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Central Command Rest and Recuperation Hub-to-Hub Airlift Network Analysis

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THESIS

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AFIT/LSCM/ENS/11-03

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Abstract

The primary purpose of this research effort was to discover the efficiency and effectiveness of the historical hub-to-hub R&R airlift network. This study analyzed the hub-to-hub aircraft efficiency rates and introduced capacity changes in the airlift network with the use of Arena simulation to improve network performance. Furthermore, this study created simple heuristic options for the future airlift framework required to meet USCENTCOM's forecasted R&R transportation demand under the premise of a CY11 country 1 drawdown and an upscale of combat and support forces within country 2.

There were several important outcomes of this research effort. First, this study designed the future framework for R&R airlift passenger operations with a focus on leveraging simple heuristics to increase intertheater commercial aircraft utilization to 89.7 percent while also adding four additional weekly sorties in the strategic port to intratheater hub routes. As a result, this study demonstrated that passenger velocity at the strategic port could be increased by 20.6 hours on the average and 24.9 hours at the 90th percentile with a decrease in the transient passenger footprint at the strategic port by 215 passengers on the average. This transient passenger footprint reduction also opens up further opportunities for cost savings by contracting support personnel and facilities at the strategic port for future operations. Finally, this study found that the use of a simple heuristic could increase commercial aircraft seat utilization rates by approximately 10 percent yielding an estimated $26.5M in yearly savings in contract airlift.

Acknowledgments

Taking on this challenge was a lot of fun and a great learning experience that could not have been accomplished without the help of many people. I would like to thank my wife and brand new baby boy. A special thanks to my brother and mother for reading this thesis and providing valuable feedback. A sincere thank you is also in order to Dr. Donovan and Dr. Skipper both of whom provided valuable guidance and advice.

John M. Dickens

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List of Acronyms

ACL: Allowable Cabin Load
AMC: Air Mobility Command
APC: Aerial Port Code
APOD: Aerial Port of Debarkation
APOE: Aerial Port of Embarkation
AOR: Area of Responsibility
CSAHLP: Capacitated Single Allocation Hub Location Problem
CONUS: Continent of the United States
FOB: Forward Operating Base
GATES: Global Air Transportation and Execution System
GRASP: Greedy Randomized Adaptive Search Procedure
HLP: Hub Location Problem
I-Channel: Intratheater Channel
ITARS: Intratheater Airlift Request System
JDPAC: Joint Distribution Planning and Analysis Center
MILP: Mixed Integer Linear Programming
MOLP: Multi Objective Linear Programming
PAX: Passenger
POD: Point of Debarkation
POE: Point of Embarkation
R&R: Rest and Recuperation
SAAM: Special Assignment Airlift Mission
SA: Simulated Annealing
STARS: Scheduled Theater Airlift Routing System
TACC: Tanker Airlift Control Center
TDY: Temporary Duty
ULN: Unit Line Number
USCENTCOM: United States Central Command
USTRANSCOM: United States Transportation Command

CENTRAL COMMAND REST & RECUPERATION HUB-TO-HUB AIRLIFT NETWORK ANALYSIS

I. Introduction

Background and Motivation

The United States Central Command's Rest and Recuperation Leave Program (R&R) is an important Morale, Welfare and Recreation initiative. It is intended to provide U.S. service members and civilians deployed for 12 or more months in one of 17 contingency countries in support of country 1 and 2 the opportunity to recoup from the rigors and stresses of the combat environment. Additionally, this program provides an unparalleled opportunity for deployed personnel to reconnect with friends and family members.

There are several factors involved with this complex R&R program. The authorized percentage of personnel on R&R at any given time can be no more than 10 percent of the combat and support forces who meet the eligibility requirements. Airfare expenses are funded by the U.S. government, not the traveler. Furthermore, those personnel who meet the eligibility requirements, 12 months deployed or 270 days in theater, are permitted at commander discretion to expend up to 15 days of non-chargeable leave, as well as 18 days of non-chargeable leave, for those serving a 15 month deployment.

The expedient transportation of these heroes to and from the theater of operations is of concern to Air Mobility Command (AMC) as all commercially contracted airlift is coordinated through the Special Assignment Airlift Mission (SAAM) cell at the Tanker

Airlift Control Center (TACC). The transportation network that supports this program is a hub and spoke airlift network. The R&R intertheater gateway for inbound and outbound passenger movement is located at the theater strategic port. This location is the pivot foot for the entire hub-to-hub R&R airlift network. It supports a two-way queue that stages and prepares R&R passengers for onward movement to two CONUS hubs as well as six intratheater hubs.

Participating passengers are transported through a hybrid network that relies on the use of both military and commercial capabilities. U.S. service members and civilians are funneled from their respective Forward Operating Bases (FOB) to the theater strategic port on military airlift (C130/C17) for onward transport via AMC commercial chartered airlift from an international airport destined for two major commercial hubs; one is CONUS 1 for east coast destined passengers and the other is CONUS 2 for west coast destined passengers. Additionally, the return portion of this transportation network uses the same two CONUS hubs to transport passengers back to the same international airport for continued onward ground transport to the theater strategic port then air transport via C130/C17 to each passengers respective intratheater hub. This process is a hybrid approach that uses both finite military and civilian airlift capabilities to transport R&R passengers and requires a highly synchronized nodal system to ensure efficient and effective utilization of programmed assets.

The primary motivation for this study was to assess that the United States Central Command (USCENTCOM) had an effective and efficient hub-to-hub R&R airlift transportation network. By-products of a near-optimal hub-to-hub transportation system are an increased USCENTCOM combat capacity and a network that appropriately balances efficiency and effectiveness. It was essential to study this area to ensure it met the current and future needs of USCENTCOM and those personnel eligible for R&R travel. Furthermore, the outcomes of this study can help guide the future airlift framework for military R&R operations.

Problem Statement

A recent study conducted in March 2010 by AMC/A9 reported that total transportation wait time at the theater strategic port for the 90th percentile of country 1 and 2 R&R passengers was 3.7 days and 5.1 days, respectively. These transportation wait times at the theater strategic port inspired a needed review of the historical hub-to-hub R&R airlift network with an emphasis on appropriately balancing efficiency with effectiveness. Using simulation modeling, hub-to-hub aircraft efficiency was assessed and changes were introduced to the network to balance efficiency and effectiveness. Furthermore, this study conducted an in-depth analysis with intertheater airlift heuristics options to maximize efficiency and effectiveness trade-offs to meet USCENTCOM's forecasted R&R transportation demand under the premise of a Calendar Year 2011 (CY11) country 1 drawdown and an upscale of combat and support forces within country 2. An additional outcome of this research was to provide AMC forecasted intertheater hub passenger throughput values, i.e. average passenger wait time, passenger wait time at the 90th percentile, average number of passengers in the queue and maximum number of passengers in the queue. These values were extracted from the simulation model that leveraged a forecasted R&R passenger arrival rate for CY11 to aid AMC in its effort to selecting an alternative intertheater hub for the theater strategic port.

II. Literature Review

To study the performance of the R&R airlift network and recommend improvements the following streams of literature were examined: hub and spoke, airlift network optimization, and simulation modeling.

Hub and Spoke

Hub and spoke literature focuses primarily on three areas of research: performance, type, and the hub location problem (HLP). The hub and spoke concept has been the centerpiece for transportation networks, providing economies of scale and greater cost effectiveness. Within a hub and spoke framework, a main operating location serves as a hub and used to offload and upload personnel and equipment for onward transportation to the various forward operating locations or spokes (AFDD 2-6, 1999). The hub is generally fully interconnected to facilitate interactions, while the non-hub locations are typically only connected to one available hub. The primary advantage of the hub and spoke delivery network is the combining of passengers and equipment traffic into efficient airplane loads (O'Kelly, 1995). The action of bundling passenger flows enables airlift planners to leverage larger capacity aircraft which results in increased passenger mile savings. One study reported that the hub and spoke network decreases total network costs but the trade-off is an increase in individual travel miles (Bryan, 1999). In this study efficiency and effectiveness were the two critical performance factors measured. Thus, this study continued to leverage the use of the hub and spoke concept within the R&R airlift network.

The hub and spoke concept differs from the direct delivery method. The direct delivery method is a completely interconnected network where passengers and equipment bypass intermediary operating locations or hubs moving point to point from point of embarkation (POE) to point of debarkation (POD) (AFDD 2-6, 1999). One study reported that the direct delivery method is highly effective because it shortens travel time for equipment and personnel. However, it can be highly inefficient when resources are limited because of the large number of links that are required (Bryan, 1999). Therefore the delivery method is not an appropriate tool for a large-scale steady state transportation system where the key performance factors of efficiency and effectiveness both require an appropriate balance.

There are two types of hub and spoke networks. The single assignment hub and spoke model links the spokes to a single hub. The multiple assignment model allows each non-hub location to be linked to more than one hub. When the multiple assignment model is leveraged, passenger sorting at the non-hub location must be accomplished to determine which hub will be used for downstream transport (Bryan, 1999). This study focused purely on the single assignment model since infrastructure in theater currently only supports the linkage of each FOB to one specific hub.

The hub location problem directly ties into the hub and spoke network design concept and it has been well covered in contemporary literature. The HLP focuses on communication, mail delivery, and passenger/cargo transportation networks (O'Kelly, 1995). Several methods have been applied to HLP including: linear programming (LP), multi-objective linear programming (MOLP), and heuristics based on tabu search, greedy randomized adaptive search procedure (GRASP), branch and bound and simulated annealing. The overall objective of the HLP is to minimize total costs.

One variation of the HLP is the capacitated single allocation hub location problem (CSAHLP). In this problem a set of known nodes are considered that exchange traffic on a daily basis. The average traffic between all pairs of nodes is known and the traffic must be routed and consolidated to at least one but no more than two hubs. However, there is a traffic capacity restriction on the hub(s) in the problem. This problem has been solved using a mixed integer LP-based branch and bound formulation (MILP) where two heuristics are used to obtain initial upper bounds for the MILP. This is a technique that is useful in pruning the branch and bound tree. The two heuristics used to obtain initial upper bounds were simulated annealing (SA) and random descent. Each heuristic proved to be a better aid in finding the optimal solutions in different situations (Ernst, 1999). This HLP variation and approach appears to be more applicable to this research effort given that all the hubs being considered to replace the theater strategic port intertheater have capacity constraints.

Airlift Network Optimization and Simulation Modeling

Airlift network optimization models are broadly categorized as intelligent but inflexible. The first airlift network research focused on determining optimal aircraft routing assignments with linear programming techniques, as introduced by Ferguson and Dantzig. The purpose was to assign aircraft to network routes in order to maximize profits under stochastic demand with a known distribution (Ferguson, 1956). Military airlift networks however, often differ from civilian networks in that requirements are not always in steady state and are influenced by large events resulting in large variance (Baker, 2002). This uncertainty in demand creates unique challenges for developing optimal or near-optimal military airlift networks.

With the advancements in computing power, LP solutions to military airlift networks and uncertain demand have been developed to consider a time constrained environment. In 2002, Baker described a LP model that could optimize strategic airlift to move equipment and personnel from varying origins through a network to many destinations with heterogeneous aircraft and ground support capabilities (Baker, 2002). This model was called NRMO and was also successful in helping the Air Force analyze other important issues such as aircraft fleet modernization and acquisition, airfield resource procurement, and multi-role aircraft utilization (Baker, 2002).

Baker reported that optimization models are prescriptive and are used to recommend a specific course of action. Baker's study noted that NRMO provided an optimal solution in accordance with the models objective function. In contrast, Baker also commented that simulation models can capture more details than an optimization program and can be controlled and guided by heuristics (Baker, 2002). In 2003, Wu conducted a study and presented an optimizing simulator model of the military airlift problem. The researchers also noted that an optimal solution is closely aligned with the objective function used in execution of the model. Thus, while a solution may be optimal, it may also be an imperfect measure (Wu, 2003). In retrospect, airlift network optimization models have been beneficial in finding optimal solutions but computer simulation is another powerful method for examining airlift performance without the limits of a rigid objective function.

Unlike airlift network optimization models, simulation modeling has been characterized as robust with the ability to handle a high degree of uncertainty but requires careful model validation. The trade-off with simulation however has been that it is not exact and does not provide an optimal solution. In 1995, Morton reported that simulation was more widely accepted in the Air Force culture when compared to optimization as it has the ability to track a higher level of detail and accommodate a great deal of uncertainty. For example, simulation can report the utilization of individual aircraft by specific tail number. However, the disadvantage with simulation was it did not provide optimal solutions but was more geared towards the what-if scenarios (Morton, 1995). Another study conducted by Stucker in 1999 further validated this finding by noting that simulation models required prescribed rules or heuristics to allocate resources to requirements. Furthermore, that study also noted that simulation provided estimates of aircraft flows and deliveries whereas airlift optimization was best suited to provide optimal resource allocations (Stucker, 1999). Because the purpose of this study was to improve upon an existing and somewhat fixed-node network, simulation was used with an emphasis on heuristic development as the source for system improvement.

In 1999, a study conducted by Kellner provided important simulation model validation techniques. This study reported that real world data should be used to help validate and tune the simulation model. This type of validation is crucial as the value of the simulation outputs is highly dependent upon the accuracy of the model parameters (Kellner, 1999). Thus for the purposes of this research effort, the simulation model was calibrated and validated against 16 different categories using real world data to ensure credible model results were produced. Kellner also reported in his research that in a deterministic model only one simulation run is necessary. However, when a stochastic model is leveraged, the outputs will vary from one replication to the next (Kellner, 1999). Thus since the simulation model used a stochastic distribution, it was run for multiple replications and the model outputs were averaged to provide credible estimates.

III. Methodology

Historical R&R Airlift Network

The historical R&R passenger airlift network is a single assignment model design feeding countries 1 and 2 with passengers traveling to/from two hubs within CONUS. The theater strategic port serves as the intertheater R&R passenger hub or transshipment node. This intertheater hub bundles and transports passengers to/from two CONUS hubs located at CONUS 1 and CONUS 2. Furthermore, the theater strategic port also bundles and transports passengers destined/originated to/from two intratheater hubs, IT Hub 11 and IT Hub 12, that service country 1and three intratheater hubs, located at IT Hub 22, IT Hub 21, and IT Hub 23, enabling country 2 passenger operations. Continuing further, each of these intratheater hubs are connected to single locations within each respective theater with no location connected to more than one hub, with the exception of two Forward Operating Bases (FOB). Figure 1 depicts a broad overview of the R&R airlift network.

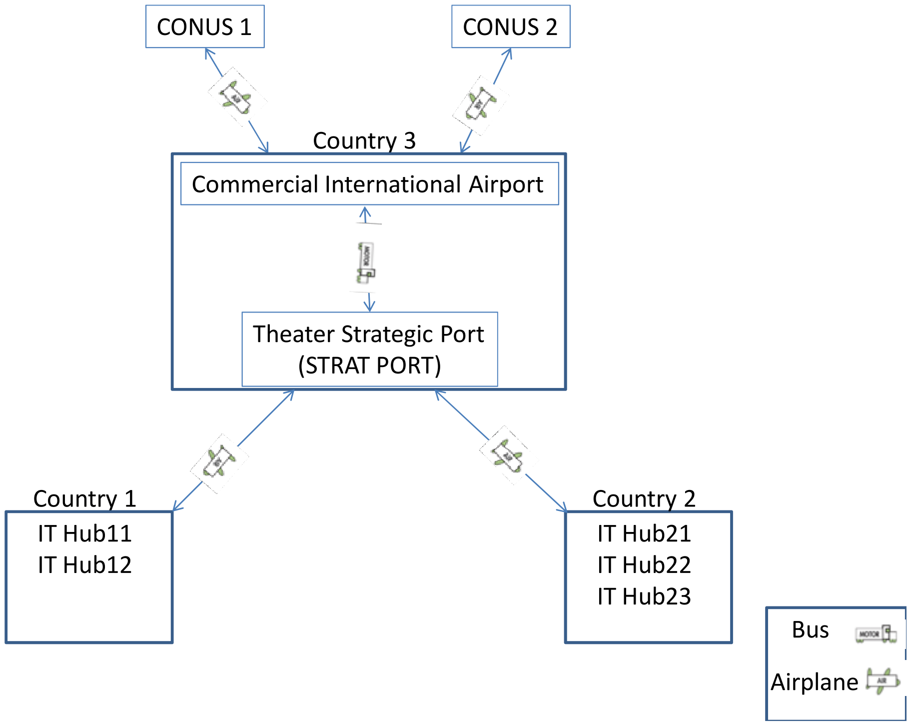


Figure 1: R&R Airlift Network Overview

The ultimate goal is to achieve the appropriate balance between efficiency and effectiveness within the hub-to-hub airlift transportation network. This is challenging and often requires balance or trade-offs between efficiency and effectiveness measures. The overall performance of the hub and spoke also depends on how efficiency and effectiveness are measured and the priority or importance of each. For example, improvements in seat utilization rates often results in increased passenger waiting time (Skipper, 2002).

Data Collection

In order to develop a useful simulation model, it was necessary to collect real world data that characterized the historical hub-to-hub R&R airlift network. However, attaining the ideal mix of real world data was not possible as several challenges existed. The first involved the Air Force logistics information system referred to as Global Air Transportation and Execution System (GATES). GATES is an AMC logistics enabling information system that captures and records time-series cargo, passenger, and aircraft information within its realm and scope of operations. This research relied heavily on GATES but there were some limitations with the logistics information system.

Within GATES, limited passenger data queries can be manually developed to user defined specifications. However a few drawbacks of GATES include: the inability to process large quantities of information without system failure, narrow options for user query development, and meager location-to-location data coverage. For example, GATES produced a passenger data output for a single Aerial Port Code (APC) which did not report the entire trip for any given passenger. The data extracted would only display the current APC, the APOE, and the APOD. The inability for GATES to produce each leg of any passenger's trip or at a minimum the final destination within the data queries made this research effort a challenge. However, the purpose of this research was not to test GATES and discover its weaknesses because it is a powerful logistics information system that did provide useful data for this effort.

The second challenge and the first finding of this research effort entailed operator discipline at GATES input locations. More specifically, each passenger that signs up for travel at an APC should be branded a specific code within GATES by the operator. Those travelers who are on R&R leave should receive an RS code within the logistics information system identifying them as traveling on special combat leave. Unfortunately, due to a lack of data- input discipline in the field, the RS code was used sparingly which made this research effort a challenge as the data did not accurately represent the entire system.

More specifically, over the time span of one year, GATES data confirmed that 173,594 passengers flew within the hub-to-hub R&R airlift network although not all passengers traveling through the R&R network were necessarily on R&R leave. That network being carefully defined as passengers traveling and counted one-way from the theater strategic port to either CONUS 1 or CONUS 2. However, 70,559 passengers were coded RS within GATES. Assuming 95 percent of 173,594 passengers were on R&R leave brings the final yearly total to 164,914 R&R passengers. This was an aggregate 57.3 percent failure rate for GATES operators, within country 1 and 2, to code R&R passengers as RS. Possible reasons for these input failures may have been due to deficient training, high turnover, lack of guidance, poor quality control, and enforcement. Regardless, this obstacle made it impossible to determine the number of true R&R travelers that arrived the theater strategic port from each of the main intratheater hubs. This was a problem that could only be partially cured by using a strategy of proportionality to determine an approximation of those R&R travelers from each main intratheater hub.

Given these challenges with both GATES and the human error element, extracting a large portion of the data was accomplished with assistance from AMC data records personnel. AMC was able to successfully pull and provide passenger data for each of the main intratheater hubs servicing countries 1 and 2 for Fiscal Year 2010 (FY10). This data was specific to all passengers traveling from an intratheater hub to the theater strategic port regardless of the travel code that was assigned within GATES. The purpose behind this strategy was to provide the complete picture for the entire theater strategic port airlift network, not just RS coded passengers as this coding scheme did not accurately represent the true input of R&R passengers into the airlift network.

Once the annual passenger movement values were tallied from each intratheater hub to the theater strategic port, the next step was to assign proportionate values for those passengers traveling on R&R leave. Table 1 depicts the percentage values by intratheater hub used to determine the proportions that reflect the passenger quantities that arrived the theater strategic port from each of the five intratheater hubs. The proportion percentage column depicts the data that was used in the simulation model to develop the assign module with the attribute labeled "Passenger Type".

Table 1: Apportioning Passenger Traffic

Origin	Total Passengers to Theater Strat Port	RS coded passengers	Proportion %	Proportion Passengers
IT Hub11	98,227.00	27,657.00	0.32	54,803.51
IT Hub12	68,892.00	0.00	0.22	38,436.71
IT Hub21	44,258.00	12,726.00	0.14	24,692.74
IT Hub22	24,231.00	9,090.00	0.08	13,519.13
IT Hub23	347.00	8.00	0.00	193.60
FOB11	27,477.00	6,920.00	0.09	15,330.16
FOB12	9,291.00	305.00	0.03	5,183.70
Country 4	23,597.00	13,848.00	0.08	13,165.41
FOB13	5.00	5.00	0.00	2.79
Country 3	14,816.00	0.00	0.05	8,266.25
TOTALS	311,141.00	70,559.00	1.00	173,594.00

Table 1 displays several other important types of data. Most important is to understand how the annual theater strategic port passenger arrivals are determined by each intratheater hub. For example, GATES reported that 173,594 passengers flew within the hub-to-hub R&R airlift network. IT Hub 11 moved a proportion of 31.5 percent of the total passenger traffic to the theater strategic port in FY10. Therefore for the purposes of this research effort, IT Hub 11 moved 31.5 percent of the 173,594 passengers that flew within the hub-to-hub R&R airlift network or 54,803 R&R passengers. This same logic was applied to each of the four remaining intratheater hubs to include other locations serviced by the theater strategic port, which are FOB 11, FOB 12, and FOB 13 all of which are located in Country 1. Other locations serviced by the theater strategic port are Country 3 which hosts the theater strategic port, and Country 4 which hosts one FOB.

In order to determine accurate theater strategic port passenger arrival rates for simulation model development, GATES aircraft mission data was extracted for those commercial aircraft missions departing the theater strategic port and destined for either CONUS 1 or CONUS 2. The aircraft mission data was collected spanning a timeframe from 1 November 2009 to 31 October 2010 providing a full year's worth of data. It was then organized in a time-series fashion and aggregated into daily arrival values. For example, if the data displayed two MD11 aircraft, each carrying 300 passengers, departing the theater strategic port destined for CONUS 1 on 2 January 2010, then the total passengers that arrived the theater strategic port on 2 January 2010 was 600 passengers. To further illustrate, if the data showed an additional 140 passengers departing the theater strategic port in a B767 destined for CONUS 2 on 2 January 2010 then the total passengers that arrived the theater strategic port on 2 January 2010 was 740. This approach was used to determine the R&R passenger arrival distributions for the theater strategic port on a quarterly and annual basis. The first Calendar Year 2010 (CY10) quarter distribution was applied to the Arena simulation model to provide accurate and realistic theater strategic port arrival rates. Other data necessary for model development is shown in Tables 2 and 3.

Table 2: Theater Strategic Port to CONUS 1 Mission and Passenger Data

Aircraft Type	% Aircraft Type Used	International Airport Missions to CONUS1	Number of Passengers Moved	Average Number of Passengers Moved
MD11	0.59	242.00	67,925.00	280.68
DC0103	0.41	168.00	43,301.00	257.74
76730	0.00	0.00	0.00	0.00
B77720	0.00	1.00	120.00	120.00
B75720	0.00	1.00	164.00	164.00
TOTALS	1.00	412.00	111,510.00	n/a

Table 3: Theater Strategic Port to CONUS 2 Mission and Passenger Data

Aircraft Type	% Aircraft Type Used	International Airport Missions to CONUS2	Number of Passengers Moved	Average Number of Passengers Moved
MD11	0.04	13.00	1,682.00	129.38
DC0103	0.04	13.00	1,813.00	139.46
76730	0.93	333.00	58,589.00	175.94
B77720	0.00	0.00	0.00	0.00
B75720	0.00	0.00	0.00	0.00
TOTALS	1.00	359.00	62,084.00	n/a

The aggregate values were derived from the GATES aircraft mission data. This type of data proved useful in determining capacity approximations for commercial air movement from the theater strategic port to either CONUS 1 or CONUS 2. Furthermore, this data showed that the primary airlift capabilities used to transport CONUS 1 destined passengers were the MD11 and DC10 aircrafts whereas the B767 was the primary airlift capability used to transport CONUS 2 destined passengers. Ultimately, this data was pivotal to simulation model development and even more so in simulation model validation where the missions flown and passenger averages were used to fine tune the simulation model.

Efficiency

USCENTCOM uses theater assigned airlift assets on a routine basis to move equipment and passengers into, out of, and within its theater of operations. These airlift assets operate what are referred to as Intratheater channel (I-channel) missions providing scheduled service within the USCENTCOM Area of Responsibility (AOR) (Intratheater Airlift LOI, 2010). Country 1 and 2 each use five C130 and two C17 aircraft for the I-channel missions (I-channel slides, 2009). Because airlift assets are scarce the minimum utilization standard required for continued service is 75 percent Allowable Cabin Load (ACL) (Intratheater Airlift LOI, 2010).

USCENTCOM measures aircraft efficiency in terms of passenger (PAX) pallet equivalents with respect to aircraft to create a conversion factor that is used in the efficiency equation. Table 4 illustrates the conversion factors and passenger and pallet capacities for each airplane used in USCENTCOM's transportation network.

Table 4: Passenger to Pallet Normalization Factors

Aircraft Type	Conversion Factor	Pallet Positions	Maximum Number of Passengers
C130H	12.6	6	72
C130J	15.14	8	115
C17	10.5	18	189
IL76	n/a	9	0
AN124	n/a	42	0

The following equation is used in conjunction with Table 4 to calculate aircraft efficiency:

$$\text{Efficiency} = \frac{\left(\frac{(\text{PAXOn} + \text{PAXThru})}{\text{conversion factor}} + \text{PalletOn} + \text{PalletThru}\right)}{\text{MaxPallet}}$$

Where: PAXOn = Number of passengers getting on the aircraft
PAXThru = Number of passengers staying on the aircraft from the last leg
PalletOn = Number of pallets being placed on the aircraft
PalletThru = Number of pallets staying on the aircraft from the prior leg
MaxPallet = Maximum number of pallets for the aircraft type

This research effort did not use the equation above to measure intratheater airlift efficiency. The need for simplicity and limitations in data and time prevented this approach. However, efficiency with regards to intratheater airlift at a hub-to-hub operational level or one-way return leg traffic was measured by using the published allocated seats per aircraft type for R&R passengers versus the number of R&R travelers that filled those seats in the airlift network simulation. For the purposes of this research, efficiency was defined as the average utilization or number of seats filled by each aircraft assigned to a particular inter to intratheater hub route. This provided a simple performance measure that can be communicated to AMC.

Table 5 illustrates how seats were allocated for R&R passengers on a C17 aircraft across varying legs or routes. For example a C17 traveling from the strategic port to FOB 1 on Sunday for its routine I-channel mission had a total of 158 seats with 100 of those seats allocated for R&R passengers and the remaining for residual passengers such as Unit Line Number (ULN), Temporary Duty (TDY), and emergency leave passengers. This table assumed that no cargo was inhibiting or preempting total seat allocation for the aircraft.

Table 5: Seats (R&R/RESIDUAL)

	C17	Seats (R&R/RESIDUAL)
From	**To**	**SUN**
Strat Port	FOB 1	158 (100/58)
FOB 1	FOB2	158 (0/58)
FOB 2	FOB 1	158 (0/58)
FOB 1	Strat Port	158 (100/58)

Measuring intertheater airlift efficiency was calculated by a similar method as that used for the intratheater airlift. Each commercial aircraft that was used for the intertheater transport of passengers was purchased with a standard seat allocation range. For example an MD11 was purchased with a range of seats from 330 to 350 in capacity (Phillips, 2010). Thus, the average of this range was 340 seats for each MD11 that flew a mission in support of R&R traveler movement. Actual historical usage data was used to compare against the aircraft and its average purchased seating capacity to calculate aircraft efficiency. Table 6 illustrates the types of aircraft used to facilitate intertheater passenger transport and its average seating capacity purchased (Phillips, 2010).

Table 6: Aircraft and Average Seating Capacity

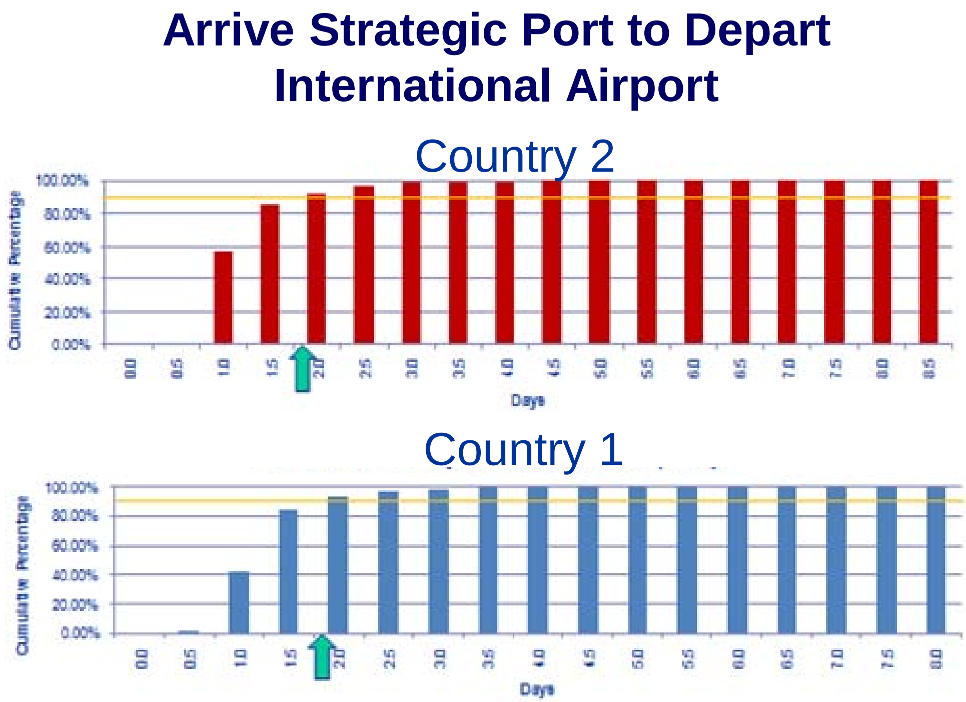
Aircraft Type	Average Seat Capacity
MD11	340
DC10	340
B767	240
B757	196

Effectiveness

During this study, USCENTCOM was in the process of evolving its I-channel intratheater airlift network in an effort to boost transportation effectiveness. The new airlift network or E-channel was essentially a push to increase intratheater airlift capacity by restructuring the priority movement system and eliminating the Intratheater Airlift Request System (ITARS). The change became effective for country 1 on 1 Nov 2010. The change became effective for country 2 sometime in early 2011 (Hilscher, 2010). This study did not incorporate the E-channel airlift network. Limitations in data, written guidance, and the need for simplicity prevented this approach.

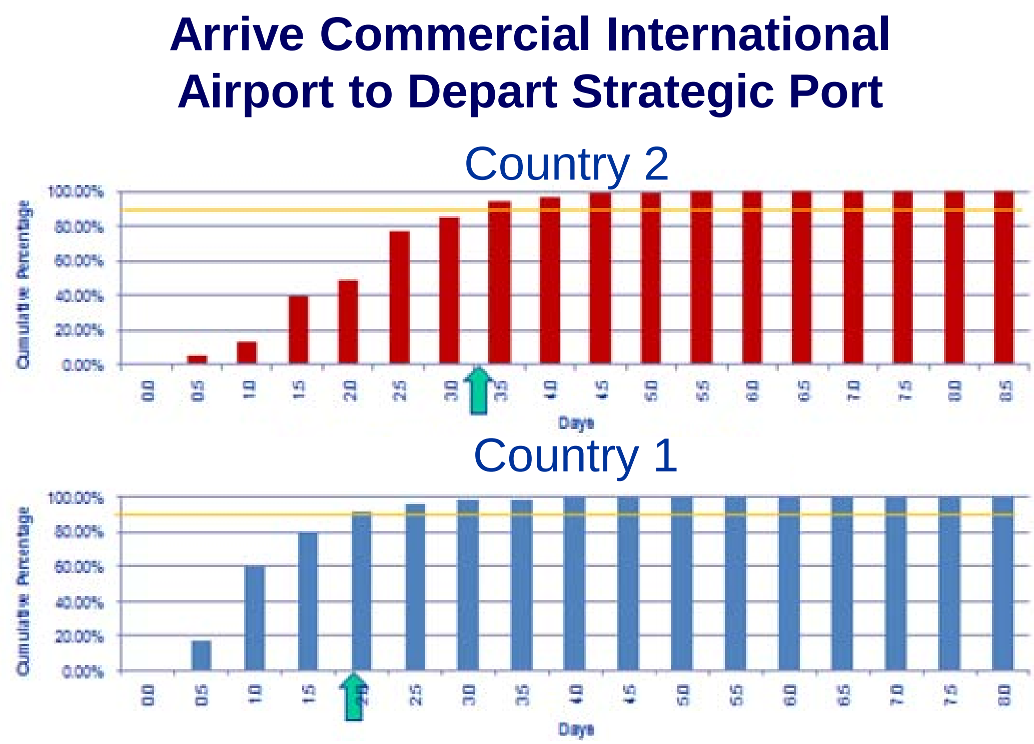
This research effort was a continuation of the 15 Mar 2010 study conducted by AMC/A9. In that study the researcher pulled historical data from FY 10 to measure total wait time, travel time, and leave time for each traveler that had a destination of CONUS 1 or CONUS 2 (Nance, 2010). This methodology was also a limitation of the AMC/A9 study as not all passengers destined for CONUS 1 or CONUS 2 can be assumed to be on R&R leave. In that study effectiveness was measured by the total time from a spoke-to-spoke perspective for each traveler in the system at the 90th percentile for all travelers.

Some of the more significant findings of the AMC/A9 study that were further validated by this study related to passenger data. In the AMC/A9 study, only 2,140 passengers had full spoke-to-spoke data. Furthermore, only 23,812 passengers had full hub-to-hub data (Nance, 2010). This was significant when FY10 experienced an outbound movement of 173,594 passengers within the hub-to-hub R&R airlift network. Additionally, Figures 2 and 3 illustrate the total time spent at the theater strategic port for both country 1 and 2 R&R travelers. The 90th percentile is used.



Source: Nance, 2010

Figure 2: CONUS-Bound Passenger Wait at the Theater Strategic Port by Country



Source: Nance, 2010

Figure 3: FOB-Bound Passenger Wait at the Theater Strategic Port by Country

Key highlights from Figures 2 and 3 are a total of approximately 5.1 queue days for country 2 passengers at the 90th percentile and 3.7 queue days for country 1 passengers at the 90th percentile are spent waiting for transportation at the theater strategic port. This study used AMC/A9's results or accumulated queue days at the theater strategic port for each intratheater hub route as a template for simulation development and validation.

Other studies examining intratheater airlift have also looked at similar ways to measure effectiveness. Before the I-channel network existed there was an airlift transportation network using different hubs, routes and airlift assets to execute operations. It was referred to as the Scheduled Theater Airlift Routing System (STARS).

Using this STARS framework for comparison purposes, a researcher designed a regional hub and spoke heuristic and tested it with historical demand data. More importantly, the researchers' primary performance measures were efficiency and effectiveness. Effectiveness was measured in total queue-days and efficiency was measured through system wide utilization (Charlesworth, 2007). This study used average and wait days at the 90^{th} percentile at the theater strategic port as an effectiveness measure as this is an easily understood metric to help illustrate R&R program performance.

Simulation Model Development

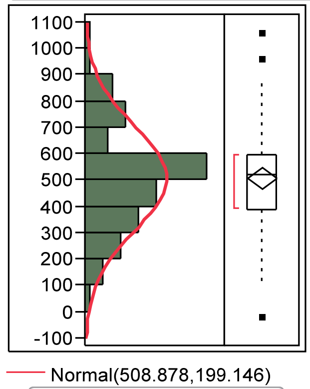
Developing an Arena simulation model without knowing the precise theater strategic port arrival rates from each of the five main intratheater hubs was a daunting task. For comparison purposes, it was similar to having five different buckets and determining if they were sized correctly without knowing how much water is flowing into each of them. The researcher knew precisely the size of the buckets but due to data limitations could only approximate the flow of the water. This problem was partially remedied by using the AMC/A9 study to mold the simulation queue lengths. Additionally, GATES did provide accurate aircraft mission data to use for the aggregate arrival rate values. Thus, the passenger flow for the entire simulation model is reflective of the actual hub-to-hub R&R airlift network based upon accurate time-series historical passenger data.

The simulation model used for this research effort is a hub-to-hub airlift network characterized by airlift capabilities or capacities and passenger flow or arrival rates. The first module in the simulation model was a passenger create node labeled "Arriving

Passengers" that followed a normal distribution with a mean of 508.88 passengers and a standard deviation of 199.15 passengers. Passengers entered the airlift network at a daily constant following the normal distribution. Figure 4 illustrates the same normal distribution used for the passenger arrival rate in the Arena simulation model.

Distributions

TOTAL



Quantiles

100.0%	maximum	1075.0
99.5%		1075.0
97.5%		952.6
90.0%		797.6
75.0%	quartile	597.0
50.0%	median	518.5
25.0%	quartile	386.5
10.0%		260.9
2.5%		121.7
0.5%		0.0
0.0%	minimum	0.0

Moments

Mean	508.87778
Std Dev	199.14603
Std Err Mean	20.991835
Upper 95% Mean	550.58811
Lower 95% Mean	467.16745
N	90

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	508.87778	467.16745	550.58811
Dispersion	σ	199.14603	173.69767	233.4003

-2log(Likelihood) = 1207.33584554013

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.986300	0.4687

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Figure 4: Historical Passenger Arrival Distribution

The data that derived this normal distribution was extracted from the GATES aircraft mission data spanning the timeframe of 1 Jan 2010 to 30 Mar 2010. This specific timeframe was chosen by the researcher as this data closely resembled the same data set that was used by AMC/A9 in its research effort. Figure 4 also shows that this normal distribution passed the goodness-of-fit test in that its p-value was not significant at an alpha of five percent.

Once the passengers entered the system, they were branded by an assign module with two attributes that guided the model in process selection. For example, one attribute branded each passenger with a specific APOD number identifying the individual as a traveler destined to either CONUS 1 or CONUS 2. These APOD percentages were based upon the raw GATES aircraft mission data. This attribute was important as it determined the flow of passengers to either CONUS 1 or CONUS 2. The second attribute was a passenger type which is a percentage based number given to each passenger to inform the model which intratheater hub the passenger arrived from. The percentages used in this attribute were based upon the proportion percentage data in Table 1. This attribute was important as it determined the flow of passengers to each of the five main intratheater hubs at the end of the model thus ensuring the final return leg of their trip is the correct one.

After passengers flow through the attribute assignment module the next step in the model was a decision node labeled "Theater Strategic Port to CONUS 1 or CONUS 2". In this node passengers were farmed to their respective processes based upon the APOD attribute assigned to them from the previous module. Passengers with the APOD numerical value of one flowed to the CONUS 2 flight process queue and the remaining passengers with the APOD numerical value of two were guided to the CONUS 1 flight process queue to await airlift. Both the CONUS 1 and CONUS 2 flight queues used the same signal method for dispatching groups of passengers. For example, CONUS 2 bound passengers queued in the hold for signal CONUS 2 module until a minimum threshold of 100 passengers condition was met. Since this type of airlift is demand-triggered, much like a taxi, it was necessary for a minimum number of passengers to accumulate before an aircraft was ordered to transport the group.

Once the minimum threshold condition was met, the CONUS 2 initialize create node entity dispatched through the hold for condition CONUS 2 queue enroute to the signal CONUS 2 node. As this entity passed through the signal CONUS 2 node, the model sent a unique signal to the hold for signal CONUS 2 node which released the CONUS 2 passenger group up to a maximum capacity known as the variable Maximum Batch to process on a flight destined for CONUS 2. Once the group of passengers were released from the queue they were batched into a single entity, signifying an airplane load. The next step for the batched load of passengers was to enter the CONUS 2 flight process, which was a 24 hour process.

Upon completion of the flight process, the batched passengers reached another decision node where if the minimum threshold condition was met, the batch continued to another assign module; otherwise the batch waited for the queue to reach the minimum threshold before proceeding to the assign module. Once the minimum threshold condition was met, the batched passengers continued through an assign module which simply determined the size of the batch, which would always meet or exceed the minimum threshold and never exceed the maximum airplane capacity also known as the Maximum Batch variable. The Maximum Batch variable capacities represented the maximum average purchased seats and reflect actual aircraft capacity as seen in Table 6. Thus, from reviewing Table 6 the simulation model CONUS 2 Maximum Batch was 240 which represented a B767 aircraft whereas the CONUS 1 Maximum Batch was 340 which represented either a DC10 or an MD11 aircraft.

Once the batch of passengers passed through the assign module the subsequent move was to pass through the signal CONUS 2 node. As the batched load traveled through this node the model sent a unique signal to the hold for signal CONUS 2 module to release the next batch of passengers for the CONUS 2 flight process. The next batch of passengers were assured to meet the minimum threshold as this condition had been verified from the previous decision node. This method was appropriate for both the CONUS 1 and CONUS 2 flight queues as it was not logical or cost effective to dispatch an expensive commercially charted aircraft to transport a handful of passengers; rather a queue needed to be leveraged to ensure a minimum number of passengers were stacked to justify the expense of the flight.

As the batched passenger entity cleared the signal node it then continued through a separate module that reversed the batching processes. This separation node was appropriate as these passengers entered a new process that simulated R&R leave. The R&R leave process was guided by a triangular distribution with a mean of 16.77 days and a minimum of 16.3 days and a maximum of 17.5 days. As passengers completed the R&R leave process, they continued to a return flight process to the theater strategic port. This 24 hour flight process did not use a queue as passengers were pre-booked on return flights prior to entering the R&R leave process.

Once the passengers completed the return trip flight back to the theater strategic port, they entered another decision node labeled “Theater Strategic Port to Intratheater Hubs”. The model was guided by the passenger type numerical attribute to correctly flow passengers to their respective intratheater hub queues for onward transportation. Each queue for the passenger's respective intratheater hub followed the same process for transporting passengers. For example, a passenger with a passenger type one numerical value was flowed by the model to the IT Hub 11 flight process where he/she would await airlift in a queue. The process was defined by using a set of resources that are essentially aircraft with different capacities characterized by unique schedules of operation. These aircraft schedules were based upon the real-world I-Channel airlift network for each of the theater strategic port to respective intratheater hub routes.

As passengers completed the respective flight process, they were recorded and entered an artificial country specific delay process. This process added on an artificial waiting time that otherwise would not have been captured by the simulation model due to data limitations. More specifically, this was the front end time it took for a passenger to depart from their respective FOB and arrive the theater strategic port. This included the time it took to travel to an intratheater hub and wait for onward airlift transportation to the theater strategic port, if necessary. Additionally, this time was also the back end travel that it took for a passenger to arrive at their home FOB once they departed the theater strategic port, signifying the completion of their R&R trip. Each of these times were country 1 and 2 specific and based upon the AMC/A9 study results. For example, the artificial delay for country 2 passengers was a total of six days whereas the artificial delay for country 1 passengers was a total of three and a half days. Upon completion of the artificial delay each passenger entered a dispose node, signifying the passenger's arrival at his/her respective intratheater hub as well as the passenger's departure from the simulation model.

Model Assumptions and Heuristics

The simulation model was based upon several assumptions and heuristics in an effort to develop a usable abstract of the historical hub-to-hub R&R airlift network. The following are a list of assumptions upon which the model was based: no aircraft maintenance delays, no weather delays, no passenger delays, no issues with the flight crews and ground crews or equipment and resources supporting operations. Even though these types of events occurred within the context of the hub-to-hub R&R airlift network operations, they were not necessary aspects that required incorporation into the simulation for it to be a usable abstract of reality. In other words, the simulation model produced usable data without including every level of detail that occurred in daily operations.

The simulation model was also driven through the use of several heuristics in order to mimic real world hub-to-hub R&R airlift network operations. The decision node labeled "More than 1 Flight" was guided by a heuristic that was based upon the queue length hold for signal CONUS 1 queue. The decision node was defined by an expression that allowed arriving passengers to stack in the hold for signal CONUS 1 queue so long as it was less than or equal to 585 passengers; otherwise a second flight process labeled "CONUS 1 Flight 2" was activated to transport the remaining passengers up to a maximum batch size of 340 seats. This action cycled continuously until the hold for signal CONUS 1 queue reached its steady state operational capacity of less than or equal to 585 passengers.

Another key heuristic involved the variables labeled "Restart CONUS 1" and "Restart CONUS 2". These values set the minimum condition threshold that guided the model as to when a batch should be released and placed in a flight process. If these restart levels were set unnecessarily low then it would be possible for flight utilization seating rates to drop. Another factor that impacts the flight utilization seating rate was the arrival rate of passengers. For example, the Restart CONUS 2 variable was highly sensitive to changes because CONUS 2 did not experience the same volume of passenger arrivals when compared to CONUS 1. These heuristics were used for simulation model development, i.e. Restart CONUS 1 is 1, Restart CONUS 12 is 1, and Restart CONUS 2 is 100. These three values most accurately represented the real world data and were critical for comparison purposes when new heuristics were introduced into the model.

Another important heuristic involved the I-channel airlift that transported passengers from the theater strategic port to their respective intratheater hub. These aircraft followed the heuristic to load any number of passengers up to a maximum seating capacity. In other words, this action was more like a bus route as the aircraft servicing these intratheater hubs would stop at the theater strategic port to pick up even one passenger that needed transportation. This was the exact opposite of demand-triggered airlift where aircraft were dispatched based upon a minimum threshold of passengers available for loading, such as with the CONUS 1 and CONUS 2 flights.

Simulation Data

Generating data for analysis began with the simulation model run parameters. The simulation model was controlled by user defined specifications, i.e. run time, warm-up, start date, etc. For this research effort, the model was warmed-up for a period of 60 days. This was to ensure the network was at steady state operations prior to data collection. Once the model was warmed up, it was run for 150 days as this reflected the number of time-series GATES aircraft mission data points collected for arrival rate distribution development. It was also important to note that each model started on the first Monday in January 2010.

Once the data was collected, there were several key areas analyzed. Those areas included the following: aircraft scheduled utilization, passengers in and out, average total passenger time, hold for signal CONUS 1 and CONUS 2 queues, flight process average wait time for each intratheater hub, number of passengers waiting for flight process for each intratheater hub, and aircraft seized for each aircraft servicing the intratheater hubs and the theater strategic port. As previously stated, data points were averaged using the grand mean to ensure a credible analysis was conducted.

Validation

Ensuring that the simulation model represented a usable abstract of the historical hub-to-hub R&R airlift network was one of the most important steps in the process of this research effort. Within Arena the researcher was able to flood the model with passengers by using deterministic arrival rates.   The model was temporarily set up to allow 1,500 passengers to enter the airlift network on a constant daily basis to ensure the airlift capacities reflected real world I-channel seating allocations across a daily, weekly and monthly timeframe.   Table 7 illustrates the daily seating capacities for routes departing the theater strategic port destined for each of the five intratheater hubs. Each intratheater hub and its respective seating capacities are alternately shaded for ease of use.

Table 7: Published Aircraft Seating Capacity

Aircraft Capacity	Mon	Tue	Wed	Thu	Fri	Sat	Sun	HUB
C130	0	30	0	0	0	30	0	IT Hub11
C17	0	87	87	87	0	87	87	
C17	143	143	143	143	143	143	143	
C17	87	87	87	87	87	87	87	IT Hub12
C17	87	0	0	0	87	0	0	
C17	100	100	100	100	100	100	100	IT Hub21
C17	0	53	0	53	0	53	0	
C130	53	0	0	0	53	0	53	IT Hub22
C17	0	89	0	89	0	89	89	
C17	0	0	53	0	0	53	0	IT Hub23
TOTALS	470	589	470	559	470	642	559	3759

Table 7 was used as a guide for the researcher to ensure these airlift capacities were accurately captured by the simulation model. Once this airlift capacity validation step was accomplished, the passenger arrival rate was subsequently changed back to the stochastic distribution that was derived from the time-series GATES aircraft mission data.

The next important step in model validation was to ensure the queue lengths or average wait times at the theater strategic port for each of the five intratheater hubs in the simulation model reflected the AMC/A9 study results. This task was accomplished by running the model with the arrival rate following the stochastic normal distribution. The model outputs reported that most of the theater strategic port to intratheater hub airlift route capacities were too large for the volume of arriving passengers. In other words, the distribution passenger arrival rate that was derived from the GATES aircraft mission data was not concentrated enough for some of the theater strategic port to intratheater hub routes to build a queue that reflected the AMC/A9 study results. This presented an interesting problem and required the researcher to make the assumption that passenger seats were being preempted by higher priority cargo; thus, seats for passenger movement did not always exist in the real world airlift network as it did on paper. Table 8 provides an output of the results from this assumption and validation procedure.

Table 8: Percentage Cargo Load Preempting Hub-to-Hub Passenger Seating

Cargo Load on Passenger Seats	0%	21%	41%	45%
Strat Port to IT Hub11 Queue Wait	n/a	1.03	n/a	n/a
Strat Port to IT Hub12 Queue Wait	0.85	n/a	n/a	n/a
Strat Port to IT Hub21 Queue Wait	n/a	n/a	1.8	n/a
Strat Port to IT Hub22 Queue Wait	n/a	n/a	n/a	1.98
Strat Port to IT Hub23 Queue Wait	1.68	n/a	n/a	n/a

As shown in Table 8, the columns labeled with percentages represent the approximate cargo space that was impeding the flow of passengers or displacing R&R passenger seating. The values below the column percentages represent the average queue waiting time in days at the theater strategic port once the additional cargo load was introduced into the model. The areas that are highlighted blue in Table 8 represent the cargo load percentage levied for each the theater strategic port to intratheater hub route to mimic the AMC/A9 study average queue length or wait time at the theater strategic port results.

The final steps for validation involved comparing some of the simulation model data against the real world data that was extracted from the GATES aircraft mission data set. These data parameters included the following: commercial aircraft missions flown from the theater strategic port to CONUS 1 and CONUS 2, the number of passengers in and out of the system, the average batch size for CONUS 1 and CONUS 2 missions, the total time the average passenger spends in the system, and the average wait times from hub-to-hub. Once these parameters were validated, the model proved to be an appropriate and useful abstract of the real world hub-to-hub R&R airlift network. Table 9 illustrates this comparison by using the real world averages in comparison to the grand means produced by the Arena model simulation.

Table 9: Real World and Simulation Data Comparison

Data Comparison	Raw data Jan - Mar 10	Simulation Data	AMC A9 Study	Difference	% Difference
CONUS 1 Average Passenger Batch	276.30	277.00	n/a	-0.70	0.00
CONUS 1 Aircraft Utilization Rate	0.81	0.82	n/a	0.00	0.00
CONUS 1 Aircraft Missions Flown	104.00	107.00	n/a	-3.00	0.03
CONUS 2 Average Passenger Batch	196.00	199.00	n/a	-3.00	-0.02
CONUS 2 Aircraft Utilization Rate	0.82	0.83	n/a	-0.01	-0.02
CONUS 2 Aircraft Missions Flown	85.00	82.00	n/a	3.00	0.04
Total Passengers Enter System	45,799.00	46,313.00	n/a	-514.00	-0.01
Total Passengers Exit System	43,523.00	45,602.00	n/a	-2,079.00	-0.05
Total Passenger Days in System	n/a	25.73	23.36	2.37	0.09
CONUS 1 Average Queue Wait Time (days)	n/a	1.27	1.14	0.13	0.10
CONUS 2 Average Queue Wait Time (days)	n/a	1.20	1.21	0.01	0.01
Strat Port to IT Hub11 Average Queue Wait Time (days)	n/a	1.03	1.09	0.06	0.06
Strat Port to IT Hub12 Average Queue Wait Time (days)	n/a	0.85	0.86	0.01	0.01
Strat Port to IT Hub21 Average Queue Wait Time (days)	n/a	1.80	1.91	0.11	0.06
Strat Port to IT Hub22 Average Queue Wait Time (days)	n/a	1.98	2.10	0.12	0.06
Strat Port to IT Hub23 Average Queue Wait Time (days)	n/a	1.68	1.60	-0.08	0.05

Table 9 shows that the differences in outputs between the simulation model and the aggregate real world data or the AMC/A9 study were acceptable in every category.

Future Airlift Framework

Developing a usable future hub-to-hub R&R airlift framework was an interesting task. Forecasted and historical troop levels were provided by USTRANSCOM Joint Distribution Planning and Analysis Center (JDPAC) for both country 1 and 2 to determine the average combined troop levels for January through March 2010 and January through March 2011 timeframes, as illustrated in Table 10.

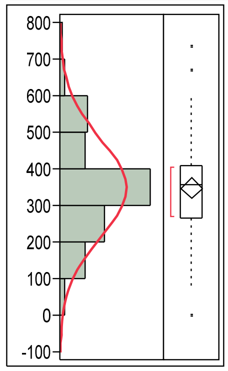
Table 10: Quarterly Average Combined Troop Levels for Country 1 and 2

Jan - Mar CY10 Average	Jan - Mar CY11 Average	Proportion
201,666.67	138,000.00	0.68

Once this was accomplished, the proportion of the two quarterly averages was forged and leveraged for the creation of a new passenger arrival rate distribution for CY11. For example, on 1 Jan 2010 289 passengers arrived the theater strategic port for R&R airlift to CONUS; this number was multiplied by the proportion value in Table 10 to derive the CY11 number of passengers for 1 Jan 2011 at the theater strategic port for R&R airlift. This logic was applied to all the time series GATES aircraft mission data that was used in the previous simulation models arrival rate distribution illustrated in Figure 4 in an effort to develop a new distribution to be used for a simulation model aimed at building the CY11 hub-to-hub R&R airlift framework. Figure 5 features the normal (348.24, 136.23) distribution used for the future or CY11 hub-to-hub R&R airlift framework arrival rate.

Distributions

CY 11



Quantiles

100.0%	maximum	736.00
99.5%		736.00
97.5%		651.85
90.0%		545.70
75.0%	quartile	408.25
50.0%	median	355.00
25.0%	quartile	264.75
10.0%		178.60
2.5%		83.53
0.5%		0.00
0.0%	minimum	0.00

Moments

Mean	348.24444
Std Dev	136.23182
Std Err Mean	14.360094
Upper 95% Mean	376.77765
Lower 95% Mean	319.71124
N	90

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	348.24444	319.71124	376.77765
Dispersion	σ	136.23182	118.8231	159.66448

-2log(Likelihood) = 1138.99337156946

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.986281	0.4675

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Figure 5: CY11 Passenger Arrival Distribution

Once the forecasted normal distribution was created for the passenger arrival rate, it was programmed into the CY11 simulation model. However the percentage of passengers from each intratheater hub also needed to be adjusted in accordance with the forecasted troop levels for both country 1 and 2.

Developing usable and logical intratheater hub passenger arrival percentages was a difficult task as the forecasted troop levels for country 2 had increased and country 1 had decreased significantly. Once the passenger arrival distribution was created, the researcher used the forecasted total passengers for CY11 to use as a baseline in creating the arrival percentages for each intratheater hub. The total forecasted CY11 R&R passenger movement equaled 118,790 passengers. This figure was then multiplied by 75.8 percent to determine the total number of passengers that arrived from country 1 and 2. The 75.8 percent was based off historical data where the remaining 24.2 percent of the passengers had arrived from Country 3, Country 4, or other FOB's serviced by the theater strategic port. Next, the researcher needed to approximate the proportions of the arriving passengers from each of the intratheater hubs that would total 75.8 percent. Table 11 illustrates the approximated proportion percentages of the arriving passengers from each intratheater hub.

Table 11: Intratheater Hub Passenger Percentages

Origin	Proportion %	Proportion Passengers
IT Hub11	0.18	21,681
IT Hub12	0.13	15,206
IT Hub21	0.29	34,204
IT Hub22	0.16	18,726
IT Hub23	0.00	268
FOB11	0.09	10,490
FOB12	0.03	3,547
Country 4	0.08	9,009
FOB13	0.00	2
Country 3	0.05	5,657
TOTALS	1.00	118,790

These percentages were used as an attribute assignment to identify which intratheater hub passengers arrived from and would eventually return to upon completion of R&R leave. There were some additional subtle differences between the original simulation model based upon historical data and the one used for this portion of the research effort.

The CY11 hub-to-hub simulation model differed from the original model based upon historical data in a few minor ways. For instance, the historical hub-to-hub model had the ability to exercise three daily commercial flights from the theater strategic port to CONUS 1 and CONUS 2. This was necessary due to the large volume of passengers that the theater strategic port experienced during January through March 2010. This model differed in that at maximum only two aircraft can be dispatched per day due to the significantly lower volume of passengers that can arrive with the newly developed distribution when compared to the previous models arrival rate distribution. For example, if the passenger volume arriving the theater strategic port in a given day did not meet the minimum threshold condition for a given heuristic, then at most only one aircraft with a capacity of 340 seats would depart the theater strategic port for both CONUS 1 and CONUS 2 destined passengers. In contrast, if the passenger volume arriving the theater strategic port in a given day exceeded the minimum threshold condition for a given heuristic, then at most a second aircraft with a capacity of 240 seats would also depart the theater strategic port for both CONUS 1 and CONUS 2 destined passengers. This CY11 simulation model was used to test and record the performance of the airlift network when multiple commercial airlift heuristics were introduced.

Summary

Developing, testing, and validating a usable hub-to-hub simulation model turned out to be an arduous task. Data collection for simulation model development proved to be a timely and tedious process due to GATES limitations. Additionally, fine tuning the simulation model into a usable abstract of the hub-to-hub R&R airlift network was also a detail intensive task. Ultimately, the Arena simulation model was used to help increase the performance of the hub-to-hub R&R airlift network and provide heuristic options for a future hub-to-hub R&R airlift network based upon country 1 and 2 forecasted troop levels.

IV. Results

Analysis

With the exception of the first section in this chapter labeled, effectiveness and efficiency of the historical hub-to-hub R&R airlift network, all subsequent results were collected exclusively through the use of Arena simulation. Furthermore, the researcher assumed that an effective military airlift network would yield a two day wait or less for 90 percent of the passengers between the strategic hub and intratheater hubs. The researcher also assumed that an efficient military airlift network would score an average of approximately 75 percent aircraft utilization within the transportation network.

Effectiveness and Efficiency of the Historical Hub-to-Hub R&R Airlift Network

One of the primary motivations for this research effort was to determine how efficient and effective the historical hub-to-hub R&R airlift network operated. Accomplishing this task was possible with the use of the GATES aircraft mission data. All commercial flights that originated from the theater strategic port and destined for either CONUS 1 or CONUS 2 were examined over the timeframe from 1 November 2009 to 31 October 2010. See example of data in Appendix A. Additionally, those flights that originated in either CONUS 1 or CONUS 2 and destined for the theater strategic port were also examined. Each individual flight was analyzed given the number of passengers that were on the aircraft inbound and outbound with respect to the number of average seats that were purchased for transport in accordance with Table 6. Aggregate utilization rates by aircraft were calculated and organized in Tables 12 A and B.

Table 12 A: Commercial Flight Utilization Rates Out

Aircraft	Msns Out	Aircraft Utilization Out	Seats Available	Passengers Flown Out	Empty Seats Out
MD-11	242	0.85	82,280	69,607	12,673
DC10	168	0.79	57,120	45,114	12,006
B767	333	0.74	79,920	58,589	21,331
B777	1	n/a	n/a	120	n/a
B757	1	n/a	n/a	164	n/a
TOTALS	745	0.79	219,320	173,594	46,010

Table 12 B: Commercial Flight Utilization Rates In

Aircraft	Msns In	Aircraft Utilization In	Seats Available	Passengers Flown In	Empty Seats In
MD-11	225	0.80	76,500	60,857	15,643
DC10	124	0.81	42,160	34,058	8,102
B767	310	0.75	74,400	55,586	18,814
B777	0	0.00	n/a	0	n/a
B757	0	0.00	n/a	0	n/a
TOTALS	659	0.78	193,060	150,501	42,559

As Tables 12 A and B illustrate, the historical hub-to-hub R&R airlift network for commercial assets is characterized as moderately efficient. The highest utilization rates were for the outbound MD11 airframe with an aggregate score of 84.5 percent. In contrast, the lowest aircraft utilization rates were recorded for the outbound B767 airframe with an aggregate score of 73.5 percent. Furthermore, as Table 13 illustrates, the total numbers of empty seats that departed and arrived the theater strategic port were vast given the recorded aircraft utilization rates in Table 12.

Table 13: Empty Seats and Cost

International Airport Status	Empty Seats
Departed	46,010
Arrived	42,559
TOTAL	88,569
Total Cost at $1500 Per Seat	$132,853,500

Table 13 shows a total of 88,569 empty seats across a one year period. This equates to approximately 260 empty MD11s that were purchased and flown with no passengers on board at a cost of $132,853,500 assuming each seat is valued at $1,500. This study developed heuristics for airlift planners to improve commercial aircraft utilization rates along with the various trade-offs and is presented later in this chapter.

Analyzing the effectiveness of the commercial assets used to support the historical hub-to-hub R&R airlift network was an interesting task. When comparing the simulation results with the AMC/A9 results it was apparent that the historical hub-to-hub R&R airlift network was not as effective as it potentially could be. For instance, the theater strategic port to CONUS 2 queue averaged 1.21 days in the AMC/A9 study yet the simulation model produced an average of .157 days wait. This gap was filled by the researcher through the introduction of a 25 hour waiting process in the simulation prior to entering the CONUS 2 flight queue. Since the simulation was based upon arrival rates and airlift capacities the gap in the real world CONUS 2 queue was most likely explained by policy, i.e. passenger decompression, pre-departure requirements processing, bus transportation from the theater strategic port to the commercial international airport, etc. The introduction of this 25 hour process into the simulation nearly aligned the CONUS 1 and CONUS 2 queue wait times. However, this gap suggests some effectiveness gains could be made in the CONUS 2 transportation wait queue.

Determining the efficiency of the hub-to-hub R&R airlift network was accomplished through the use of simulation. Simulation was able to provide utilization rates for each of the aircraft that provided R&R seating capacity from the theater strategic port to each of the five intratheater hubs. Table 14 displays those efficiency rates and the associated wait times for a passenger at each hub prior to the introduction of new airlift capacity into the simulation model.

Table 14: Historical Hub-to-Hub Aircraft Utilization Rates

AMC/A9 Study Results			Simulation Model Results				
Avg Wait Time		90th Percentile Wait Time	Avg Number in Queue	Max Number in Queue	Utilization		
					C17	C17	C130
IT Hub11	1.09	1.99	140	560	0.97	0.90	0.94
IT Hub12	0.86	1.55	58	272	0.91	0.91	n/a
IT Hub21	1.91	3.27	129	312	0.99	0.96	n/a
IT Hub22	2.1	3.31	84	207	0.93	n/a	0.97
IT Hub23	1.6	2.78	2	8	0.07	n/a	0.02
TOTALS	1.51	2.58	413	1,359	n/a	n/a	n/a

Each of the aircraft for four of the five intratheater hubs displayed high utilization rates. This is explained through the extended wait times that the average passenger experiences at each of the hubs. The only exception are the aircraft that service IT Hub 23. For IT Hub 23, the utilization rates were 7 percent and 2 percent for the C17 and C130, respectively, servicing that location. A possible explanation for these low aircraft utilization rate is IT Hub 23 received a very low volume of passengers. Thus, approximately one to eight passengers traveled on these aircraft per flight. Never the less, this hub-to-hub R&R airlift network is characterized as highly efficient and moderately effective with the exception of the theater strategic port to IT Hub 23 routine I-Channel leg which is highly inefficient and moderately effective.

Historical Hub-to-Hub R&R Airlift Capacity Changes

Once the researcher had developed a usable simulation abstract of the historical hub-to-hub R&R airlift network, it was leveraged to make performance improvements by adjusting capacity on the routes. The results are illustrated in Table 15.

Table 15: Theater Strategic Port to Intratheater Hub New Seat Allocations

Hub	Average Wait Time	90th Percentile Wait Time	Average Number in Queue	Max Number in Queue	Utilization Rates: Cargo Displacement	C17	C17	C130	Mon	Wed	New seat
IT Hub11	1.09	1.99	140	560	21%	0.97	0.90	0.94	n/a	n/a	0
IT Hub12	0.86	1.55	58	272	0	0.91	0.91	n/a	n/a	n/a	0
IT Hub21	0.60	1.23	50	188	41%	0.91	0.99	n/a	n/a	0.48	53
IT Hub22	0.70	1.29	29	103	45%	0.83	n/a	0.91	n/a	0.34	53
IT Hub23	1.21	2.46	1	4	0	0.02	n/a	0.03	0.18	n/a	5
TOTALS	0.89	1.70	278	1,127	n/a	n/a	n/a	n/a	n/a	n/a	111

To reduce the passenger wait times at the 90th percentile to approximately two days or less required one additional weekly sortie for each of the theater strategic port to country 2 intratheater hub routes when compared to the historical framework. Additionally, Table 15 illustrates the additional airlift frequency required to reduce the theater strategic port to IT Hub 23 hub route to an approximate average one day wait per passenger and 2.46 day wait at the 90th percentile. One additional aircraft route was added to the theater strategic port to IT Hub 23 route occurring on Monday with 5 seats earmarked for R&R passengers destined for IT Hub 23. The researcher chose not to add any additional airlift capacity to the IT Hub 23 route as the minimal flow of passengers from the theater strategic port to this intratheater hub did not justify the added expense of any increased airlift frequency. It is also important to note that increased effectiveness resulted in decreased airlift efficiencies.

Table 16 illustrates the required seating capacities for each of the routes from the theater strategic port to the five intratheater hubs. This data was extracted by converting the cargo displacement from Table 15 into numerical seating capacities and adding the new seating requirements from Table 15 which are subsequently listed as "New Seats" for each applicable intratheater hub route.

Table 16: Historical Aircraft Seating Capacity

Aircraft Capacity	Mon	Tue	Wed	Thu	Fri	Sat	Sun	HUB
C130	0	22	0	0	0	22	0	IT Hub11
C17	0	67	67	68	0	68	68	
C17	112	112	112	112	112	112	112	
C17	87	87	87	87	87	87	87	IT Hub12
C17	87	0	0	0	87	0	0	
C17	59	59	59	59	59	59	59	IT Hub21
C17	0	34	0	34	0	34	0	
New Seats	0	0	53	0	0	0	0	
C130	29	0	0	0	29	0	29	IT Hub22
C17	0	50	0	50	0	50	50	
New Seats	0	0	53	0	0	0	0	
C17	0	0	53	0	0	53	0	IT Hub23
New Seats	5	0	0	0	0	0	0	
TOTALS	379	431	484	410	374	485	405	2968

Table 16 aggregates various information into a usable format for airlift planners to reference and use. This refined airlift network required three additional sorties and 791 less postured seats when compared to the published hub-to-hub network outlined in Table 7. The added seating capacity, labeled "New Seats" does not specify a capability requirement; rather, it displays the required capacity necessary to lower the passenger wait time at the 90th percentile to approximately two days for each route. The capability necessary to meet the new seating capacity requirement should be decided by the airlift planners as only they understand the careful management of intratheater airlift capabilities, i.e. C130, C17, etc.

Historical R&R Intertheater Airlift Heuristic Options

With the use of simulation, these heuristics were tested and can inform airlift planners on the associated trade-offs in aircraft utilization with respect to passenger wait time and the number of passengers in the queue. In order to shape the commercial airlift network into a more efficient system, the heuristics in Table 17 can be applied. Heuristic 1 is the baseline heuristic which most closely characterized the raw data. Heuristic 1 is recorded in Table 17 for comparison purposes.

The Hold for signal CONUS 1 Queue was the master queue for all commercial R&R flights from the theater strategic port destined to CONUS 1. The numerical value to the right of the heuristic sets the threshold for the queue size and triggers a second aircraft mission to transport passengers to CONUS 1. For example, in heuristic 1, if the queue size was 585 or less for CONUS 1, then only one aircraft was dispatched to transport R&R passengers. In contrast, if the queue size was larger than 586, then two aircraft were dispatched to carry R&R passengers to CONUS 1. Both CONUS 1 Restart variables were set to 1, which meant that only one passenger needed to be available for an aircraft to dispatch and depart the theater strategic port for CONUS 1.

Heuristic 1 for CONUS 2 was based solely upon the Restart CONUS 2 variable. This variable established the minimum number of passengers in the queue for an aircraft to become available for passenger transport. For example, if the Restart CONUS 2 variable was 100 and there were 500 passengers in the queue awaiting airlift, then only one aircraft was dispatched with a capacity of 240 seats. In contrast, if there were 99 passengers in the queue awaiting airlift, then no aircraft was dispatched until at least one additional passenger entered the queue. Table 17 displays each of the heuristics used in this study and associated data category values.

Table 17: Historical Commercial Aircraft Heuristics

CONUS 1 SPECIFIC	Heuristic 1	Heuristic 2	Heuristic 3	Heuristic 4	Heuristic 5
Hold for Signal CONUS 1.Queue <=	585	685	935	1,235	3,000
Restart CONUS 1 =	1	1	1	1	300
Restart CONUS 1 2 =	1	1	1	1	1
Average Batch	277	289	309	319	339
Aircraft Utilitzation Rate	81.5	85	91	94	99
Total Flights	107	103	96	93	88
Average Queue Wait Time	1.27	1.4	1.69	2.09	2.13
90th Percentile Wait Time	2	2	3	3	4
Average Number in Queue	352	402	511	590	532
Maximum Number in Queue	529	627	881	1,127	1,289
CONUS 2 SPECIFIC	**Heuristic 1**	**Heuristic 2**	**Heuristic 3**	**Heuristic 4**	**Heuristic 5**
Restart CONUS2 =	100	125	150	175	225
Average Batch	199	206	219	228	239
Aircraft Utilitzation Rate	82.9	86	91	95	100
Total Flights	82	77	73	71	69
Average Queue Wait Time	1.19	1.25	1.35	1.44	1.71
90th Percentile Wait Time	2.01	2.04	2.04	2.04	2.04
Average Number in Queue	28	36	54	77	114
Maximum Number in Queue	416	428	464	507	550

The various heuristics also highlight the trade-offs that can be made to increase aircraft efficiency. Most important to note is the increase in the theater strategic port base capacity to support transient R&R passengers for almost every instance that airlift utilization was increased. Since the theater strategic port is the intertheater hub for the hub-to-hub R&R airlift network, CONUS 2 and CONUS 1 destined maximum passenger totals need to be aggregated to understand the complete picture for base infrastructure requirements of transient passengers. To illustrate further, Figures 6, 7, 8, and 9 depict each category of data in relation to increased aircraft utilization rates displayed on the x-axis.

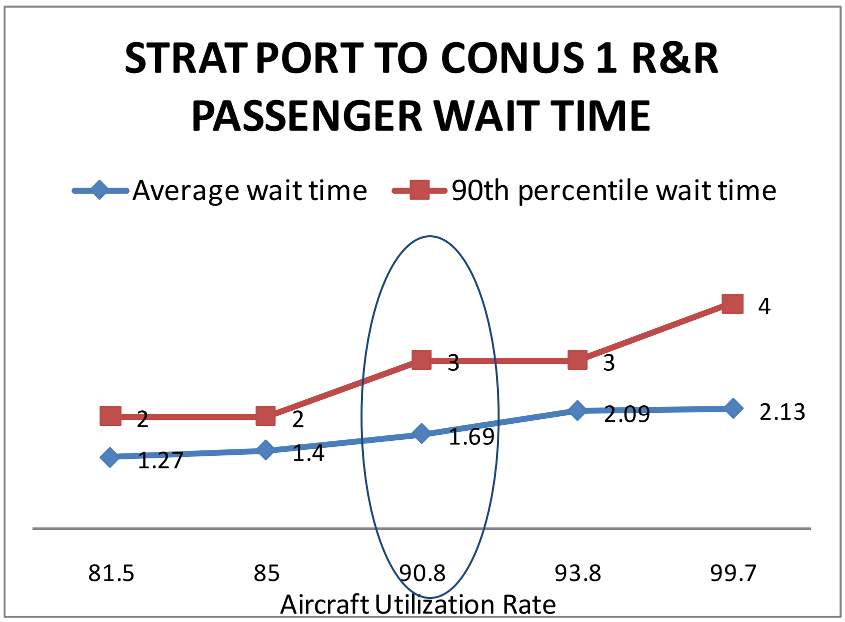


Figure 6: Passenger Wait Time at Theater Strategic Port to CONUS 1

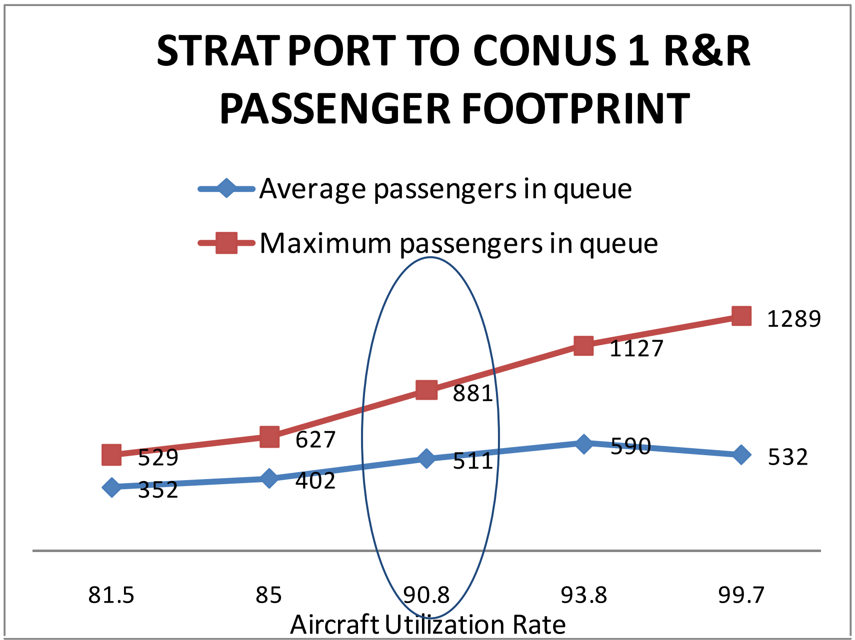


Figure 7: Passenger Footprint at Theater Strategic Port to CONUS 1

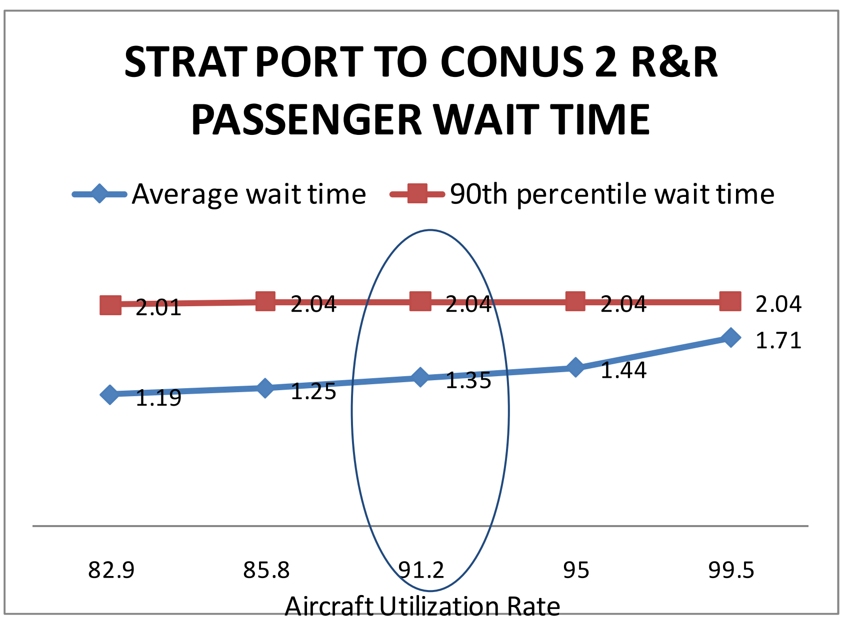


Figure 8: Passenger Wait Time at Theater Strategic Port to CONUS 2

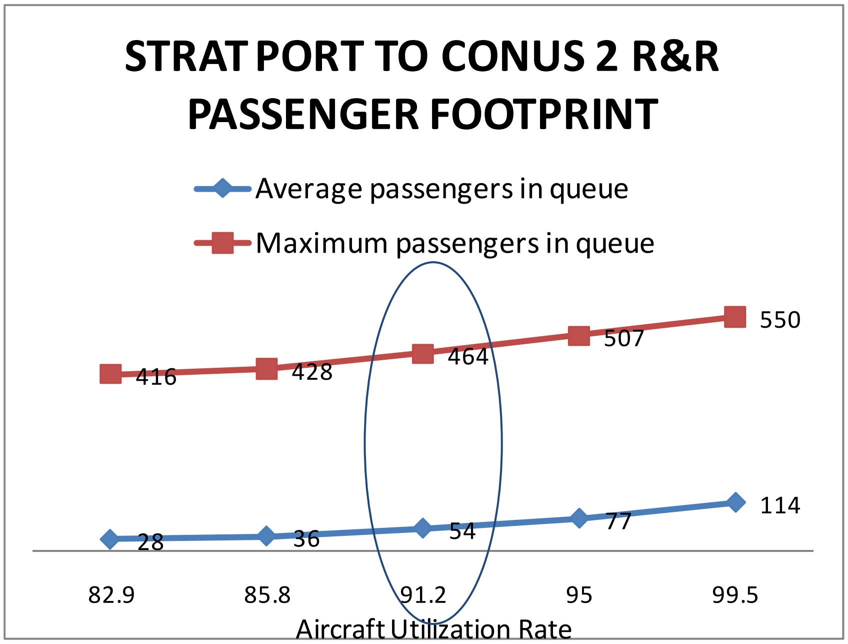


Figure 9: Passenger Footprint at Theater Strategic Port to CONUS 2

Figures 6, 7, 8, and 9 illustrate the same data as Table 17 but in a different manner. Most notable is the theater strategic port base capacity required to support 99.7 percent CONUS 1 aircraft efficiency and 99.5 percent CONUS 2 aircraft efficiency. In total, the maximum passengers in the queue that the theater strategic port experienced with these efficiencies equaled 1,839 passengers. When compared to the actual historical utilization rates this was a maximum difference of 894 total additional passengers with an additional 20.64 hours and 12.48 hours average wait time per passenger for CONUS 1 and CONUS 2 destinations, respectively. Figures 6, 7, 8, and 9 also illustrates that the sweet spot for each of the strategic port to CONUS hub routes is at approximately a 91 percent commercial aircraft efficiency rate. The third heuristic for each of these routes could have been levied to reduce waste without adding on a great amount of passenger wait time at either the average or the 90th percentile.

Future Hub-to-Hub Airlift Framework and Heuristics for CY11

Another objective of this research effort was to develop heuristic options for the future hub-to-hub R&R airlift network. The researcher applied the new arrival rate distribution as described in Figure 5, which details the distribution parameters into the simulation model and introduced new heuristics for airlift planners to reference and use. The heuristics in Table 18 are also accompanied with the associated trade-offs and illustrated in Figures 10 and 11.

Table 18: CY11 Commercial Aircraft Heuristics

CONUS 1 / CONUS 2 SPECIFIC	Heuristic 1	Heuristic 2	Heuristic 3	Heuristic 4	Heuristic 5
Hold for Signal CONUS 1.Queue <=	450	575	800	1,700	5,000
Restart Flt 1 =	1	1	200	250	250
Restart Flt 2 =	1	1	1	1	1
Average Batch	248	267	288	311	340
Aircraft Utilitzation Rate	79.6	84.1	89.7	94.3	100
Total Flights	127	118	110	101	91
Average Queue Wait Time	1.02	1.25	1.14	1.45	5.2
90th Percentile Wait Time	2	2	2	5	9
Average Number in Queue	357	440	402	1,128	1,829
Maximum Number in Queue	779	888	1,087	1,915	2,850

Heuristics 1 and 2 do not batch passengers as the flight restart values equal one passenger in the queue.

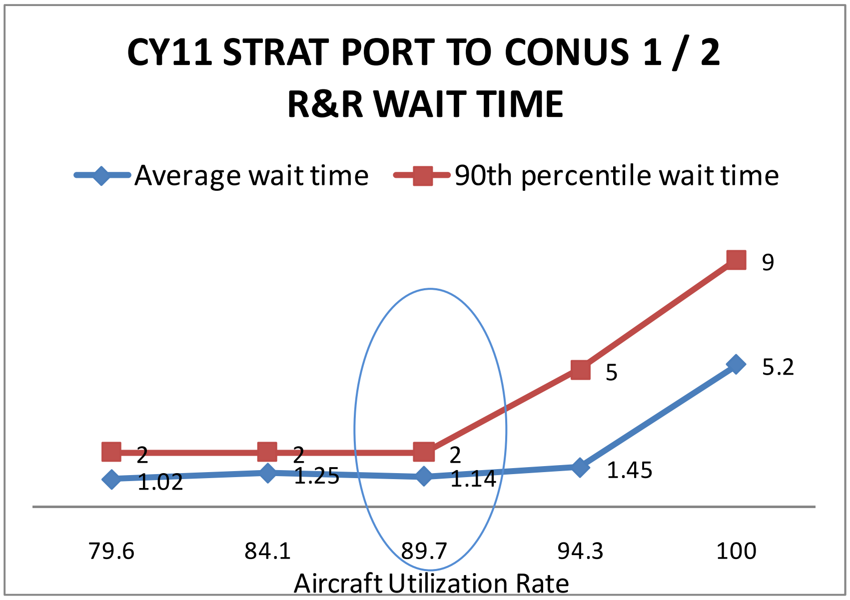


Figure 10: CY11 Passenger Wait Time at Theater Strategic Port to CONUS 1 / 2

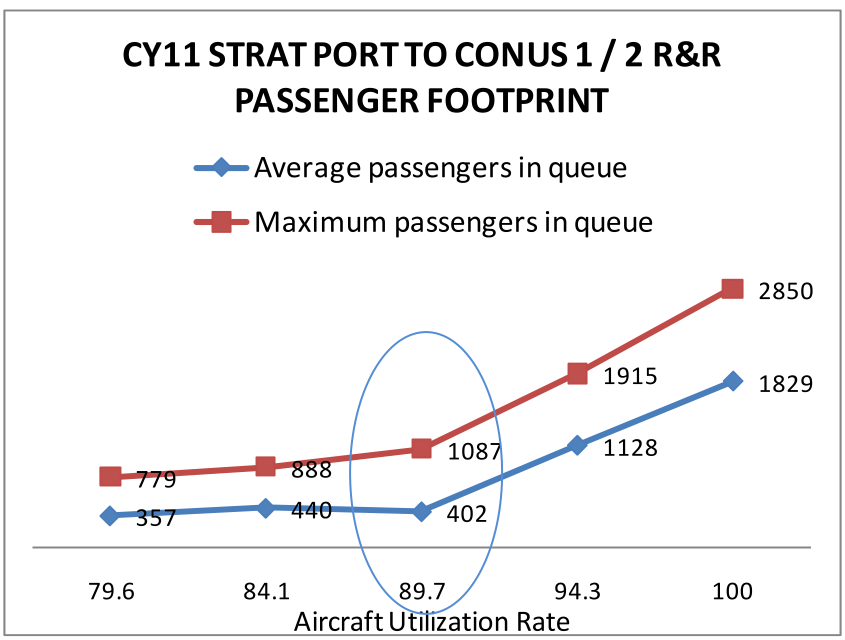


Figure 11: CY11 Passenger Footprint at Theater Strategic Port to CONUS 1 / 2

Figures 10 and 11 illustrate the associated trade-offs as the x-axis displays the aircraft utilization rates. Noticeable trends exist in this figure. Most noteworthy are the increases in all categories once aircraft utilization rates exceed 89.7 percent. Thus this study recommends that heuristic 3 be leveraged for CY11 commercial intertheater airlift operations. This heuristic increases the commercial aircraft utilization rate by approximately 10 percent when compared to the historical outbound aircraft utilization rates without adding excessive wait time at either the average or the 90th percentile.

It was interesting to collect the hub-to-hub data once the new arrival rate distribution had been introduced into the CY11 model. Since the CY11 model used the same intratheater airlift cargo loads that displaced passenger seating as shown in Tables 8 and 15, it was no surprise that the new passenger arrival rate distribution did not adequately provide enough passenger flow to fill most of the available seats for the theater strategic port to IT Hub 11 and IT Hub 12 routes. Thus, the next challenge was to effectively and efficiently leverage queues for each of the routes departing the theater strategic port destined to any one of the five intratheater hubs. Since too many seats were allocated to R&R passenger movement from the theater strategic port to country 1 and not enough from the theater strategic port to country 2, the researcher concluded that swapping the aircraft scheduling and seating framework and cargo loads displacing passenger seat percentages for the countries would be a good starting point to increase the performance of the network. Table 19 illustrates the CY11 theater strategic port to intratheater hub framework and shows the passenger wait time at the 90th percentile, the average number of passengers and maximum number of passengers in each intratheater hub queue.

Table 19: Forecasted CY11 Theater Strategic Port to Intratheater Hub Framework

		90th	Average		Utilization Rates							
Hub	Average Wait time	Percentile Wait Time	Number in Queue	Max Number in Queue	Cargo Displacement	C17	C17	C130	Mon	Wed	Fri	New seats
IT Hub11	0.77	1.87	56	178	44%	0.99	0.92	n/a	n/a	n/a	n/a	0
IT Hub12	0.67	1.24	30	117	47%	0.94	n/a	0.72	n/a	0.66	0.81	53
IT Hub21	0.48	1.10	56	237	49%	0.80	0.97	0.76	n/a	n/a	n/a	0
IT Hub22	0.56	1.06	33	129	48%	0.93	0.83	n/a	n/a	0.82	n/a	53
IT Hub23	1.20	2.45	1	6	94%	0.30	n/a	0.31	0.50	n/a	n/a	5
TOTALS	0.74	1.54	176	667	n/a	n/a	n/a	n/a	n/a	n/a	n/a	111

For the future network, it was possible to introduce sufficient capacity to ensure that 90 percent of passenger waited no more than 1.87 days for all the routes except IT Hub 23. The researcher chose not to add any additional capacity to the IT Hub 23 route as the low volume of passengers did not justify the added expense of resources required to lower the wait time to two days or less at the 90th percentile. Other important areas are the total average number of passengers in the queue and total maximum number of passengers in the queue columns as these figures should help AMC determine the theater strategic port transient passenger support requirements. Furthermore, this hub-to-hub intratheater network required four additional weekly sorties and 1,638 less postured seats when compared to the published framework outlined in Table 7. This data also suggests that more capacity was available for cargo movement than previous airlift network designs. This was a result of a decrease in passenger volume based upon the JDPAC forecast. Lastly, it is important to note that increased effectiveness resulted in decreased airlift efficiencies.

Table 20 illustrates the required two-way traffic seating capacities for each of the routes from the theater strategic port to the five intratheater hubs. This data was extracted by converting the cargo displacement and new seating capacity requirements from Table 19 into numerical seating capacities.

Table 20: CY11 Aircraft Seating Capacity

Aircraft Capacity	Mon	Tue	Wed	Thu	Fri	Sat	Sun	HUB
C17	56	56	56	56	56	56	56	IT Hub11
C17	0	30	0	30	0	30	0	
C130	28	0	0	0	28	0	28	IT Hub12
C17	0	47	0	47	0	47	47	
New Seats	0	0	53	0	53	0	0	
C17	0	44	44	44	0	44	44	IT Hub21
C17	73	73	73	73	73	73	73	
C130	0	0	53	0	0	0	0	
C17	45	45	45	45	45	45	45	IT Hub22
C17	45	0	0	0	45	0	0	
New Seats	0	0	53	0	0	0	0	
C17	0	0	5	0	0	5	0	IT Hub23
New Seats	5	0	0	0	0	0	0	
TOTALS	253	295	383	295	301	300	294	2121

Table 20 clearly indicates that the forecasted arrival rate distribution enables more military airlift capacity to be dedicated to cargo movement while still effectively balancing efficiency and effectiveness of the hub-to-hub R&R airlift network.

A final comparison between the hub-to-hub airlift network based upon historical data and future hub-to-hub airlift network derived from JDPAC forecasts needs to be demonstrated. Table 21 illustrates the aggregate differences and the decrease in the transient passenger footprints experienced at the theater strategic port when the CY11 framework is leveraged.

Table 21: Transient Passenger Comparison

Hub-to-Hub Airlift Network	Commercial Heuristics Employed	Strat Port to Intratheater Hub Network	Average Passnegers in Queue	Maximum Passengers in Queue
Historical	Table 17, Heuristics 1 and 2	Table 14	793	2,304
CY11	Table 18, Heuristic 3	Table 19	578	1,754
Difference	n/a	n/a	215	550

It is important to note that the average number of passengers in the queue and the maximum number of passengers in the queue columns represent the total passenger footprint resulting from leveraging specific commercial heuristics combined with a specific theater strategic port to intratheater hub network. Essentially there are two queues at the theater strategic port. One queue is required to support the theater strategic port to CONUS traffic and the other queue is for the theater strategic port to intratheater hub traffic. When combined the totals provide clarity on the entire footprint of transient passengers that the theater strategic port needs to be prepared to host and support for onward movement. As the data suggests, possible savings can be attained by contracting support requirements in infrastructure and deployed personnel at the theater strategic port for future R&R operations.

Summary

Overall the historical hub-to-hub R&R airlift network can be characterized as slightly out of balance. Passengers are experiencing unnecessary wait times that could be easily remedied with the application of simple heuristics. Commercial aircraft utilization rates can be increased to 89.7 percent in the CY11 network with the average passenger, independent of CONUS destination, spending on average 1.14 days wait at the theater strategic port while meeting the 2 day wait threshold at the 90th percentile. Furthermore, the data suggests that current base infrastructure and personnel at the theater strategic port can support, if not decrease and continue to support, the CY11 airlift network that leverages heuristic 3 in Table 18 which produces an average 89.7 percent commercial airlift utilization rates to include passengers returning from R&R leave with an approximate two day wait or less at the theater strategic port at the 90th percentile.

V. Conclusion

The results of the multiple simulation runs demonstrated that improvements to the historical hub-to-hub R&R airlift network can be achieved. More specifically, the historical theater strategic port to intratheater hub R&R airlift wait times at the 90th percentile can be reduced to approximately two days with relatively minimal effort, i.e. three additional sorties per week when compared to the published framework in Table 7. More impressive results can be achieved with the forecasted CY11 model by adding four additional weekly sorties when compared to the published framework in Table 7 while leveraging heuristic 3 in Table 18 for commercial airlift operations.

More importantly, monetary savings can be realized in the commercial aircraft operations realm by leveraging heuristic 3 in Table 18 for CY11 operations. Table 22 outlines the potential savings by comparing heuristic 1, which closely resembled the 79 percent historical utilization rate with heuristic 3 which yielded an 89.7 percent utilization rate over the period of one year. Both of these heuristics were displayed in Table 18.

Table 22: CY11 Heuristic 3 Estimated Savings

CY11 Heuristic 1	Value	CY11 Heuristic 3	Value
Total Missions Flown	508	Total Missions Flown	440
B767 Missions	143	B767 Missions	75
MD11 Missions	365	MD11 Missions	365
Total Seats Purchased	158,420	Total Seats Purchased	142,100
Empty Seats	32,318	Empty Seats	14,636
Waste at $1500 Per Seat	$48,477,000	Waste at $1500 Per Seat	$21,954,000
		Savings	$26,523,000

An estimated $26,523,000 can be saved per year by leveraging heuristic 3 alone. However, Table 23 illustrates that average and passenger wait times at the 90th percentile can be decreased at the theater strategic port when a combination of heuristic 3 is leveraged in conjunction with adding the four additional sorties to the weekly theater strategic port to intratheater hub schedule.

Table 23: Passenger Velocity Comparison

Hub-to-Hub Airlift Network	Average Passenger Wait Time (days)	Passenger Wait Time at 90th Percentile (days)
Historical Network	2.74	4.58
Recommended CY11 Network	1.88	3.54
Difference	0.86	1.04
% Difference	31.50%	22.62%

As Table 23 illustrates, the CY11 airlift network developed by the researcher moved passengers 20.64 hours faster on the average with a 24.96 hours decrease in wait time at the 90th percentile when compared to the historical R&R hub-to-hub airlift network. However adding four additional weekly sorties per week to the network will yield added expense in fuel costs as all other costs are assumed to be fixed. Furthermore, other uncalculated savings can be realized by reducing deployed personnel and infrastructure at the theater strategic port to support future transient passenger R&R operations. These types of savings could be tremendous when appropriately calculated and accumulated over an annual timeframe. Other areas that could be contracted at the theater strategic port include: housing, passenger terminal facilities, restrooms, dining facilities, Morale, Welfare and Recreation activities and facilities, bus support, administrative support, etc.

Recommendations for CY11 R&R Airlift Planners

Ultimately, the theater strategic port queue for outbound commercial passengers destined to CONUS could be more effectively leveraged to increase commercial aircraft utilization rates and reduce waste. This study showed that this task can be accomplished by leveraging heuristic 3 in Table 18. If intratheater airlift planners have the resources to generate four additional weekly sorties to meet the forecasted theater strategic port to intratheater hub airlift framework outlined in Table 20, then it would effectively reduce average and passenger wait times at the 90th percentile at the expense of decreased military aircraft utilization rates. At the minimum, this study recommends leveraging heuristic 3 in Table 18 for future commercial airlift operations. Additionally, if possible this study also recommends generating the additional four weekly sorties required to increase effectiveness of the theater strategic port to intratheater hub routes. These two actions when coupled will reduce the transient passenger footprint at the theater strategic port and appropriately balance the hub-to-hub R&R airlift network.

Limitations

The following are a list of limitations: this study did not focus on the administrative processes that are involved with the R&R passenger movements, i.e. policies, regulations, Air Force Instructions, Air Mobility Command Instructions, etc. There are future opportunities for study and analysis in an effort to improve the coding of passengers in the GATES logistics information system. Improvements in this area would result in better research as a result of enhanced data integrity. This study did not focus on the technological processes involved with moving R&R passengers, i.e. Army systems, Global Decision Support System, Single Mobility System, Global Transportation System, etc. This study found that GATES had several limitations pertaining to data queries, i.e. limited data coverage, limited data query options, and the system crashed during large data pulls. These are a list of areas for improvement that could be studied and analyzed in an effort to increase the effectiveness and usability of GATES. This study did not focus on the civilian industry of airlift operations. This study did not incorporate the USCENTCOM E-Channel airlift network. This study did not focus on intratheater airlift or spoke to hub airlift as this was purely a hub-to-hub research effort and thus other opportunities for improvement exist within the airlift network. This study was limited in scope to a hub-to-hub analysis due to data limitations impacting passenger arrival rates from the five intratheater hubs to the intertheater hub at the theater strategic port. Lastly, the future airlift network was designed using JDPAC forecasts and the results are only as accurate as the forecast. Thus, the actual R&R passenger wait times and aircraft efficiency rates are likely to be different from the results in this study.

Future Research

There are several areas that require future research with regards to the R&R hub-to-hub airlift network. Determining an alternate theater strategic port within the USCENTCOM AOR is of particular interest to USTRANSCOM. The hub location problem was detailed in Chapter two and requires further study where additional data that outlines aircraft flying hour costs and airfield characteristics should be collected and effectively analyzed in order to make an effective and objective alternate intertheater hub selection.

Another area for future study involves analyzing the variance in the passenger arrival rates for the R&R program. As previously mentioned, the authorized percentage of personnel on R&R leave is capped at 10 percent for any unit at unit commander discretion. Perhaps this authorization window is too great and consequently introduces too much variance on the R&R airlift network. Other alternatives may exist and need to be further analyzed and tested in order to enhance the effectiveness and efficiency of the R&R airlift network.

Appendix A: Theater Strategic Port Passenger Arrival Data Example

C32	C31	TOTAL	Date	Day	Year	Qtr
0	289	289	1/1/10 6:45 PM	fri	2010	1
425	169	594	1/2/10 6:15 PM	sat	2010	1
229	593	822	1/3/10 4:35 PM	sun	2010	1
216	0	216	1/4/10 12:00 AM	mon	2010	1
172	571	743	1/5/10 12:10 AM	tue	2010	1
240	330	570	1/6/10 10:59 PM	wed	2010	1
218	321	539	1/7/10 6:55 PM	thur	2010	1
155	0	155	1/8/10 12:00 AM	fri	2010	1
238	741	979	1/9/10 4:58 AM	sat	2010	1
229	329	558	1/10/10 8:06 PM	sun	2010	1
240	330	570	1/11/10 8:15 PM	mon	2010	1
224	310	534	1/12/10 8:50 PM	tue	2010	1
0	307	307	1/13/10 7:17 PM	wed	2010	1
265	166	431	1/14/10 8:00 PM	thur	2010	1
236	328	564	1/15/10 7:02 PM	fri	2010	1
0	509	509	1/16/10 5:30 PM	sat	2010	1
481	330	811	1/17/10 7:45 PM	sun	2010	1
167	240	407	1/18/10 7:10 PM	mon	2010	1
145	172	317	1/19/10 7:12 PM	tue	2010	1
221	303	524	1/20/10 8:40 PM	wed	2010	1
173	311	484	1/21/10 7:47 PM	thur	2010	1
234	0	234	1/22/10 12:00 AM	fri	2010	1
0	606	606	1/24/10 11:01 PM	sat	2010	1
237	519	756	1/23/10 5:30 PM	sun	2010	1
192	275	467	1/25/10 9:59 PM	mon	2010	1
46	109	155	1/26/10 6:40 PM	tue	2010	1
0	276	276	1/27/10 7:10 PM	wed	2010	1
240	328	568	1/28/10 6:20 PM	thur	2010	1
236	330	566	1/29/10 6:26 PM	fri	2010	1
235	410	645	1/30/10 6:50 PM	sat	2010	1
200	321	521	1/31/10 7:11 PM	sun	2010	1

Appendix B. Historical Network Hub to Hub Passenger Wait Time

Commercial Heuristic 1

C31				C32		
100%	maximum	2		100%	maximum	4.04
99.5%		2		99.5%		2.04
97.5%		2		97.5%		2.04
90.0%		2		90.0%		2.01
75.0%		2		75.0%		1.04
50.0%	median	1		50.0%	median	1.04
25.0%		1		25.0%		1.04
10.0%		1		10.0%		1.04
2.5%		0		2.5%		1.04
0.5%		0		0.5%		1.04
0.0%	minimum	0		0.0%	minimum	1.04

Commercial Heuristic 2

C31				C32		
100%	maximum	3		100%	maximum	4.04
99.5%		2		99.5%		3.04
97.5%		2		97.5%		2.04
90.0%		2		90.0%		2.04
75.0%		2		75.0%		1.04
50.0%	median	1		50.0%	median	1.04
25.0%		1		25.0%		1.04
10.0%		1		10.0%		1.04
2.5%		0		2.5%		1.04
0.5%		0		0.5%		1.04
0.0%	minimum	0		0.0%	minimum	1.04

Commercial Heuristic 3

C31				C32		
100%	maximum	3		100%	maximum	4.04
99.5%		3		99.5%		3.04
97.5%		3		97.5%		2.04
90.0%		3		90.0%		2.04
75.0%		2		75.0%		2.04
50.0%	median	2		50.0%	median	1.04
25.0%		1		25.0%		1.04
10.0%		1		10.0%		1.04
2.5%		0		2.5%		1.04
0.5%		0		0.5%		1.04
0.0%	minimum	0		0.0%	minimum	1.04

Commercial Heuristic 4

C31				C32		
100%	maximum	4		100%	maximum	4.04
99.5%		4		99.5%		3.04
97.5%		4		97.5%		2.04
90.0%		3		90.0%		2.04
75.0%		3		75.0%		2.04
50.0%	median	2		50.0%	median	1.04
25.0%		1		25.0%		1.04
10.0%		1		10.0%		1.04
2.5%		1		2.5%		1.04
0.5%		0		0.5%		1.04
0.0%	minimum	0		0.0%	minimum	1.04

Commercial Heuristic 5

C31				C32		
100%	maximum	9		100%	maximum	5.04
99.5%		8		99.5%		3.04
97.5%		7		97.5%		3.04
90.0%		4		90.0%		2.04
75.0%		3		75.0%		2.04
50.0%	median	2		50.0%	median	2.04
25.0%		1		25.0%		1.04
10.0%		0		10.0%		1.04
2.5%		0		2.5%		1.04
0.5%		0		0.5%		1.04
0.0%	minimum	0		0.0%	minimum	1.04

Historical Strategic Port to Country 2 Intratheater Hub Routes

C21				C22				C23		
100%	maximum	3.78		100%	maximum	2.69		100%	maximum	2.99
99.5%		2.94		99.5%		2		99.5%		2.93
97.5%		2.08		97.5%		1.73		97.5%		2.76
90.0%		1.23		90.0%		1.29		90.0%		2.46
75.0%		0.86		75.0%		1.06		75.0%		1.7
50.0%	median	0.49		50.0%	median	0.69		50.0%	median	1.21
25.0%		0.17		25.0%		0.29		25.0%		0.57
10.0%		0.03		10.0%		0.07		10.0%		0.25
2.5%		0		2.5%		0		2.5%		0
0.5%		0		0.5%		0		0.5%		0
0.0%	minimum	0		0.0%	minimum	0		0.0%	minimum	0

Appendix C. CY11 Network Hub to Hub Passenger Wait Time

Commercial Heuristic 1

C31 / C32		
100%	maximum	2
99.5%		2
97.5%		2
90.0%		2
75.0%		1
50.0%	median	1
25.0%		1
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Commercial Heuristic 2

C31 / C32		
100%	maximum	2
99.5%		2
97.5%		2
90.0%		2
75.0%		2
50.0%	median	1
25.0%		1
10.0%		1
2.5%		0
0.5%		0
0.0%	minimum	0

Commercial Heuristic 3

C31 / C32		
100%	maximum	3
99.5%		3
97.5%		3
90.0%		2
75.0%		2
50.0%	median	1
25.0%		1
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Commercial Heuristic 4

C31 / C32		
100%	maximum	6
99.5%		5
97.5%		5
90.0%		5
75.0%		4
50.0%	median	3
25.0%		2
10.0%		1
2.5%		0
0.5%		0
0.0%	minimum	0

Commercial Heuristic 5

C31 / C32		
100%	maximum	15
99.5%		14
97.5%		12
90.0%		9
75.0%		7
50.0%	median	5
25.0%		3
10.0%		2
2.5%		1
0.5%		0
0.0%	minimum	0

CY11 Strategic Port to Country 1Intratheater Hub Routes

C11				C12		
100%	maximum	6.02		100%	maximum	3.37
99.5%		3.86		99.5%		2.12
97.5%		3.02		97.5%		1.66
90.0%		1.87		90.0%		1.24
75.0%		1.02		75.0%		1.03
50.0%	median	0.59		50.0%	median	0.63
25.0%		0.19		25.0%		0.27
10.0%		0.04		10.0%		0.06
2.5%		0		2.5%		0
0.5%		0		0.5%		0
0.0%	minimum	0		0.0%	minimum	0

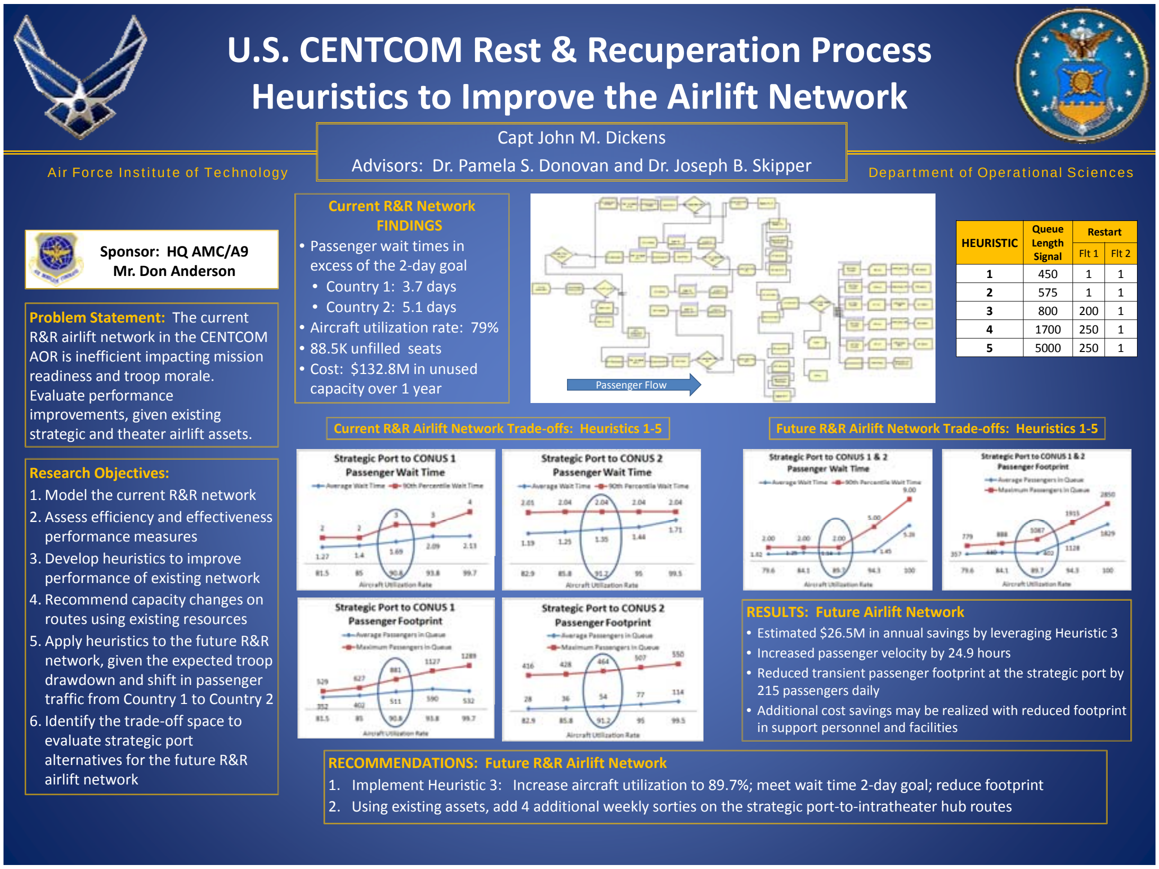
CY11 Strategic Port to Country 2Intratheater Hub Routes

C21		
100%	maximum	4.38
99.5%		3.07
97.5%		1.9
90.0%		1.1
75.0%		0.71
50.0%	median	0.32
25.0%		0.13
10.0%		0.02
2.5%		0
0.5%		0
0.0%	minimum	0

C22		
100%	maximum	3.12
99.5%		2.11
97.5%		1.55
90.0%		1.06
75.0%		0.78
50.0%	median	0.53
25.0%		0.25
10.0%		0.05
2.5%		0
0.5%		0
0.0%	minimum	0

C23		
100%	maximum	3.8
99.5%		2.99
97.5%		2.83
90.0%		2.45
75.0%		1.67
50.0%	median	1.2
25.0%		0.56
10.0%		0.26
2.5%		0
0.5%		0
0.0%	minimum	0

Appendix D. Quad Chart



Appendix E. Blue Dart

The United States Central Command's Rest and Recuperation Leave Program (R&R) is an important Morale, Welfare and Recreation initiative. It is intended to provide U.S. service members and civilians deployed for 12 or more months in one of 17 contingency countries in support of country 1 and 2 the opportunity to recoup from the rigors and stresses of the combat environment. Additionally, this program provides an unparalleled opportunity for deployed personnel to reconnect with friends and family members.

The primary purpose of this research effort was to assess the efficiency and effectiveness of the historical hub-to-hub R&R airlift network. This study analyzed the hub-to-hub aircraft efficiency rates and introduced capacity changes in the airlift network with the use of Arena simulation to improve network performance. Furthermore, this study created simple heuristic options for the future airlift framework required to meet USCENTCOM's forecasted R&R transportation demand under the premise of a CY11 country 1 drawdown and an upscale of combat and support forces within country 2. Lastly, this study provided aggregate passenger throughput values at the theater strategic port to aid AMC in its effort in selecting an alternate strategic port for future R&R passenger operations.

Arena simulation was used for airlift network performance improvements and data collection. Historical data spanning a three month timeframe was collected and leveraged in the creation of the simulation models used in this study. Furthermore AMC/A9 provided data that was used in validating and shaping the historical airlift network Arena simulation model. Data was then collected from the simulation models and analyzed to see where efficiency and effectiveness gains could be exploited. GATES also provided data that was analyzed to assess the efficiency of the intertheater commercial airlift operations.

There were several important outcomes of this research effort. First, this study designed the future framework for R&R airlift passenger operations with a focus on leveraging simple heuristics to increase intertheater commercial aircraft utilization to 89.7 percent while also adding four additional weekly sorties in the strategic port to intratheater hub routes. As a result, this study proved that passenger velocity at the strategic port could be increased by 20.6 hours on the average and 24.9 hours at the 90th percentile with a decrease in the transient passenger footprint at the strategic port by 215 passengers on the average when compared to the historical airlift network. This transient passenger footprint reduction also opens up further opportunities for cost savings by contracting support personnel and facilities at the strategic port for future R&R operations. Finally, this study found that the use of a simple heuristic could increase commercial aircraft seat utilization rates by approximately ten percent when compared to the historical network yielding an estimated $26.5M in yearly savings in contract airlift.

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Vita

Captain John M. Dickens graduated from Oak Ridge High School in Oak Ridge, TN in 1997. He also graduated from the Air Force Academy Preparatory School in 1998 and the Air Force Academy in 2002. He earned a B.S. in History and was commissioned a second lieutenant in May 2002 and has since served as a Logistics Readiness Officer.

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14. ABSTRACT
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