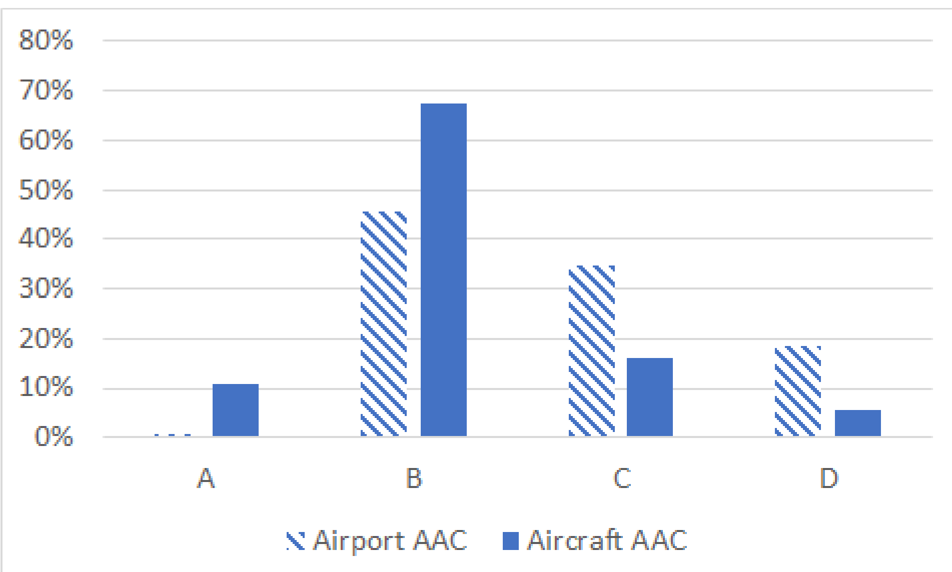

FIGURE 17: AAC Category of Primary Runway at Airports used by AMT and the AMT Fleet

The AMT fleet are 54% Type I and 46% Type II ADG Type II (Figure 18). More than 92% of the airports used by AMT have a primary runway with Type II or greater.

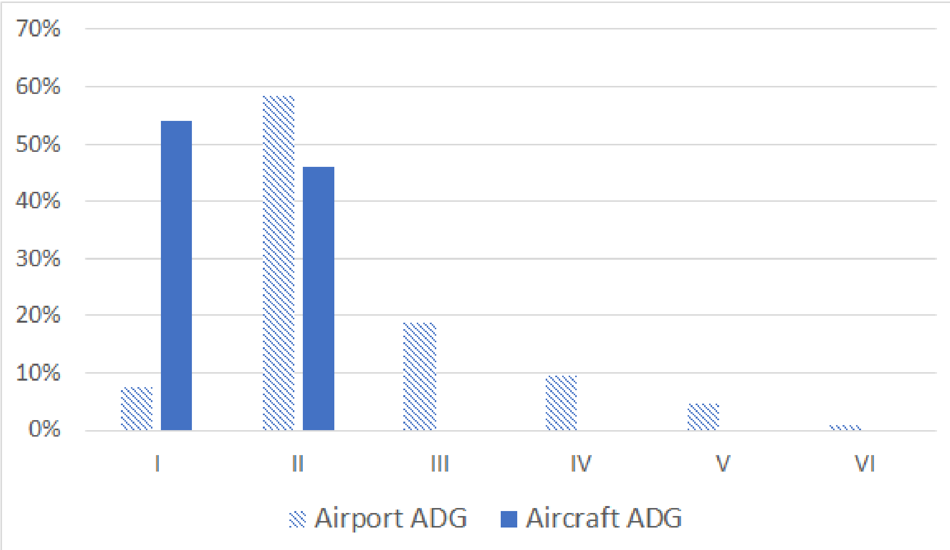

FIGURE 18: AAC Category of Primary Runway at Airports used by AMT and the AMT Fleet

Less than 3% of the total AMT flights operated at airports where the primary runway was not designed to support the aircraft operated (e.g. airport AAC Type A with an aircraft of Type B, or airports ADG Type I with aircraft ADG Type II). Eighty four percent (84%) of the mismatch were with regards to AAC related to jet aircraft (e.g. LJ35, GLF3) operations. Sixty-five percent of the AAC mismatches occurred at 5 airports: KLZU, KVPA, KSIY, KFOT, KAHN.

CONCLUSIONS AND FUTURE WORK

Aero Medical Transportation (AMT) services provide transportation of patients, medical teams, and organs for the U.S. healthcare system. An estimated 67% of the total AMT services are interfacility transfers and delivering specialty care and organs. These flights are predominantly conducted using Fixed Wing aircraft operating from the nation's NPIAS airports.

Over the period 2019 and 2020 there were 64,000 flights per year uniformly distributed across seasons with average of 180 flights per day (max 277).

The average aircraft operates approximately once every two days on flights with average stage-length of 237 nautical miles and average duration of 64 minutes.

The AMT fleet is made up of multi-engine turboprops (45%), jets (32%) and single-engine turboprops (19%). Although turboprops are 64% of the fleet, they perform 81% of the operations.

Fifty-two percent of the flights occur at night.

The average vehicle visited 49 unique airports, 42% of the flights were shuttle (I.e., origin-destination-origin), 58% included a dogleg. The AMT aircraft preferred airports with RNAV and GPS approaches with Aircraft Approach Category B, and ADG Class II.

The analysis shows that the NPIAS airports are largely equipped with navigation equipment, and runway/taxiway infrastructure to support the AMT operations at those airports.

Single-engined turbo-prop aircraft are uniquely defined to support the range of stage-lengths required for the U.S. AMT services demanded.

Future Trends

The coverage and type of AMT services provided is based on the economic viability of each individual market. Changes in Medicare coverage (circa 2000) resulted in growth of AMSP services across of the country (2% per year). Increased scrutiny into the billing practices (i.e., overbilling) may result in increased regulations and the leveling-off in growth. Further as the coverage of the U.S. AMT demand approaches 100%, coupled with consolidation of the industry, the growth is expected to slow.

Trends towards providing additional services including pediatric care, neo-natal care and other niche health care services could result in small increases in the number of operations using the existing fleet and facilities.

Challenges faced by the industry include increasing service availability (i.e., all weather) and maintaining safety levels in an increasingly dense air traffic environment in metropolitan areas (i.e., drones, UAM, and other helicopter traffic).

Increased availability could be improved longer runways in specific (currently under-served) regions, and additional GPS approaches.

In the future fixed wing AMT missions could be by electric powered aircraft. These aircraft have the potential to significantly reduce operating costs and emissions. Also, remotely piloted and pilot-less aircraft (i.e. Autonomous) could significantly reduce costs of providing the AMT service.

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