Title. Operational Statistics of Fixed-Wing Aero Medical Transportation in the U.S. (2019-2020)

Author names and affiliations.

Lance Sherry[1], Charlie Wang[1]

[1]Center for Air Transportation Systems Research at George Mason University, 4400 University Drive, MS:4A6, Fairfax, Virginia, 22031, USA

lsherry@gmu.edu

703-993-1711

Corresponding author.

Lance Sherry[1] lsherry@gmu.edu

Highlights

- Aero Medical Transportation (AMT) services provide transportation of patients, medical teams, and organs for the U.S. healthcare system.
- 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.
- There are an average of 180 fixed-wing flights per day (max 277)
- The average fixed-wing aircraft operates approximately once every two days on flights with an average stage length of 237 nautical miles and an average duration of 64 minutes
- The AMT fixed-wing 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.
- The average fixed-wing vehicle visited 49 unique airports,
- Less than 3% of AMT fixed-wing operations were conducted at airports where the aircraft had a higher approach speed than the approach speed designated for the airport primary runway.

Abstract

This paper aims to characterize the operations of Fixed Wing Aeromedical transportation in the U.S. for the period 2019-2020. This information can be used for aircraft design, airport and air traffic control infrastructure assessment and funding, and industry sector analysis and strategic planning. Data from 13 publicly available databases were combined to identify aeromedical transportation flights and generate operational statistics including the number of vehicles, ownership, flight distances, flight frequency, geographic distribution, and the types of airports, air traffic control, and navigation systems used.

Keywords

Aeromedical Transportation
Fixed Wing Aeromedical Transportation
Flight Operations
Air Traffic Control
Emergency Medical Services

INTRODUCTION

Aero Medical Transportation (AMT) services provide transportation of patients, medical teams, and organs for the U.S. healthcare system. Aero Medical Transportation Service Providers (AMTSPs) are the entities that provide the transportation service.

The majority (97%) of medical transportation in the U.S. is conducted 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.

There are four categories of AMT operations (Steenhoff, et.al. 2021):

(1) Scene response (33% of ATM),
(2) Inter-facility transfers (54%),
(3) Delivering specialty care and organs (13%)
(4) Repatriation from outside the U.S. (statistics not recorded).

Scene response is conducted primarily using Rotary Wing aircraft that can land and takeoff from accident scenes and at hospitals (Loyd et.al. 2020). Inter-facility transfer, and delivering specialty care and organs, are almost exclusively conducted with Fixed Wing Aircraft between airports.

Inter-facility transfer, and medical team, and organ transportation, using fixed-wing aircraft is a growing segment of the AMT services provided. The number of fixed-wing aircraft in the AMT fleet has grown an average of 2.2% per year over the last decade along with an average of 3.6% per year expansion in the number of AMT bases. This growth is driven by: (1) the introduction, in 2002, of Federal Health Insurance (i.e. Medicare) coverage for air ambulance services based on a “reasonable cost,” (2) the consolidation of Level 1 Trauma Hospitals in metropolitan areas, such that citizens living in rural areas, with lower-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.

Twelve databases were combined to provide the date for the analysis of the operations of the AMT in the U.S. The main findings of this analysis:

- AMT fixed-wing operations appear to have reached demand saturation. Over the period 2019 and 2020, there were 64,000 fixed-wing flights per year uniformly distributed across seasons with an average of 180 fixed-wing flights per day (max

277). The average fixed-wing aircraft operates approximately once every two days on flights with an average stage length of 237 nautical miles and an average duration of 64 minutes. Fifty-two percent of the fixed-wing flights occur at night.

- The AMT fixed-wing 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. Single-engined fixed-wing turbo-prop aircraft are uniquely well defined to support the range of stage-lengths required for the U.S. AMT services demanded.
- The average fixed-wing vehicle visited 49 unique airports, 42% of the fixed-wing flights were shuttle (i.e., origin-destination-origin), 58% included an additional intermediate stop. The AMT fixed-wing aircraft preferred airports with RNAV and GPS approaches that provide all-weather landings, airports that supported Aircraft Approach Category B (i.e. approach speeds less than 120 knots), and ADG Class II (i.e. wingspan < 24 meters and tail height less than 9.1 meters). Less than 3% of AMT fixed-wing operations were conducted at airports where the aircraft had a higher approach speed than the approach speed designated for the airport primary runway.
- The analysis shows that 55% of the National Plan Integrated Airport Systems (NPIAS) (FAA, 2020) airports are used by AMT fixed-wing operations. Seventy-three percent (73%) of these airports support all-weather operations navigation equipment.

The paper is organized as follows: the next section provides a short overview of the AMT industrial sector. The following section describes the data and process used to characterize AMT operations. The next section describes the results. The final section provides a conclusion with a discussion and future trends.

2. OVERVIEW OF THE AERO MEDICAL TRANSPORT (AMT) INDUSTRY

AMT Services are provided by Aero Medical Service Providers (AMTSPs). The characteristics of the AMT services available are shaped by regulatory, economic, and technological forces.

Aero Medical Transportation Service Providers (AMTSPs)

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

Hospital-affiliated AMTSPs provide medical services, medical staff, and medical equipment. They either own and operate the aviation services or contract for the aviation services from independents. Independent AMTSPs employ medical and flight crews to provide air ambulance services. Hospital-affiliated operators are generally not-for-profit, while Independent operators are for-profit.

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 AMTSPs, typically in regions where dedicated aero medical services are not economically viable, provide both medical services and aviation services.

Before 2002, AMTSPs were predominantly owned and operated by hospitals. In 2002, Medicare, a Federal Health Insurance program, created a national fee schedule for air ambulances based on a “reasonable cost” for emergency medical services (EMS). This schedule increased the Medicare reimbursement rate for AMT, in particular for rural transports. This directly resulted in a 27% increase in the number of fixed-wing aircraft registered by AMTSPs since 2007, and an increase of 69% in the number of rotary-wing aircraft registered by AMTSPs since 2007.

AMTSP Statistics

According to the most recent Atlas & Database of Air Medical Services (AAMS/CUBRIC, 2019), in the U.S, there are 303 AMSTPs operating out of 1,114 bases (i.e., helipads and airports).

AMT services are provided by rotary-wing and fixed-wing aircraft. Rotary wing aircraft operate from helipads located at hospitals, helipads located at airports, or stand-alone helipads. Fixed-wing aircraft operate between airports. One hundred and eighty-one (181) AMSTPs (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 283 fixed-wing aircraft registered to AMSTPs. 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 all located at Federal government-supported airports that are part of the National Plan of Integrated Airport Systems (NPIAS).

AMT Service Regulations

In the U.S., AMT services are regulated by a patchwork of State and Federal regulations. States regulate the medical services related to patient safety. The Federal government - Department of Transportation/Federal Aviation Administration (FAA) - regulates the aeromedical flight operations conducted under 14 CFR Part 135 regulations. The FAA also provides air traffic control and navigation services (e.g., RNAV(GPS), ILS, etc.), and supports the development of airport infrastructure through an Airport Improvement Program (AIP).

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

In the U.S. AMTSPs can achieve voluntary accreditation from the Commission on Accreditation for Medical Transport Systems (CAMTS - camts.org). One hundred fifty-three (153) U.S. AMTSPs currently hold CAMTS accreditation.

Airport Roles in Supporting AMT Services

AMTSPs are typically based at airports. To support AMT services, airports provide hangar, ramp, helipads (for rotary wing), office space/sleeping quarters, fuel sales, weather reporting services, de-icing services and snow removal (if necessitated by prevailing weather conditions), secure (i.e., gated) access to the airport, and signage for ground ambulances.

To ensure the availability of transportation services, AMTSPs prefer to operate out of airports with IFR services including instrument approaches and departure procedures. Most airports with AMT services are included in the FAA's NPIAS and have the widespread availability of RNAV (GPS) approaches. These airports include a mix of towered and non-towered facilities.

Airports are inclined to welcome AMTSPs as tenants. AMTSPs generate revenues from long-term (5-10 year) leases and fuel sales. AMTSPs also provide the airport the opportunity to show to showcase the benefits of the airport to the region by providing a "community service."

AMTSPs, operating as for-profit enterprises, choose the airport 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. AMTSPs also consider the presence of competing AMTSPs and market saturation.

AMT Aircraft

AMT aircraft are operated under Federal Regulations for Commuter and on Demand Operations known as a Part 135 certificate. These aircraft must have equipment that specifically meets the standards defined in an Advisory Circular AC 135-14B: Helicopter Air Ambulance Operations. These regulations identify minimum performance standards such as those for sealed, flame-retardant, moisture-resistant panels, stretchers, restraining devices, medical oxygen systems, and Medical Portable Electronic Devices (MPEDs). There are also standards for supplemental lighting, and requirements for multiple electrically powered auxiliary systems. Aircraft used for AMT services must be equipped with advanced life support equipment.

Pressurization and noise are two other aircraft 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 concerning the specifics of aviation medicine, including changes in physiology and the behavior of gases.

Part 135-14B stipulates that all AMT 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).

3 METHOD OF ANALYSIS

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

Twelve sources of data were required to perform the analysis for AMT rotary-wing fleet operations (Table 3-1). Eleven 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 Figure 3-1.

TABLE 1: List of data sources used to perform the fixed-wing 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.	AAMS 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 Type Reference	Manufacturer name & code, Model #	FAA Order 7360
Traffic Flow Management Systems (TFMS) data, CY 2019 2020 - TailNumber_RW_FW_030921	Flight track data (all flights, aggregate results, Tail Numbers de-identified	FAA (on request) https://aspm.faa.gov/aspmhelp/index/Traffic_Flow_Management_System_(TFMS).html
ADS-B Data	Flight track data (only transponding flights)	FlightAware https://flightaware.com/commercial/firehose/
Airport Distances	Airport Lat/Long, Elevation	FAA https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showDistanceCalculationToolForm
BTS Airport Latitude/Longitude	Airport Lat/Long	Bureau of Transportation Statistics

		https://adip.faa.gov/agis/public/#/airportSearch/advanced
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 CFIP https://www.faa.gov/air_traffic/flight_info/aeronav/aero_data/
FAA Aircraft Characteristics Database	RDC categories for aircraft types (AAC, ADG)	FAA Office of Airports https://www.faa.gov/airports/engineering/aircraft_char_database/
RDC Database by Runway	AAC and ADG for Primary Airport Runways	FAA Office of Airports https://www.faa.gov/documentLibrary/media/Advisory_Circular/draft_150_5300_13a.pdf

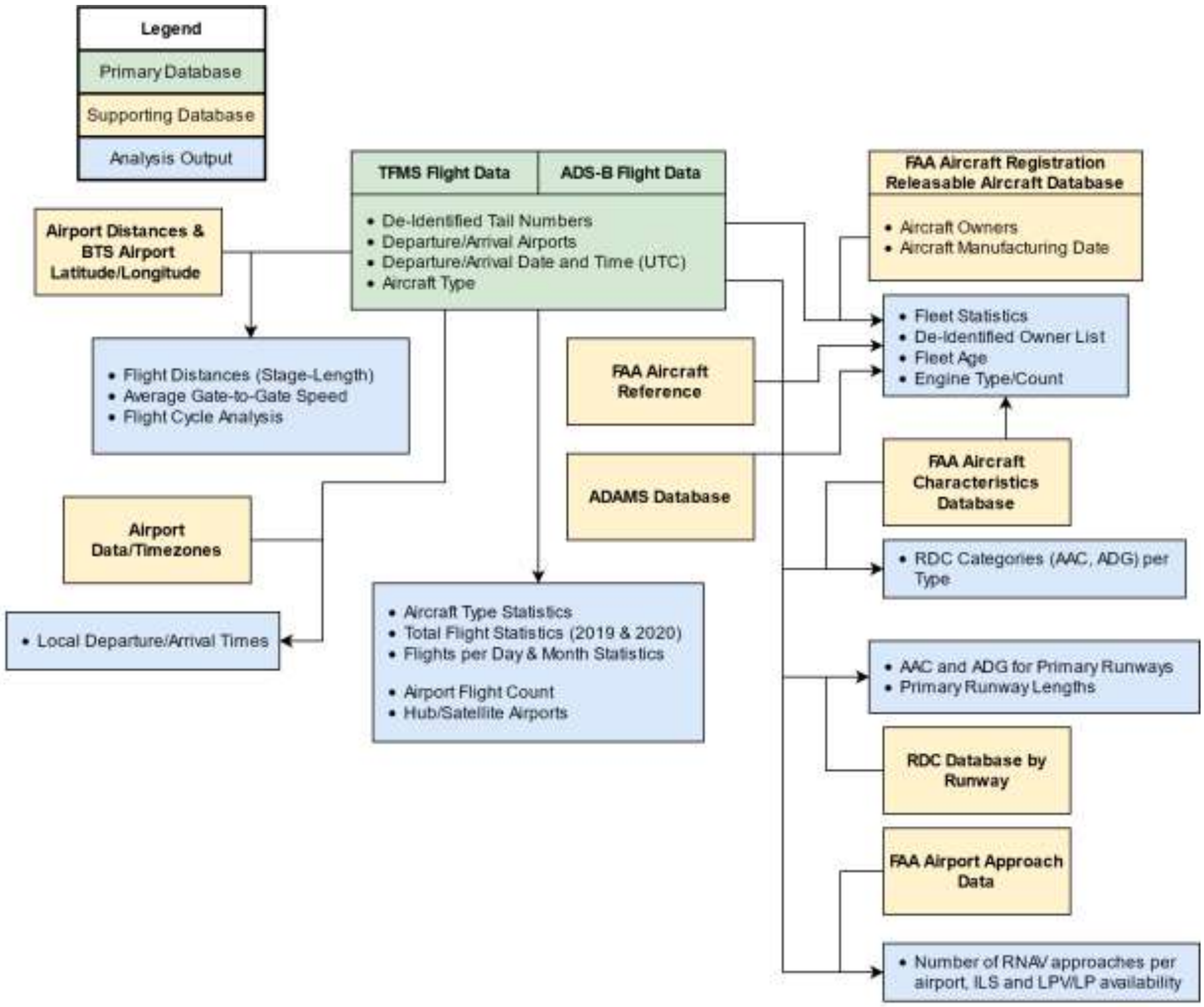

FIGURE 1: Relationship between data-bases for AMT fixed-wing analysis

The data were processed as follows (Figure 1):

1. **Aircraft Ownership**: ADAMS Database 2019 (AAMS, 2019, AAMS, 2020; CUBRC, 2020) is a public database that identifies Aircraft Owners (i.e., AMSPs). The AMSP List was supplemented and checked using publicly available secondary and tertiary sources including company websites.
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 Characteristics**: Aircraft characteristics (type, engine count) were identified by matching Tail Numbers to the public aircraft database provided by the FAA.
4. **Operational Flight Statistics**: Tail Numbers were submitted in a query to operational flight track databases. The database 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.

To better analyze the operational flight statistics the following manipulations of the data were performed:

a. **Local Times**: The flight operations data was processed to convert UTC time to local times and account for daylight 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 needed to be given to airports outside of the continental US (Alaska and Hawaii) as the codes may vary and require a modified search value criterion.
d. **Discontinuities**: 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 by the same aircraft 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 30% of the total flights. The typical reason is legs flown VFR are not captured by TFMS. In this way, the flight counts reported represent a floor for total flights as there may be additional flights in between the discontinuities 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 the above methods, the flight duration was assigned the average duration (65 minutes).
e. **Day/Night Operations**: For this study, daytime operations were considered to occur between 06:00 and 18:00. With uniform daily flight counts, over a year, the count of flights in day/night would average out.

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. **Air Traffic Control Statistics**: Instrument Flight Rules (IFR) counts were made under the assumption that the flight that was IFR were those that were included in the TFMS data. All other flights were considered to be Visual Flight Rules (VFR).
7. **Airport Statistics**: Airports were analyzed for a count of AMT operations, the number of hub and satellite airports, facilities available at airports (ILS, RNAV, LPV/LP, tower control). The data in the Airport database used for the 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 are reported as percentages of the airports in the database.

4. CHARACTERISTICS OF AMT OPERATIONS

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

1. Fleet Characteristics
2. Aircraft Ownership
3. Fleet Flight Operations
4. Aircraft Flight Operations
5. Asymmetry Between Fleet and Flight Operations
6. Operations Time of Day
7. Air Traffic Control
8. Airport Infrastructure
9. AMT Fleet and Airport Compatibility

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 were multi-engine turboprops such as the Beechcraft King Air. Twenty percent (20%) of the fleet were single-engine turboprops such as the Pilatus PC12 and the Cessna 208 Caravan. The Pilatus PC-12 is the most popular aircraft for AMT.

Thirty-two percent (32%) of the fleet were multi-engine jets such as the Lear Jet and the Cessna Citation. The Cessna 210 Centurion, Cirrus SR22 are examples of single-engine pistons.

TABLE 2: AMT fixed-wing 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 3-2). 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) at 16.6%, and Lear Jet 35 (LJ35) at 12.4%.

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

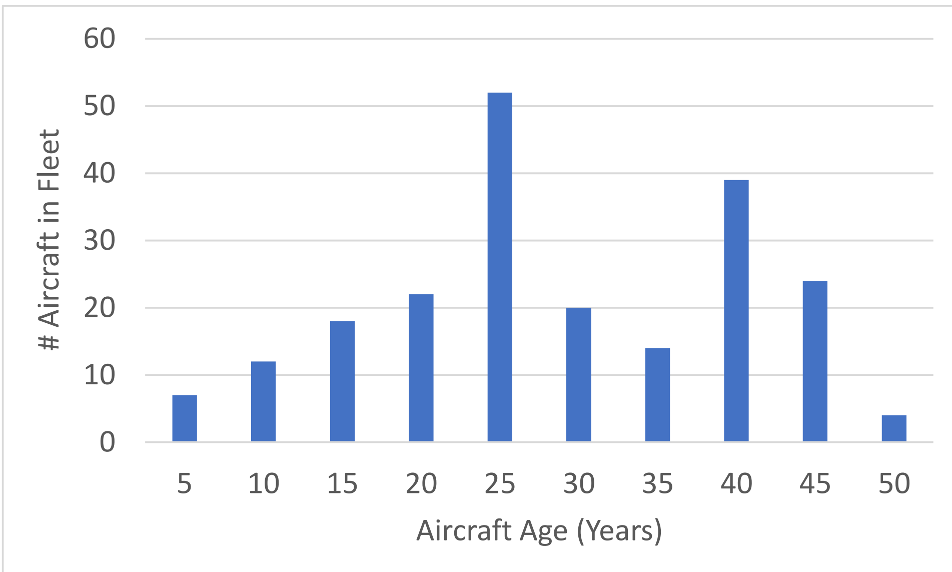

FIGURE 2: Age of fixed-wing AMT fleet

Aircraft Ownership

The FAA Vehicle Registration Database identified 109 owners (i.e. vehicle "registrants") for the 283 vehicles. The top 5 owners operate 25% of the fixed-wing fleet (70 out of 283 vehicles). Twelve (12) owners have 4 or more aircraft. Ninety-seven (97) owners have 3 or fewer aircraft. Fleet ownership may be more consolidated as several owners may be subsidiaries of a holding company. For example, Privately-held Global Medical Response (GMR) operates under the names Air Evac Lifeteam, Guardian Flight, Med-Trans Corp., and REACH Air Medical Services brands. Subsidiaries were not aggregated in this analysis.

Fleet Flight Operations

Total Annual Flights In 2019 was 65,994, and 62,063 in 2020 (Figure 3). In 2019, the mean and median flights per day were 181 flights. 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 were 169 flights. In 2020 the minimum number of flights per was 78 flights, the max was 277 flights (Table 3).

Daily flight operations do not exhibit seasonality and the difference between 2019 and 2020 is not statistically significant. The reduction in flight counts in the Spring of 2020 can be accounted for by a slowdown at the start of the COVID-19 nationwide lockdown in April and May 2020.

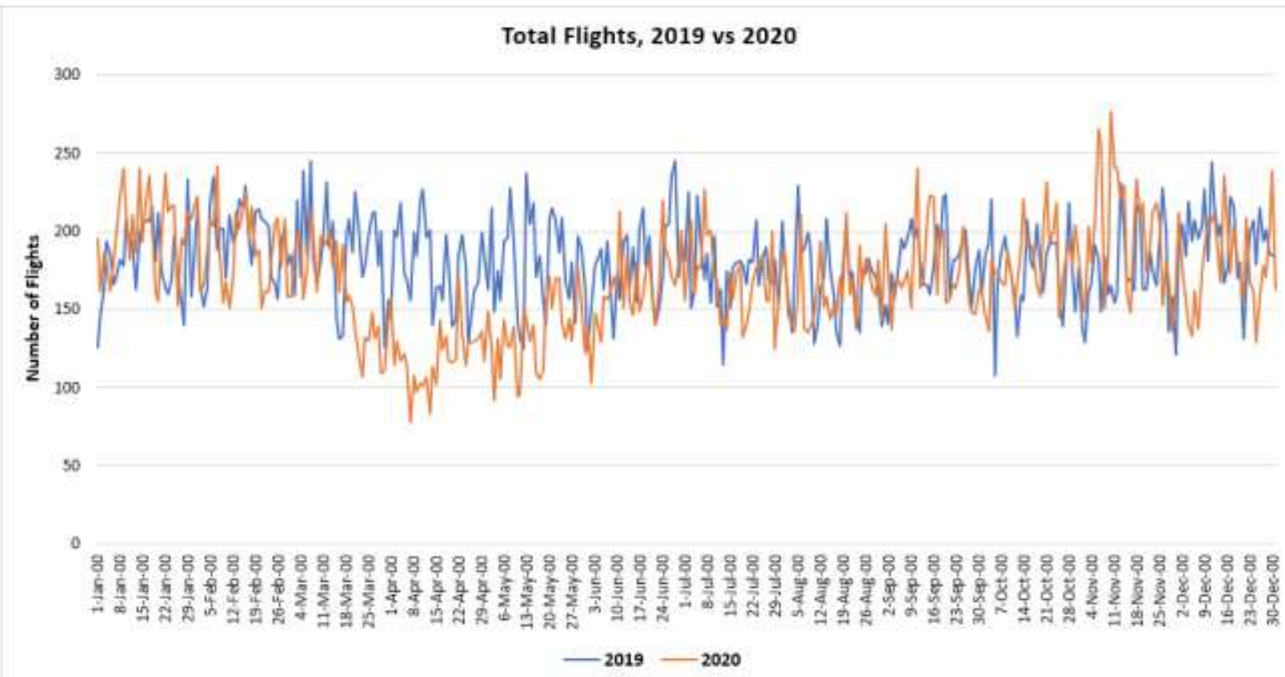

FIGURE 3: Daily flight counts for AMT fixed-wing fleet in 2019 and 2020

TABLE 3: AMT fixed-wing 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

Aircraft Flight Operations

The average number of flights per day for aircraft in the fleet is 0.61 flights per day (Figure 4). Of the aircraft in the AMT fleet, 76% (218) performed 1 or fewer 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.

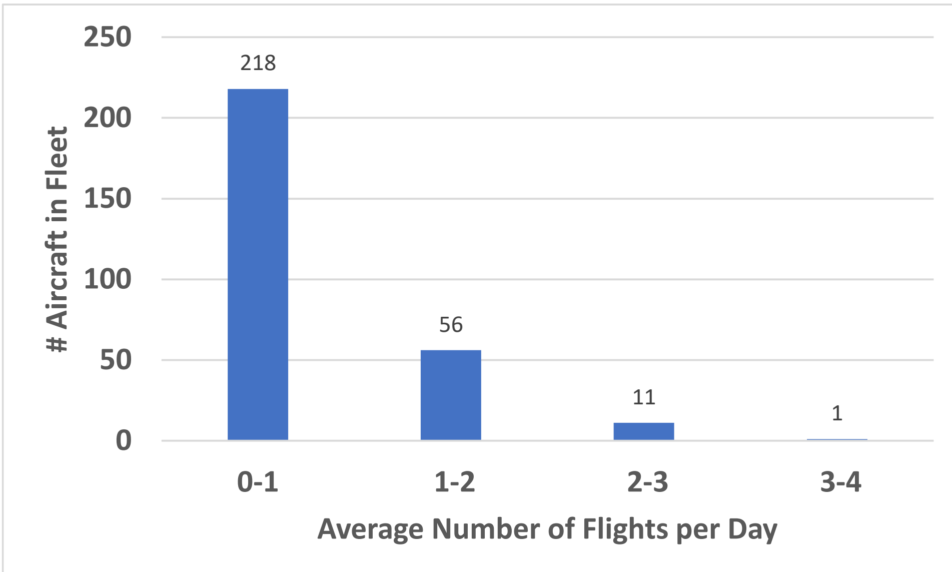

FIGURE 4: Average AMT fixed-wing flights per day per tail number

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

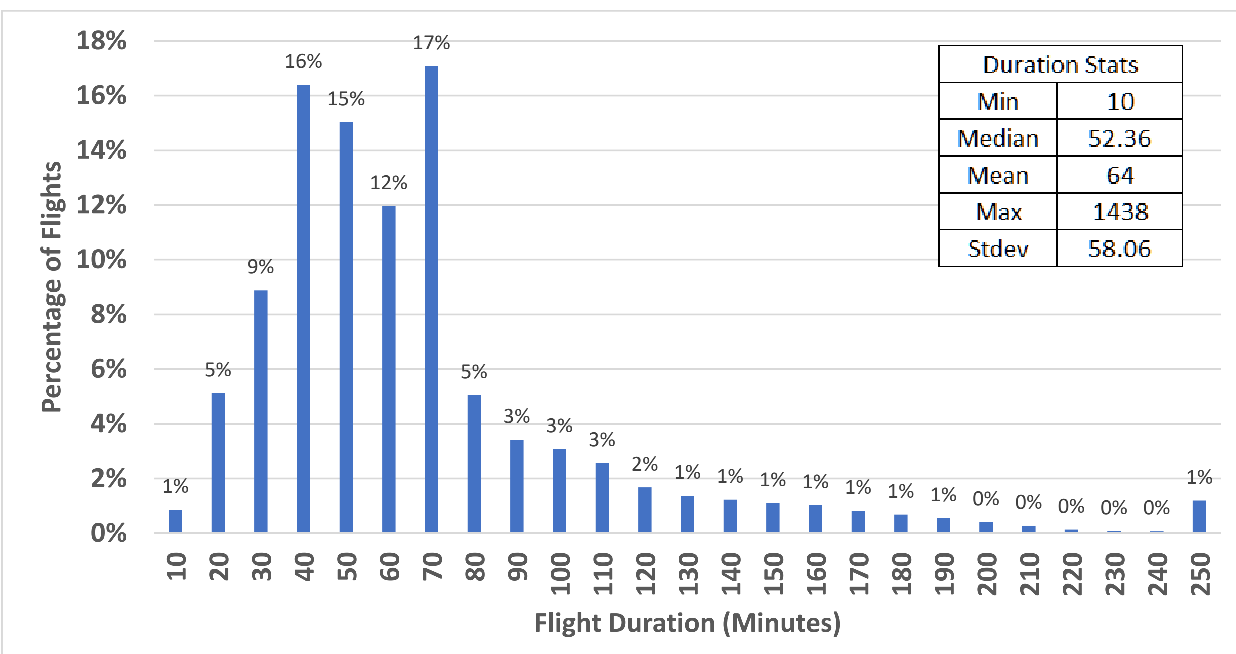

FIGURE 5: AMT fixed-wing aircraft flight duration

The stage length for the AMT fleet averaged 237 n.m. with a median of 165 n.m. (Figure 6). The histogram shows a concentration (81%) of flights between 0 to 300 n.m. and a long right tail from 300 n.m. to over 1000 n.m. flights. Nineteen percent (19%) of the flights were greater than 300 n.m.

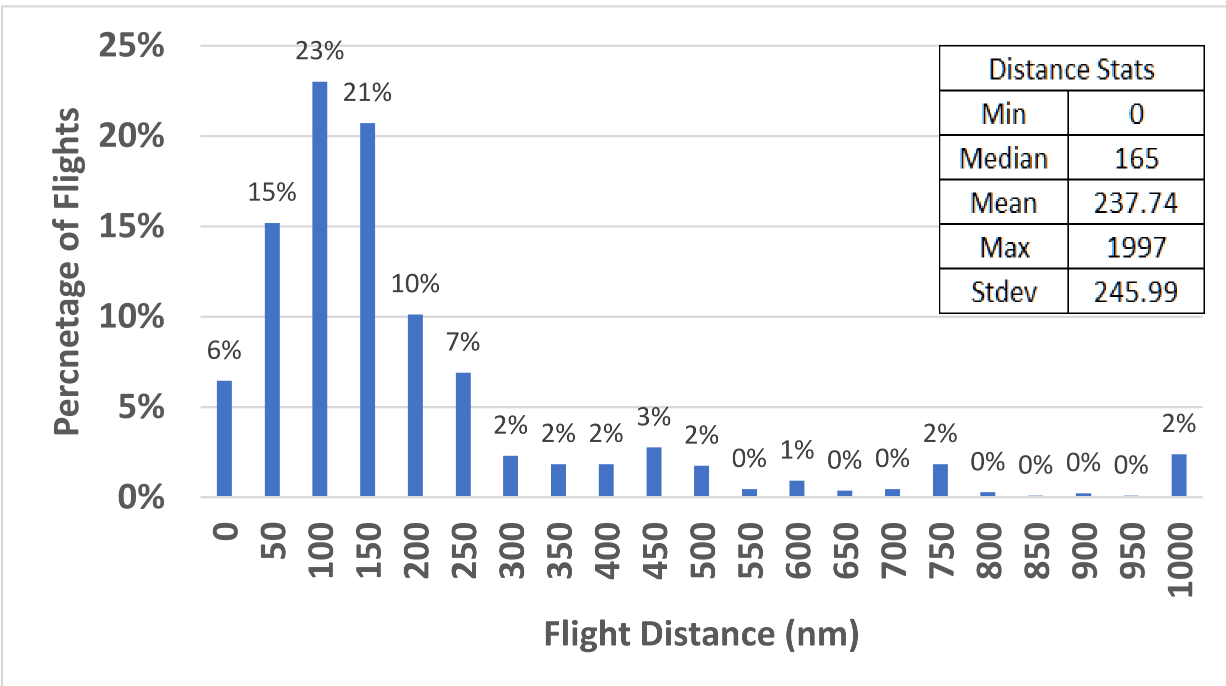

FIGURE 6: AMT fixed-wing aircraft flight distance

Analysis of stage-length flown by each aircraft type identified an asymmetry. Ninety percent (90%) of the flights with a stage length between 50 n.m. and 300 n.m. were conducted by turboprops. For flights with stage-length greater than 300 nm., the flights were evenly split between jets and turbo-props.

Out of all turboprop operations, 88% of flights are less than 300 nm. Several flights (9%) were less than 50 n.m. These flights departed from a domicile airport to another airport. For example, one is domiciled at FXE (Fort Lauderdale Executive) and takes s short hop to FLL (Fort Lauderdale International) to presumably pick up a transport before flying on to Orlando, Tampa, or elsewhere.

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 4). 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 4: AMT fixed-wing 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 (Table 5). The single-engine turboprop Pilatus (PC12) is the work-horse of the fleet. While the Pilatus (PC12) is only 18% of the AMT fleet, the PC12 performs 40% of the total operations (57,529).

The next most active aircraft types in the fleet are the twin-engine turbo-prop King Air (BE20 and BE9L). The King Air constitute 38% of the fleet and conducted 31% of the operations (45,429).

Amongst the jets, the Lear Jets (LJ31, LJ35, LJ45) make up 18% of the fleet with 11% of the operations (14,464).

TABLE 5: AMT fixed wing total flights per type for the top 7 aircraft types

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%

Operations Time of Day

There were 10% more fixed-wing AMT flights departing at night (55%) than during the day (45%). Fifty-three percent (53%) of the flights had a nighttime departure that also arrived during the night. Forty-one percent (41%) of the flights had a daytime departure and daytime arrival. Six percent (6%) crossed over. Four percent (4%) had a daytime departure that arrived during the night, 2% of flights had a nighttime departure and arrived during the day.

Air Traffic Control

Seventy percent (70%) of the AMT fixed-wing flights operated in airspace that required the use of Air Traffic Control services and operated under Instrument Flight Rules (IFR) flights. Thirty percent (30%) of the AMT fixed-wing flights operated under Visual Flight Rules (VFR). Jets operated 76% of their flights IFR. Turboprops operated 68% of the flights IFR. The percentage of AMT jet flights that operated IFR (76%) is less than the percentage of the general aviation jet IFR operations (97%). The percentage of AMT turboprops that operated IFR (68%) is in the same range as the percentage of general aviation turboprop IFR operations (FAA, 2020a).

Airport Infrastructure

The National Plan of Integrated Airport Systems (NPIAS) includes 3,310 U.S. airports. AMT operations used 55% of the airports (1,837 airports). Forty-three percent (43%) of the airports (785 of the 1,837 airports) 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 Table 6. The majority of these airports are in the Inter-Mountain, and Pacific coast region, plus Alaska.

TABLE 6: Top ten airports for AMT fixed-wing operations

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

Flight Patterns and Airports Served

Analysis of flight patterns indicates that 42% of the flights were “shuttle” operations from a Base airport to a destination airport and then back to the Base airport. The remaining 58% of the flights were multi-leg trips that did not immediately return directly to the Base airport. These trips may have been to reposition the aircraft or combined patient transports trips.

The average AMT fixed-wing aircraft visited 49 different airports at least once during the period analyzed. The average airport with more than 1,000 fixed-wing AMT flights per year served on average 74 satellite airports. The average airport with more than 2,000 AMT fixed-wing flights per year served on average 95 satellite airports.

The distribution of unique airports visited by an AMT fixed-wing aircraft was not uniform. Sixty-three percent (63%) of the fixed-wing AMT aircraft visited less than the mean unique airports (49) during the period analyzed. Example flight networks from airports LZU (Gwinnett County, Ga.), FCM (Eden Prairie, Mn., and BFI (King County, Wa.) are shown in Figure 7 and Table 7. Note that the majority of airports served from the Base airport had less than 5 flights during the period analyzed. For example, of the 155 airports served from FCM, 78% of the airports had less than 5 flights, only 22% had more than 5 flights.

FIGURE 7: Example airports served from a Base Airport

TABLE 7: AMT fixed wing sample of operations from Base airports

Airport	City, State	# Of Airports Served	# of Airport Served with < 5 Flights	% of Airports Served with < 5 Flights	Average Distance from Base to Airport Served (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

AMT Fleet and Airport Compatibility

Runway Design Codes (RDCs) establish design standards for airport and aircraft compatibility (Advisory Circular 150/5300-13A). The RDCs can be used to assess the compatibility of the aircraft and the runways and taxiways.

The Airport Approach Category (AAC) establishes the range of appropriate approach speeds defined by Categories A through E. The AMT fixed-wing fleet is composed of 64% Category B (approach speed 90 to 120 knots), 31% Category C (approach speed 121 to 140 knots), and 5% Category D (approach speed 141 to 160 knots). Forty-six percent (46%) of the airports used by AMT aircraft had a primary runway AAC Category B, while 35% of the airports had a primary runway AAC Category C.

The Aircraft Design Group (ADG) defines wingspan and tail height (Group I through IV). The fixed-wing AMT fleet is 54% ADG Group I and 46% ADG Group II. More than 92% of the airports used by AMT operations had a primary runway with Type II or greater.

Less than 3% of the total AMT fixed-wing flights operated at airports where the primary runway was not designed to support the aircraft operated (e.g. airport AAC Type B with an aircraft of Type C, or airports ADG Type I with aircraft ADG Type II). Eighty-four percent (84%) of this mismatch are related to the AAC for jet aircraft (e.g. LJ35, GLF3) operations. Sixty-five percent of the AAC mismatches occurred at 5 airports: KLZU (Gwinnett County, Ga.), KVPC (Cartersville, Ga.), KSIY (Siskiyou County Airport, Montague, Ca.), KFOT (Rohnerville Airport Fortuna, Ca.), KAHN (Athens/Ben Epps Airport, Athens, Ga.)

One of the key considerations in the choice of the airport used for fixed-wing AMT 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 fixed-wing operations occur at airports with a primary runway length of more than 4,000 ft (Figure 8). Sixty-two percent 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 the longer runways was always selected.

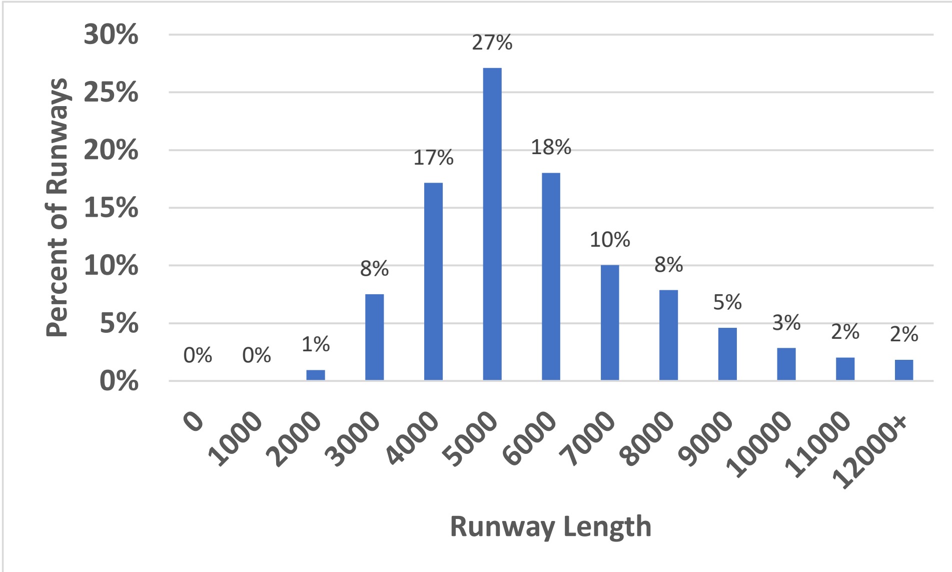

FIGURE 8: Primary Runway Lengths (feet) at Airports used by ATM fixed-wing fleet

Jets tended to use airports with longer primary runway lengths (Figure 9). 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.

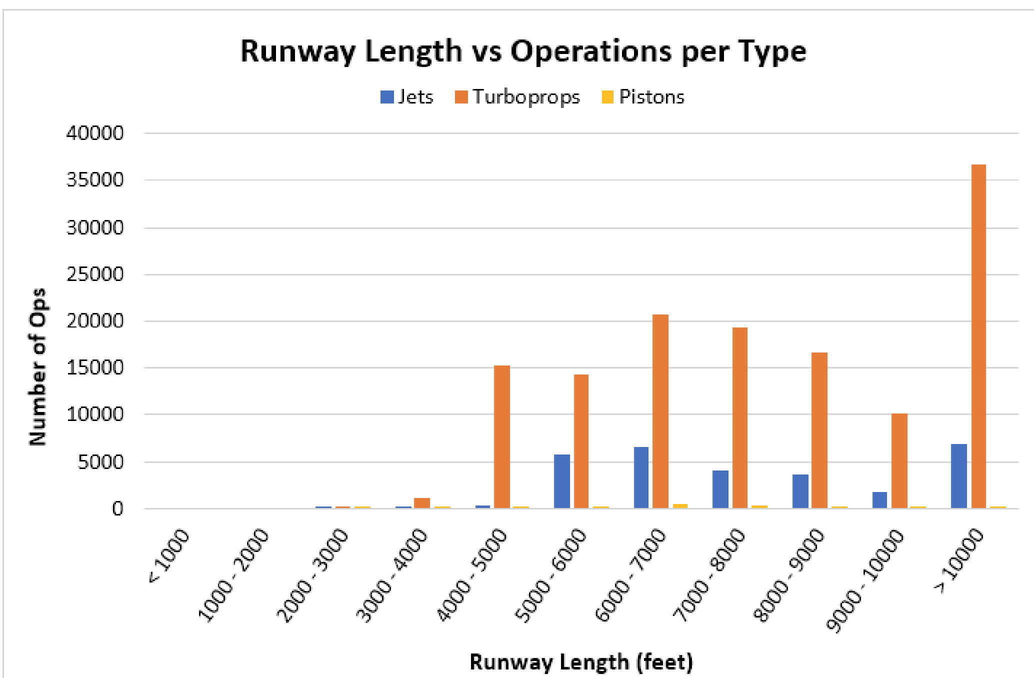

FIGURE 9: Primary Runway Length at Airports used by ATM vs Operations per Type

Another key factor in the choice of airports for AMT fixed-wing operations is the ability to operate at night and during weather with low visibility and/or low clouds. These operations can occur when the airport has approach navigation equipment and associated published approach procedures. The navigation equipment such as a ground-based Instrument Landing System (ILS) has dedicated antennas on the ground that send reference signals that are used to guide the aircraft. Another type of approach known as Radio Navigation (RNAV) uses a combination of satellite Global Positioning System (GPS) and other ground-based navigation signals to accurately guide the aircraft on the approach. Airports can have both ILS and RNAV approaches.

Analysis of the types of Approaches available at the 1,837 airports used by AMT fixed-wing aircraft operations identified that 27% of the airports had neither ILS nor RNAV-type approaches (Figure 10). The majority of the airports had RNAV (GPS) (73%), ILS Localizer approaches (34%), RNAV (RNP) (6%), and ILS Localizer/DME (4%). Keep in mind airports can have multiple approach types such as RNAV (GPS) and ILS.

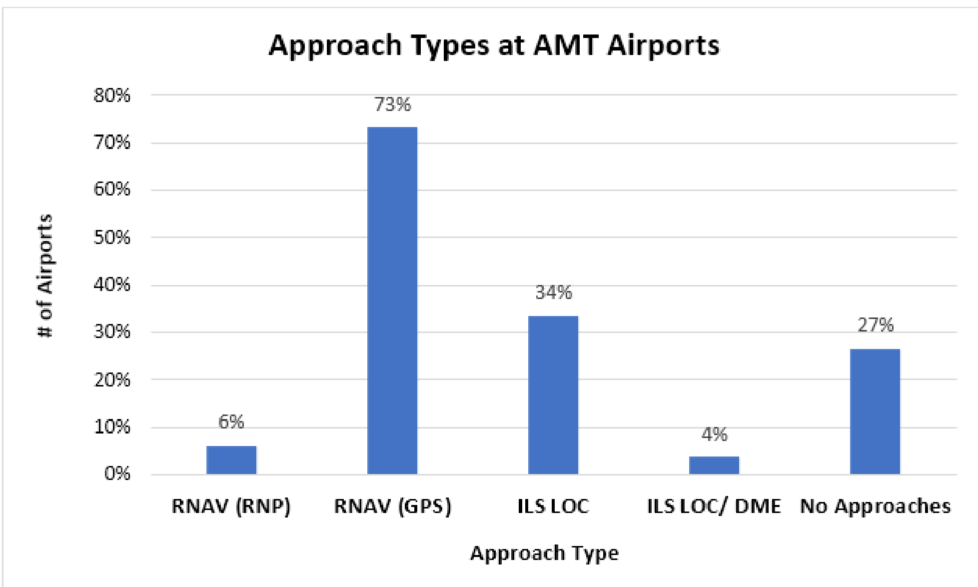

FIGURE 10: RNAV Approaches at the airports that visited by AMT fixed-wing flights

5. CONCLUSIONS

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.

AMT fixed-wing operations appear to have saturated demand requiring the industry to migrate from growth models to product differentiation. Over the period 2019 and 2020, there were 64,000 fixed-wing flights per year uniformly distributed across seasons with an average of 180 fixed-wing flights per day (max 277). The average fixed-wing aircraft operates approximately once every two days on flights with an average stage length of 237 nautical miles and an average duration of 64 minutes. Fifty-two percent of the fixed-wing flights occur at night.

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

The average fixed-wing vehicle visited 49 unique airports. Forty-two percent (42%) of the fixed-wing flights were shuttle (i.e., origin-destination-origin), 58% included an additional intermediate stop.

Fixed-wing AMT operations in the U.S. are well supported by Federal and State air transportation value-chain. Federal regulators certify and inspect aircraft, airports, air operations, and medical equipment. State regulators provide oversight of medical operational processes and AMTSP operational processes.

Fixed-wing AMT flights leverage the NPIAS airport infrastructure, and air traffic and navigation services. The AMT fixed-wing aircraft preferred airports with RNAV and GPS approaches that provide all-weather landings. Less than 3% of AMT fixed-wing operations were conducted at airports where the aircraft had a higher approach speed than the approach speed designated for the airport primary runway.

Future Trends

As is the case for all industry sectors, the AMT services are shaped by changing economic, infrastructure, regulatory, social, and technological forces. The coverage and type of AMT services provided are based on the economic viability of each market. Changes in Medicare coverage (circa 2002) resulted in the growth of AMTSP services over the last decade averaging 6.6% per year for rotary-wing and 2% per year for fixed-wing. However, the market may have reached saturation. Also, increased regulation of billing practices (i.e., overbilling) may result in the leveling-off in growth in traditional patient transport and consolidation of the industry (GAO, 2017).

One of the future growth opportunities for AMSPs is providing medical services at the point of care (Lyng, et.al., 2021). These services include pediatric care, neonatal care, and other niche health care services. These services could result in small increases in the number of operations using the existing fleet and facilities.

Air traffic control services and navigation equipment provide both an opportunity to increase service availability (i.e., all-weather) and to maintain safety levels in an increasingly dense air traffic environment in metropolitan areas (i.e., drones, UAM, and other helicopter traffic). Increased services and improved safety would be facilitated by improved weather services, better coordination of NOTAMS, and improved airspace coordination and navigation procedures (e.g. RNAV(GPS) for airports without precision approach procedures)

Technological changes are also creating opportunities. In the future, AMT missions could be conducted using electric-powered aircraft (ADAC Luftrettung, 2020; Mahvelatishamsabadi & Emadi, 2021). 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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