The Information Exchange Digital Mechanics in the Future of Air Traffic Services

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Abstract—The air transportation system is becoming more congested as new initiatives are included into the NAS. The air transportation demand is gradually increasing in the U.S. due the integration of new aerospace vehicles. With this, increases the ATC workload amongst the ATC community providing more services to more systems. The research investigates the multiple articles regarding the ATC delay challenges in the national air transportation system. The research analysis on the workforce data associated to the aviation traffic flow data for both current and future operation. The research will also determine if the air transportation technological infrastructure supports current and future ovation operations within the U.S. The significance of the research is that it will provide whether the current technological system provide effective or efficient support to future aerial initiatives.

Index Terms—Workload, Air Traffic Service, Air traffic Control, Digital, UAS And UAM 3

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1 INTRODUCTION

Global air transportation is a complex network infrastructure joined with airlines, airports, professionals, and nations. The complexity of the air transportation network requires the integration of critical nodes such as ATS. ATS's are considered the composers of the air traffic flow within the air transportation system. ATS provides vital support to ensure passenger and cargo arrives at the intended destination safe and timely manner. In the U.S., four ATS groups ensure the air traffic flow within the NAS is seamless as required. The nations' four ATS' service providers are airport control towers, TRACON, ATRCC, and ATCSCC. The ATS providers are vital to ATM infrastructure providing public and private air transport services (FAA, n.d.). A 2020 FAA "Air Traffic by the Number" report provides an FY 2020 quantitative record of over 31.9 million flights flown across the U.S. Although FY 2020 flight reports are down 40% compared to the FY 2019 43.8 million, the information provides an idea of the national air transportation system's state [1]. The records provided from the report were based soley on the ATRCC's services to aircraft in their respective Flight Information Region (FIR). This amount's capacity most requires an effective digital information exchange network for both data and verbal communication to aircraft in flight.

The information in the report captures the flight information for general aviation such as helicopters, commercial and private airplanes. However, it does not capture initiatives added to the national air transport, increasing these numbers by thousands or perhaps millions. Aerial vehicles initiatives integrated into the air transport system under consideration are UAS, UAM, and Space Transport [2]. Although some of these initiatives are either under development, testing, or new to the air transportation system, the future network mechanics will be even more complex. The significance of the study is to investigate the digital network infrastructure design to support these vehicles in the air transportation system. The study is needed to find out if the current air service plan supports the future of the aerospace industry. The study will teach readers the challenges of network capacity and examine the forecast data associated with the future workload and air traffic capacity.

The current air transportation network's second leading cause in the National Aviation System is volume-based delays. The data provided from the BTS database regarding the National Aviation System is defined as non-weather conditions, heavy traffic volume, air operations, and air traffic control [1]. The investigation focuses on the National Aviation System's delay regarding air traffic control workload, forecast capacity, and digital support network infrastructure. The purpose of the research is to examine whether the ATC delays are due to insufficient system support or too many technological systems during air operations. The study results will determine the most significant concern regarding the ATC delays and their effect on

2 RESEARCH QUESTION AND HYPOTHESIS

Some research authors suggest ATC is part of the delay problem in domestic and international travel [3]. The suggestion was based on traffic flow vs ATC support analysis research regarding the interaction methods. However, it does not analyze the ATC technology systems in place to manage air traffic flow. Are the current technologies in place able to support the present and future of the air transportation systems?

Independent Variables: The aviation air traffic current and forecast flights to 2040.

Dependent Variables: The ATC service providing support to the current and forecast system.

1. ATC Workload
2. ATS Technological Support

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2.1

2.1.1 Delimitation

1) Research focused on the U.S. Air Transportation System
2) Data provided from the FAA Forecast Report for FY 2020 and 2021
3) Data provide from FAA Workload Plan
4) Aviation Performance data form the BTS website
5) ATC Workload Forecast provided from BLS

2.1.2 Limitations & Assumptions

1) Weather air traffic delay research conducted
2) FAA forecast data accurate within 85-100% tile
3) BTS forecast data accurate within 85-100% tile
4) BLS forecast data accurate within 85-100% tile

2.1.3 List of Acronyms

- ARTCC - Air Route Traffic Control Center
- ATC - Air Traffic Control
- ATCSCC - Air Traffic Control System Command Center
- ATM - Air Traffic Management
- ATS - Air Traffic Services
- BLS - Bureau of Labor and Statistics
- BTS - Bureau of Transportation Statistics
- FAA - Federal Aviation Administration
- FIR - Flight Information Region
- JATOC - Joint Air Traffic Operation Command
- NAS - National Airspace System
- TRACON - Terminal Approach Radar Control
- UAS - Unmanned Aerial System
- UAM - Urban Air Mobility

3 LITERATURE REVIEW

3.1 Air Traffic Management Network Infrastructure Digital and Ergonomics

The importance of understanding the national air traffic management is to first the infrastructure made up of air traffic control and centers that manage the ATS in the NAS. When examining the "Air Traffic by the Number" and the "Air Traffic Controller Workplan" data, its apparent the job of an ATC could be quite daunting (FAA, n.d.). The air service infrastructure is one of many supporting elements in the national air transportation system joined with air navigation facilities, airports, and other control stations. The information passed "From and To" these elements are essential to the mechanics of flight operations [4]. National controlling facilities are staffed with air traffic control professionals who provide navigation services to the aircraft within the NAS. As the airspace flight and traffic volume expands, the FAA is challenged with balancing the workload of the Air Navigation Service Providers (ANSP). The FAA strives to maintain Certified Professional Controllers (CPCs) or those who are in training, also known as CPC-ITs to sustain the mechanics of air traffic services.

3.2 Traffic Trends

Note. The trending projected workforce analysis based on air traffic operations. Chart is derived from the FAA's Air Traffic Workplan 2021-2030.

The Air Traffic Control Work Force Plan (ATCWFP) is FAA planned approach to fill the gaps with air traffic controller professionals to meet the increasing capacity of aircraft in the national air transportation system [4]. The plan includes historical data regarding ATC staff members per Tower, TRACON, ATRCC, and others. The report estimates a planned projection associated with the aerospace forecast. The FAA Workplan report provides an analysis that shows the historical and predicated traffic flow trend. The chart shows that the air traffic flow's peak in 150 million reported flight operations in 2000. Since 2000, the peak of air traffic gradually declined until the gradual increase in 2019 before the devastating turn of the COVID-19 Pandemic [4]. However, the FAA predicts the traffic flow will increase in the next decade and possibly sustain an upwards trend as new initiatives, spaceflights, and UAS vehicles join in the airspace. Nonetheless, FAA has predicted the outcome and developing technologies to mitigate stressors for professionals in Air Traffic Services [4].

The author of a scholarly dissertation suggests manned aircraft has dominated the skies for decades; however, unmanned systems are gaining ground with more active flight operations [1]. The author investigates the occupational stressors encountered by national ANSP. Research shows changes and functional procedures added to the essential duties of the ATC harm performance [1]. The certainty of new vehicles such as unmanned systems and urban air mobility vehicles will cause an increased flux of ATS by ATCs. The research study evaluates the integration effect of ATS when UAS vehicles are added to the NAS. The author recommends further research in mitigation practices and processes that wouldn't affect ATC' performance level. The assumption is UAS automation provides minimum impact to ATC performance; however, further research is needed to validate the hypothesis [1].

A research article examines the neurophysiological metrics in Air Traffic Management (ATM) [5]. The authors examined the neuromeric in Human Factors (HF) addressing the ATM need. The research assessed the workload of ATCs HF ergonomics regarding human-machine interaction and UAS automation [5]. The evaluation of neuroscience knowledge has demonstrated the applicability of neurophysiological metrics. The assessment on ATC's showed applicable results in mental workload, vigilance, cognitive training, behavior control, and crew cooperation [5]. The author acknowledges the importance of sustaining attention and recall from interruption, which is influenced by the increase in ATC operations.

3.3 Digital Infrastructure Research in the Air Transportation System

The national aviation leaders acknowledge that research is needed to explore additional methods to support aircraft within the ATM system [2]. The ATS infrastructure adjusted procedures and directives should support new initiatives and growing deployments like UAM and UAS. This is

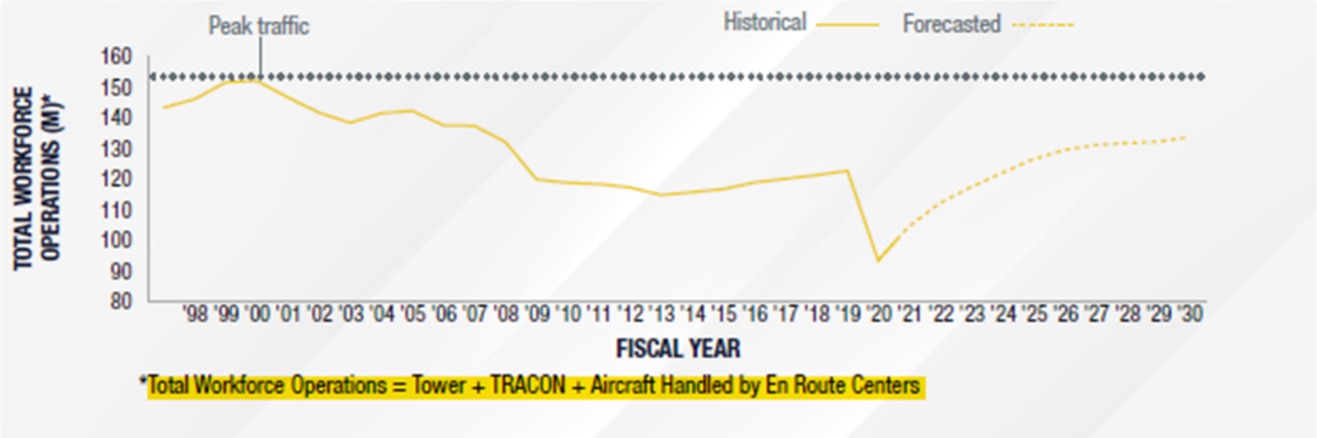


Fig. 1. Traffic Trends — The trending projected workforce analysis based on air traffic operations. Chart is derived from the FAA's AirTraffic Workplan 2021-2030.

also true for launch vehicles passing through the airspace mitigating risk in the legacy ATM infrastructure. Research studies are examining different approaches to sustain or develop effective digital initiatives to prepare for the future of aviation service growth. An author from a research journal investigated remote systems control tower for air traffic management and examined a multimodal augmentation approach to support ATCs [6]. The author conducted an experiment involving 16 professionals to participate in four different ecological scenarios. The experiments observe the ATC performance using single and multi-remote towers while providing ATC assistance to pilots [6].

The author applied modality practices using the single or multi-RT to overcome ergonomic challenges during ATC operations [6]. The conclusive evidence from the experiment is that ATC performance induced workload and lower performance when provided ATSs on a remote tower. Providing ATS using Remote Towers is a more cost-effective approach for those airports whose air traffic throughput is low. The remote tower is a more cost-effective approach for ATCs at smaller airports to sustain air traffic services and manage the airspace within their assigned regions using minimal hardware [7]. In recent years, air traffic management professionals have identified infrastructure deficiencies regarding the capabilities that cascade into flight delays [7]. However, as these aviation professionals implement innovative technologies to increase air traffic flow efficiency, new challenges occur, such as inducing ATC workload. The significant concerns in Human-Computer-Interaction (HCI) are performance level, marginal error (system and/or human), and limited information during automation processing [7]. Although remote tower technology assumes to be an appropriate approach to support ATCs, more research is needed to determine an alternative approach to support ATCs during unexpected circumstances in the future congested airspace [7].

Supporting International Civil Aviation Organization (ICAO) Global Air Navigation Plan (GANP) strategy, the FAA's NextGen digital infrastructure comprises three core enterprise centers. The three enterprise systems that make up the ATS infrastructure are the System Wide Information Management (SWIM) Enterprise Control Center (SECC), Navigation and Surveillance Enterprise Control Center (NECC), and the Voice and Data Enterprise Control Center [4]. Each center plays a unique role in supporting the digital enterprise for air traffic services. NECC provides oversight for NextGen support navigation and surveillance services, including the Automatic Dependence Surveillance-Broadcast (ADS-B) and Wide Area Augmentation System (WAAS) support for aviation. In addition, other services are managed under the NECC to include Traffic Information Service-Broadcast (TIS-B) and Flight Information Service-Broadcast (FIS-B) within the national airspace [4].

VECC manages two separate non-verbal and verbal communications services, the Data Comm Network Services (DCNS) and the NAS Voice Switch (NVS). The DCNS is a digital link used to support ATC clearance, traffic flow management, and flight crew request [4]. The SECC is the critical ATS node that provides digital information to air traffic service providers' national and international domains. The SECC manages the SFDPS, which offers flight and aeronautical information exchange to service providers. ARTCC and TRACON facilities leverage the SWIM Visualization Tool designed to provide ATC displayed traffic on the surface at major airports [4]. The core of the ATS information exchange mechanism relies on the interoperability of data messages distributed through the SWIM infrastructure. The SWIM is the central source of information distribution to ATS users using a business service model associated with four categories of data: weather, flight/flow, aeronautical, and surveillance. Using the Amazon Web Services (AWS), the messages are routed from NEMS to users on SWIM Cloud Distribution Service SCDS [8]. The backbone of the SWIM infrastructure is supported by the (SCDS).

The SCDS distributes services across six ATS sub available services; SWIM Terminal Data Distribution System (STDDS), Traffic Flow Management System (TFMS), Aeronautical Information Management (AIM) Federal NOTAMS Distribution System (AIM_FNS), Integrated Terminal Weather Service (ITWS), Time Based Flow Management (TBFM), and SWIM Flight Data Publication Service (SFDPS) [9]. The JMS API, also known as Brokers, establishes a bridge to ensure these messages are distributed and received amongst the ATS infrastructure users.

SWIM Enterprise Control Center (SECC)

The SWIM Enterprise Control Center (SECC) provides oversight of NextGen SWIM services such as STDDS and SFDPS.

Navigation and Surveillance Enterprise Control Center (NECC)

The Navigation and Surveillance Enterprise Control Center (NECC) provides oversight of NextGen navigation and/or surveillance services such as ADS-B and WAAS.

Voice and Data Enterprise Control Center (VECC)

The Voice and Data Enterprise Control Center (VECC) provides oversight of NextGen voice and data services such as Data Comm and NVS.

Fig. 2. Enterprise Control Centers and Data Services - The three-core center which makes up the FAA digital enterprise and services provided to aviation consumers. The screenshot image is captured from the FAA's ATO CyberDayBriefing in 2020.

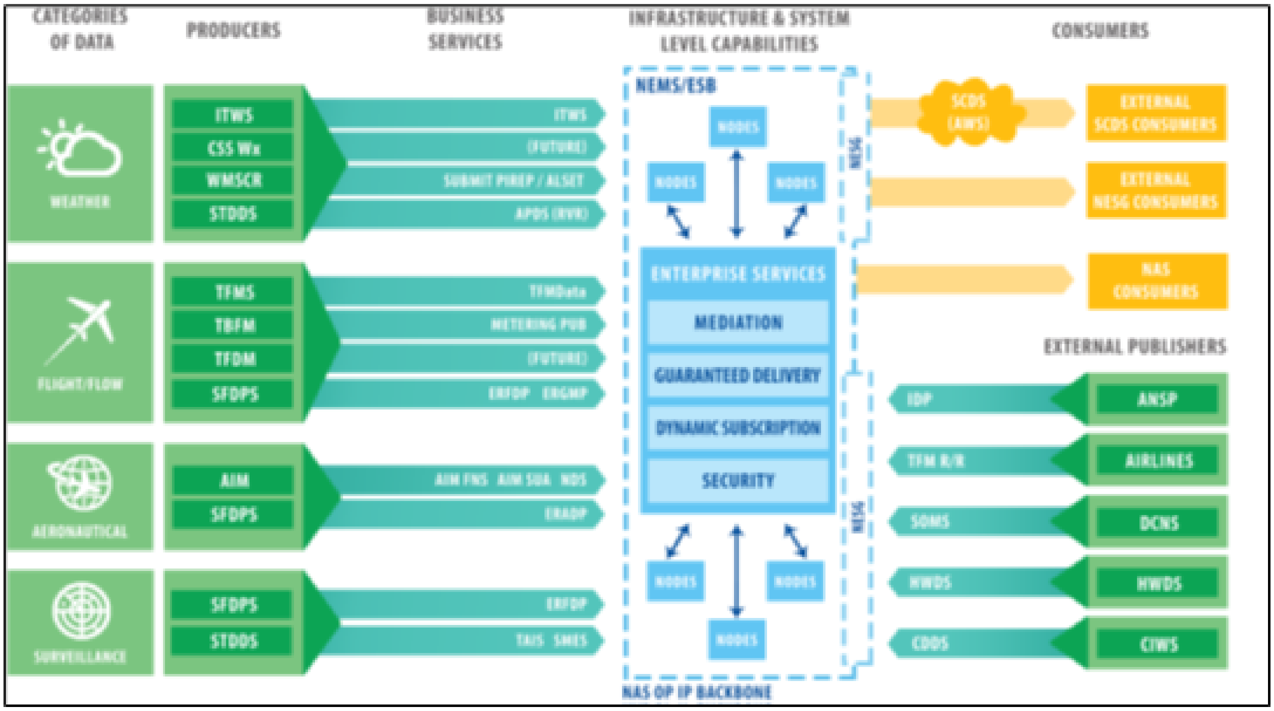


Fig. 3. SWIM BusinessService - The image is the SWIM business services infrastructureand information exchange architecture to provided services to aviationprofessionals. The source screenshot is derived formed the "SWIM Cloud DistributionServices" 2019 briefing.

3.4 Air Traffic as a Service in the Airspace

The national air traffic flow across the U.S. continues to restore operations to normal as the nation recovers during the Pandemic. As more citizens become vaccinated, the air transport comfort level rises, resulting in higher demand for air travel. Today, the national air traffic capacity averages 16.5 million flights handled by the FAA yearly. FAA services to commercial, rotorcraft, taxi, general aviation, and military contribute to the yearly total of over 488 million in gross annual earnings [4] . The network of services provides information exchanges to key players and organizations supporting ATS. A study from the Journal of Transportation System found that a quarter of the national airport was involved in delayed flights during peak travel periods [10]. The ATC at facilities nationwide provides data communication and verbal communications as a service to pilots during travel. However, the ATM offers more service through data communication methods than verbal due to different mitigation risk factors.

The national ANSPs are 25 ATRCCs, 147 TRACON, and 520 Tower facilities of experienced ATCs standing by to support aviation consumers [4] . The air transportation network is the travel infrastructure that supports aviation during the five phases of flight: Taxi/Ground, Departure/Takeoff, Cruise, Approach, and Landing. New vehicles such as UAS and later UAM enables additional research in providing air traffic control services while in the air transportation network.

The operational constraint for a space-based vehicle, UAM, and UAS in an already congested airspace provides structural challenges in the NAS [1]. The research studies were conducted to investigate an approach in support of an air traffic control infrastructure for UAM and general aviation [1]. An example comes for the Journal of Aerospace Information System, which examines how to mitigate congestion during UAM operations. The conclusive results show evidence of a complex air traffic mitigation approach in the airspace; however, further studies is needed to evaluate whether it benefits ATC performance and sustains the current workload [1]. The information management system is of global importance to ATM systems providing worldwide interoperability and accuracy of digital exchange [11]. Research study provides information on a possible approach to incorporate a centralized network known as Advanced Flexible Use of Airspace Service (AFUAS) through SWIM [2]. The authors focus on a conceptual information system design that supports all vehicle operations, including space launch assets. The AFUAS approach requires faster information distribution with high precision if services are integrated within the SWIM [2].

4 METHODOLOGY

The research is a descriptive approach applying both quantitative and qualitative methods regarding the topic. The study provides a literature review gathering scholarly articles related to traffic flow management in the U.S., air traffic infrastructure, and aerial vehicle integration. The research synthesizes the articles synthesis matrix and collects the research summary record data. The research also analyzes and applies data mining techniques to determine the subject's "Delimitation sections" information. The G-Power analysis tool is used in the study to calculate a predicted amount of sample needed to calculate a Correlation Regression based on the air traffic flow between the ATS Centers. The data mining tool used in the research is Microsoft BI using the data provided in the "Delimitation Section."

4.1 Air Traffic Control WorkForce Projection

The data contributing to the Graduate Capstone Research project derived from FAA's 2021-2040 Air Traffic Control Work Plan, FAA's Aerospace Forecast, and FAA's Operational Network (OPNET) database [4] . The data supports the research, providing evidence examining the need for a robust network expansion and system infrastructure in the future NAS. The purpose of the ATCWFP data sources is to investigate the workforce plan and determine whether the ATS is staffed to support in the aerospace forecast, including UAS, UAM, and Commercial Space Launches. The data used for this research is from Appendix X of the ATCWFP regarding the Facility Members Ranges from Towers, TRACONs, and ARTCCs. Microsoft (MS) Power Business Intelligence (BI) is the data mining tool used to analyze the WFP data and discover new information regarding the research question.

4.2 Operational Network (OPNET)

Governed under FAA Order JO 7210.55F Operational Data Reporting Requirements, OPNET is the official source of NAS air traffic operations and delay data used to analyze the performance of ATC facilities [12] . OPNET provides historical performance data from Towers, TRACONs, and ARTCCs. The purpose of the OPNET data is to collect air traffic operations counts based on general aviation, air taxi, military, and commercial and the facilities that provide ATS. The data contributes to the research by investigating the ambiguity between Forecast and OPNET reported activity datasets. This helps validate the reports and determine a count of activities not under ATS support. The data query from the OPNET database includes operational performance activity counts from national Tower, TRACONs, and ARTCCs from 1990-2021. G-Power is used to determine the sample size to a 0.95 confidence factor before analyzing the data. Stat Crunch is used to import the sample size, apply a regression analysis, and examine results.

4.3 FAA Aerospace Forecast

The FAA Aerospace Forecast 2021–2041 is developed to support budget and planning using statistical models to explain and incorporate emerging trends of the different segments of the aviation industry. The purpose is to the aerospace forecast and the ATCWFP to examine an ATS sustainment factor associated with the FAA's intended plan. The data collected from this database is the FY 2021-2041 forecast tables in the NAS's commercial space, UAS, and uncertain industries. A formula-based MS Excel application is used to conduct calculations under the following assumptions.

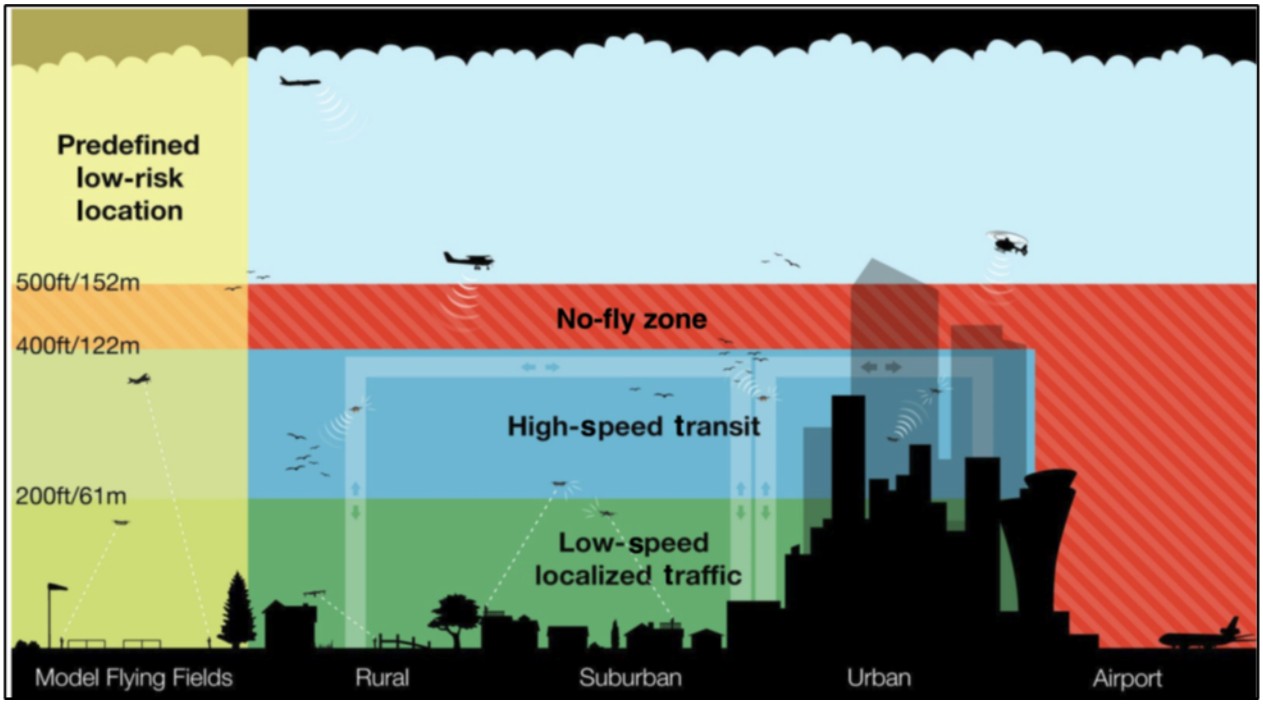


Fig. 4. Conceptual Design of Integrated Vehicles - The image is a conceptual design of the future of the national airspace while integrating new systems such as UAM and UAS. The image is captured from the “Air Traffic Assignment for Intensive Urban Air Mobility Operations.”

4.4 SWIFT Portal

The SWIFT Portal is an online service used to monitor the status and health of the SCDS in areas such as the AIM_FNS, TFMS, TBFM, SFDPS, ITWS, and STDDS systems (Website Insert). The purpose of online examination is to investigate the health of the SCDS throughout at 90-day cycle and examine the stability of the SCDS infrastructure. The data collected is from the SWIFT Portal’s "Status" page and under "View Details." The analysis tool is the SWIFT’s API online applications, providing historical and real-time message distribution and system statutes across the SCDS.

5 RESULTS AND INTERPRETATIONS

The results listed are based on three analysis areas in the ATS network: digital operations, workforce plan, and historical and forecast service volume.

5.1 Correlations Regression of Forecast Air Traffic Services

A data query regarding the 2020 ATRCCs traffic delay rankings extraction from the OPNET database was used to analyze the reported circumstances in which delay occurred. The categories were delays based on volume, equipment, weather, and runways. The data quantity shows the number of delays occurrences between January 1, 2020, and December 31, 2020.

Based on Figure 5, the leading cause of delays is obviously weather and although the aviation industry has no control, plans around this adverse occurrence. However, the data’s significance shows that the second leading cause of delays is associated with the traffic volume. The top ATRCC facilities reporting the most volume-based delays are Miami (ZMA), Jacksonville (ZJX), Washinton D.C. (ZDC), and Fort Worth (ZFW). Together these ARTCCs make up for 5,000 delays due to air traffic volume in their assigned regions. The volume delay concerns could be associated with two categories the digital infrastructure and the ATS workload. The traffic services analysis examines the traffic flow infrastructure stability by examining operation comparison between the ARTCCs and TRACON centers. The conclusive results provide which center would be in the best position to support the workload of UAS and UAM ATS service. Before the examination, the data sample size must be of high statistical power to determine the accuracy of the t-test regression model: correlation matrix. Using the G-Power analysis tool, the correlation points biserial and the Post Hoc selections provide the statical power analysis results of the intended research. The results provided a power of 0.89, meaning the sample size of only 33 data points would give a confidence level of 0.95 that the correlation data is accurately processed.

Using StatCrunch, the sample size was 33 which provides a high statical power as previously analyzed. The data from the ATS OPNET forecast was used in a regression model correlation matrix. The results show perfect, strong, and weak correlations in ai traffics service forecasts.

The results provided several suggestions within each category; however, the significant discovery shows that the ATRCC-Gen Aviation categories show a weak correlation amongst the other categories. This suggests ATRCCs are likely to provide general aviation services such as recreational, drones, pleasure planes, gliders, etc. This also indicates that most general aviation would be more likely to receive ATS from TRACONs and Towers. Perhaps the TRACON facilities may be better positioned to provide services

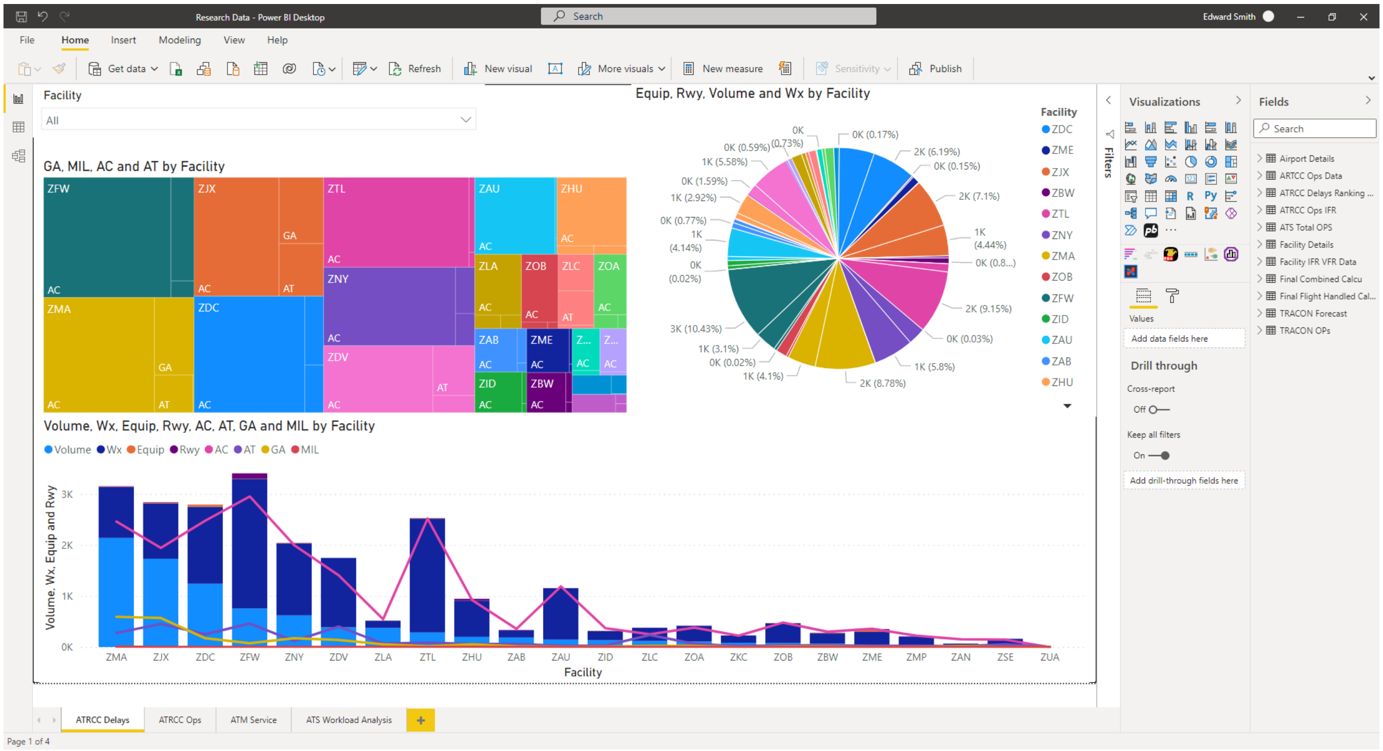


Fig. 5. MS Power Delay Analysis - The figure is a screenshot image of the MS PowerBI tool using for data mining based on the data from the FAA's OPNET database. The image captures the delay ranking reported by ATRCC from most to the least reports. The chart was developed by the author Edward P. Smith for the GraduateCapstone Research project.

to UAS and the future UAM; however, the workload may influence ATC's performance.

5.2 National Air Traffic Control Workload Forecast

The results provide new findings regarding the data provided from both the ATCWFP and the FAA OPNET database. During the ATCWFP analysis report should inconsistencies between the OPNET reports in terms of associated staffing numbers paired with ATRCC Atlanta, Oakland, Honolulu, and High Desert TRACON. This is concerning because the results show that Atlanta's ATRCC had not been identified in the plan. The Atlantic ATRCC provide service to over 2.3 million annually within the regions. There were some additional inconsistencies in the ATC Staffing totals listed in the ATRCC section. Table 1 provides the FAA's totals provided in the ATCWFP and the MS Excel "= Sum Formula" totals.

An analysis of the ATC workload examined through data mining via Microsoft BI was focused on an annual and a day-by-day per person assessment based on traffic flow forecast. The data model was also based on the Staffing forecast from the ATCWFP projection at ATRCC's, Towers, and TRACON.

The significance of the data model shows that the staff low/high range projections the workload will increase based on traffic flow forecast by almost 50%. For example, the Air Traffic Control Annual Workload (per person) section in Figure 9 shows ATRCC controller would provide ATS support from 6,092 to 7,371 in 2021. However, 20 years later, in 2041 total, the total annual service per controller is 11,790 to 14,415. The workload for all ATS facilities shows similar trends increase of about 50% by 2041, double the workload reported today. The workload also equates to the day-by-day flight handle per controller.

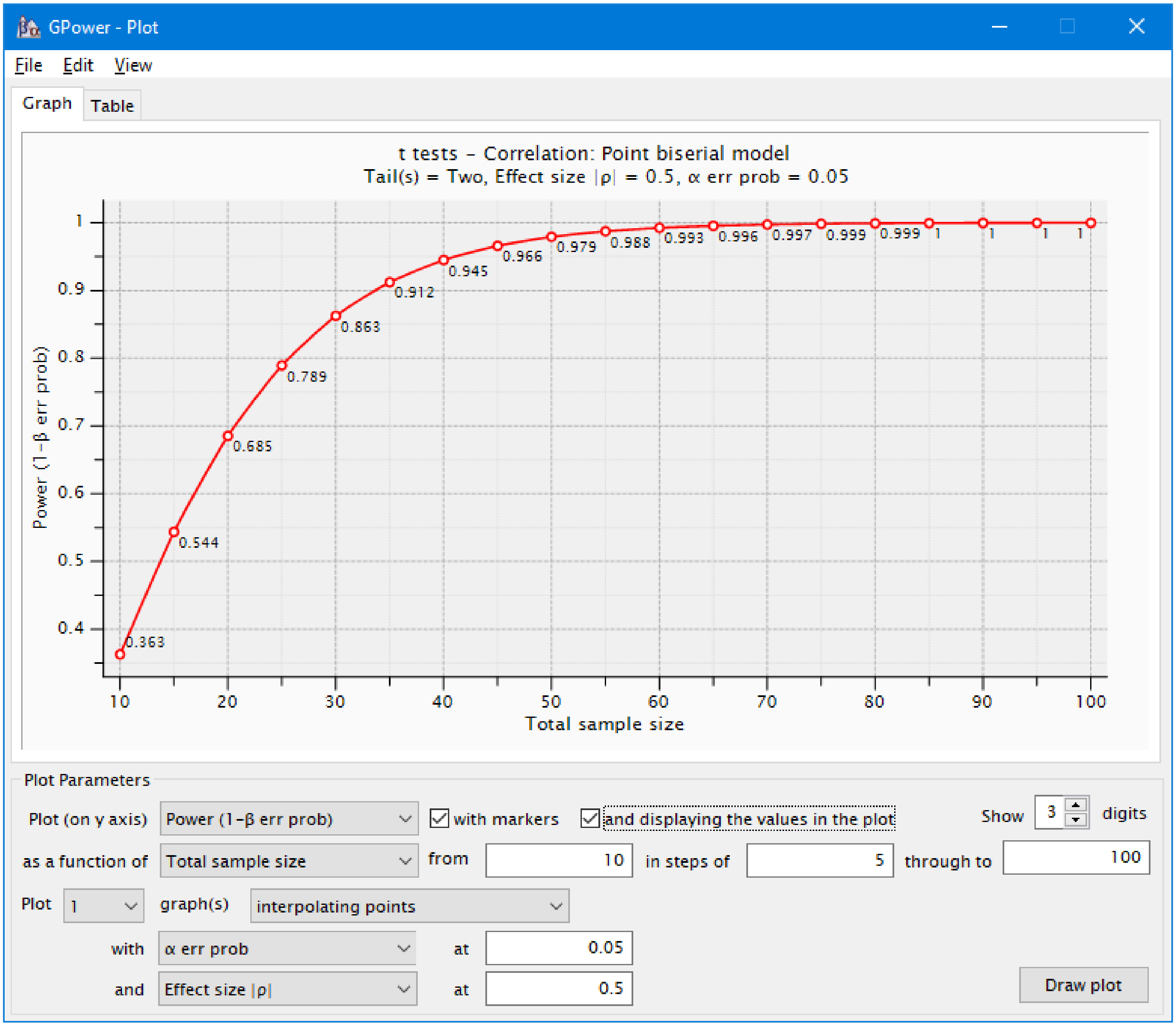
For example, the Air Traffic Control Daily Workload (per person) section in Figure 10 shows ATRCC controller would provide ATS support to 17 to 20 in 2021. However, 20 years later, in 2041 total the total annual service per controller is 32 to 39. The results show a significant increase in workload in the coming future when space vehicles, UAS, and UAM are more active within the NAS.

5.3 Digital Infrastructure Analysis via SWIM

As we've discovered through the literature review, the core of the ATS information exchange mechanism relies on the data messages distributed in the SWIM infrastructure. Figure 11 is a screenshot image of the SCDS Status Page, which shows the digital health of seven ATS business services.

The results provided evidence of significant instability concerns within the SWIM digital infrastructure, such as in the ITWS, STDDS, and TFMS service distribution.

The data shows the ITWS users experienced 28% downtime, 25% degradation, and only 47% of which was fully operational over a 90-day period. These findings suggest the ATS users were had limited weather products provided from the ITWS so ATCs had to outsource to additional weather research alternatives. The STDDS experienced 14% downtime, 27% degradation, and only 58% fully operational over a 90-day period. These findings suggest data regarding Runway Visual Range (RVR), visual runway range, trend information, and runway edge lighting were interrupted at national air traffic centers. The results also suggest



Plot Parameters

Plot (on y axis) Power (1−β err prob) ☑ with markers ☑ and displaying the values in the plot Show 3 digits

as a function of Total sample size from 10 in steps of 5 through to 100

Plot 1 graph(s) interpolating points

with α err prob at 0.05

and Effect size |ρ| at 0.5

Fig. 6. G-Power Analysis Tools Data Plot - The power input were Tail(s) = Two; Effect size $|\rho|$ =0.5; α err prob = 0.05. Total sample size = 33. The Stats results provide a Critical T of 2.0395134, Df 31, Power (1-β err prob) = 0.8947696.

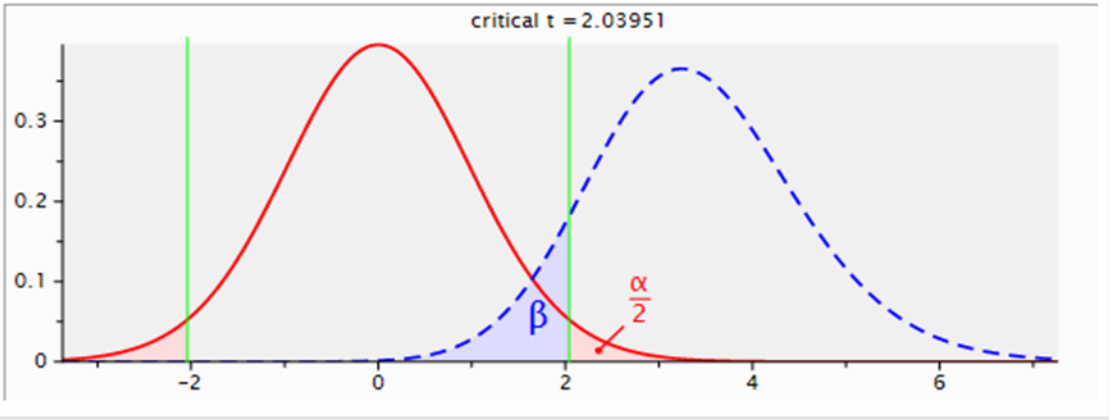
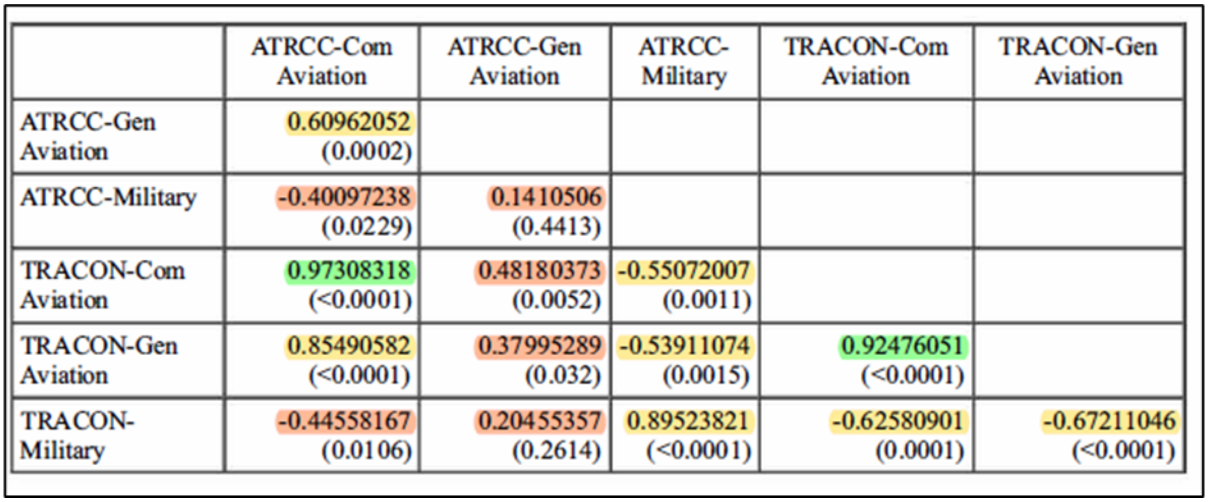
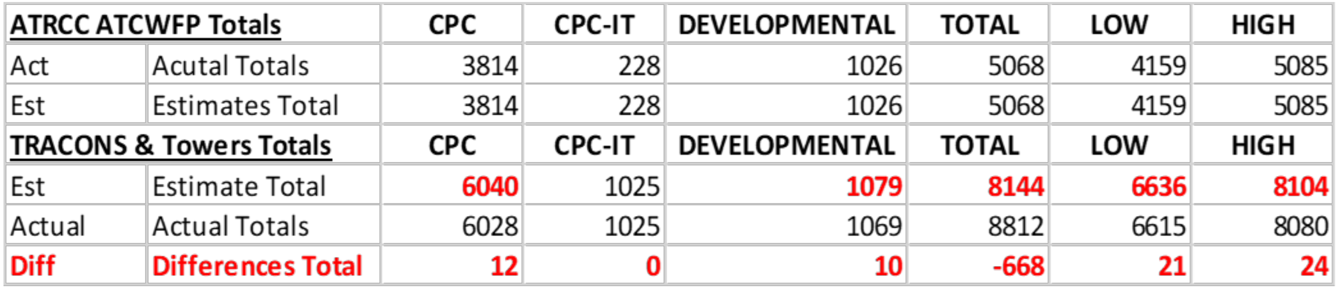


Fig. 7. G-Power Tail Distribution - The tails distribution results from the G-Power Analysis Tool prior to analyzing the sample size in StatCrunch.



	ATRCC-Com Aviation	ATRCC-Gen Aviation	ATRCC-Military	TRACON-Com Aviation	TRACON-Gen Aviation
ATRCC-Gen Aviation	0.60962052 (0.0002)				
ATRCC-Military	-0.40097238 (0.0229)	0.1410506 (0.4413)			
TRACON-Com Aviation	0.97308318 (<0.0001)	0.48180373 (0.0052)	-0.55072007 (0.0011)		
TRACON-Gen Aviation	0.85490582 (<0.0001)	0.37995289 (0.032)	-0.53911074 (0.0015)	0.92476051 (<0.0001)	
TRACON-Military	-0.44558167 (0.0106)	0.20455357 (0.2614)	0.89523821 (<0.0001)	-0.62580901 (0.0001)	-0.67211046 (<0.0001)

Fig. 8. Regression Model: Correlation Matrix - The figure is the results of a T-Test Regression Correlation Matrix generated in Stat Crunch using the data from the OPNET and MS Excel calculation by Edward Smith (Green=Perfect, Yellow=Strong, Orange=Weak). The source is generated by Edward Smith a Graduate student at Embry Riddle Aeronautical University.



ATRCC ATCWFP Totals		CPC	CPC-IT	DEVELOPMENTAL	TOTAL	LOW	HIGH
Act	Acutal Totals	3814	228	1026	5068	4159	5085
Est	Estimates Total	3814	228	1026	5068	4159	5085
TRACONS & Towers Totals		**CPC**	**CPC-IT**	**DEVELOPMENTAL**	**TOTAL**	**LOW**	**HIGH**
Est	Estimate Total	6040	1025	1079	8144	6636	8104
Actual	Actual Totals	6028	1025	1069	8812	6615	8080
Diff	Differences Total	12	0	10	-668	21	24

Fig. 9. The table shows inconsistencies highlighted in "Red" between the staffing totals in the FAA ATCWFP and the calculation in MS Excel. The ATCWFP is also missing critical staffing data for the four other national air traffic centers. The table and calculations were by Edward Smith a graduate student at Embry Riddle Aeronautical University.

flight/track data from and to over 150 airports and 100 TRACONs experienced an interruption. This may have caused a cascading effect developing other issues such as flight times in the air traffic flow in its assigned region. The TFMS experienced 9% downtime, 21% degradation, and only 70% of which was fully operational over a 90-day period. The results only suggest air traffic centers experienced flight data and flow information interruption which ATCs may have used legacy methods to provide ATSs. Providing more digital services such as Remote Towers integrations would create greater instability within the digital infrastructure.

6 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

7 DISCUSSION

The research provides interesting findings regarding the future of the ATS infrastructure as more vehicles integrate into the aerospace. The literature reviews were connected to the basic mechanics within the ATS infrastructure and how the information exchange distributions. These mechanical nodes are ATC performance based on workload and ergonomics, air traffic service flow, and digital infrastructure. The research synthesized the literature review into three topis areas National ATC Workload Forecast, Correlations Regression of Forecast Air Traffic Services, and Digital Infrastructure Analysis via SWIM. Using for databases and nine different datasets provide the information needed to determine a hypothesis. The research questions asked were the current technologies in place able to support the present and future of the air transportation systems? The first hypothesis stated that the existing national ATS technological infrastructure supports aviation traffic within 20 years. The null hypothesis stated that the current national ATS technological infrastructure does not support aviation traffic within 20 years. Based on the results from the research, the null hypothesis best validates the future of the air transportation system due to ATC staffing insufficiencies, workload increase, and digital infrastructure instabilities.

8 CONCLUSION

There are some evident concerns regarding the future of air transportation, and the development and deployment of flight systems are produced at an exponential rate far beyond the expansion of the air traffic infrastructure. New air traffic center nodes concepts such as National Ground Control Stations (NGCS) in the NAS regions should be examined to support the UAS expansion. Additional approaches to examine are nodes to support the future of UAM in the airspace to assist ATCs at the TRACONs. The

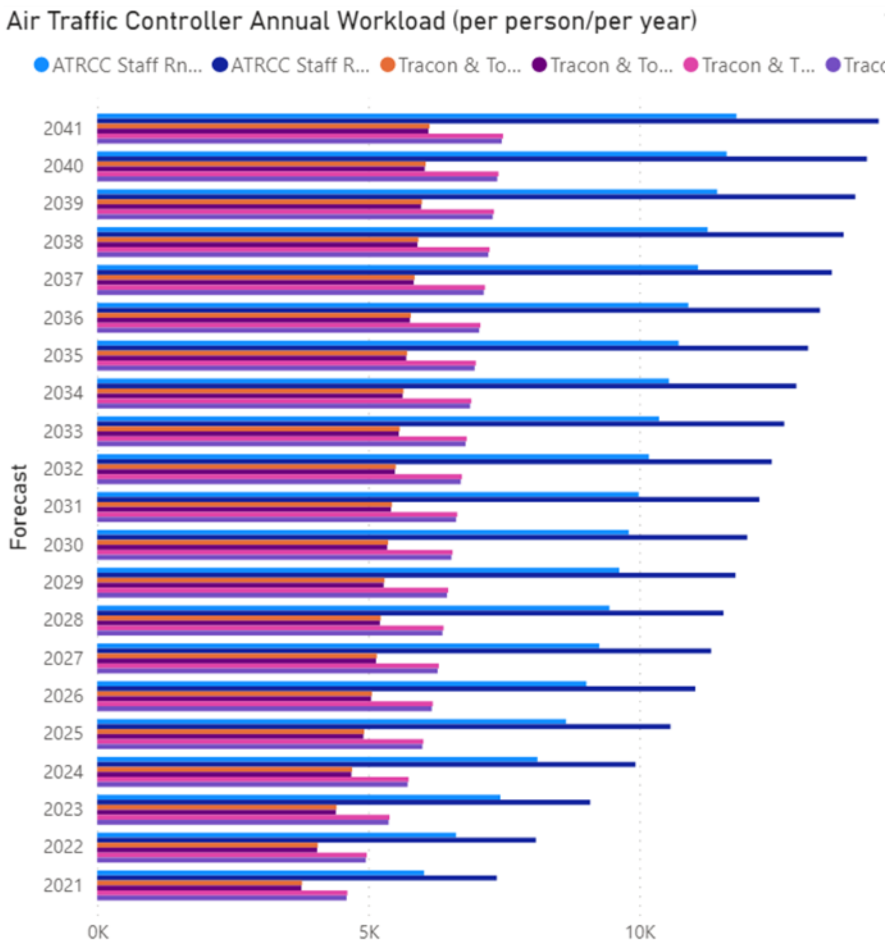


Fig. 10. Air Traffic Controller Annual Workload Forecast Analysis — The figure is a MS Power BI data model of the ATC annual workload forecast based on the traffic flow and flight handled threshold per year, per controller. The model was developed by Edward Smith using MS Power BI and the data provided from the ATCWFP and OPNET Traffic Flow forecast.

air traffic control digital infrastructure is also at risk for bottleneck data processing due to more digital communications methods or an increased cybersecurity vulnerability. The adverse results to either of these digital risks would certainly cripple the air traffic service infrastructure.

9 RECOMMENDATIONS

The FAA should consider re-analyzing the current workforce plan forecast to ensure the data associated to the traffic flow forecast operations meets the workload intent. The FAA should also include the workload intent effects to the ATCs performance via ergonomics and psychological factors. Although the SWIM infrastructure continues to mature, an approach should be in place to mitigate degradation and downtimes so digital operations are transparent to the users. In most cases, the elephant in the room when digital information exchange discussion is involved is cybersecurity and how to mitigate against adversaries within this field. There are cyber threat vulnerabilities to avionics systems, air traffic centers, and communication technologies within the air transportation infrastructure. As more aircraft are integrated into the NAS the risk will become bigger and significant safety risk to pilots, passengers, and national bystanders. More research is needed to examine the cybersecurity concerns and practices within the ATS. Additional research should investigate how the FAA plans to address the radio frequency (RF) cybersecurity concern as UAM and UAS are integrated into the airspace.

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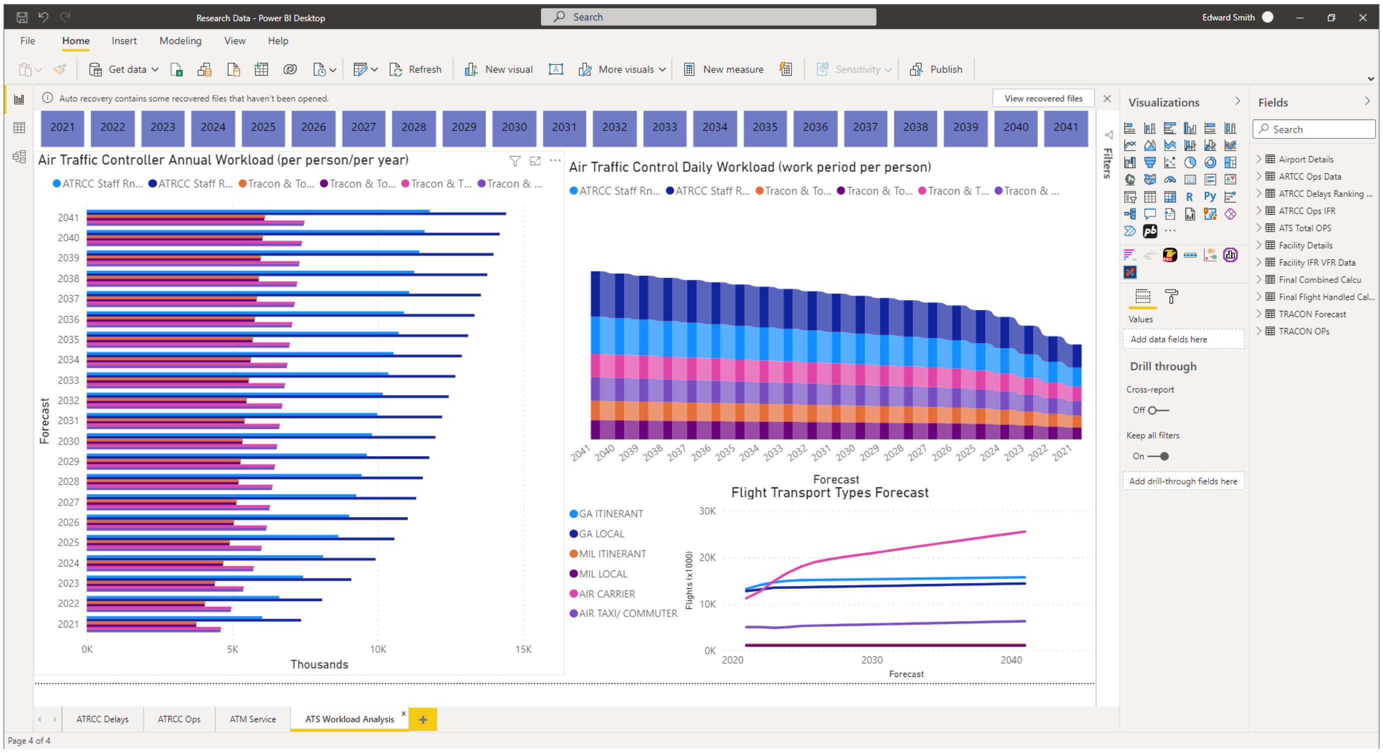
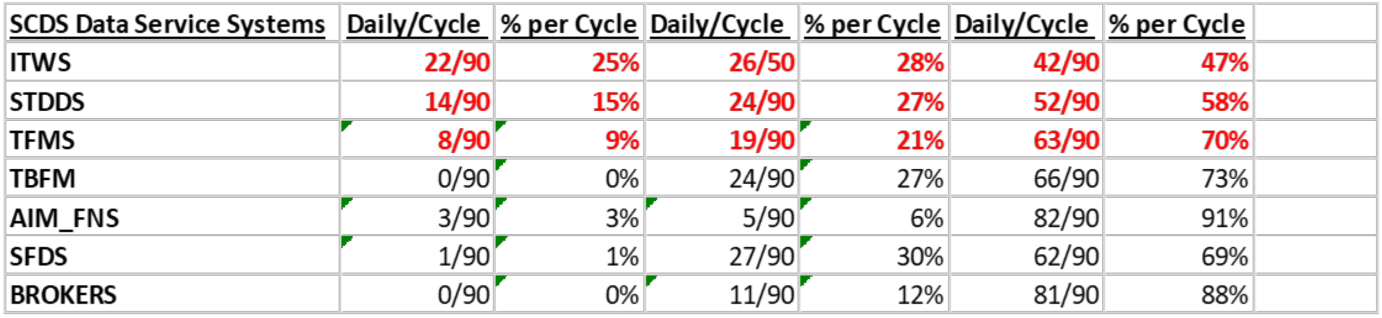


Fig. 11. Air Traffic Controller Daily Workload Forecast Analysis - The figure is a MS Power BI data model of the ATC daily workload forecast based on the traffic flow and flight handled threshold per work period, per day, per controller. The model was developed by Edward Smith using MS Power BI and the data provided from the ATCWFP and OPNET Traffic Flow forecast.

Fig. 12. SWIFT Portal SCDS Health Status - The figure is the SWIM Cloud Distribution System (SCDS) health status in the previous 90-day cycle listing historical degradation, downtime, and operational message statuses. The Source is derived from SWIFT Portal - SCDS Status (faa.gov).



SCDS Data Service Systems	Daily/Cycle	% per Cycle	Daily/Cycle	% per Cycle	Daily/Cycle	% per Cycle	
ITWS	22/90	25%	26/50	28%	42/90	47%	
STDDS	14/90	15%	24/90	27%	52/90	58%	
TFMS	8/90	9%	19/90	21%	63/90	70%	
TBFM	0/90	0%	24/90	27%	66/90	73%	
AIM_FNS	3/90	3%	5/90	6%	82/90	91%	
SFDS	1/90	1%	27/90	30%	62/90	69%	
BROKERS	0/90	0%	11/90	12%	81/90	88%	

Fig. 13. SCDS System Health Status — The table are the calculations based on daily occurrence in the SCDS in a 90-day digital cycle. The calculations were conducted in MS Excel by using data from the SWIFT Portal table developed by Edward Smith a graduate student from Embry Riddle Aeronautical University.

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