SIMULATION MODELING AND ANALYSIS OF THE IMPACT OF INDIVIDUAL MOBILITY AUGMENTEE LOSS AT THE TANKER AIRLIFT CONTROL CENTER

THESIS

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Abstract

The Tanker Airlift Control Center (TACC) operates as the execution arm for Air Mobility Command's Global Reach mission. The Command and Control Directorate (XOC) monitors the execution of missions tasked to the 18th Air Force. Approximately 70% of the personnel on the operations floor are considered Individual Mobility Augmentees (IMA). Adjustments in manpower, specifically the loss of IMAs, at the TACC/XOCG may impact their responsiveness to mission deviations. This research develops a discrete event simulation using a combination of SME and historical data to capture the activities of a section of the personnel on the operations floor and the potential impact of a reduction in manpower. Our analysis shows a statistically significant reduction in the number of missions completed along with a statistically significant increase in the total mission deviation time with both levels of manpower reductions examined. For the two specific levels of manpower losses, we implement the concept of resource pools to complete tasks for a group of mission desks instead of specific personnel assigned to each desk. These resource pools are one possible method of handling a loss of manpower at the TACC by more evenly spreading out workload to appropriate personnel. We also examine whether our reduced manning models can adequately handle the anticipated reduced post contingency operation mission load. Once again we pool resources and still find a very heavy workload with some noticeable improvements in system performance with longer duration shifts.

To my father, thank you for your continuous support and encouragement.
To my mother, I know this accomplishment would have made you very proud.

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SIMULATION MODELING AND ANALYSIS OF THE IMPACT OF INDIVIDUAL MOBILITY AUGMENTEE LOSS AT THE TANKER AIRLIFT CONTROL CENTER

I. Introduction

1. Background

The 618th Air and Space Operations Center (Tanker Airlift Control Center), AOC (TACC), is based out of Scott AFB, IL. As a command and control center, the TACC is responsible for the planning, scheduling, and execution of global airlift, air refueling, and aeromedical evacuation operations tasked to the 18th Air Force. The organization is comprised of eight directorates that work together to accomplish Air Mobility Command's Global Reach mission. The TACC manages approximately 900 sorties per day (2010/2011) which equates to roughly one planned departure every 90 seconds (Knierim) (618th Tanker Airlift Control Center (TACC) Welcome Brief). In 2010, the TACC controlled a total of 123,464 sorties (Contributions to the Fight 2010 in Review). These sorties breakdown into 115,586 airlift sorties that transported 1,999,369 passengers and 836,991 tons of cargo; 4,003 air-to-air refueling sorties that transferred 33,758,596 gallons of fuel; and 3,875 aeromedical evacuation sorties of 20,827 movements (Contributions to the Fight 2010 in Review). Of the 115,586 airlift sorties, 34,909 of them were made by contracted civilian aircraft (Contributions to the Fight 2010 in Review). The TACC is split into three functions; planning, allocation, and execution, each with different specialized tasks to ensure mission success.

The Command and Control Directorate (XOC) is responsible for the execution portion of the TACC's mission, operating 24 hours a day, 7 days a week to provide flight planning, diplomatic clearances, and flight management from the beginning of mission execution through mission completion. The Global Operations division (XOCG) monitors and manages missions executed by the TACC. It is their job to follow each sortie of a mission and address any issues that arise beginning 24 hours prior to first sortie take off through final sortie landing and mission completion. The XOCG deals with issues that cause a deviation from the scheduled flight plan including diplomatic clearances, early and late take offs and landings, maintenance malfunctions, weather conditions, and airfield capacities.

2. Problem Statement

The task of monitoring and managing TACC missions is important to successfully maintain Global Reach. Approximately 70% of XOC manpower is comprised of Individual Mobility Augmentees (IMAs) and Guest Help (Ahner, 2011). IMAs are Air Force Reserve and Air Force National Guard members who are assigned to a unit in a temporary duty (TDY) status. At the TACC, some IMAs are traditional IMAs who fulfill their commitment of one weekend per month plus two weeks per year while others are considered non-traditional IMAs that volunteer to be put on full time orders for a given period of time such as three or six months (Burke). Guest Help are Air Force National Guard and Air Force Reserve members that are not IMAs but are on orders to work for the Active Duty. From this point forward in this document, the term IMAs will include IMAs and Guest Help personnel. Adjustments in manpower, specifically the loss of IMAs, at the TACC XOCG may impact their responsiveness to mission deviations.

3. Scope

This research focuses on the Global Operations (XOCG) division of the Command and Control Directorate (XOC) of the TACC. The XOCG deals with all 18th Air Force tasked intertheater missions including commercial and military contingency, Special Assignment Airlift Missions (SAAMs), Distinguished Visitors (DVs), air evacuation, air refueling, coronet, and exercise missions. Rockwell Arena Simulation Software was used to model the execution process of the TACC XOCG to study the mission impact of manpower adjustments. Data for this research was obtained from the Mission Support Directorate (XON) of the TACC and Subject Matter Experts (SME) of XOCG. The model is based on data from calendar year 2010. This year was chosen as both the wars in Iraq and Afghanistan were ongoing as well as several relief events were supported. We consider this data to provide an appropriate representation of the activities of the TACC.

4. Irregular Operations Management

The Airline Operations Control Center (AOCC) is the commercial sector's counterpart to the TACC. The AOCC is dicided into strategic and operational groups. The strategic group handles the initial schedule planning and designation of aircraft while the tactical group handles the execution tasks (Clarke, 1998). The AOCC is comprised of three functional groups: airline controllers, on-line support, and off-line support (Clarke, 1998). The airline controllers have tasks similar to those of the TACC XOCG. They are responsible for solving any problems that develop during flight operations. The on-line and off-line support groups are similar to the other groups of the XOC and carry out tasks including checking weather conditions, ramp control, flight planning, maintenance, and station operations (Clarke, 1998).

The AOCC and TACC have several similarities among their tasks. The task of the operations control center is to solve any problems that arise during the operational flight period. These irregular operations include adverse weather conditions, extended time to load/unload the aircraft, take-off and landing delays, equipment failure, unexpected maintenance, and airport space constraints. Regardless of the cause of the irregular operations, the main goal of the operations control center is to get the flight back on schedule or adjust the schedule so that the effect to the mission is minimized.

Irregular operations have been modeled in many ways including PERT/CPM programs, mixed integer programs, and network flows. Stojkovic et al. (2002) modeled irregular operations using a PERT/CPM program that could be viewed as the re-optimize stage of flight scheduling after initial scheduling was completed. Their model included task duration as well as the task start times as in other models, showing that including task duration is important (Stojkovic et al., 2002). Abdelghany et al. (2004) and Abdelghany et al. (2008) used mixed integer programs to look at the topic. These models are intended to detect current and future issues so they can be addressed proactively and possibly fixed before affecting the actual flight schedule. Abdelghany et al. (2004) focuses on crew recovery during irregular operations, noting that information regarding aircraft and flight attendants needs to be incorporated to make the model more complete. Abdelghany et al. (2008) includes schedules and resource assignment to achieve a close to real-time response while striving to minimize the total cost associated with recovering all flights under consideration of alterations. Mathaisel (1996) used an Out-of-Kilter network flow algorithm to model irregular operations and provide information to a graphical user interface accessible by all parties involved in the planning, scheduling, and re-planning steps to improve efficiency of operational command and control by implementing a method of seamless communication. In addition to irregular operations, the TACC faces additional challenges due to its 24/7 operations requirements.

5. 24/7 Operations and Shift Work

The XOC directorate of the TACC operates 24 hours per day, 7 days per week monitoring and managing missions. For the XOCG, these 24/7 operations are divided into two or three overlapping shifts depending on the availability of personnel. Typically shifts are eight and a half hours, where the half hour is overlap to bring incoming personnel up to speed on tasks at hand. Alternatively, shifts are adjusted to 12 and a half hours to make sure all desks are occupied and all missions are being monitored. Each full time person works 15 to 17 shifts per month. Since missions must be monitored at all times, XOCG workers do not receive designated breaks during their shift. Personnel are expected to eat lunch when they have time and make trips to the restroom/water fountain as quick as possible. All appointments including doctors, training requirements, and physical training must be completed outside of scheduled duty hours. (Burke, 2012)

While 24/7 operations are inevitable in this case, they do take a toll on the workers possibly causing fatigue, irritability, and decreasing alertness. The main shift of concern during shift work is the night shift. The underlying factors for this include disrupted circadian rhythm, shortened and disturbed sleep, disturbed social life, and possible impaired health (Folkard, 2003). Regardless of the length of the shift, those working the night shift showed signs of reduced or compromised safety and productivity (Folkard, 2003).

Shift length during shift work is an additional area of interest. The XOC currently has some personnel operating on two 12 hour shifts and other personnel operating on three 8 hour shifts. Different shift lengths may play a part in the completion and accuracy of tasks. As the length of a shift increases beyond eight hours, risk of accident or injury increases (Folkard, 2005). According to research by Tucker et al. (1998), workers on 12 hour shifts have a greater decrease in alertness as they approach the end of a 12 hour shift versus the decreased alertness of workers approaching the end of an 8 hour shift. On a typical 12 hour shift rotation, this period of decreased alertness falls in the afternoon or early morning. In many industries, the middle of the afternoon constitutes one of the more busy times. Smith et al. (1998) discussed the research of several studies regarding the effects of 12 hour shifts versus 8 hour shifts. The research concluded that other than concern of fatigue and safety, there were not great differences between working 8 and 12 hour shifts (Smith et al., 1998). When looking at successive 12 hour shifts a decrease in productivity from successive 8 hour shifts was observed (Smith 1998). This research considers altering the length of shifts to investigate the impact on the TACC mission.

6. Design and Analysis of Simulation Experiments

Simulation is a powerful tool used to analyze new systems and alterations to current systems. Models can be beneficial to experiment, evaluate, and compare system alternatives by allowing experimentation without actually altering or creating the system.

Through simulation, problems, bottlenecks, and design shortfalls can also be brought to light. It is important for the simulation model to be well verified and validated to provide beneficial information to the user.

Simulations have previously been used to analyze airline operations. Lee et al. (2003) developed a discrete event simulation model that could be used as a tool to evaluate the robustness of flight schedules regarding the event of unexpected disruptions and the effectiveness of recovery policies. The tool included information concerning the type of aircraft, crew, airport, delays, and weather conditions. Airline operations at airports, mostly focused on aircraft turnaround time, were modeled by Wu (2005) using a combination of a discrete event simulation and Markov Chain algorithms. This simulation provides observation to how the entire system behaves and reveals gaps between real delays and inherent delays. Bazargan-Lari et al. (2003) developed a simulation model of the 24/7 maintenance operations of the Continental Airlines Newark Fleet. The model was used to investigate manpower requirements and scheduling. Similar to some of these studies, a discrete-event simulation was used in this research.

7. Methodology

This research models the operations floor of the TACC focusing on the tasks and operations carried out by the personnel of the XOC directorate to investigate potential impacts to the TACC's mission due to the loss of IMA manpower. The operations floor personnel that work in the XOCG division of the TACC are the focus of this research. Their task is to monitor all intertheater missions including combat delivery, strategic airlift, air refueling, and aeromedical evacuation operations around the world from the time a mission enters execution until mission completion.

During mission monitoring, issues may arise causing mission deviations. The correction and adjustment to missions due to these issues is the main task of the XOCG operations floor personnel. Mission deviations can be caused by numerous events but the personnel of the XOCG work to minimize mission deviation times and achieve successful mission completion. Using a combination of historical and Subject Matter Expert data from the TACC, the current system was simulated and analyzed. The focus of the analysis is to determine the impact to the mission due to a decrease in manpower. The analysis includes: varying the quantity of IMAs in the XOCG workforce, varying the quantity of missions that are monitored by the TACC, and varying the duration of shifts worked by personnel.

8. Outline

Chapter 2 provides details about the development of the model in addition to initial analysis and results. Chapter 3 is a case study focused on further analysis in a comparison of multiple systems. Chapter 4 concludes the thesis discussing significant findings and providing recommendations for further research.

II. Simulation of XOCG Floor Operations at the 618th AOC (TACC)

1. Introduction

The 618th Air and Space Operations Center (Tanker Airlift Control Center) (AOC TACC) operates as the execution arm for Air Mobility Command (AMC) missions. The Command and Control Directorate (XOC) exercises AMC Commander's authority of AMC assigned and gained missions. The Global Operations (XOCG) division of this directorate is responsible for monitoring these AMC assigned and gained missions and attending to any issues that arise possibly causing a mission deviation. These issues include late or early takeoffs or landings, airfield capacity limitations, maintenance malfunctions, and unexpected weather conditions. Operating 24 hours a day, 7 days a week, the TACC works to accomplish AMC's Global Reach mission. A reduction in manpower may impact the XOCG's ability to respond to mission discrepancies in a timely manner.

2. Overview

The XOCG operations floor is responsible for monitoring missions and attending to any issue or discrepancy that arises from initial sortie takeoff to final sortie landing. The operations floor personnel work together to ensure all missions are completed successfully. Approximately 70% of these personnel are Individual Mobility Augmentees (IMA). The TACC is interested in the potential impact to their daily tasks if the IMA personnel are removed.

3. Model Development

The XOCG operates continually checking, updating, and changing mission specifics to ensure successful mission completion. Trained and experienced personnel are required to accomplish the tasks on the operations floor of the XOCG. Approximately 70% of the XOCG's personnel are considered Individual Mobility Augmentees (IMA). There is interest in the impact of the loss of these IMAs on the success of the XOCG's mission. To investigate the impact of IMA loss, this research models the XOCG division of the XOC at the 618th AOC (TACC). A discrete-event simulation is used to model the floor operations of the personnel of the XOCG.

3.1 Floor Operations

The operations floor of the TACC is where the mission monitoring takes place. This research investigates the portion of the floor involving XOCG personnel which consists of 17 desks. Each desk constitutes a workstation with several computers operated by an individual person. Six of these desks are operated by controller (1C3) personnel and the other eleven desks are operated by Global Operations Directors (DO), Deputy Directors of Operations (DDO), or Station Coordinator (MOG) personnel. The 1C3 personnel field an average of 1500 phone calls per shift (Burke, 2012). These calls include flight updates of take offs and landings and in-flight issues. It is the job of the 1C3s to track these updates and route issues to the proper person for rework. In addition to answering calls, 1C3s complete checklists and update flight plans when determined necessary by the DO or DDO personnel. When a 1C3 receives a question that they cannot answer, the call is routed to a flight manager or a DO or DDO personnel. This research focuses on the DO, DDO, and MOG personnel along with 1C3s but excludes the flight manager personnel. The workload is split among the DO and DDO personnel by mission type since each desk monitors different types of missions. The MOG personnel focus on the airfield limitations of a predetermined set of airfields. There are six DO desks, three DDO desks, and two MOG desks on the floor.

Each of the DO desks monitor different types of missions and the DDO desks oversee the DO desks as well as have additional tasks. The DO1 desk monitors C-17 contingency missions, deploy and redeploy missions. The DO2 desk monitors C-5 and Commercial contingency missions, support missions, and abandoned tails. The DO3 desk monitors Special Assignment Airlift Missions (SAAM), Air Evacuation (AE), 89 Airlift Wing missions (Distinguished Visitors [DV]), and high visibility missions. The DO4 desk monitors C-17, C-5, and Commercial Channel missions, AE and special missions. The DO5 desk monitors Short-Notice Air Refueling (A/R) and standard A/R missions. The DO6 desk monitors Coronet missions. The DDO1 desk oversees the DO1 and DO2 desks and updates and checks the Air Tasking Orders (ATO). The DDO2 desk oversees the DO3 and DO4 desks and monitors special DVs. The DDO3 desk oversees the DO5 and DO6 desks and monitors Homeland Defense of Tankers. Personnel working the DDO desks typically have more experience working the floor than DO personnel. In addition to the DO and DDO desks that focus on specific types of missions, the two MOG desks focuses on missions based on location. The MOG desks check maximum on ground for designated airfields. It is their job to coordinate the aircraft at each airfield to make sure there is space to land, load/unload, and take off as well as fuel available if needed. Desks are grouped on the floor according to the type of missions they monitor. DO1-4 and DDO1-2 desks are considered the airlift desks, DO5-6 and DDO3 desks are considered the tanker desks, and the MOG desks are separate. The MOG desks are differentiated by task. The execution MOG desk focuses on immediate changes to missions and the long range MOG desk focuses on 24 hours out and prior (planning). Within each grouping personnel are interchangeable as to which desk they can work within the level of DO or DDO.

The floor operates 24 hours a day, 7 days a week, 365 days a year monitoring missions. This shift work is broken up differently depending on the type of personnel. The 1C3 personnel work approximately sixteen 12 hour shifts per month. DO and DDO personnel work eight hour shifts with one half hour overlap when adequate manpower is available. When manpower is low, the shifts are extended to 12 hours with one half hour overlap. Regardless of the length of shift, personnel work approximately 15 to 17 shifts per month. The shifts for personnel manning the MOG desks differ. The execution MOG desk is manned 24 hours per day while the long range MOG desk is manned 16 hours per day. Both operate on eight hour shifts when adequate personnel are available. When eight hour shifts are being worked, they are split into day, swing, and midnight shift which are 0630-1500, 1430-2300, and 2230-0700 respectively. Personnel working on the floor are expected to be at their desks as much as possible during their shift. This means there are no designated breaks and all training and appointments are to be completed outside the hours personnel are scheduled to work on the floor.

The personnel that work on the floor are categorized as either active duty military or Individual Mobility Augmentees (IMAs). Active duty personnel are Air Force Officers and Air Force Civil Enlisted Airmen assigned full time to work at the TACC.

Included in the IMAs are traditional IMAs working one weekend per month plus two weeks per year and guest help which consists of Air Force Reserve and Air Force National Guard members that volunteer to be on full time orders for a predetermined period of time. IMAs make up 70% of the personnel of the XOCG. The loss of the IMAs may impact the XOCG's responsiveness to mission issues and is the focus of this research.

3.2 Conceptual Model

The simulation model focuses on the DO and MOG personnel and their interactions with the DDO personnel. Mission arrival is where the model starts. As each mission arrives to the operations floor (XOCG) for monitoring, it is directed to the associated DO desk according to the type of mission. Once at the desk, the DO monitors the mission for on time take off and landing of each sortie. If an issue arises during the mission, the DO works with the 1C3 personnel and sometimes DDO personnel to fix it so that the mission is successful. The majority of the work done by the XOCG personnel is when an issue arises. When an issue arises, it can be identified in one of several ways: a call to the TACC answered by a 1C3 or noticed on the notepad, a computer program at each desk, by the monitoring DO or DDO personnel. If received as a phone call to a 1C3, the 1C3 determines which desk is monitoring the mission and needs to be informed of the issue. Next, the DO personnel determine the proper course of action to fix the issue or change the flight plans. This decision may require the assistance of DDO personnel depending on the type and severity of the issue. After a course of action is determined by the DO, the 1C3 is informed and updates the mission. This mission update may require the 1C3 to complete a checklist, waiver, or add notes to the notepad. When determining the course of action for a mission involving a MOG location, the MOG desk must be involved to ensure the changes made to the mission are supported by the airfield. After the mission is updated, the DO returns to monitoring the mission through completion. Figure 1 shows the process flow of the tasks of each DO desk.

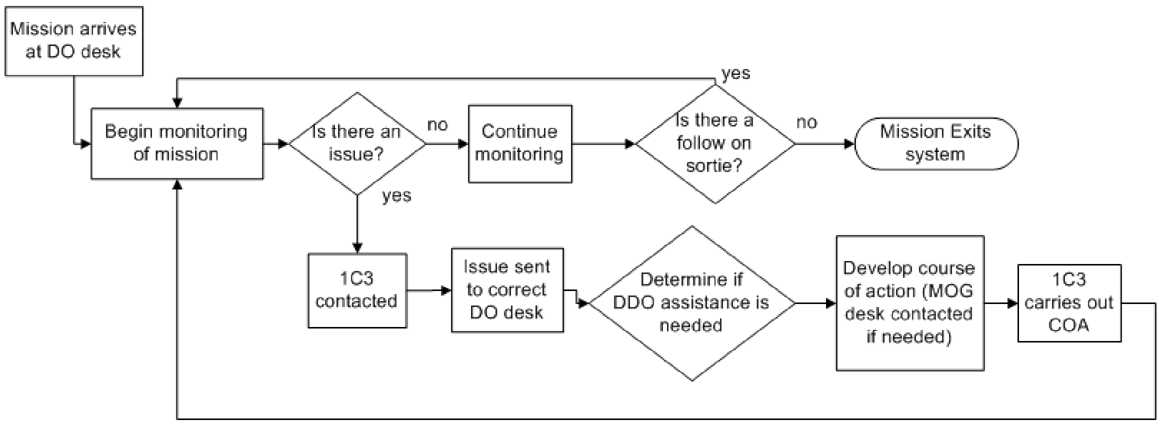

Figure 1: Process Flow of each DO Desk

It is common for personnel to be working on several tasks while waiting for a response on another. To model this multi-tasking capability, the personnel resources are doubled for the DO1-4 and MOG desks. The 1C3 resources are increased by one for each shift. Only the DDO interactions with DOs are being modeled so those resources are not doubled. The DO5 and DO6 desk resources are not doubled either due to the fact that they monitor less missions, but each of their missions incorporate multiple aircraft. The multi-tasking of these desks is included in the task completion times since it is common for them to be working several tasks for a single mission at once.

3.3 Assumptions

Throughout model development, various assumptions had to be made such that the model scope was maintained. Some key assumptions are:

- Only DDO interactions with the DOs are modeled, none of the DDO's additional tasks;
- Time requirements of the DDOs are the same as the DOs in the model;
- Personnel resources are doubled for the airlift DO and MOG desks to better model the ability of personnel to multi-task;
- The model includes the execution MOG desk and only assistance provided by the long range MOG desk;
- The ground time between sorties is not modeled;
- For decreased manpower analysis, available resources are assigned to the different groups of personnel: airlift DOs, airlift DDOs, and the tanker cell, rather than the individual desks;
- All personnel scheduled to work show up and do not call in sick or arrive late; and
- The ability to make up time during ground time or mission rescheduling is not modeled in the simulation.

4. Supporting Data

Data for this research was gathered from several sources. The Deputy Chief and Deputy Division Chief of the XOCG provided background information and an understanding of the operations and tasks of the XOCG including Subject Matter Expert (SME) information used in creating the model. The Mission Support Directorate (XON) of the TACC provided mission data for the missions monitored by the TACC for the years 2004-2012. The data included mission ID, departure and arrival dates and locations, type of aircraft, type of mission, operating group, and number of passengers and cargo onboard. These eight years of data were analyzed to determine a year to base the model. The data from 2010 was then used to create the model. This year was chosen as both the wars in Iraq and Afghanistan were ongoing and several relief missions were operated by the TACC during that year.

4.1 Input Analysis

Data regarding process times and tasks was obtained from SMEs in XOCG. This data included task completion times for the different types of personnel on the floor represented in the model. The data is presented in Table 1 along with the selected distributions. DO desks one through four are considered the airlift desks and task completion times for these four desks are the same. DO desks five and six are considered the tanker cell and task completion times for these two desks are the same. Task completion times for 1C3s and the MOG desks are the same regardless of the mission type. Task completion times for the 1C3s were provided by two SME sources. Information from both sources was used to create a distribution for the model. The difficult task completion time provided for the MOG desk, included the total task completion time for each individual task. It is common for the MOG personnel to be waiting on a response from someone and working other tasks during that wait period. To better represent this task in the model, the SME completion time estimate of between 60 and 90 minutes, was modified to allow some chance of much smaller times with a 90 minute maximum. Only the interaction of the DDOs with the DO is directly modeled. Detailed information and task completion times were not available to clearly model the additional tasks of the DDOs. While DDO task completion time is shorter than that of the DO, in the model the task completion time used is the DO time.

Table 1: SME Collected Data and Selected Distributions

Task Description	Model Distribution
DO1-4 Desks Simple Task	Constant (5) minutes
DO1-4 Desks Difficult Task	Triangular (15, 20, 30) minutes
DO5-6 Desks Simple Task	Uniform (5, 30) minutes
DO5-6 Desks Difficult Task	Uniform (1, 8) hours
1C3 Simple Task	Constant (3) minutes
1C3 Difficult Task	Triangular (10, 30, 45) minutes
MOG Desk Simple Task	Uniform (2, 3) minutes
MOG Desk Difficult Task	Minimum(90, Exponential (75)) minutes
DDO Tasks	Distribution matches DO task

If a mission has a deviation or issue, the DO must "touch" that mission to correct the deviation. Once a sortie has an initial deviation, the chance of additional "touches" to that sortie increases. An empirical distribution was developed to represent the number of times a sortie will be "touched" once there is an initial deviation. This distribution is different for the airlift and tanker desks. For the airlift desks, the additional "touch" empirical cumulative distribution function is Discrete (0.25, 1, 0.318, 5, 0.386, 6, 0.455, 7, 0.523, 8, 0.591, 9, 0.659, 10, 0.795, 12, 0.864, 13, 0.932, 14, 1.0, 15). For the tanker desks, the additional "touch" empirical cumulative distribution function is Discrete (0.65, 1, 0.825, 2, 1.0, 3). In addition to data regarding process times for personnel, data regarding mission details was analyzed.

Calendar year 2010 data provided by XON was analyzed to determine various inputs for the model. The number of missions, number of sorties per mission, duration of sorties, percentage of deviations, and percentage of MOG affected sorties were determined for each DO desk. Details of mission type breakup were provided by SME of XOCG. Once separated by monitoring DO desk, the data was analyzed to gain inputs for the simulation. Several inputs were pulled directly from the data including number of missions, number of sorties, number of deviations, and number of MOG affected sorties. The list of airfields monitored by the MOG was obtained from the XOCG. The MOG has been monitoring these airfields since they started operations shortly after September 11, 2001. Table 2 provides a summary of the input data obtained directly from the historical data, by each desk.

Table 2: Direct Data Inputs

Desk	Number of missions	Percent of total missions	Number of sorties	Number of deviations	Percent missions with deviation	Number of MOG affected missions	Percent of MOG affected missions
DO1 Desk	9,948	17%	20,771	10,939	53%	7,774	37%
DO2 Desk	6,981	12%	18,384	9,368	51%	6,562	36%
DO3 Desk	7,023	12%	17,726	6,666	38%	4,606	26%
DO4 Desk	16,859	29%	31,693	12,238	39%	10,485	33%
DO5 Desk	2,584	4%	5,384	1,740	32%	878	16%
DO6 Desk	3,784	6%	7,623	2,852	37%	2,563	34%
TDD Desk	11,063	19%	22,940	-	-	-	-

Missions monitored by the XOC operations floor are monitored by either the XOCG or the XOCR. The XOCR includes the TDD Desk referenced in Table 2 above. The Theater Direct Delivery (TDD) portion of the floor operates as its own complete TACC to handle AMC missions that are intratheater missions. TDD missions are not modeled in detail in this research but were included in the data analysis for completeness. This model focuses on the XOCG division of the XOC operations floor.

Additional input data required further analysis. The number of sorties per mission and flight duration of a sortie were analyzed to find a distribution that best fit the data. Empirical distributions were used to describe this data for the model. Theoretical distributions were fit to the data using JMP Statistical software; however, no fit distribution passed a goodness of fit test. The flight duration of sortie data had several values that were not logical for flight times. These values represented a fraction of a percent of the total number of sorties. To represent these longer flight times, the flight duration data was truncated at a logical value based on the data. Tables 3 and 4 provide the empirical cumulative distribution functions formed for the model.

Table 3: Cumulative Distribution Functions for Number of Sorties per Mission

Desk	Number of Sorties per Missions
DO1 Desk	Discrete(0.51,1,0.72,2,0.85,3,0.92,4,0.96,5,0.98,6,0.99,7,1.0,8)
DO2 Desk	Discrete(0.26,1,0.51,2,0.77,3,0.90,4,0.95,5,0.97,6,0.98,7,0.99,8,1.0,9)
DO3 Desk	Discrete(0.46,1,0.64,2,0.74,3,0.88,4,0.92,5,0.95,6,0.97,7,0.98,8,0.99,9,1.0,10)
DO4 Desk	Discrete(0.51,1,0.77,2,0.90,3,0.96,4,0.98,5,0.99,6,1.0,7)
DO5 Desk	Discrete(0.33,1,0.79,2,0.89,3,0.94,4,0.96,5,0.98,6,0.99,7,1.0,8)
DO6 Desk	Discrete(0.19,1,0.88,2,0.96,3,0.99,4,1.0,5)

Table 4: Cumulative Distribution Functions for Flight Duration of a Sortie

Desk	Flight Duration of a Sortie
DO1 Desk	Continuous(0.14,1,0.25,2,0.43,3,0.60,4,0.67,5,0.75,6,0.84,7,0.90,8,0.93,9,0.94,10,0.95,11,1.0,15) hours
DO2 Desk	Continuous(0.08,1,0.19,2,0.28,3,0.37,4,0.49,5,0.63,6,0.75,7,0.85,8,0.91,9,0.94,10,0.95,11,1.0,16) hours
DO3 Desk	Continuous(0.16,1,0.33,2,0.43,3,0.51,4,0.59,5,0.70,6,0.79,7,0.86,8,0.91,9,0.95,10,0.97,11,0.98,12,1.0,16) hours
DO4 Desk	Continuous(0.11,1,0.27,2,0.37,3,0.46,4,0.58,5,0.70,6,0.80,7,0.89,8,0.95,9,0.97,10,0.98,11,1.0,16) hours
DO5 Desk	Continuous(0.26,1,0.43,2,0.52,3,0.57,4,0.61,5,0.65,6,0.72,7,0.81,8,0.88,9,0.93,10,0.95,11,0.96,12,1.0,16) hours
DO6 Desk	Continuous(0.29,1,0.64,2,0.75,3,0.80,4,0.85,5,0.88,6,0.92,7,0.95,8,0.97,9,0.98,10,1.0,16) hours

This same method of data analysis was used to determine the arrival rate of missions to the operations floor. The historical data was analyzed to find the inter-arrival times between missions, distributions were fit, and an exponential distribution was selected as best fit. This follows Khintchine's Theorem which states that over time all inter-arrival rates form an exponential distribution. The inter-arrival rate of missions to the operations floor used in the model is exponential ($\mu = 7.45$) minutes.

5. Verification and Validation

Crucial to any simulation model is verification that the model is coded correctly and validation that the model reasonably represents the system to be analyzed. The process flow of the model was reviewed with several XOCG floor personnel. To ensure the model represented the nature of the system as scoped for this research, several comments and suggestions were implemented into the final model. A numerical check was also conducted comparing the simulation outputs to the historical data. The percentage of missions through each desk in the model is within +/- 2% of the mission breakup from the historical data as shown in Table 5. The total number of missions simulated by the model is 13% higher than the number of missions represented in the historical data. This higher number of mission can be explained in part since we did not include any ground time in our simulation.

Table 5: Validation Metrics

Desk	Percent of Missions (Historical)	Percent of Missions (Model)
DO1 Desk	17%	16%
DO2 Desk	12%	13%
DO3 Desk	12%	13%
DO4 Desk	29%	27%
DO5 Desk	5%	5%
DO6 Desk	6%	6%
TDD Desk	19%	20%

6. Simulation Design and Methodology

The key focus of this research is the impact of the loss of IMAs from the XOC. This impact would be realized through the time and efficiency of responding to mission discrepancies. Outputs include:

- Resource utilization rate for each type of resource
- Total mission deviation time
- Number of missions completed

Several factors were varied to determine different possible situations for the TACC. These factors include:

- Quantity of available personnel
- Quantity of missions to monitor
- Duration of shift worked

In addition to determining which outputs to collect and which factors to adjust, a simulation warm up period and resource requirement calculation were needed. A warm up period of 80 days was established, shown in Figure 2, to eliminate any initialization bias due to the model starting empty and idle. Resource utilization was used to determine the warm up period.

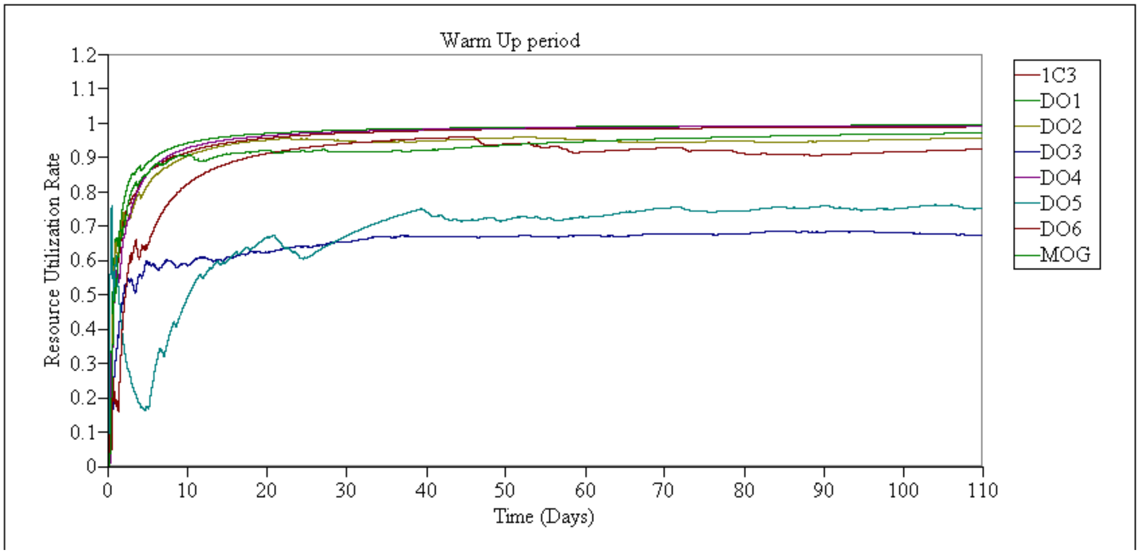

Figure 2: Warm Up Period Determination

Resource requirements are grouped based on the desks they are trained to work. The DDO1 and DDO2 desks are considered the airlift DDO desks. The DO1, 2, 3, and 4 desks are considered the airlift DO desks. The DO5 and 6 and DDO3 desks are considered the tanker cell desks. Both MOG desks are grouped together. Each group of desks has a required number of personnel to cover daily tasks. The resources in the model are based on the number of personnel working on the XOCG floor in January 2012. The personnel are either active duty (AD) or Individual Mobility Augmentees (IMA). The baseline model has the number of resources required to cover each desk with one resource for each shift, with each resource working 15 shifts per month. Table 6 provides the breakdown of resources used for the different versions of the system being modeled. The required personnel are the number of resources the XOCG has available to cover the desks for one month. The base model resources are the number of personnel required to cover the desks 24/7 for one month. The 50% IMA reduction resources are the number of personnel available to cover the desks 24/7 for one month if 50% of the IMA personnel were removed. The 100% IMA reduction resources are the number of personnel available to cover the desks 24/7 for one month if 100% of the IMA personnel were removed. For all manning reductions, the number of IMAs for each resource are rounded up to the next integer. In addition, the remaining personnel are pooled into groups to cover all desks within a modeled resource area (airlift DDO, airlift DO, tanker, MOG). The model assumes that personnel will be trained to cover the needed desks and are therefore equally divided among the groups of desks as needed. Since there are no 1C3 IMA resources working the floor, the resources for the 1C3s are not altered in the model.

Table 6: Available Resources in Model

Resource	AD	IMA	Required Personnel	Base Model	50% IMA Reduction	100% IMA Reduction
DDO(1-2)	1	11.4	13	12	7.8 → 8	3.6 → 4
DO(1-4)	11	15.6	26	24	15.6 → 17	7.2 → 8
Tanker(DO 5,6 DDO3)	7	11	19.5	18	11.7 → 12	5.4 → 6
MOG	3	9	11.4	12	7.8 → 9	3.6 → 4
Total	22	47	69.9	66	42.9 → 46	19.8 → 22

7. Results and Analysis

The simulation model is run over a one year time period, 365 days, after an 80 day warm up period to eliminate any initialization bias. Twenty replications were done to ensure sufficiently accurate statistics were captured. Initial analysis on the system includes three levels of manpower: current levels (base model), 50% IMA reduction, and 100% IMA reduction. In a reduced manpower state, the capability of having one person work every desk is not possible. The model groups resources and assumes that cross-training would be completed where necessary. The airlift desks resources are all airlift DO and DDOs working during the shift. The tanker desks resources are all tanker DOs and DDOs working the shift. The MOG desk is as modeled in the base model and 1C3 resources are not affected as there are no IMAs working those desks. The results for resource utilization rate, number of missions completed, and mission deviation time are shown in the following Tables and Figures. All statistics presented are the average over 20 replications of the simulation.

Reviewing resource utilization rates as shown in Table 7, provides insight to how busy personnel are on a regular basis. Utilization rates near 100% do not allow for any major changes in business of the system. In the instance of an influx of work, these already very busy personnel would not be able to accommodate the additional workload. For the base model, the resource utilization rates represent the personnel at each desk individually. For the reduced manpower models, the utilization rates are for a pool of personnel determined by desk group. It is not surprising that DO1 and DO4 desks have high utilization rates in the base model as they monitor 17% and 29%, respectively, of the missions that flow through the system. The DDO utilization rates are lower in the simulation due to not all of their tasks being modeled. The MOG desk utilization is also high which is representative of the actual system since all the DO desks have some interaction with the MOG desk which accounts for about 26% of the total missions. The 1C3 utilization is presented but is not analyzed due to the lack of IMA personnel working 1C3 desks.

Table 7: Resource Utilization Rate

Desk Group	Resource	Base Model	50% IMA Reduction	100% IMA Reduction
Airlift DO Desks	DO1 Desk	100%	92.70%	99.99%
	DO2 Desk	96.69%	92.70%	99.99%
	DO3 Desk	67.08%	92.70%	99.99%
	DO4 Desk	100%	92.70%	99.99%
Airlift DDO Desks	DDO1 Desk	58.58%	85.07%	99.99%
	DDO2 Desk	50.06%	85.07%	99.99%
Tanker Desks	DO5 Desk	73.15%	95.97%	100%
	DO6 Desk	94.97%	95.97%	100%
	DDO3 Desk	30.22%	95.97%	100%
	MOG Desk	99.82%	100%	98.94%
	1C3 Desks	99.38%	84.17%	62.32%

The reduced manpower models show the effects of utilization when the resources are grouped to cover the desks. The overall airlift personnel utilization increases for the 100% IMA reduction. This is expected since this cut equates to 70% less available personnel to accomplish the tasks at hand. The tanker personnel utilization increases as well for this reduction. With the airlift resource group, the desks with the higher utilization rates individually are decreased slightly and the desks with the lower utilization rates are increased. This is because the personnel from the less busy desks are being used to help complete tasks for the busy desks. The resource group for the tanker desks has some additional changes due to the manpower available. In the 50% reduction model, the DO difficult task with DDO assistance requires two resources to complete the task. In the 100% reduction model it only requires one resource to complete this task, because there is only one resource available to cover the tanker desks. For the 50% reduction model, a portion of tasks require waiting for two available resources which adds to the total mission deviation time. This does not take place in the 100% reduction model.

The MOG resource utilization rate is not greatly affected as this desk does not experience the effects of the pooled resources to aid in task completion. For the 50% IMA reduction, the resource utilization rate decreases compared to the 100% IMA reduction for the airlift and tanker resources, indicating that a 50% IMA reduction versus a 100% IMA reduction would be a more agile system to handle influxes in tasks. The MOG desk utilization increases for the 50% cut indicating that in this alternative the MOG desk may be a bottleneck in the system. While resource utilization aids in determining how busy personnel will be, the number of missions completed and total mission deviation add to the understanding of the altered system.

The number of missions through the system aids in showing the impact of a manpower loss. Instinct indicates that the less manpower available, the less missions would be completed, when reviewed over the same time period. The number of missions entering the system is the same for all three manpower levels. The number of missions completed, or leaving the system, changes due to increased waiting time because of less manpower available to accomplish tasks.

The decrease in number of missions completed is evident at all six DO desks as shown in Table 8 and Figures 3-5. In the 100% IMA reduction model, the available resources are so few for the tanker desks that, the difficult DO task that needs assistance from the DDO only has one resource available. This means that only one resource is required regardless of the task to be completed, whereas for the base and 50% IMA reduction models the difficult DO task that needs assistance from the DDO requires two resources to complete it.

Table 8: Number of Missions Completed

Desk Group	Desk	Base Model	50% IMA Reduction	100% IMA Reduction
Airlift Desks	DO1 Desk	10820	8990	8104
	DO2 Desk	8260	5978	4096
	DO3 Desk	8351	7078	6221
	DO4 Desk	17296	17117	15674
Tanker Desks	DO5 Desk	3533	3461	2746
	DO6 Desk	4190	4046	3183
	Total	52450	46670	40024

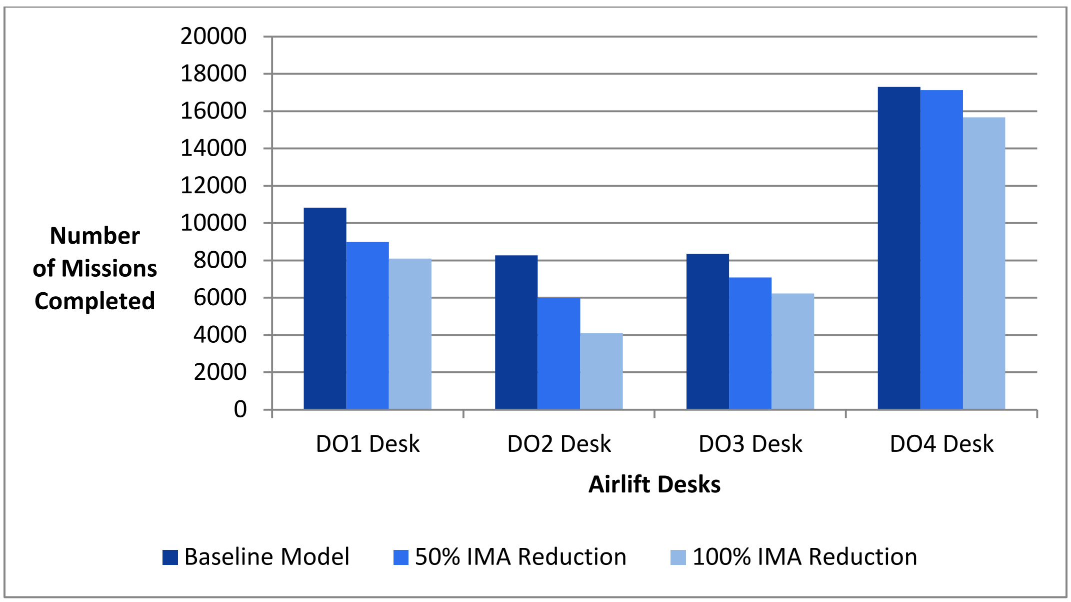

Figure 3: Number of Missions Completed - Airlift Desks

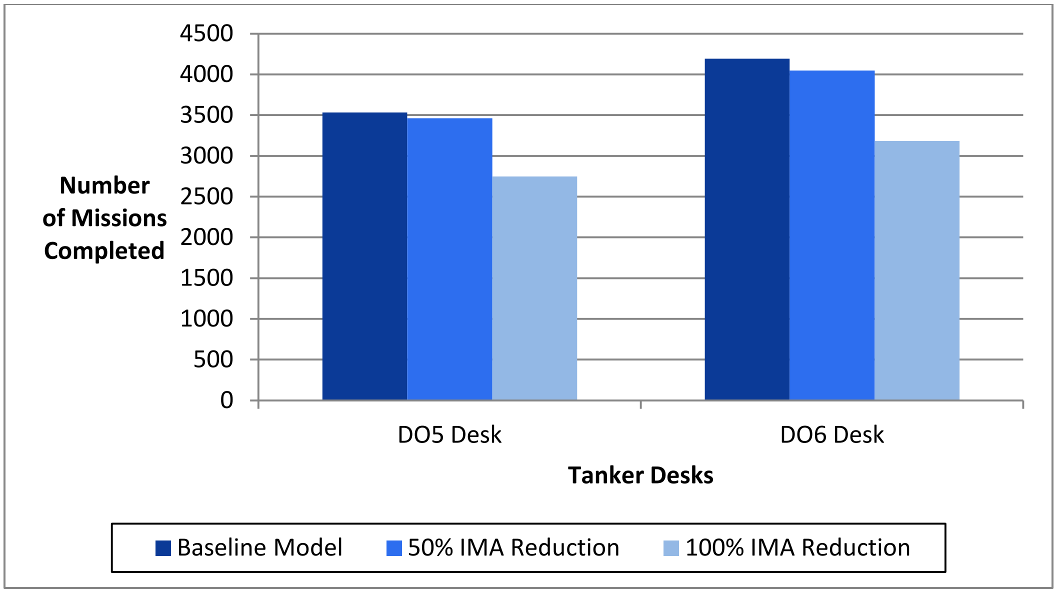

Figure 4: Number of Missions Completed - Tanker Desks

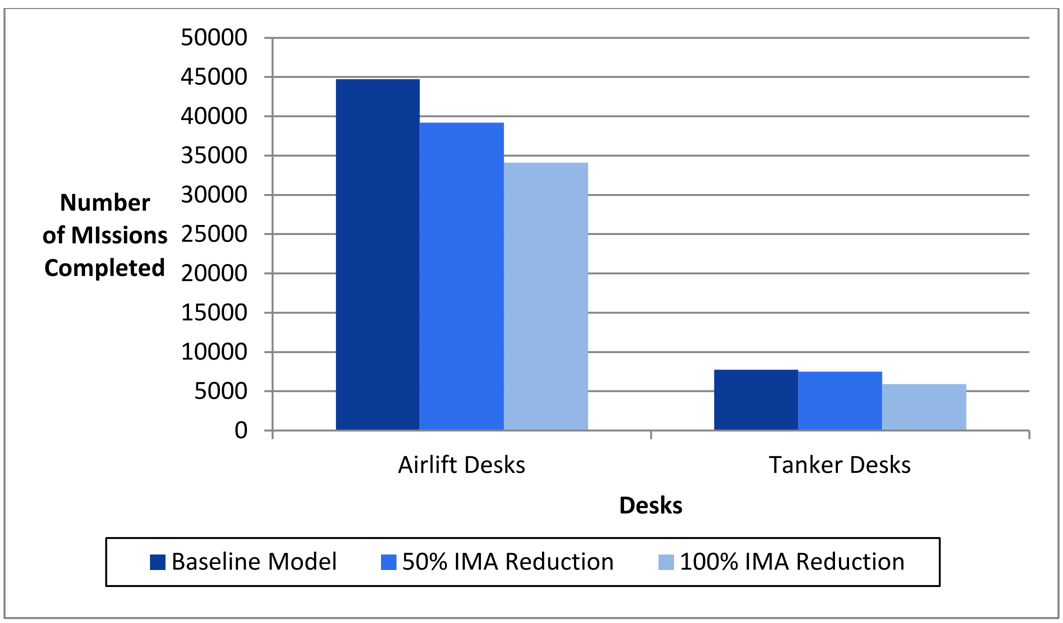

Figure 5: Number of Missions Completed - Desk Groups

To investigate the significance of the differences in number of missions completed, two sample t-tests were conducted at 95% confidence on the difference of the mean number of missions completed. The confidence intervals shown in Tables 9 and 10 will hold for each desk individually with 95% confidence. Using Bonferroni's approach, these confidence intervals will hold for all six desks with at least 70% confidence, for the airlift desks with at least 80% confidence, and for the tanker desks with at least 90% confidence. These t-tests provide evidence that there is a statistically significant change in the number of missions completed due to the manpower reduction. The difference in the means increases as fewer personnel are available to cover tasks. This indicates that as manpower decreases, fewer missions are completed due to waiting for personnel to accomplish tasks.

Table 9: Comparison of Baseline to 100% IMA Reduction – Missions Completed

Desk	Base Model	100% IMA Reduction	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	10820	8104	2716	2642.2	2789.8
DO2 Desk	8260	4096	4164	4070.8	4257.2
DO3 Desk	8351	6221	2130	2049.3	2210.7
DO4 Desk	17296	15674	1622	1491	1753
DO5 Desk	3533	2746	787	756.3	817.7
DO6 Desk	4190	3183	1007	972.2	1041.8

Table 10: Comparison of Baseline to 50% IMA Reduction – Missions Completed

Desk	Base Model	50% IMA Reduction	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	10820	8990	1830	1779.6	1880.4
DO2 Desk	8260	5978	2282	2236.2	2327.8
DO3 Desk	8351	7078	1273	1211.7	1334.3
DO4 Desk	17296	17117	179	83.2	274.8
DO5 Desk	3533	3461	72	33.1	110.9
DO6 Desk	4190	4046	144	103.2	184.8

The total mission deviation is the difference between the scheduled mission completion time and the actual completion time in the model. Mission deviations are caused by issues and mission discrepancies that occur after the initial sortie take off. In reality, some, if not all, of the mission deviation time can be made up during ground time or changing the schedule of the sorties in a mission. These capabilities are not present in the model, therefore, the mission deviation is the total difference between the scheduled time and actual execution time of a mission as if no time can be made up. Mission deviation aids in showing the increased amount of time aircraft and crews have to wait when fewer personnel are available to address an issue.

An increase in total mission deviation is observed when the manpower is reduced as shown in Table 11 and Figures 6 – 8. The total mission deviation increases some with the 50% reduction and increases more with the 100% reduction for the DO desks 1, 3, 5, and 6. Desk 3 was at the lowest utilization of the airlift desks in the base model so as resources that were used to complete DO3 tasks are pulled to complete other tasks, there are fewer resources available causing the total mission deviation to increase. Desk 2 however, does not follow this trend. Both reduced manpower models have higher total mission deviation times than the base model, but the 50% reduction is higher than the 100% reduction. This is most likely due to the fact that the resources for desk 2 were at 97% utilization in the base model. In this event, when resources are reduced and shared with the other desks in a similar manner to the resources from desk 3, that loss of manpower dedicated to desk 2 tasks is more noticeable. Whereas in the 100% reduction model, the quantity of missions through the system is decreased creating less tasks to be completed so the fewer resources do not have as big an impact. For the tanker desks, a similar event occurs with the total mission deviation time.

Table 11: Total Mission Deviation (hours)

Desk Group	Desk	Base Model	50% IMA Reduction	100% IMA Reduction
Airlift Desks	DO1 Desk	554.7	1033.4	1117.8
	DO2 Desk	178.9	1252	799.1
	DO3 Desk	87.2	713.0	866.6
	DO4 Desk	714.1	688.7	779.5
Tanker Desks	DO5 Desk	12.2	120.5	895.0
	DO6 Desk	53.0	250.0	1056.3

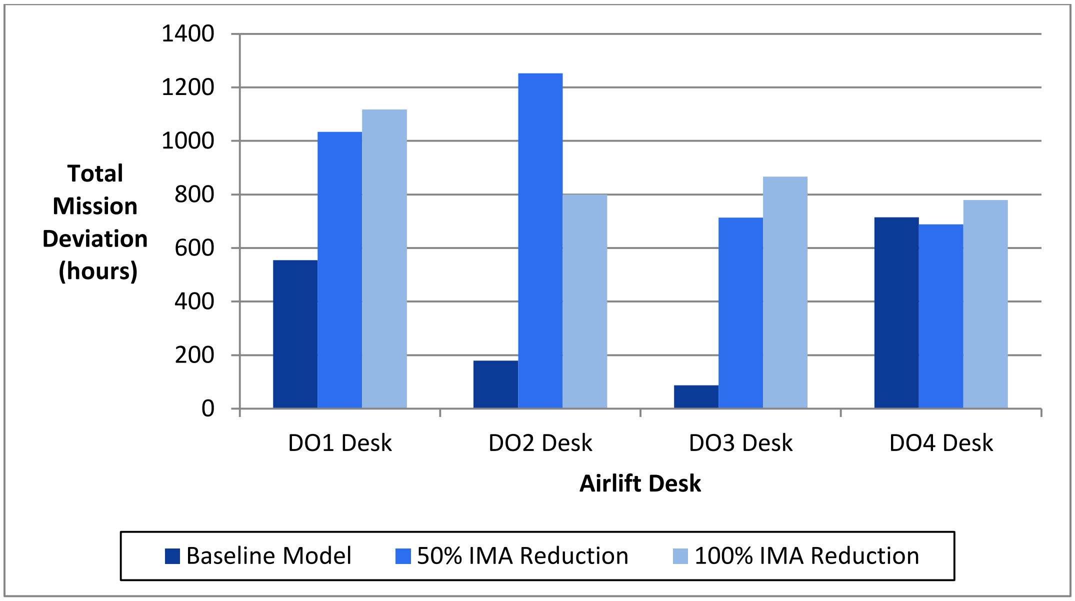

Figure 6: Total Mission Deviation - Airlift Desks

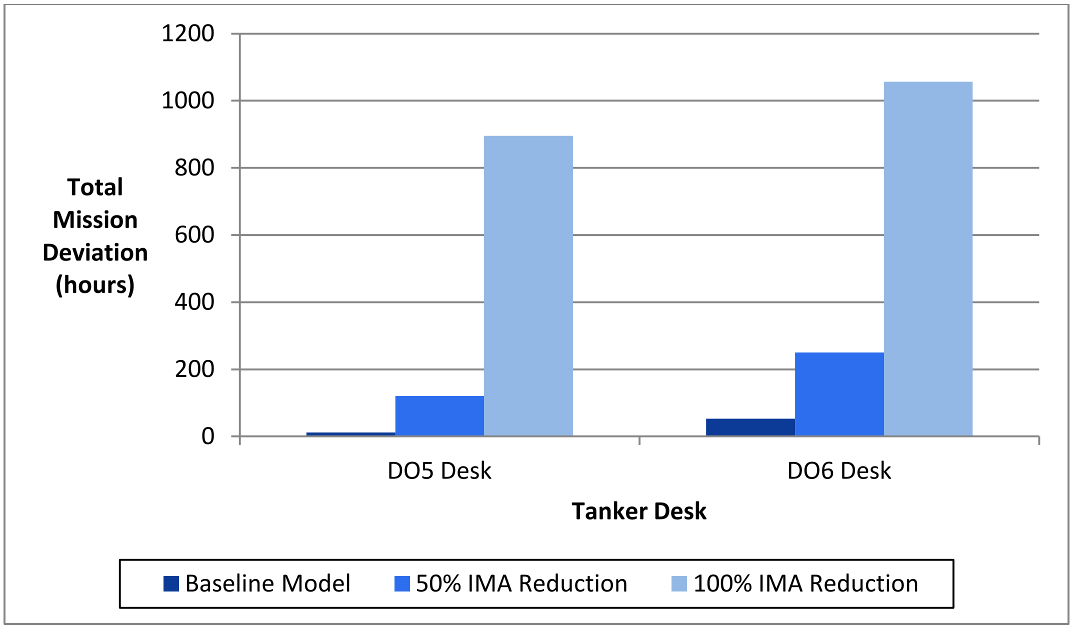

Figure 7: Total Mission Deviation - Tanker Desks

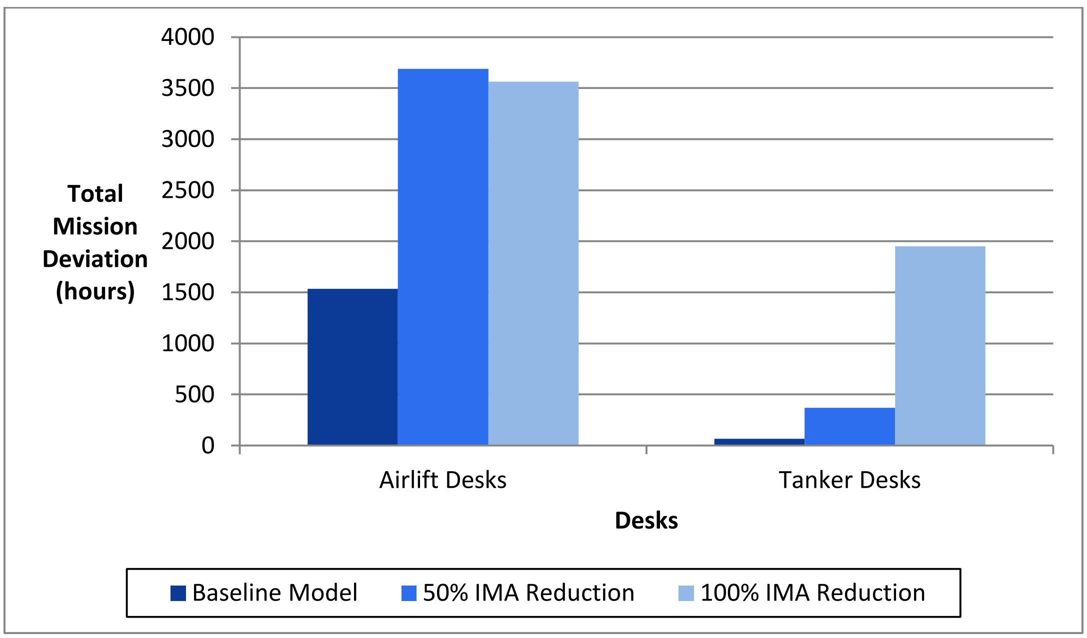

Figure 8: Total Mission Deviation - Desk Groups

Two sample t-tests were conducted at 95% confidence for the total mission deviation values as well. A confidence interval was created for each individual desk comparing the means of the total mission deviation for the base model to the 50% reduction and the base model to the 100% reduction. These confidence intervals, shown in Tables 12 and 13, will hold for each desk individually with 95% confidence. Using Bonferroni's approach, these confidence intervals will hold for all six desks with at least 70% confidence, for the airlift desks with at least 80% confidence, and for the tanker desks with at least 90% confidence. None of the t-tests indicate that the means of the total mission deviations are equal; therefore, showing that there is a statistically significant difference when the manpower is reduced. For the majority of the desks, the mean difference is larger for the 100% reduction than the 50% reduction indicating that as the manpower decreases the total mission deviation time increases because more time is spent waiting for personnel to respond to issues.

Table 12: Comparison of Baseline to 100% IMA Reduction – Mission Deviation (hrs)

Desk	Base Model	100% IMA Reduction	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	554.7	1117.8	-563.1	-598.7	-527.5
DO2 Desk	178.9	799.1	-620.2	-718.9	-521.5
DO3 Desk	87.2	866.6	-779.4	-805.9	-752.9
DO4 Desk	714.1	779.5	-65.4	-85.9	-44.9
DO5 Desk	12.2	895.0	-882.8	-906.6	-859
DO6 Desk	53.0	1056.3	-1003.3	-1029.7	-976.9

Table 13: Comparison of Baseline to 50% IMA Reduction – Mission Deviation (hrs)

Desk	Base Model	50% IMA Reduction	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	554.7	1033.4	-478.7	-506.4	-451
DO2 Desk	178.9	1252	-1073.1	-1097.7	-1048.5
DO3 Desk	87.2	713.0	-625.8	-639.9	-611.7
DO4 Desk	714.1	688.7	25.4	10.1	40.7
DO5 Desk	12.2	120.5	-108.3	-113.9	-102.8
DO6 Desk	53.0	250.0	-197	-206.3	-187.7

In addition to investigating each desk individually, the groups of desks were analyzed for both number of missions completed and total mission deviation as shown in Tables 14 and 15. Confidence intervals were created for the mean number of missions completed and the mean total mission deviation between the base model and the 100% IMA reduction model. These confidence intervals will hold for each group at 95% confidence and both groups together with at least 90% confidence based on Bonferroni's approach. Two sample t-tests were conducted on these intervals. The t-tests for the airlift desks for both missions completed and total mission deviation indicate that there is a significant difference in the mean when manpower is reduced. The t-test for the tanker desks for both missions completed and total mission deviation indicate that there is a significant difference in the mean when manpower is reduced. The result of this analysis of the groups of desks corresponds to the results determined by analyzing each desk individually.

Table 14: Comparison of Baseline to 100% IMA Reduction - Missions Completed

Desk	Base Model	100% IMA Reduction	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
Airlift Desks	44728	34097	10631	10409	10853
Tanker Desks	7723	5930	1793	1744.7	1841.3

Table 15: Comparison of Baseline to 100% IMA Reduction - Mission Deviation

Desk	Base Model	100% IMA Reduction	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
Airlift Desks	1534.8	3563	-2028.2	-2126.1	-1930.3
Tanker Desks	65.24	1951.2	-1885.9	-1933.4	-1838.6

8. Conclusions

Determining the potential impact of the loss of IMA personnel is important in preparing for changes in the future for the TACC. These results provide initial insight towards the impact of resource utilization, the number of missions completed, and total mission deviation in a reduced manpower state. This initial insight indicates that as fewer personnel are available, fewer missions will be completed and the total mission deviation time will increase over a set period of time. For both the 50% and 100% reduction models, the resource utilization increases overall for the model. This increase in utilization rate shows that while more tasks may be able to be accomplished by fewer personnel, the altered system is less agile in the event of a influx in tasks to be completed.

The reduced manpower models present the concept of resource pools to complete tasks instead of specific personnel assigned to certain tasks. These resource pools are one possible method of handling a loss of manpower at the TACC. Other methods including the duration of shifts worked by personnel and the quantity of missions monitored by the XOCG will be investigated in the next portion of this research.

III. Case Study

1. Introduction

The Tanker Airlift Control Center (TACC) acts as the execution arm of Air Mobility Command (AMC) to aid in achieving Global Reach. The TACC plans, allocates, and executes strategic airlift, air refueling, and aeromedical evacuation missions around the world. The Command and Control (XOC) directorate operates 24 hours a day, 7 days a week, 365 days a year to ensure successful mission completion. The Global Operations (XOCG) group focuses on providing flight monitoring and mission management assistance to AMC inter-theater missions. The TACC is concerned with the impact a potential manpower loss would cause.

2. Background

XOC personnel operate 24 hours a day, 7 days a week to provide flight planning, diplomatic clearances, and flight management from the beginning of mission execution through mission completion. The XOCG monitors and manages the missions executed by the TACC. It is their job to follow each sortie of a mission and address any issues that arise beginning 24 hours prior to first sortie take off through final sortie landing and mission completion. The XOCG deals with issues that cause a deviation from the scheduled flight plan including diplomatic clearances, early and late take offs and landings, maintenance malfunctions, weather conditions, and airfield capacities. Approximately 70% of XOC personnel are Individual Mobility Augmentees (IMA) a portion of which are employed by the XOCG. In the XOCG, there are two types of IMAs: traditional IMAs and guest help. Traditional IMAs are Air Force National Guard and Air Force Reserve members that serve one weekend per month plus two weeks per year. Guest help are Air Force National Guard and Air Force Reserve members that volunteer to be put on full time orders to work at the TACC for a predetermined period of time. The impact of the loss of these IMAs is the focus of this research.

3. Simulation

The operations floor of the XOCG was modeled using Rockwell Arena simulation software. The simulation focuses on XOCG personnel and the impact a reduction in personnel would have on the utilization rate of personnel resources, number of missions completed, and total mission deviation time.

3.1 Model Development

The simulation model focuses on the tasks of the XOCG operations floor personnel. The operations floor has several types of tasks and different personnel are required for each of these tasks. Personnel include controllers (1C3), Global Operations Directors (DO), Deputy Directors of Operations (DDO), and Station Coordinators (MOG). While all personnel are included in the simulation, the analysis focuses on the DO, DDO, and MOG personnel since the 1C3 personnel do not have any IMAs on the operations floor. The model simulates the six DO desks each with a specific type of mission assigned to it, two MOG desks, six 1C3 desks, and the interactions the DDOs have with these desks. The DDO desks are not fully modeled as only a portion of their tasks were clearly defined. Mission arrival to the operations floor is where the simulation begins. As missions arrive to the operations floor, they are sent to the specific DO desk assigned to monitor that type of mission. Once in execution, if an issue arises it can be identified by the crew of the aircraft or by DO or DDO personnel. If an issue is identified by the crew they call the TACC and speak to a 1C3. The 1C3 then identifies the correct DO desk assigned to the mission and forwards the information. Once an issue is identified by the DO, they determine a course of action to correct the issue. In some cases, the DO will require assistance to determine the correct course of action. This is where the DDO personnel come in. Each DDO personnel is assigned two DO desks to oversee. After a course of action is determined, the 1C3 carries it out by completing a checklist, waiver, or updating the notepad and informing the crew of the plan. Once an issue has been corrected, the DO personnel return to monitoring it until full mission completion. Some missions require the assistance of the MOG desk. The MOG desk oversees a predefined list of airfields to assure there is adequate space to land, unload/load cargo, and take off and if fuel is available if needed. If a mission involves an airfield monitored by the MOG desk, the course of action determined by the DO must be reviewed by the MOG personnel to ensure it is possible. Figure 9 shows the process flow of the simulation model for one DO desk. The model simulates these operations and focuses on the resources required to complete them.

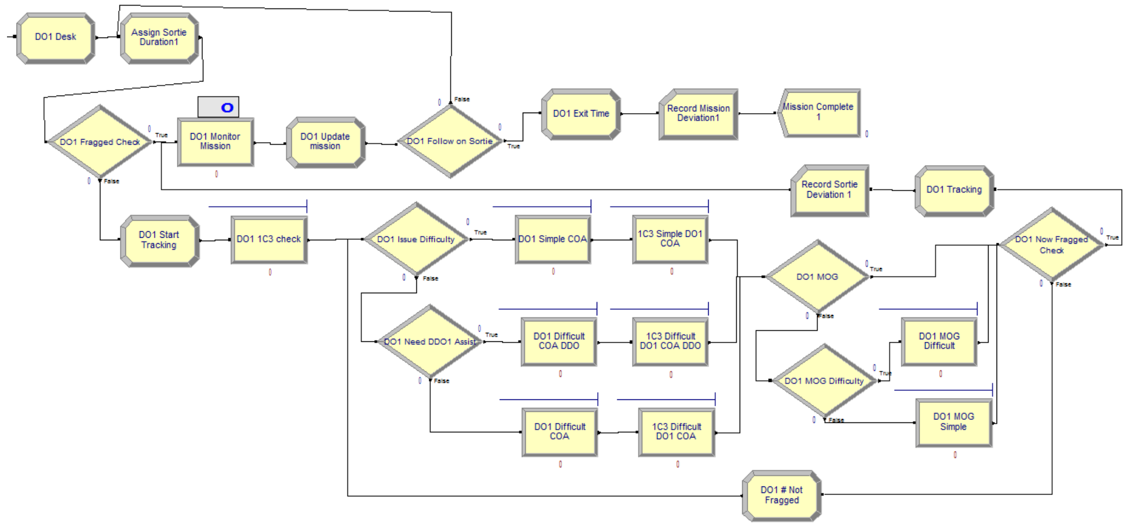

Figure 9: Process Flow of a DO desk

3.2 Supporting Data, Verification and Validation

Data for the model was provided through SME expertise and historical data from the Mission Support Directorate (XON). The SME data included specifics about the process flow and task completion times for each of the desks on the XOC portion of the operations floor. Details of how the mission types were divided among the desks were also provided. Calendar year 2010 historical data was used to obtain distributions for the number of missions to each desk, the number of deviations, number of sorties that comprise a mission, duration of sorties, and the arrival rate of mission to the operations floor. The model was run for a period of 365 days plus a warm up period of 80 days to eliminate initialization bias. Each model was run for 20 replications and the averages for resource utilization, number of missions completed, and total mission deviation were analyzed.

Model verification and validation is an important part of model development. To validate that the model reasonably represents the system being analyzed, the process flow was reviewed with several personnel who work the XOCG operations floor. Their comments and suggestions were incorporated into the final model to ensure that the model represented the nature of the system as scoped for this research. To verify the model, a numerical check was conducted comparing the simulation outputs to the historical data. The percentage of missions monitored by each desk in the model is within +/- 2% of the mission breakup from the historical data. The total number of missions simulated in the model is 13 % higher than the number of missions represented in the historical data. This higher number of missions can be explained in part since ground time is not included in the simulation model.

4. Initial Results and Analysis

Initial analysis of the system included investigating several manpower levels with operations as run currently. The baseline model is of the current operations and manpower levels at the XOCG. Manpower reductions of 100% of the IMA resources and 50% of the IMA resources were also investigated. For the reduced manpower models, the personnel resource assignments were adjusted to a resource pool (airlift DO, airlift DDO, tanker, MOG) assigned to a group of desks (airlift, tanker, MOG) instead of an individual person being assigned to each specific desk. In a reduced manpower environment, this is one option to cover the tasks of all the desks.

The results of the baseline model align with the historical data and SME input on how the system being modeled operates. The reductions in manpower cause a decrease in the number of missions completed and an increase in the total mission deviation. With less available manpower, it is expected that fewer tasks can be accomplished and that tasks that are accomplished have to wait longer for personnel to address an issue. The impact is larger for the 100% IMA reduction than for the 50% IMA reduction. In addition, we see level utilization among the airlift DO, DDO, and tanker desks with the pooling of resources at both reduced manpower levels.

5. Comparison of System Alternatives

Further analysis of the system included investigating the effects of a decrease in missions monitored by the XOC and increasing shifts from 8 hours to 12 hours. A 10% decrease in missions monitored was investigated to roughly represent anticipated reductions. To isolate the effect of a reduced number of missions with the 100% IMA reduction manning levels, we compared the original 2010 mission levels against our 10% decrease in mission arrival rate. The only change in the reduced arrival model is the number of missions being monitored by the XOC operations floor. The mission type breakup, resource pool organization, and duration of shifts are the same as in the original 100% IMA reduction model.

For analysis of the system with a 10% decrease in mission arrival rate, the resource utilization, number of missions completed, and total mission deviation were reviewed. The resource utilization, as shown in Table 16, was not affected by the decrease in the arrival of missions to the XOC operations floor. This indicates that even with a significant reduction in the number of missions to monitor, personnel utilization will remain extremely high with the loss of all IMAs.

Table 16: Resource Utilization

Desk Group	Resource	Original Arrival	Reduced Arrival
Airlift DO Desks	DO1 Desk	99.99%	99.99%
	DO2 Desk	99.99%	99.99%
	DO3 Desk	99.99%	99.99%
	DO4 Desk	99.99%	99.99%
Airlift DDO Desks	DDO1 Desk	99.99%	99.99%
	DDO2 Desk	99.99%	99.99%
Tanker Desks	DO5 Desk	100%	100%
	DO6 Desk	100%	100%
	DDO3 Desk	100%	100%
	MOG Desk	98.94%	98.29%
	1C3 Desks	62.32%	61.47%

As expected, the number of missions completed as shown in Table 17 and Figures 10 – 12, is reduced with the reduced arrival model. While the arrival rate is decreased by 10%, the results of the number of missions completed does not match this 10% exactly. The mission completions decrease between 3% - 7% for each desk, indicating that a slightly larger percentage of missions entering the floor are being successfully processed with the reduced mission load.

Table 17: Number of Missions Completed

Desk Group	Desk	Original Arrival	Reduced Arrival
Airlift Desks	DO1 Desk	8104	7821
	DO2 Desk	4096	3815
	DO3 Desk	6221	5958
	DO4 Desk	15674	14928
Tanker Desks	DO5 Desk	2746	2615
	DO6 Desk	3183	3044
	Total	40024	38181

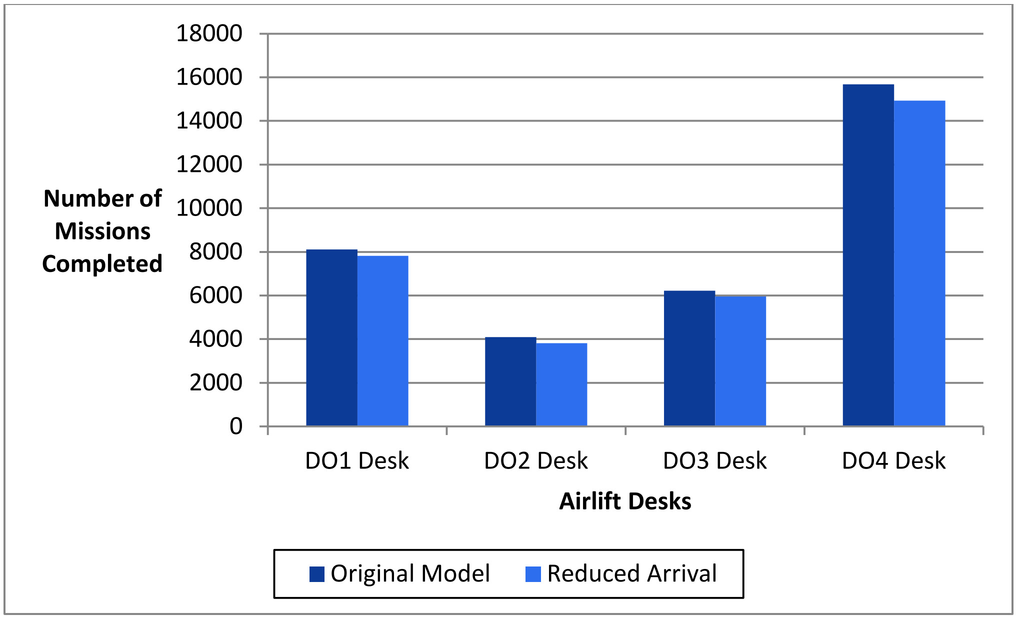

Figure 10: Number of Missions Completed - Airlift Desks

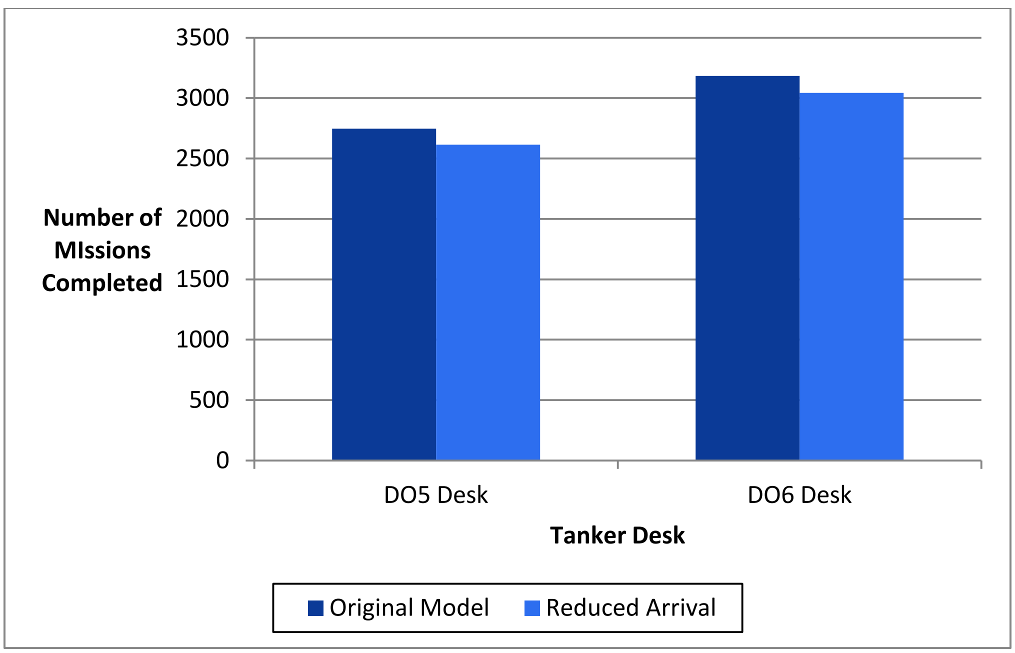

Figure 11: Number of Missions Completed - Tanker Desks

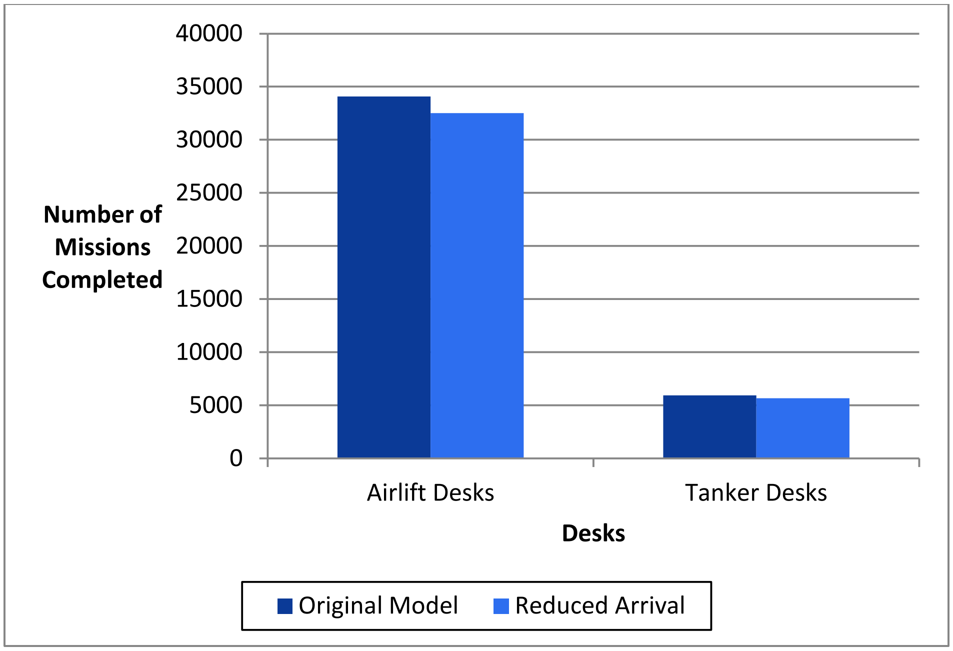

Figure 12: Number of Missions Completed - Desk Groups

As in the initial analysis, 95% confidence intervals were created for the number of missions completed by desk, as provided in Table 18. These confidence intervals hold individually at 95% confidence. Based on Bonferroni's approach, the confidence intervals hold for all six desks with at least 70% confidence, the airlift desks with at least 80% confidence, and the tanker desks with at least 90% confidence. The two sample t-tests provide evidence that the number of missions completed is statistically different when the arrival rate of missions to the operations floor is decreased 10%. By observation, each desk has about 100 to 300 less missions completed except desk 4. This might be due to the fact that desk 4 monitors the most missions out of the six desks.

Table 18: Comparison of Number of Missions Completed

Desk	Original Arrival	Reduced Arrival	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	8104	7821	283	187	380
DO2 Desk	4096	3815	281	157	405
DO3 Desk	6221	5958	264	174	353
DO4 Desk	15674	14928	746	585	906
DO5 Desk	2746	2615	131	97.6	164
DO6 Desk	3183	3044	139	103	175

Total mission deviation is the total difference between the scheduled mission completion time and the actual mission completion time. When the arrival rate of missions is decreased, the total mission deviation time decreases as shown in Table 19 and Figures 13 – 15.

Table 19: Total Mission Deviation

Desk Group	Desk	Original Arrival	Reduced Arrival
Airlift Desks	DO1 Desk	1117.8	1066.2
	DO2 Desk	799.1	733.4
	DO3 Desk	866.6	828.0
	DO4 Desk	799.5	747.3
Tanker Desks	DO5 Desk	894.9	816.7
	DO6 Desk	1056.3	954.6

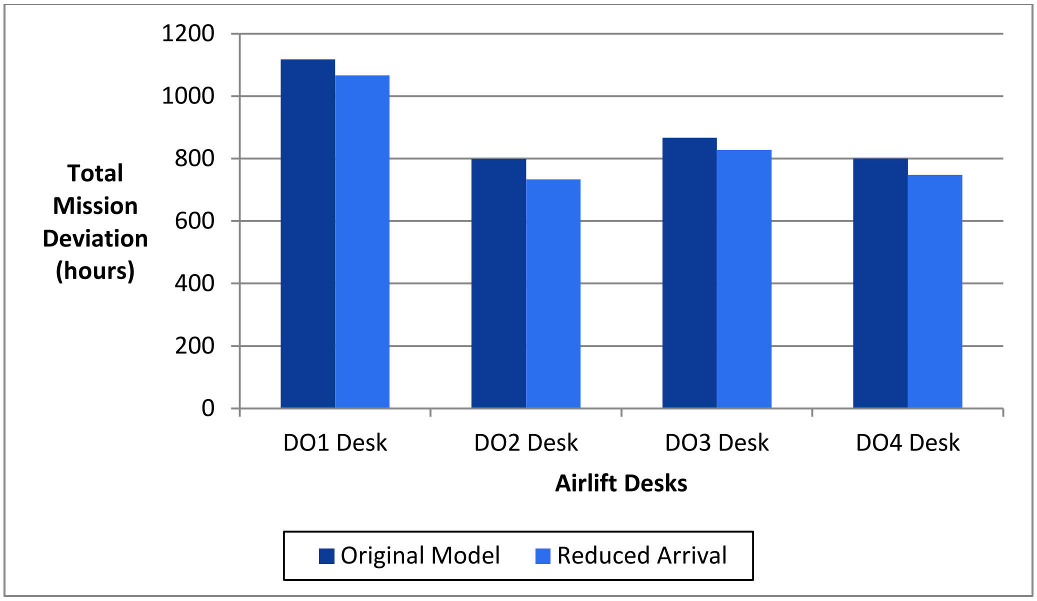

Figure 13: Total Mission Deviation - Airlift Desks

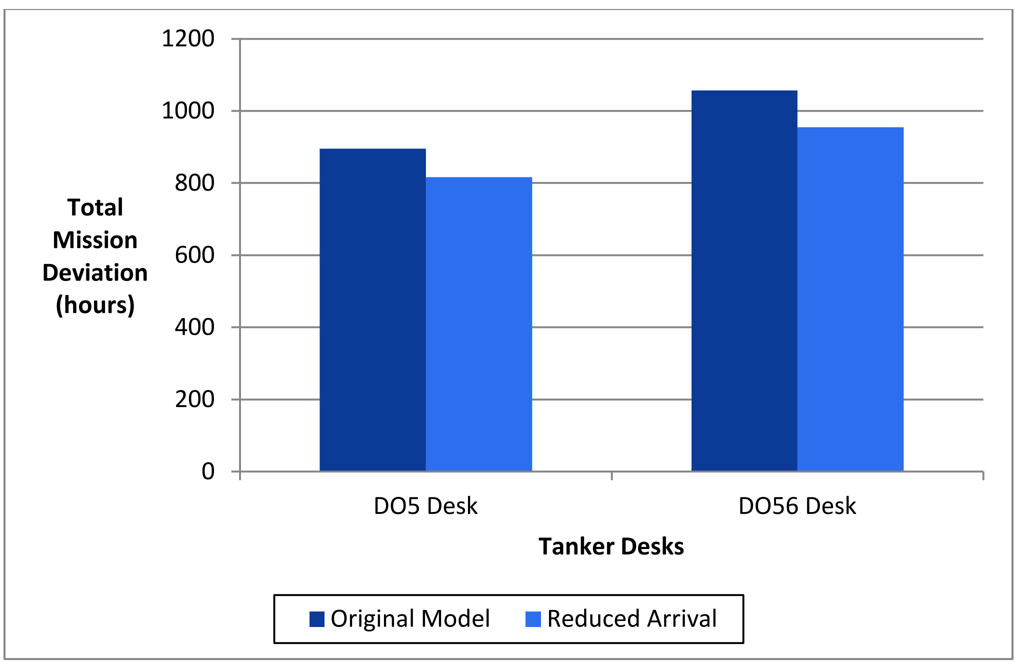

Figure 14: Total Mission Deviation - Tanker Desks

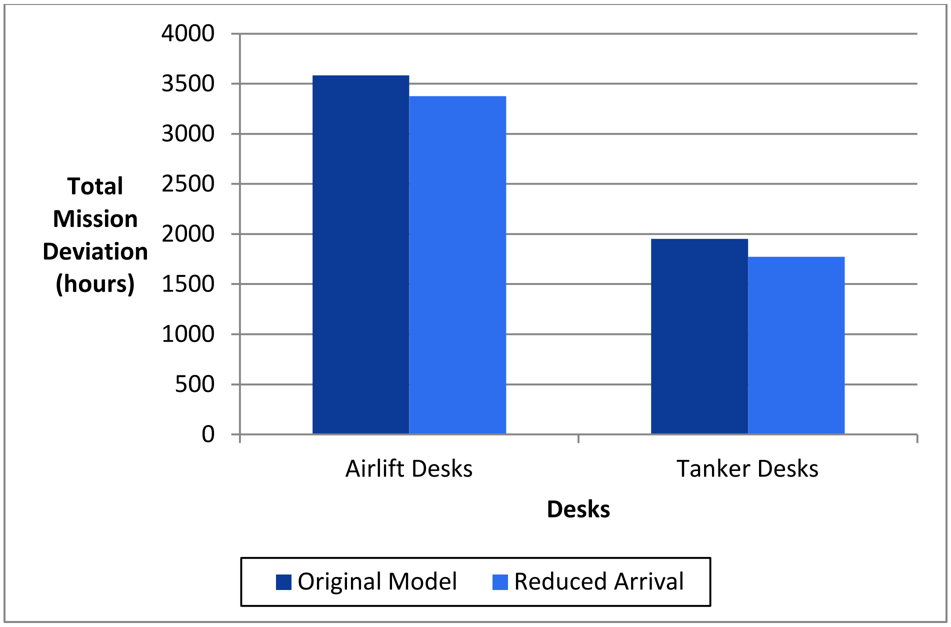

Figure 15: Total Mission Deviation - Desk Groups

Confidence intervals were created at the 95% confidence level for the total mission deviation between the original 100% IMA reduction model and the 100% IMA reduction model with reduced arrival rate. These confidence intervals are shown in Table 20 and will hold for each desk individually at 95% confidence. Using Bonferroni's approach they will hold for all six desks with at least 70% confidence, the airlift desks with at least 80% confidence, and the tanker desks with at least 90% confidence. Two sample t-tests were conducted on these confidence intervals and show evidence that there is a statistically significant difference for the total mission deviation between the two models for all desks except desk 2. The t-test for desk 2 fails to reject that the mean total mission deviation time is statistically equal when the arrival rate of missions is reduced. The total mission deviation decreased by more than one day for all six desks.

Table 20: Comparison of Total Mission Deviation

Desk	Original Arrival	Reduced Arrival	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	1117.8	1066.2	51.6	20.3	82.9
DO2 Desk	799.1	733.4	65.7	-97.6	229
DO3 Desk	866.6	828.0	38.5	7.77	69.3
DO4 Desk	799.5	747.3	32.2	11.4	53
DO5 Desk	894.9	816.7	78.2	41.5	115
DO6 Desk	1056.3	954.6	102	67.4	136

In addition to analyzing each desk individually, the desk groups were reviewed. Confidence intervals at the 95% level were constructed for both the airlift and tanker desk groups for both the number of missions completed and the total mission deviation. Two sample t-tests were conducted on these confidence intervals and the results are presented in Tables 21 and 22. The confidence intervals will hold at 95% confidence for each desk group individually and with at least 90% confidence for both desks groups together for each measure. The t-tests indicated that there is a statistically significant difference between the number of missions completed and the total mission deviation when the arrival rate of missions to the XOC operations floor is decreased.

Table 21: Comparison of Number of Missions Completed - Desk Groups

Desk	Original Arrival	Reduced Arrival	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
Airlift Desks	34097	32523	1574	1318	1830
Tanker Desks	5930	5660	270	220	319

Table 22: Comparison of Total Mission Deviation - Desk Groups

Desk	Original Arrival	Reduced Arrival	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
Airlift Desks	3563	3374.9	188	36.1	340
Tanker Desks	1951.2	1771.3	180	113	247

Analysis of the duration of shifts was also conducted using the reduced number of missions. In the current system, personnel work 8 hour shifts and work approximately 15 shifts per month. In the adjusted system, personnel work 12 hour shifts and work approximately 15 shifts per month. The number of shifts worked per month does not change, just the duration of the shifts worked. For this analysis, the 50% IMA reduction model was used. The 100% IMA reduction model was initially investigated, but since so few resources are available to cover 8 hour shifts, changing the shifts to 12 hours did not provide any great difference in resources available. The 8 hour shift model is the 50% IMA reduction with the reduced arrival rate and the same resource allocation as in the original analysis. The 12 hour shift model is the 50% IMA reduction with the reduced arrival rate and adjusted resource allocation to simulate 12 hour shifts. Resource utilization, number of missions completed, and total mission deviation are analyzed in this model comparison.

The resource utilization rate decreases for both models as shown in Table 23 due to the decreased mission arrival rate for the airlift and tanker desks. The 12 hour shifts utilization rate decreases even more since there are more people available per shift to cover tasks of the airlift and tanker desks. The MOG desk remains at 100% utilization, indicating that this desk may be a bottleneck in the system that may require further analysis. While the MOG desk does gain additional personnel with 12 hour shifts, there are still not as many personnel allocated to cover the large amount of tasks that the MOG desk must accomplish when compared to the airlift and tanker desks. The 1C3 utilization rate increases from the 8 hour shift model to the 12 hour shift model. This is because while there are more personnel available to complete tasks more tasks are completed and, therefore, more missions are completed with 12 hour shifts.

Table 23: Resource Utilization

Desk Group	Resource	8 hour shifts	12 hour shifts
Airlift DO Desks	DO1 Desk	90.35%	85.99%
	DO2 Desk	90.35%	85.99%
	DO3 Desk	90.35%	85.99%
	DO4 Desk	90.35%	85.99%
Airlift DDO Desks	DDO1 Desk	80.48%	70.02%
	DDO2 Desk	80.48%	70.02%
Tanker Desks	DO5 Desk	88.78%	60.12%
	DO6 Desk	88.78%	60.12%
	DDO3 Desk	88.78%	60.12%
	MOG Desk	100%	100%
	1C3 Desks	81.38%	95.43%

When 12 hour shifts are implemented in the simulation, the number of missions completed increases as shown in Table 24 and Figures 16 – 18. With more available personnel to accomplish tasks, it makes sense that more tasks can be completed and therefore, more missions completed as they are not waiting on personnel to work an issue.

Table 24: Number of Missions Completed

Desk Group	Desk	8 hour shifts	12 hour shifts
Airlift Desks	DO1 Desk	8670	10214
	DO2 Desk	5838	7073
	DO3 Desk	6693	7401
	DO4 Desk	16189	17904
Tanker Desks	DO5 Desk	3164	3199
	DO6 Desk	3732	3815
	Total	44286	49606

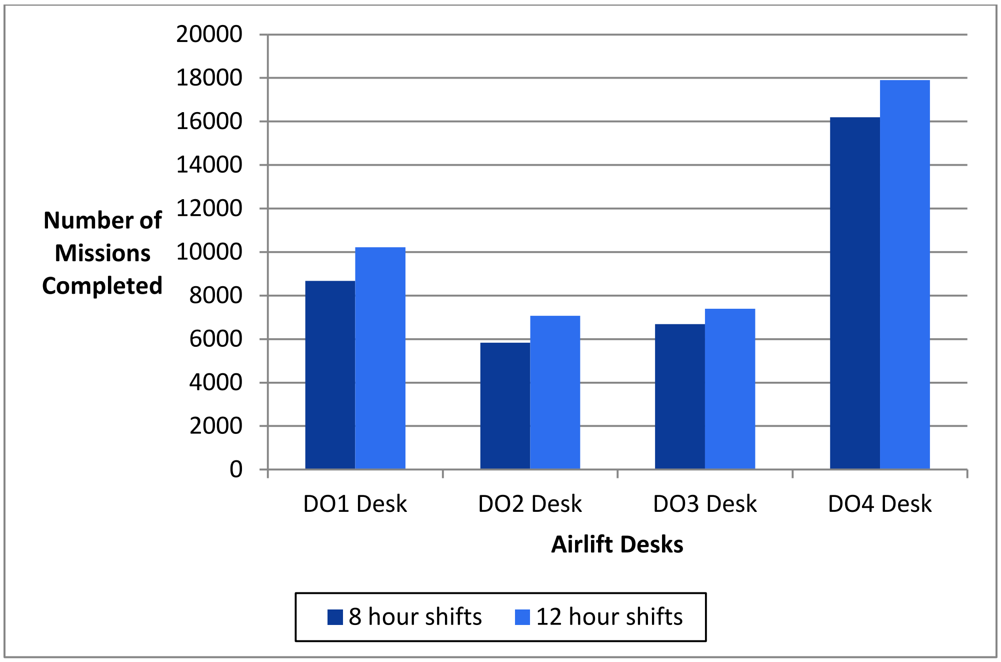

Figure 16: Number of Missions Completed - Airlift Desks

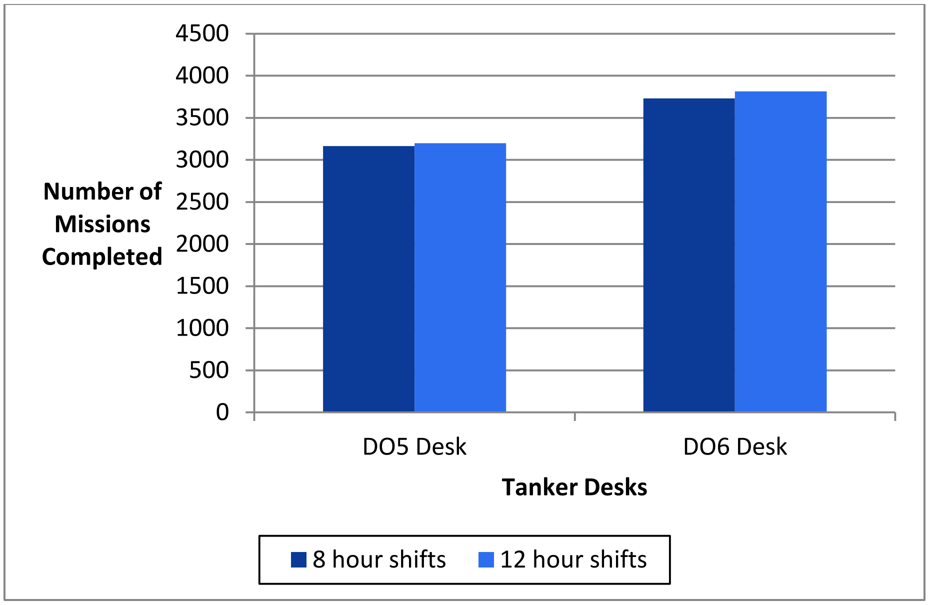

Figure 17: Number of Missions Completed - Tanker Desks

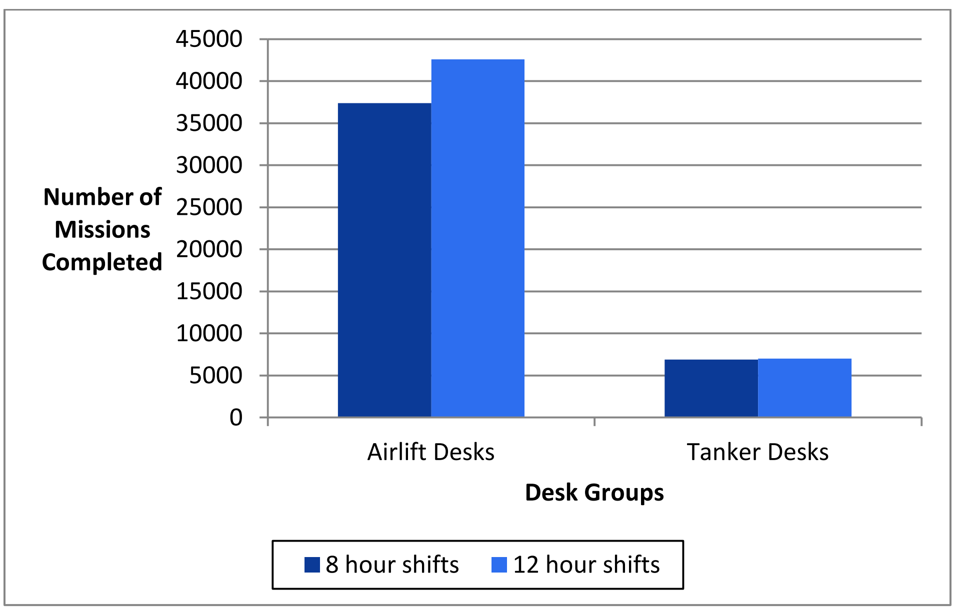

Figure 18: Number of Missions Completed - Desk Groups

Confidence intervals at the 95% confidence level were created for each desk individually and are shown in Table 25. These confidence intervals hold for each individual desk with 95% confidence. Based on Bonferroni's approach, they hold for all six desks with at least 70% confidence, the airlift desks with at least 80% confidence, and the tanker desks with at least 90% confidence. Except for desk 5, the two sample t-tests conducted indicate that there is a statistical difference in the number of missions completed when the shift duration is changed from 8 hours to 12 hours. Since the mean difference is negative, this indicates that changing the shift duration from 8 hours to 12 means completing more tasks and thus more missions.

Table 25: Comparison of Number of Missions Completed

Desk	8 hour shifts	12 hour shifts	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	8670	10214	-1544	-1613.6	-1474.4
DO2 Desk	5838	7073	-1235	-1284.9	-1185.1
DO3 Desk	6693	7401	-708	-760.4	-655.6
DO4 Desk	16189	17904	-1715	-1791.6	-1638.4
DO5 Desk	3164	3199	-35	-75	5
DO6 Desk	3732	3815	-83	-122.7	-43.3

The total mission deviation was analyzed as well. As expected, since more missions are completed, the total mission deviation time decreases for each desk when shift duration is changed from 8 hours to 12 hours as shown in Table 26 and Figures 19 – 21.

Table 26: Total Mission Deviation

Desk Group	Desk	8 hour shifts	12 hour shifts
Airlift Desks	DO1 Desk	928.4	370.7
	DO2 Desk	1123.9	442.3
	DO3 Desk	620.8	230.0
	DO4 Desk	608.5	227.2
Tanker Desks	DO5 Desk	90.2	24.1
	DO6 Desk	191.8	53.1

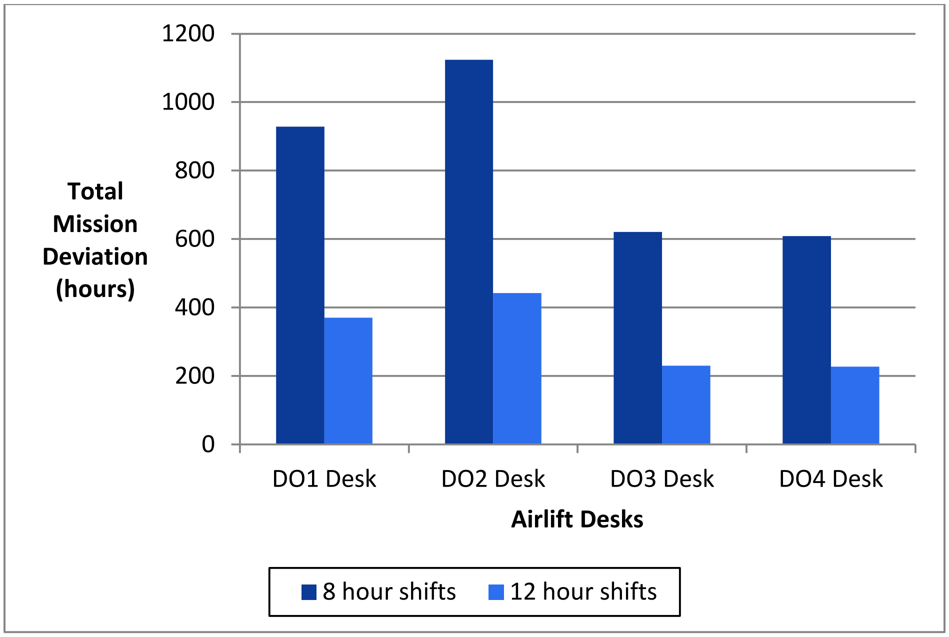

Figure 19: Total Mission Deviation - Airlift Desks

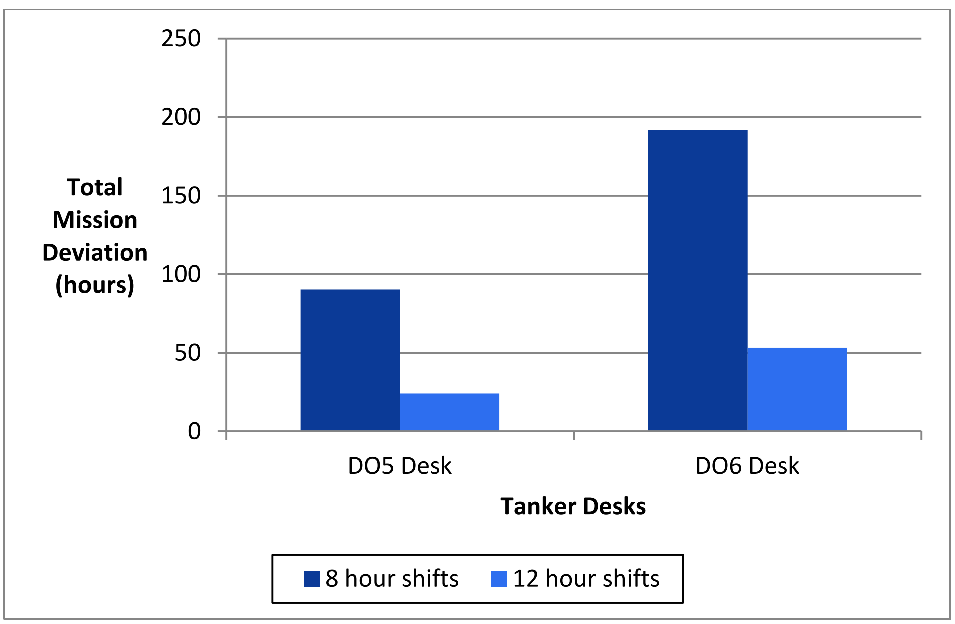

Figure 20: Total Mission Deviation - Tanker Desks

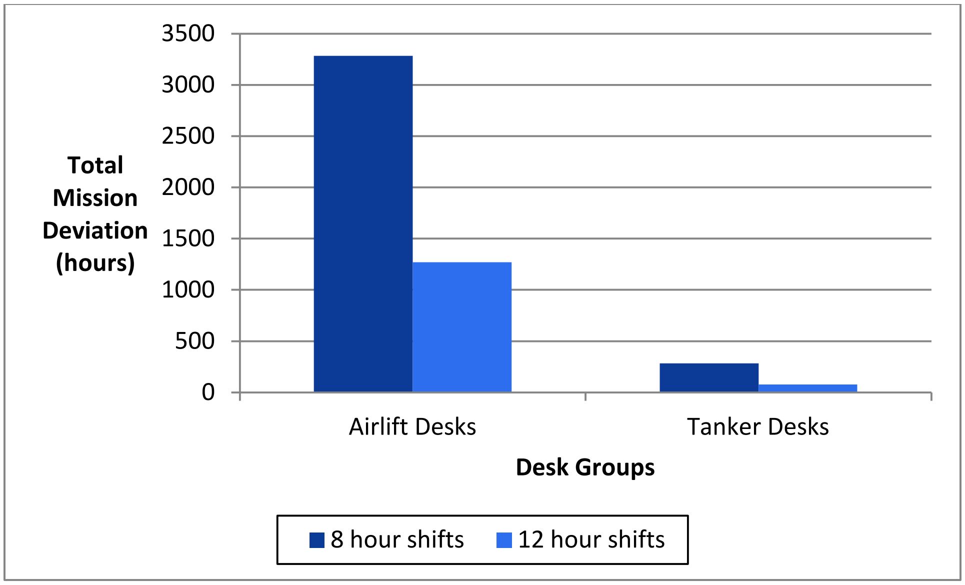

Figure 21: Total Mission Deviation - Desk Groups

In the statistical analysis, 95% confidence intervals were created for each desk as shown in Table 27. These confidence intervals will hold for each desk individually at 95% confidence. They will hold for all six desks with at least 70% confidence, for the airlift desks with at least 80% confidence, and for the tanker desks with at least 90% confidence according to Bonferroni's approach. The two sample t-tests conducted indicate that there is a statistically significant difference in the total mission deviation time when the shift duration is changed from 8 hours to 12 hours for every desk. The mean difference is positive for each desk indicating that changing the shifts from 8 hours to 12 hours decreases the total mission deviation time.

Table 27: Comparison of Total Mission Deviation

Desk	8 hour shifts	12 hour shifts	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
DO1 Desk	928.4	370.7	558	538	578
DO2 Desk	1123.9	442.3	682	658	705
DO3 Desk	620.8	230.0	391	377	405
DO4 Desk	608.5	227.2	381	369	393
DO5 Desk	90.2	24.1	66.1	62.4	69.7
DO6 Desk	191.8	53.1	139	133	144

The desk groups were also analyzed for this alternative. Again 95% confidence intervals were created for each group as shown in Tables 28 and 29. Both confidence intervals for the number of missions completed will hold with at least 90% confidence according to Bonferroni's approach. The same is true for the confidence intervals for total mission deviation. The two sample t-tests conducted on these confidence intervals indicated that there is a statistical difference between the number of missions completed and the total mission deviation when the shift duration is changed from 8 hours to 12 hours. The mean difference for the number of missions completed is negative indicating more missions will be completed for both groups of desks. The mean difference for total mission deviation is positive indicating that the total mission deviation will decrease for both groups of desks when 12 hour shifts are used versus 8 hour shifts. These conclusions correspond to the conclusions made when analyzing each desk individually.

Table 28: Comparison of Number of Missions Completed - Desk Groups

Desk	8 hour shifts	12 hour shifts	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
Airlift Desks	37391	42593	-5202	-5328	-5076
Tanker Desks	6896	7015	-119	-176.5	-61.5

Table 29: Comparison of Total Mission Deviation - Desk Groups

Desk	8 hour shifts	12 hour shifts	95% Confidence Interval		
	Mean	Mean	Estimated Mean Difference	Lower Bound	Upper Bound
Airlift Desks	3281.6	1270.2	2011.4	1945	2077.8
Tanker Desks	282.0	77.2	204.8	196.3	213.3

6. Conclusion

Determining the potential impact of the loss of IMA personnel is important in preparing for changes in the future for the TACC. The results presented in this chapter take a further look into possible situations for a future state TACC. The results provide insight towards the impact of a manpower reduction on resource utilization, the number of missions completed, and the total mission deviation. The two topics focused on in this chapter are a change in the number of missions monitored by the TACC, specifically a 10% decrease in missions, and a change in shift duration worked by the personnel, specifically an increase from 8 hour shifts to 12 hour shifts. Both of these models incorporate the resource pools as determined in Chapter 2 as one possible method of handling a decrease in manpower. The model analyzing the decrease in arrival rate of missions indicated that when fewer missions are required to be monitored, the total mission deviation decreases meaning more missions are completed at the scheduled time or closer to the scheduled time. In the model analyzed, decreasing the arrival rate of missions did not really effect the resource utilization however which is very high signifying that this is not a very agile system that can handle a large influx of tasks. The model analyzing the change in shift duration from 8 hours to 12 hours shows that increasing shift duration can aid in balancing the effect of a manpower loss. This is not a perfect solution, however, as this means personnel have to work longer shifts which increases the chance of fatigue and mistakes as well as possibly causing a decrease in morale toward work.

IV. Conclusion

1. Research Summary

This research investigates the potential impact of a loss of IMA personnel to the operations floor of the TACC. The system is analyzed under several scenarios including two potential levels of manpower reduction, decreased number of missions monitored, and increased shift duration worked. A combination of SME data and historical data was used to develop the simulation model of the current system.

In the initial analysis, the system was modeled to match the current setup of operations. The main change investigated was a reduction in the personnel resources. For both the 50% IMA reduction and 100% IMA reduction models, the remaining personnel resources were modeled as a pool of resources versus an individual resource assigned to each individual desk. This pool of resources is one method of handling the reduction of manpower to cover the same number of desks on the operations floor. The pooled resources helped cover tasks for the busier desks with manpower from the less busy desks. As expected, when manpower was decreased the number of missions completed decreased and the total mission deviation increased. Changes in missions completed and total mission deviation were both statistically and practically significant. Resource utilization increased overall with the levels consistent across all desks within each of the resource pools.

Further analysis of the system led to investigating a reduction in missions arriving to the TACC operations floor and changing the duration of a shift from 8 hours to 12 hours. The reduction in missions indicated that while the resource utilization was not greatly affected, the percentage of the number of missions completed increased slightly and the total mission deviation decreased. The change in shift duration indicated that with longer shifts fewer resources can make up a portion of the difference in manpower reductions. In this scenario, the number of missions completed increased somewhat and the total mission deviation decreased a noticeable amount. This follows the idea of getting more for less. Overall the research presents some insights to possible impacts of manpower reductions and some strategies that could be implemented to handle the increased workload.

2. Future Work

The simulation model developed along with the analysis conducted in this research, clearly demonstrated potential negative impacts to the TACC operations floor with anticipated manpower losses, even with projected workload reductions in a post contingency environment. Model assumptions, such as not explicitly accounting for ground time, were driven by the data available. With more detailed data, additional fidelity could be added to this or another simulation to better match actual operations. Future studies could look at expanding the scope of the simulation to incorporate other TACC elements with potential of sharing manpower as well as moving beyond execution process to look at planning taskings.

Appendix: Quad Chart

Simulation Modeling and Analysis of the Impact of Individual Mobility Augmentee Loss at the Tanker Airlift Control Center

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Department of Operational Sciences (ENS)
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Background

The TACC operates as the Execution arm for Air Mobility Command's Global Reach mission. They plan ,allocate, and execute combat delivery, strategic airlift, air refueling, and aeromedical evacuation operations around the world. Approximately 70% of the personnel of the Command and Control Directorate (XOC) of the TACC are Individual Mobility Augmentees (IMA). There is concern about the impact a loss of these IMAs would cause to the TACC mission. This research focuses on the Global Operations (XOCG) portion of the TACC operations floor. The XOCG personnel monitor missions during the execution phase and attend to any issues that arise.

Methodology

Discrete-Event Simulation was used to investigate possible scenarios adjusting manpower levels, the number of missions monitored, and shift duration.

Key Assumptions

- Ground time between sorties is not modeled
- Cannot make up any mission deviation time during the mission
- Resources are pooled by desk groups for
- reduced manpower models
- Airlift DO and MOG resources doubled to model multi-tasking
- Only DDO interactions with DOs are modeled

Validation and Verification

- Process flow reviewed with operations floor personnel
- Review of model outputs with historical data

Desk	Percent of Missions (Historical)	Percent of Missions (Model)
DO 1 Desk	17%	16%
DO 2 Desk	12%	13%
DO 3 Desk	12%	13%
DO 4 Desk	29%	27%
DO 5 Desk	5%	5%
DO 6 Desk	6%	6%
TDD Desk	19%	20%

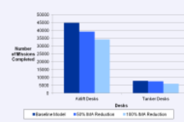
Simulation Model

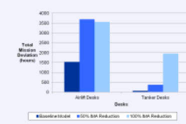
Run Time: 445 Days (365 days + 80 day warm up)
Replications: 20

Initial Analysis

- Investigate current system at current manpower level, 50% IMA reduction, and 100% IMA reduction
- Resource pools are implemented in reduced manpower models

Desk Group	Resource	Base Model	50% IMA Reduction	100% IMA Reduction
Airlift DO Desks	DO1 Desk	100%	92.70%	99.99%
	DO2 Desk	96.69%	92.70%	99.99%
	DO3 Desk	67.08%	92.70%	99.99%
	DO4 Desk	100%	92.70%	99.99%
Airlift DDO Desks	DDO1 Desk	58.58%	85.07%	99.99%
	DDO2 Desk	50.06%	85.07%	99.99%
Tanker Desks	DO5 Desk	73.15%	95.97%	100%
	DO6 Desk	94.97%	95.97%	100%
	DDO3 Desk	30.22%	95.97%	100%
	MOG Desk	99.82%	100%	98.94%
	1C3 Desks	99.38%	84.17%	62.32%

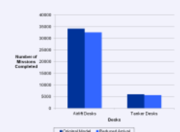




Post Contingency Mission Load Analysis

- 100% IMA Reduction – number of missions monitored decreased 10%

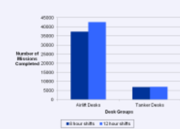
Desk Group	Resource	Original Arrival	Reduced Arrival
Airlift DO Desks	DO1 Desk	99.99%	99.99%
	DO2 Desk	99.99%	99.99%
	DO3 Desk	99.99%	99.99%
	DO4 Desk	99.99%	99.99%
Airlift DDO Desks	DDO1 Desk	99.99%	99.99%
	DDO2 Desk	99.99%	99.99%
Tanker Desks	DO5 Desk	100%	100%
	DO6 Desk	100%	100%
	DDO3 Desk	100%	100%
	MOG Desk	98.94%	98.29%
	1C3 Desks	62.32%	61.47%



Increased Shift Duration Analysis

- 50% IMA Reduction Model – 10% decreased number of missions, shifts increased from 8 hrs to 12 hrs (15 shifts per month)

Desk Group	Resource	8 hour shifts	12 hour shifts
Airlift DO Desks	DO1 Desk	90.35%	85.99%
	DO2 Desk	90.35%	85.99%
	DO3 Desk	90.35%	85.99%
	DO4 Desk	90.35%	85.99%
Airlift DDO Desks	DDO1 Desk	80.48%	70.02%
	DDO2 Desk	80.48%	70.02%
Tanker Desks	DO5 Desk	88.78%	60.12%
	DO6 Desk	88.78%	60.12%
	DDO3 Desk	88.78%	60.12%
	MOG Desk	100%	100%
	1C3 Desks	81.38%	95.43%



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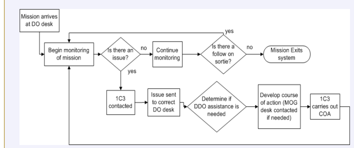
Operations Floor Process Flow



Personnel Resources Modeled

Manpower breakdown Jan 2012 (AD, IMA, Required Personnel)

Each person works 15 shifts per month, Shift duration 8 hours (Base Model, 50% IMA Reduction, 100% IMA Reduction)

Resource	AD	IMA	Required Personnel	Base Model	50% IMA Reduction	100% IMA Reduction
DDO(1-2)	1	11.4	13	12	7.8 → 8	3.6 → 4
DO (1-4)	11	15.6	26	24	15.6 → 17	7.2 → 8
Tanker(DO 5,6 DDO 3)	7	11	19.5	18	11.7 → 12	5.4 → 6
MOG	3	9	11.4	12	7.8 → 9	3.6 → 4
Total	22	47	69.9	66	42.9 → 46	19.8 → 22

Rounded up to next integer

Conclusions

- Research clearly demonstrates potential negative impacts to the TACC operations floor with anticipated manpower reductions
- Resource pools are one method of handling a manpower reduction
- Increasing shift duration combined with the resource pools indicated that fewer resources can accomplish more tasks

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14. ABSTRACT
The Tanker Airlift Control Center (TACC) operates as the execution arm for Air Mobility Command's Global Reach mission. The Command and Control Directorate (XOC) monitors the execution of missions tasked to the 18th Air Force. Approximately 70% of the personnel on the operations floor are considered Individual Mobility Augmentees (IMA). Adjustments in manpower, specifically the loss of IMAs, at the TACC/XOCG may impact their responsiveness to mission deviations. This research develops a discrete event simulation using a combination of SME and historical data to capture the activities of a section of the personnel on the operations floor and the potential impact of a reduction in manpower. Our analysis shows a statistically significant reduction in the number of missions completed along with a statistically significant increase in the total mission deviation time with both levels of manpower reductions examined. For the two specific levels of manpower losses, we implement the concept of resource pools to complete tasks for a group of mission desks instead of specific personnel assigned to each desk. We also examine whether our reduced manning models can adequately handle the anticipated reduced post contingency operation mission load and identify that longer duration shifts make noticeable improvements.

15. SUBJECT TERMS
Discrete Event Simulation, Manpower Reduction, Tanker Airlift Control Center (TACC), Command and Control Directorate (XOC), Operations Floor

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