Task J: Aircraft Arrival Management Systems (AAMS) Demonstration Project

Delta vs. U.S. Airways Final Report

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1 EXECUTIVE SUMMARY

1.1 Purpose

The purpose of the Aircraft Arrival Management System (AAMS) Next Generation Air Transportation System (NextGen) Task J project is to demonstrate the feasibility and benefits of a time-based aircraft flow management system to precondition the arrival traffic at a single airport and to quantify the benefits of the system. The demonstrations are designed to identify the feasibility, efficacy, and benefits of a multi- and single-user, Airline Operation Center (AOC) based, aircraft flow management system. The commercially available ATH Group Inc. Airline Attila™ system was installed as the flow management system to coordinate and combine the business needs of the participating carriers and provide a carrier-centric Required Time of Arrival (RTA) to inbound aircraft. The Minneapolis-St. Paul International Airport element of this project is an extension of the initial operational and benefit-cost analysis performed at the Charlotte-Douglas International Airport (CLT) with US Airways. Both at MSP and CLT, the AAMS project provides evidence of system-wide and airline-specific benefits that can be attributed to the assessed systems.

1.2 Project Document Overview

This project document summarizes all the information, analysis and conclusions obtained during both the US Airways Group/CLT and Delta/MSP phases of the AAMS Project. The AAMS is an airline-centric, business rule and time based flow management system developed to pre-condition the aircraft arrivals into Charlotte Douglas International Airport (CLT) and Minneapolis-St. Paul International Airport (MSP). In commissioning this research project, the Federal Aviation Administration (FAA) desired an independent benefits and costs determination that an AAMS does not require expensive development or installation of aircraft or ground technologies, or expensive changes to the Air Traffic Control (ATC) system, or substantial changes in airline or ATC operating procedures to achieve measurable benefits. In performing this independent analysis, ERAU and MCR were also commissioned to measure real-time operational benefits and cost savings to the airlines from the AAMS while controlling for environmental and other system conditions over a number of phases: baseline (pre-AAMS installation), single-user AAMS operations at CLT and MSP, and multi-user AAMS operations (CLT only).

The **General Information** section includes the project methodology (test plan), AAMS system description, and deviations from the test plan which occurred during the project. Details of the testing procedures are contained in the **Test Description** section. The **Airport Characterization** section includes descriptive data of the airports usual traffic patterns, arrival rates and time lines, airline/aircraft demographics, and dwell time statistics. This data was primarily compiled using the AAMS system by its vendor.

The **Performance Analysis** section contains the descriptive statistics and regression analysis performed by ERAU for the baseline (Passive Phases) and AAMS operation period (Active Phases). Based on the comparison of the benefits with and without the AAMS operation, the **Cost – Benefit Analysis** section quantifies the direct (primary) and indirect (secondary) benefits observed during the project.

The last two sections (**Issues and Observation** and **Conclusions – Recommendations**) provide other observations by the research team outside the analysis contained in the Cost – Benefit Analysis.

1.3 Operational Analysis Summary

At CLT, traffic flows north or south over four corner posts in nine arrival banks that often exceed or meet the FAA called arrival rate. Similarly, traffic flows east or west over six corner posts into MSP in seven arrival banks that have a tendency to approach or exceed the FAA called arrival rate. These banks are primarily driven by the schedule of the airport's largest tenants who are also the participating carriers (US Airways/PSA Airlines and Delta Air Lines).

It has also been noted in the course of the operational analysis that the weather during the Active Phase of the MSP demonstration was unseasonably mild. Additionally, CLT suffered from a runway closure for construction during the demonstration. An overview of the Operational analysis is provided in Table 1.

1.4 Benefits Analysis

The Cost Benefit Analysis (CBA) quantifies the costs (primarily incurred by the airlines) for implementation of the AAMS system and compares those costs to the benefits to the participating carrier, Delta Air Lines (only mainline) or US Airways/PSA, and the system-wide operations of the AAMS airports identified through pre- and post AAMS implementation analyses. Overall, the AAMS demonstration project confirms the viability of the AAMS concept and provides an evidence of measurable benefits, including monetized benefits that can be attributed to the AAMS (summarized in Table 2).

The CBA further confirms the viability of the AAMS concept and suggests that if implemented, the AAMS will generate considerable benefits to participating airlines as well as overall AAMS airport operations.

Table 1. AAMS Operational Analysis Overview

	Task J CLT Active 1 Single-User AAMS US Airways	Task J CLT Active 2 Multi-User AAMS US Airways & PSA	Task J MSP Single-User AAMS Delta Mainline
Dates	12/13/2010 to 6/13/2011	6/14/2011 to 12/13/2011	11/1/2011 to 4/30/2012
Average Total Number of Arrivals per Day	742	674	532
Average Number of RTAs Sent per Day	138	146	124
Extrapolated Annual Arrivals	270,830	246,010	194,180
Total Fuel Saved (pounds)	470,072	2,073,454	4,109,401
Annualized Fuel Savings (pounds)	1,518,373	4,531,801	8,241,381*
TMA Flight Time Saved in Active Phases (seconds)	18.74	17.82	Not Observed
Flight Time Saved per “Compliant” Aircraft (Seconds) (see s6.2.2.2)	43.32	31.81	29.00
System Wide Flight Time Saved per Aircraft (seconds)	Not Observed	15.94	50.00
RTA Compliance for Aircraft Receiving RTA	35.1%	34.8%	34.5%
RTA Compliance for all Arrivals	6.50%	7.60%	7.70%
Improved On-Time Performance	Yes	Yes	Yes

(*)MSP Representative Day figure

Table 2. Monetized Benefits Summary (for first year of operation)

	US Airways-CLT		*Delta Air Lines-MSP*	
	Active Phase 1	*Active Phase 2*	*All Observations*	*Representative Days*
Total System Costs	$1,587,458	$4,337,458	$1,553,530	$1,553,530
System Monetized Benefits	$1,232,774	$5,649,473	$12,328,152	$5,242,340
System Benefit/Cost Ratio	0.78	1.30	7.94	3.37
Total Participant Costs	$1,587,458	$1,587,458*	$1,553,530	$1,553,530
Participant Monetized Benefits	$1,130,337	$3,127,668	$3,330,214	$1,373,975
Participant Benefit Cost Ratio	0.71	1.97	2.16	0.88

(*)One Airline Attila™ system

1.5 Issues and Observations

Over the course of the AAMS demonstration phases, and on further review, a number of observations and areas of potential future study were identified. One area of study was the interaction of pilot compliance rate and AAMS benefit which is believed to grow exponentially with compliance. The study of the interplay of TMA and AAMS was seen as positive in the CLT phases but has been difficult to determine in the MSP demonstration. The system is also noted as having susceptibilities involving inaccurate called arrival rates, airport flow direction, and irregular operations. Additional observations based on the experience of the AAMS operations about the airport and airline characteristics that lead to greater benefits have been outlined while discussion of the goal function impact is limited due to the proprietary nature of the functions. Additionally, ATH Group has identified flying time and distance reductions outside the corner ports during the CLT demonstration.

1.6 Conclusions—Recommendations

The CBAs of the AAMS demonstration projects identifies costs and benefits (both direct and indirect) of single- and multi-user AAMS concept using commercially available systems. The analysis of operational data collected in pre- and post-AAMS implementation CLT Active Phase 2 and MSP Active Phase periods suggests that there are observable system-wide and airline-specific benefits. The Cost-Benefits ratios estimated using only ADOC-based monetized benefits imply that the AAMS-related costs could be quickly recovered. In addition, the analysis provides evidence of benefits that cannot be monetized within the framework of this project: Improved arrival predictability and environmental benefits. Also, while the PVT was monetized, it was not included in the CBA.

Outside of the airport configuration differences and the CLT runway closures, several notes about the conditions at the two airports can be made. In addition to the difference in the interaction between the TMA and AAMS operations at MSP and CLT, it has been noted that TMA was inactive for as many as 15 percent of arrivals during some periods while MSP generally had approximately 99 percent of its arrivals under TMA operations, even with the unseasonably restrained weather experienced during the MSP Active Phase. This observation may indicate that the TMA AAMS interaction may be a candidate for further study with careful monitoring of this and other parameters. Furthermore, the goal functions reflected different business needs of the participating air carriers and were notably different. In particular, due to the proprietary nature of the goals, general observations about the goal functions are that US Airways primarily sought to reduce fuel consumption while Delta sought improved airport capacity and on-time performance.

The AAMS demonstration projects confirm the viability of the AAMS concept and suggest that if implemented, the AAMS concept will generate considerable benefits to participating airlines as well as the overall AAMS airport operations.

2 GENERAL INFORMATION

2.1 Purpose

The purpose of the Aircraft Arrival Management System (AAMS) Next Generation Air Transportation System (NextGen) Task J project is to demonstrate the feasibility and benefits of a time-based aircraft flow management system to precondition the arrival traffic at a single airport and to quantify the benefits of the system. The demonstrations at Charlotte Douglas International Airport (CLT) and Minneapolis-St. Paul International Airport (MSP) were designed to identify the feasibility, efficacy, and benefits of single- and multi-user, Airline Operations Center (AOC) based, aircraft flow management system. Embry-Riddle Aeronautical University, in partnership with ATH Group, US Airways Group, Delta Air Lines, and MCR, LLC examined the installation of the commercially available ATH Group Inc. Attila™ systems. The installed systems acted as the flow management system to coordinate and combine the business needs of the participating carriers and provided an airline-centric Required Time of Arrival (RTA) to inbound aircraft.

The primary objectives of this AAMS Project are to:

- Investigate how AOC-based metering tools may support NextGen time-based metering concepts.
- Demonstrate that a single- or multi-user AAMS does not require expensive development or installation of aircraft or ground technologies, or expensive changes to the Air Traffic Control (ATC) system or substantial changes in airline or ATC operating procedures.
- Confirm that a single user AAMS system provides real-time operational benefits and cost savings to the airlines and AAMS airports.

2.2 Scope

As the project was in essence run as two separate demonstrations in tandem, the project's scope, and many other aspects, is most readily discussed by demonstration phase.

US Airways-CLT

Testing the AAMS operations involved three phases of data collection which make up the foundation for the operational and statistical analyses:

1. AAMS Passive Operation (CLT Passive Phase): During the initial phase of three months, input messages were processed and RTA calculations were made; however, the RTAs were not sent out (uplinked) to the participating aircraft. The benefits obtained in the Passive Operation phase were measured to create the

"statistically zero" baseline scenario that is compared with the benefits obtained during the latter two phases of testing.

2. AAMS Active Operation (CLT Active Phase 1): In this phase, the system operated with the same configuration for an additional six months. RTA messages are computed and sent to the US Airway's aircraft and by comparing the benefits measured during the AAMS Active Operation with that of the Passive Operation, the net AAMS benefits can be determined with a single participating airline partner.
3. AAMS Active Exchange Operation (CLT Active Phase 2): The second active phase marks the beginning of the multi-user environment. In this active stage, the same data that was collected in CTL Active Phase 1 was compiled, and the RTAs were sent to the en route aircraft using the AAMS systems installed in the AOCs to work in coordination with the AAMS Exchange system. Assigned RTAs and actual corner post arrival data were collected for comparison. This period is called the AAMS Exchange Operation.

The Data Collection and Analysis Report - Passive (Deliverable 17) provided a detailed analysis of the baseline data collected during the AAMS CLT Passive Operation. This report was accepted by the Federal Aviation Administration (FAA) on April 5, 2011. The Passive Operation was conducted from September 13, 2010 through December 12, 2010. Additional passive data was collected from February 4, 2011 through February 16, 2011, when the system was inadvertently not operating. Another subsample of passive data was collected during 17 days of the runway construction period from August 15, 2011 to October 24, 2011, where an alternative schedule of passive and active operations was employed to facilitate a separate comparative benefit analysis.

The Data Collection and Analysis Report – Active (Deliverable 18) provided a detailed analysis of data collected during both phases of the AAMS CLT Active Operation including a separate analysis of the runway construction period data (From August 15, 2011 to October 24, 2011; Runway 18C/36C was closed for construction). CLT Active Phase 1 data collection was conducted from December 13, 2010 through June 12, 2011, excluding the February 4 – 16 time frame and times when the AAMS system was disconnected because of weather, equipment failures, electric power outages or other temporary conditions. CLT Active Phase 2 data collection was conducted from June 12, 2011 through December 13, 2011.

The Cost Benefit Analysis (Deliverable 19) provided a detailed analysis of quantifiable and non-quantifiable benefits that can be attributed to the AAMS operations in both CLT Active Phases.

Final-CLT Data Collection and Analysis Report (Deliverable 20) detailed the overall test conditions and results from all parts of the AAMS and AAMS exchange operations in the Active Phases of the CLT demonstration.

Delta Air Lines-MSP

Testing the AAMS operations at MSP involved two phases of data collection which make up the foundation for the operational and statistical analyses:

1. AAMS Passive Operation Phase (MSP Passive Phase): During the initial phase of six months, input messages were processed and RTA calculations were made; however, the RTAs were not sent to the participating aircraft. The benefits obtained in the Passive Phase were measured to create the “statistically zero” baseline scenario that is compared with the benefits obtained during the latter two phases of testing.
2. AAMS Active Operation Phase (MSP Active Phase): In this phase, the system operated with the same configuration for an additional six months. RTA messages are computed and sent to the Delta Air Lines aircraft. The benefits are estimated by comparing the “dwell” times and fuel burned recorded during the AAMS Active Phase with those of the Passive Phase. The “dwell time” is defined as the time when the aircraft is between the arrival fix and touchdown.

DELTA/Minneapolis Airport Characterization – Passive Data Collection Report (Deliverable 26) provided a detailed analysis of the airport and its airspace in operation. This report also included analysis of the AAMS MSP Passive Phase data that would serve as the base upon which to estimate the AAMS benefits. The data analyzed came from November 1, 2010 to April 30, 2011. This report was accepted by the FAA on February 24, 2012.

DELTA/MSP Quick Look Report: Three Months Active Phase Data (Deliverable 27) provided the analysis of the AAMS performance and benefits used the full MSP Passive Phase data set with the first three months of MSP Active Phase data (November 1, 2011-January 31, 2012) to provide an overview of the demonstration’s progress that was accepted by the FAA on April 10, 2012.

FINAL - DELTA Data Collection and Analysis Report – Active (Deliverable 28) reports the findings of the performance and benefits analysis for the Delta/MSP AAMS demonstration. The results were calculated using the full MSP Passive Phase and MSP Active Phase (November 1, 2011-April 30, 2011) data sets. FAA accepted the report on September 5, 2012.

2.3 Project Methodology

2.3.1 Aggregate Benefits Analysis

In the aggregate benefit analysis the statistically significant differences between two samples of data (passive/baseline, active/single-user AAMS periods) are examined. In particular, the following variables are analyzed:

- Average "dwell times" for different corner posts and arrival configurations
- Average "dwell times" with and without Traffic Management Advisory (TMA) metering
- Average "dwell times" with and without runway closures
- Average "dwell" fuel consumption
- Average times en route per flight
- Average fuel consumption per flight
- Number of flights that arrived as scheduled (A0)
- Number of flights that arrived within 15 minutes of schedule (A14)
- Average actual taxi-in times
- Average actual taxi-out times

While the data carries a considerable amount of noise due to potential changes in the environment, the analysis of statistically significant differences in these variables between the two data collection periods shows the "big picture" of AAMS benefits.

Prior to the analysis, ATH's .atx file arrival data was validated using actual departure and arrival data from the corresponding participating carrier's Aircraft Communications Addressing and Reporting System (ACARS) equipped aircraft's Out, Off, On and In (OOOI) electronically generated data. Actual fuel consumption for both data collection periods for participating flights was provided by the participating carriers in the corresponding demonstrations. For "dwell" fuel consumption for each type of arriving aircraft the Base of Aircraft Data (BADA) from EUROCONTROL were used.

2.3.2 "Representative Days" Analysis

To reduce the amount of noise in the data and make a more robust comparison between the baseline and active AAMS periods, a subsample of "representative days" was used. To be considered as "representative", a day should have A14 performance of at least70%. Having been first used in the CLT AAMS Demonstration, it was determined by a US Airways and research team consensus that when more than 70% of flights at the study airport on a particular day arrive within 15 minutes of schedule, it indicates that there were no major weather or other disruptive events that significantly affected airline and airport operations. Thus, such days better reflect undisrupted operations of the airline with and without the AAMS. The "representative days" analysis included the same variables as the aggregate benefit analysis.

2.3.3 Multiple Regression Analysis

Multiple regression analysis has been employed to avoid aggregation biases and provide parameter estimates that can be attributed solely to the variable under investigation. This analysis therefore controls for multiple environmental and operational conditions to identify the

AAMS impact on participating and non-participating traffic. Before regressions were performed, multicollinearity and heteroscedasticity tests were run to ensure that the data conformed to classical regression assumptions.

US Airways-CLT

Two regression analyses were conducted for the "dwell time" as the dependent variable. The first regression was performed with the of CLT Passive and CLT Active Phase 1 data, while the data for the second regression included all three CLT phases of data collection. The first regression is presented in Equation 1. The second regression is presented in Equation 2.

$$\begin{aligned} DTime_i = {} & a + b_1 ACT1_i + b_2 OPTC_i + b_3 OPTF_i + b_4 OPTS_i + b_5 TMA_i + b_6 TMA_i * MOV_i \\ & + b_7 TCI_i + b_8 TCI_i * ACT_i + b_9 CF_i + b_{10} CF_i * ACT_i + b_{11} RWCL_i + b_{12} UNARMS_i \\ & + b_{13} MAJICN_i + b_{14} MAJICS_i + b_{15} SHINEN_i + b_{16} SHINES + b_{17} CTFN_i + b_{18} CTFS_i + e_i \end{aligned} \quad (1)$$

$$\begin{aligned} DTime_i = {} & a + b_1 ACT1_i + b_2 ACT2_i + b_3 OPTC_i + b_4 OPTF_i + b_5 OPTS_i + b_6 TMA_i + b_7 TMA_i * MOV_i \\ & + b_8 TCI_i + b_9 TCI_i * ACT_i + b_{10} CF_i + b_{11} CF_i * ACT_i + b_{12} RWCL_i + b_{13} UNARMS_i \\ & + b_{14} MAJICN_i + b_{15} MAJICS_i + b_{16} SHINEN_i + b_{17} SHINES + b_{18} CTFN_i + b_{19} CTFS_i + e_i \end{aligned} \quad (2)$$

Where:

- *DTime* is "dwell time" for flight *i*.
- *a* is constant.
- *ACT*1 is the dummy variable that becomes "1" if an arrival was performed during Active Phase 1 period and "0" otherwise.
- *ACT*2 is the dummy variable that becomes "1" if an arrival was performed during Active Phase 2 period and "0" otherwise.
- *OPTC* is the dummy variable that becomes "1" if an arriving flight was optimized and complied (received an RTA and passed a corner post within 60 seconds of the RTA).
- *OPTF* and *OPTS* are the dummy variables that become "1" when an arriving flight received an RTA and moved in its direction and "0" otherwise. *OPTF* indicates that the RTA prescribed the flight to expedite and it did, but did not pass the corner post within 60 seconds of the RTA. *OPTS* indicates that the RTA required the flight to slow down and flight tried to comply, but did not pass the corner post within 60 seconds of the RTA.
- *TMA* is the dummy variable that becomes "1" if TMA was operational and "0" otherwise.
- *TMA**MOV* is the dummy variable that becomes "1" when an arrival was performed when TMA was operational and the flight received an RTA and moved in its direction within 15 minutes of receiving the RTA, and "0" otherwise.
- *TCI* is the dummy variable that becomes "1" if a flight was flagged as a Tactical Cost Index (TCI) Flight and "0" otherwise. (See Section 5.1.2 for additional information on TCI.)

- *TCI*ACT* is the dummy variable that becomes "1" if a flight was flagged as a TCI Flight and performed while the AAMS was in an active phase and "0" otherwise.
- *CF* is the dummy variable that becomes "1" if a flight was flagged as a Critical Flight (CF) and "0" otherwise.
- *CF*ACT* is the dummy variable that becomes "1" if a flight was flagged as a CF and performed while the AAMS was in an active phase and "0" otherwise.
- *RWCL* is the dummy variable that becomes "1" if an arrival was performed when at least one of the runways at CLT was closed and "0" otherwise.
- *UNARMS* is the dummy variable that indicates that an arrival was performed through UNARM corner post and South arrival configuration.
- *MAJICN* is the dummy variable that indicates that an arrival was performed through MAJIC corner post and North arrival configuration.
- *MAJICS* is the dummy variable that indicates that an arrival was performed through MAJIC corner post and South arrival configuration.
- *SHINEN* is the dummy variable that indicates that an arrival was performed through SHINE corner post and North arrival configuration.
- *SHINES* is the dummy variable that indicates that an arrival was performed through SHINE corner post and South arrival configuration.
- *CTFN* is the dummy variable that indicates that an arrival was performed through CTF corner post and North arrival configuration.
- *CTFS* is the dummy variable that indicates that an arrival was performed through CTF corner post and South arrival configuration.
- *e* is the error term.

UNARM North variable is not included to the equation to be used as a reference. The coefficients of interest are *b1* through *b10* in Equation 1 and *b1* through *b11* in Equation 2. The remaining regression terms are used to control for factors that may influence the "dwell time" and are not managed by the AAMS.

Delta Air Lines-MSP

The regression model is presented below and was performed with all data, data filtered for the participating carrier (Delta), data for traffic on representative days, and data for Delta flights on representative days. The parameters of the regression are designed to mirror the regressions used for CLT.

$$\begin{aligned} DTime_i = {} & a + b_1 ACT_i + b_2 OPTC_i + b_3 OPTF_i + b_4 OPTS_i + b_5 TMA_i + b_6 TMA_i * MOV_i + b_7 RWCL_i \\ & + b_8 SHONNE_i + b_9 OLLEEW_i + b_{10} OLLEEE_i + b_{11} DELZYW_i + b_{12} DELZYE + b_{13} TRGETW_i \\ & + b_{14} TRGETE_i + b_{15} TWINZW_i + b_{16} TWINZE_i + b_{17} BITLRW_i + b_{18} BITLRE_i + e_i \end{aligned}$$

Where:

- *DTime* is "dwell time" for flight *i*.
- *a* is constant.
- *ACT* is the dummy variable that becomes "1" if an arrival was performed during Active Operation Phase and "0" otherwise.
- *OPTC* is the dummy variable that becomes "1" if an arriving flight was optimized and complied (received an RTA and passed a corner post within 60 seconds of the RTA).
- *OPTF* and *OPTS* are the dummy variables that become "1" when an arriving flight received an RTA and moved in its direction and "0" otherwise. *OPTF* indicates that the RTA prescribed the flight to expedite and it did, but did not pass the corner post within 60 seconds of the RTA. *OPTS* indicates that the RTA required the flight to slow down and flight attempted to comply, but did not pass the corner post within 60 seconds of the RTA.
- *TMA* is the dummy variable that becomes "1" if TMA was operational and "0" otherwise.
- *TMA*MOV* is the dummy variable that becomes "1" when an arrival was performed when TMA was operational and the flight received an RTA and moved in its direction within 15 minutes of receiving the RTA, and "0" otherwise.
- *RWCL* is the dummy variable that becomes "1" if an arrival was performed when at least one of the runways at MSP was closed and "0" otherwise.
- *SHONNE* is the dummy variable that indicates that an arrival was performed through SHONN corner post and East arrival configuration.
- *OLLEEW* is the dummy variable that indicates that an arrival was performed through OLLEE corner post and West arrival configuration.
- *OLLEEE* is the dummy variable that indicates that an arrival was performed through OLLEE corner post and East arrival configuration.
- *DELZYW* is the dummy variable that indicates that an arrival was performed through DELZY corner post and West arrival configuration.
- *DELZYE* is the dummy variable that indicates that an arrival was performed through DELZY corner post and East arrival configuration.
- *TRGETW* is the dummy variable that indicates that an arrival was performed through TRGET corner post and West arrival configuration.
- *TRGETE* is the dummy variable that indicates that an arrival was performed through TRGET corner post and East arrival configuration.
- *BITLRW* is the dummy variable that indicates that an arrival was performed through BITLR corner post and West arrival configuration.
- *BITLRE* is the dummy variable that indicates that an arrival was performed through BITLR corner post and East arrival configuration.
- *e* is the error term.

SHONN West variable is not included to the equation to be used as a reference. The coefficients of interest are b_1 through b_6. As with the CLT regressions, the remaining regression terms are used to control for factors that may influence the "dwell time" and are not managed by the AAMS.

2.4 AAMS System Description

2.4.1 Overview

The AAMS is a ground based aircraft time based metering system that uses derived RTA messages, electronically sent to the aircraft, to manage corner post arrival times to improve the sequencing of arriving aircraft. In the case of the Task J MSP AAMS Program, the RTAs are derived internally by Delta Air Lines, while the Task J CLT AAMS Program with the US Airways Group added the additional approval step of real time coordination with a second AAMS Exchange server after initial RTA generation by US Airways and PSA.

The Task J MSP AAMS operation utilizes a commercially available time based aircraft metering system, ATH Group's Attila™ Managed Arrivals System, which has been in use by Delta Air Lines at Atlanta Hartsfield International Airport (ATL) since 2006, as well as MSP and Detroit Metropolitan Wayne County Airport (DTW) since 2011. The system has also been in use at CLT since 2010 for the CLT AAMS demonstration with US Airways and PSA. The system adjusts the arrival time (increases or decreases the speed of the aircraft), based on the airline's business needs, airport capacity and other factors, with the purpose of managing the arrival flow more efficiently. Figure 1 outlines the conceptual relationships between these components of the AAMS demonstration platforms. Furthermore, Figure 2 outlines the basic conceptual relationship between the individual Airline AAMS and the final RTAs issued with approval of the AAMS Exchange.

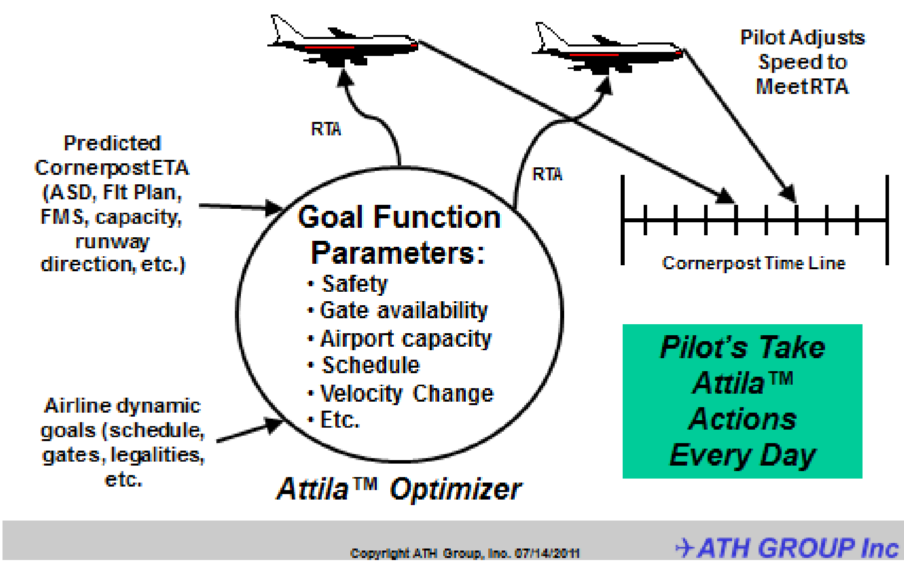

Figure 1. AAMS's Attila™ Operational Concept

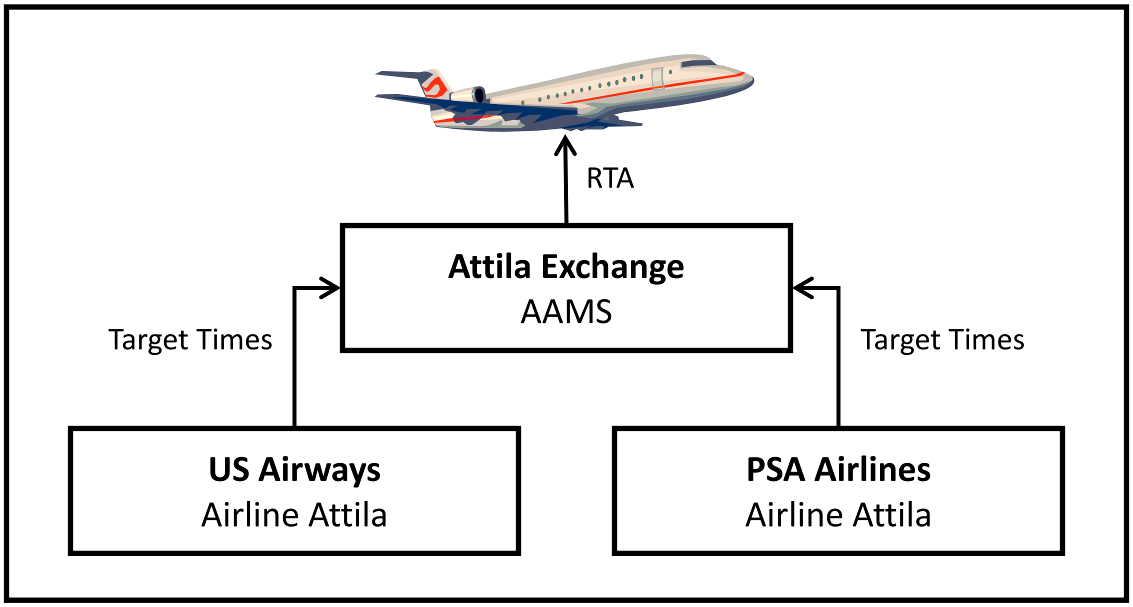

Figure 2. Conceptual CLT AAMS Exchange Configuration

2.4.2 Test Environment

The AAMS Test System is an operational time based aircraft metering system that ran in an operational airline environment 24- hours a day in the CLT and MSP Active Phases. During these phases the AAMS Test System sent operational RTA messages to participants aircraft (US Airways/PSA and Delta Air Lines) arriving into CLT and MSP. US Airways and PSA aircraft received RTA messages via their onboard ACARS or AeroData system with the goal of preconditioning the CLT arrival flow using RTA times at the aircraft's arrival fix (MAJIC, UNARM, SHINE and CTF) into CLT. Once the RTAs were calculated for MSP, Delta Air Lines aircraft received RTA messages via their onboard ACARS with the intention of preconditioning the MSP arrival flow using RTA times at the aircraft's arrival fix (TWINZ, BITLR, DELZY, TRGET, SHONN, and OLLEE) into MSP.

As part of this process, AAMS application generated Time Event (ATX) files, aircraft four dimensional trajectories, and airport configuration files. These files formed the primary data source for system testing and evaluation.

The objective of the AAMS Passive Phases of the two demonstrations was to run the system for a period of months when input messages were processed and RTA calculations were done, however the RTAs would not be sent out (uplinked) to the participating aircraft. The benefits obtained in the passive phases were measured in order to create a "statistical zero" baseline scenario that was compared with the benefits obtained during the active operations.

The CLT test environment involved two operational airlines and their operations centers, the US Airways and PSA aircraft inbound to CLT, Embry-Riddle Aeronautical University College of

Business, and ATH Group data center. Similarly, the MSP test environment involved the operational airline (Delta), the airline's operations center, the Delta Air Lines aircraft inbound to MSP, Embry-Riddle College of Business, and the ATH Group data center in Lanham, MD.

2.4.2.1 Test System

For CLT Active Phase 1, a US Airways centric AAMS operated to allow evaluation of standalone benefits at CLT. The US Airways AAMS was complemented by an AAMS at PSA Airlines with RTA requests being brokered by an AAMS Exchange system before the airlines uplinked the requests to the aircraft. It should be remembered, that while PSA is a part of the US Airways Group, for the purpose of the AAMS demonstration PSA's AAMS system is handled separately.

The Delta Air Lines airline-centric AAMS system was evaluated individually to determine that it does generate benefit when run as a standalone system in MSP. No other AAMS components are part of this demonstration.

2.4.2.2 Locations

The operational evaluation location consisted of several sites:

- ERAU College of Business
- FAA Headquarters in Washington DC
- ATH Group's software and data center and facility in Lanham, Maryland.
- Specific to CLT:
  - US Airways Information Technology facility in Phoenix, Arizona (PHX)
  - US Airways Operations Control Center in Pittsburg, Pennsylvania
- Specific to MSP:
  - Delta Air Lines Information Technology facility in Atlanta, Georgia
  - Delta Air Lines Operations Control Center in Atlanta, Georgia

Data was shared between Delta Air Lines or US Airways Group and ATH Group using secure Virtual Private Network (VPN) tunnels. ATH Group in turn made operational data files available in the project library on a secure FTP site. Files were made available to ERAU within two to three days of the operational evaluation.

2.4.2.3 Description

The operational system at Delta Air Lines's facility in Atlanta generated target times and RTA messages for MSP and US Airways provided similar data for CLT from its Phoenix facility. These and other data were collected and archived for analysis.

This system also generated:

- *.trj trajectory files for all aircraft operation into the studied airports
- *.atx files with time events for participating carrier aircraft
- *.stl files that record certain important aspects of airport operation such as called rates and arrival directions.

2.4.2.4 System Context

The AAMS analysis suite connected to the project libraries in the ATH Group data center FTP site. This allowed all the tools in the suite next day access to data about all flights operating into CLT and MSP. Figure 3 outlines this AAMS test system context.

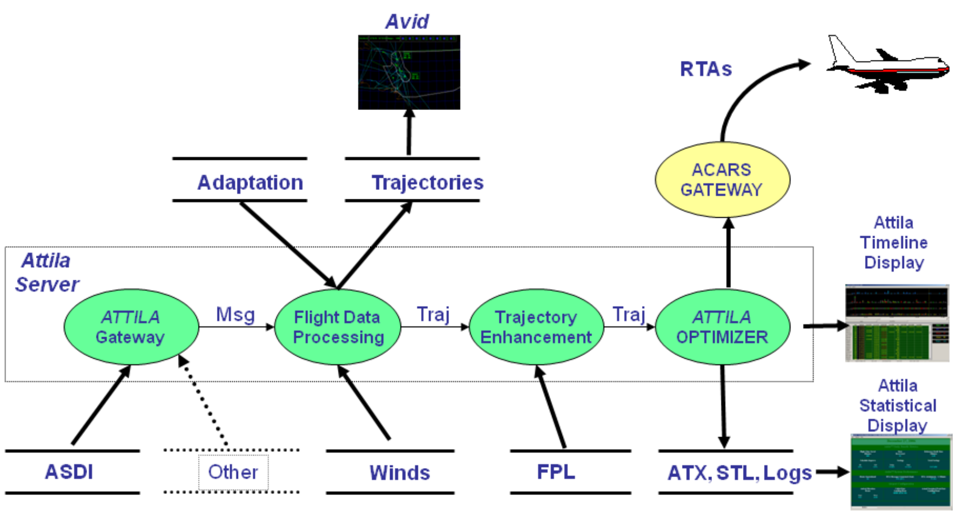

Figure 3. AAMS Test System Context

2.4.3 Test Failure and Prevention Procedures

2.4.3.1 AAMS Software Application

The AAMS and associated software applications were installed and underwent calibration and validation processes during the CLT and MSP Passive Phases.

Both the passive and active data collection periods are large enough to minimize any potential risk regarding installation and validation process. If problems presented in either the passive or active data collection periods, the amount of data collected over the various Active and Passive Periods of both demonstrations should have been sufficient to mitigate any noise appearing in the data due to data collection delays.

2.4.3.2 Data Collection Information

The following is the list of risks that were identified that could have impacted the data collection process and the actions taken to prevent or mitigate them for both demonstrations:

- Lack of connectivity from the information sources
    - The data collection periods were long enough to avoid or reduce the risk of not collecting the amount of data needed to calibrate and evaluate the AAMS concept and AAMS operation.
- Server failure
    - US Airways-CLT:
        - Backup servers were installed at Lanham, MD, and were used to backup data on a routine basis in case of failure of the main servers.
    - Delta Air Lines-MSP:
        - Delta had already installed a Fail Active Attila™ software (2 MSP Attila™ systems running simultaneously), with automatic fail over capability.
        - Backup data storage was done at Lanham, MD, and was to be used to store the information on a routine basis in case of main server failure.
- Weather: Weather factors could impact the developing of the normal air traffic operations at the demonstration airports and cause loss of data.
    - US Airways-CLT:
        - The extension of the period for the data collection process could reduce the potential risk of not collecting enough data for statistical analysis due to weather conditions. The problems caused by weather conditions should not be statistical significant to impact the results obtained from the demonstration.
    - Delta Air Lines-MSP:
        - The active data collection period has been selected over the same months of the year as the Passive data collection to minimize weather and environmental differences.
        - In addition, the 12 month period (6 months passive, 6 months active) for the data collection process reduced the potential risk of not collecting information needed for developing the statistical analysis due to weather conditions. The problems caused by weather conditions should not be statistical significant to impact the results obtained from the operational evaluation.
- Black Book procedure (US Airways-CLT Only): crew members could be confused with the utilization and the information needed from the black book operations.
    - Crews received a flight manual bulletin and training explaining the black book procedures, as well as, the overall project emphasizing that the identities of the personnel involved in the testing would remain anonymous, assuring that the evaluation team could obtain better feedback from the personnel involved in the demonstration. (Black book procedures are further discussed in Section 4.1.1.)

2.4.3.3 Operational Procedures

The following is the list of potential risks that could have influenced in the data collection process as well as the actions taken to prevent or mitigate the event:

- Airline operational procedures: Airline operational procedures could cause an inability to perform specific procedures that are necessary to achieve RTAs, thus, some aircrew members may choose not to participate in the operational evaluation.
    - US Airways-CLT
        - Coordination with US Airways and PSA was conducted to mitigate operational conflicts between the AAMS flight trials and the airlines procedures.
        - Coordination between the airlines’ operational departments was conducted to assure the privacy of information and safety of the operations during the demonstration.
    - Delta Air Lines-MSP
        - Coordination with Delta Air Lines to mitigate operational conflicts between the AAMS operational evaluation flights and the airline’s procedures.
        - Coordination between the airline’s operational departments to assure the privacy of information and safety of the operations during the demonstration.
- Airline Fleet: Participating aircraft may not have the performance and communications capability to meet the RTA generated by their airline’s AOC.
    - US Airways-CLT
        - PSA’s OCC ensured that proper operational information was sent to their aircraft and that the participating aircraft were capable (from the performance point of view) of meeting the RTAs generate by the AAMS demo system software.
        - All US Airways mainline aircraft are equipped with FMS and ACARS.
    - Delta Air Lines-MSP
        - ATH and Delta ensured that proper operational information was sent to the aircraft and also ensured that the participating aircraft were capable (from the performance point of view) of meeting the RTAs generate by the AAMS demo system software. All Delta aircraft are equipped with FMS and ACARS systems required by the project.
- ATC operations: ATC could notice a change in the normal traffic operations due to the implementation of the AAMS concept and the utilization of the system software.
    - AAMS operations should be transparent to ATC operations.
    - US Airways-CLT

        - Coordination has been conducted with Atlanta Center and Charlotte tower to inform them about the AAMS demonstration. Close monitoring of the ATC activities was performed with the input and information collected from the aircrews (black book procedure) in order to mitigate any potential conflict between the AAMS activities and the ATC operations.
    - Delta Air Lines-MSP
        - Coordination with Minneapolis Center and Minneapolis tower to inform them about the AAMS operational evaluation. Close monitoring of the ATC activities was performed with the input and information collected from the aircrew member in order to mitigate any potential conflict between the AAMS activities and the ATC operations.

2.5 Deviations from Test Plan

2.5.1 CLT Overview

The CLT Active Phase 1 was programmed to occur from December 13, 2010 through June 12, 2011. Multiple transitional issues between December 13, 2010 and February 3, 2011 have made the data collected in this period unusable. Also, the AAMS system was in the passive mode from February 4, 2011 to February 16, 2011. Finally, an electrical power outage and subsequent server failure on June 10, 2011 have shortened the CLT Active Phase 1 data collection by an additional three days. Because of issues experienced in transition from passive to active operations, and from active to exchange operations, the CLT Active Phase 1 data was collected from February 17, 2011, through June 9, 2011.

2.5.2 CLT Multiple Passive Periods

While the original plan included only a single passive data collection period, the second passive period data was collected because of a problem with the AAMS software. On February 4, 2011 a software update was installed, which prevented the RTA messages from being sent. This was not noticed until February 15, and a software correction was installed on February 16. Since the RTA messages were not sent to US Airways aircraft, the period from February 4 through February 16 2011 effectively became a part of passive data collection.

2.5.3 CLT Runway Closure Period

The CLT Active Phase 2 was operational from June 13, 2011 to December 13, 2011. This time frame included a 71 day period from August 15, 2011 to October 24, 2011 when Runway 18C/36C was closed for construction. During this period, an alternating schedule of passive and active operations was employed to allow separate, comparative benefits analysis during the construction period.

2.5.4 Software – Performance Enhancements

US Airways-CLT

In both active operation phases, updates to the system were made as unanticipated issues arose. AAMS operational changes during both active phases are presented in Table 3.

Table 3. US Airways Group AAMS Operational Change Log

Implemented	*Version*	*Description*	*Notes*
12/13/2010	602-CLT	Initial CLT operational release	Operational with arrival rate template in place.
12/15/2010	602-CLT-U1	Updates to correct TCI message processing	Prior to this update TCI flights were being sent RTAs
12/21/2010	602-CLT-U2	Update to clt.aex.ini to send RTA equal to UAK (not UEK) and put in new dwell constants	Prior to this update flights were being sent no change RTAs
1/4/2011	602-CLT-U3	Correct rate template for DST, update Mach range for A319/A320/A321	Rate template had been off by 1 hour (35 rate was from 10pm to 6am, was changed to 11pm to 7am)
1/7/2011	602-CLT-U4	Turn on FDP detect of arrival direction, update STARS for 1/13 chart update	
1/12/2011	602-CLT-U5	Update ATG to make default taxi in times for AWE & JIA in parameters (defaults changed from 6/7 to 7/8)	
1/26/2011	602-CLT-U6	Updated dwell times (refinement), FDP updates (use of weight parameter in auto dir detection), charting updates	Dwell times refined based on newer data with correct arrival direction
2/2/2011	602-CLT-U7	Updated rate template per US Airways request	Template now is 35 at 11pm and 85 at 7am (was 80 at 7am)
2/4/2011	602-CLT-U8	Corrected taxi-in adjustment to schedule, update GF parameters per US Airways discussion	
2/8/2011	602-CLT-U9	Minor GF refinement, parameters change for ATX date output	Ref date in ATX now to reflect local departure date
2/16/2011	602-CLT-U10	Correct problem in OGI causing missing data in header of RTA message going to FOS	No RTA messages went out from 2/4 (U8) to 2/16 due to this problem

Implemented	*Version*	*Description*	*Notes*
3/16/2011	602-CLT-U11	Add opt area filter, change overnight rate to 44, goal function revisions	GF changes based on simulation testing and agreed with US Airways at meeting on 3/12
4/28/2011	602-CLT-U12	Maintenance update - FDP fixes, FTE/AFD persistence, Mach update for A319/320/321 to .80 top range	IROP filter in place but not activated
6/7/2011	602-CLT-U13	Maintenance update - FTE/AFD persistence refinement, opt suppress filter and alerts capability, ATD and ASD problems resolved.	IROP filter enabled, AEX output column added to ATX
6/12/2011	602-CLT-U14	Exchange support update - OGI updated to allow sending of exchange assigned RTA, FDP maint update, PSA Attila ini updates	Changes required for going operational with PSA and exchange
6/15/2011	602-CLT-U15	PSA JS tail number ini change	PSA has 5 tail numbers that are not PS but are JS, OGI output setup modified to account for this.
9/21/2011	602-CLT-U16	AFD minor update for Attila Exchange (name of input file changed to .aas), running stats output including TCI daily count, FDP maint update, ARC update, EGI update	FDP bug fixes, other updates to non-production processes (TI,MI,AFS)
10/7/2011	602-CLT-U17	AFD update to not use DepExpirationTime and to output ArrRateT and ArrRateV in Pending section of ATH	
10/19/2011	602-CLT-U18	ASD updated for change in ASDI input format (ASDI namespaces)	Problem caused loss of input data on 10/18 & 19.
10/25/2011	602-CLT-U19	Additional ASD updated for change in ASDI input format	Problem with some erroneous position reports due to zeros being dropped in data
11/1/2011	602-CLT-U20	FDP maint update (ETA jump), EGI update (time synchronization)	Adaptation update

Implemented	*Version*	*Description*	*Notes*
11/2/2011	602-CLT-U21	ASD updated for a problem with coordination point lat/lon conversion	
11/16/2011	602-CLT-U22	FDP maint update (bad DEP caused pos reports to be rejected), AFD maint to protect against rare case when a large RTA change can get generated, ARC to correct archiving upon restart	
11/28/2011	602-CLT-U23	Updated dwell times and slow down parameters (takes advantage of direction specific FDP capability)	Prelim version of this update was put in place on 11/23
12/6/2011	602-CLT-U24	FDP maint update (bad position data problem, multiple sources issue, arrival time)	Corrects problem with arrival time when SMA data was being received.

Delta Air Lines-MSP

Over the course of the demonstration the software behind the AAMS has been modified to improve performance and correct any issues that arose. These adjustments are described in Table 4.

Table 4. Delta Air Lines AAMS Software Revision Log

Implemented	*Version*	*Description*	*Notes*
11/2/2011	603-u12	ASD updated for a problem with coordination point latitude/longitude conversion	
11/17/2011	603-u13	FDP maintenance update (bad DEP caused pos reports to be rejected), AFD maintenance to protect against rare case when a large RTA change can get generated, ARC to correct archiving upon restart, GSR update for MVT output for long international flights and a new filter to block MVT for specified flights.	Taxi tables updated
11/29/2011	603-u14	Updated dwell times and slow down parameters for all 3 installs. Slow down parameters take advantage of arrival direction specific capability.	Prelim update was made on 11/23/11 for MSP and DTW
12/8/2011	603-u15	FDP maintenance update (bad position data problem, multiple sources issue, arrival time), GSR recompile, ADX restructuring for messages.ini, SGI addition of time stamp data	Corrects problem with arrival time when SMA data was being received.
12/16/2011	603-u16	Changed SanityCheckThresholdMinutes setting to 6645 in *.ath.ini files (corrects rare case of a bad MVT being generated)	
1/6/2012	Stats-5-6 u2	update of aircraft types data used by the stats package	
2/14/2012	603-u17	GSR update to eliminate delay in MVT output, OGI parameter change to not send no change RTAs and AFD updates for additional output in .ath	AFD change is for upcoming ACI change
2/28/2012	603-u18	Increased time for GSR to stop	Changes to atl_proc, msp_proc, dtw_proc services

Implemented	*Version*	*Description*	*Notes*
3/20/2012	603-u19	GSR updates for file naming, gate availability corrections, FTE update for updating GSR generated AUX data, minor ATD update.	Taxi tables updated, IATA-ICAO codes updated. Opt Mach updated for MD8x, MD90
3/27/2012	603-u20	Updated MSP & DTW goal functions (DTW same as ATL, MSP slightly different in Time in Queue and Queued Advisory components)	Taxi tables updated

2.5.5 Other Deviations

US Airways-CLT

During the January and February 2011 timeframe, the CLT Passive Phase data was rerun in fast time mode to resolve several issues. None of the data reruns compromised the validity of the data.

- The AAMS software was updated with a new release impacting the data sets. These changes corrected certain operational conditions such as arrival rates and directions not being updated. In addition, ATH Group added certain fields to the .atx file at ERAU's request to facilitate data consolidation and analysis.
- The AAMS software did not automatically adjust for the change to Daylight Savings Time, which indicated an incorrect arrival time.
- Adjustments to Dwell times were necessary, from the impact of the changes described above. For example, incorrect arrival directions markedly changed expected dwell times.
- An automatic landing direction detection feature was added to protect against recording an incorrect landing direction. This software logic monitors the actual arrival azimuth with respect to the runway and resets the landing direction if this differs from the called direction by more than a parameter.

During the CLT Active Phase 1 Period several changes were implemented primarily to increase the number of flights optimized by the AAMS to enhance the AAMS performance.

- One change included adding an arrival rate template to the system. The template was derived by looking at average arrival rates, as a function of time of day over several months. The template then provides an average or nominal arrival rate for the subject airport for any time of day. This template provides a mechanism to continue operations, if the entered "called" rate deviates from the observed rate by more than a designated parameter. If the operator enters a valid called rate, this will immediately override the template.
- The allowable mach range for A319/A320/A321 aircraft was increased to .80 mach to

better fit how the fleet was operating. Analysis of the speeds flown by these aircraft independent of the AAMS showed that they were routinely flying at speeds of about .80, even though the AAMS mach range limitation was set for 0.79. This analysis also showed that increasing the allowable mach range to a more practical limit would allow the AAMS to send more RTAs to flights that would benefit from speeding up, and have a greater impact on the optimization. These values were changed with the permission of US Airways flight operations. Flights were closely monitored to insure that resulting RTAs were reasonable. This change did result in getting more aircraft into the solution and greater benefits for US Airways.

- Goal function parameters were updated to better accommodate US Airways business goals. Analysis of US Airways arrival patterns into CLT showed that a significant portion of flights were arriving early by several minutes. US Airways indicated that this was by design and a structure they wanted to preserve. The AAMS goal functions were adjusted such that flights arriving in this range would not be slowed on account of schedule until they were about 15 minutes early. With this schedule goal function in place, the intention was to have a stronger push away from times of highest queuing. In particular, the goal was to be able to move flights ahead of a developing queue where practical. To accomplish this goal an explicit queue goal component was introduced. This goal component looks at the predicted arrival queue at the predicted arrival time for the subject flight. It then assigns a "penalty" to the predicted arrival time depending on the projected runway queue at that time. This penalty function provides a small pressure to move this flight away from the higher queue values. The pressure is stronger in the early direction moving flights near the beginning of a queue a little earlier to avoid the queue if possible.
- An optimization area filter was added, such that optimization would not take place until the subject aircraft was inside a US NAS Center boundary. Analysis showed that some flights, particularly flights coming from the Caribbean, often become eligible for optimization at times when they are not in ACARS range. The net result was that an RTA might be generated some time before it could be sent. Once it was sent, enough time might have elapsed that the RTA became unattainable within operating norms. Since all flights within the US NAS Center boundaries are also within ACARS range, the NAS Center boundaries were used as a filter when optimizing flights. Only flights that are within a NAS Center are eligible for optimization.
- During parts of some days (primarily relating to weather conditions) the airport would experience irregular conditions. During these times the AAMS prediction functions did not work well, because the operational conditions at the airport precluded normal activities. Also, since these times occasionally involved only a portion of the day it became impractical for the operator to enter this information via the Attila Computer Interface (ACI). An Irregular Operations (IROP) filter that looks at these prediction

results and suspends optimizations when during these conditions developed. Once the prediction functions come back into tolerance, the optimization is automatically resumed.

During CLT Active Phase 2 Operation Period additional changes were implemented primarily due to a change in the ASDI data.

- In October 2011 a change in the ASDI data was introduced. There was more data at the end of the trajectory than previously was the case. The data seemed to show an additional sensor near the CLT airport. The data appeared to be consistent with the existing trajectory. It began inside the corner post and continued to the end of the runway in some cases. This additional data caused Attila™ a problem, in that the algorithm for calculating RER (estimate at the runway threshold) did not recognize the new data. The net result was that the values calculated for RER were too large. However, since the corner posts times were not affected, the system operation was not affected. Analysis of this new data showed that it had the KSMA identifier in all cases. ATH then adapted the data type qualifier to recognize SMA data: KSMA. The system then was able to choose a single sensor inside the corner post. Once ATH had determined which data was affected, ATH re-ran all affected data with the new RER algorithm. This included all passive data, all runway closure data, and some exchange data. Data in the FTP site was updated with RER corrected data for the purpose of benefit analysis.

Since AAMS data presented in the .atx files were originally intended for internal purposes only, the format of these file is somewhat proprietary and does not allow for an easy compilation with other flight data, such as provided by US Airways. Most of the difficulties were related to the date convention and were resolved. However, even after several adjustments and passive data reruns, the format of the .atx is still not ideal for matching with US Airways data. This issue was identified early in the project and all possible changes were made.

Delta Air Lines-MSP

The design of the MSP Passive and Active Phase dates was intended to minimize seasonal variations between the data collection phases. In particular, it should be noted that the MSP is known to have severe winters and did experience considerable winter weather in the MSP Passive Phase. The experienced weather in the MSP Active Phase has been unseasonably mild. This variance on the weather conditions can also be seen in the MSO Passive and Active Phase data where 18% of passive traffic occurred on non-representative days while only 1% did so during the MSP Active Phase.

Also during the demonstration, Delta introduced and adjusted initiatives to improve its operational performance. The majority of these initiatives was in place for Passive and Active Phases and should not provide a source for excessive variation.

The AAMS itself experienced operational interrupts during the MSP Active Phase. A summary of operational interrupt events is disclosed in Table 5. The majority of the status notations cite weather conditions while a few lack a reason for disconnect.

Table 5. AAMS Operation Interruptions (all times local)

Date	Hours Operational	Comments
1/13/2012	6.25	Off at 09:54 (reason N/A)
1/17/2012	2.88	Off at 04:52 (no reason given; VFR)
1/18/2012	8.82	On at 05:11
2/21/2012	3.78	Off at 05:46 due to weather (snow and fog)
2/22/2012	-	Off (no reason given; VFR)
2/23/2012	-	Off (haze)
2/24/2012	-	Off (snow and fog)
2/25/2012	-	Off (snow)
2/26/2012	-	Off (snow, fog, and haze)
2/27/2012	0.81	On at 05:11
2/28/2012	2.76	Off at 04:45 (snow and haze)
2/29/2012	-	Off (rain, sleet, snow, and fog)
3/1/2012	-	Off (snow and fog)
3/2/2012	9.67	On at 06:18

3 AIRPORT CHARACTERISTICS FINDINGS

3.1 Airport Characteristics

The airport characteristics for MSP are based on the MSP Passive Phase data. The CLT characteristics analysis was conducted using a subset of CLT Passive Phase 1 data collected April 20 through June 13, 2010.

3.1.1 Arrival Rate

US Airways-CLT

CLT has a maximum called arrival rate between 80-85 flights per hour (from FAA Called Arrival Rate) in good weather conditions. This rate decreases when weather, noise and/or fire-rescue restrictions limit the runways utilization. Figure 4 shows FAA's Airport Arrival Demand Chart on June 30, 2010 at CLT.

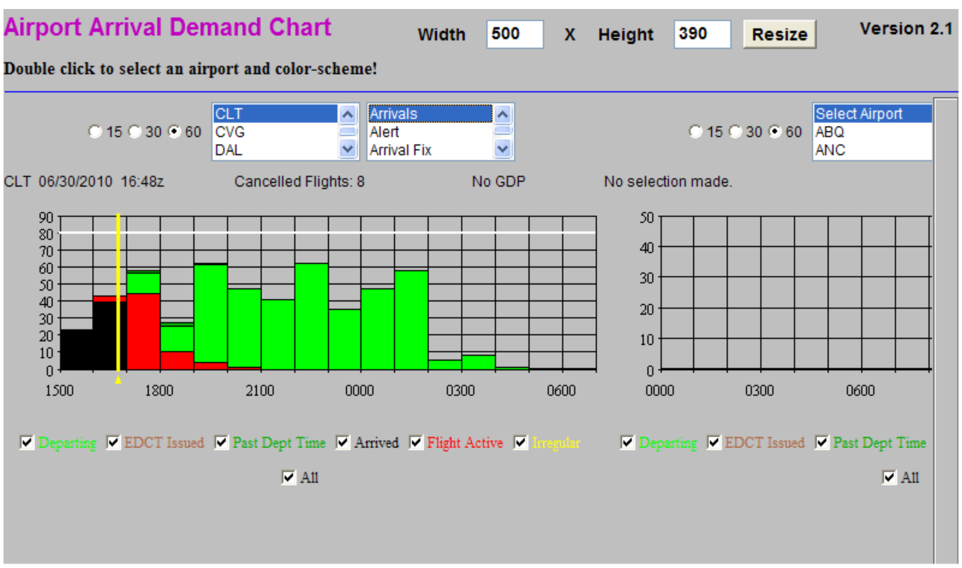

Figure 4. FAA's Airport Arrival Demand Chart for CLT (times are GMT)

The white horizontal line in Figure 4 represents the FAA Called Arrival Rate, which on this day was 80 arrivals per hour.

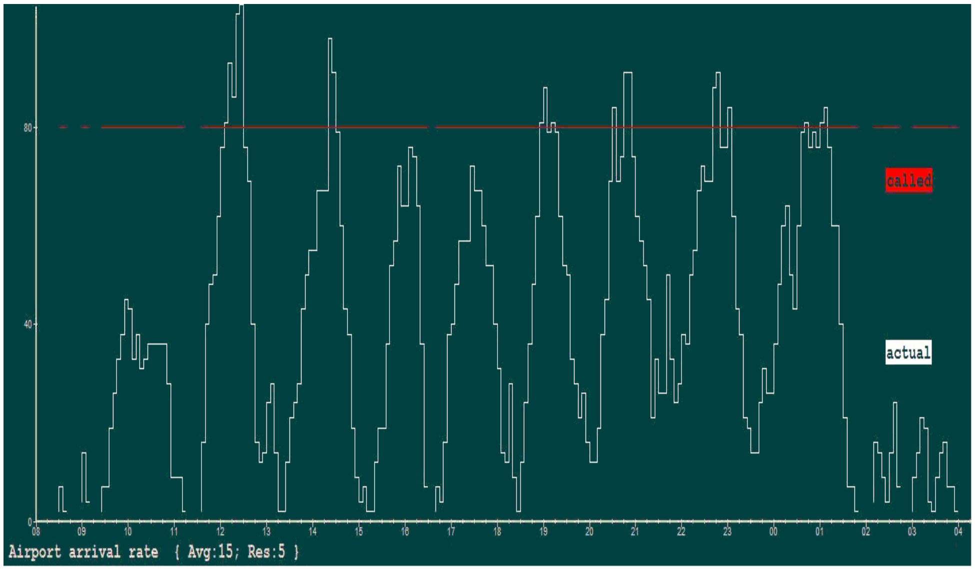

Figure 5. CLT Airport Arrival Rate for a Single Day

The plot (white line), seen in Figure 5, represents the measured arrival rate for a "typical" day at CLT. It can be clearly seen that CLT has nine distinct arrival banks distributed throughout the day. The FAA Called Rate, represented by the red line, is also shown in the preceding diagram. Note that the actual arrival rate does occasionally rise higher than the called rate during the arrival banks.

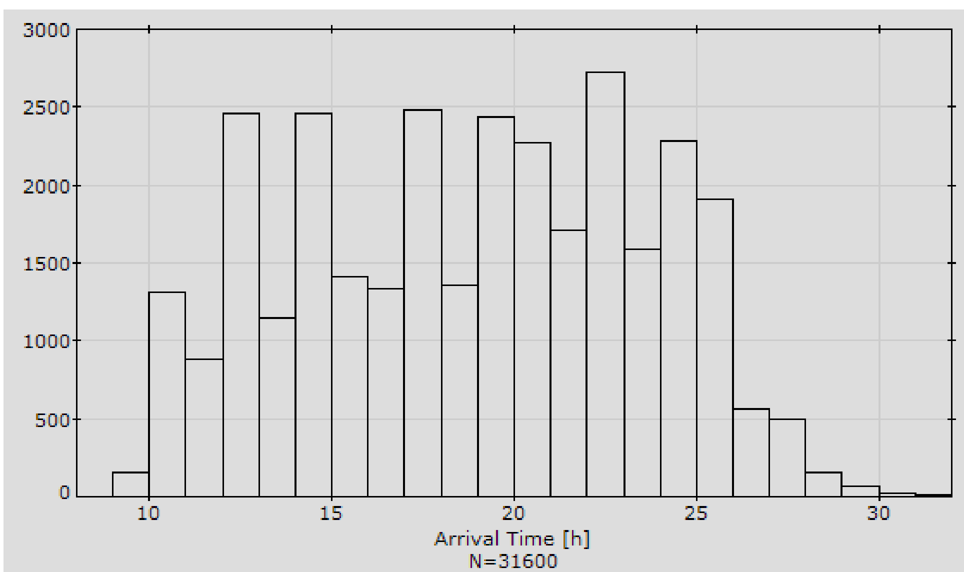

Figure 6. CLT Airport Arrival Timeline for 50-day Analysis Period

Figure 6 represents approximately 31,600 arrivals to CLT during the 50-day analysis period. It shows multiple arrival-banks (i.e., the peaks). Note however that the bank structure is not quite as defined as seen in Figure 5. This is to be expected, since there is some variation in the time of day when each individual flight arrives. In other words, when the data set is increased from 1 day to 50 days; the variation of the actual arrival time of the individual flight lowers the peaks and increases the valleys.

Delta Air Lines-MSP

MSP has a maximum called arrival rate of 90 flights per hour (per FAA Called Arrival Rate) in ideal weather conditions. This rate decreases when weather, runway closures, noise and/or fire-rescue restrictions limit the runways utilization.

Figure 7 shows FAA's Airport Arrival Demand Chart on December 7, 2011 at MSP. The white horizontal line represents the FAA Called Arrival Rate (90 arrivals per hour).

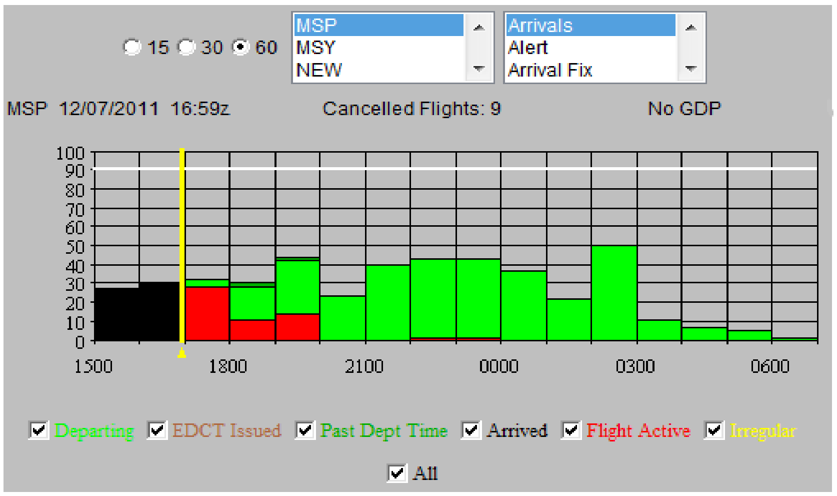

Figure 7. FAA's Airport Arrival Demand Chart for MSP (times are GMT)

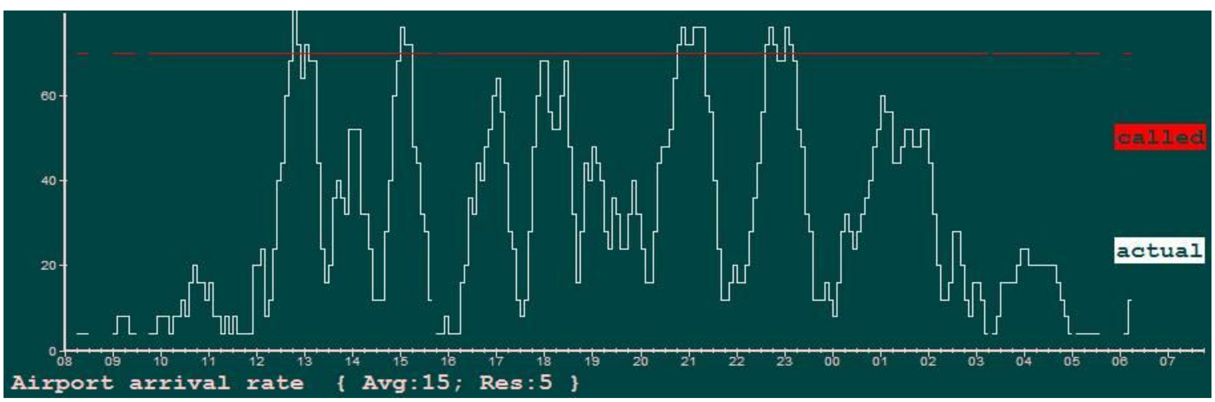

Figure 8. MSP Arrival Rate for a Typical Day

Figure 8 provides a plot of MSP's actual arrival by time of day for a "typical" single day. The plot (white line), seen in Figure 8, represents the measured arrival rate. It can be clearly seen that MSP has seven distinct arrival banks distributed throughout the day. The Called Rate, represented by the red line, is also shown in the preceding diagram. Note that the actual arrival rate does occasionally rise higher than the called rate during the arrival banks.

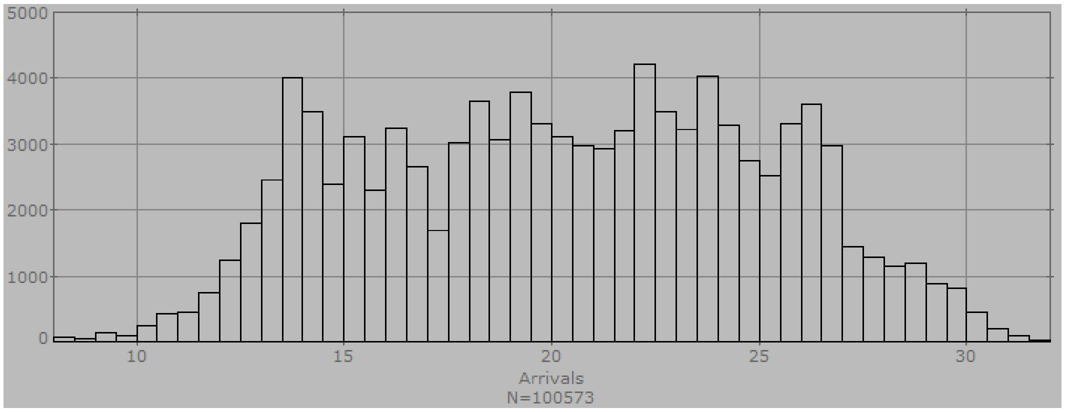

Figure 9. MSP Arrival Timeline for the six month Passive Analysis Period

Figure 9 illustrates the arrival timeline for the entire six-month analysis period. This represents approximately 100,573 arrivals to MSP during the passive analysis period. It shows multiple arrival-banks (i.e., the peaks). Note, however, that the bank structure is not quite as defined as can be seen in Figure 8. This is to be expected, since there is some variation in the time of day when each individual flight arrives and the dataset includes a shift in traffic due to daylight savings time. In other words, when the data set is increased from one day to six months; the variation of the actual arrival time of the individual flight lowers the peaks and increases the valleys.

As concluded in the CLT AAMS Program, the accuracy of the FAA Called Arrival Rate as a predictor of the actual arrival rate was not good enough to calculate arrival queues and was not used in the MSP AAMS Program.

3.1.2 Airport Orientation

The orientation of an airport principally refers to the orientation of the primary runways, which is an important factor during airport planning and design. Ideally, all aircraft operations should be conducted into the wind; however, wind conditions vary with time, thus requiring careful examination of prevailing wind conditions at the airport. This section will provide an overview of the airport configuration, with respect to the airport-centric and airspace-centric variables that plays a role in the analysis of MSP and CLT arrivals.

3.1.2.1 Direction of Operations

US Airways-CLT

As seen in the Figure 10 and Figure 11 below, the landing direction of the airport's operation is not a constant. The operational landing direction is dependent upon weather events (e.g., wind pattern and storms) that influence which arrival flow air traffic control will use. For example, Figure 10 provides an example of a day when the airport had a south-arrival flow, and where all south runways (18R, 18C, 23, and 18L) were used for arrival traffic into the airport. Figure 11 provides an example of a day when the airport had a north-arrival flow, and where all north runways (36L, 36C, 36R, and 5) were also used for the arrivals to the airport.

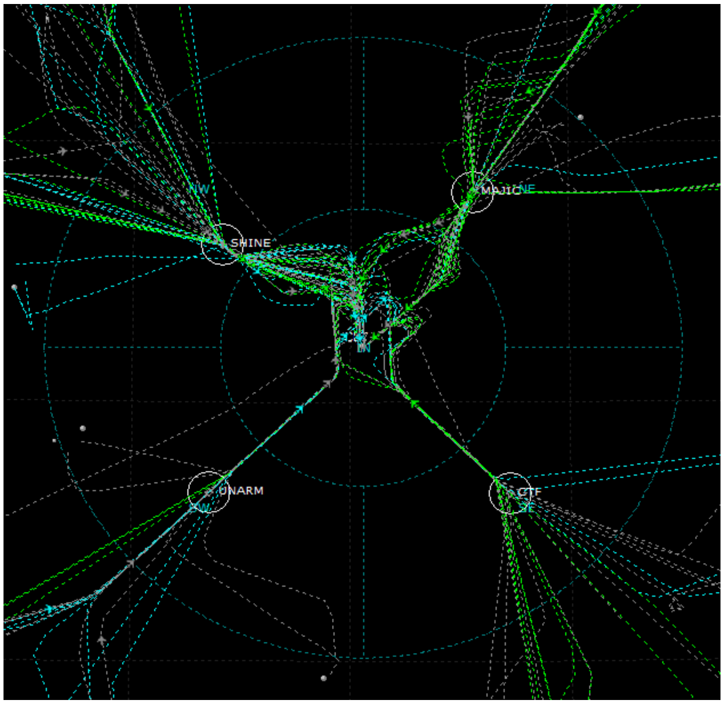

Figure 10. Example of South-Arrival Flow into CLT Airport

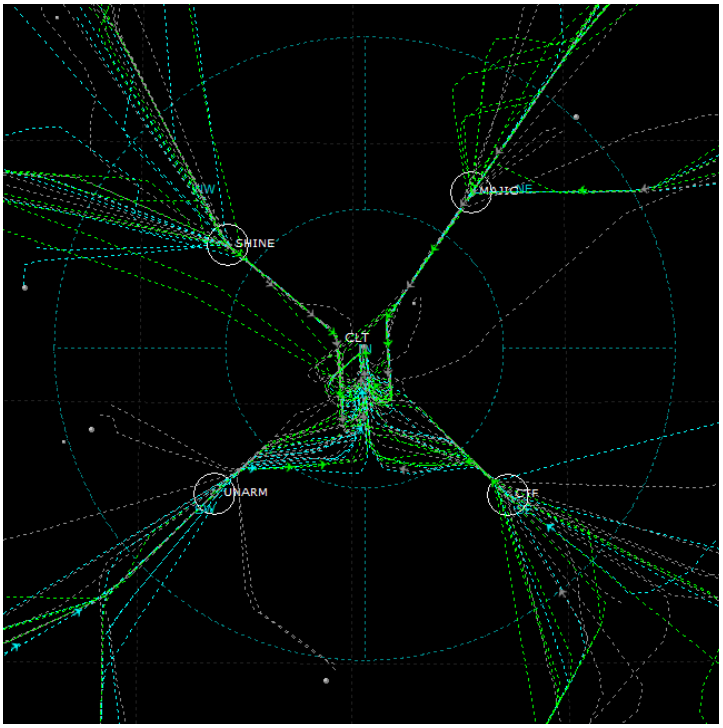

Figure 11. Example of a North-Arrival Flow into CLT Airport

The use of runways is also constrained by local airport regulations, e.g., runway 18R/36L can only be used between 7:30 am to 8:00 pm due to fire/rescue requirements. Runways 36C and 36R are only available from 7:00 am to 11:00 pm due to noise restrictions.

Delta Air Lines-MSP

As seen in the Figures 12 and 13, the landing direction of the airport's operation is not a constant. The operational landing direction is dependent upon weather events (e.g., wind pattern and storms) that influence which arrival direction air traffic control will use.

For example, Figure 12 provides an example of a day when the airport had an East-arrival flow, and where the two primary East runways (12L and 12R) were used for arrival traffic into the airport.

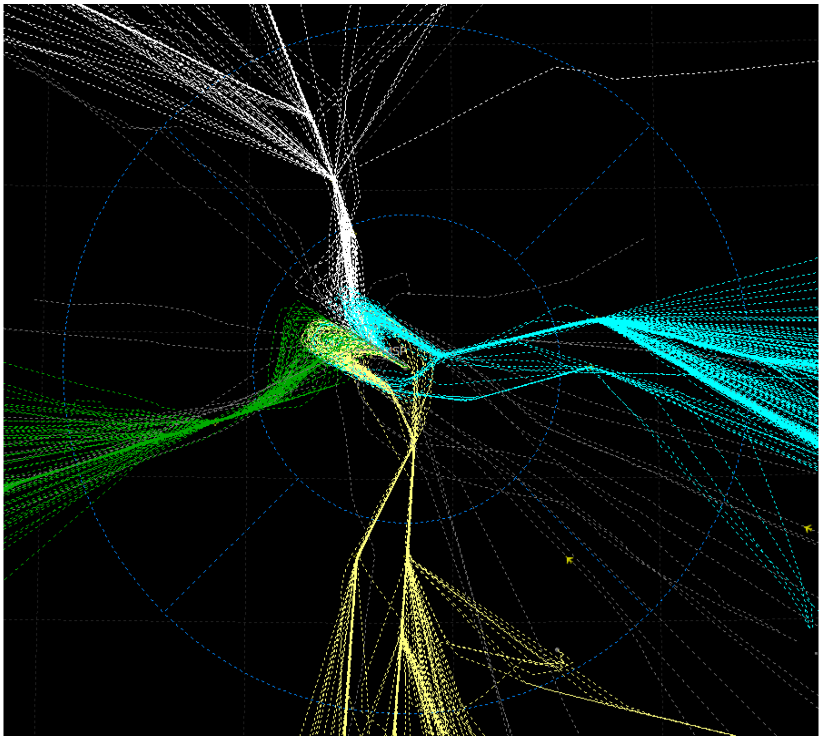

Figure 12. Example of East-Arrival Flow into MSP

Figure 13 provides an example of a day when the airport had a West-arrival flow, and where all west runways (30R, 30L and 35) were used for the arrivals to the airport.

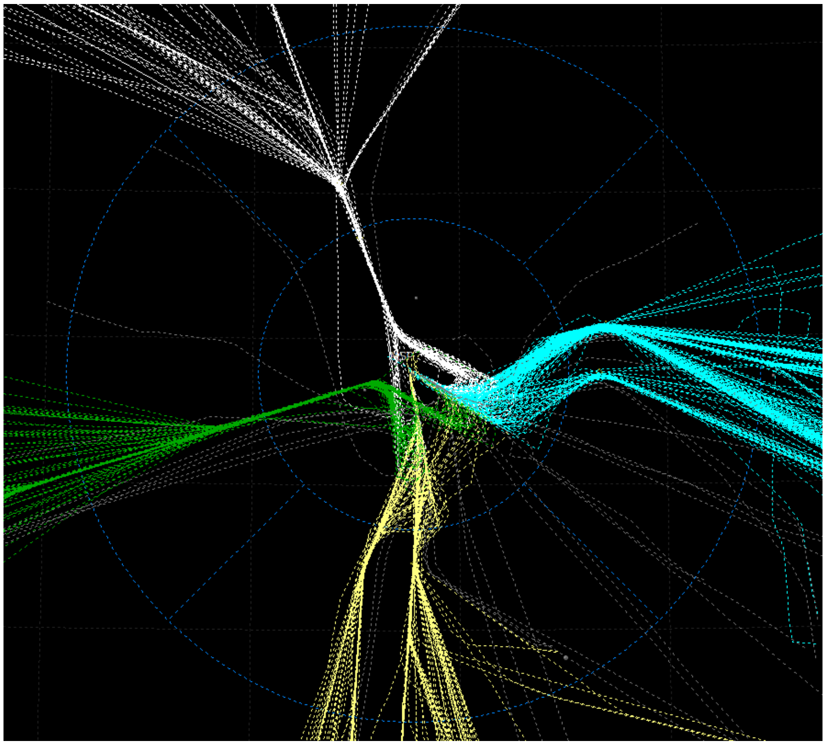

Figure 13. Example of a West-Arrival Flow into MSP

3.1.2.2 Daily Arrival Patterns

US Airways-CLT

As described above, the CLT airport has a north/south arrival flow. Figure 14 provides the daily arrival patterns for CLT over the 50-day analysis period.

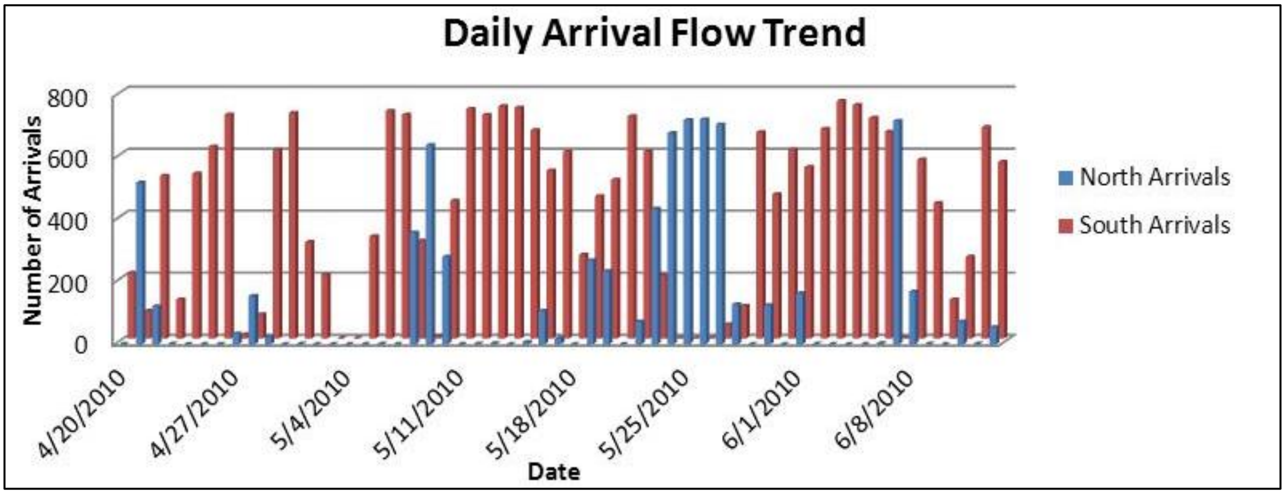

Figure 14. Daily Trends of Arrival Flow Direction (Blue-North Arrivals, Red-South Arrivals)

Based on the sample provided in Figure 14, it can be determined that the primary arrival direction of operations is the south orientation. (Note: Days where there are no north or south arrivals indicate a missing day of data). The figure above also shows that for some days the direction of air traffic operation changed during the day, meaning the arrival flow switched from one direction to another, primarily due to a change in the weather pattern.

The results obtained from the 50-day analysis of arrivals to CLT airport indicated that, despite the fact that the airport has both North and South arrivals; the dominant direction of arrivals to the airport favors the South arrival flow. From the 50-day analysis, approximately 76% of arrivals (or 23,677 flights) approached the airport using the South arrival flow.

It is understood that weather is a primary driver in the arrival direction, which can result in a changing operation for a period of time. Figure 15 shows the timeline (throughout a day) of the arrival flow into the airport (for the entire analysis period), which further demonstrates that the South arrival flow was the dominant operation pattern for the airport during this time period.

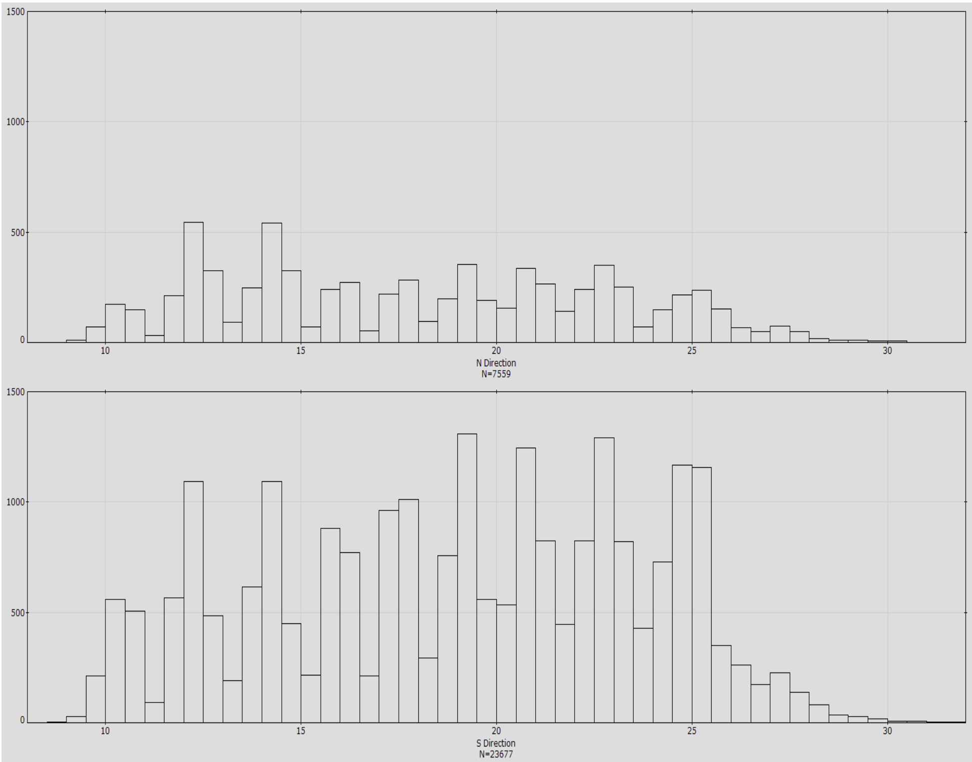

Figure 15. Timeline of Arrival Flow (Top - North arrivals, Bottom - South arrivals)

Delta Air Lines-MSP

As described above, the MSP has primarily an East/West arrival flow. Figure 16 provides the daily arrival patterns for MSP over the six-month analysis period.

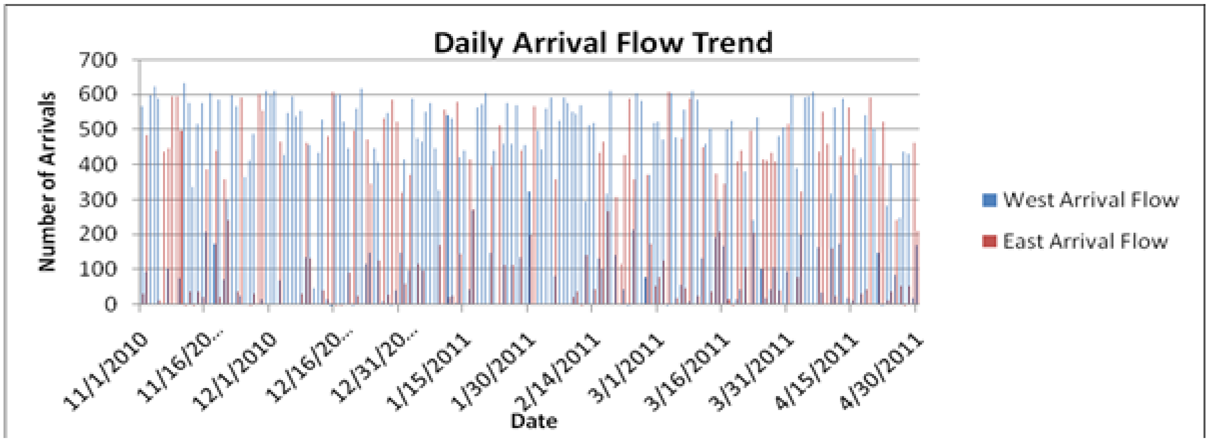

Figure 16. Daily Trends of Arrival Flow Direction

Based on the sample provided in Figure 16, it can be determined that the primary arrival direction of operations is the West orientation. (*Note: Days where there are no East or West arrivals indicate a missing day of data*).

Figure 16 above also shows that for some days the direction of air traffic operation changed during the day, meaning the arrival flow switched from one direction to another, primarily due to a change in the weather pattern.

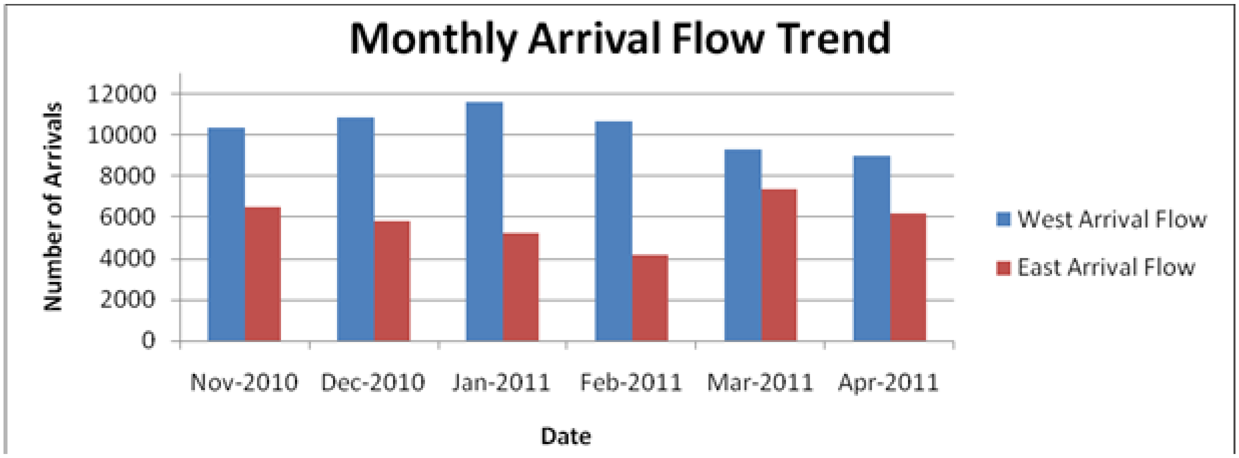

Figure 17. Monthly Trend of Arrival Flow Direction

Figure 17 shows a clearer trend of arrival orientation, when the arrival flow is categorized monthly and plotted respectively. The dominance of the West-arrival flow is more evident in Figure 17 above than from the daily breakdown of the arrival flow direction displayed in Figure 16.

The results obtained from the six-month analysis of arrivals to the MSP indicated that, despite the fact that the airport has both East and West arrivals; the dominant direction of arrivals to the airport favors the West arrival flow. From the six-month analysis, approximately 64% of arrivals (or 61,539 flights) approached the airport using the West arrival flow.

It is understood that weather is a primary driver in the arrival direction, which can result in a changing operation for a period of time. Figure 18 shows the timeline (throughout a day) of the arrival flow into the MSP (for the entire analysis period), which further demonstrates that the West arrival flow was the dominant operation pattern for the airport during this time period.

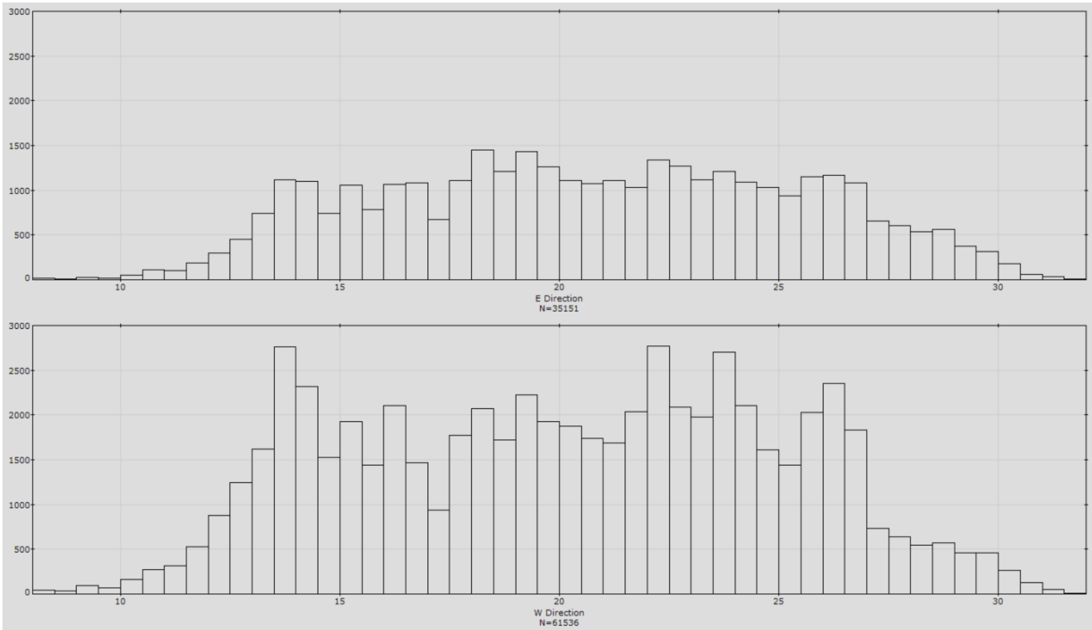

Figure 18. Timeline of Arrival Flow (Top - East arrivals, Bottom - West arrivals)

3.1.3 Arrival Flow Quadrant Definition

US Airways-CLT

The adaptation data of the CLT airport and airspace characteristics was incorporated into the analysis suite. This included the adaptation of the runways, the Standard Instrument Departure (SID) procedures, the Standard Terminal Arrival Routes (STAR), and arrival fixes for the airport.

The airspace around the CLT airport, shown in the Figure 19, was divided into sections known as the inner circle (IN) and the outer circle (OU). The OU was further divided equally into four (4) quadrants, whose areas (for each quadrant) equaled the area occupied by the inner circle (useful for analyzing traffic density). Each of the quadrants roughly captures one of the arrival flows into the airport. The OU's quadrants were labeled NW, NE, SE, SW; the quadrants were designed such that each arrival fix was well encapsulated within a quadrant, and each arrival flow did not encroach on an adjacent quadrant.

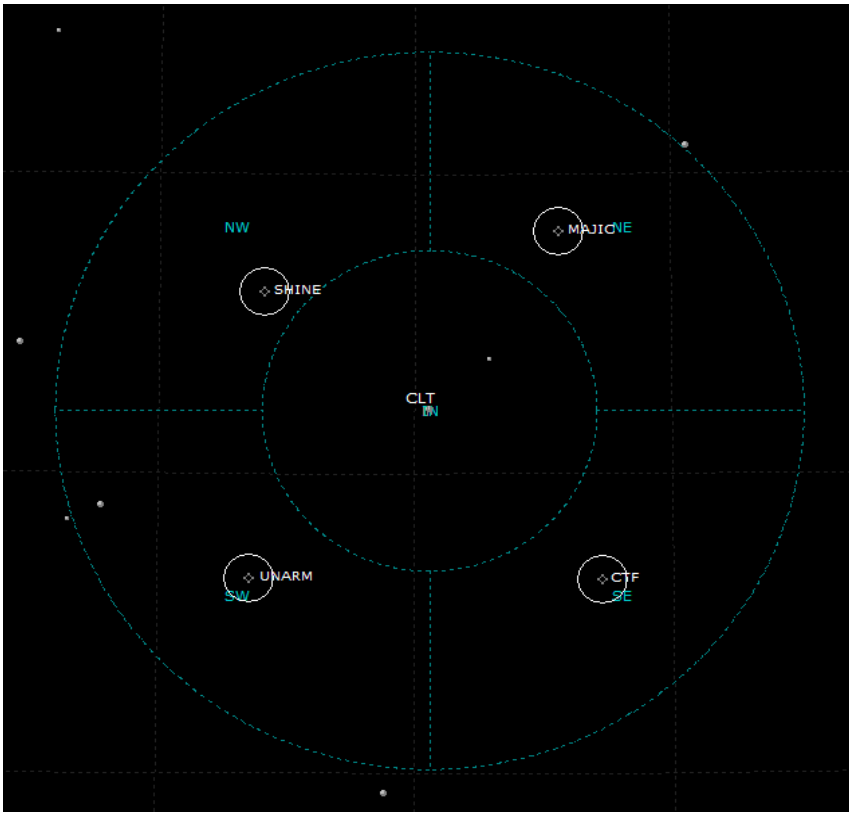

Figure 19. CLT Airspace Quadrants

Delta Air Lines-MSP

The adaptation data of the MSP and airspace characteristics was incorporated into ATH Group's analysis suite. This included the adaptation of the runways, the Standard Instrument Departure (SID) procedures, the Standard Terminal Arrival Routes (STAR), and arrival fixes for the airport.

The airspace around the MSP, shown in Figure 20, was divided into sections known as the inner circle (IN) and the outer circle (OU). The OU was further divided equally into four (4) quadrants, whose areas (for each quadrant) equaled the area occupied by the inner circle (useful for analyzing traffic density). Each of the quadrants roughly captures one of the arrival flows into the airport. The OU's quadrants were labeled N, S, E and W; the quadrants were designed such that each arrival fix was well encapsulated within a quadrant, and each arrival flow did not encroach on an adjacent quadrant.

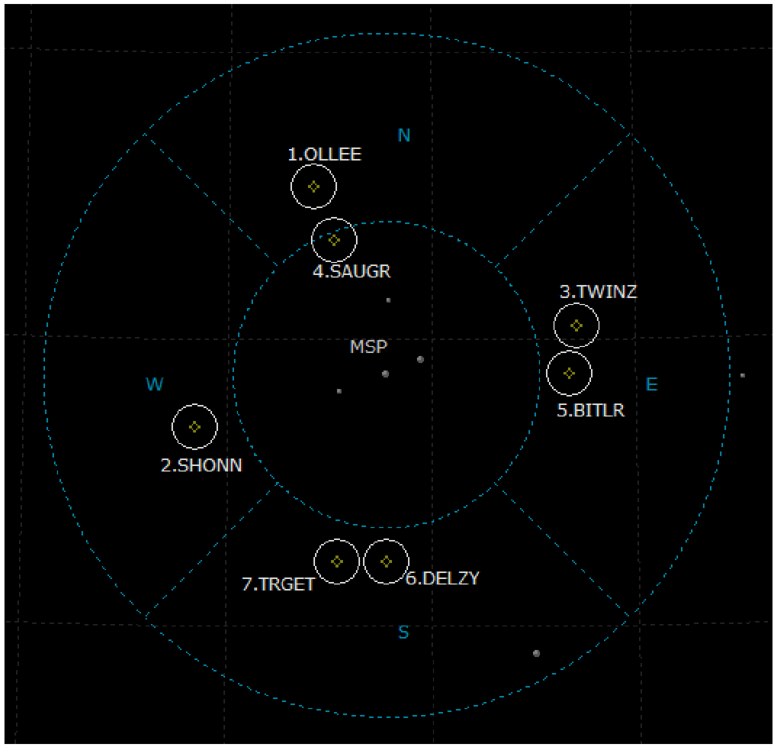

Figure 20. MSP Airspace Quadrants

3.2 Arrival Aircraft Population Characteristics

US Airways-CLT

Once the adaptation was completed, a customized configuration of AwSim™ was setup for the CLT AAMS analysis. This included the definition of metrics that would assist in analyzing the arrival flow into the airport, creating statistics, and analyzing correlations of some of the results.

The metrics defined were divided into two categories: airport centric and airspace centric. These metrics were intended to provide a measurement of how the arrival traffic to CLT flowed on any given day with details for each arrival stream. FAA's Enhanced Traffic Management System (ETMS) messages were used by ATH's AwTrak™ program to generate flight trajectories. These trajectories were then used by the customized AwSim™ application to perform analysis of the airport's arrival flow.

Delta Air Lines-MSP

Once the adaptation was completed, a customized configuration of AwSim™ was setup for the MSP AAMS analysis. This included the definition of metrics that would assist in analyzing the arrival flow into the airport, creating statistics, and analyzing correlations of some of the results.

The metrics defined were divided into two categories: airport centric and airspace centric. These metrics were intended to provide a measurement of how the arrival traffic to MSP flowed on any given day with details for each arrival stream. FAA's ASDI messages were used by ATH's AwTrak™ program to generate flight trajectories. These trajectories were then used by the customized AwSim™ application to perform analysis of the airport's arrival flow.

3.2.1 Airlines

US Airways-CLT

While CLT airport serves as a hub for US Airways and its regional carriers, other airlines also operate in this airport. The following table shows the population breakdown of the airlines that operate into CLT.

Table 6. Breakdown of Airline Flights Arriving into CLT Airport

Airline	Count	%
US Airways	10,188	34.8%
PSA Airlines	5,819	19.9%
Mesa Airlines	2,383	8.1%
Republic Airlines	2,163	7.4%
Air Wisconsin	1,878	6.4%
Piedmont	1,744	6.0%
Express Jet	438	1.5%
Delta Air Lines	374	1.3%
American Eagle	351	1.2%
JetBlue Airlines	236	0.8%
AirTran Airways	222	0.8%
American Airlines	192	0.7%
General Aviation	1,092	3.7%
Other	2,168	7.4%
Total	**29,248**	

For the 50-day analysis period, it is clear that US Airways and PSA Airlines share the majority of the arrival population into the CLT airport. This is an important statistic as it shows that US Airways and PSA Airlines will provide a significant population to conduct the AAMS operation in CLT.

Delta Air Lines-MSP

While the MSP serves as a hub for Delta Air Lines and its regional carriers, other airlines also operate at the airport. Table 7 shows the population breakdown of the airlines that operate into MSP.

Table 7. Breakdown of Airline Flights Arriving into MSP

Airline	Count	Share
Delta Air Lines	29,634	27.8%
Mesaba Airlines	17,440	16.4%
Compass Airlines	10,414	9.8%
Pinnacle Airlines	10,357	9.7%
SkyWest Airlines	8,229	7.7%
Southwest Airlines	2,830	2.7%
Sun Country Airlines	2,801	2.6%
Comair	2,113	2.0%
American Airlines	1,751	1.6%
Bemidji Airlines	1,713	1.6%
Express Jet	1,700	1.6%
Shuttle America	1,607	1.5%
United Airlines	1,582	1.5%
US Airways	1,510	1.4%
General Aviation	2,912	2.7%
Other	9,859	9.3%
Total	**106,452**	**100%**

For the six-month passive analysis period, it is clear that Delta Air Lines is the largest carrier of the arrival population into the MSP. This is an important statistic as it shows that Delta Air Lines will provide a significant population to conduct the AAMS operation in MSP.

3.2.2 Aircraft Types

US Airways-CLT

In addition to analyzing the airline population breakdown for arrivals to CLT, the population breakdown of the aircraft types used by US Airways and PSA Airlines was also analyzed and presented in Table 3.

The ‘Aircraft Type’ column represents the International Civil Aviation Organization (ICAO) Type Identifier for the aircraft. From the table, it is again clear that US Airways uses large jets (primarily Boeing and Airbus), whereas PSA uses medium jets (Canadair CRJs).

Table 8. Aircraft Type Population Breakdown for US Airways and PSA Airlines

Aircraft Type	Count	%
B734	2,659	26.10%
A319	2,497	24.50%
A321	2,173	21.30%
A320	1,711	16.80%
B733	588	5.80%
B752	215	2.10%
B762	162	1.60%
A333	117	1.10%
A332	61	0.60%
Generic	4	0.00%
B737	1	0.00%
US Airways Total	**10,188**	
CRJ2	3,795	65.20%
CRJ7	2,024	34.80%
PSA Total	**5,819**	

Note: the aircraft type noted as 'Generic' indicates that type information was missing in the flight plan data or could not be matched up with any adapted types.

Delta Air Lines-MSP

In addition to analyzing the airline population breakdown for arrivals to MSP, the population breakdown of the aircraft types used by Delta Air Lines are summarized in Table 3.

The "Aircraft Type" column gives the indicated International Civil Aviation Organization (ICAO) Type Identifier for the aircraft. From the table, it is again clear that Delta Air Lines uses large jets (with 38% being Airbus, 31% Boeing and 31% McDonnell-Douglas aircraft).

Table 9. Aircraft Type Population Breakdown for Delta Air Lines

Aircraft Type	Count	%
A319	4,772	16.10%
A320	5,847	19.73%
A332	35	0.12%
A333	460	1.55%
DC94	49	0.17%
DC95	2,381	8.03%
MD88	2,110	7.12%
MD90	4,726	15.95%
B737	3	0.01%
B738	2,376	8.02%
B752	4,108	13.86%
B753	2,049	6.91%
B757	1	0.00%
B763	349	1.18%
B764	180	0.61%
B767	1	0.00%
B744	187	0.63%
Delta Total	**29,634**	**100%**

3.2.3 Flight Duration

US Airways-CLT

Flight Duration, one of the airport-centric metrics, presents information about the time-length of flights arriving into CLT. From the following illustration, it is seen that the average flight duration for flights arriving to CLT is approximately 74 minutes.

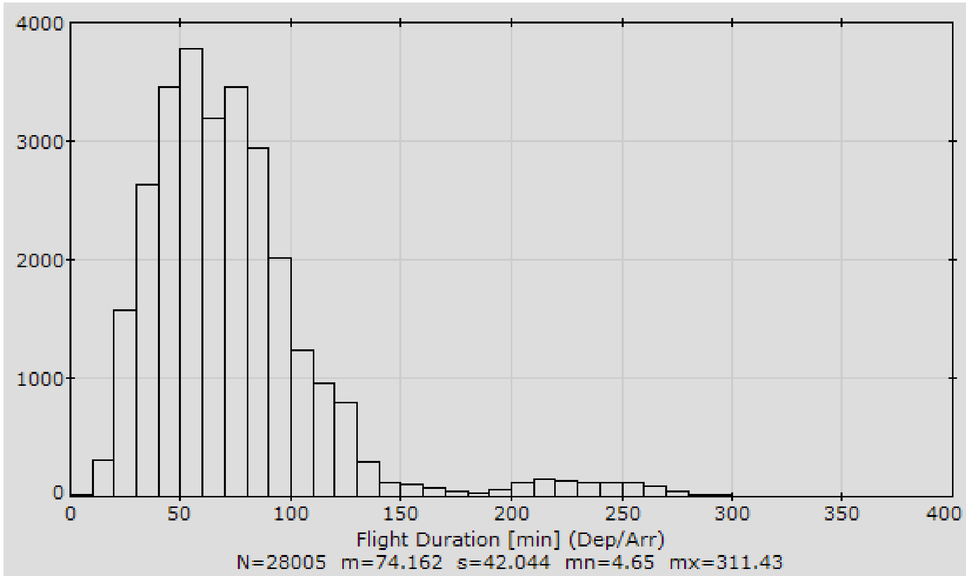

Figure 21. Flight Duration Statistics for Arrivals into CLT

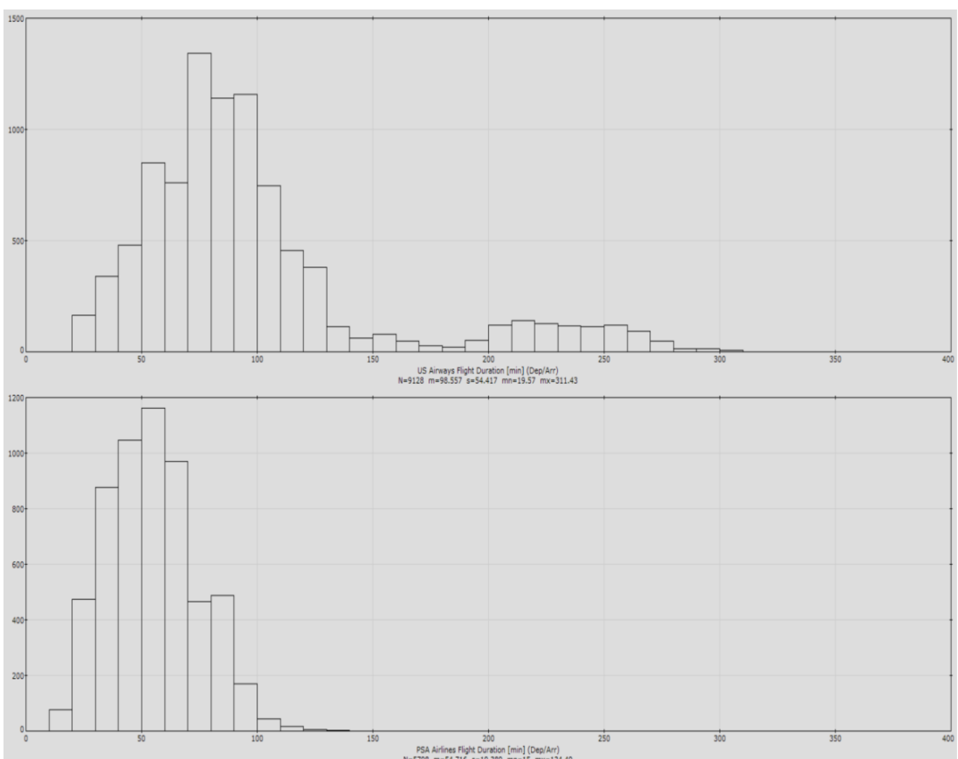

Figure 22. Flight Duration for US Airways (top) and PSA Airlines (bottom) into CLT

Delta Air Lines-MSP

Flight Duration, one of the airport-centric metrics, provides insight about the duration of flights arriving into MSP. From Figure 20, it is seen that the average flight duration for flights arriving to MSP is approximately 103 minutes. Figure 24 compares the flight durations for all MSP arrivals against those for Delta arrivals.

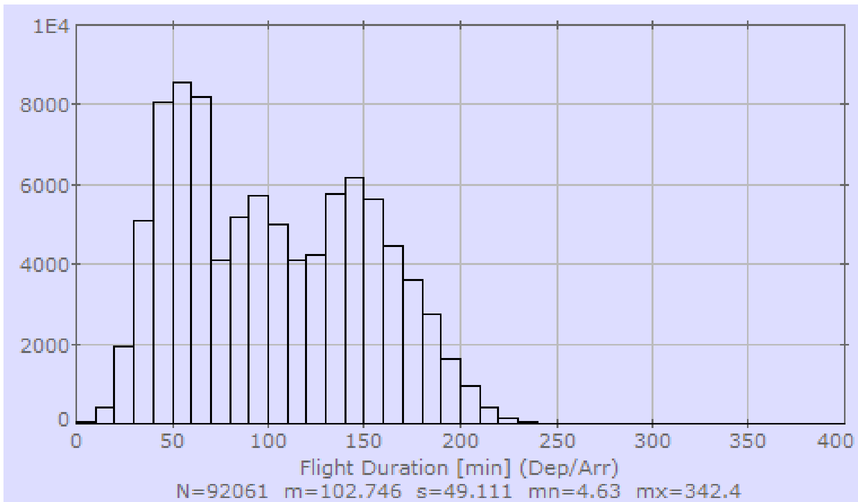

Figure 23. Flight Duration Statistics for Arrivals into MSP

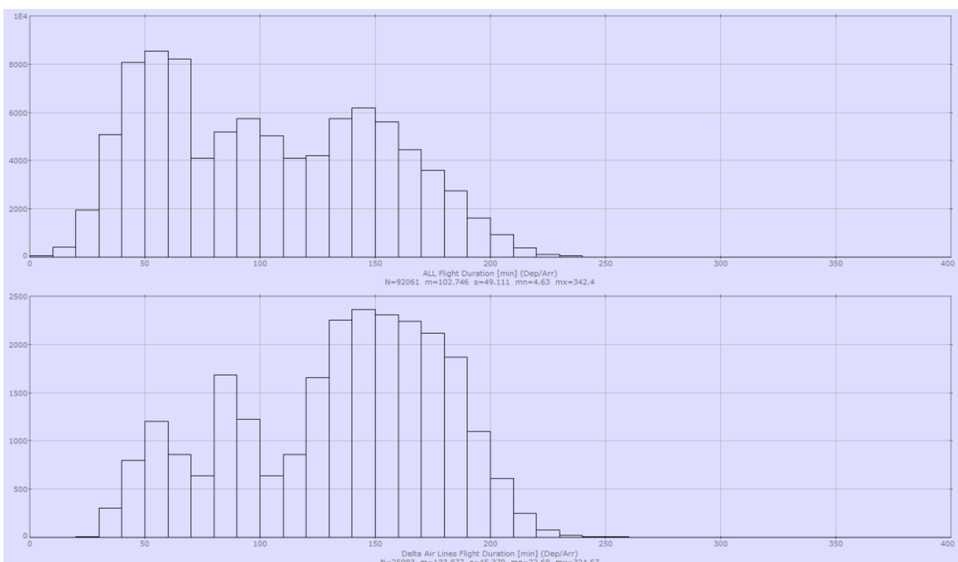

Figure 24. Flight Duration for All arrivals (top) and Delta Air Lines (bottom)

3.3 Average Corner Post to Runway (Dwell) Times

"Dwell Time" is a key parameter in configuring the AAMS operation. Dwell time is defined in this study as the flight times from the corner post (arrival fix) to the arrival runway.

US Airways-CLT

The average corner post to runway times were analyzed for all arrivals to CLT, not just US Airways and PSA Airlines. The following illustration presents the breakdown of the dwell times, with respect to each corner post through which the aircraft arrival flows approach CLT.

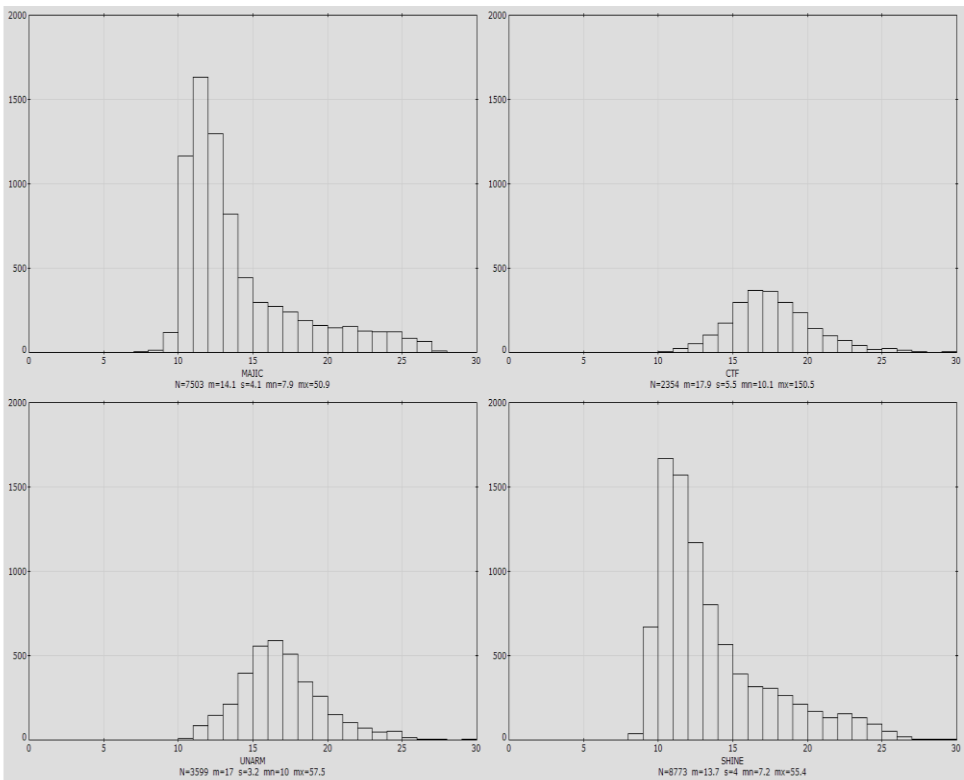

Figure 25. Average Corner Post to Runway Dwell Times

The preceding illustration (Figure 25) shows that the arrival fixes MAJIC (top left) and SHINE (bottom right) hosts the majority of the traffic flow to the airport, whereas the arrival fix CTF (top right) hosts the minority of that traffic flow. The average dwell times at these corner posts are shown in Table 10.

Table 10. Average (Nominal) Dwell Times for Arrivals for Individual Corner Post

Fix Name	Traffic Count for Fix Pass	Average Dwell Time to Arrival (minutes)
MAJIC	7503	14.1
CTF	2354	17.9
UNARM	3599	17.0
SHINE	8773	13.7

The average dwell times are further divided into North and South arrivals of US Airways and PSA Airlines. These Dwell Times are shown in Table 11 below.

Table 11. Nominal Corner Post to Landing Dwell Times for North and South Arrivals

Fix Name	Traffic count for Fix Pass	Nominal Dwell Time to Arrival	US Airways		PSA Airlines	
			Nominal Dwell time (N Arrivals)	Nominal Dwell time (S Arrivals)	Nominal Dwell time (N Arrivals)	Nominal Dwell time (S Arrivals)
MAJIC	7503	14.1	19.7	12.5	18.9	12.4
CTF	2354	17.9	15.3	18.6	16.2	17.8
UNARM	3599	17	15.8	17.9	15.7	17.6
SHINE	8773	13.7	18.6	12.2	18.3	12.4

3.3.1 Minimum Corner Post to Runway Times

Table 12. Minimum Corner Post to Landing Dwell Times for North and South Arrivals

Fix Name	Traffic count for Fix Pass	Nominal Dwell Time to Arrival	US Airways		PSA Airlines	
			Nominal Dwell time (N Arrivals)	Nominal Dwell time (S Arrivals)	Nominal Dwell time (N Arrivals)	Nominal Dwell time (S Arrivals)
MAJIC	7503	14.1	11.9	9.2	12	8.7
CTF	2354	17.9	10.1	11.1	10.8	13.1
UNARM	3599	17	10.8	10.8	10.1	11.3
SHINE	8773	13.7	10.7	10.7	10.7	8.7

The minimum dwell times to runway were also analyzed and presented in Table 12, where the dwell times are shown for the North and South arrivals of US Airways and PSA Airlines flights.

Delta Air Lines-MSP

The average dwell times were calculated for all arrivals into MSP. Figure 26 presents the breakdown of the dwell times, with respect to each corner post through which the aircraft arrival flows approach MSP.

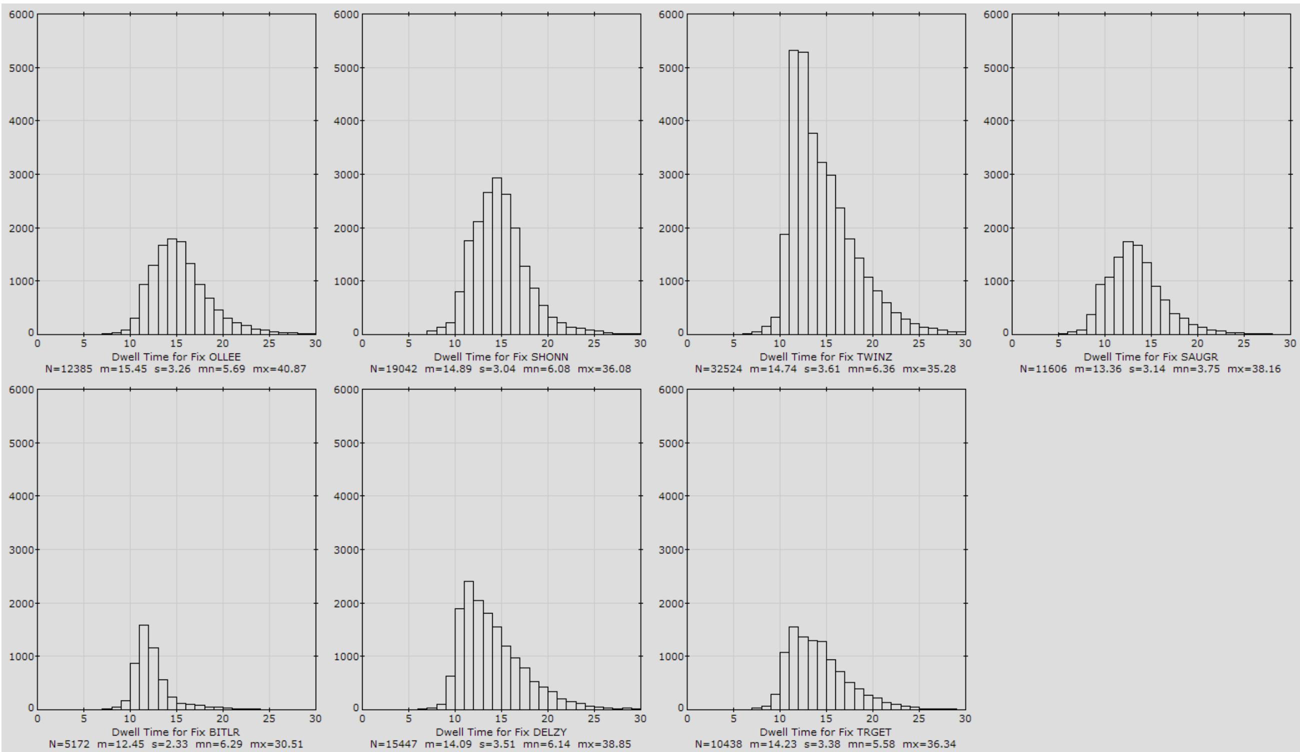

Figure 26 Average Corner Post to Runway Dwell Times

Figure 26 shows that the arrival fixes SHONN (top row, second graph) and TWINZ (top row, third graph) hosts the largest share of the traffic flow to the airport, whereas the arrival fix BITLR (bottom row, first graph) hosts the smallest share of that traffic flow.

The average dwell times from these corner posts are shown in Table 13 while the average dwell times are further divided into East and West arrivals of Delta Air Lines as shown in Table 14 below.

Table 13 Average (Nominal) Dwell Times for Arrivals from Individual Corner Post

Fix Name	Traffic Count for Fix Pass	Average Dwell Time to Arrival (minutes)
TWINZ	31,799	14.76
BITLR	4,644	12.47
DELZY	15,161	14.10
TRGET	10,232	14.24
SHONN	18,706	14.91
OLLEE	11,922	15.42

Table 14. Nominal Corner post to Landing Dwell Times for East/West Arrivals (minutes)

Fix	Traffic count for Fix Pass	Nominal Dwell Time to Arrival	Delta Air Lines	
			Nominal Dwell time (E Arrivals)	Nominal Dwell time (W Arrivals)
TWINZ	31,799	14.76	17.0	13.2
BITLR	4,644	12.47	15.4	12.0
DELZY	15,161	14.10	16.3	12.7
TRGET	10,232	14.24	16.6	13.1
SHONN	18,706	14.91	13.7	15.7
OLLEE	11,922	15.42	14.4	16.3

3.4 Airspace Events

US Airways-CLT

Airspace centric metrics of events that occurred around the airport and surrounding airspaces were also identified.

These events at CLT are illustrated as follows:

- Airspace Enter events (lime green color) - triggered when aircraft cross a defined airspace boundary, which in this case was either the outer-circle airspace or the inner-circle airspace,
- Cruise End events (gray color) - triggered when the cruise phase of the aircraft ends,
- Arrival Fix Pass events (light green) - triggered when aircraft cross a defined Fix point, which in this case were the arrival fixes defined for the airport,
- Hold Start events (yellow color) - triggered when aircraft vector away from the anticipated travel route, and travel in a defined pattern that categorize the maneuver as Hold,
- Arrivals (cyan color) - triggered when aircraft arrive at the airport, and

- Tick event (blue color) - captured only inside the outer circle, this was a one per minute heartbeat event used to view traffic density.

Figure 27 shows the generated events for the airspace around CLT, and reflects the entire analysis period.

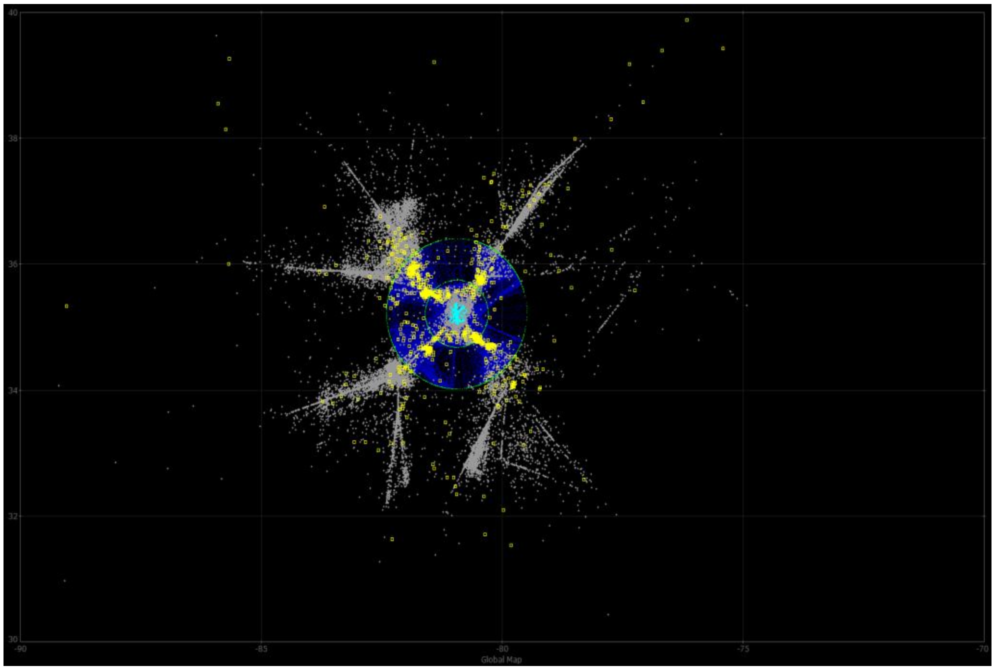

Figure 27. Map of Airspace Events Generated around CLT Airport

From the preceding illustration, it was noticed that the majority of the Cruise-End events occur outside of the outer-circle airspace. Furthermore, the majority of the Hold events occur between the outer and inner-circle airspaces, closer to the arrival fixes.

Figure 28 presents a timeline of the events shown in the preceding illustration, color-coded respectively to the corresponding event.

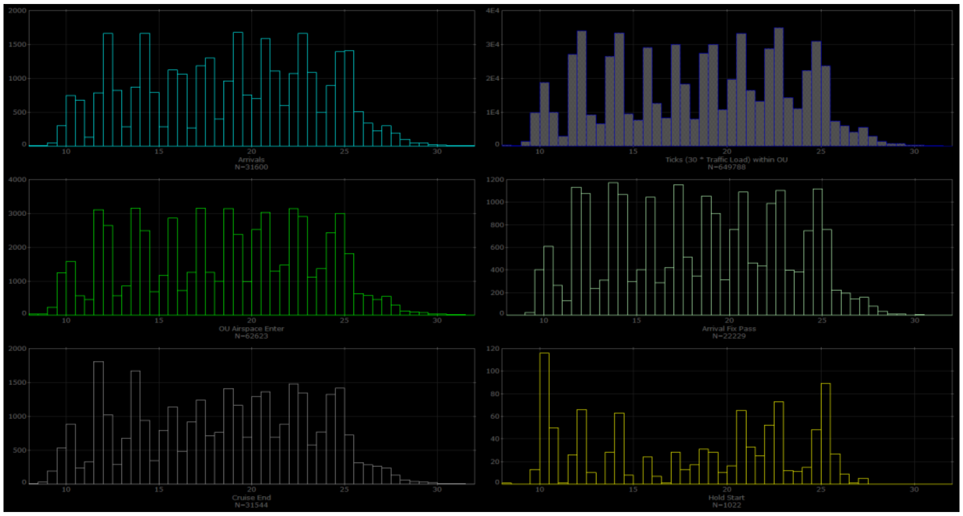

Figure 28. Timeline of Airspace Events Generated around CLT Airport

The previous illustration highlights some important observations about the events generated during the analysis of the CLT airport:

- Highest number of holds occurs early on in the day,
- The Arrival Fix Pass events occur in waves, spaced out every 90 - 120 minutes,
- The Outer Airspace Entry event almost follows the same pattern as the Arrival events. This was because most of the flights that enter the outer airspace, after a given period of time, arrive at the airport thus generating an Arrival event.

Figure 29 describes the arrival events that are generated once a trajectory has ended at the arrival airport, or close to the airport (within a given tolerance). The following figure shows the arrival timelines of All arrivals (top left), US Airways (top right), PSA (bottom left), and all other airlines (bottom right).

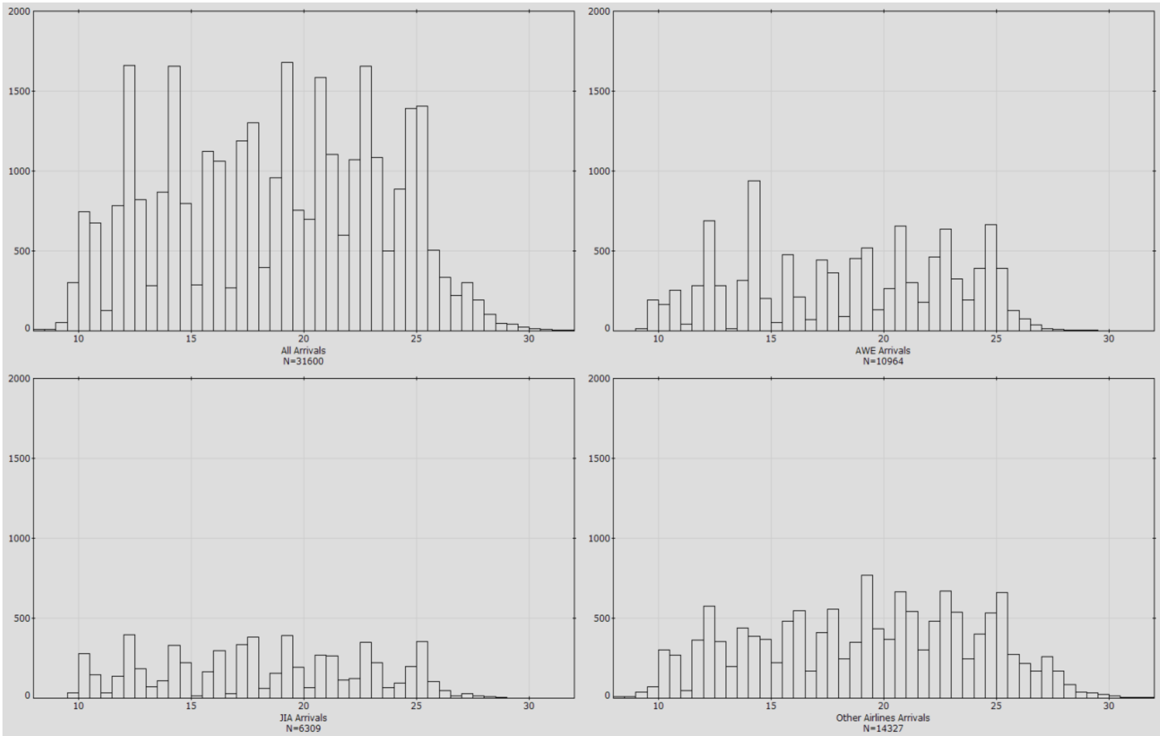

Figure 29. Arrival Timelines for CLT

Delta Air Lines-MSP

Figure 30 provides an illustration of the following generated events for the airspace around MSP:

- Airspace Enter events (lime green color) - triggered when aircraft cross a defined airspace boundary, which in this case was either the outer-circle airspace or the inner-circle airspace,
- Cruise End events (gray color) - triggered when the cruise phase of the aircraft ends,
- Arrival Fix Pass events (light green) - triggered when aircraft cross a defined Fix point, which in this case were the arrival fixes defined for the airport,
- Hold Start events (yellow color) - triggered when aircraft vector away from the anticipated travel route, and travel in a defined pattern that categorize the maneuver as Hold,
- Arrivals (cyan color) - triggered when aircraft arrive at the airport.

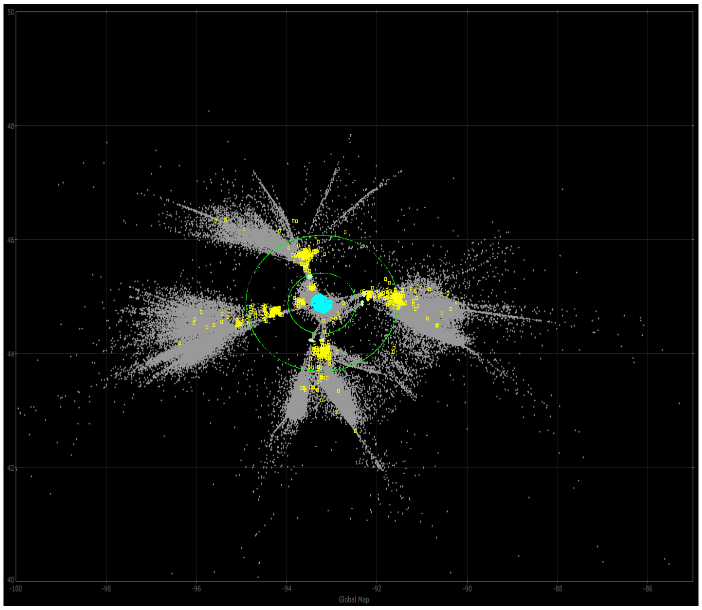

Figure 30. Map of Airspace Events Generated around MSP

From this illustration, it is noted that the majority of the Cruise-End events occur outside of the outer-circle airspace. Furthermore, the majority of the Hold events occur between the outer and inner-circle airspaces, closer to the arrival fixes.

Figure 31 presents a timeline of the events shown in the preceding illustration, color-coded respectively to the corresponding event. Each chart in Figure 17 shows the number of flights (vertical axis) in each hour of the day over a 30 hour period (horizontal axis). The data set is for the period between November 7, 2010 and March 13, 2011.

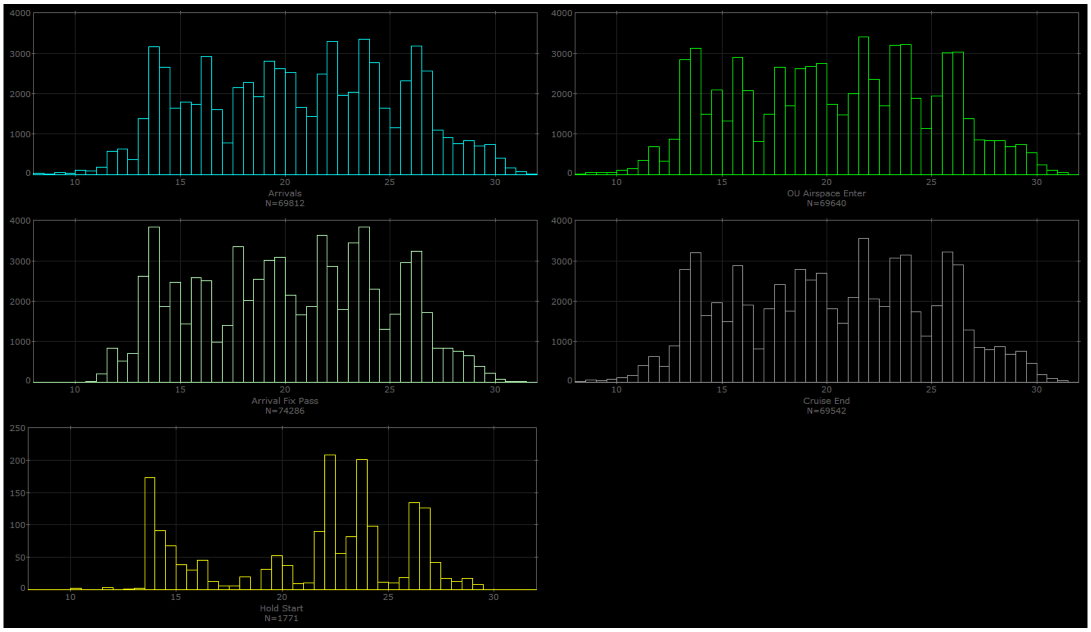

Figure 31. Timeline of Airspace Events Generated around MSP

The previous illustration highlights some important observations about the events generated during the analysis of the MSP, including:

- There are two distinct peaks of holds (yellow chart, bottom left) that occur for the arrival flow: one during the morning rush hour, and the other during the evening rush hour, as shown in Figure 31 above.
- The Arrival Fix Pass events (light green, middle left) occur in waves, spaced out every 90 - 120 minutes.
- The Outer Airspace Entry event (lime green, top right) almost follows the same pattern as the Arrival events. This is because most of the flights that enter the outer airspace, after a given period of time, arrive at the airport thus generating an Arrival event.

Figure 32 describes the arrival events that are generated once a trajectory has ended at the arrival airport, or close to the airport (within a given tolerance). Each chart shows the number of flights (vertical axis) in each hour of the day over a 30 hour period (horizontal axis). The figure shows the arrival timelines of all arrivals (top), and Delta Air Lines (bottom).

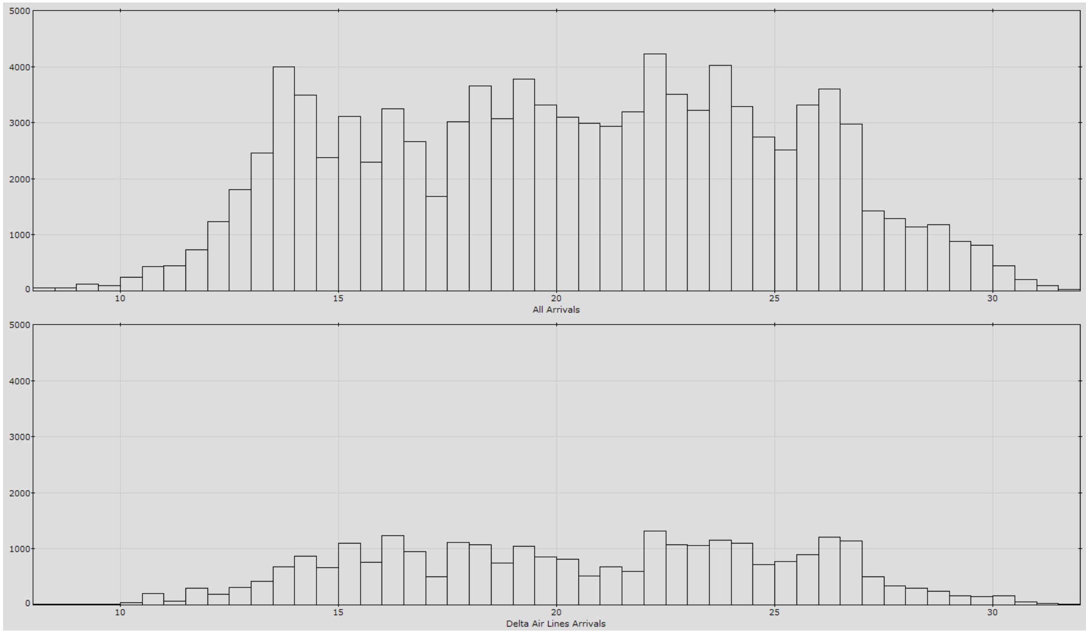

Figure 32. Arrival Timelines for MSP

3.5 Data Correlations

3.5.1 Arrival Rate versus Dwell Time Correlations

US Airways-CLT

The relationship of the arrival rate to the dwell time for each corner post is shown in Figure 33.

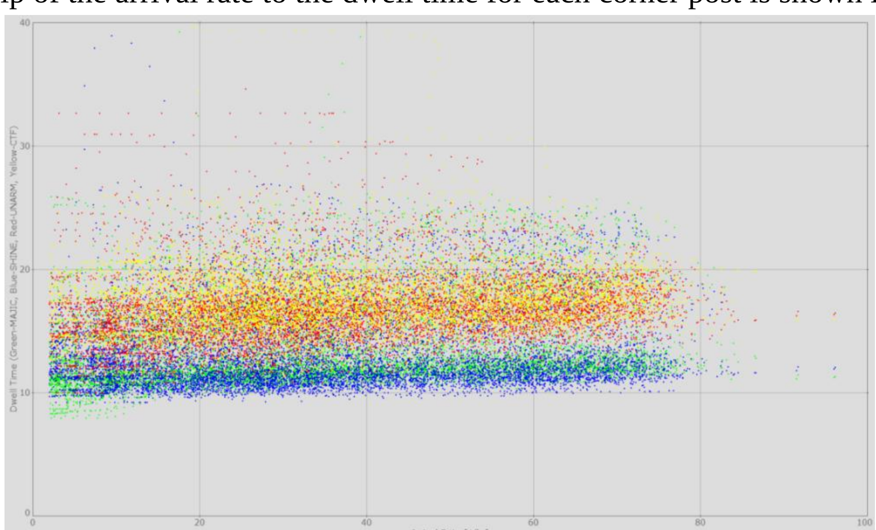

Figure 33. Correlation of Arrival Rate to Fix-Pass Dwell Time
(Color Legend: Green-MAJIC, Blue-SHINE, Red-UNARM, and Yellow-CTF)

In the figure above it does appear that as the arrival rate increases the dwell time also increases. This can be seen more clearly by observing the individual trend lines for each corner post in the following figures.

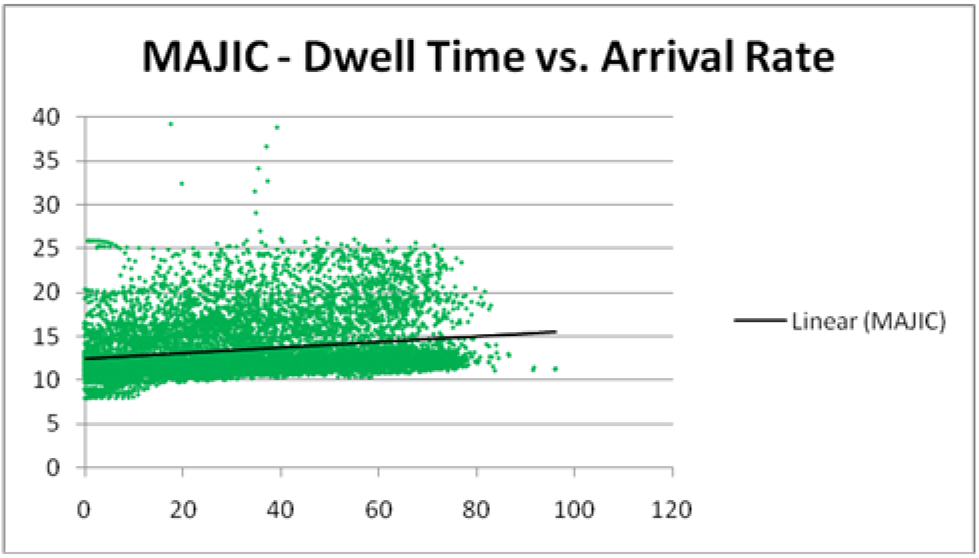

Figure 34. Correlation of Arrival Rate to MAJIC Dwell Time (minutes and flights per hour)

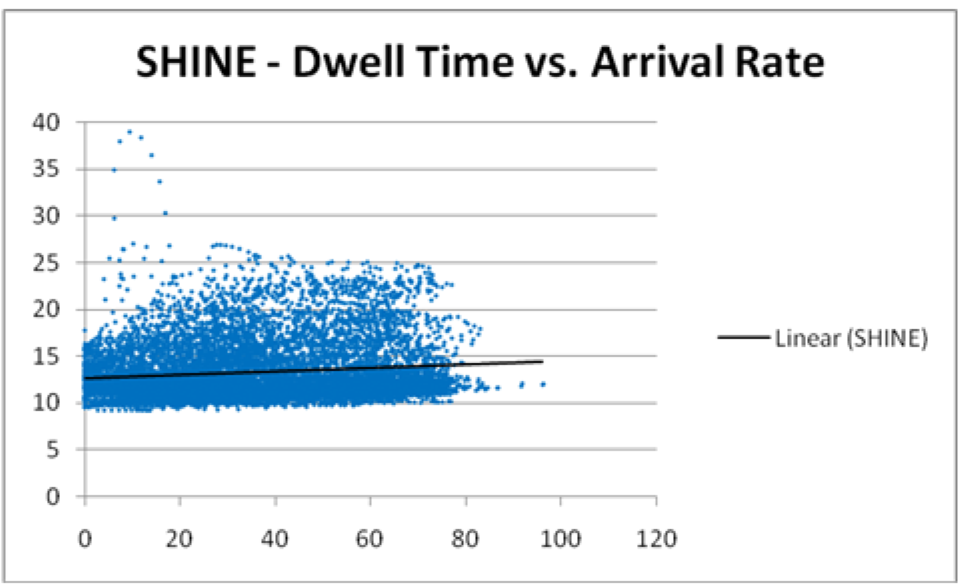

Figure 35. Correlation of Arrival Rate to SHINE Dwell Time (minutes and flights per hour)

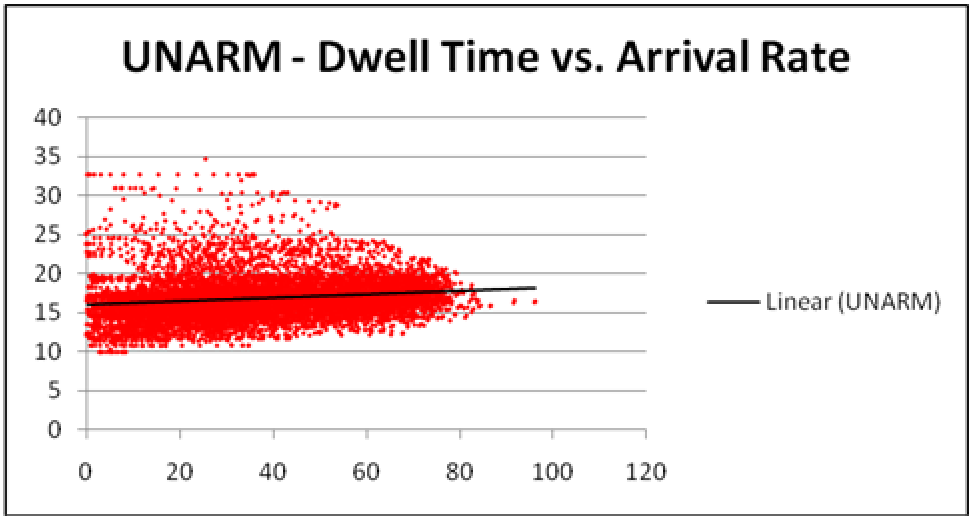

Figure 36. Correlation of Arrival Rate to UNARM Dwell Time (minutes and flights per hour)

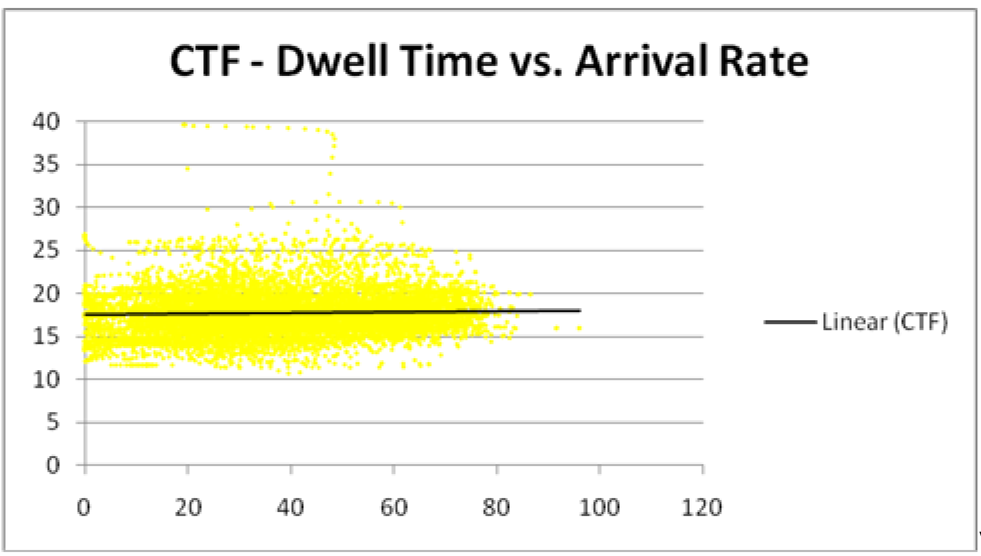

Figure 37. Correlation of Arrival Rate to CTF Dwell Time (minutes and flights per hour)

The preceding analysis shows that UNARM and MAJIC have the strongest correlation between the arrival rate and the dwell time while CTF has the weakest.

Delta Air Lines-MSP

The relationship of the arrival rate to the dwell time for each corner post is shown in the Figures 18 through 25. For each figure, the horizontal axis is the arrival rate, while the vertical axis is the dwell time (time from corner post to landing).

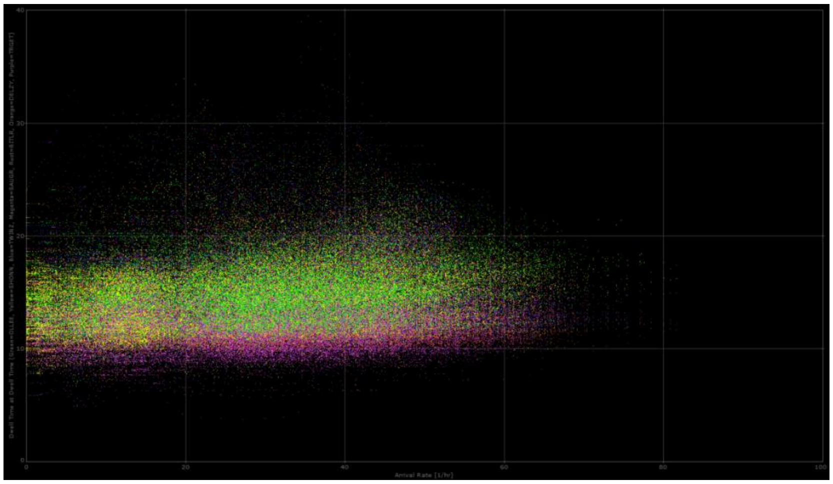

Figure 38. Correlation of Arrival Rate to Fix-Pass Dwell Time (Color Legend: Green=OLLEE, Yellow=SHONN, Blue=TWINZ, Magenta=SAUGR, Rust=BITLR, Orange=DELZY, Purple=TRGET)

In Figure 38 it appears that as the rate increases the dwell time also increases. This can be seen more clearly by observing the individual trend lines for each corner post. The subsequent figures show that all of the corner posts have relatively strong correlations between the arrival rate and the dwell time.

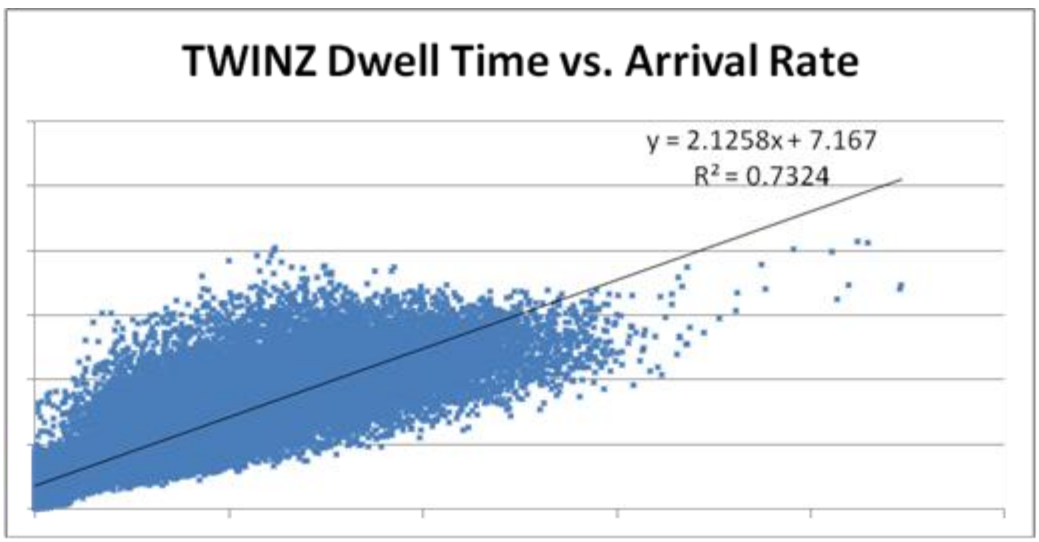

Figure 39. Correlation of Arrival Rate to TWINZ Dwell Time

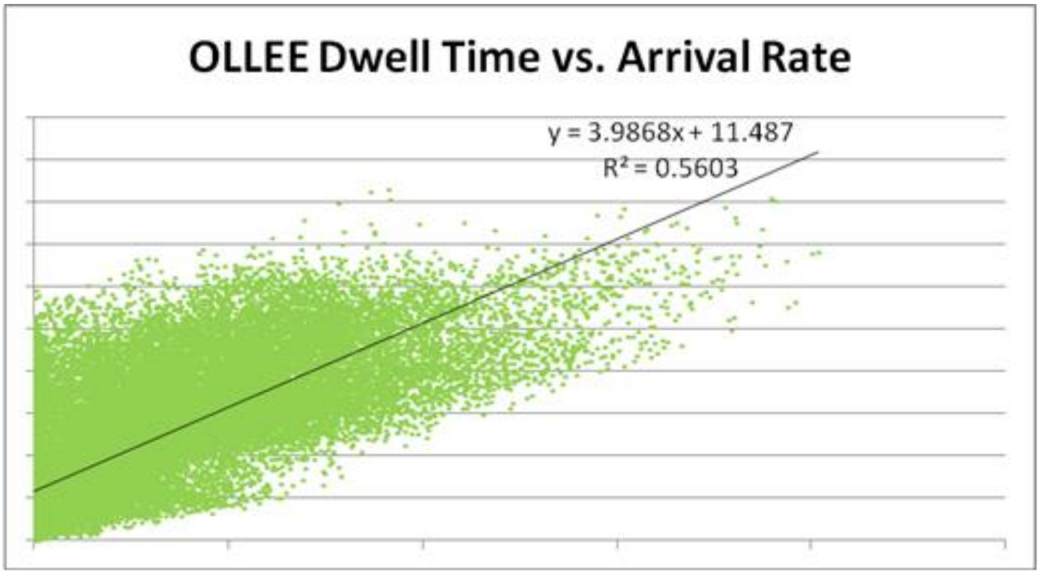

Figure 40. Correlation of Arrival Rate to OLLEE Dwell Time

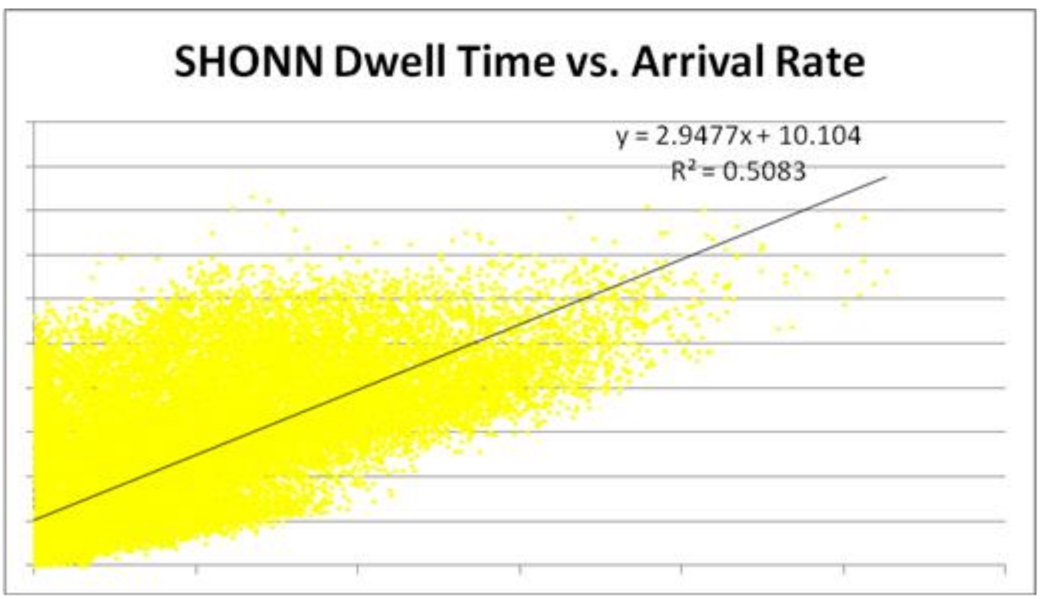

Figure 41. Correlation of Arrival rate to SHONN Dwell Time

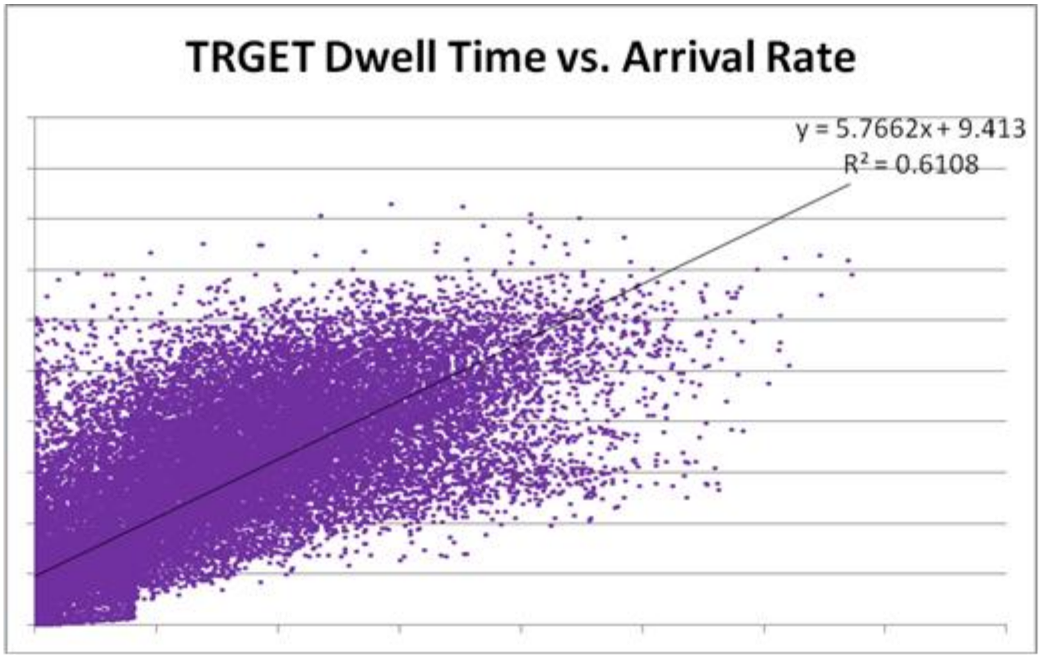

Figure 42. Correlation of Arrival Rate to TRGET Dwell Time

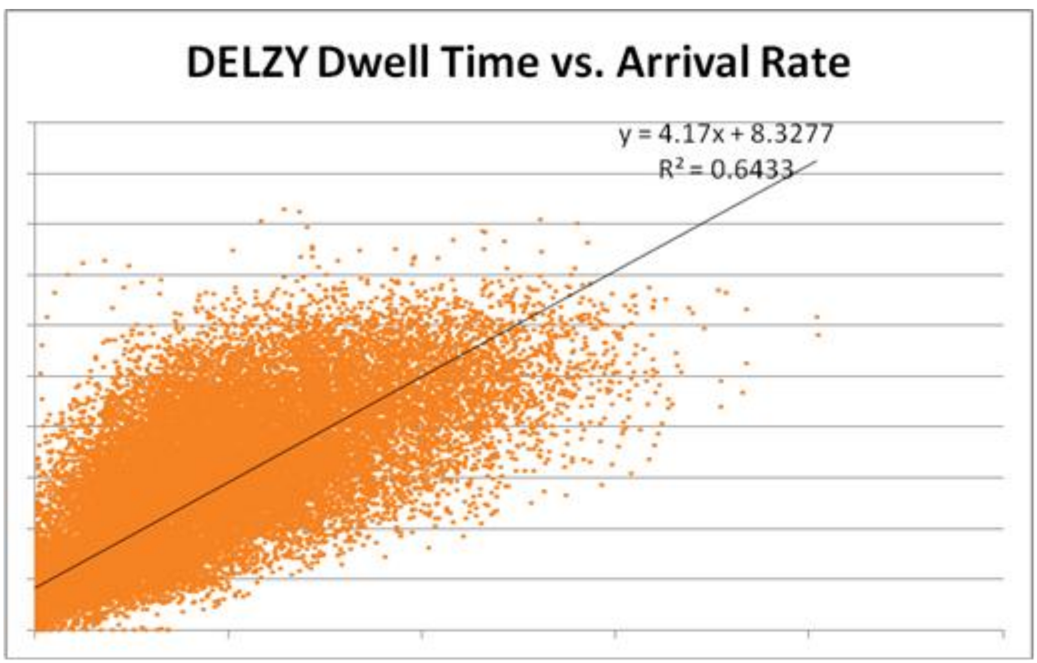

Figure 43. Correlation of Arrival Rate to DELZY Dwell Time

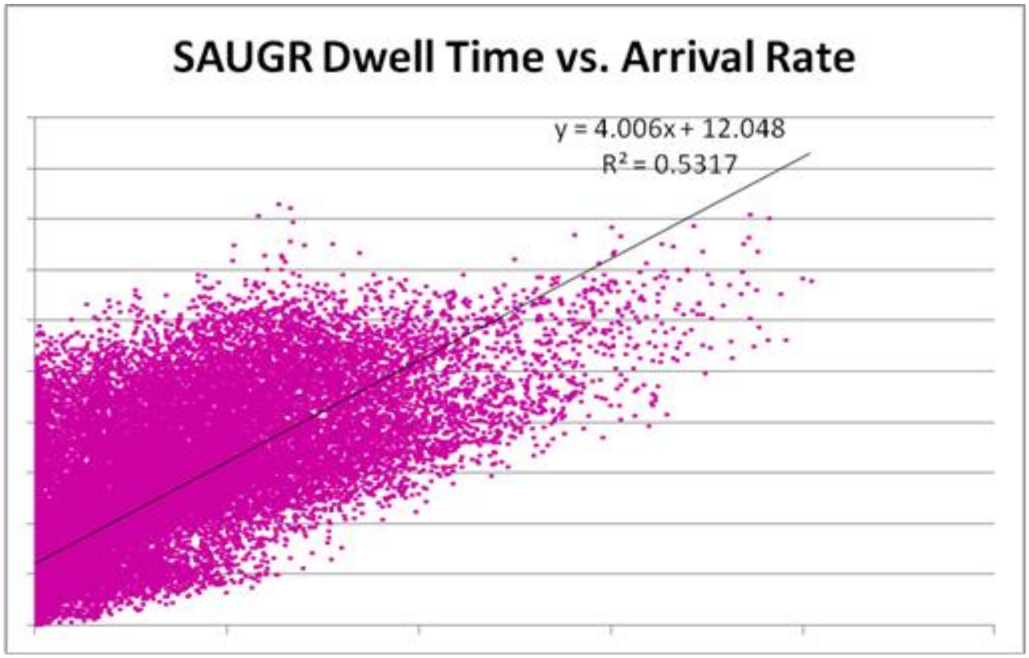

Figure 44. Correlation of Arrival Rate to SAUGR Dwell Time

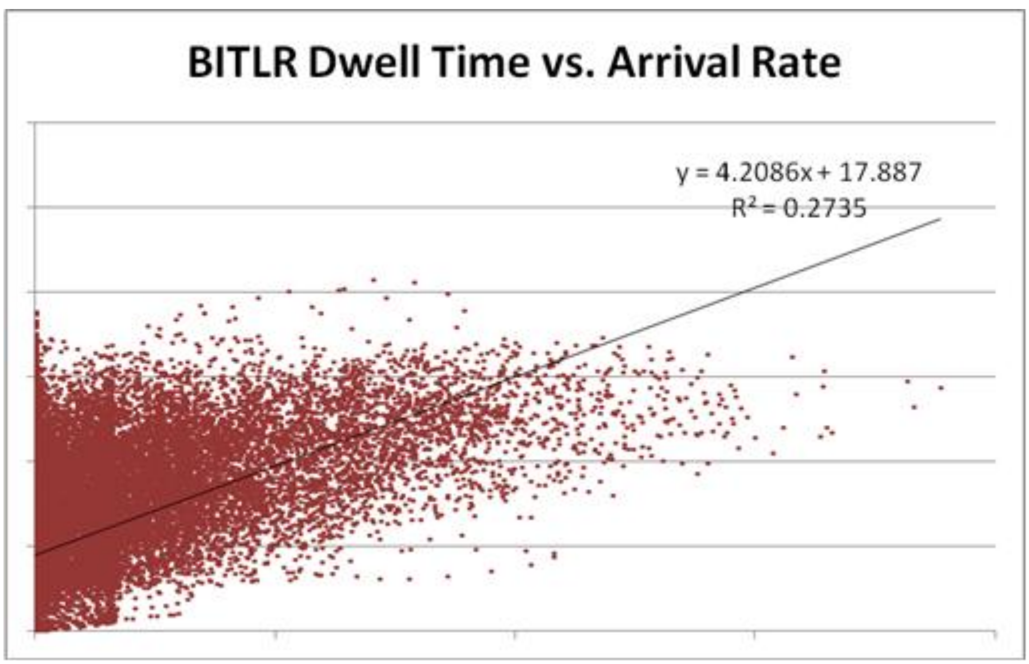

Figure 45. Correlation of Arrival Rate to BITLR Dwell Time

3.5.2 Correlations to Outer Ring (OU) Entry Time

US Airways-CLT

The following set of three timeline charts in Figure 49 indicates the following:

- The outer ring (OU) entry rate against the outer ring entry time (top), which clearly shows the nine distinct arrivals banks,
- The excess dwell distance as it relates to the OU entry time (center), which shows that during the same time as the peak entry rates (the arrival banks) increase, the excess dwell distance also increases. The excess dwell distance was any additional distance over direct distance from the cornerpost fix to the airport fix
- The averaged excess dwell distance as it relates to the OU entry time (bottom), which shows even more clearly that the excess distance was correlated to the arrival rate into the outer-ring. The averaged excess dwell distance was the average of excess distance for all flights within a 15 minute time window around the flight being considered.

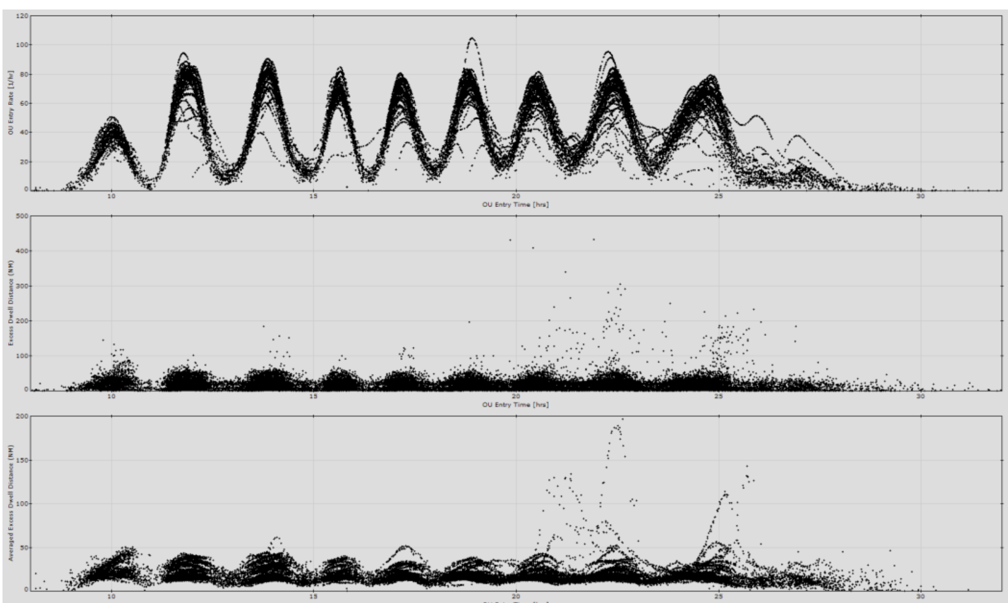

Figure 46: Correlation of the OU Entry Rate, Excess Distance and Average Excess Distance to the OU Entry Time

Figures 47 and 48 below indicate the following:

- The excess distance within the outer-ring against the outer-ring entry time. (top)
- The outer ring entry rate. (bottom)

Examining the two timelines, a clear relationship exists between entry rate and excess distance. One interesting exception was in the first bank which has a relatively low entry rate but has the highest excess distance. This was a result of noise/runway restrictions during the early morning hours.

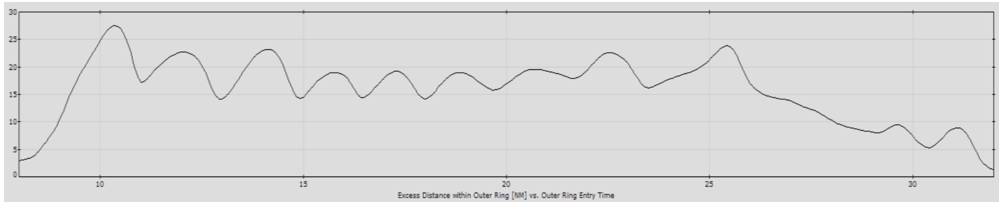

Figure 47: Correlation of Excess Distance within the Outer-Ring to the OU Entry Time

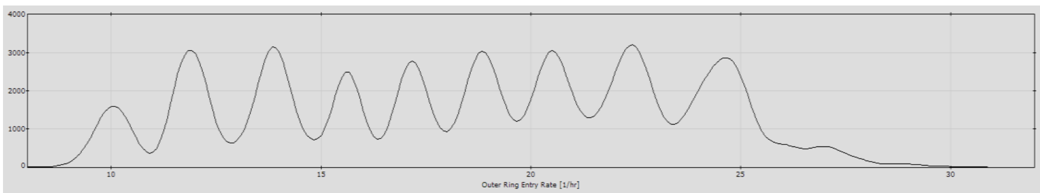

Figure 48: OU Entry Rate

Delta Air Lines-MSP

The following set of four timeline charts in Figure 49 indicates the following:

- The outer ring (OU) entry rate against the outer ring entry time (top), which clearly shows the seven distinct arrivals banks. There are two separate datasets observed, one during daylight savings time (November 1-6, 2010 and March 13-April 30, 2011), and another (the majority) period when daylight savings time ended (November 7, 2010 to March 12, 2011).
- The arrival fix pass rate against the entry time (second), which shows some distinct arrival banks but more importantly, shows a uniform conformance followed by the majority of the population. As with the earlier case, there are two separate datasets observed, one during daylight savings time (November 1-6, 2010 and March 13-April 30, 2011), and another (the majority) period when daylight savings time ended (November 7, 2010 to March 12, 2011).
- The runway arrival rate as it relates to the OU entry time (third), and
- The excess distance (NM) within the OU as it relates to the OU entry time.

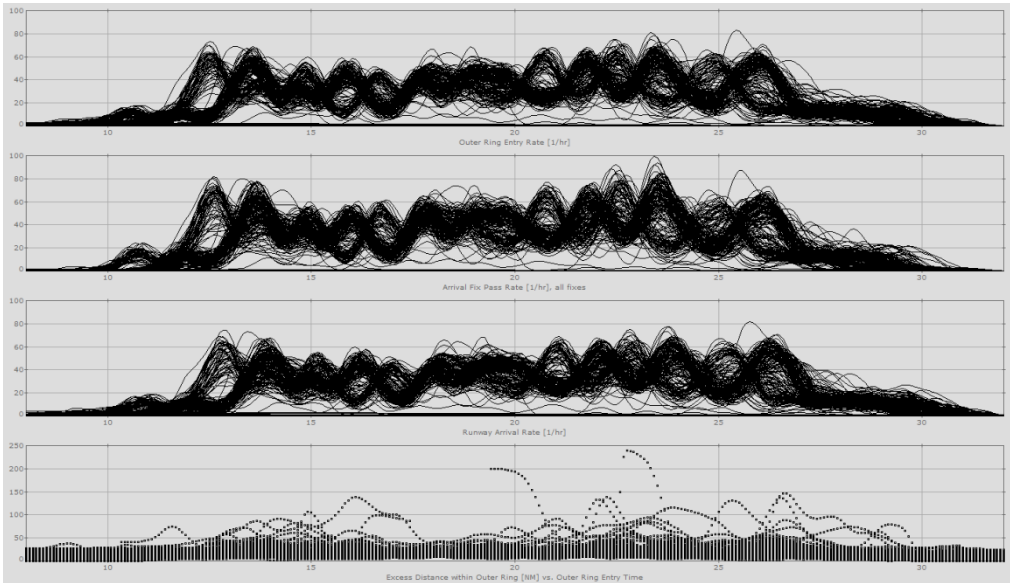

Figure 49. Correlation of the OU Entry Rate, Arrival Fix Pass Rate, Runway Arrival Rate and Excess Distance to the OU Entry Time (for the entire Passive-period)

When looking at just one period or the other (i.e., when DST has ended or started) a more uniform pattern amongst daily operation is noticed, as depicted in Figure 50.

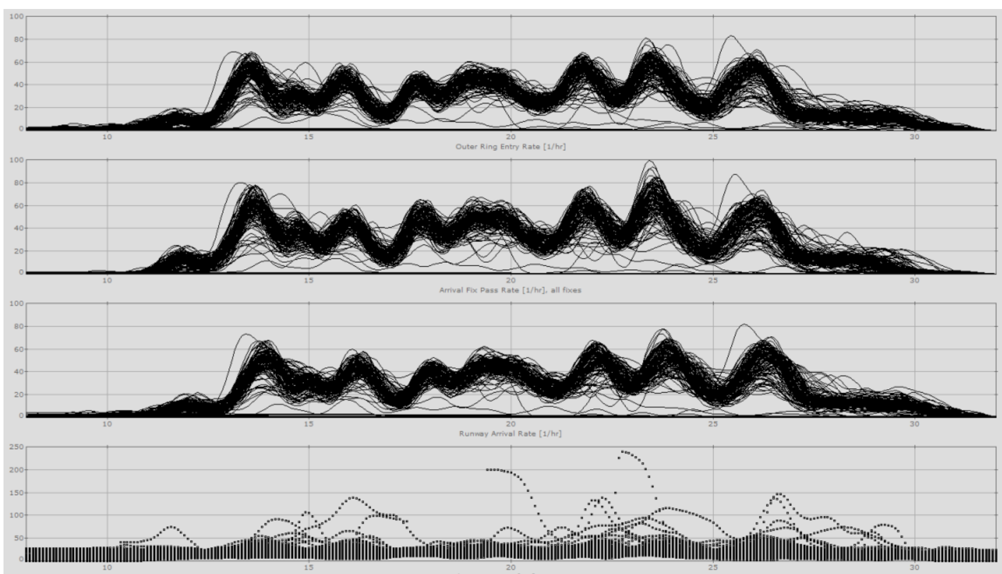

Figure 50. Correlation of the OU Entry Rate, Arrival Fix Pass Rate, Runway Arrival Rate and Excess Distance to the OU Entry Time (for period when DST ended: Nov.7, 2010 - Mar.12, 2011)

Figures 51 and 52 provide the following:

- The excess distance within the outer-ring against the outer-ring entry time (below)
- The outer ring entry rate (page 75).

Examining the two timelines, a clear relationship exists between entry rate and excess distance. One interesting exception is in the first bank which has a relatively low entry rate but has the highest excess distance. This is a result of noise and runway restrictions during the early morning hours.

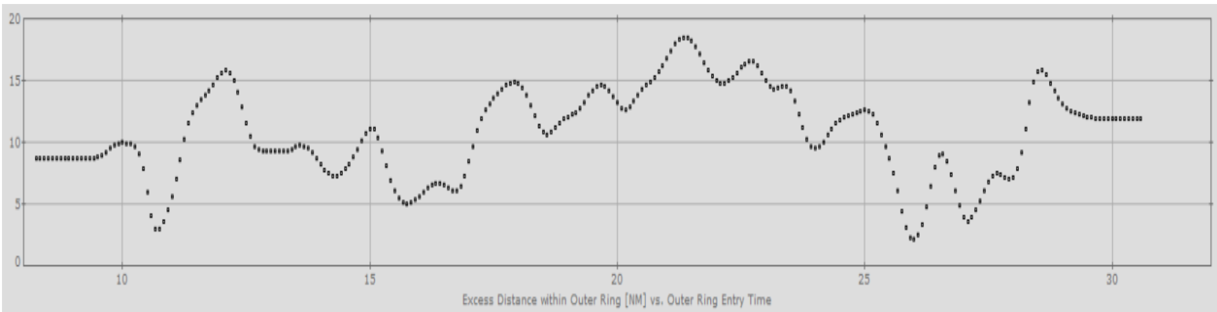

Figure 51. Correlation of Excess Distance within the Outer-Ring to the OU Entry Time (for a single day)

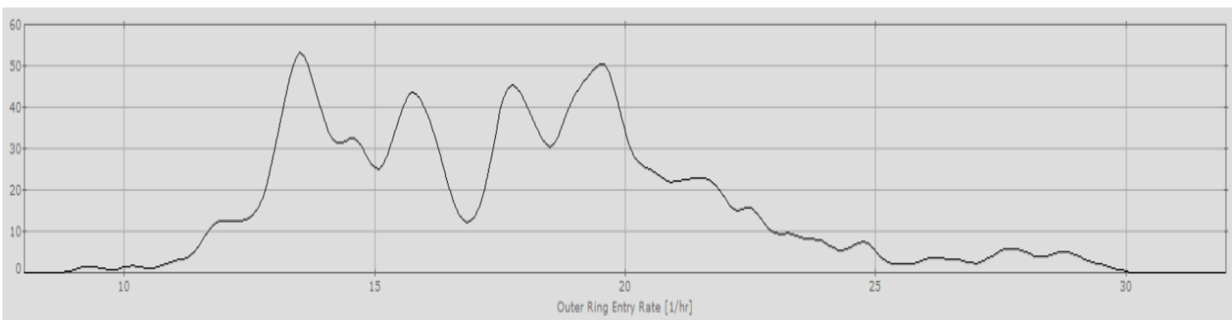

Figure 52. OU Entry Rate (for a single day)

4 TEST DESCRIPTION

This section provides detailed description of the active and passive test procedures used in the pre exchange test (single user) and operational exchange tests (multi user). In addition, it describes the methods used by both aircrews and AOC personnel to execute the test procedures.

4.1.1 Black Book Testing

The purpose of the black book test was to verify that the pilot's perception of estimated corner post time is consistent with the software's calculation of the estimated corner post time. During the CLT Passive AAMS data collection phase, the Task J Research Team worked with US Airways to collect aircraft Flight Management System (FMS) information and other aircraft related data. The purpose of this data was to correlate the software's prediction and potential RTA, with the on board FMS, the flight plan prediction and US Airways operational procedures.

US Airways and ATH have developed an instruction and data collection form which was given to a select group of US Airways Check Airmen (CKAM). US Airways Check Airmen were assigned specific "fly" trips each month. The forms were printed and distributed to the CKAMs prior to beginning the Black Book Test. The involved trip pairing data was provided to all parties participating in the Black Book Test.

The US Airways team would select individual flights with a CKAM as the pilot. During the Black Book test, the RTA data for those CLT bound flights were manually provided to the Dispatcher, who then sent an ACARS message to the crew with the RTA and planned corner post (i.e., "AAMS requests Flight 42 to cross MAJIC at 1230z. If there is a conflict, follow the ATC instructions and disregard the application RTA message.")

The CKAM then adjusted speed to meet the RTA and recorded the requested data, when time and safety permitted. The CKAMs were notified that AAMS system RTA was an internal US Airways program, and that it should not be discussed on the radio.

The Black Book Test was run for three weeks on a few flights per day to collect the necessary data.

4.1.2 AAMS Data

There are three main types of data files generated by the AAMS operational software that are used for statistical purposes:

- .atx - this file contains a record for each completed flight containing event time and other data on the flight. The file is a text file that can be imported into a spreadsheet or database.
- .stl - this file contains a status log of AAMS operations, it records when RTA

generation was on or off, changes in airport arrival rate and in airport configuration.

- .trj - this file contains the as flown trajectories, recorded when the flight has been completed.

The .atx and .stl file are used by the AAMS statistic program to generate the daily statistics. The definition of the data fields in these two files are provided in this document.

The .trj file is used by AViD to visualize the flown traffic for a day and also by FlightScope™ in doing -day analysis. The .trj content is defined in the AwSim™ Data File Standards (A-REF-046) document.

Each of the files is written as a serial numbered file, with the file closed out at the end of the day (this is defined by an initialization parameter as eight hours after midnight GMT). Until the file is closed out, the file type has an underscore character (_) appended to it to indicate it is still an open file.

After the day is closed out, the archiving program runs and merges (if there are multiple files in the day due to a restart) and puts the files into a daily directory with the file name for each of the files being YYMMDD.

Additional Information about the AAMS data can be found in the AAMS MSP Data Collection and Test Plan document.

4.1.3 Non AAMS Data

US Airways-CLT

US Airways provided the following data monthly for statistical analysis purposes:

- Operational statistics for each US Airways and PSA flight arriving to CLT during active data collection period, including scheduled and actual departure and arrival times, scheduled and actual taxi times and total fuel consumed.
- Scheduled and actual taxi out times for each US Airways and PSA flight departing CLT during active data collection period.
- All US Airways and PSA flights that were designated as TCI flights during active data collection period (TCI is a program to US Airways to conserve fuel by adjusting cruise speeds of flights not in danger of arriving late).
- All US Airways and PSA flights that were designated as CF during active data collection period.
- Archived FAA NOTAM data with CLT runway closures dates and times.

The FAA provided TMA metering status data for CLT.

Delta Air Lines-MSP

In addition to the data collected through the AAMS the following have also contributed to the analysis:

- TMA operation status records from the FAA to allow an analysis of any conflicts or synergies between TMA and AAMS system operations
- NOTAM data concerning runway closures obtained from Minneapolis St. Paul Metropolitan Airports Commission (MSP MAC)
- Trip Fuel consumption provided by Delta Air Lines
- A log of software, goal function, or any other system related changes implemented during the Active and Passive Periods provisioned by ATH
- Scheduled and Actual Departure and Arrival Times furnished by Delta Air Lines
- Scheduled and Actual Taxi-In and Taxi-Out Times provided by Delta Air Lines

The MSP Runway NOTAMs and TMA records were used to partition the AAMS data sets for more thorough analysis of the interactions of AAMS with these related events.

4.2 Passive Phases

In the Passive Phases, the optimal RTAs were calculated by the AAMS application. However, since the Passive Phases were an offline analysis using recorded data, the calculated RTAs were not sent to the aircraft. This was to ensure that the system algorithm is properly calibrated for the airport's operations.

The steps to accomplish this included:

- Importing the necessary data into the system software (Class I or II ASDI data, winds, schedule, runway direction, FAA called landing rate, airline goal function),
- Calculating the RTA,
- Not sending the RTA to the aircraft,
- Measuring the benefits using AST.

This process was performed on the CLT and MSP Passive data sets. A graphical overview of the data capture in the AAMS is provided in Figure 53.

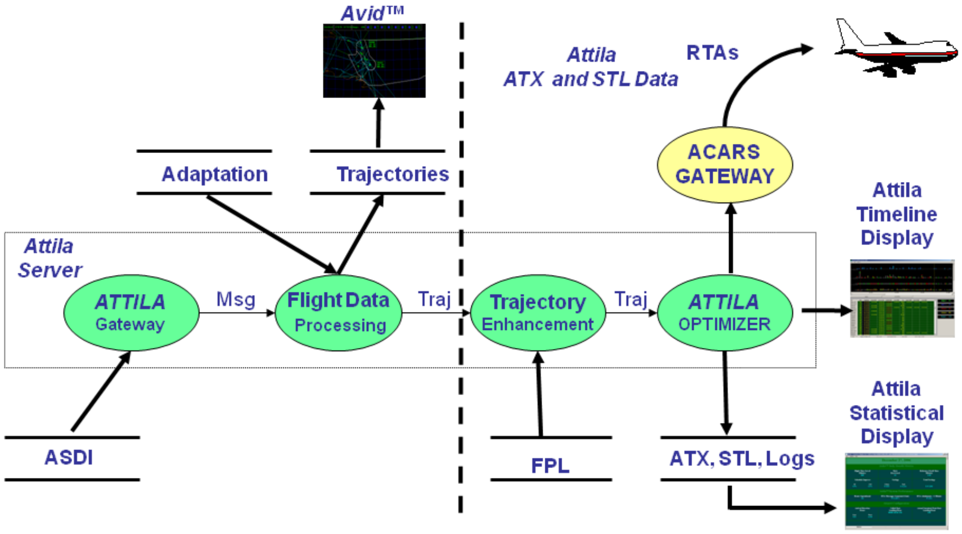

Figure 53. AAMS Data Capture Partition

4.3 Active Phases

During the CLT and MSP Active Phases the AAMS software calculated the optimal RTAs. Differing from the Passive Phases, in the Active Phase RTAs were uplinked to the participating aircraft. The designation of the aircraft (tail number) and the ACARS and AeroData messaging capability was provided by the airlines.

It is expected that if the system worked as designed and the pilots met the assigned RTAs, then the AAMS benefits should become apparent when compared to the Passive Phase.

The steps to accomplish this included:

1. Importing the necessary data into the system software (Class I ASDI data, winds, schedule, runway direction, FAA called landing rate, airline Goal Function),
2. Calculating the RTA,
3. Sending the RTA to the aircraft,
4. Measuring benefits using the AST.

4.3.1 Single Airline AAMS

The CLT Active Phase 1 and MSP Active Phase of the data collection were procedurally similar to the passive phase. In this phase the AAMS calculated the RTAs applying the same methodology as in the passive phase, but the RTAs were sent to participating aircraft using a single airline-centric system. Assigned RTAs and actual corner post arrival data were collected for comparison. Only US Airways mainline aircraft participated in the CLT Active Phase 1.

4.3.2 Multiple Airline AAMS

The CLT Active Phase 2 marked the beginning of the multi-user environment at CLT. PSA fleet was added to the demonstration environment. In this active stage, the same data that was collected in CLT Active Phase 1 and MSP Active Phase was compiled, and the RTAs were sent to the en route aircraft using the AAMS systems installed in the AOCs to work in coordination with the AAMS Exchange system. Assigned RTAs and actual corner post arrival data were collected for comparison. This period is called the CLT AAMS Exchange Operation.

5 PERFORMANCE ANALYSIS

The operational performance at the AAMS airports is outlined in the following sections and is categorized by AAMS airport and operational Phase.

5.1 AAMS Passive Period Performance at CLT

5.1.1 Descriptive Statistics

Figure 54 provides overall descriptive information about the data used in the analysis. Eighty seven percent (87%) of all arrivals recorded in the first passive period with 13% recorded in the second passive period. Of the total 71,933 arrivals, 35% belong to US Airways (USA), 18% belong to PSA and the remaining 47% represent non-participating air carriers and general aviation traffic.

Figure 54 also presents the distribution of arrivals among four corner posts at CLT: UNARM, MAJIC, SHINE, and CTF with 21%, 27%, 33% and 19%, respectively. In addition, 61% of all arrivals were conducted during the south runway arrival configuration, while the north runway configuration was active during 39% of arrivals. About 88% of arrivals occurred when TMA metering was on. About 46% of arrivals occurred while at least one of the runways at CLT was closed and 8% of US Airways flights were conducted under the carrier's TCI program. Under the agreement between ATH and US Airways, TCI flights cannot be optimized and effectively are treated as non-participating flights. Representative days that are defined as days when more than 70% of flights arrive within 15 minutes of scheduled arrival time (A14) encompass 94% of the passive data collected.

The baseline statistical information is presented in the following sections. In addition to actual distribution histograms for each variable, the best-fit theoretical distributions are also provided. In addition to mean, standard deviation, range and other descriptive statistics information, the change in the distribution property will provide addition insights on the impact of the AAMS on arriving traffic.

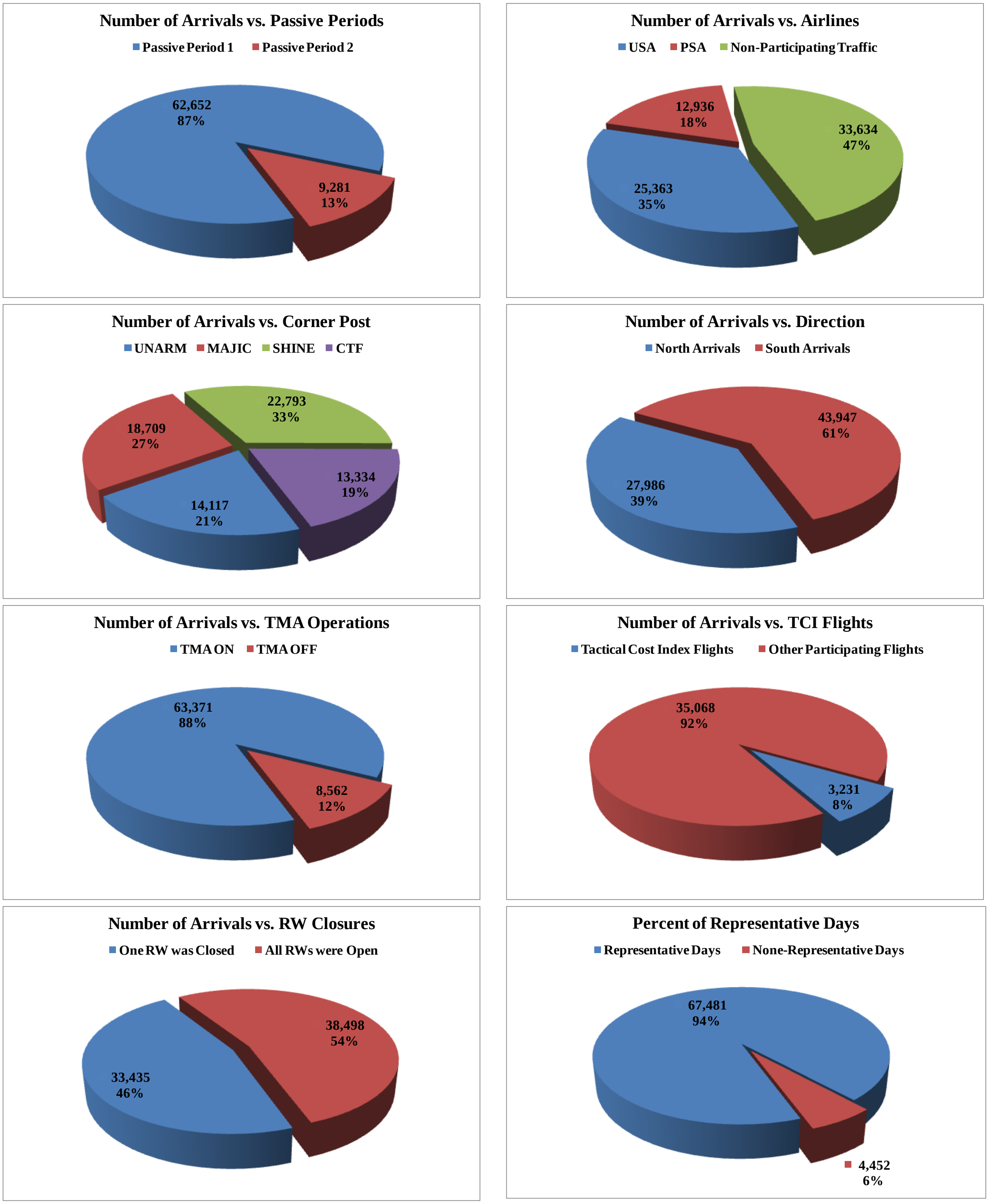

Figure 54. Data Description and Distribution for Passive Periods

5.1.2 Data Summary

The data is summarized as follows:

- Table 15 presents averages and standard deviations of dwell times for each corner post and arrival configuration, status of TMA operations and runway closures.
- Table 16 summarizes the dwell and total fuel consumption.
- Table 9 presents the baseline data for en route, taxi in and taxi out times.
- Table 10 contains the information on the baseline on-time arrival and taxi performance. All data is presented for the overall passive data collection period, as well as for two passive periods separately.

Table 15. Baseline Data for Dwell Times (minutes)

	All Passive Data		*Passive Period 1*		*Passive Period 2*	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*
UNARM SOUTH	18.02	2.73	18.12	2.75	17.14	2.34
UNARM NORTH	16.86	2.76	17.00	2.80	15.71	2.08
MAJIC SOUTH	13.52	6.01	13.45	6.19	14.01	4.54
MAJIC NORTH	19.97	6.61	19.90	6.83	20.34	5.07
SHINE SOUTH	13.13	5.07	13.18	5.34	12.82	2.68
SHINE NORTH	18.46	5.20	18.57	5.10	17.85	5.68
CTF SOUTH	18.52	4.45	18.51	4.16	18.57	5.92
CTF NORTH	16.45	4.83	16.47	5.02	16.32	3.31
TMA is ON	16.39	5.77	16.40	5.85	16.32	5.23
TMA is OFF	15.76	5.53	15.80	5.63	15.52	4.88
All Runways	16.24	5.22	16.32	5.21	15.83	5.23
Closed Runway	16.41	6.34	16.34	6.45	17.20	4.95

Table 16. Baseline Data for Dwell and Total Fuel Consumption (pounds)

	All Passive Data		*Passive Period 1*		*Passive Period 2*	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*
Dwell Fuel Consumption	1,177	679	1,178	691	1,174	600
Total Fuel Consumption	9,848	12,110	9,886	12,228	9,592	11,270

Table 17. Baseline Data for En Route and Taxi Times (minutes)

	All Passive Data		*Passive Period 1*		*Passive Period 2*	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*
Total Time En Route (USA and PSA)	93.7	67.3	93.8	67.9	92.7	63.4
Total Time En Route (All Traffic)	77.6	47.3	77.2	46.1	79.7	53.7
Taxi In Time	8.16	4.21	8.08	4.12	8.72	4.77
Taxi Out Time	18.15	8.49	18.18	8.58	17.93	7.93

Table 18. Baseline Data for On-Time Arrival and Taxi Performance

	All Passive Data	*Passive Period 1*	*Passive Period 2*
	Percent of Flights	*Percent of Flights*	*Percent of Flights*
Flights Arrived As Scheduled USA and PSA (A0)	64.9%	64.9%	61.9%
Flights Arrived within 15 min USA and PSA (A14)	86.8%	86.8%	84.0%
Flights Arrived As Scheduled All Traffic (A0)	66.8%	66.8%	59.0%
Flights Arrived within 15 min All Traffic (A14)	87.1%	87.1%	82.5%
Flights Taxied In As Scheduled	56.8%	56.8%	53.4%
Flights Taxied Out As Scheduled	71.0%	71.0%	69.3%

5.2 AAMS Active Periods Performance at CLT

5.2.1 AAMS Active Phase 1 (Single Airline Period)

5.2.1.1 Descriptive Statistics

Figure 55 provides overall descriptive information about the data collected. Of the total 81,131 arrivals during the CLT Active Phase 1 period, 34% belong to US Airways (USA), 17% belong to PSA and the remaining 49% represent non-participating air carriers and general aviation traffic. Figure 55 also presents the distribution of arrivals among the corner posts at CLT; UNARM, MAJIC, SHINE, and CTF with 21%, 26%, 33% and 20%; respectively. In addition, 67% of all arrivals were conducted during the south runway arrival configuration, while the north runway configuration was active during 33% of arrivals. About 87% of arrivals occurred when TMA metering was on. About 56% of arrivals occurred while at least one of the runways at CLT was closed. US Airways TCI and CF programs contained 1,671 and 129 flights, respectively. Under the agreement between ATH and US Airways TCI and CF flights cannot be optimized and are treated as non-participating flights. The overall potential optimization pool for the CLT Active Phase 1 period consisted of 24,296 flights (29.2% of all arrivals); 15,404 RTAs were issued (18.5% of all arrivals), and 5,408 flights (6.5% of all arrivals) complied with an issued RTA. RTA compliance was recorded if a flight passed a corner post within 60 second of an issued RTA.

More extensive statistical information is presented in the following sections. In addition to actual distribution histograms for each variable, the best-fit theoretical distributions are also provided. Besides mean, standard deviation, range and other descriptive statistics information; the change in the distribution property provides additional insights to the impact of the AAMS on arriving traffic.

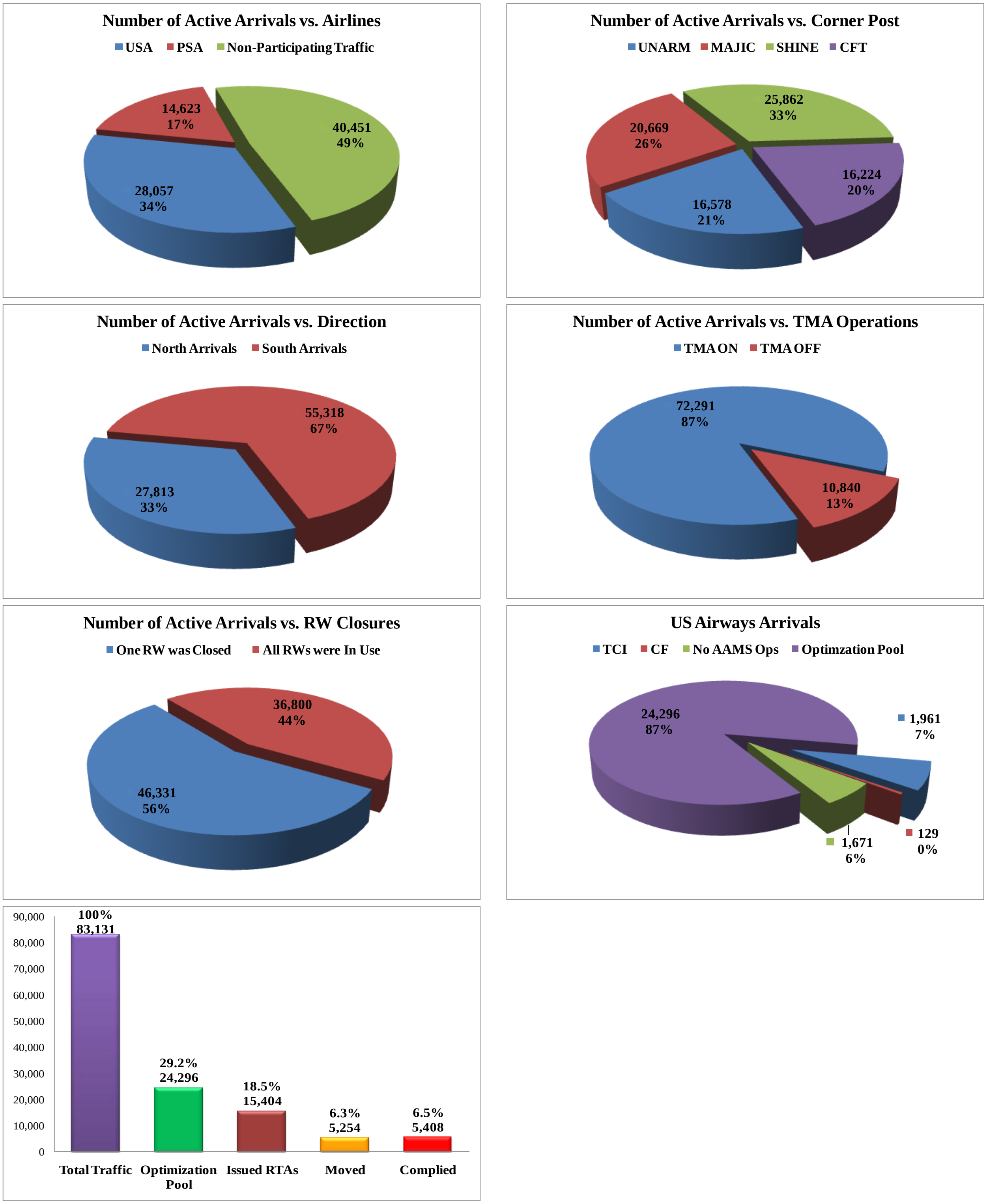

Figure 55. CLT Active Phase 1 Data Description and Distribution

5.2.2 AAMS Active Phase 2 (Exchange Operations)

5.2.2.1 Descriptive Statistics

Figure 56 provides overall descriptive information about the data collected during the CLT Active Phase 2 period.

The CLT Active Phase 2 period represents 43% of the total arrivals that were recorded and analyzed in all data collection periods. Of the total 117,080 arrivals during the CLT Active Phase 2 period, 34% belong to US Airways, 18% belong to PSA Airlines (PSA) and the remaining 48% represent non-participating air carriers and general aviation traffic. Figure 23 also presents the distribution of arrivals among the corner posts at CLT; UNARM, MAJIC, SHINE, and CTF with 20%, 26%, 34% and 20%; respectively. In addition, 69% of all arrivals were conducted during the south runway arrival configuration, while the north runway configuration was active during 31% of all arrivals. About 91% of arrivals occurred when TMA metering was on. About 55% of arrivals occurred while at least one of the runways at CLT was closed. US Airways TCI and CF programs included 2,746 and 223 flights, respectively. Under the agreement between ATH and US Airways TCI and CF flights could not be optimized and were treated as non-participating flights. The overall potential optimization pool for the CLT Active Phase 2 period consisted of 57,487 flights (49.1% of all arrivals); 25,493 RTAs were issued (21.8% of all arrivals), and 8,867 flights (7.6% of all arrivals) complied with an issued RTA. RTA compliance was recorded if a flight passed a corner post within 60 second of an issued RTA.

Figure 57 provides descriptive statistics for a subsample of data collected during the runway construction period from August 15 to October 24, 2011. Out of the total 48,193 arrivals during this period, 27% (13,030) of the arrivals were conducted when the AAMS was in passive mode, while 73% (35,163) flights arrived when the AAMS was in active exchange mode. Similar to the overall CLT Active Phase period, of the total arrivals during the runway construction period, 34% belong to US Airways, 18% belong to PSA Airlines (PSA) and the remaining 48% represent non-participating air carriers and general aviation traffic. Figure 24 also presents the distribution of arrivals among the corner posts at CLT; UNARM, MAJIC, SHINE, and CTF with 21%, 26%, 34% and 19%; respectively. About 85% of arrivals occurred when TMA metering was on. On active days of the runway construction period US Airways TCI and CF programs included 924 and 53 flights, respectively. The overall potential optimization pool for the CLT Active Phase 2 of the runway construction period consisted of 17,408 flights (49.5% of all arrivals); 7,157 RTAs were issued (20.4% of all arrivals), and 2,415 flights (6.9% of all arrivals) complied with issued RTAs. Overall, the sample of runway construction period is remarkable similar to the whole CLT Active Phase 2.

More extensive statistical information is presented in the following sections. In addition to actual distribution histograms for each variable, the best-fit theoretical distributions are also provided. Besides mean, standard deviation, range and other descriptive statistics information; the change in the distribution property provides additional insights to the impact of the AAMS on arriving traffic. As described below, the runway construction subsample is very similar to the rest of the data collection period with respect to the distribution of arrivals among corner posts, runway configurations, TMA operations, mix of participating and non-participating airlines, and optimization rates.

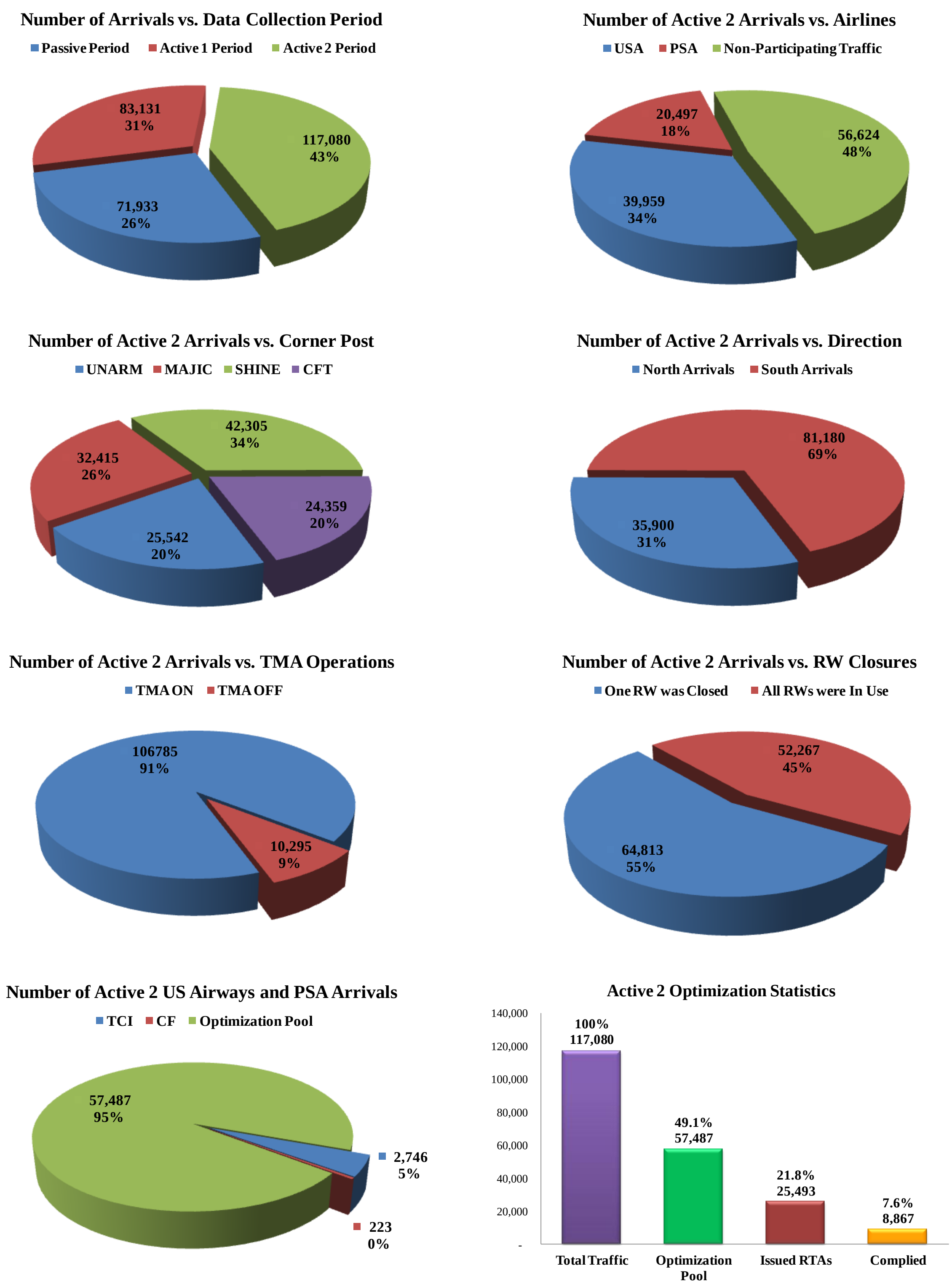

Figure 56. CLT Active Phase 2 data description and distribution

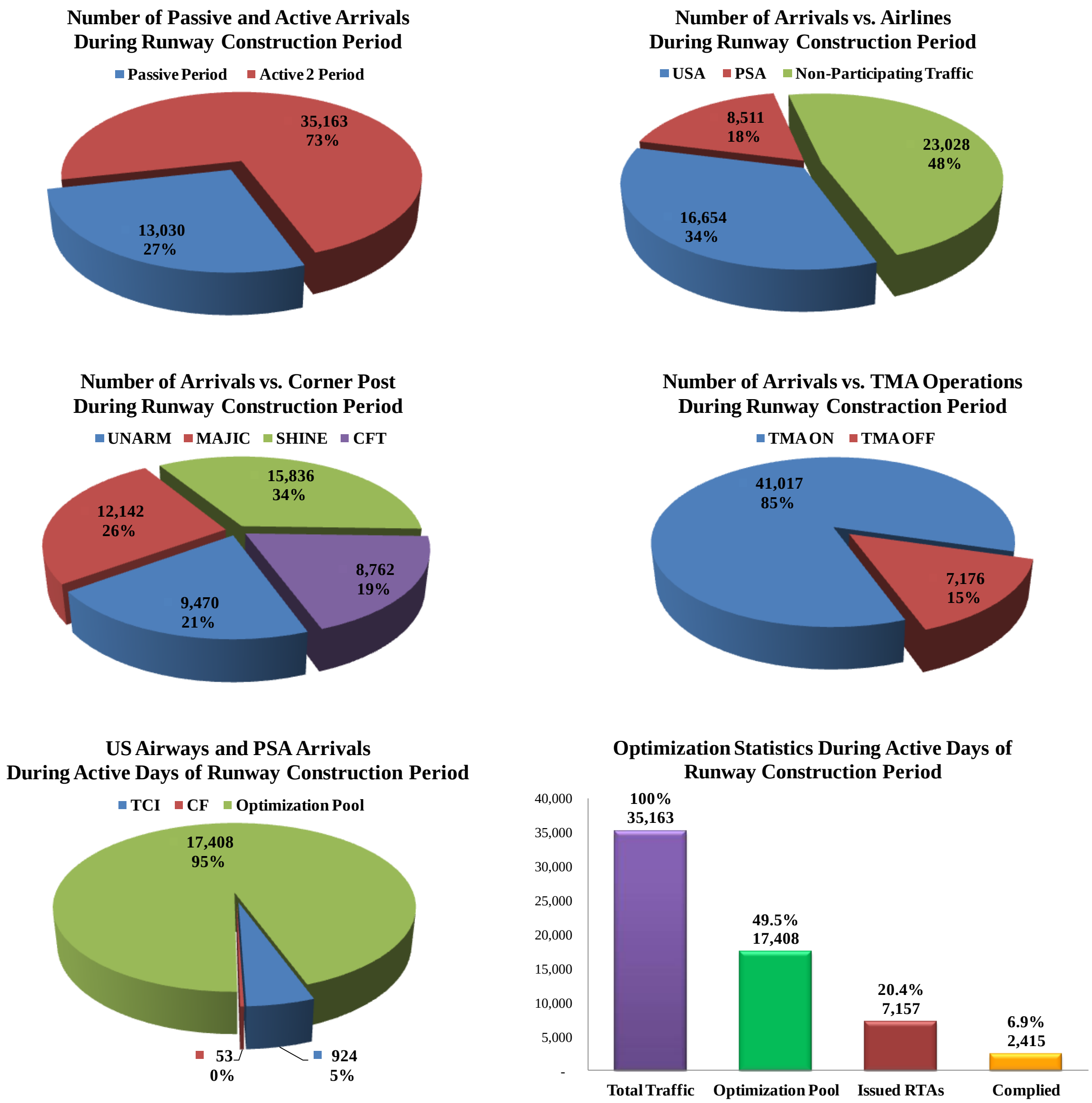

Figure 57. Runway construction period subsample data description and distribution

5.2.3 Data Summary (CLT Active Phase 1 and Active Phase 2)

The AAMS Test Procedures Plan specified the data to be collected during the CLT Active AAMS operation phases. The data is summarized and the mean differences between the CLT Passive and Active Phase 1 and Active Phase 2 Operation are provided as follows.

- Table 19 presents averages and standard deviations of dwell times for each corner post and arrival configuration, status of TMA operations and runway closures.
- Table 20 summarizes the dwell and total fuel consumption.
- Table 21 presents the data for en route, taxi in and taxi out times.
- Table 22 contains information on the on-time arrival and taxi performance.

Each table has two panels: Panel A presents the data for all phases of data collection; and Panel B presents the data subset for the runway construction period (August 15 – October 24, 2011).

Table 19. CLT Active Phases Data for Dwell Times (minutes)

Panel A. All Phases of Data Collection.

	Passive Data		*Active Phase 1 Data*		*Active Phase 2 Data*		*Difference in Means*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
UNARM SOUTH	18.02	2.73	18.53	6.82	17.96	7.38	0.51	-0.06
UNARM NORTH	16.86	2.76	16.67	10.09	15.66	7.12	-0.19	-1.20
MAJIC SOUTH	13.52	6.01	14.11	6.13	13.13	7.38	0.59	-0.39
MAJIC NORTH	19.97	6.61	19.39	7.76	19.19	6.48	-0.58	-0.78
SHINE SOUTH	13.13	5.07	13.85	6.02	12.95	7.42	0.72	-0.18
SHINE NORTH	18.46	5.20	17.59	7.82	17.88	7.17	-0.87	-0.58
CTF SOUTH	18.52	4.45	19.3	7.79	18.22	8.90	0.78	-0.30
CTF NORTH	16.45	4.83	17.44	10.76	15.83	5.91	0.99	-0.62
TMA is ON	16.39	5.77	16.57	6.59	15.70	6.75	0.18	-0.69
TMA is OFF	15.76	5.53	16.85	13.39	16.09	11.49	1.09	0.33
All Runways	16.24	5.22	16.26	6.5	15.47	7.57	0.02	-0.77
Closed Runway	16.41	6.34	17.05	9.19	16.16	8.13	0.64	-0.25

Panel B. Runway Construction Period Subsample.

	Passive Data		*Active Phase 1 Data*		*Active Phase 2 Data*		*Difference in Means*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
UNARM SOUTH	18.31	4.24	N/A	N/A	18.30	8.01	N/A	-0.01
UNARM NORTH	15.20	3.76	N/A	N/A	15.43	7.96	N/A	0.23
MAJIC SOUTH	12.50	6.03	N/A	N/A	13.15	9.28	N/A	0.65
MAJIC NORTH	19.64	6.09	N/A	N/A	19.30	6.73	N/A	-0.34
SHINE SOUTH	13.39	6.56	N/A	N/A	13.37	6.89	N/A	-0.02
SHINE NORTH	18.16	6.01	N/A	N/A	17.76	7.07	N/A	-0.40
CTF SOUTH	17.88	7.54	N/A	N/A	18.20	9.76	N/A	-0.32
CTF NORTH	15.66	3.97	N/A	N/A	15.45	6.22	N/A	-0.21
TMA is ON	15.93	5.84	N/A	N/A	16.07	6.61	N/A	0.14
TMA is OFF	15.22	9.55	N/A	N/A	16.26	14.05	N/A	1.04
All Runways	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Closed Runway	15.84	6.48	N/A	N/A	16.13	7.89	N/A	0.29

Table 20. CLT Active Phases Data for Dwell and Total Fuel Consumption (pounds)

Panel A. All Phases of Data Collection.

	Passive Data		*Active Phase 1 Data*		*Active Phase 2 Data*		*Difference in Means*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
Dwell Fuel Consumption	1,177	679	990	731	935	686	-187	-242
Total Fuel Consumption	9,848	12,110	10,148	12,081	10,500	13,581	300	652

Panel B. Runway Construction Period Subsample.

	Passive Data		*Active Phase 1 Data*		*Active Phase 2 Data*		*Difference in Means*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
Dwell Fuel Consumption	947	611	N/A	N/A	957	791	N/A	10
Total Fuel Consumption	10,716	14,115	N/A	N/A	10,464	14,183	N/A	-252

Table 21. CLT Active Phases Data for En Route and Taxi Times (minutes)

Panel A. All Phases of Data Collection.

	Passive Data		*Active Phase 1 Data*		*Active Phase 2 Data*		*Difference in Means*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
Total Time En Route (USA and PSA)	93.7	67.3	96.4	68.3	97.5	74.6	2.7	3.8
Total Time En Route (All Traffic)	77.6	47.3	81.2	58.2	80.8	58.8	3.6	3.2
Taxi In Time	8.2	4.2	9.3	5.03	9.1	5.0	1.1	0.9
Taxi Out Time	18.2	8.5	18.9	9.7	19.8	10.5	0.7	1.6

Panel B. Runway Construction Period Subsample.

	Passive Data		*Active Phase 1 Data*		*Active Phase 2 Data*		*Difference in Means*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
Total Time En Route (USA and PSA)	98.6	76.4	N/A	N/A	97.1	75.4	N/A	-1.5
Total Time En Route (All Traffic)	81.6	60.7	N/A	N/A	81.1	59.7	N/A	-0.5
Taxi In Time	8.3	3.9	N/A	N/A	8.2	4.1	N/A	-0.1
Taxi Out Time	21.4	10.3	N/A	N/A	21.4	9.9	N/A	0.0

Table 22. CLT Active Phases Data for On-Time Arrival and Taxi Performance

Panel A. All Phases of Data Collection.

	All Passive Data	***Active Phase 1 Data All Flights***	***Active Phase 1 Data Optimized and Complied Flights***	***Active Phase 2 Data All Flights***	***Active Phase 2 Data Optimized and Complied Flights***
	Percent of Flights	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*
Flights Arrived As Scheduled USA and PSA (A0)	64.9%	53.8%	58.2%	57.5%	58.3%
Flights Arrived within 15 min USA and PSA (A14)	86.8%	79.8%	82.6%	81.3%	83.1%
Flights Arrived As Scheduled All Traffic (A0)	66.8%	53.2%	61.8%	58.2%	62.7%
Flights Arrived within 15 min All Traffic (A14)	87.1%	78.8%	83.2%	81.9%	84.3%
Flights Taxied In As Scheduled	56.8%	48.0%	N/A	61.7%	N/A
Flights Taxied Out As Scheduled	71.0%	65.0%	N/A	63.9%	N/A

Panel B. Runway Construction Period Subsample.

	Passive Data	***Active Phase 1 Data All Flights***	***Active Phase 1 Data Optimized and Complied Flights***	***Active Phase 2 Data All Flights***	***Active Phase 2 Data Optimized and Complied Flights***
	Percent of Flights	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*
Flights Arrived As Scheduled USA and PSA (A0)	55.1%	N/A	N/A	57.6%	59.8%
Flights Arrived within 15 min USA and PSA (A14)	78.9%	N/A	N/A	81.4%	83.1%
Flights Arrived As Scheduled All Traffic (A0)	52.7%	N/A	N/A	58.2%	62.3%
Flights Arrived within 15 min All Traffic (A14)	78.7%	N/A	N/A	82.6%	84.1%
Flights Taxied In As Scheduled	67.5%	N/A	N/A	68.0%	N/A
Flights Taxied Out As Scheduled	60.1%	N/A	N/A	60.0%	N/A

5.3 AAMS Passive Period Performance at MSP

5.3.1 Descriptive Statistics of the Sample

Figure 58 provides a visual overview of the data used in the analysis. In the 105,630 arriving flight records 73% belong to Delta Air Lines flights and 27% represent flights by non-participating carriers and general aviation activity. Additionally, this traffic was distributed across six corner posts at MSP: SHONN, OLLEE, DELZY, TRGET, TWINZ, and BITLR with 20%, 13%, 16%, 11%, 35%, and 5% of the recordings, respectively. The arrivals were also configured from the East in 38% of the records and 62% from the West. TMA metering is indicated as having been active for 96% of the recorded flights. Eighty-one percent (81%) of flights arrived while all runways were open. Representative days where 70% or more of arriving participating carrier flights were completed within 15 minutes of their scheduled arrival time (A14) comprise 82% of the flights in the data.

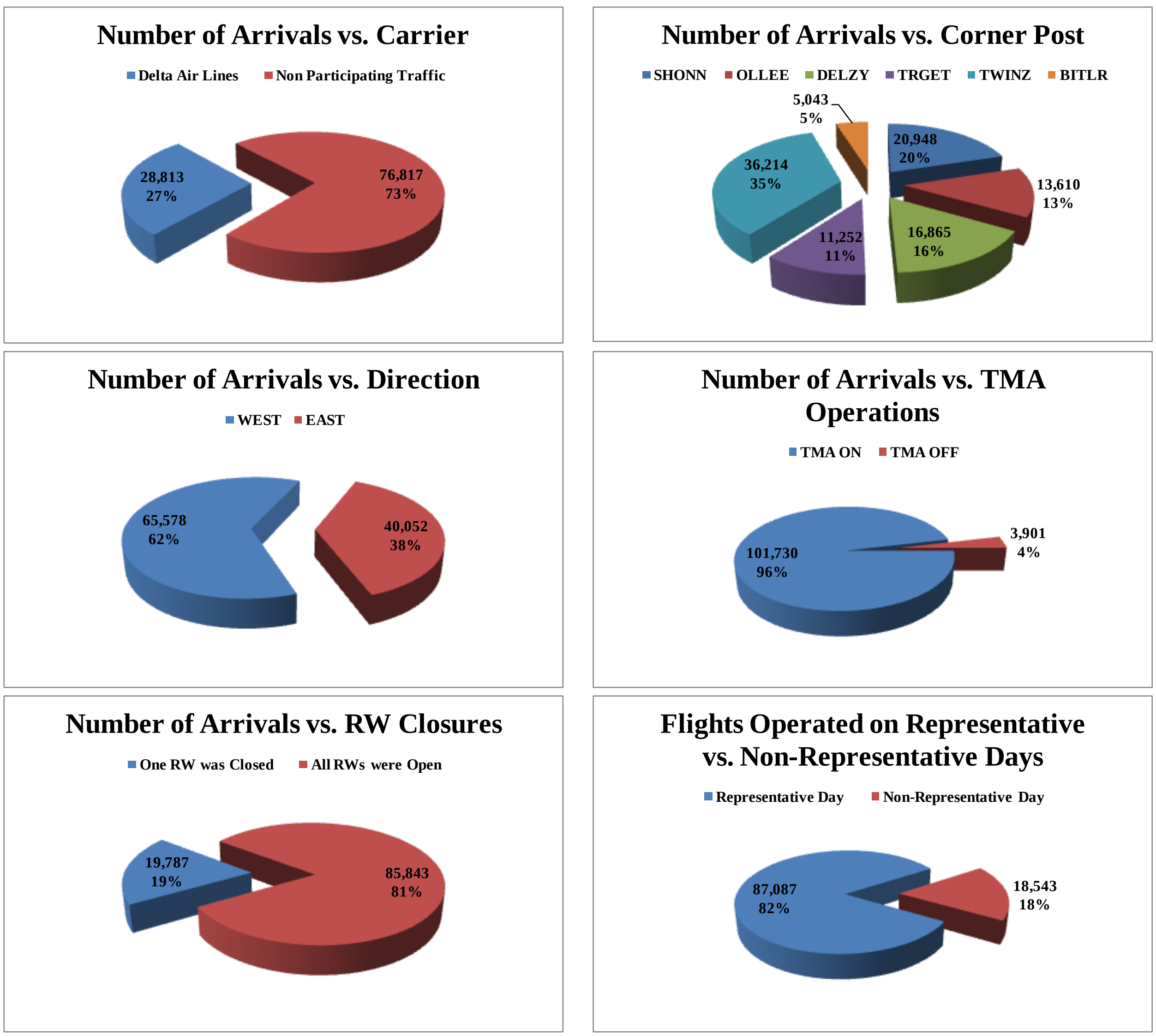

Figure 58. MSP Passive Phase Data Description and Distribution

5.3.1.1 Dwell Time Summary

A summary of the dwell times at each corner post is presented in Table 23. Further data summary is included in the MSP Active Phase data summary in section 5.4.1.1.

Table 23. Summary of Passive Period Corner Post Dwell Times by Direction (minutes)

Corner Post	Mean Dwell Time		Standard Deviation	
Direction	**East**	**West**	**East**	**West**
SHONN	15.7		8.7	
	14.8	16.2	11.7	6.1
OLLEE	16.6		10.3	
	15.9	17.1	12.1	9.1
DELZY	14.8		8.0	
	17.4	13.2	9.2	6.7
TRGET	14.8		6.3	
	17.4	13.3	6.5	5.6
TWINZ	15.7		8.6	
	18.5	13.8	9.4	7.3
BITLR	12.5		2.5	
	15.7	12.0	4.0	1.8

5.4 AAMS Active Period Performance at MSP

5.4.1 Descriptive Statistics

The descriptive evaluation of the data for the 100,680 recorded MSP Active Phase flights is outlined in Figure 59. Of these flights records, 27% belonged to Delta Air Lines flights and 73% represented non-participating carriers and general aviation activity. The flights flew across MSP's six corner posts—SHONN, OLLEE, DELZY, TRGET, TWINZ, and BITLR with 19%, 14%, 16%, 11%, 34%, and 6% of flight records, respectively. East arrivals comprised 38% of the data and west arrivals made up 69% of the flights. TMA is also indicated as being active in 96% of flight records and 76% of flights arrived while all runways were open. Furthermore, with the unseasonably good weather this winter, only 1% of recorded flights operated on the two non-representative days in this period.

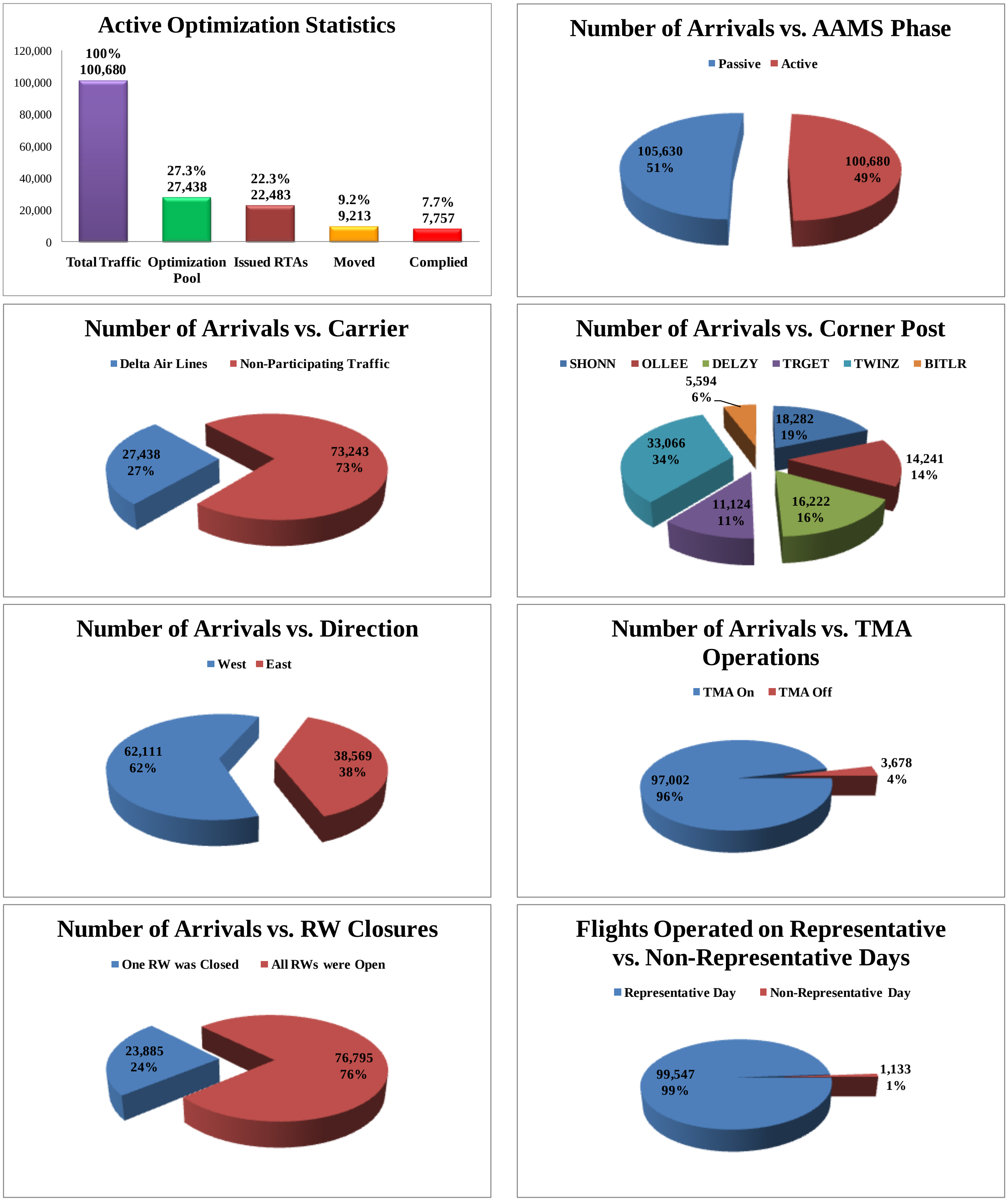

Figure 59. MSP Active Phase Data Description and Distribution

5.4.1.1 Data Summary

The following is a summary of the data collected over the course of the MSP AAMS demonstration. Aggregate and representative dwell times are provided in Table 24 and Table 25 as well as difference in MSP Active and Passive Phase means. Similarly, Table 26 and Table 27 offer summaries of the MSP Active, Passive and Phase difference in means for the dwell fuel consumption and trip fuel, respectively. On time arrival performance is outlined in Table 28 and Table 29 for various flight categories over the active and passive periods for the aggregate and representative days.

Table 24. Aggregate Dwell Times for Passive and Active (minutes, seconds)

	Passive Phase Data (minutes)		*Active Phase Data (minutes)*		*Difference in Means (seconds)*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active - Passive*
SHONN East	14.7	17.0	13.2	13.5	-91*
SHONN West	16.1	11.4	15.6	19.7	-27*
OLLEE East	15.8	12.1	13.2	18.9	-157*
OLLEE West	17.1	9.1	16.3	6.4	-45*
DELZY East	17.4	9.2	12.3	25.0	-106*
DELZY West	13.2	6.7	12.5	12.0	-52*
TRGET East	17.4	6.5	16.4	11.2	-50*
TRGET West	13.3	6.6	12.8	5.7	-30*
TWINZ East	18.5	9.5	16.6	14.4	-68*
TWINZ West	13.8	13.2	13.2	7.8	-36*
BITLR East	15.7	4.0	16.2	18.4	29
BITLR West	12.0	18.4	12.1	6.4	3
TMA On	15.4	10.9	14.5	11.6	-53*
TMA Off	14.7	9.5	13.5	41.5	-73
Runways Open	15.4	10.3	14.4	13.8	-64*
Runway Closed	15.2	13.3	14.9	10.3	-20*

*** Indicates Statistical Significance**

Table 25. Representative Day Dwell Times for Passive and Active (minutes, seconds)

	Passive Phase Data (minutes)		*Active Phase Data (minutes)*		*Difference in Means (seconds)*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active - Passive*
SHONN East	13.9	11.1	13.2	13.5	-42*
SHONN West	15.9	11.8	15.6	19.7	-18
OLLEE East	14.8	11.6	13.2	18.9	-95*
OLLEE West	16.8	8.7	16.3	6.4	-31*
DELZY East	16.3	6.8	15.6	25.1	-40*
DELZY West	12.9	5.9	12.3	12.0	-36*
TRGET East	16.4	3.9	16.6	11.3	12
TRGET West	13.1	5.6	12.7	5.7	-21*
TWINZ East	17.2	8.2	17.3	14.4	4
TWINZ West	13.6	10.3	13.1	7.8	-27*
BITLR East	15.4	3.8	16.2	18.4	46
BITLR West	12.0	1.8	12.1	6.4	3
TMA On	14.8	9.2	14.5	11.7	-21*
TMA Off	13.4	7.6	13.5	41.5	7
Runways Open	14.8	8.7	14.4	13.8	-25*
Runway Closed	14.9	10.8	14.8	14.2	-5

*** Indicates Statistical Significance**

Table 26. Dwell Fuel for Passive and Active Phases (pounds)

	Passive Phase		*Active Phase*		*Difference in Means*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active-Passive*
All Flights	892	596	826	562	-66
Representative Days	857	534	825	562	-32

Table 27. Trip Fuel for Delta Flights in Passive and Active Periods (pounds)

	Passive Phase		*Active Phase*		*Difference in Means*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active-Passive*
All Flights	20,531	25,692	19,869	20,532	-662
Representative Days	20,379	25,513	19,865	20,547	-514

Table 28. Aggregate On-Time Arrival and Taxi-In Performance

	All Passive Phase	*All Active Phase*	*Active Phase OPTC*
	Percent of Flights	*Percent of Flights*	*Percent of Flights*
Delta Flights Arrived as Scheduled (A0)	60.5	77.3	83.5
Delta Flights within 15 minutes (A14)	80.1	91.1	93.1
All flights arrived as scheduled (A0)	59.5	74.8	82.4
All Flights within 15 minutes (A14)	79.5	89.9	91.9
Flights Taxi In as Scheduled	68.5	66.5	66.8

Table 29. Representative Day On-Time Arrival and Taxi-In Performance

	All Passive Phase	*All Active Phase*	*Active Phase OPTC*
	Percent of Flights	*Percent of Flights*	*Percent of Flights*
Delta Flights Arrived as Scheduled (A0)	64.7	77.6	83.9
Delta Flights within 15 minutes (A14)	84.3	91.3	93.2
All flights arrived as scheduled (A0)	63.7	75.2	82.6
All Flights within 15 minutes (A14)	83.8	90.1	92.1
Flights Taxi In as Scheduled	70.1	66.6	66.9

6 COST - BENEFITS ANALYSIS

6.1 Overview

The purpose of the AAMS NextGen Task J project is to demonstrate the feasibility and benefits of a multi-user, time based, aircraft flow management system to pre-condition the arrival traffic at a single airport and to quantify the benefits of the system. Since ATH's Airline Attila™ and Attila Exchange™ systems currently are in use at several airports, this commercially available AAMS requires no development costs and fits well with the NextGen mid-term (2013-2018) implementation concept. Task J evaluates Airline Attila™ and Attila Exchange™ systems as AAMS services which coordinate and combine the unique business needs of two airlines, US Airways and PSA; and which provide airport-centric RTAs to the arriving CLT aircraft in real-time. A second Airline Attila™ AAMS was installed at MSP to provide RTAs to Delta flights. The project presents evidence of system-wide and airline-specific benefits that can be attributed to the assessed systems.

6.1.1 Basis of Recommendations

The Cost Benefit Analysis (CBA) Report quantifies the costs (primarily incurred by the airlines) for implementation of the AAMS system and compares those costs to the benefits to the participating and non-participating airlines and the NAS identified through pre- and post AAMS implementation operation analysis. The report addresses both direct (primary) benefits such as reduction in delays and improved arrival predictability, and indirect (secondary) benefits such as environmental impacts. Calculating costs and benefits requires the allocation of certain system costs and monetizing benefits. While evident, some benefits could not be monetized within the framework of this project and reported separately. In addition, since the FAA and participating airlines assign different values to Airline Direct Operating Costs (ADOC) per airborne minute, the analysis provides two estimates of benefits. These estimates are (1) system-wide (using the FAA methodology) and (2) solely attributed to participating airlines (using figures provided by US Airways and Delta Air Lines).

6.1.2 Benefits Identified

The AAMS related benefits identified through pre- and post-AAMS implementation analysis are described in Section 6.2 and 6.3. Overall, the AAMS demonstration project confirms the viability of the AAMS concept and provides an evidence of measurable benefits that can be attributed to the AAMS. The magnitude for observed benefits at the CLT demonstration was higher in the CLT Active Phase 2 than in the single-airline AAMS in CLT Active Phase 1 that can be explained by the improved performance with increased optimization rates and compliance. This effect is reinforced by the performance in the MSP Active Phase.

6.1.3 Costs Identified

US Airways-CLT

The AAMS related costs presented in this report were installation, maintenance and license fees of Airline Attila™ and Attila Exchange™ systems provided by ATH, as well as actual costs incurred by the airlines over the course of the project. The AAMS demonstration project uses ATH's commercially available Airline Attila™ solution, which is installed independently at US Airways, and at PSA. In addition, the AAMS demonstration project uses ATH's Attila Exchange™ system as the AAMS Exchange flow management system to coordinate and combine the unique business needs of these two airlines and to provide airport-centric RTAs to the arriving CLT aircraft. ATH's 2011 pricing for Airline Attila™ and Attila Exchange™ are a onetime $415,000 installation fee (including equipment costs) and an $80,000 per month maintenance and license fee per system. Therefore, the Year 1 cost per system used in this report is $1,375,000. The Year 2 cost per system used in this report is $960,000.

In addition, US Airways has incurred following AAMS-related costs:

- Initial IT implementation cost: $94,000.
- Aircraft Situational Display to Industry (ASDI) Class 1 feed: $1,900 per month per feed. Annual costs for two feeds are $45,600.
- ASDI Class 1 audit: $22,283 annually; 120 hours at $75 per hour of IT labor to support the audit. Total annual cost for the audit is $31,283.
- Annual IT support costs: 10 hours for break/fix (desktop support) and 30 hours of change management and other miscellaneous support - $3,000 in annual IT support costs (40 hours total at $75 per hour)
- Project management support: 10 hours per month at $100 per hour. Total annual project management support cost is $12,000.
- Data analytics, awareness communication, and other operational analysis support: 20 hours per month at $100 per hour. Total annual data and operational analysis support is $24,000.
- US Airways transaction costs for RTA messages: $14.90 per 10,000 messages. Assuming about 50,000 RTA messages transmitted per year, total annual US Airways transaction cost is $74.50.
- PSA AeroData charge per RTA message: $0.25. Assuming about 10,000 RTA messages transmitted per year, total annual PSA transaction cost is $2,500.

Therefore, the total annual AAMS related costs are $209,957.50 for US Airways and $2,500.00 for PSA. Table 30 provides a summary of all costs related to the installation, operations and maintenance of the AAMS. The AAMS demonstration project utilized three AAMS systems in the CLT Active Phase 2 period: Two Airline Attila™ systems and one Attila Exchange™.

However, the CBA presented in this report was performed in two distinct versions: First CBA addresses system-wide benefits from the FAA point of view, while second CBA addresses only the benefits that can be attributed solely to the airline that would have invested in the AAMS (US Airways). Since both participating in this demonstration project airlines belong to US Airways system, US Airways would not have invested in three AAMS. One AAMS would generate the same benefits to US Airways at CLT and, thus, the user-specific CBA considers only costs related to one AAMS. An overview of these expenses for both configurations is provided in Table 30.

Table 30. US Airways Costs Related to Installing, Operating and Maintaining the AAMS

	Year 1 AAMS cost installation, maintenance and license fee	*Year 2 AAMS cost maintenance and license fee*	*US Airways and PSA annual AAMS related costs*	*Total costs for system-wide analysis in Year 1*	*Total costs for US Airways analysis in Year 1*
Single-user AAMS (One Airline Attila™ system)	$1,375,000	$960,000	$212,458	$1,587,458	$1,587,458
Multi-user AAMS (Two Airline Attila™ systems and Attila Exchange™)	$4,125,000	$2,880,000	$212,458	$4,337,458	$1,587,458

Delta Air Lines-MSP

The costs for MSP AAMS demonstration are most significantly driven by installation and licensing fees for the ATH Airline Attila™. In addition to these expenses, the operating airline, Delta, incurred expenses in its installation and maintenance. In total:

- $415,000—ATH installation and hardware costs (only incurred the first year)
- $169,530—Delta's initial IT installation costs for the system (see below for details)
- $960,000—ATH's monthly licensing fee ($80,000 per month)
- $9,000—Delta's IT support costs (10 hours per month at $75 per hour).

While the AAMS demonstration required additional inputs, such as ASDI feed, Delta has indicated that the company incurs these costs through other programs. As a result, for the first year, the AAMS cost Delta $1,553,530 to operate. Without the installation costs, the subsequent years would cost approximately $969,000. Furthermore, the installation cost incurred by Delta's IT installation efforts are actually for all their AAMS program installations (ATL, MSP, and DTW), though it is believed that the figure would not have been materially different if it were exclusively for this demonstration.

6.2 Direct (Primary) Benefits

6.2.1 Mechanisms of Direct Benefit

The primary mechanisms of the direct benefits of the AAMS implementation, as initially identified in the demonstrations are outlined in Figure 60.

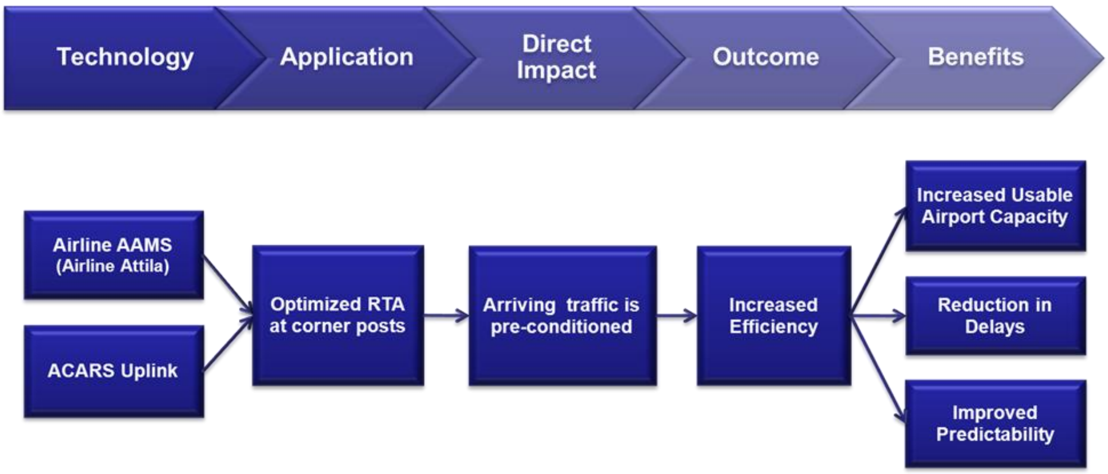

Figure 60. Direct Benefits: Benefit Mechanisms

1. Increased usable airport capacity.
   - Qualified participating aircraft receive RTAs that require speed increases to arrive earlier at the corner posts and potentially filling the empty slots forward in time. As a result, some of the otherwise lost airport arrival slots (spoilage) are recovered, thus, increasing airport arrival throughput.

2. Reduction in delays.
   - Arriving traffic is preconditioned leading to shorter arrival queues, which result in shorter total en route and in terminal area (dwell) times for both AAMS and non-AAMS flights.
   - The benefit of the demonstration of AAMS is a reduction in time and distance flown at low altitudes, thus producing saving in fuel and other airline's direct operating costs (ADOC) for both AAMS and non-AAMS flights.

3. Improved arrival predictability.
   - AAMS traffic preconditioning leads to a better on-time arrival performance, thus improving airline operational efficiency and quality of service. With improved arrival predictability the airlines will be able to plan and manage their resources more efficiently (gates, ground crews, maintenance, flight and cabin crews, etc.). Passengers will receive a better service with more predictable arrival times and fewer missed connections.

6.2.2 Reductions in Delays

The reductions in dwell time and dwell fuel are the main benefits that are associated with “Reduction in Delays” primary benefits. Dwell time reduction leads to savings in ADOC and Passenger Value of Time (PVT). Dwell fuel reduction (included in the ADOC savings) allows estimating the secondary (environmental) benefits of the AAMS.

6.2.2.1 Dwell Time

In dwell time benefit analysis, the research team followed the methodology described in Section 4.1.

US Airways-CLT

Table 31 presents mean values and standard deviations of “dwell times” for all days of data collection periods (aggregate analysis). Symbol (*) indicates statistical significance of the difference in means among the CLT phases of data collection.

Table 31. Dwell Times for All CLT Phases of Data Collection (All Days)

	Passive Data (minutes)		*Active Phase 1 Data (minutes)*		*Active Phase 2 Data (minutes)*		*Difference in Means (seconds)*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
UNARM SOUTH	18.02	2.73	18.53	6.82	17.96	7.38	31*	-4
UNARM NORTH	16.86	2.76	16.67	10.09	15.66	7.12	-11	-72*
MAJIC SOUTH	13.52	6.01	14.11	6.13	13.13	7.38	35*	-23*
MAJIC NORTH	19.97	6.61	19.39	7.76	19.19	6.48	-35*	-47*
SHINE SOUTH	13.13	5.07	13.85	6.02	12.95	7.42	43	-11*
SHINE NORTH	18.46	5.20	17.59	7.82	17.88	7.17	-52*	-35*
CTF SOUTH	18.52	4.45	19.3	7.79	18.22	8.90	47*	-18*
CTF NORTH	16.45	4.83	17.44	10.76	15.83	5.91	59*	-37*
TMA is ON	16.39	5.77	16.57	6.59	15.70	6.75	11*	-41*
TMA is OFF	15.76	5.53	16.85	13.39	16.09	11.49	65*	20*
All Runways	16.24	5.22	16.26	6.5	15.47	7.57	1	-46*
Closed Runway	16.41	6.34	17.05	9.19	16.16	8.13	38*	-15

Table 32. Dwell Times for All CLT Phases of Data Collection (Representative Days)

	Passive Data (minutes)		*Active Phase 1 Data (minutes)*		*Active Phase 2 Data (minutes)*		*Difference in Means (seconds)*	
							Active 1 - Passive	*Active 2 - Passive*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
UNARM SOUTH	17.85	2.51	18.00	4.21	17.71	5.99	9	-8*
UNARM NORTH	16.85	2.74	15.82	4.75	15.51	6.73	-62*	-80*
MAJIC SOUTH	13.29	5.67	13.49	4.26	12.87	6.61	12*	-25*
MAJIC NORTH	19.83	6.71	18.56	6.23	19.18	6.23	-76*	-39*
SHINE SOUTH	12.90	4.81	13.38	4.92	12.56	5.13	28*	-20*
SHINE NORTH	18.39	5.13	16.66	4.52	17.68	6.07	-104*	-42*
CTF SOUTH	18.34	4.36	18.68	5.36	17.89	7.18	21*	-27*
CTF NORTH	16.45	4.91	16.66	3.89	15.79	5.71	13*	-40*
TMA is ON	16.25	5.66	16.00	4.88	15.55	5.69	-15*	-42*
TMA is OFF	15.54	5.48	15.46	7.71	15.42	10.41	-5	-7
All Runways	16.09	5.07	15.60	4.77	16.02	7.67	-30*	-4
Closed Runway	16.27	6.30	16.39	5.86	15.05	5.43	7*	-73*

The analysis of dwell time using only the subsample of representative days demonstrates shorter "dwell times" in both active periods than in the passive period for most corner posts and arrival configurations. Most negative differences in dwell times between the CLT Active Phase 1 period and the Passive periods are statistically significant and range from 62 seconds for UNARM North to 104 seconds for SHINE North arrivals. Comparison of dwell times between the CLT Active Phase 2 and the Passive Phase periods shows that the differences for all corner posts and arrival configurations are negative and statistically significant ranging from 20 seconds for SHINE South to 80 seconds for UNARM North arrivals. In general, the subsample of representative days provides more convincing evidence of the AAMS benefits in terms of shorter dwell times for CLT arrivals conducted during both active periods.

Delta Air Lines-MSP

Aggregate dwell time analysis shows that only BITLR East and BITLR West arrivals did not demonstrate statistically significant reductions in dwell time in the MSP Active Phase period. The rest of the corner posts and arrival configuration approaches had shorter dwell times in the MSP Active Phase period than in the MSP Passive Phase.

The dwell time aggregate benefit is presented in Table 33 below. The data represents the complete MSP Passive Phase set and the full MSP Active Phase set and demonstrates consistent and significant reduction in dwell times.

Table 33. Aggregate Dwell Times for MSP Passive and Active (minutes, seconds)

	Passive Phase Data (minutes)		*Active Phase Data (minutes)*		*Difference in Means (seconds)*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active - Passive*
SHONN East	14.7	17.0	13.2	13.5	-91*
SHONN West	16.1	11.4	15.6	19.7	-27*
OLLEE East	15.8	12.1	13.2	18.9	-157*
OLLEE West	17.1	9.1	16.3	6.4	-45*
DELZY East	17.4	9.2	12.3	25.0	-106*
DELZY West	13.2	6.7	12.5	12.0	-52*
TRGET East	17.4	6.5	16.4	11.2	-50*
TRGET West	13.3	6.6	12.8	5.7	-30*
TWINZ East	18.5	9.5	16.6	14.4	-68*
TWINZ West	13.8	13.2	13.2	7.8	-36*
BITLR East	15.7	4.0	16.2	18.4	29
BITLR West	12.0	18.4	12.1	6.4	3
TMA On	15.4	10.9	14.5	11.6	-53*
TMA Off	14.7	9.5	13.5	41.5	-73
Runways Open	15.4	10.3	14.4	13.8	-64*
Runway Closed	15.2	13.3	14.9	10.3	-20*

*** Indicates Statistical Significance**

The representative days dwell time statistics are outline in Table 34 and also show strong dwell time reductions over the passive period.

Table 34. Representative Day Dwell Times for MSP Passive and Active (minutes, seconds)

	Passive Phase Data (minutes)		*Active Phase Data (minutes)*		*Difference in Means (seconds)*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active - Passive*
SHONN East	13.9	11.1	13.2	13.5	-42*
SHONN West	15.9	11.8	15.6	19.7	-18
OLLEE East	14.8	11.6	13.2	18.9	-95*
OLLEE West	16.8	8.7	16.3	6.4	-31*
DELZY East	16.3	6.8	15.6	25.1	-40*
DELZY West	12.9	5.9	12.3	12.0	-36*
TRGET East	16.4	3.9	16.6	11.3	12
TRGET West	13.1	5.6	12.7	5.7	-21*
TWINZ East	17.2	8.2	17.3	14.4	4
TWINZ West	13.6	10.3	13.1	7.8	-27*
BITLR East	15.4	3.8	16.2	18.4	46
BITLR West	12.0	1.8	12.1	6.4	3
TMA On	14.8	9.2	14.5	11.7	-21*
TMA Off	13.4	7.6	13.5	41.5	7
Runways Open	14.8	8.7	14.4	13.8	-25*
Runway Closed	14.9	10.8	14.8	14.2	-5

*** Indicates Statistical Significance**

6.2.2.2 Multiple Regression Estimation of Dwell Times

The multiple regression analysis described in section 2.3.3 is outlined below with results for both AAMS demonstrations.

US Airways-CLT

Table 35 presents the parameter estimates for three dwell time regression analyses conducted by the research team. The first regression analysis uses the data from the CLT Passive Phase and Active Phase 1. The second regression analysis uses the data from all three periods of data collection. The third regression analysis uses the data from the runway construction period. There are two main reasons for the segregation of the runway construction period data into a separate subsample. First, since the airport capacity and, consequently, the operational conditions are seriously affected by runway closers, comparing the active data with passive data collected in similar operational conditions provides more reliable estimates. Second, running the same regression model on a different subsample of data (runway construction period versus the overall sample of all three data collection periods) allows for a robustness check for the results estimated in the first two regressions.

Table 35. Parameter Estimates for CLT Dwell Time Regression Analyses

	Active Phase 1		*Active Phase 2*		*Runway Construction Period*	
Regression Terms	Coefficient (seconds)	t-statistics	Coefficient (seconds)	t-statistics	Coefficient (seconds)	t-statistics
Constant	973*	162.75	978*	217.92	935*	96.39
ACT1	42*	9.31	48*	10.91	*N/A*	*N/A*
ACT2	*N/A*	*N/A*	-16*	-8.04	8	1.73
OPTC	-43*	-6.39	-32*	-7.53	-46*	-4.38
OPTF	11	1.23	5	0.79	15	0.82
OPTS	7	0.82	2	0.20	-21	-0.74
TMA	23*	5.75	-17*	-6.81	-17*	-2.79
TMA*MOV	-19*	-2.70	-18*	-3.73	-15	-1.22
TCI	-42*	-6.50	-39*	-5.35	-95*	-3.05
TCI*ACT	-16	-0.51	-39*	-3.66	8	0.24
CF	-26	-0.20	-61	-1.57	-32	-0.71
CF*ACT	-43	-0.32	19	0.41	0	0.00
RWCL	17*	6.77	20*	10.95	*N/A*	*N/A*
UNARMS	86*	14.97	121*	28.32	176*	18.81
MAJICN	194*	31.89	210*	45.23	244*	25.21
MAJICS	-184*	-33.43	-164*	-39.93	-145*	-16.19
SHINEN	102*	17.27	123*	27.69	149*	16.34
SHINES	-208*	-38.56	-177*	-44.31	-120*	-13.95
CTFN	-5	-0.75	7	1.51	8	0.72
CTFS	106*	18.49	136*	31.90	164*	17.31

(*) Indicates statistical significance

The coefficients of interest are the ones for the first eleven variables following the constant term. The rest of the regression terms are included to control for the environmental factors, such as runway closures and arrivals conducted via a particular corner post and arrival configuration. As indicated by the coefficients of control variables, different corner posts and arrival configurations result in quite different "dwell times", but those differences are beyond the AAMS control. As expected, during the runway closures periods, dwell times are longer by 17-20 seconds on average. Runway closure variable is not included in the runway construction period regression because, by the subsample design, all of the arrivals in this period were conducted when one runway was closed. Also, *ACT1* variable is not included in the runway construction period regression because the runway construction period was in the middle of the CLT Active Phase 2 period, when the AAMS Exchange operations were in effect.

The results of the regression analyses can be interpreted as follows: Any negative and statistically significant coefficients indicate shorter dwell time. Therefore, as suggested by the parameter estimates of the CLT Active Phase 1 regression, there were no system-wide benefits (the coefficient of *ACT1* is not negative and significant). However, optimized and complied flights (the coefficient of *OPTC*) had 42 seconds shorter dwell times than the rest of the flights. In addition, it seems that the flights that moved towards their prescribed RTAs, but did not comply with them for a variety of reasons (e.g., alternative ATC instructions), did not demonstrate any reductions in dwell times. As indicated by negative and statistically significant coefficient of *TMA*MOV*, the TMA and AAMS have worked well together reducing the "dwell times" of flights that moved towards their RTAs when TMA was operational by 19 seconds. By US Airways decision, TCI and CF were excluded from the AAMS optimization solution. One of the airline concerns was to examine how the AAMS may influence the arrivals of TCI and CF. As indicated by statistically not significant coefficients of *TCI*ACT* and *CF*ACT* the AAMS operations did not affect TCI and CF.

In the CLT Active Phase 2 regression analysis, the signs and magnitude of statistically significant coefficients are similar to the Phase 1 regression. However, the analysis suggests that the AAMS Exchange operations provided system-wide benefits. As indicated by the statistically significant coefficient of *ACT1*variable, all arrivals conducted in the CLT Active Phase 2 period had 16 second shorter dwell times than arrivals in the Passive Operations period. A plausible explanation of this new result is that the optimization and compliance rates were somewhat higher in CLT Active Phase 2 of active AAMS operations than in CLT Active Phase 1. Optimized and complied flights also shortened their dwell time in the CLT Active Phase 2 period: as indicated by the coefficient of *OPTC* their dwell time savings were 32 seconds. Similar to CLT Active Phase 1 period, flights that moved in the direction of the RTA when the TMA was operational had 18 seconds shorter dwell times. Also, as in CLT Active Phase 1 period, TCI and CF were not affected by the AAMS operations.

Runway construction period regression analysis supports the finding of the two first regressions: optimized and complied flights were saving 43 seconds of dwell time during this period. One difference in the estimates of this regression, compared to the first two analyses is that the coefficient of the interaction term between the TMA and AAMS (*TMA*AAMS*), while of the same sign and similar magnitude, is not statistically significant. A potential explanation of this result is a smaller sample with fewer observations.

Delta Air Lines-MSP

Multiple regression analyses were performed on the data collected from the active and passive periods to quantify the temporal benefits of the AAMS. In addition to an aggregate data regression run on all observations, three additional regressions were run on the data to insure the robustness of the results. The second regression was run on all Delta flights in the demonstration. The third and fourth parameter estimates, as provided in Table 36, were calculated in regressions for flights on representative days and participating (Delta) flights on these days. The additional regressions are intended to assist in determining if the participating traffic had any difference in benefit and to assist in determining if any difference in benefits could be attributed to operation on representative days.

As previously stated, the first six regression terms, parameter values for which are presented in Table 36, are of most interest. The variables not included in the first six, and the TMA variable, control for variation outside the control of the AAMS program. In particular, the arrival configuration has a significant impact on the dwell times.

The regression result suggests that the system saw benefits in the form of reduced dwell times with statistical significance in the ACT parameter. Interestingly, the results do not indicate that optimized and complied flights (OPTC) experienced significant improvements over other traffic, however flights that moved forward to meet an RTA (OPTF) did see benefit. TMA operation (TMA and TMA*MOV) appears to have been detrimental to AAMS dwell time improvements in all four regressions. Between the four regressions it should be noted that the ACT parameter offers the greatest reduction for the participating traffic with a reduction of 55 seconds while all observations show a reduction of 50 seconds, representative days a reduction of 23 seconds, and 20-second reductions for Delta flights on representative days.

Table 36. Parameter Estimates for MSP Dwell Time Regression Analyses

	All Observations		*Participating Traffic*		*Representative Days*		*Delta on Rep. Days*	
Regression Terms	Coefficient (seconds)	t-Statistics	Coefficient (seconds)	t-Statistics	Coefficient (seconds)	t-Statistics	Coefficient (seconds)	t-Statistics
(Constant)	933*	94.15	875*	44.11	888*	86.44	810*	37.04
ACT	-54*	-15.80	-55*	-6.62	-23*	-6.77	-20*	-2.33
OPTC	-10	-1.00	-10	-0.88	-10	-1.02	-10	-0.86
OPTF	-29*	-2.44	-27	-1.98	-29*	-2.50	-26	-1.87
OPTS	-27	-1.57	-22	-1.18	-24	-1.45	-18	-0.94
TMA	42*	4.71	113*	6.05	65*	7.01	155*	7.51
TMA*MOV	28*	2.74	23	1.91	27*	2.70	20	1.64
RW CL	20*	4.92	18*	2.14	22*	5.61	21*	2.42
SHONNE	-111*	-14.43	-124*	-10.08	-132*	-16.85	-148*	-11.16
OLLEEW	52*	7.03	9	0.53	49*	6.69	10	0.55
OLLEEE	-80*	-9.18	-104*	-4.66	-111*	-12.52	-136*	-5.59
DELZYW	-185*	-26.06	-202*	-15.66	-190*	-26.92	-211*	-15.59
DELZYE	42*	5.27	21	1.41	13	1.58	-12	-0.75
TRGETW	-169*	-21.31	-182*	-8.70	-170*	-21.50	-182*	-8.22
TRGETE	68*	7.22	77*	2.92	44*	4.65	45	1.57
TWINZW	-142*	-23.43	-148*	-13.25	-144*	-23.78	-150*	-12.72
TWINZE	123*	18.92	125*	10.00	93*	14.18	91*	6.76
BITLRW	-225*	-24.89	-239*	-12.30	-219*	-24.60	-232*	-11.50
BITLRE	9	0.46	24	0.50	6	0.33	23	0.45

*** Indicates Statistical Significance**

6.2.3 Arrival Performance and Predictability

Arrival predictability is addressed by estimating the percentage of flights that arrived as scheduled (A0) and within 15 minutes of schedule (A14) in all data collection periods. Table 37 presents on-time arrival and taxi performance for the overall sample of passive and active days.

Table 37. On-Time Arrival and Taxi Performance (All Days)

	All Passive Data	***Active Phase 1 Data All Flights***	***Active Phase 1 Data Optimized and Complied Flights***	***Active Phase 2 Data All Flights***	***Active Phase 2 Data Optimized and Complied Flights***
	Percent of Flights	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*
Flights Arrived As Scheduled USA and PSA (A0)	64.9%	53.8%	58.2%	57.5%	58.3%
Flights Arrived within 15 min USA and PSA (A14)	86.8%	79.8%	82.6%	81.3%	83.1%
Flights Arrived As Scheduled All Traffic (A0)	66.8%	53.2%	61.8%	58.2%	62.7%
Flights Arrived within 15 min All Traffic (A14)	87.1%	78.8%	83.2%	81.9%	84.3%
Flights Taxied In As Scheduled	56.8%	48.0%	N/A	61.7%	N/A
Flights Taxied Out As Scheduled	71.0%	65.0%	N/A	63.9%	N/A

As indicated by the percent of flights arrived as scheduled and within 15 minutes of scheduled times, optimized and complied flights in both active phases demonstrated better on-time performance than the other flights in the same periods.

Table 38. On-Time Arrival and Taxi Performance (Representative Days)

	All Passive Data	*Active Phase 1 Data All Flights*	*Active Phase 1 Data Optimized and Complied Flights*	*Active Phase 2 Data All Flights*	*Active Phase 2 Data Optimized and Complied Flights*
	Percent of Flights	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*	*Percent of Flights*
Flights Arrived As Scheduled USA and PSA (A0)	66.7%	58.6%	66.7%	61.2%	61.7%
Flights Arrived within 15 min USA and PSA (A14)	88.3%	84.1%	88.3%	84.5%	85.4%
Flights Arrived As Scheduled All Traffic (A0)	68.3%	57.1%	68.3%	61.2%	65.4%
Flights Arrived within 15 min All Traffic (A14)	88.2%	82.5%	88.2%	84.6%	86.5%
Flights Taxied In As Scheduled	57.0%	48.3%	N/A	64.3%	N/A
Flights Taxied Out As Scheduled	71.3%	66.5%	N/A	65.5%	N/A

As presented in Table 38, the on-time arrival performance for the subsample of representative days follows the pattern of the overall sample: A0 and A14 performance for all arriving traffic is lower in both active periods than in the passive period, but optimized and complied flights demonstrated better performance than the other flights in corresponding periods.

While optimized and complied flights seem to exhibit better on-time arrival performance in both active periods, this benefit cannot be monetized. Typically, an airline would be benefited from better on-time arrival performance through the block time reductions. However, a decision to reduce the block times requires a great amount of data that would include extensive observations and the analysis of seasonal performance. This project does not provide sufficient data to infer if the AAMS operations result in potential block time reductions.

Delta Air Lines-MSP

Arrival predictability is addressed by estimating the percentage of flights that arrived as scheduled (A0) and within 15 minutes of schedule (A14) in both data collection periods. Table 39 presents on-time arrival and taxi performance for the overall sample of passive and active days. Using representative days to try to filter away irregular operations, Table 40 presents the performance figures for representative day operations.

Table 39. Aggregate On-Time Arrival and Taxi-In Performance

	All Passive Phase	***All Active Phase***	***Active Phase OPTC***
	Percent of Flights	*Percent of Flights*	*Percent of Flights*
Delta Flights Arrived as Scheduled (A0)	60.5	77.3	83.5
Delta Flights within 15 minutes (A14)	80.1	91.1	93.1
All flights arrived as scheduled (A0)	59.5	74.8	82.4
All Flights within 15 minutes (A14)	79.5	89.9	91.9
Flights Taxi In as Scheduled	68.5	66.5	66.8

Table 40. Representative Day On-Time Arrival and Taxi-In Performance

	All Passive Phase	***All Active Phase***	***Active Phase OPTC***
	Percent of Flights	*Percent of Flights*	*Percent of Flights*
Delta Flights Arrived as Scheduled (A0)	64.7	77.6	83.9
Delta Flights within 15 minutes (A14)	84.3	91.3	93.2
All flights arrived as scheduled (A0)	63.7	75.2	82.6
All Flights within 15 minutes (A14)	83.8	90.1	92.1
Flights Taxi In as Scheduled	70.1	66.6	66.9

As indicated by the percent of flights that arrived as scheduled and within 15 minutes of scheduled times, the flights in both Active Phase sets demonstrated better on-time arrival performance. In addition, optimized and complied flights displayed better on-time performance than the other flights in the same periods while taxi-in performance was slightly lower during the Active Phase.

6.2.4 Average Fuel Consumption

US Airways-CLT

Even though total fuel consumption depends on many factors, the average figures of total fuel consumption demonstrate that airline operations and schedules at CLT were quite stable over the data collection periods. “Dwell” fuel consumption, while affected by the AAMS, also depends on the airline fleet mix that is used to serve CLT. Thus, if the airlines use smaller aircraft to serve CLT in active phases, the average figures of “dwell” fuel would be lower than in the Passive Operations even without the AAMS actions. Nonetheless, as presented in Table 41 the aggregate analysis demonstrates that average dwell fuel was reduced by 187 pounds in CLT Active Phase 1 and by 242 pounds in CLT Active Phase 2.

Table 41. CLT Dwell and Trip Fuel for All Phases of Data Collection (All Days)

	Passive Data		***Active Phase 1 Data***		***Active Phase 2 Data***		***Difference in Means***	
							Active 1 - Passive	***Active 2 - Passive***
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
Dwell Fuel Consumption	1,177	679	990	731	935	686	-187*	-242*
Total Fuel Consumption	9,848	12,110	10,148	12,081	10,500	13,581	300	652

Fuel consumption is in pounds. (*) indicate statistical significance.

Table 42 presents the averages and standard deviations of dwell and total fuel consumption for the subsample of representative days. Similar to the aggregate analysis, average dwell fuel consumption was lower in the CLT Active Phase 1 by 221 pounds and by 245 pounds in the CLT Active Phase 2.

Table 42. CLT Dwell and Trip Fuel for All Phases of Data Collection (Representative Days)

	Passive Data		***Active Phase 1 Data***		***Active Phase 2 Data***		***Difference in Means***	
							Active 1 - Passive	***Active 2 - Passive***
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*		
Dwell Fuel Consumption	1,167	675	946	579	922	631	-221*	-245*
Total Fuel Consumption	9,713	12,098	9,947	11,951	10,355	13,359	234	642

Fuel consumption is in pounds. (*) indicate statistical significance.

Delta Air Lines-MSP

While many factors play a role in fuel consumption at the various stages of flight, the AAMS operational benefits on fuel consumptions can most reliably be seen in the dwell fuel consumption. Aggregate dwell fuel reductions, as presented in Table 43, amounted to approximately 66 pounds of fuel per arrival for all flights and approximately 32 pounds for arrivals on representative days.

Table 43. MSP Dwell Fuel for Passive and Active Phases (pounds)

	Passive Phase		*Active Phase*		*Difference in Means*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active-Passive*
All Flights	892	596	826	562	-66
Representative Days	857	534	825	562	-32

The total fuel consumed by arriving flights at MSP operated by Delta, outlined in Table 44, indicates that, while subject to a myriad of other factors, average fuel consumption was reduced by 662 pounds of fuel with a reduction of 514 pounds for the subset of flights on representative days.

Table 44. Trip Fuel for Delta Flights in Passive and Active Periods (pounds)

	Passive Phase		*Active Phase*		*Difference in Means*
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Active-Passive*
All Flights	20,531	25,692	19,869	20,532	-662
Representative Days	20,379	25,513	19,865	20,547	-514

6.2.5 Monetizing Dwell Time and Fuel Benefits

The reductions in dwell times outlined in the regressions for the active and passive periods can be used to develop dollar values for the impact of the AAMS on the airspace's traffic. The main benefits of the AAMS installation that can be monetized are the reductions in the ADOC. The impact of the dwell time reduction on ADOC is calculated in a manner similar to the fuel benefit. In this case, the appropriate reductions are used with ADOC figures for the traffic type found in the "FAA Economic Analysis Guide for 2011". The ADOC values for air carriers, air taxis, and general aviation are $69.80, $20.00, and $11.40 per airborne minute, respectively. These values were then multiplied by the total time saved for each aircraft category which in turn was calculated by determining how many flights meet the description of the category and each of the relevant regression parameters.

US Airways-CLT

The regression analysis for the CLT Active Phase 1 estimated 43.32 seconds savings in "dwell time" for optimized and complied flights. In addition, flights that moved in the direction of the RTAs during periods when the TMA was operational saved 18.74 seconds in "dwell times". Since in the CLT Active Phase 1 there were 5,408 optimized and complied flights and 5,007 flights that were moved by the AAMS when the TMA was operational, total "dwell time" savings accumulate into 5,468 minutes. Total ADOC savings for the CLT Active Phase 1 are found to be $381,653.24. Given that the CLT Active Phase 1 period consisted of 113 days total annual ADOC savings are estimated to be **$1,232,773.73** (annualized using 365 days per year). The ADOC savings include fuel, oil, crew, and maintenance of the aircraft. US Airways uses a somewhat lower ADOC figure for the ADOC per airborne minute than the FAA of $64.00 per airborne minute. By applying this number, total annual single-airline AAMS ADOC savings are estimated to be **$1,130,336.95**.

The regression analysis for the CLT Active Phase 2 period estimated that all arriving flights in this periods had 15.94 seconds shorter “dwell times” than in the Passive Operation period. In addition, during this period optimized and complied flights and those that moved to the RTA direction when TMA was operational had 31.81 and 17.82 seconds savings in “dwell times” respectively.

There were 113,704 total Air Carrier, 4,144 Air Taxi, and 4,923 General Aviation (GA) arrivals at CLT in the Active Phase 2 period. Total figures of “dwell time” saved for Air Carrier, Air Taxi, and GA arrivals are 30,202; 1,101; and 1,308 minutes respectively. By multiplying the numbers of minutes saved by the corresponding ADOC figures, the total system-wide savings of $2,144,983.49 are estimated. In addition, there were 8,867 optimized and complied flights and 5,389 flights that moved towards their RTAs when TMA was operational. Those flights saved 4,701 and 1,600 minutes of “dwell time” respectively producing $328,139.27 and $111,704.66 of the ADOC savings. The overall ADOC savings for the CLT Active Phase 2 period are $2,584,827.42. Since the CLT Active Phase 2 period contained 167 active days, annualizing this figure over 365 days produces the total annual system-wide ADOC savings of **$5,649,473.11**.

Using aircraft type-specific fuel burn data for arriving aircraft, the research team estimated that optimized and complied flights saved 333,934 pounds of fuel during the CLT Active Phase 1 period. Flights that moved towards the RTAs while TMA was operational saved 136,137 pounds of fuel over the same period. Therefore, total fuel savings for the CLT Active Phase 1 period are 470,072 pounds (about 69,641 gallons). Using 365 days per year, the annual fuel savings for a single-airline AAMS are estimated to be **1,518,373 pounds** (about 224,945 gallons).

To monetize the benefits that can be attributed only to U.S. Airways, non-participating traffic benefits are excluded from the previous estimation. Thus, only 52% of total arrivals during the CLT Active Phase 2 period were conducted by the two participating airlines: U.S. Airways and PSA. Consequently, only 60,456 arrivals with “dwell time” savings of 15.94 seconds can be credited to the participating airlines. Overall, including total arriving traffic, optimized and complied flights, and flights that moved towards the RTAs when TMA was operational, the participating airlines saved 22,360 minutes of “dwell time” during the CLT Active Phase 2 period. Using the US Airways figure of $64.00 per minute, the overall ADOC savings are estimated to be $1,431,015.05. The annualized ADOC savings for the multi-user AAMS operations that can be attributed to the participating airlines are expected to be **$3,127,667.63**.

Table 45 presents a summary of annualized values for “dwell time” and fuel benefits estimated using the FAA guidance for system-wide benefits and US Airways ADOC values for the participating airlines.

Table 45. CLT Annualized Values of Dwell Time and Fuel Benefits

	System-wide Benefits (FAA)		*Participating Airlines Benefits (USA and PSA)*
	ADOC	*Fuel (pounds)*	*ADOC*
Active Phase 1 Single-user AAMS	$1,232,774	1,518,373	$1,130,336.95
Active Phase 2 Multi-user AAMS	$5,649,473	4,531,801	$3,127,667.63

Delta Air Lines-MSP

From the statistically significant variables in the Delta/MSP regressions AAMS is responsible for the three of the parameters. The ACT and OPTF parameters offer improvements in dwell times and, as a result, reductions in fuel consumption and operating costs. Similarly, the TMA*MOV produced an increase in dwell time and resultant fuel consumption.

For the subsequent calculations it should be noted that there were 27,438 Delta arrivals, 96,330 total air carrier arrivals, 2,293 air taxi arrivals, and 3,021 general aviation arrivals during the six month of active AAMS.

To estimate the fuel savings for the aircraft involved, the calculated dwell time savings for the corresponding parameters are matched with the BADA low altitude consumption figures for each aircraft type. As noted in the initial discussion of the regression results, the impact of regressing on all days or only representative days offers a range of benefit, presumably due to the effect of snowfalls. The results of the fuel savings estimations for using the all days and representative days regressions are outlined in Table 46.

Table 46. MSP Dwell Fuel Benefit (pounds)

	All Observations	***Representative Days***
Impact Over 6 Months	*Fuel Saved (pounds)*	*Fuel Saved (pounds)*
ACT	4,169,179	1,775,761
OPTF	199,767	199,767
TMA*MOV	(259,545)	(250,276)
Total	**4,109,401**	**1,725,252**
Annualized Total	**8,241,381**	**3,459,985**

The fuel savings calculated in Table 46 are not used in subsequent monetization calculations as the fuel savings are rolled into the Aircraft Direct Operating Costs (ADOC) category. The ADOC impact has been calculated using the regression results and is presented in Table 47 and are calculated with only representative days and all observations.

Table 47. MSP Dwell Time Aircraft Direct Operating Cost (ADOC) Benefits

	All Observations	*Representative Days*
Benefit Over 6 Months	*ADOC Savings*	*ADOC Savings*
Delta Air Lines	$1,660,545	$681,341
System Wide	$6,113,412	$2,599,626
Annualized Delta	**$3,330,214**	**$1,373,975**
Annualized System	**$12,328,152**	**$5,242,340**

6.3 Indirect (Secondary) Benefits

While the indirect benefits associated with the AAMS generally cannot be quantified within the framework of this project an acknowledgement of these benefits provides insights into the value of AAMS.

6.3.1 Environmental

Environmental concerns place significant constraints on sustainable growth for aviation and, according to the FAA, should be addressed when assessing any operational improvements. In the AAMS demonstration project there are two potential environmental benefits—reduced noise, and reduced emissions.

6.3.1.1 Reduced Noise

As previously demonstrated, the AAMS operations resulted in shorter dwell times for arriving traffic comparing to the passive operation period. Consequently, arriving aircraft generate less noise at low altitudes in the vicinity of the airport. The exact estimation of noise reduction due to shorter dwell time is beyond the AAMS demonstration project scope. However, it is the research team’s consensus that reduced noise is one of the environmental benefits of the AAMS.

6.3.1.2 Reduced Emissions

Aircraft jet engines, like many other vehicle engines, produce carbon dioxide (CO_2), water vapor (H_2O), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), unburned or partially combusted hydrocarbons (also known as volatile organic compounds (VOCs)), particulates, and other trace compounds. A small subset of the VOCs and particulates are considered hazardous air pollutants (HAPs). Aircraft engine emissions are roughly composed of about 70 percent CO_2, a little less than 30 percent H2O, and less than 1 percent each of NO_x, CO, SO_x, VOC, particulates, and other trace components including HAPs. Combustion of one pound of fuel yields 3.15 pounds of carbon dioxide gas. Carbon dioxide emissions are therefore 3.15 times the mass of fuel burned. A summary of the carbon dioxide reductions is provided in Table 48 for CLT Active Phases and MSP regressions of All Observations and Representative Days.

Table 48. Annualized CO_2 Emission Reduction Summary

Panel A. CLT CO_2 Emission Reduction.

	Active Phase 1	*Active Phase 2*
Reduced CO_2 Emission (pounds)	4,782,875	14,275,173

Panel B. MSP CO_2 Emission Reduction.

	All Observations	*Representative Days*
Reduced CO_2 Emission (pounds)	25,960,350	10,898,953

US Airways-CLT

As discussed in Section 6.2.5, single-user AAMS operations are expected to generate annual fuel savings of 1,518,373 pounds, thus, generating environmental benefits equal to a reduction of 4,782,875 pounds of CO2 per year. Multi-user AAMS operations are expected to save 4,531,801 pounds of fuel per year, generating annual environmental benefits of 14,275,173 pounds of CO2.

Delta Air Lines-MSP

The estimated annual CO_2 reductions for the AAMS operations using the representative days analysis is 10,898,953 pounds of CO_2 per year. Similarly, the figure using the all days data the gain is 25,960,350 pounds of CO_2 per year.

6.3.2 Safety and Productivity

The research team has consulted with multiple subject matter experts in the fields of safety, air traffic control, and airline operations management, including US Airways and Delta Air Lines operations personnel, dispatchers and ATC specialists, and concluded that the AAMS operations has not affected the areas of safety and productivity of airline and ATC personnel. Consequently, there are no indirect benefits or disbenefits to report in the areas of safety and productivity.

6.4 CBA Summary

The CBA of the AAMS from the demonstrations at CLT and MSP identified a suite of benefits that could be realized as early as the first year of operation. Table 49 outlines these benefits and costs in the first year for the single- and multi-user AAMS based on the cost structures of the participating carriers. Also identified and presented are benefits not directly recoverable to an airline operator, including passenger value of time (PVT) calculated using the FAA 2011 PVT rate and the dwell time savings used in the monetizing analysis.

Table 49. Costs and Benefits of AAMS in the First Year of Operations

	US Airways-CLT		*Delta Air Lines-MSP*	
	Active Phase 1	***Active Phase 2***	***All Observations***	***Representative Days***
Total System Costs	$1,587,458	$4,337,458	$1,553,530	$1,553,530
System Monetized Benefits	$1,232,774	$5,649,473	$12,328,152	$5,242,340
System Benefit/Cost Ratio	0.78	1.30	7.94	3.37
Total Participant Costs	$1,587,458	$1,587,458*	$1,553,530	$1,553,530
Participant Monetized Benefits	$1,130,337	$3,127,668	$3,330,214	$1,373,975
Participant Benefit Cost Ratio	0.71	1.97	2.16	0.88
Benefits not included in the CBA				
Improved Arrival Predictability	Flights that arrived in the active periods demonstrate better A0 and A14 performance.		Flights that arrived in the active period demonstrate better A0 and A14 performance. Optimized and complied flights show A0 and A14 improvement over other active flights.	
Passenger Value of Time	$1,157,901	$5,230,587	$6,113,412	$2,599,626
Reduced CO_2 Emission (pounds)	4,782,875	14,275,173	25,960,350	10,898,953
Reduced Noise	With shorter dwell times, flights produce less noise at low altitude in vicinity of airport.		With shorter dwell times, flights produce less noise at low altitude in vicinity of airport.	

(*)One Airline Attila™ system

7 ISSUES AND OBSERVATIONS

7.1 Pilot Participation

As observed in the course of the project, pilot participation is essential to the success of the AAMS. The CBA shows that in CLT Active Phase 1, when the average compliance rate was 6.5% of total arrivals, the AAMS related costs exceeded the benefits. However, in CLT Active Phase 2 with the average compliance rate of 7.6%, the benefits were much higher and substantially exceeded the costs. Figure 61 presents the optimization and compliance rates as percentage of total arrivals for both active periods. Figure 62 presents the participating carriers' compliance rates as percentage of issued RTAs. During both active periods the average compliance rates for US Airways and PSA were 35.2% and 32.5% respectively. Also, the compliance rates were quite volatile, fluctuating between 32.6% and 38.1% for US Airways and 26.7% and 38.4% PSA. While compliance rates depend on many factors that beyond pilots' control (e.g., alternative ATC instructions), higher pilots' participation rates should be encouraged as even a small increase percent of optimized traffic seems to generate substantial system-wide benefits. It is equally believed, though not readily testable in the MSP demonstration, that the same principles linking better compliance and significant increases in benefits hold true in both demonstrations.

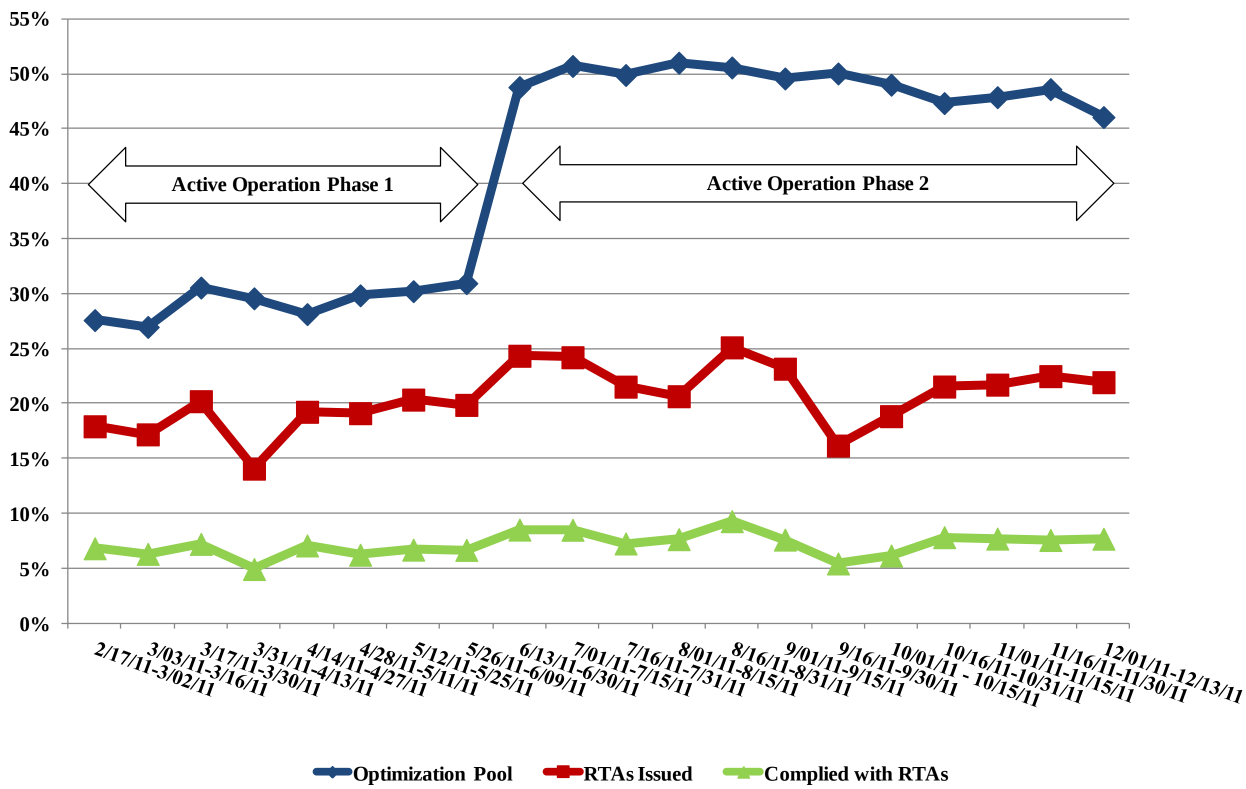

Figure 61. CLT Optimization and Compliance Rates as Percentage of Total Arrivals

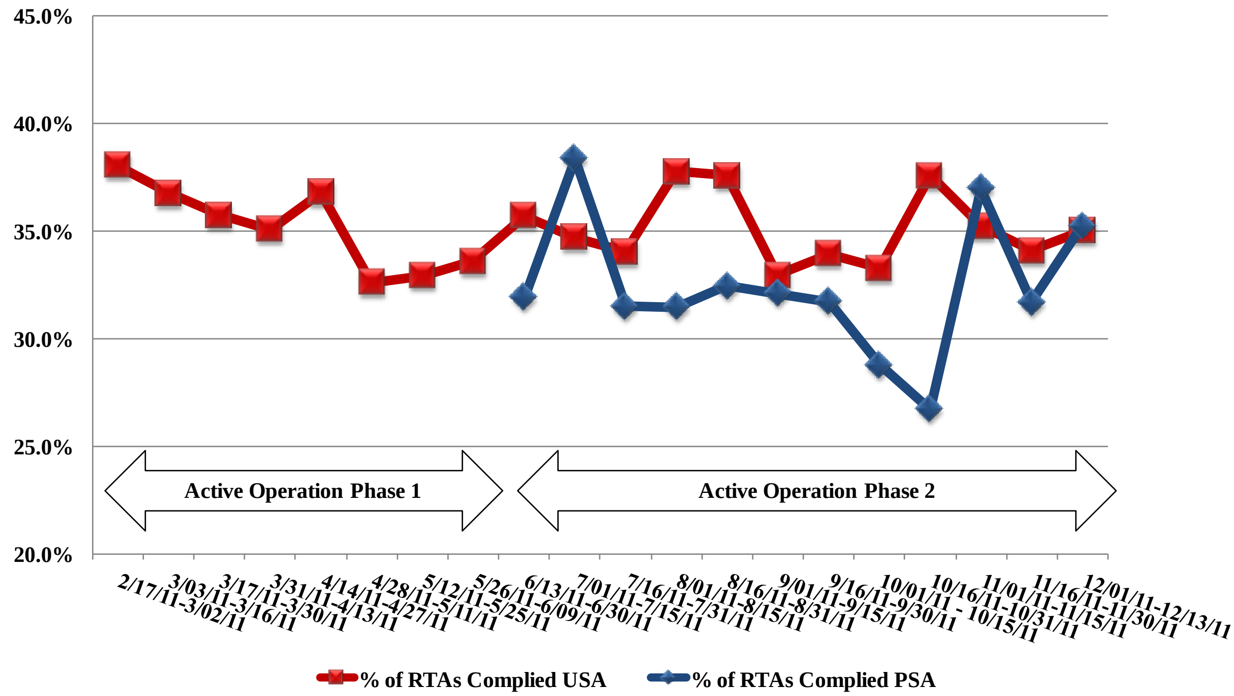

Figure 62. US Airways and PSA Compliance Rates as Percentage of Issued RTAs

7.2 Optimization Rates

To assess AAMS optimization rates the CLT Active Phase 1 period was partitioned into eight biweekly periods. Figure 63 depicts the optimization rates over CLT Active Phase 1 period expressed as the percentage of all flights arrived in each period. The optimization pool and issued RTA rates exhibit a slight uptrend, while the percent of optimized and complied flights hovers around 6.7% over all periods. As presented in Table 3 during the CLT Active Phase 1 period the AAMS software was updated multiple times. The most significant updates took place on March 16, 2011 and April 28, 2011. Figure 64 presents the optimization rates before and after the updates. The updates increased the optimization pool and number of generated RTAs; however the compliance rate stayed within a range of 6.4% to 6.6%.

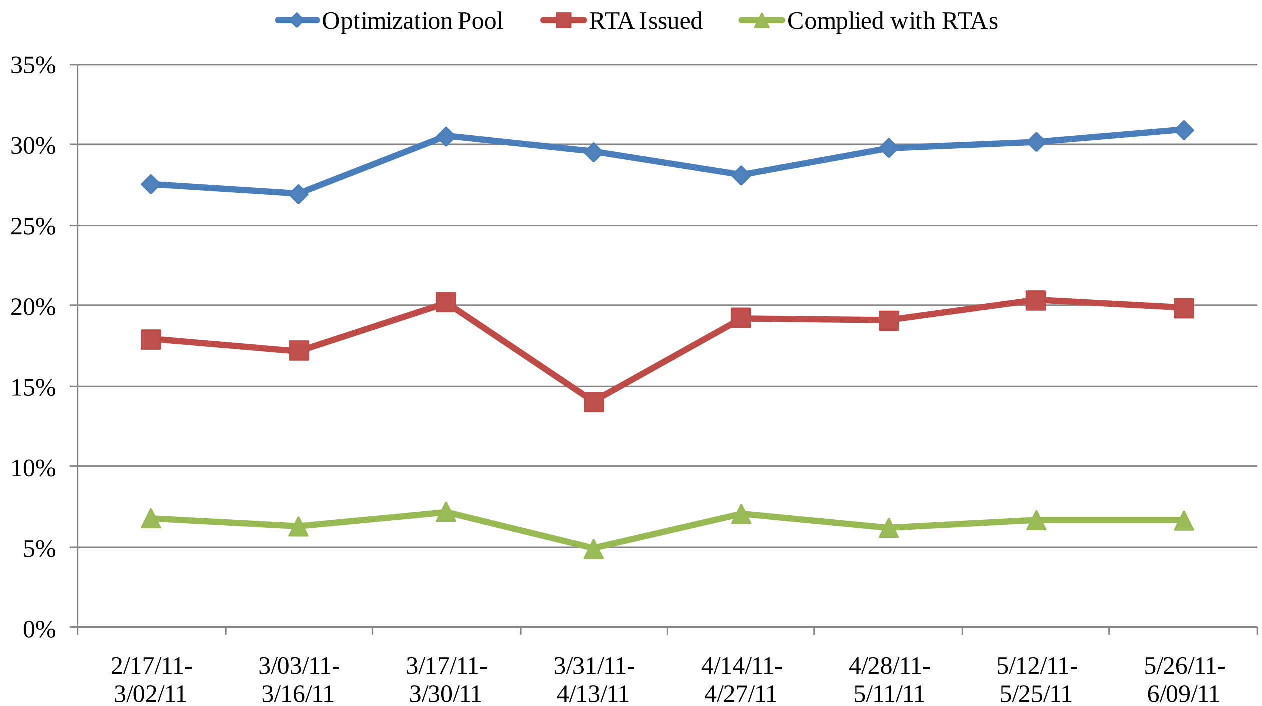

Figure 63. Optimization Rates over CLT Active Phase 1 Period

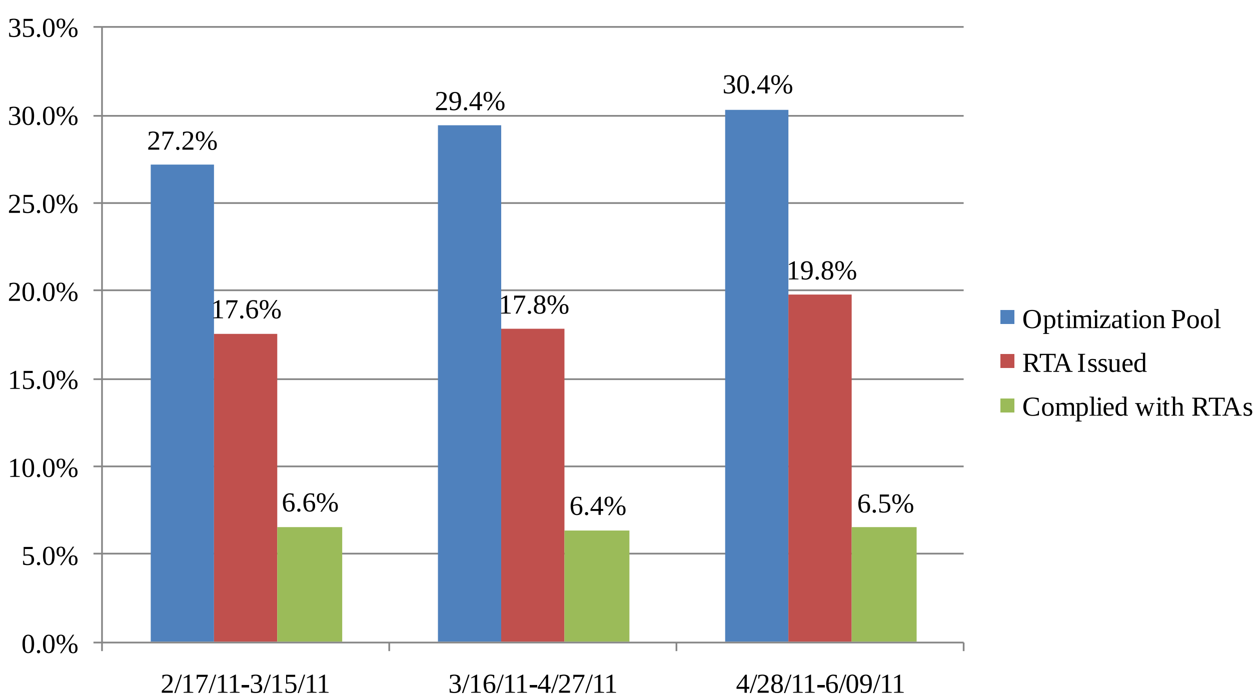

Figure 64. Optimization Rates after Major CLT AAMS Software Updates

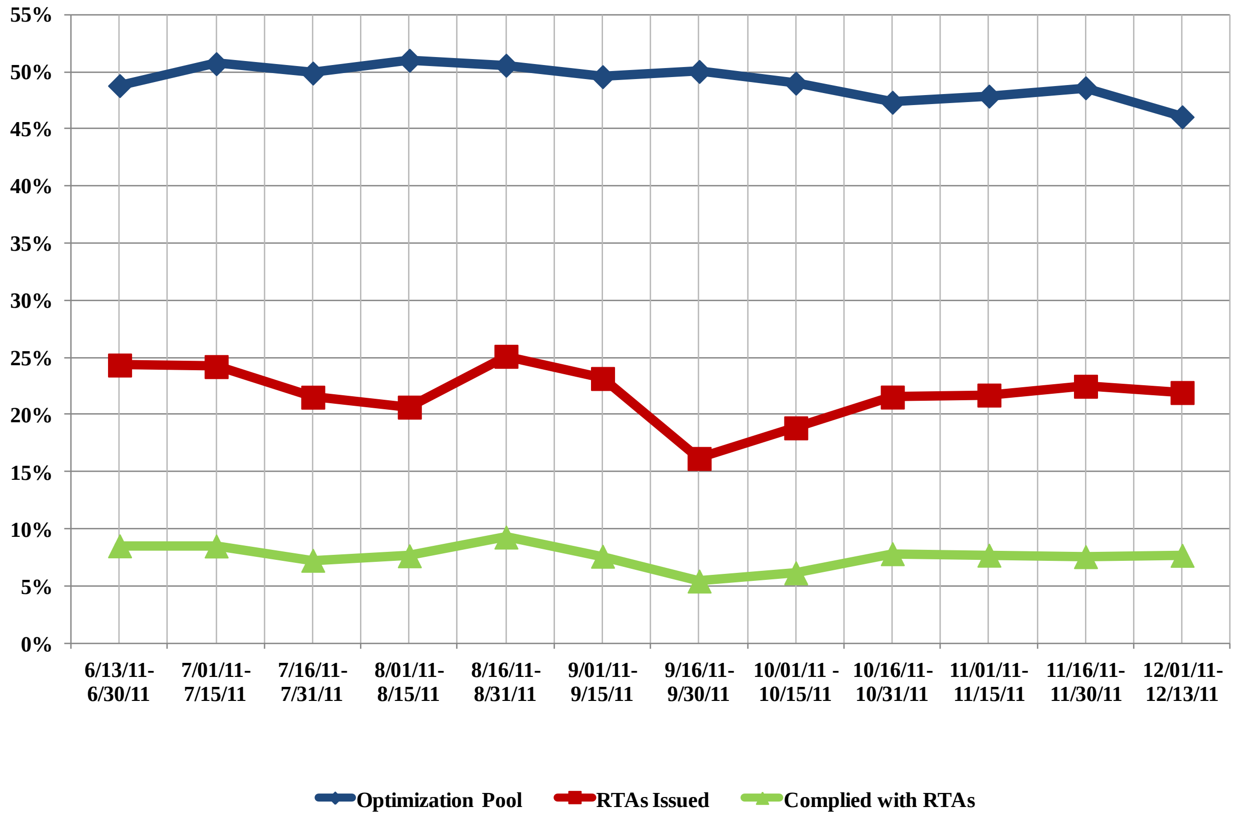

Figure 65. CLT **Optimization Rates over Active Phase 2 Period**

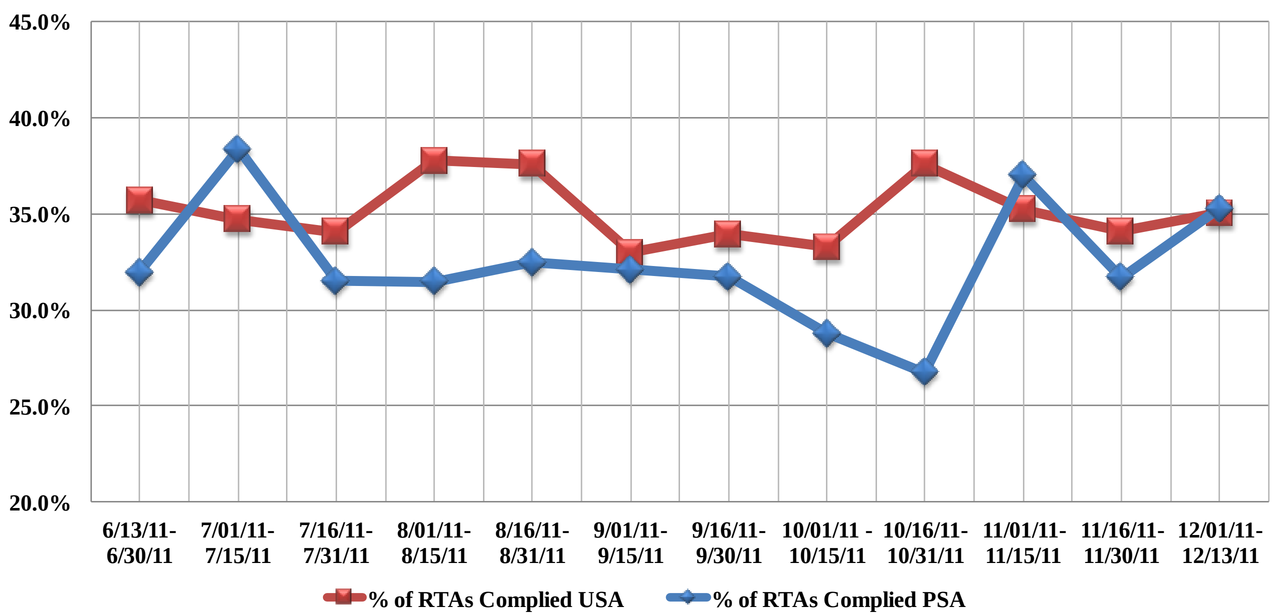

Figure 66. Percent of RTAs Complied for US Airways and PSA over Active Phase 2

The biweekly RTA issue rates show a few points considerably below the average rate. There are two explanations most readily available for this. The first is inactivity of the system due to irregular operations, weather, or disconnect. The largest deficit from Figure 67 in issued RTAs is about the time of an AAMS software update that attempted to reduce the number of ACARS messages issued by only sending RTA to aircraft that needed to adjust speed to meet the RTA.

Unlike the RTA issue rates, the compliance rates, depicted in Figure 68, did not have any notable dips; however, a gentle decline in compliance is perceivable on inspection. The results of the benefits and operational analysis do not indicate that these compliance rates had not been sufficient for evaluative purposes.

Of further interest in the study of the AAMS optimization rates is the contrast and interplay between the MSP and CLT RTA issue and compliance rates and AAMS impact. In particular, while the CLT optimization pool grew considerably from CLT Active Phase 1 to CLT Active Phase 2, only modest increases in RTA issue and compliance rates were observed; however, considerable impact gains were seen. Similarly, with an optimization pool proportionally smaller than both CLT Active Phases, the MSP demonstration saw similar RTA issue and compliance rates as a percentage of total traffic. It would as a result, stand to consider the potential impact of AAMS operational concerns such as arrival flow conditions and airline goal function RTA issue rates. While recalling the US Airways optimization pool carve-outs for the TCI and CF programs, it is apparent that the MSP AAMS, in short, had a greater impact using a distinctly smaller portion of the inbound flight pool.

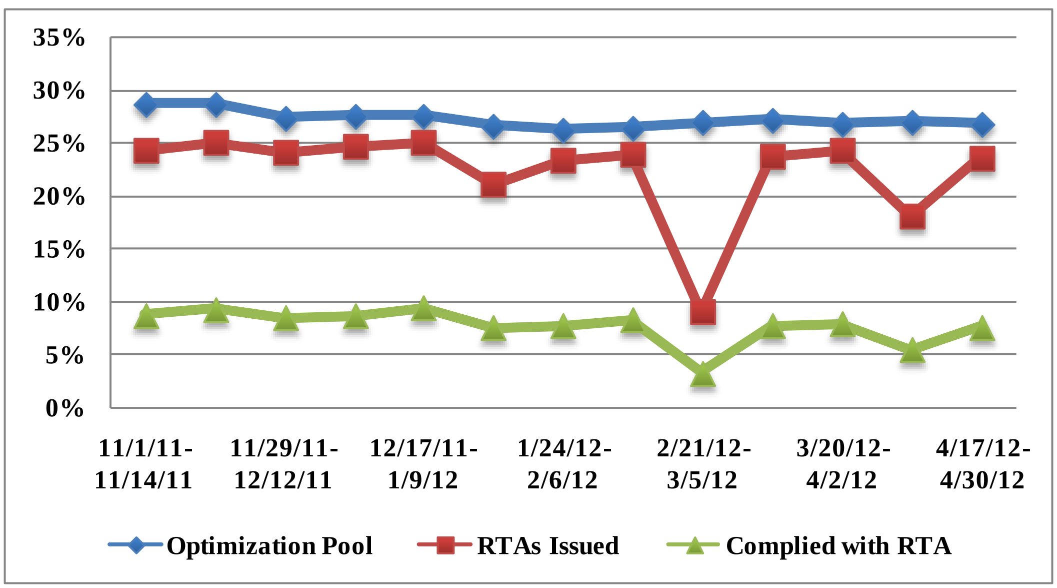

Figure 67. MSP Bi-Weekly Period Optimization Rates as Percentage of Traffic

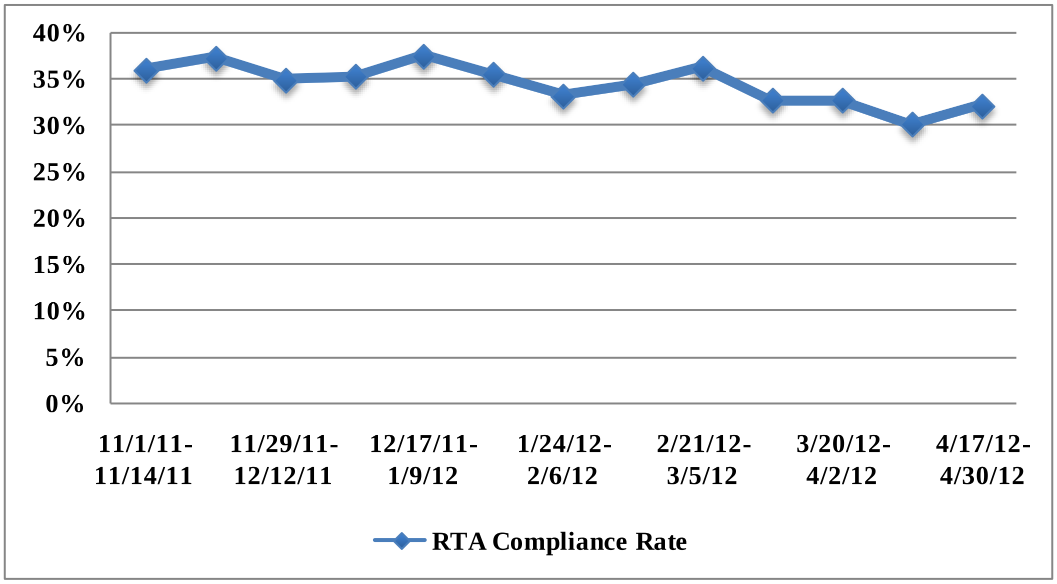

Figure 68. Bi-Weekly Period Percent of Delta RTAs Complied

7.3 Interaction with TMA

The interaction between TMA and the AAMS at CLT has been documented as having driven additional dwell time reductions for AAMS flights that were moved under TMA (TMA*MOV) nearing twenty seconds. This contrasts with the finding in the MSP analysis, where in the regressions performed on all carriers indicate an increase in dwell time for flights that were moved by AAMS under TMA operations. It may also be noted that the Delta-only regressions do not indicate that the TMA*MOV metric was significant, possibly indicating that the disbenefit seen in the all flights regressions is partly driven by some characteristic of Delta's arriving flights. Also of interest, is the disparity in the number of flights arriving while TMA was active at CLT and MSP. At MSP a mere four percent of flights arrived while TMA was inactive while CLT saw as much as 15 percent of its flights arrive with TMA inactive. Additional investigation would be required for any further conclusions.

7.4 Conditions for Maximum Gain

On empirical inspection of the operational data it appears that the AAMS optimal conditions for gain would involve regular operations when the arrival demand is peaked. Such conditions make maximum use of predicting capabilities of the AAMS and its system-wide optimization. When the demand rate is significantly lower than the called arrival rate there are no enough corner post traffic conflicts to allow the AAMS optimization to generate significant efficiency gains. In addition, in the low demand periods the ATC would easily handle potential corner post conflicts without jeopardizing efficiency. Also, during irregular operations the AAMS predicting capabilities are reduced and, thus, optimization engine is affected.

High percentage of participating traffic is also required to achieve maximum gains. Thus, in the average compliance rates were 6.5%, 7.6%, and 7.7% in the CLT Active Phase 1, CLT Active Phase 2, and MSP Active Phase respectively. While data from only two airports cannot be used for a reliable statistical analysis, it seems that even a modest increase in compliance rate (from 6.5% to 7.6-7.7% resulted in substantial increase in efficiency gains. Active engagement of the pilots through training and educational programs would improve the participation rates.

7.5 Goal Functions

The AAMS airline goal functions used in the demonstrations were developed to suit the proprietary desires of the participating carriers. As a result, only limited information about the goal functions is available for the analysis in this report. It can be said, however, that on a macro scale, US Airways Group generally pursued fuel savings while Delta sought to maximize airport capacity and improved arrival performance. The limited nature of this information has, as noted accordingly, made some comparative analyses less definitive.

7.6 Timely Detection of Airport Flow Configuration and Accuracy of the Called Arrival Rate

The algorithms in the Attila™ systems acting as the engines behind the AAMS demonstration are heavily reliant on the accuracy of a few key parameters. The airport flow configuration and call rate drive the much of how the RTA's are generated and latency in detecting, adjusting, or identifying the correct value of either of these can have profound impact on the benefit of the system. In essence, these issues have the effect of "undoing" the system calibration and can quickly unravel the precondition effect offered by the AAMS. Ideally, the AAMS algorithms would be fed these parameters accurately in real time for maximum benefit.

In the beginning of the CLT demonstration, it was found that the FAA called arrival rate was too conservative to achieve maximum benefit and the AAMS was eventually modified to generate its own internal arrival rate. Furthermore, the initial AAMS installation at CLT did not feature an IROP filter to suspend AAMS operations while irregular conditions rendered the algorithm results ineffective. These features have greatly improved the AAMS usability and stability of the AAMS impact in the later stages of CLT and the duration of the MSP demonstration. For the duration of both demonstrations, the air traffic control desks of the airline AAMS operators were responsible for the timely entry of the orientation of airfield operations to maintain AAMS efficacy.

7.7 Recalibration of Algorithms to Changing Environment

Further along the principles discussed concerning the algorithms in Section 7.6, a number of factors impact how well the AAMS conditions the flows into the target airport. Indeed, the careful evaluation of the existing flows at the demonstrations airports in the airport characterization findings shows just how carefully the algorithms have to be matched to the conditions, configurations, and procedures seen at the airport. The calibration performed for the AAMS installations involved feeding large quantities of data into the algorithms to develop models for predicting the behavior of the traffic. Over the course of the demonstrations the AAMS responded to changes in the operating environment—most notably, the CLT runway closure periods. The software adapted to the events with incremental learning and updates with minimal operational issues. The arrival of new arrival fixes and runways, however, would create completely new flow dynamics that would likely need some additional calibration activity.

7.8 Benefits Outside of Corner Posts (by ATH Group)

As requested by FAA, ATH Group independently preformed the Incoming Excess Distance (IXD) analysis by using the *AwSim*™ tool IXD on the CLT demonstration without verification of results or methods by ERAU. The primary function of IXD is to compare a reference file to an object file and obtain the differences between the two files. In this operational evaluation, the object file used was the “realized” (or as-flown) trajectory, and the reference file used was the flight-plan (or planned trajectory).

The results were that:

- AAMS Exchange operations produced a benefit outside of the corner post, and,
- ATH’s “day of” metrics as measured by the AST compare very closely to the results of ERAU’s Dwell Time savings results when Excess Distance is added to the results.

7.8.1 Background

For this analysis, an “area of analysis” surrounding each arrival fix of the airport was created. This area was a circle of 100NM radius around each arrival fix (Figure 69).

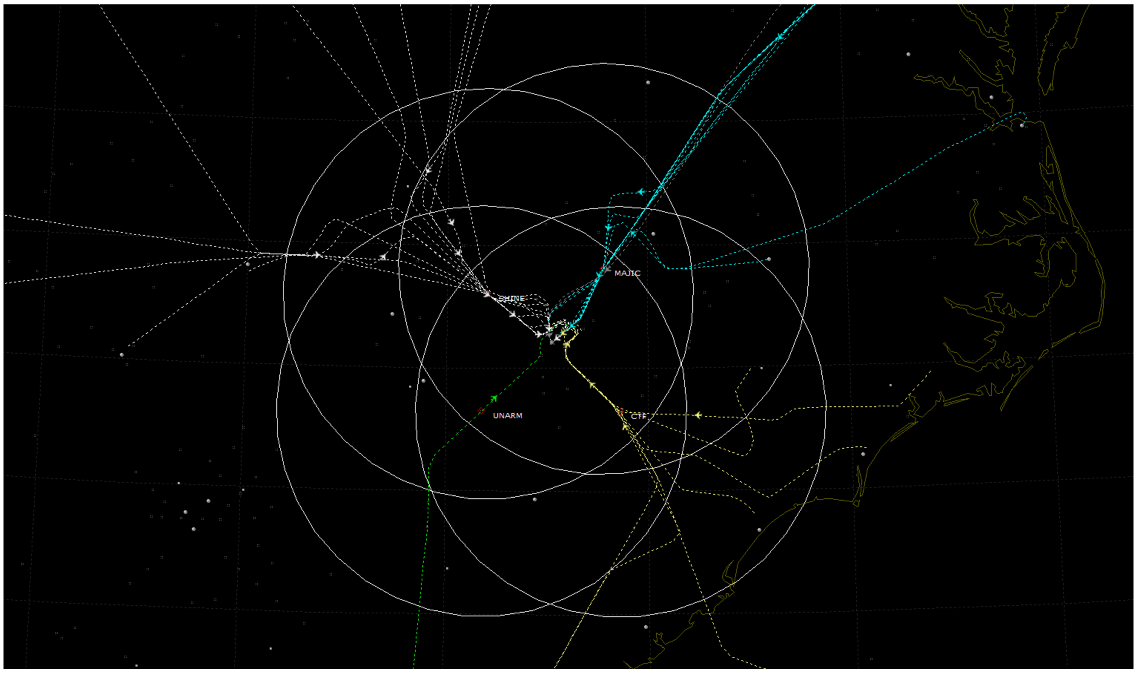

Figure 69. 100nm circle around each corner post

ATH then calculated the different metrics of interest from the moment a flight crossed into this circle to the moment that the same flight crossed (abeam) the arrival fix point.

Three metrics were generated that describe the difference between the reference trajectory and the object trajectory in terms of deviation from flight plan, excess distance, and excess time.

These metrics are:

- *dMaxLatDev* - This describes the lateral deviation between the “as flown” trajectory and the flight plan trajectory expressed as nautical miles. (Figure 70). This is a good measure of the amount of deviation, and it has the advantage of being less affected by such events as holding.
- *dDur* - dDur is the measure of the difference in duration within the area (excess time), measured in minutes. This metric is defined as the difference in the flight-duration, in minutes, between the planned and flown trajectories.
- *dExcDist* – dExcDist is the difference between the Track Length (which is the actual path the flight took) and the direct distance (straight-line distance connecting two points). dExcDist is the difference in excess distance between the planned and flown trajectories.

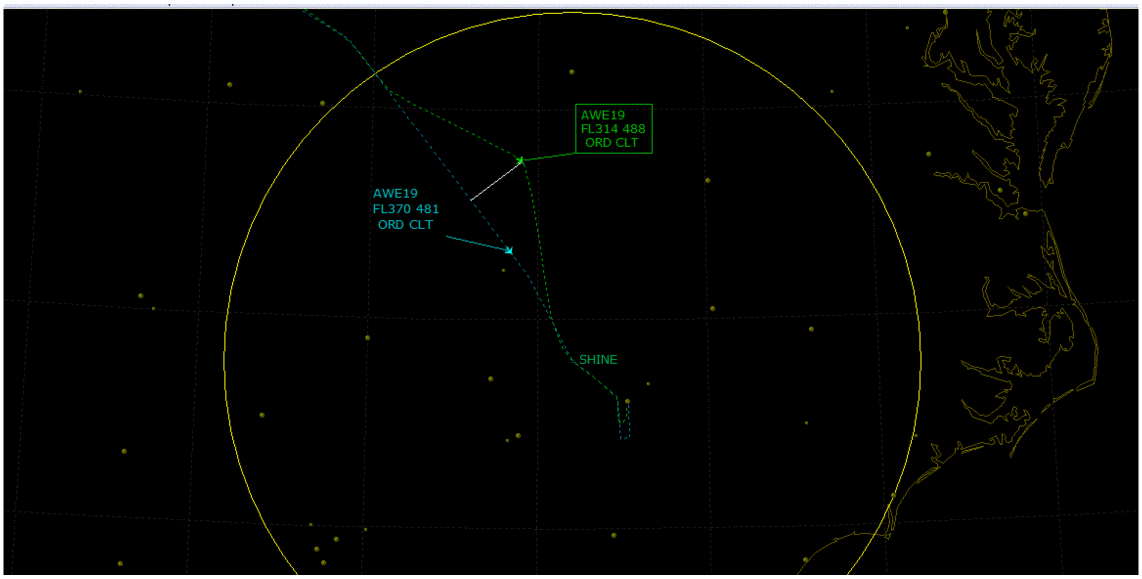

Figure 70. Maximum Lateral Deviation of a flight en route to the airport

7.8.2 Data

ATH used three sets of data for this analysis. These were: AAMS Passive, AAMS Active, and AAMS Exchange.

The CLT Passive Phase data set comprises data taken between September 16, 2010 and December 12, 2010 in CLT. During this period, the AAMS optimization system was running and generating RTAs. These RTAs were collected, but were not sent to the aircraft.

The CLT Active Phase 1 data set comprises data taken between December 13, 2010 and June 12, 2011 in CLT. During this period, the AAMS optimization system was running and generating RTAs. These RTAs were actively transmitted to the aircraft, and results were measured.

The CLT Active Phase 2 data set comprises data taken between June 14, 2011 and December 13, 2011 in CLT. During this period, the AAMS optimization system was running independently at two airlines, and generating RTAs. These RTAs were then sent to the AAMS Exchange function for approval and then back to the airline where they were transmitted to the aircraft.

7.8.3 Filters

The data was filtered for trajectories had much greater (or much less) excess distance than could reasonably be attributed to AAMS optimization. This occurred, for example, when ATH observed a small dMaxLatDev (indicated very little lateral deviation) and very large excess distance. This condition exists for the most part due to holding near the corner post.

ATH see that holding events typically result in a small lateral deviation and a large excess distance. To remove these cases, ATH filtered data with an excess distance greater than 30 nm (Figure 71).

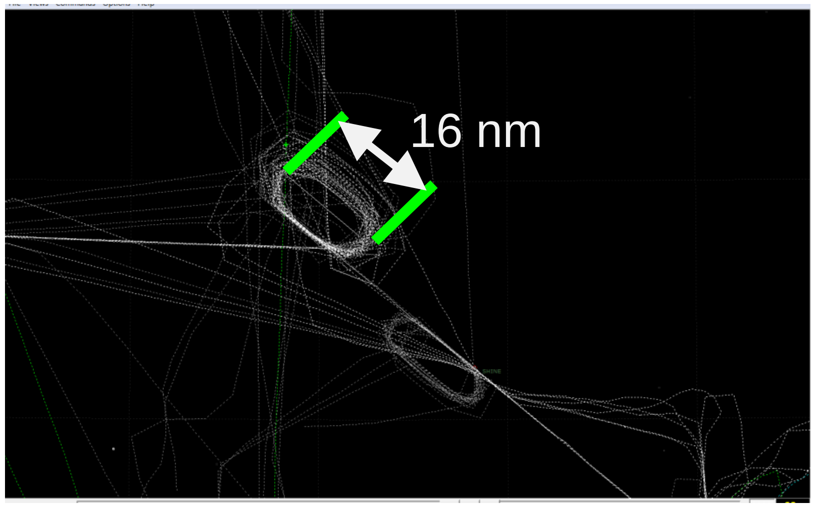

Figure 71. Holding

7.8.4 Results

Table 50 summarizes the results for each of these periods.

Table 50. Excess Distance for US Airways Group Participating Traffic

Period	US Airways Flights				PSA Flights			
	Mean dDur (min)	Mean dExcDist (NM)	Mean dMaxLatDev (NM)	Number of Flights	Mean dDur (min)	Mean dExcDist (NM)	Mean dMaxLatDev (NM)	Number of Flights
Attila™ Passive Ops	0.39	0.30	-0.70	17,463	-1.43	0.00	-1.36	8,294
Attila™ Single User Active Ops	0.21	0.00	-1.07	32,968	-2.14	-0.60	-1.95	16,822
Attila Exchange™ Ops	0.04	-0.10	-1.02	11,135	-1.88	-0.60	-2.04	5,538
Attila Exchange™ Runway Closed Ops	0.28	0.10	-0.94	12,607	-1.77	0.10	-1.18	6,006
Attila Exchange™ Post Runway Closed Ops	0.23	-0.20	-1.27	18,756	-1.9	-0.70	-2.11	8,620
Benefit between Passive Attila™ and Attila Exchange™ Active Ops	0.25	0.40	0.57		0.47	0.70	0.75	

Table 51. Excess Distance for All Other Carriers

	All other flights			
Period	Mean dDur (min)	Mean dExcDist (NM)	Mean dMaxLatDev (NM)	Number of Flights
Attila™ Passive Ops	-0.07	-0.30	-1.72	19,220
Attila™ Single User Active Ops	-0.26	-0.60	-2.05	39,239
Attila Exchange™ Ops	-0.24	-0.40	-1.78	13,675
Attila Exchange™ Runway Closed Ops	-0.14	-0.30	-1.67	14,145
Attila Exchange™ Post Runway Closed Ops	-0.32	-0.70	-2.11	20,230
Benefit between Passive Attila™ and Attila Exchange™ Active Ops	0.29	0.35	0.36	

If one assumes that Passive AAMS Ops is the baseline, then one should expect to see all of these metrics decrease during CLT AAMS Single User Active and AAMS Exchange phases (i.e., all numbers are lower during Active Attila™ operations). This indicates that less time and/or distance had been flown within the defined area, and that AAMS was generating benefit.

Note that there is a clear reduction in both flight time and flight distance in the CLT AAMS Single User Active and AAMS Active Exchange phases versus the AAMS Passive time period.

7.9 Methods of AAMS Exchange RTA Brokerage for Independent Airlines

While the AAMS demonstration at CLT did not make extensive use of the arbitrating functions in the AAMS Exchange, some basic conclusions can be drawn about its function.

- An AAMS Exchange would likely only be needed when the airport under AAMS operation has two or more independent airlines. Indeed, even though US Airways and PSA operated separate AAMS installations for the demonstration, it should be noted that this was for demonstrative purposes. That is if the installation was for other purposes, a single airline AAMS could have theoretically handled both US Airways and US Airways Express flying at CLT.
- Due to the low number of RTA de-conflict actions seen at CLT, the few conclusions can be drawn about the RTA brokerage method in use at CLT.

As a result, while nothing can be conclusively said of the exchange brokerage methods, it can be suggested that based on the findings involving the CBA and optimization rates that an effective exchange method could involve preference for honoring requested RTAs that are most likely to be achievable as all requested RTAs are designed to be ostensibly feasible. While ideally the exchange would favor the requested RTAs that would generate the greatest system and airline benefit, this could prove especially difficult to broker with competing needs while the feasibility of the requested RTAs would generally be easier to evaluate. The feasibility, by extension of the compliance and optimization findings, would also generally boost benefits by helping to improve the optimization and compliance rates and resultant system and airline benefits.

Other potential methods of distributing conflicting RTAs among participating airlines could be based on an airline market share at the AAMS airport or a special agreement among the airlines. Further studies are recommended to develop the AAMS Exchange brokerage methods.

7.10 Airport Characteristics that Lead to Higher Benefits

Since this study is limited to only two airports, a rigorous statistical analysis cannot be conducted to examine what airport characteristics lead to higher benefits. However, from a theoretical perspective and the observations of the AAMS operations at two airports, the following characteristics lend themselves to greater benefits:

- Airports with one or two carriers offering a large portion of the traffic into the airport (optimization pool size)
- Airports that operate close to capacity for the large portion of the day
- Airports with constrained capacity and variable demand
- Airports that are located in areas without inherent severe weather conditions that often lead to irregular operations

7.11 Airline Characteristics that Lead to Higher Benefits

The airline characteristics that generally offer the greatest benefit opportunities with AAMS are generally related to peaked demand by the participating carrier into the AAMS airport. In general, this would mean that carriers operating a hub or connecting complex at the airport would be an ideal candidate for participation in an AAMS. Additionally, it would be helpful to the simplicity of implementation for the carrier involved to have a large portion of its flight schedule operated from a single Operations Center (mainline versus express).

8 Conclusions—Recommendations

The CBAs of the AAMS demonstration projects identifies costs and benefits (both direct and indirect) of single- and multi-user AAMS concept using commercially available ATH Attila™ systems. The analysis of operational data collected in pre- and post-AAMS implementation periods suggests that there are observable system-wide and airline-specific benefits. The Cost-Benefits ratios estimated using only ADOC-based monetized benefits imply that the AAMS-related costs could be quickly recovered. In addition, the analysis provides evidence of benefits that cannot be monetized within the framework of this project: Improved arrival predictability and environmental benefits. Also, while the PVT was monetized, it was not included in the CBA.

The AAMS demonstration projects confirm the viability of the AAMS concept and suggest that if implemented, the AAMS concept will generate considerable benefits to participating airlines as well as the overall AAMS airport operations.

8.1 Impact of Different Airport and Air Traffic Operating Environments

Perhaps the largest impact of concern is the interaction between the AAMS and TMA. The demonstration found a strong symbiotic relationship between the two systems at CLT, especially in CLT Active Phase 2 when TMA was operating while 91% of flights arrived. The MSP demonstration saw mixed results with some of the regressions indicating a negative reaction between TMA and AAMS moved flights and other regressions involving Delta flights showing no statistical interaction while 96% of MSP's arrivals were under TMA operation. These results are at odds with one another, but may suggest that studying the interaction of TMA and AAMS could require monitoring how many flights arrive under TMA.

8.2 Impact of Different Corporate Operating Policies (Goal Functions)

The identification of the impact of specific corporate goals implemented in the demonstrations by the different participating carriers has been muddled by a few factors that have been difficult to control. In addition to the intrinsic differences at the two airfields that have mostly been controlled against themselves with the CLT and MSP Passive Phases, there have been human factors issues in the execution of the demonstration. Efforts had been made to address most of these human factors; however, with only limited knowledge of the proprietary goal functions and the different human factors and RTA compliance issues, discussion of the impact of the goal function impact would be highly speculative.

8.3 Tangible and Intangible System Benefits Obtained at Two Different Sites

Over the course of the two demonstrations at MSP and CLT a suite of benefits has been identified. These benefits identified of a tangible nature are largely of a financial nature, and the difference in the impacts measured at the two airports can be attributed to a number of factors.

The intangible benefits include notable improvements in arrival predictability (A14) for involved traffic as well as environmental benefits such as low altitude noise reductions and decreased greenhouse gas and VOC emissions

8.4 Lessons Learned at Two Different Sites

Among the many lessons learned over the course of the demonstrations is the experience involving variable airport operating characteristics. In particular, the systems have been unable to use the FAA called rates and that the system is highly dependent on knowing the airport orientation.

9 Appendix A: Acronyms

Acronym	*Meaning*
4D	4 Dimensional
AAMS	Aircraft Arrival Management System
ACARS	Aircraft Communications Addressing and Reporting System
ADOC	Airline Direct Operating Cost
AEX	Attila Exchange™ System
AOC or OCC	Airline Operations Center/Operations Control Center
ASDI	Aircraft Situational Display to the Industry
ATC	Air Traffic Control
AST	Attila Statistical Tool (software)
ATH	ATH Group, Inc.
ATL	Hartsfield-Jackson Atlanta International Airport
BADA	EUROCONTROL's Base of Aircraft Data
CF	Critical Flights
CKAM	Check Airman (US Airways)
CLT	Charlotte Douglass International Airport
DAL or DL	Delta Air Lines, Inc. (based on ICAO and IATA identifiers)
DME	Distance Measuring Equipment
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FMS	Flight Management System
FTB	Florida NextGen Test Bed
GA	General Aviation
HAP	Hazardous Air Pollutants
IROP	Irregular Operations
NEAR	Next-Generation Advanced Research Lab
NAS	National Airspace System
NextGen	Next Generation of Air Transportation System
NM	Nautical Miles
OOOI	(Electronically Captured) Out, Off, On and In aircraft data
PSA or JIA	PSA Airlines
PVT	Passenger Value of Time
RTA	Required Time of Arrival
TCI	Tactical Cost Index
TMA	Traffic Management Advisory
TBO	Trajectory Based Operations
USA or AWE	US Airways (based on ICAO identifiers)
VOC	Volatile Organic Compounds
VPN	Virtual Private Network