RESTRUCTURING DEPOT MAINTENANCE

OCCUPATIONAL SERIES TO IMPROVE FLEXIBILITY

GRADUATE RESEARCH PROJECT

Andrew J. Levien, Major, USAF

AFIT/ILS/ENS/10J-03

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/ILS/ENS/10J-03

RESTRUCTURING DEPOT MAINTENANCE OCCUPATIONAL SERIES TO IMPROVE FLEXIBILITY

GRADUATE RESEARCH PROJECT

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

Andrew J. Levien, MS

Major, USAF

June 2010

AFIT/ILS/ENS/10J-03

RESTRUCTURING DEPOT MAINTENANCE OCCUPATIONAL SERIES TO IMPROVE FLEXIBILITY

Andrew J. Levien, MS
Major, USAF

Approved:

______// signed //________________________ ____17 May 10___
Dr. Timothy Pettit, Lt Col, USAF (Advisor) date

______// signed //_______________________ ____17 May 10___
Dr. Alan Johnson (Reader) date

AFIT/ILS/ENS/10J-03

Abstract

This research addresses Air Force Material Command's desire to develop a flexible depot workforce to meet the demands of maintaining an ever-changing and aging aircraft fleet. Air Force depot maintenance personnel are currently (and have been for quite some time) categorized in very narrow occupational specialties, resulting in the approximately 23,000 personnel to be spread over 171 different occupational specialties. Much of the depot work maintenance workload has decreased in volume but increased in velocity, thereby demanding a more flexible workforce that can perform skills from multiple occupational specialties in support of Lean strategies for production.

This study provides a comprehensive analysis into the potential strategies and ways ahead to best synchronize occupational series use in a transitional environment. This research addresses several questions: (1) what experimental and analytical models exist or can be created to determine if occupational series should be combined; (2) what series should be combined or created anew; and (3) how are series combined correctly to retain critical knowledge and promote product quality. A methodology is developed that can be applied to any production work environment to see the effects on production time as a result of cross-training.

Acknowledgments

I would like to express my sincere appreciation to my faculty advisors, Lt Col Timothy Pettit and Dr. Alan Johnson, for their guidance and support throughout the course of this graduate research effort. The insight and experience was certainly appreciated. I would, also, like to thank sponsor, Mr. Steve McBride, from the Air Force Materiel Command for both the support and latitude provided to me in this endeavor.

I am, also, indebted to the many maintenance professionals who spent their valuable time explaining the processes and procedures they use in the KC-135 depot production lines at Tinker AFB. Special thanks goes to Mr. Craig Rayner who served as my liaison and was always available to answer my questions.

Andrew J. Levien

Table of Contents

Page

List of Figures

Page

List of Tables

Page

RESTRUCTURING DEPOT MAINTENANCE OCCUPATIONAL SERIES TO IMPROVE FLEXIBILITY

I. Introduction

Background and Motivation

"Between 1987 and 2002, the Department of Defense (DOD) downsized the civilian workforce in 27 key industrial facilities by about 56 percent" (U.S. Government Accountability Office, 2003). This U.S. Government Accountability Office (GAO) report, *DOD Civilian Personnel: Improved Strategic Planning Needed to Help Ensure Viability of DOD's Civilian Industrial Workforce*, required the services to develop a strategic workforce plan to ensure they were meeting the needs of the workforce and mission requirements even though these cuts were so dramatic. One of the clear concerns of the GAO is the viability of the depots. Several of their tasks were outsourced, yet, by law they are still required to retain at least 50% of depot maintenance funds to be spent for public sector performance—in other words, all depot maintenance cannot be all contracted out; however, they still must prove depot viability. The report also states three challenges that are affecting the services ability to create a successful plan to ensure the viability of the depots—high retirement eligibility in next 5 to 7 years, difficulty implementing multi-skilling, and increased training funding to re-vitalize workforce. This research project focuses on one of those challenges--"the services are having difficulty implementing multi-skilling—an industry and government best practice for improving the flexibility and productivity of the workforce—even though this technique could help depot planners do more with fewer employees" (U.S. Government Accountability Office, 2003). To reduce the number of employees, depots need to either reduce unnecessary/unused job series or combine job series (cross-train) to enable employees to perform multiple tasks. This research focuses on the combining of job series—i.e. creating a more flexible workforce. Workforce flexibility is defined as the ability of the workforce to adjust to accomplish new or different tasks as the demand for tasks change.

In 2007-2008, the Air Force consolidated certain maintenance Air Force Specialty Codes (AFSC) in an effort to posture those career fields to support future generation aircraft technologies and maintenance concepts while developing a more flexible and efficient workforce to accommodate the Department of Defense Program Budget Decision 720 manpower cuts. AFSCs for military personnel are similar to job series for civilian personnel. The decision to cut manpower and consolidate certain AFSCs made it clear that that Air Force leadership was seeking to ensure the maintenance workforce is properly trained and utilized by combining career fields that are similar and/or may not be fully utilized. At the field level, maintenance personnel are consistently asked to perform tasks that are not in their "normal" career field because leaders realize the value of flexibility.

Visits to civilian industry partners by AFMC/A4 personnel have indicated that civilian organization's workforce is very streamlined. Additionally, from a tour of a Harley Davidson Motorcycle assembly plant, it was discovered that they create very flexible workforce teams. They have much fewer specialties and train their workers on multiple tasks while still producing a quality product.

Air Force depot maintenance personnel are currently (and have been for quite some time) been categorized in very narrow occupational specialties, resulting in the approximately 23,000 personnel to be spread over 171 different occupational specialties. Much of the depot work maintenance workload has decreased in volume but increased in velocity, thereby demanding a more flexible workforce that can perform skills from multiple occupational specialties in support of Lean strategies for production.

However, the Air Force must also take into account the potential loss of knowledge—i.e. the loss of depth to create breadth—and the expense to gain the breadth—i.e. the cost of training the workforce in the new tasks. Several articles touch on this topic and are discussed at length in the literature review.

Research Objectives, Questions, and Hypotheses

This study provides a comprehensive analysis into the potential strategies and ways ahead to best synchronize occupational series use in a transitional environment. This research will address several questions: (1) what experimental and analytical models exist or can be created to determine if occupational series should be combined; (2) what series should be combined or created anew; and (3) how are series combined correctly to retain critical knowledge and promote product quality. Question 1 is addressed through a thorough literature review. Question 2 is addressed by gathering data on the KC-135 programmed depot maintenance (PDM) process at Tinker AFB and using that data in a derived model to calculate cross-training production gains and costs. Question 3 is addressed through the literature review and through data gathered from personnel in the

KC-135 production line. The third question is a source for further research because this paper only touches the surface of this topic. The key objective is to create an optimally balanced and flexible workforce to meet the changing demands of the depot production lines—a workforce that can meet and/or exceed the production goals of depot. The hypothesis of this research is that combining certain occupational series will create a more flexible workforce, thus enabling the Air Logistics Centers (ALCs) to improve their current production goals.

Assumptions

Assumption 1: The research clearly identified who the subject matter expert (SME) is for the job series of interest and they provided an accurate opinion about the possible consolidations. If a SME is influenced in his/her decision due to Union pressures, desire not to cross-train, or any other reason, then the results might be skewed.

Assumption 2: The developed model assumes that each task is independent of each other. For example, the length of time to complete one operation has no bearing on the time to complete another operation. This is most likely not true, but it is an assumption that needed to be made to get distributions for each operation. With enough data, this assumption can be overcome.

Assumption 3: Although the literature review lists a couple of references about how long tasks take for a specialist versus a cross-trained worker, no hard data exists. Therefore, an assumption was made that the task would take 20% longer by a cross-trained worker. However, in Chapter 4, a sensitivity analysis was performed to determine the effect of choosing 20% versus a higher or lower factor.

Limitations

Limitation 1: Modeling every task in the sample process (KC-135 depot) would require months of full-time data gathering and effort. Therefore, only a sampling of the tasks were analyzed to test the methodology. To get a 100% accurate picture of the results of cross-training on the production time, all tasks would need to be mapped.

Limitation 2: Only two experts were consulted about the complexity of the KC-135 depot process. In order to get a real consensus on the complexity, one would need to survey many workers and managers involved in the process to have a better grasp of the real effect of cross-training.

Implications

This project will have a definite impact on the way ALCs are organized and maybe even how future civilian consolidation efforts are undertaken. While the model developed is specific to the KC-135 PDM process, the methodology used to develop that model is generic and can be used to ascertain the usefulness of cross-training in any production-type environment. It allows managers to see the effect of cross-training on actual production efforts.

II. Literature Review

Research questions one and three depend heavily on interpreting the literature on past research. To address these questions, this literature review focused on three main areas: (1) past/current cross training efforts in a military environment; (2) studies about the optimal workforce composition and the differences between specialists and generalists; and (3) monetary cost of cross-training. The first area, cross-training in a military environment does not specifically address the stated research questions, but it puts this paper into the proper context. In order to determine the usefulness of this research at an Air Force maintenance facility, it is important to understand if and how the military has developed a more flexible workforce in the past. The next three sections directly answer question 1 (what experimental and analytical models exist or can be created to determine if occupational series should be combined) and question 3 (how are series combined correctly to retain critical knowledge and promote product quality). The primary theory of this research is that a more flexible workforce gives an organization a roadmap for success and the next four sections clearly identify past research on this topic.

Cross-Training in a Military Environment

Cross-training has been common-place in the military for many years. The decisions as to which career fields to combine has not always been made public and it seems that Air Force leadership has consolidated based on anecdotal information versus actual data. One recent study, by Ken Marentette titled "An Objective Decision Tool for Use in Considering AFSC Pairs Consolidations" (2008) did attempt to develop a mathematical model to select which AFSC pairs make sense to think about combining. The model takes into account Subject Matter Experts (SME) opinion of the similarity of their career fields in terms of their everyday job and in terms of the training those career fields undergo as the main contributing factors. The model also takes into account the training time of each AFSC. A key parameter they use is the workload savings coefficient. This coefficient is the “potential efficiencies gained as a result of consolidation, given as a percentage of original manpower levels.” (p. 16) His research uses a coefficient of 8.5% based on previous research that was cited in the paper. This positive coefficient assumes that the work force becomes more efficient as organizations cross-train. While this may be true from a macro scale, it doesn’t take into account the actual time it takes to complete tasks. It assumes that there was some “dead time” in certain career fields and by cross-training, that “dead time” is now productive time. His study looks at the AFSC consolidation from a macro level, instead of at a task or operation level. However, his research “removes a significant portion of subjectivity from the AFSC consolidation process,” (2009) which is the primary goal of this research paper.

Another study conducted by Paskin and Treviño (2007) modeled the KC-135 PDM flight controls repair cell in an effort to find ways to improve the efficiency in the process. This research appeared to be geared towards Value Stream Mapping the process and looking for areas for improvement, however, in the process, they identified that one of the major areas for improvement was actual consolidation of tasks. Some of the tasks that were being completed by one specialty should be moved to another specialist. In other words, cross-training should occur to reduce the downtime for certain specialists. The model used a software package that was developed by other researchers and if put in the hands of the right people could probably be used to map any process and show ways to improve process flow. The results of Paskin and Trevino's research do not appear to have been implemented or acted upon. This may be because of the complexity of the unknown nature of the software used. A key take-away from this research is how their model accounted for the task completion time of specialists versus generalists. They do not specifically state what numbers they used to account for this because the model has it built in based on the skill level of the technician selected to complete the task. However, they do say that they lowered the skill level from high to medium when they cross-trained a technician on a low-skill task. Their model attempts to demonstrate the steady state of the learning curve of the employees and hence tasks do take longer when completed by generalists instead of specialists.

Determining the Optimal Workforce Composition

Several articles discussed the benefit/cost trade-offs of using a specialist versus cross-trained workers. One premise is that if organizations are too flexible, they may lose the depth of knowledge that comes with specialization. If organizations are too specialized, they may not be flexible enough to meet the customer's needs. This is described in a model that Chakravarthy and Agnihothri (2005) developed for an organization that provides services to two types of customers to answer the question of what is best, total flexibility, total specialization, or some combination. Their model is supposed to allow managers to make decisions about cross-training. They try to describe the optimal workforce balance between specialists and generalists in a service-type industry—but it could be applied elsewhere. They understand that both flexibility and specialization come with a cost. One of their conclusions is that service organizations can't have all flexible servers—some level of expertise needs to be maintained by some.

The right percentage of flexible servers (or workers) is depended on the efficiency of a flexible server versus a dedicated server. According to Figure 1, as the efficiency level of a flexible server goes down, the percentage of an organizations workforce that should cross-train also goes down. If a flexible person is just a flexible (100% or E = 1) as a dedicated server, then system efficiencies will be gained by cross-training them. It is key to find that balance to determine how many to cross-train.

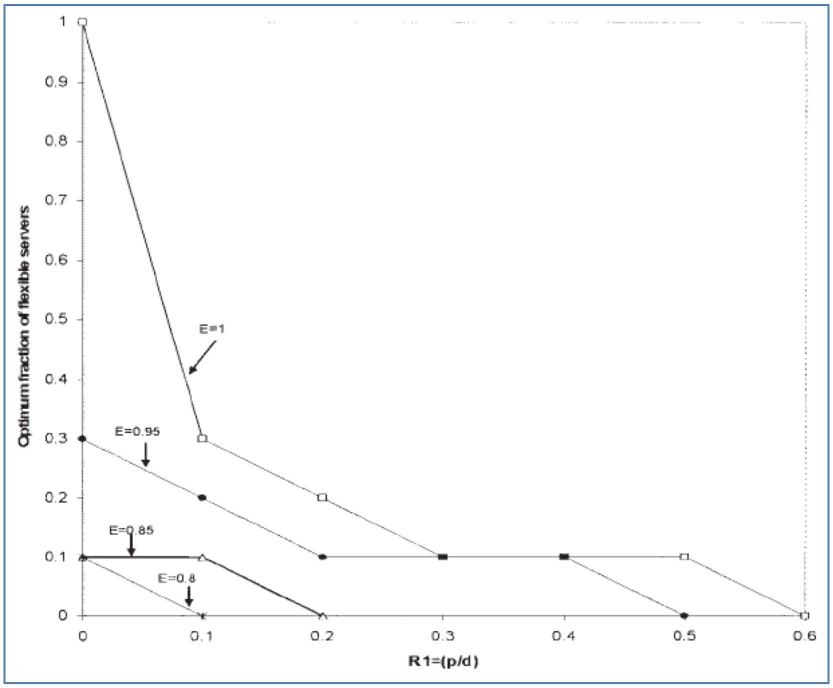


Figure 1: Optimal Fraction of Flexible Servers (Chakravarthy & Agnihothri, 2005)

A study by Molleman and Slomp (1999) takes a team of workers who perform in a certain work center and looks at the task they perform. It looks at what is the optimal mix of multi-functionality and redundancy. They developed a model to study how three factors, multi-functionality, redundancy, and work efficiency, will affect team performance when absenteeism and product demand vary. Their study has a direct correlation to aircraft maintenance organizations. Multi-functionality is the number of different tasks one worker has mastered and redundancy is the number of workers that are qualified to perform a specific task. They also take into account work efficiency—how efficient is a worker at a particular task. They study how these three factors will affect team performance when absenteeism and product demand vary. They conclude that each task should be mastered by at least 2 workers and the more uniform the distribution of multi-functionality the better the team performance. In the conclusion when they try to justify their validity, they discuss some other research on the Social Comparison Theory—this theory states that workers on teams prefer complementary jobs, not the same jobs. Team members expect that this will enhance their own identity as well as the group performance. They really look at cross-training from a team perspective. A team of employees should have experts on each task, but everybody should be "trained" on all tasks. This concept of a cross-trained team is another way to look at trying to improve the efficiency of an organization.

Question 3—how do we ensure we don't lose the depth of knowledge of experts when we cross-train—is directly addressed by McCreery and Krajewski, in "Improving Performance Using Workforce Flexibility in an Assembly Environment with Learning and Forgetting Effects" (1999). They use a simulation model of an assembly line and an experimental design that incorporated product variety and task complexity; they show that as task complexity increases, cross-training should be kept low, but as product variety increases, cross training should be increased. It talks about what is the right balance (Figure 2).

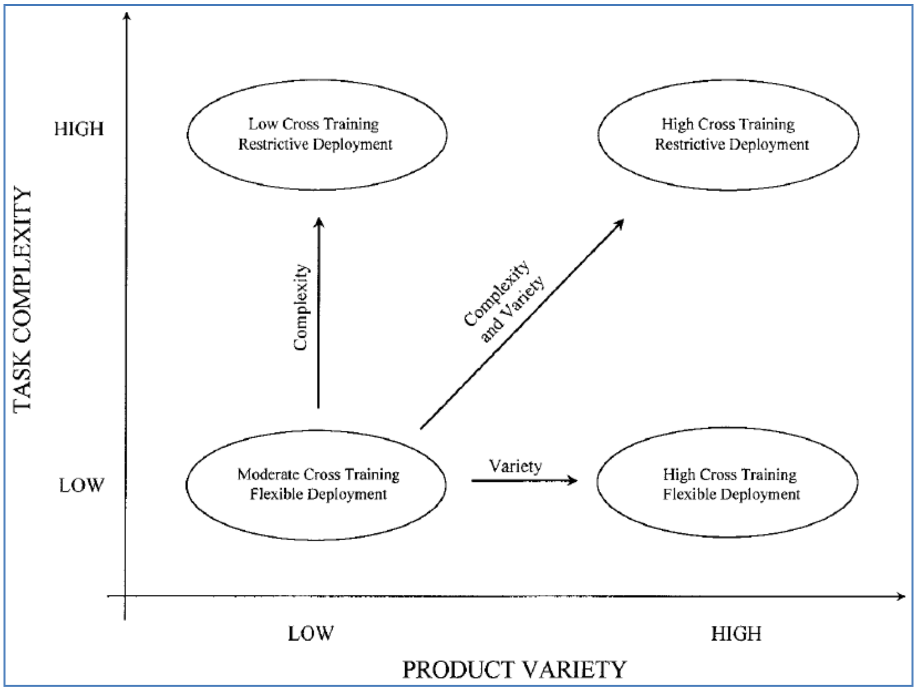


Figure 2: Cross Training Employment Matrix (McCreery & Krajewski, 1999)

Their article also addresses the difficult topic of how much longer it takes for cross-trained versus specialist workers to complete tasks. "In discussions with manufacturers, we have found task time variations of 10% to 20% to be representative of their product lines." (p. 2039) In other words, a cross-trained worker takes 10-20% longer than a specialist worker to complete the task at hand.

Pinker and Shumsky (The Effeciency-Quality Trade-off of Cross Trained Workers, 2000) note the difference in quality of service will vary between specialists and generalists. A good example is in the medical world—delivering a baby. An emergency room doctor may not be very good at delivering babies because he/she does it once in a long while, while an OB/GYN doctor will be much better because he/she does it all the time. There can be a trade-off in quality if organizations cross-train the wrong skill set.

Several skills are experience driven, not necessarily just training driven. As organizations cross-train more of their workforce, the quality of their work goes down (Figure 3). The key is finding the balance of quality with the profit of the organization.

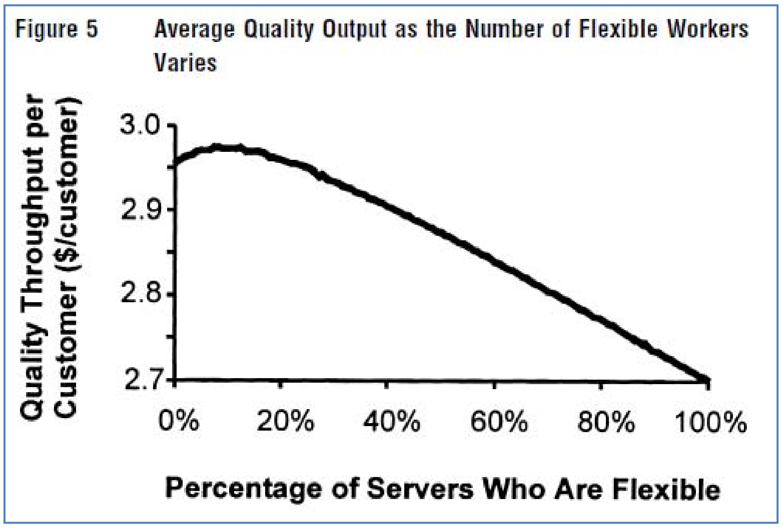


Figure 3: Average Quality Output of Flexible Workers (Pinker & Shumsky, 2000)

There are at least a dozen other articles about this topic, but they all state the same things: cross-training creates flexibility, but with a cost. They attempt to create models that capture that cost, so decision makers can balance the projected benefits with the estimated costs.

Dietz and Rosenshine (Optimal Specialization of a Maintenance Workforce, 1997) use an analytical (vs. simulation modeling) approach to gain insight into the creating an optimal specialization strategy. Their optimization method explicitly recognizes the economic tradeoff between lower per-person costs and the lower average utilization resulting from specialization. They devised a list of maintenance specialties that were created out of a combination of certain tasks. They have the aggregate annual costs for each specialty which includes direct training costs, opportunity costs of increased training time, and pay. They assume that the annual cost of a maintenance technician with a full range of skills is roughly 50% more than that of a typical technician with a highly specialized skill. Then, if they have a maximum annual manpower budget and a workflow chart that shows which tasks must be completed in what order, they calculate the specialty mix that meets their financial and production goals. It all reads well, but it is very hard to see how this can be applied to anything other than their simple example. A researcher would need to create a completely new analysis for each maintenance environment. This article does point out additional data that needs to be gathered: (1) Cost of training a person in a new task; (2) Change in salary if a person learns/performs more tasks; (3) Number of tasks a person currently performs and how much "free" time they have to perform new tasks if trained; (4) Are their tasks waiting to be done because no one who is trained to do them is available to do them? I.e. is there a bottleneck?; and (5) How much productivity time is lost when a generalist is doing a task versus a specialist? I.e. does a person doing their secondary task do it 90% as fast as a specialist?

Cost savings may be realized even if the "generalist" is 50% slower/less productive than the "specialist" according to Brusco and Johns (Staffing a Multi-Skilled Workforce with Varying Levels of Productivity: An Analysis of Cross-Training Policies, 1998). They present an integer linear programming model for evaluating cross-training configurations at the policy level. The data was collected from a large paper mill in the United States and is based on a single-shift operation. The results indicate that asymmetric cross-training structures that permit chaining of employee skill classes across work activity categories are particularly useful. The study examines the importance of cross-training as a source of workforce flexibility. They define productivity as the efficiency of an employee working in a specific activity category. Productivity can range from 0 to 100%. They define a cross-training structure as a policy that governs the number of work activity categories for which employees are cross-trained, the level of productivity for cross-training, and the framework for deciding which skill classes are trained for various work activity categories. They state that increased flexibility makes it more difficult to determine the number of employees in each skill class and subsequently more difficult to estimate the benefits of additional cross training. With increased cross-training it makes it difficult to determine the differences between specialties anymore and therefore organizations don't know if they need more of a certain specialty or just more people that are cross-trained across more than one specialty…therefore, organizations should eliminate the narrow specialties in their organizations and create new "job series" that encompass all the tasks they should accomplish. Their results indicated that a service delivery system may realize a large portion of available cost savings by cross-training employees in work activity categories even if the nature of the work in these categories precludes cross-training at 100% productivity. They conclude that cross-training has benefits even if the new "generalist" is not as productive as the "specialist" at a task.

Cost of Cross Training

The literature on the actual monetary cost of cross-training seems lacking. Nembhard (A Real Options Model for Worforce Cross-Training, 2005) discusses how the real options approach can be used to mathematically calculate the costs of cross training.

The real options approach is the extension of financial option theory to options on real (i.e. non-financial) assets. He attempted to calculate the NPV (net present value) of the future benefits/costs associated with cross-training personnel. If the NPV is positive, then cross-training should be done. If it is negative, then cross-training would not be a wise decision. The research model is extremely technical and it might be hard to duplicate due to the number of assumptions that make his model work.

Summary of Literature

Significant research appears to have been done on the effect of cross-training and trying to utilize cross-training to increase the efficiency of organizations. The literature can be grouped in two distinct ways: (1) the theoretical results of cross-training and (2) mathematical calculations about the effect on production of the cross-training decision. The first group of literature keys on past research and opinions of the effect of cross-training. Because it is so theoretical in nature, it fails to provide direct guidance for managers to follow but does given them some information to ponder when making the decisions to cross-train or not. The second group of literature, the math models, appears to be very complex, but even more noteworthy, fairly specific to a specific industry, process, or operations. They don't appear to be able to be applied easily to other areas that a practitioner may be interested in. Therefore, this literature review provides a starting point for the methodology development and some basic guidelines for determining the benefits and costs of cross-training in this research paper.

III. Methodology

The goal of this project was to design a model that could be used for multiple applications to help leaders determine which career fields can be combined to improve workforce flexibility. However, after a thorough literature review, it became clear that developing a model that fits all environments is not practical. Therefore, this research develops a methodology, instead of a specific model, that can be applied to numerous work centers. This methodology is based on task completion so it is applicable to most manufacturing or process oriented work centers.

The methodology developed has 8 basic steps:

1) Create an ordered list of all operations/tasks that are completed in the work center. It must note which tasks can be done in parallel and which are sequential.

2) Based on historical data, determine the distribution of the length of time for each task (this research used Rockwell's Arena Input Analyzer to determine the best fit distribution), the number of people required to perform the task, and the occupational series required to perform the task.

3) Develop a list of resources available to the work center. Specifically, gather data about the current number of personnel in the work center and what their occupational series is.

4) Get input from work center employees and supervisors about the following

    a. How difficult is the task to accomplish on a scale of 1-5 (5 being the most difficult)?

    b. How difficult would it be to train a technician of a different career field, but in the same work center to perform the task on a scale of 1-5 (a 1 means they just have to be trained once or twice and a 5 means they must be trained 5 or more times)?

5) Create a discrete-event simulation Model that sequences all operations in the system.

    a. First create the model to mirror how the work center functions now.

b. Then modify it by allowing other occupational series to perform the tasks that were noted to be less difficult to perform and not difficult to train others on; however, modify the time to complete the task by 20% (this is an assumption because no data was gathered to confirm this diagnosis and no firm literature was found to give a good estimate; some research did use 10-20%).

6) Compare the simulations for time to complete the work center functions.

7) Compute the costs of cross-training (it will be the difficult to train number, multiplied by the length of time it takes to do the task, multiplied by 2 (the trainers and trainees time).

8) Decide whether the cost of cross-training is worth the change in work completion time. Also take into account subjective factors such a quality loss before making the decision to cross-train or not.

Step 4 above is similar to what Marentette's (2008) study did—SME's opinions were gathered. One difference is that this research gathered opinions on specific tasks, not on an overall career field. This distinction allowed calculations on the actual affect of cross-training on task completion.

This methodology is geared towards modeling each task as they occur as opposed to grouping some tasks together. Grouping the tasks into major jobs and modeling those major jobs can be advantageous. It aggregates tasks together to eliminate some variations that may occur from task to task, it keeps entities that pass through the model together removing the assumption that the tasks are independent, and it simplifies the model making it easy to follow. However, the major problem with grouping is the assignment of resources. If resources (primarily people) are shared among the different groups, some of the groups may consume the resources the entire time and never release them to the other groups. Grouping is not the best method when trying to measure the affect of cross-training in a production environment.

IV. Results and Analysis

Analysis Overview

To test the methodology, the KC-135 depot maintenance line at Tinker AFB was used as a test case. However, a couple disclaimers must be made. After selecting the KC-135 line and visiting the location, it was discovered that they already cross-trained their maintenance personnel to their fullest extent. The goal of this research was to try to find ways to reduce the occupational series within AFMC, but the KC-135 line only had 5 aircraft maintenance related occupational series: 2610—Electronic Integrated Systems Mechanic, 2892—Aircraft Electrician, 3806—Sheet Metal Mechanic, 8801—Miscellaneous Aircraft Overhaul, and 8852—Aircraft Mechanic. The 2610s, 2892s, and 3806s are fairly specialized skills so cross-training others on their tasks might be more difficult. The 8801s are just supervisors (WS 14, 15, and 16s). The 8852s are the most "generic" of the occupational series and it was discovered that the KC-135 line already used them on many cross-training tasks. (See Appendix A for the complete list of their current workforce) They actually have over 430 8852s, but within that occupational series, they are sub-assigned a specific specialty. These specific specialties are: AA—Aircraft, 1A—Engines, AH—Hydraulics, BA—Rigging, AG—Fuels, and 7H—Gear. As can be seen, within the occupational series, they have specialized significantly—they pulled "easier, more routine" tasks from the specific occupational series (like Engines, Hydraulics, etc) and made them part of the 8852s task. For the purposes of this research, the specific specialties (Gear and Hydraulics—the only two 8852s that are employed on the modeled tasks) were separated and treated like different specialties and then studied for potential cross-training. However, any cross-training between these skill sets will

NOT reduce the number of occupational series (they all are already one series—8852). This major job also utilized AS—sheet metal (OS 3806) employees, so these three specialties (gear, hydraulics, and sheet-metal) were studied for potential cross-training. However, this process will help prove or disprove the model. As a side note, it was also discovered that the other aircraft production lines at Tinker AFB operate this way. Therefore, although this research may show ways to cross-train, there may not be any gains towards reducing the number of occupational series.

Overview of KC-135 PDM Process

The KC-135 PDM is conducted by the 564th Aircraft Maintenance Squadron (AMXS) at Tinker AFB, OK. The 1221 personnel in the 564 AMXS are responsible for maintaining safe and mission capable aircraft and performing engineering analysis for future repairs. PDM is a periodic inspection and repair process that is required on all 408 KC-135 aircraft every 60 months. In FY09, they inspected and repaired 48 aircraft and they have 54 scheduled in FY10. They average 28 aircraft in work at any one time and they are currently averaging around 201 days per aircraft, although their production flow is built on a 167 day flow.

In Jan 09, the KC-135 implemented a new concept of operations called the staggered line concept (Figure 4). This concept separated the primary maintenance activities into two distinct processes—a speedy line and an extended line. To accomplish this, several tasks were added to the Inspection Dock (IDOCK) process to determine which process the aircraft would enter. It also added the complete gear removal, inspection, and re-installation to the IDOCK process to enable the aircraft to be moved during the speedy or extended line process. As seen in Figure 5, there are only three doors into building 3001 (between spots 5 and 6 and in front of spots 1 and 12). This means aircraft need to be moved for others to enter or exit; hence, it is important that the gears be installed on the aircraft throughout these two processes. The overall process is as follows:

1) Aircraft arrival
2) Pre-dock (paint strip, wash, etc)
3) IDOCK
4) Speedy or Extended Flow Line
5) Systems Checks
6) Post Dock
7) Aircraft Departs

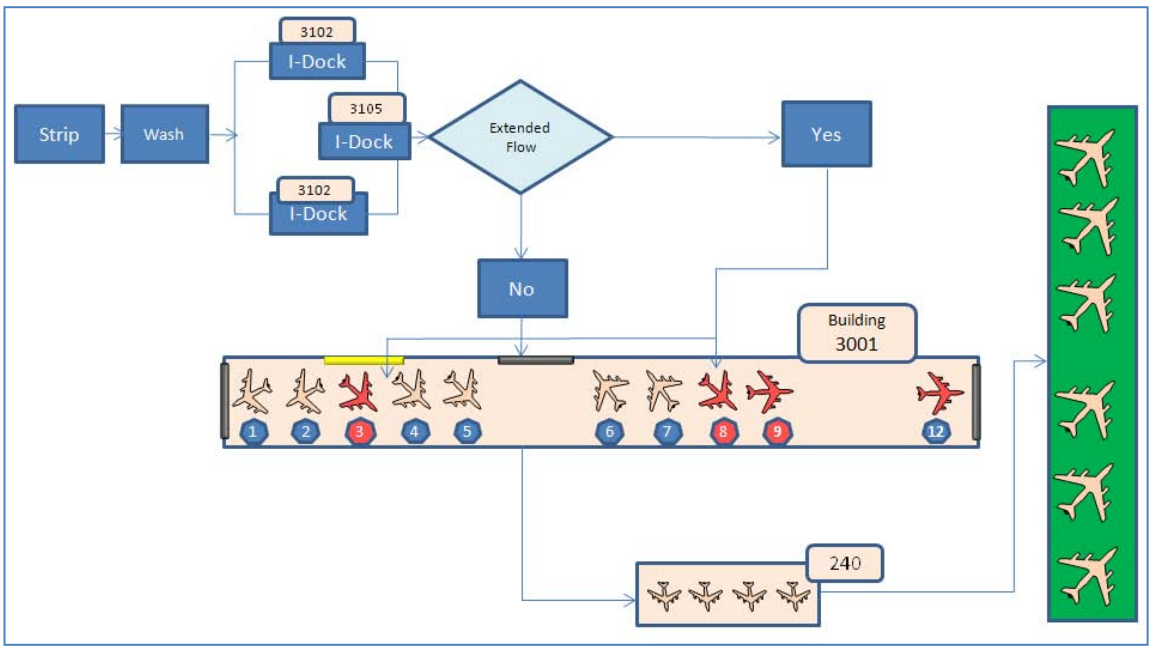


Figure 4: KC-135 Staggered Line Concept

This research focused on the IDOCK process because that is where the current bottleneck of the process is located. IDOCK has an average queue time (wait time) of 27 days from when the aircraft leaves pre-dock and IDOCK starts. This is due to the length of time an aircraft is spending in IDOCK. IDOCK consists of seven major jobs (Figure 5):

1) BC—Rewire
2) BB—Inspections
3) BE—Trunnion Bolts/Shear Pins
4) BA—Jack to Jig/Remove Gear/Shore
5) BD—Milk Bottles
6) BF—820 Bolts Remove and Replace
7) BG—Install Gear/Down Jack/Mask Off

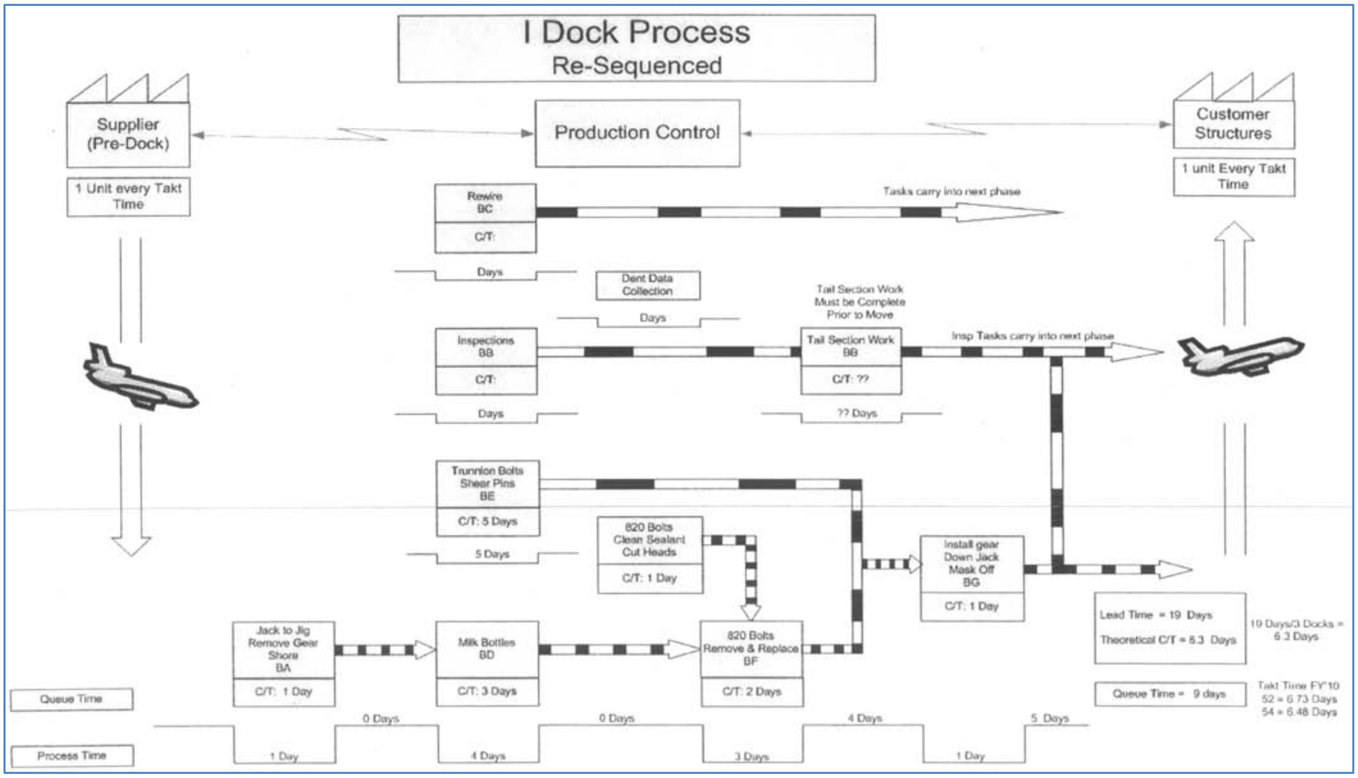


Figure 5: KC-135 IDOCK Process

As seen in the IDOCK process map (Figure 5), some of these major jobs can be done simultaneously, while others are done in series. This research narrowed in on major job BA, but future research could address the entire IDOCK process.

Step 1: Ordered List of Tasks

Step 1 of the methodology was to create an ordered list of all operations and tasks (Figure 6). This was gathered from the historical data from the Programmed Depot Maintenance Scheduling System (PDMSS). This data contained the following information:

1) Tail number
2) Major job ID (a major job consists of many operations)
3) Operation ID (a operation is a specific task or job that must be completed)
4) Type of operation
5) Type of mechanic required (what specialty)
6) Work Unit Code
7) Number of mechanics required
8) The standard time to complete the operation
9) The actual time the mechanic recorded for operation completion
10) The data the operation was complete
11) The date the Major Job started
12) The date the Major Job Finished
13) A description of the operation

	A	B	C	D	E	F	G	H	I	J	K	L	
1	TAIL_NR	MAJOR_JOB	SEL_OP_NR_ID	TYPE_OPERATION	SKILL_CD	WUC	WRKR_QY	STD_HR	ACTL_HR	OP_COMPLETE_DT	MAJOR_JOB_START	MAJOR_JOB_FINISH	DESCRIPTION
2	57001427	BA	01144	E	AS	11000	2	0.1	0.1	18-Jun-09	28-Apr-09	15-Aug-09	1B67(J) - JACK/JIG/SHORE - PRI
3													BODY & WING SHORING USED
4													
5													REF 76 AMXG 09-04
6													
7	57001427	BA	01145	E	AS	11000	2	0.1	0.1	18-Jun-09	28-Apr-09	15-Aug-09	1B67(J) - JACK/JIG/SHORE - PRI
8													WOODEN PADS TO BE USED TC
9													
10													REF 76 AMXG 09-04
11													
12													
13	57001427	BA	01146	E	AS	11000	1	0.1	0.1	18-Jun-09	28-Apr-09	15-Aug-09	1B67(J) ツJACK/JIG/SHORE - PRI
14													ENSURE AIRCRAFT IS COMPLET
15													PROPER BALLAST IS INSTALLED

Figure 6: Example Data from PDMSS

Data consisted of all aircraft going through the IDOCK process from 13 Jan 09 to 8 Dec 09. 13 Jan 10 was selected as the start date, because that is when the staggered line concept was implemented in IDOCK, so any data collected before than could not be appropriately compared to the newer data. The data covered 44 aircraft that started, but not necessarily completed, IDOCK. Thirty aircraft were selected to use for the primary data analysis and left the other 14 for distribution validation (Although distribution validation was not completed for this research project). To filter out the 14 for validation, every 4th aircraft was selected and removed from the primary data. Of the 30 remaining aircraft, there were 772 different operations with data. An operation is a task that was performed on the aircraft under a separate task identification number. Several of those 772 tasks were only done on a few aircraft. This was due to several tasks that were unique to a specific aircraft or problem. In order to develop the standard process seen by most aircraft, all operations that occurred on less than 24 of the aircraft were filtered out—this left 113 operations. An interesting side note is that 52 of the 113 operations occurred more than once on an airplane. According to the data analysts at PDM, this must have been a data entry problem. Looking at it further, the data collected on these operations were identical, so the duplicates were ignored.

The tasks then need to be put in order. This was done through observation and based on input from the KC-135 analysts (see Appendix B for order). Several of the tasks were prerequisite for others, but a majority of them could be done in parallel if enough resources (people) were available to perform the task.

Step 2: Distribution of Completion Times of Tasks

The next step was to determine the distributions for the amount of time each of these 58 operations took to complete. The actual completion time data was analyzed using the Input Analyzer function of Rockwell Automation Technologies program, Arena 12.0. A sample of the data is shown in Figure 7.

	A	B	C	D	E	F	G	H
3	Average of ACTL_HR	SEL_OP_NR_ID						
4	TAIL_NR	01144	01145	01146	01147	01148	01158	01165
5	57001427	0.1	0.1	0.1		13.9	17.7	7
6	57001438	0.1	0	0.1	0.3	7.3	16.4	10.1
7	57001454	0.6	0.3	0	2.9	36.9	24	30.3
8	57001459	2.5	7.4	0.1	4.4	14.6	17.1	10.7
9	57001469	0.3	0.3	0.1	2.9	37.9	20.9	13.8
10	58000001	0.1	0.1	0.1	2.1	3.5	24	18.1
11	58000009	0	0	0.1		13.9	7.1	7.2
12	58000018	2.3	4.2	0.1	0	12.2	10.2	3.3
13	58000021	1.1	3	2.3	3	7.4	141.8	16.4
14	58000023	0.3	0.3	0.3	0.9	7	4	1.1
15	58000030	0	0	0	0	0.7	13.8	10.1
16	58000056	0.1	0.1	0.1	0.1	12	9.5	7.1
17	58000062	0.1	1.8	0.2	0	13.1	0.1	11.8
18	58000079	0.1	0.1	0.1	0.1	6.9	11.3	7.2
19	58000083	0.1	0.1	0.5	3.3	12.4	20	10.5
20	59001453	6.2	0.1	0.3		13	12	6
21	59001463	1.8	2	1.5	8	13.4	9.7	9.4
22	59001467	0.1	0	0.1	0.2	13.2	43.3	9.5
23	61000310	0.5	0.5	0.5	0	32.3	25	19.8
24	62003498	1.1	2.1	1.3		10	13.9	10.1
25	62003502	0.1	0.1	0.1	0.1	3.8	9.4	3.7
26	62003528	1	1	1	2	6.3	1	2.1
27	63007984	0.1	0.1	0.1	2.8	4.1	11.1	4.1
28	63007987	0.1	0.1	0	0.1	15.2	16.1	19.3
29	63007999	0.2	0.2	0.2	1.5	12.6	5.4	8
30	63008002	0.6	0.6	0	0.1	8	16.5	8
31	63008008	0.3	0.3	0.1	2	10	29.6	10
32	63008885	15	12	0.1	0.3	26.9	23.9	19.5
33	64014837	0.8	0.8	0.1	4.1	12.5	28.8	18.7

Figure 7: Actual Completion Times from PDMSS

Input analyzer was able to provide the most likely distribution of the data based on the square error, the chi square test p-value, and the Kolmogorov-Smirnov Test p-value. This data proved to be fairly problematic because none of the data clearly followed a clear distribution. As Figure 8 shows, the Chi Square Test p-value was only .0675. Normally, an analyst would like that value to be well above .05. In many of the cases, the p-value was actually less than .05, which can be seen in Figure 9. There are several reasons for these distribution problems. The basic premise of garbage in, garbage out can cause problems—it basically comes down, did the mechanic put the correct data in? The two main causes of this could be: (1) The database only requires mechanics to put a completion time in. Therefore, if they didn't put a start time in, the database will automatically calculate the completion time from the last time that mechanic was logged into the system as at work or when the last task was completed. (2) The mechanics may have documented task completion for several jobs at once, leading them to just put the "standard" completion time into the database or leading the system to assume some tasks took 0 hours to complete.

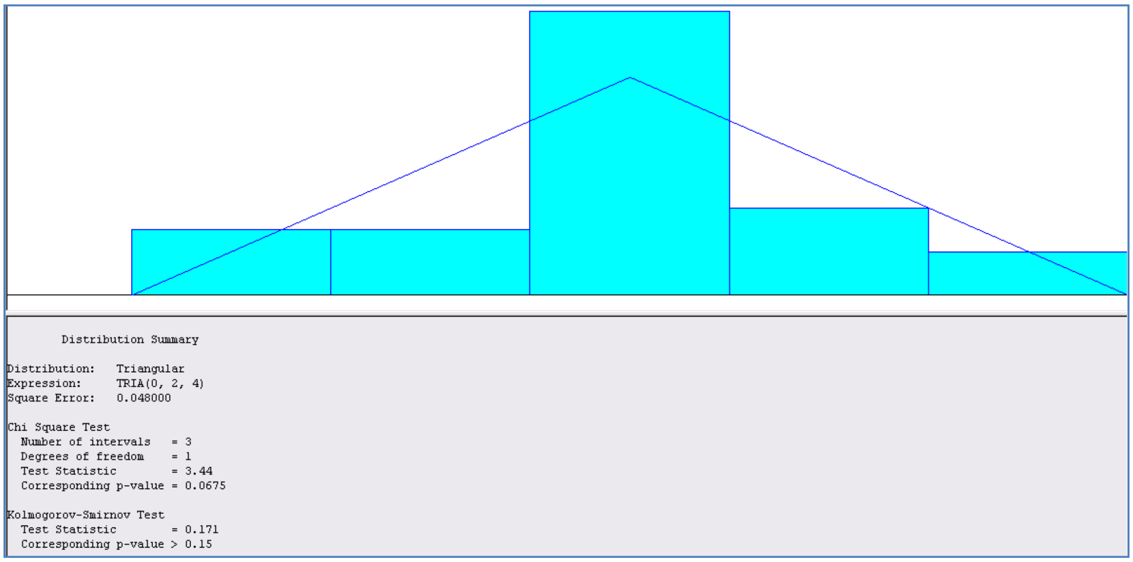


Figure 8: Sample Arena Input Analyzer Histogram

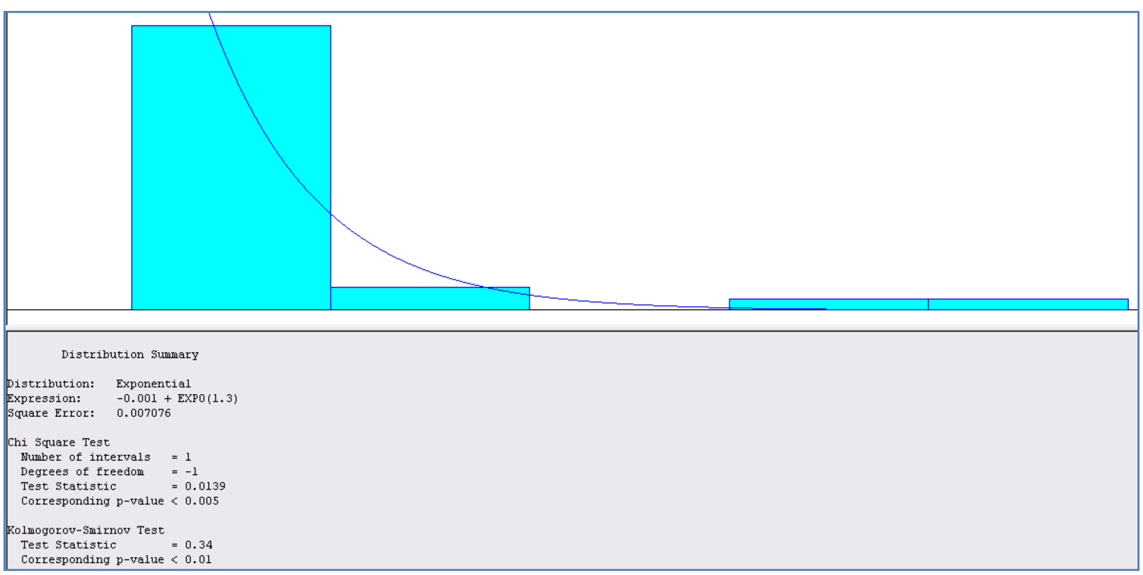


Figure 9: Sample Arena Input Analyzer Histogram

These reasons can explain some of the outliers and some of the reasons a majority of the actual times are exactly the same as the standard time. This was particularly true with tasks whose standard time was less than 15 minutes. Over 50% of the recorded completion times were exactly the standard. Additionally, some of the data indicated that there might be two different distributions for the same data set—in other words, it peaked at a certain value then had another peak at higher values. This could be caused by a unique problem on a specific airplane, a seasonal issue, or a problem in the workplace at a particular time. This particular problem should be looked at more in the future. To deal with the first two problems (outliers and zeros), all zeros and some outliers that were more than 4 standard deviations away from the mean were removed. The p-values of the distributions with zeros removed only were compared with the distributions with high values and zeros removed. The distribution that had the highest p-value was selected for use in the Arena model. Eight outliers and 192 zero values (11 percent of the data points) were actually removed; leaving 1445 data points to determine the final distributions.

Arena determined that a Weibull distribution was the best fit for many of the operations. However, when an Exponential or Lognormal distribution was fit to the same data, the square error and p-values was not much different. Therefore, to better understand the distributions, the "second" best fit was sometimes used, depending on the p values. One problem or assumption with this data is that all the tasks are independent of each other. For example, the length of time to complete one operation has no bearing on the time to complete another operation. This is not true, but it is an assumption that needed to be made to get distributions for each operation. With enough data, this assumption can be overcome. The actual distributions are shown in Appendix C.

Step 3: List of Resources

The actual IDOCK workforce included 71 employees broken out in Table 1:

Table 1: IDOCK Employees

AS = SMCO (OS 3806)	43
AA = Aircraft (OS 8852)	11
AH = Hydraulics (OS 8852)	6
BA = Rigging (OS 8852)	6
1A = Engines (OS 8852)	1
7H = Gears (OS 8852)	4

Those 71 employees are shared among all seven major IDOCK major jobs. Major job BA utilizes all of the different specialists listed above during their operations, but only AS, 7H, and AH are used in the tasks that were modeled in this research. Additionally, the actually number made available to this model was scaled down to better reflect the resources actually in major job BA at any given time. The modified models (to allow cross-training) combined all employees into one pool to complete certain tasks. The final scale for this model is in Table 2. The scaled down pool was determined from through the validation of the model explained in Step 5 (to get the simulated flow time to match reality as closely as possible).

Table 2: Major Job BA Personnel

AS = SMCO (OS 3806)	6
AA = Aircraft (OS 8852)	0
AH = Hydraulics (OS 8852)	2
BA = Rigging (OS 8852)	0
1A = Engines (OS 8852)	0
7H = Gears (OS 8852)	3

The other resource constraint is the number of work stations. IDOCK has three available work stations—therefore, they can only work on 3 aircraft at a time.

Step 4: Input from Work Centers

The second set of data points was collected during a visit to Tinker AFB in December 2009. During that visit, two supervisors provided information on 74 operations:

1) The certainty of task occurrence (All the time or percentage of the time)
2) Any pre-requisite tasks
3) Task priority (1-5)
4) Expected duration of the task
5) # of personnel needed to complete the task
6) Occupational series required to complete the task
7) How complex is the task (1-5)
8) How difficult to train a new mechanic on the task (1-5)
9) What kind of training is required to complete the task (OJT, Formal School)

When the 74 operations that supervisors provided input on were matched with the 113 operations that were left from PDMSS, 58 operations were left to analyze (Appendix D). These operations consisted of 1760 data points.

Step 5: Create Multiple Discrete Event Simulation Models

After a distribution was determined for each operation, an Arena model was created to simulate the flow of an aircraft through these 58 operations. The process started with the aircraft arrival. Aircraft arrive every 7 calendar days because their plan is to have 54 aircraft this year (which equates to one every 6.75 days). However, the model was built to account for duty days so the model was configured for an aircraft to arrive every 5 days. The first process the aircraft encountered was pre-dock. Based on the historical data over the last year, the best distribution is a triangular with minimum of 10.5 days, average of 15 days, and maximum of 36.5 days (again, this is calendar days, so it was converted to duty days—minimum of 8.5 days, average of 11 days, and maximum of 26.5 days). The Chi Square test of a triangular distribution gave a p-value of .545; therefore it is an acceptable representation of the data. After pre-dock, the aircraft enters IDOCK. This part of the Arena model is shown in Figure 10. As was described earlier in the overview of the KC-135 depot process, the IDOCK has many major jobs. This Arena model mapped out 58 of the jobs for the BA major job. Some of those jobs occurred in parallel and some in series.

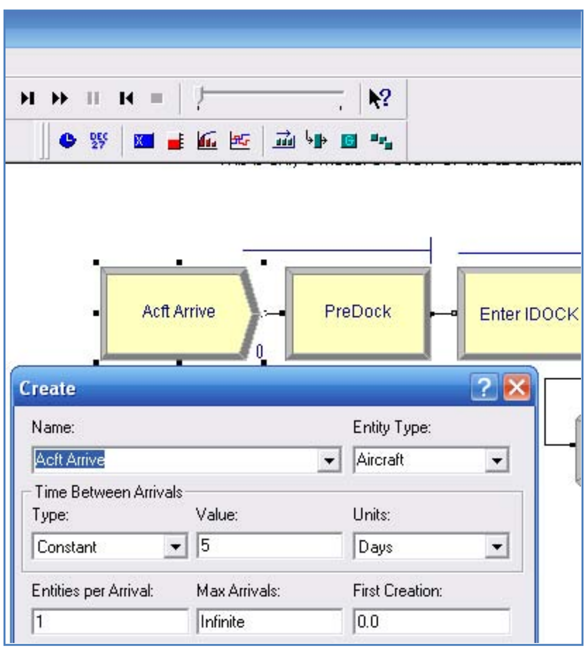


Figure 10: Arena Model of Pre-Dock

The simulations were run for 760 days with a warm-up period of 30 days to allow at least 3 airplanes to enter the system. It was run based on the work center running 24 hours a day. Therefore, the results are converted to actual duty days by dividing the results by 16 (work hours per day for this process). It was also run without consideration weekends (which is non-work time) so all comparisons with actual data is done using duty days, not calendar days. The model was replicated 100 times. The Current State Model is in Appendix E. Some results of the Current State Model are in Table 3 (all are averages over the 100 repetitions)—complete results are in Appendix F.

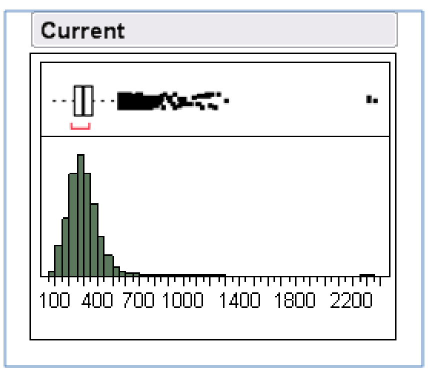
Table 3: Current State Simulation Results

Time to complete tasks	297.5 hours; 18.6 duty days
Aircraft through process	144.2
7H Utilization	49.2%
AS Utilization	57.4%
IDOCK Space Utilization	82.6%
Operation 32184 Waiting Time	71.0 hours
Operation 32204 Waiting Time	44.4 hours
Operation 32205 Waiting Time	47.5 hours
Operation 32206 Waiting Time	51.4 hours
Operation 32256 Waiting Time	56.3 hours
Operation 32257 Waiting Time	61.2 hours
Operation 32500 Waiting Time	64.3 hours
Operation 32504 Waiting Time	64.6 hours

Validation of Current State Simulation Results

The validation of the current state simulation results is important to determine whether the model is an accurate representation of reality. However, this is very difficult to do because of the availability of accurate data. According to the data in PDMSS, the average time to complete major job BA for the 30 aircraft that were modeled was 108 calendar days. This is definitely an inaccurate representation of reality because the aircraft is out of IDOCK in an average of calendar 21.8 days. PDMSS also shows the date the major job started and the date a specific task was completed. When those two data points are subtracted from each other (for the 58 tasks that were modeled) gives an average of 42.6 calendar days (or 31.3 duty days) until last task modeled is complete. This does not match up with when an aircraft leaves IDOCK because some of the tasks can be completed or continued during other phases of IDOCK, so that is not a necessary comparison. Therefore, the 31.3 duty days seen in the PDMSS system should be compared with the simulation results. The simulation results of the current state, if all IDOCK personnel are including in the model, show that the time to complete all 58 modeled tasks is 138.64 hours. That converted to 8.6 actual duty days (IDOCK is mostly a 2-shift, 5-days a week operation, therefore, the hours is divided by 16 to get duty days). This does not compare well to the known average completion time of 31.3 duty days because of concurrent work. Some of the BA tasks are not started as soon as personnel become available because they may be routed to another job within IDOCK based on priorities. In order to get the model closer to the PDMSS reality of 31.3 duty days, the number of people available to work BA jobs (the resources) were cut (Table 2) to account for some of them working other jobs within BA. Even with reducing the manpower resources, the flow time only reached 18.6 duty days (Table 3). This clearly shows that any validation of the simulated data versus reality is very difficult, if not impossible. However, current state simulation results can and should be compared with the adjusted model simulation results to see if any gains can be achieved in flow time.

The current state results highlight several areas for improvement, but the key metric which defines the flow of aircraft through major job BA is the time to complete all tasks. The histogram, descriptive statistics, and confidence intervals are shown in Figure 11. The average was 297.5 hours with a rather small confidence interval, but the standard deviation is fairly large at 109.6 hours. This indicates that there is significant variability in the data and that variability may be an area that can be addresses in future research. Table 3 results also show the eight operations that had the longest wait times (that is the time waiting for a technician to become available to complete the task) because those are good areas to attack for potential increase in workforce or cross-training opportunities. Six of those were noted to have a task complexity and difficulty to train rating of 3, 4, or 5. Two of those seven (operation 32500 and operation 32504) has a task complexity and difficulty to train rating of 1—tasks that are easily completed by generalists.



Quantiles

100.0%	maximum	2348.4
99.5%		700.315
97.5%		519.942
90.0%		423.197
75.0%	quartile	354.881
50.0%	median	287.449
25.0%	quartile	227.37
10.0%		175.974
2.5%		124.263
0.5%		97.5155
0.0%	minimum	65.0076

Moments

Mean	297.51345
Std Dev	109.63961
Std Err Mean	0.9072907
Upper 95% Mean	299.29186
Lower 95% Mean	295.73505
N	14603

Confidence Intervals

Parameter	Estimate	Lower CI	Upper CI	1-Alpha
Mean	297.5135	295.735	299.2919	0.950
Std Dev	109.6396	108.3965	110.9118	0.950

Figure 11: Current State Descriptive Statistics (from JMP)

Model 2: Cross-Training Technicians on Two "Long Wait" Tasks

In the next model, the two operations mentioned above (32500 and 32504) were changed to be allowed to be completed by any technician. The following changes were made to the initial Current State Model for those two operations only. First, the resources were changed from two 7H technicians to two 7H, AH, or AS technicians; the exact technician was selected in preferred order based on which technician was available. The preferred order was always the career field that originally completed the task, followed by a person of the same occupational series (i.e. AH or 7H), and then followed by whoever was left. The three preferred order sets were:

1) AH, 7H, AS
2) 7H, AH, AS
3) AS, 7H, AH

Second, the task completion times were multiplied by 1.2 (taking into account other technicians might take longer to complete). This 1.2 was used based on discussions with managers at the depot line and data from the literature review. The selection of 1.2 was subjected to sensitivity analysis in model 3. Figure 12 shows the changes from the Current State Model.

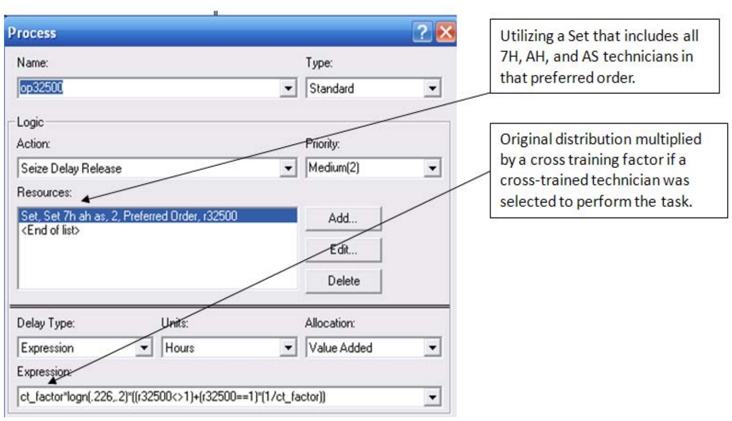
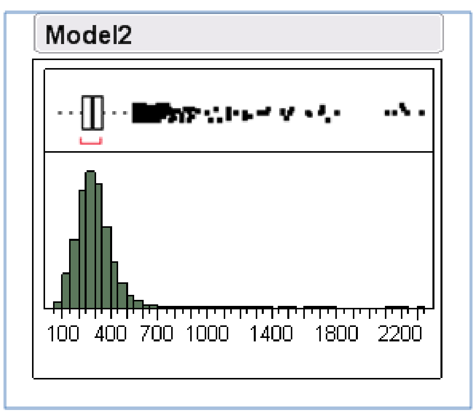


Figure 12: Model 2 Modifications

The results of the simulation are in Table 4 (full results in Appendix G) and the descriptive statistics are in Figure 13.

Table 4: Model 2 Simulation Results

	New Data Point	Change from Current State
Time to complete tasks	297.7 hours; 18.6 duty days	Negligible
Aircraft through process	144.1	Negligible
7H Utilization	49.1%	Negligible
AS Utilization	57.6%	Negligible
IDOCK Space Utilization	82.6%	Negligible
Operation 32184 Waiting Time	72.1 hours	Increase 1.1 hour
Operation 32204 Waiting Time	44.3 hours	Negligible
Operation 32205 Waiting Time	47.4 hours	Negligible
Operation 32206 Waiting Time	51.3 hours	Negligible
Operation 32256 Waiting Time	56.2 hours	Negligible
Operation 32257 Waiting Time	61.3 hours	Negligible
Operation 32500 Waiting Time	0 hours	Cut 64.3 hours
Operation 32504 Waiting Time	0.2 hours	Cut 64.4 hours



Quantiles

100.0%	maximum	2319.33
99.5%		687.195
97.5%		515.991
90.0%		422.474
75.0%	quartile	354.094
50.0%	median	288.005
25.0%	quartile	226.299
10.0%		174.333
2.5%		124.155
0.5%		97.258
0.0%	minimum	64.1347

Moments

Mean	297.72525
Std Dev	116.57543
Std Err Mean	0.9648512
Upper 95% Mean	299.61648
Lower 95% Mean	295.83402
N	14598

Confidence Intervals

Parameter	Estimate	Lower CI	Upper CI	1-Alpha
Mean	297.7252	295.834	299.6165	0.950
Std Dev	116.5754	115.2535	117.9283	0.950

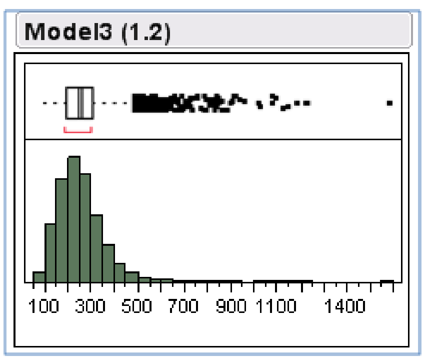
Figure 13: Model 2 Descriptive Statistics (from JMP)

Model 3: Cross-Training Technicians on all Low Complexity Tasks

A third model was then created to modify all the operations whose complexity level was chosen to be one. This resulted in 20 tasks that were modified (in addition to the two tasks already modified in Model 2) exactly as operations 32500 and 32504 were modified in model 2. Model 3 results are shown in Table 5 (full results in Appendix H) and descriptive statistics shown in Figure 14.

Table 5: Model 3 Simulation Results

	New Data Point	Change from Current State
Time to complete tasks	250.7 hours; 15.7 duty days	46.8.1 hours; 2.9 duty days
Aircraft through process	145.3	Increase 1.1
7H Utilization	44.8%	Cut 4.4%
AS Utilization	59.0%	Increase 1.6%
IDOCK Space Utilization	69.9%	Cut 12.7%
Operation 32184 Waiting Time	56.1 hours	Cut 14.9 hours
Operation 32204 Waiting Time	42.4 hours	Cut 2.0 hours
Operation 32205 Waiting Time	45.3 hours	Cut 2.4 hours
Operation 32206 Waiting Time	48.9 hours	Cut 2.5 hours
Operation 32256 Waiting Time	53.4 hours	Cut 2.9 hours
Operation 32257 Waiting Time	58.0 hours	Cut 3.2 hours
Operation 32500 Waiting Time	1.7 hours	Cut 62.6 hours
Operation 32504 Waiting Time	1.9 hours	Cut 62.7 hours



Quantiles

100.0%	maximum	1572.42
99.5%		623.136
97.5%		459.63
90.0%		365.82
75.0%	quartile	300.563
50.0%	median	240.584
25.0%	quartile	184.758
10.0%		142.3
2.5%		106.006
0.5%		85.2089
0.0%	minimum	57.8505

Moments

Mean	250.65598
Std Dev	96.527336
Std Err Mean	0.7958463
Upper 95% Mean	252.21594
Lower 95% Mean	249.09602
N	14711

Confidence Intervals

Parameter	Estimate	Lower CI	Upper CI	1-Alpha
Mean	250.656	249.096	252.2159	0.950
Std Dev	96.52734	95.43689	97.64317	0.950

Figure 14: Model 3 Descriptive Statistics (from JMP)

Cross-Training Factor Sensitivity Analysis (Model 3)

Because the load factor of 1.2 was selected somewhat arbitrarily (based on one research article and employee input), a sensitivity analysis of that factor was performed using Model 3 data. The question is: how much effect does the choice of a load factor have on the output of the model? A load factor of 1.0 means that the generalist completes the task at the same speed as a specialist does. The higher the load factor, the longer the generalists takes to complete the task. To do this analysis, model 3 was run several times with load factors ranging from 1.0 to 5. When the load factor was 4.25, the time to complete all the tasks equaled the current state (297.5 hours)—this would be considered the "break even" point. In other words, for this particular test case, as long as the load factor is less than 4.25, then cross-training could have some benefit. Figure 15 shows the relationship between the cross training load factor and the average time to complete all the tasks. The tasks that were selected for cross-training for this model were all rated a difficulty level of 1, meaning that according to their experts it would never take a generalists more than twice as long as a specialist to complete the task (meaning a load factor somewhere between 1 and 2 is appropriate for these tasks). As the figure shows, any load factor between 1 and 2 only changes the production time by 4%. Therefore, the selection of a load factor of 1.2 was justified for this simulation.

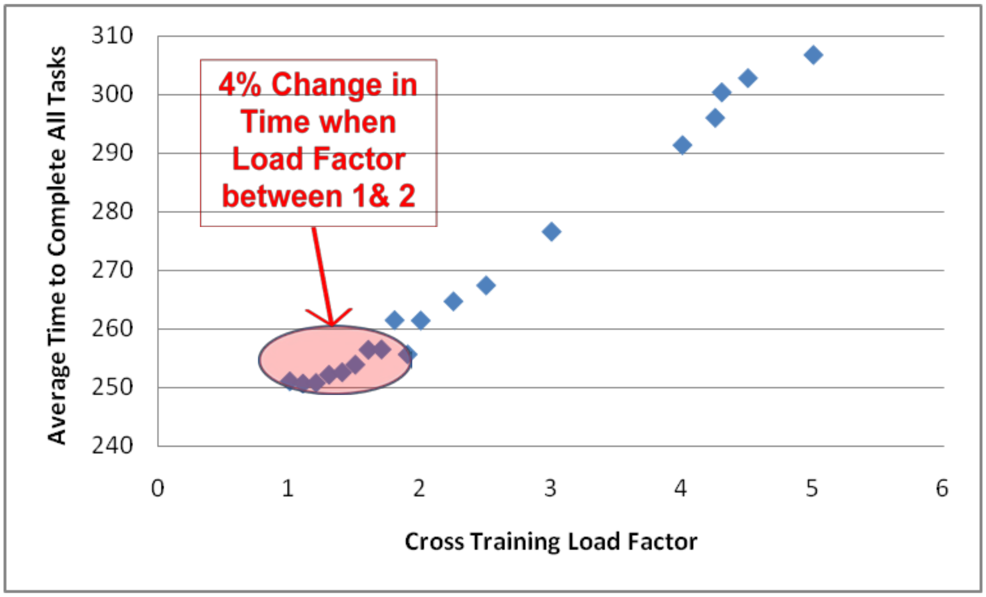


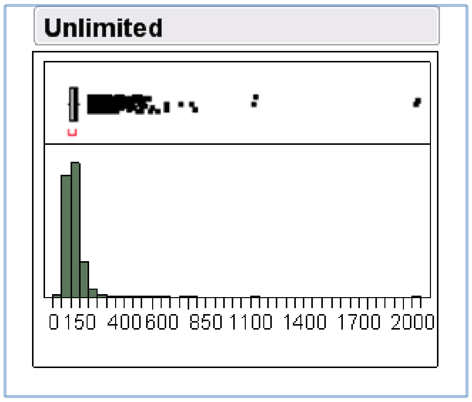
Figure 15: Load Factor Sensitivity Analysis

Model 4: Unlimited Technician Pool

In order to understand the absolute fastest these 58 tasks could get accomplished with the current occupational series, a fourth model was created with unlimited resources. The results are in Table 6 (full results in Appendix I) and descriptive statistics in Figure 16.

Table 6: Model 4, Unlimited Resources, Simulation Results

	New Data Point
Time to complete tasks	115.5 hours; 7.2 duty days
Aircraft through process	146.0
7H Utilization	n/a
AS Utilization	n/a
IDOCK Space Utilization	32.2%
All Operations Waiting Time	0



Quantiles

100.0%	maximum	2017.57
99.5%		312.73
97.5%		216.145
90.0%		162.862
75.0%	quartile	132.493
50.0%	median	106.945
25.0%	quartile	87.6388
10.0%		73.1109
2.5%		59.1701
0.5%		49.1826
0.0%	minimum	31.8354

Moments

Mean	115.45693
Std Dev	50.649259
Std Err Mean	0.4156888
Upper 95% Mean	116.27173
Lower 95% Mean	114.64213
N	14846

Confidence Intervals

Parameter	Estimate	Lower CI	Upper CI	1-Alpha
Mean	115.4569	114.6421	116.2717	0.950
Std Dev	50.64926	50.07966	51.23205	0.950

Figure 16: Model 4 Descriptive Statistics (from JMP)

Step 6: Compare Simulation Results

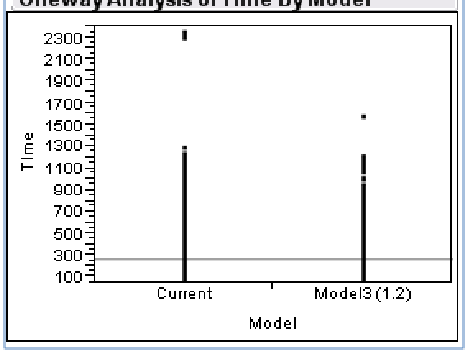
A summary of the results are shown in Table 7 (all numbers are averages).

Table 7: Comparison of Simulation Results

	Current State	Model 2	Model 3	Model 4
Time to complete tasks	297.5 hours	297.7 hours	250.7 hours;	115.2 hours
Aircraft through process	144.2	144.1	145.3	146.0
7H Utilization	49.2%	49.1%	44.8%	n/a
AS Utilization	57.4%	57.6%	59.0%	n/a
IDOCK Space Utilization	82.6%	82.6%	69.9%	32.2%
Operation 32184 Waiting Time	71.0 hours	72.1 hours	56.1 hours	0
Operation 32204 Waiting Time	44.4 hours	44.3 hours	42.4 hours	0
Operation 32205 Waiting Time	47.5 hours	47.4 hours	45.3 hours	0
Operation 32206 Waiting Time	51.4 hours	51.3 hours	48.9 hours	0
Operation 32256 Waiting Time	56.3 hours	56.2 hours	53.4 hours	0
Operation 32257 Waiting Time	61.2 hours	61.3 hours	58.0 hours	0
Operation 32500 Waiting Time	64.3 hours	0 hours	1.7 hours	0
Operation 32504 Waiting Time	64.6 hours	0.2 hours	1.9 hours	0

Model 2 showed negligible improvement from the current state, however the change from the current state to Model 3 does appear to show some improvement—the mean time to complete all tasks dropped 40.8 duty hours by cross-training the 22 low complex tasks. The results were imported into JMP statistical software for to determine whether the differences means in the data is statistically important. The null hypothesis is that the means from the Current State and Model 3 are the same. To test this, a Non-Parametric Wilcoxon test was performed (results in Figure 17). The p value equaled 0, therefore we reject the null hypothesis and conclude that the means are different. Additionally, a two-sample t-test was performed in Microsoft Excel to compare the two means. The p values were 0, confirming that the two means are statistically different. This t-test is also shown in Figure 17.

Oneway Analysis of TIme By Model



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Current	14603	2.44e+8	16738.5	41.949
Model3 (1.2)	14711	1.85e+8	12591.8	-41.949

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
244432285	41.94858	0.0000*

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1759.6834	1	0.0000*

t-Test: Two-Sample Assuming Unequal Variances		
	Model 3 (1.3)	*Current State*
Mean	250.6559832	297.5134507
Variance	9317.526561	12020.84507
Observations	14711	14603
Hypothesized Mean Difference	0	
df	28795	
t Stat	-38.82544498	
P(T<=t) one-tail	0	
t Critical one-tail	1.644906547	
P(T<=t) two-tail	0	
t Critical two-tail	1.960046317	

Figure 17: Current State versus Model 3 Time to Complete Tasks

Therefore, by cross-training employees on 22 of the 58 tasks, major job BA can be completed 40.8 hours faster—a 13.7% improvement. The waiting time for all the tasks also decreased, some more substantially than others. This waiting time reduction is what allowed the aircraft to actually get through all processes faster. However, the number of aircraft that made it through the system only increased slightly. This is due to the fact that the real limiting factor to pushing more aircraft through major job BA is the processing time, not the time waiting for a technician to become available. This was confirmed by Model 4. When unlimited personnel were made available, only 1 more aircraft (less than 1% improvement) made it through the system. Another interesting data point is that the overall technician utilization rate didn't change all that much with cross-training. The 7H utilization rate when down 4.4%, but the AS utilization rate went up 1.6%. Both rates were below 60%, indicating that the mechanics are free 40% of the time. This is an interesting phenomenon that suggests that the real limiting factor or problem with the current major job BA process is the variability of task completion. There are times that they were busy and other tasks were waiting on them, and other times when the mechanics were waiting on tasks to be ready to complete. Some of this can also be explained by the fact that some tasks require a large number of people. For example, if a task required 5 people and only have 11 people work in the section, it may take a while for 5 technicians to get free at the same time.

Step 7: Cost of Cross-Training

The cost of cross-training was calculated using several factors:

A = Average Time for a Specialist to Complete the Task
B = Training Factor (how much longer will it take to complete the task during training)

C = Number of People Involved in the Training (Trainer and Trainee)
D = Number of Times Training Must be Repeated
E = Salary of Personnel Involved in the Training (Factor C)
F = Formal Training Costs

Formula: (A*B*C*D*F + E) per task per person cross-trained

For this research,

A = gathered from PDMSS
B = 2 (assumed it takes twice as long to train as opposed to just completing the task)
C = 2 (one trainer and one trainee)
D = 2 or 4 (if the training difficulty level was 1, then the person only needed to be trained twice; if the training difficulty was 2, then person needed to be trained 4 times)
E = not used for this research; the cost was quantified in terms of hours for this research
F = 0 (all tasks that were cross-trained did not require any formal training; it is assumed that you are training a mechanic who already possesses basic aircraft maintenance skills)
Cost = A * 2 * 2 * (2 or 4)

It was calculated for each task that was cross-trained, multiplied by the number of people cross-trained on that task, and then summed together. There were 22 tasks that were subject to cross-training (16 7h-tasks, 4 as-tasks, and 2 ah-tasks). There were 11 technicians involved in the pool of technicians who were cross-trained (3 7h-technicians, 6 as-technicians, and 2 ah-technicians). The cross-training cost for these 11 technicians on all 22 tasks was 3,134 hours.

Step 8: Make Decision

Depending on the salary of these individuals, a manager must decide whether it is worth those 3,134 hours for a 13.7% gain in task completion time.

V. Discussion

Answers to Research Questions

Question 1: What experimental and analytical models exist or can be created to determine if occupational series should be combined?

Answer 1: The literature review addressed this at length. Several models have been created, but only one (Marentette K. A., 2008) discussed which jobs to combine. The rest of the models were more about what roles to combine, leaving the manager to ascertain what actual positions could be combined. Some of the models were role specific and some were task specific. Besides Marentette's model, the problem with most of these models is that they were very specific to the system or industry they were researching. In order to apply it to AFMC's research question, they would need to be adapted significantly. There is no one model that can be created to determine if occupational series should be combined. However, the methodology created in this research is a basic process that can be followed to determine which tasks should be combined with others. This methodology explains how a task-based discrete simulation model can be developed to show were production gains can be made with cross-training.

Question 2: What series should be combined or created a-new?

Answer 2: This research was unable to ascertain which occupational series should be combined or created anew because the production line selected to test the methodology only had a few occupational series. A method was created that can be used to look at work areas that have a large diversity of similar occupational series, but such areas may not exist. It appears that there is much specialization within in each occupational series, so reducing the number of occupational series may not be a realistic goal.

Question 3: How do organizations ensure they don't combine incorrectly thereby losing critical knowledge and affecting product quality?

Answer 3: Based on the literature, this is almost purely subjective. Most of the literature does suggest that some flexibility is good, but an organization must maintain a certain level of expertise (i.e. specialization). The proper degree of flexibility is a factor of the complexity of the tasks, the quality concerns of the final product, and level of utilization of current specialists. One way to overcome this might be to create a cross-trained team, as suggested by Molleman and Slomp (1999)—a team that consists of at least one expert for each task with all other team members being cross-trained on some of the other tasks. This creates a depth of knowledge, but also a breadth of some team members to help out when their utilization is low. The key to this research paper's methodology working is having an accurate opinion from the subject matter experts. If a consensus can be reached that the benefits of a flexible workforce outweighs the potential loss in depth, then a manager should feel confident in the cross-training decision. The decision cannot be made without first-level leadership and worker involvement.

Recommended Future Research

This research does not directly answer AFMCs original questions of how can the number of occupational series be reduced. Based on findings at the Tinker AFB KC-135 production line, there is limited benefits for this type of research in the future for these AFMC organizations. However, gains towards reducing the number of occupational series at specific locations might be feasible. AFMC should look at other work centers and analyze which ones have a large number of occupational series and apply this methodology to them. If “non flexible” organizations can be found within AFMC, they should be studied.

Conclusions

Using the proposed methodology, determining which tasks should be shared with other occupational series is pretty clear. A cut in production time was seen when low complexity tasks were cross-trained, but the cost of cross-training might be very high in terms of time to train the new technicians. A delicate balance needs to be drawn, based on expert opinion, about which career fields can cross-train. A more flexible workforce can be obtained if the right team is put together to study it.

Bibliography

Brusco, M. J., & Johns, R. T. (1998). Staffing a Multi-Skilled Workforce with Varying Levels of Productivity: An Analysis of Cross-Training Policies. *Decision Sciences* , 499-515.

Chakravarthy, S. R., & Agnihothri, S. R. (2005). Optimal Workforce Mix in Service Systems with Two Types of Customer. *Production and Operations Management* , 218-231.

Dietz, D. C., & Rosenshine, M. (1997). Optimal Specialization of a Maintenance Workforce. *IIE Transactions , 29* (5), 423-433.

Marentette, K. A. (2008). *An Objective Decision Tool For Use in Considering Air Force Specialty Code Pairs for Consolidation.* Wright Patterson AFB: Air Force Institute of Technology.

Marentette, K., & Johnson, A. (2009). A Measure of Cross-Training Benefit Versus Job Skill Specialization. *Computers & Industrial Engineering Journal* .

McCreery, J. K., & Krajewski, L. J. (1999). Improving Performance Using Workforce Flexibility in an Assembly Environment with Learning and Forgetting Effects. *International Journal of Production Research , 37* (9), 2031-2058.

Molleman, E., & Slomp, J. (1999). Functional Flexibility and Team Performance. *Internation Journal of Production Research* , 1837-1858.

Nembhard, D. A., Nembhard, H. B., & Qin, R. (2005). A Real Options Model for Worforce Cross-Training. *The Engineering Economist , 50*, 95-116.

Paskin, M. A., & Trevino, A. W. (2007). *Employing Organizational Modeling and Simulation to Deconstruct the KC-135 Aircraft's Programmed Depot Maintenance Flight Controls Repair Cell.* Monterey: Naval Postgraduate School.

Pinker, E. J., & Shumsky, R. A. (2000). The Effeciency-Quality Trade-off of Cross Trained Workers. *Manufacturing and Service Operations Management , 2* (1), 32-48.

U.S. Government Accountability Office. (2003). *DOD Civilian Personnel: Improved Strategic Planning Needed to Help Ensure Viability of DOD's Civilian Industrial Workforce, GAO-03-472.*

Appendix A – KC-135 Wage Grade Employees

Occ Series Code & Desc - Asgn	Pay Plan Cd	Grade	Total Of Duty Location
2610 Electronic Integrated Systems	WG	13	12
2610 Electronic Integrated Systems	WL	12	2
2610 Electronic Integrated Systems	WS	13	2
2610 Electronic Integrated Systems	WG	12	10
			26
2892 Aircraft Electrican	WL	10	3
2892 Aircraft Electrican	WS	10	4
2892 Aircraft Electrican	WL	09	6
2892 Aircraft Electrican	WG	10	50
2892 Aircraft Electrican	WG	08	27
			90
3501 Misc General Services & Support	WG	03	28
			28
3806 Sheet Metal Mechanic	WS	14	1
3806 Sheet Metal Mechanic	WG	08	76
3806 Sheet Metal Mechanic	WG	10	248
3806 Sheet Metal Mechanic	WL	09	4
3806 Sheet Metal Mechanic	WL	10	6
3806 Sheet Metal Mechanic	WS	10	15
3806 Sheet Metal Mechanic	WS	13	4
			354
5703 Motor Vehicle Operating	WG	06	3
			3
6904 Tool & Parts Attending	WS	06	2
6904 Tool & Parts Attending	WG	06	11
			13
6907 Materials Handling	WG	06	9
6907 Materials Handling	WS	06	1
			10
8801 Miscellaneous Aircraft Overhaul	WS	14	4
8801 Miscellaneous Aircraft Overhaul	WS	15	1
8801 Miscellaneous Aircraft Overhaul	WS	16	1
			6
8852 Aircraft Mechanic	WG	08	12
8852 Aircraft Mechanic	WS	13	4
8852 Aircraft Mechanic	WS	11	6
8852 Aircraft Mechanic	WS	10	18
8852 Aircraft Mechanic	WL	11	6
8852 Aircraft Mechanic	WL	10	17
8852 Aircraft Mechanic	WL	09	6
8852 Aircraft Mechanic	WG	10	346
8852 Aircraft Mechanic	WS	14	1
8852 Aircraft Mechanic	WG	11	18
			434
			964

Appendix B – Order of Tasks in IDOCK Major Job BA

OPERATION DESCRIPTION	OPERARTION NUMBER	Order
These tasks must be completed sequentially		
1B4(B)- REMOVE LH AND RH NOSE WHEEL WELL DOORS IAW: 1C-135(K)R-2-7JG-7, TASK 3-32-1 INSTALLED ON OP #'S 20505 & 20506 -	20542	1
1A1FA - REMOVE 3 EA ACCESS DOORS LOCATED ON LH SIDE OF DORSAL FIN. HOLD FOR REINSTL. REF: T.O. 1C-135(K)R-2-2JG-19 TASK 10-24-1 STEP 2. REF. T.O. 1C-135(K)R-4-2 FIG. 158	66018	2
1B20 - COVER LOWER FUSELAGE ANTENNAE WITH PROTECTIVE FOAM PADDING FOR NON-GATM A/C THERE ARE 4 ANTENNAE (IFF, TACAN, COMM1, & COMM2) FOR GATM A/C THERE ARE 5 ANTENNAE (IFF, TACAN, COMM1, COMM2, & VDL) REF AFOSH 91-100	20058	3
1B67(J) ¿JACK/JIG/SHORE - PRIOR TO JACKING ENSURE AIRCRAFT IS COMPLETELY DEFUELED AND PROPER BALLAST IS INSTALLED IAW. T.O. 1C-135(K)R-2-2JG-6 TASK 4-5.	1146	4
1B67(J) ?JACK/JIG/SHORE - PRIOR TO JACKING CALCULATE CENTER OF GRAVITY IN % OF MAC. SUBMIT 202 ENGR REQUEST IF OUT OF LIMITS. IAW.T.O. 1C-135(K)R-2-2JG-6 TASK 4-5-1 AND 4-5-2/4-5-3	1147	5
1B67(J) - JACK/JIG/SHORE - INSPECT A/C JACKS PRIOR TO USE FOR SERVICEABILITY IAW T.O. 35A2-1-1 AND OPERATING INSTRUCTIONS 76 AMXG 21-26 PARA 2.4. ALSO SEE DEFINITIZED GUIDE.REF 76 AMXG 09-04,00-96 & 76 AMXG 00-15 REF 1C-135(K)A-3-1 SPECIAL HANDLING 252 51MOCCR0010A65W	1199	6
1B67(J) SSQ TASK: JACK A/C IAW 1C-135(K) R-2-2JG-6 TASK 4-1 THRU 4-18-3, AND REF: 76AMXGOI 21-26 PARA 2.4.5.1.	32184	6.5
1B67(J) ¿JACK/JIG/SHORE - PROCURE 20 JACKS, 60 WOODEN PADS & VARIOUS BODY & WING SHORING TO JACK & SHORE A/C FOR STRUCTURAL REPAIRS, INCLUDING GAUGE INSTL. IAW.T.O. 1C-135(K)A-3-1 PAR 1-9.6 AND T.O. 1C-135-3-5 PAR 1-2 AND 1-3.REF 76 AMXG 09-04 REF 1C-135(K)A-3-1 SPECIAL HANDLING 252 51MOCCR0010A65W	1148	7
1B67(J) - JACK/JIG/SHORE - PRIOR TO USE, INSPECT ALL BODY & WING SHORING USED TO JACK & SHORE A/C FOR STRUCTURAL REPAIRS. REF 76 AMXG 09-04 REF 1C-135(K)A-3-1 SPECIAL HANDLING 252 51MOCCR0010A65W	1144	8
1B67(J) - JACK/JIG/SHORE - PRIOR TO USE, INSPECT 60 WOODEN PADS TO BE USED TO JACK & SHORE A/C FOR STRUCTURAL REPAIRS. SEE DEFINITIZED LIST. REF 76 AMXG 09-04,00-96 & 76 AMXG 00-15 REF 1C-135(K)A-3-1 SPECIAL HANDLING 252 51MOCCR0010A65W	1145	9
1B67(J) ¿JACK/JIG/SHORE - INSTALL FUSELAGE AND WING SHORING. IAW.T.O. 1C-135(K)A-3-1 PAR 1-9.6 AND IAW.T.O. 1C-135-3-5 PAR 1-2, 1-3.REF 76 AMXG 09-04, 76 AMXG 00-15	1165	10
The next two tasks may be completed in parallel		
1B67B POSITION AND SET UP TRANSIT TO ACCOMPLISH AIRCRAFT LEVELING REQUIREMENTS TO FACILITATE REMOVAL, INSPECTION, AND REPLACEMENT OF MILK BOTTLE PINS. IAW 1C-135(K)A-3-1 PARA 1-9.2	42110	12
1B67(J) ¿JACK/JIG/SHORE- JACK AIRCRAFT TO JIG POSITION IAW.T.O. 1C-135(K)A-3-1 PAR 1-9.6 THRU 1-9.6.4 AND TABLE 1-52	1158	13
The remaining tasks may be completed in parallel		
1B4(B)- REMOVE NLG IAW. 1C-135(K)R-2-7JG-6 ***MULTIPLE TASKS*** REF. PROCESS ORDER 76 AMXG 07-10	32043	14

*1B1(C)- REMOVE LH MLG IAW. 1C-135(K)R-2-7JG-1, -3 & -4 **MULTIPLE TASKS***	***32201***	14
*1B1(C)- REMOVE R/H MLG IAW. 1C-135(K)R-2-7JG-1, -3 & -4 **MULTIPLE TASKS***	***32202***	14
1B4(B)- MOVE NOSE LANDING GEAR FROM A/C TO GEAR SHOP FOR DISASSEMBLY AND REASSEMBLY. T.O. NOT REQUIRED	***32500***	14
*1B1(C)- MOVE L/H & R/H MLG FROM A/C TO GEAR SHOP FOR DISASSEMBLY AND REASSEMBLY. ***CAUTION*** ENSURE WOODEN BLOCKS ARE USED BETWEEN JACK AND LANDING GEAR. T.O. NOT REQUIRED*	***32504***	14
*1B1(C.5,6,7,8)- REMOVE L/H SIDE STRUT PARTS SIDE STRUT ACTUATOR, UPPER & LOWER SIDE STRUT SEGMENTS AND UNIVERSALS IAW. 1C-135(K)R-2-7JG-3 & 1C-135(K)R-2-10JG-5 **MULTIPLE TASKS***	***32203***	14
*1B1(C.5,6,7,8)- REMOVE R/H SIDE STRUT COMPONENTS: SIDE STRUT ACTUATOR, UPPER & LOWER SIDE STRUT SEGMENTS AND UNIVERSALS IAW. 1C-135(K)R-2-7JG-3 & 1C-135(K)R-2-10JG-5 **MULTIPLE TASKS***	***32204***	14
1B1(E)- REMOVE LH & RH MLG HOOK & SHAFT ASSY. FROM LOCK SUPPORT ASSY FOR INSPECTION IAW. 1C-135(K)R-2-7JG-3 TASK 2-69-1 STEPS 3 & 5 & TASK 2-71-2 STEPS 5 & 6.	***32030***	14
*1B1(C.2,9,10,20)- REMOVE & DISASSEMBLE L/H MLG WALKING BEAM, BEAM SUPPORT LINK & TRUNNION. IAW.1C-135(K)R-2-7JG-4 **MULTIPLE TASKS***	***32205***	14
*1B1(C.2,9,10,20)- REMOVE & DISASSEMBLE R/H MLG WALKING BEAM, BEAM SUPPORT LINK & TRUNNION. IAW.1C-135(K)R-2-7JG-4 **MULTIPLE TASKS***	***32206***	14
1B1(G,H,I,J)- REMOVE L/H MLG OLEO DOOR RODS AND HOLD FOR INSPECTION. P/N 9-65806-11/-12, 9-65876-1, 9-65876, 69-9411 IAW. 1C-135(K)R-2-7JG-1 TASK 2-17-3 STEPS 4 & 6, TASK 2-17-5 STEPS 3 & 5, TASK 2-17-7 STEPS 2 & 3.	***32741***	14
1B4(E)- INSPECT NLG TRUNNION CAPS FOR CORROSION REWORK IAW 1C-135(K)A-3-4 FIG 8-2 IF CORROSION BEYOND LIMITS NOTIFY ALS TO CALL OUT LOW % OPS FOR NLG TRUNNION BORING.	***32067***	14
1B59.B.3 - VISUALLY INSPECT NOSE GEAR TRUNNION SUPPORT FITTING FOR CRACKS CORROSION, WEAR, AND FAILED FASTENERS. AFTER THE NOSE LANDING GEAR IS REMOVED. REF: T.O.1C-135-36 SEC VII. INSPECTION IS FOR COMPONENTS NOT ON NOSE LANDING GEAR SUBMIT 173 CARDS TO CORRECT THE DEFECTS.	***32157***	14
*1B59.B.1- FROM INSIDE THE NOSE GEAR WHEEL WELL *****SPECIFICALLY INSPECT THE 3 EA. SCREWS FOR LOOSENESS THAT FASTEN THE BRACKET SUPPORTING THE NLG LOCK ACTUATOR TO THE BULKHEAD**** REF 1C-135-36 SECTION VII. REF. 1C-135(K)R-4-1 FIG. 108 IND. 13,14,15.*	***68194***	14
1B1(L)- INSPECT LH MLG EMERGENCY EXTENSION CAM ROLLER IAW 1C-135-36 PARA. 7-5.1 -	***32060***	14
1B1(L)- INSPECT RH MLG EMERGENCY EXTENSION CAM ROLLER IAW 1C-135-36 PARA. 7-5.1	***32061***	14
1B1(P)- WIPE OFF EXCESS GREASE & OIL FROM R/H MLG ACTUATOR ROD ENDS. INSPECT BEARINGS FOR CORROSION. IF CORROSION IS FOUND ROUTE TO MACHINE SHOP FOR BEARING REPLACEMENT. CALL OUT LOW % OP # 53384. T.O. NOT REQUIRED NOTIFY ALS TO PRINT OP# 73710 & ROUTE TO FIRST DROP STATION.	***32084***	14
1B25 - CLEAN AND REMOVE CORROSION FROM LH FWD TRUNNION SUPPORT CASTING. APPLY PRIMER AFTER REMOVAL. REF. 1C-135(K)A-3-4 FIG. 5-22. REF. OP# 32258	***52741***	14
1B25(C) - MLG TRUNNION SUPPORT STRUCTURE - VISUALLY INSPECT BEARING/BUSHING RETAINING SURFACE OF THE LH AFT TRUNNION SUPPORT FITTING. SEE DEFINITIZED GUIDE. IAW. T.O. 1C-135(K)A-3-4, FIGURE 5-22	***32253***	14
1B25(C) - MLG TRUNNION SUPPORT STRUCTURE - VISUALLY INSPECT BEARING/BUSHING RETAINING SURFACE OF THE RH AFT TRUNNION SUPPORT FITTING. SEE DEFINITIZED GUIDE IAW. T.O. 1C-135(K)A-3-4, FIGURE 5-22	***32254***	14

1B25(E-G) - MLG TRUNNION SUPPORT STRUCTURE - INSPECT R/H AFT MLG TRUNNION SUPPORT BOLTHEADS & ATTACHMENT NUTS. USE DEFINITIZED LIST IAW. 1C-135-3-5, FIG 5-11, 5-12. & 1C-135-36, PARA 7-2.12.2 WRITE UP DEFECTS. FIGURE 7-2-13, (IATP DETAIL 205) GET FORM T.O. 1C-135-36, FIGURE 8-1-7, "BOEING FSMP INSPECTION REPORTING FORM 38" AND FIGURE 8-1-8, FORM 38A, FIGURE 8-1-9, INSTRUCTIONS. WHEN FORM IS COMPLETE, GIVE TO SCHEDULER TO PUT IN THE FSMP BOOK.	***32256***	14
1B25(C) - MLG TRUNNIONS SUPP STRUCTURE - VISUALLY INSP BEARING AND ALL THE AREA ADJACENT TO THE BEARING ON THE LH FWD TRUNNION FOR CRACKS. SEE DEFINITIZED GUIDE IAW. T.O. 1C-135(K)A-3-4, FIGURE 5-22	***32258***	14
1B25(C) - MLG TRUNNIONS SUPP STRUCTURE - VISUALLY INSP BEARING AND ALL THE AREA ADJACENT TO THE BEARING ON THE RH FWD TRUNNION FOR CRACKS. SEE DEFINITIZED GUIDE IAW. T.O. 1C-135(K)A-3-4, FIGURE 5-22	***32259***	14
1B1(D.1,2)- CLEAN AND INSPECT ONLY THE MAIN LANDING GEAR BOLTS, PINS AND SHAFTS THAT ARE CURRENTLY BEING ROUTED. REF. 1C-135(K)A-3-3 SEC. V. REF. AFI 21-101 REF. 4A4-29-2 CHAPTER 6 & TABLE 6-2.	***32450***	14
1B1(E.2,3)- AFTER INSPECTION OF THE BORE, ALODINE (MIL-C-5541). THE TAPERED BORE AREA OF THE UPLOCK SUPPORT FITTING LH WHEEL WELL IAW 1C-135(K)A-3-4 FIG 8-1	***32044***	14
1B1(E.2,3)- AFTER INSPECTION OF THE BORE, ALODINE (MIL-C-5541). THE TAPERED BORE AREA OF THE UPLOCK SUPPORT FITTING R/H WHEEL WELL IAW 1C-135(K)A-3-4 FIG 8-1	***32045***	14
1B1- INSPECT L/H AFT OB FOLLOW UP DOOR HINGES FOR LOOSE, WORN AND/OR CORRODED CONDITION. IF DEFECTS ARE FOUND CALL OUT LOW % OP # 52881 FOR REPAIR. IAW 1C-135-36.	***32881***	14
1B1- INSPECT R/H AFT OB FOLLOW UP DOOR HINGES FOR LOOSE, WORN AND/OR CORRODED CONDITION. IF DEFECTS ARE FOUND CALL OUT LOW % OP # 52882 FOR REPAIR. IAW 1C-135-36.	***32882***	14
1B1(C)- FILL OUT & ATTACH FORMS TO OLD L/H MLG PARTS. CRATE OLD PARTS & TURN IN TO SUPPLY. T.O. NOT REQUIRED	***32675***	14
1B4(B)- FILL OUT & ATTACH FORMS TO OLD NOSE GEAR PARTS. CRATE OLD PARTS & TURN IN TO SUPPLY. T.O. NOT REQUIRED	***32687***	14
1B1(C)- FILL OUT & ATTACH FORMS TO OLD R/H MLG PARTS. CRATE OLD PARTS & TURN IN TO SUPPLY. T.O. NOT REQUIRED	***32683***	14
1B1(C)- FILL OUT & ATTACH FORMS TO OLD L/H MLG PARTS. CRATE OLD PARTS & TURN IN TO SUPPLY. T.O. NOT REQUIRED	***32688***	14
1B1(C)- FILL OUT & ATTACH FORMS TO OLD R/H MLG PARTS. CRATE OLD PARTS & TURN IN TO SUPPLY.T.O. NOT REQUIRED	***32689***	14
1B4(B)- UNCRATE NEW/OVERHAULED NOSE GEAR PARTS T.O. NOT REQUIRED	***32694***	14
1B1(C)- UNCRATE NEW/OVERHAULED LH MAIN GEAR PARTS T.O. NOT REQUIRED	***32695***	14
1B87-A REMOVE FLAP TRACK LINK SUPPORT ASSY'S FROM LEFT & RIGHT WINGS REF FOR REMOVAL ONLY. 1C-135-4-1 FIG 79 AND REF:1C-135(K)R-2-8JG-1 INSPECT CENTER FLAP TRACK CASTINGS (WS 360 & 615) AFTER SUPPORT ASSY'S ARE REMOVED FOR CRACKS, CORROSION, AND GENERAL CONDITION REF T.O. 1C-135-36 AND 1C-135-6WS-10, SECTION 1B87, FIGURE 1B87-1	***32701***	14

Appendix C: Distributions of Task Completion Times

Operation #	OC	# of Personnel	Distribution	Average (no data removed)	Zeros Removed	High Values Removed	Actual Data Points	Average (zeros removed)
01144	AS	2	LOGN(1.08, 2.78)	1.23	2	0	27	1.32222222
01145	AS	2	LOGN(1.42, 4.14)	1.3	4	0	25	1.508
01146	AS	1	LOGN(0.334, 0.443)	0.33	4	0	25	0.384
01147	7h or as	1	EXPO(1.96)	1.65	4	0	21	1.96190476
01148	AS	6	LOGN(13.9, 12.7)	13.14	0	0	29	13.137931
01158	AS	5	EXPO(20.1)	20.12	0	0	29	20.1241379
01165	AS	6	UNIF(1, 20)	10.79	0	1	28	10.7896552
01189	AS	6	EXPO(9.33)	9.01	1	0	28	9.33214286
01199	7H	2	LOGN(1.92, 8.38)	1.52	3	0	26	1.69230769
20058	AS	1	EXPO(1.22)	1.17	1	0	24	1.22083333
20542	AH	1	TRIA(0, 2, 4)	2.06	0	0	25	2.064
32030	7H	2	LOGN(0.575, 1.25)	0.71	4	0	25	0.824
32040	7H	2	EXPO(3.46)	3.34	1	0	28	3.45714286
32043	7H	2	EXPO(6.28)	7.79	0	1	28	7.78965517
32044	7H	1	LOGN(0.578, 1.23)	0.53	7	0	21	0.7
32045	7H	1	LOGN(1.05, 3.46)	1.16	3	0	25	1.304
32060	7H	1	LOGN(2.37, 10.2)	1.85	2	0	26	1.99615385
32061	7H	1	LOGN(2.55, 9.51)	1.74	4	0	24	2.025
32067	7H	1	LOGN(0.359, 0.615)	0.52	3	0	26	0.58461538
32083	7H	1	LOGN(0.384, 0.658)	0.45	6	0	23	0.56521739
32084	7H	1	LOGN(0.537, 1.12)	0.52	7	0	22	0.69090909
32157	7H	1	LOGN(1.95, 7.83)	1.56	4	0	25	1.808
32184	7H	6	TRIA(0, 8.17, 52)	20.06	0	0	29	20.0551724
32201	7H	2	EXPO(5.22)	4.68	3	0	26	5.22307692
32202	7H	2	EXPO(3.8)	5.04	5	1	23	6.09583333
32203	7H	2	LOGN(4.18, 21.9)	2.23	4	0	25	2.592
32204	7H	2	LOGN(2.43, 9.22)	1.73	3	0	26	1.93461538
32205	7H	2	EXPO(2.92)	3.98	2	1	26	4.27037037
32206	7H	2	LOGN(3.97, 19)	2.34	2	0	27	2.51111111
32253	7H	1	LOGN(2.32, 9.14)	1.46	4	0	25	1.688
32254	7H	1	EXPO(1.72)	1.37	6	0	23	1.72173913
32256	7H	2	LOGN(4.09, 19.5)	2.5	1	0	28	2.59285714
32257	7H	2	EXPO(2.46)	2.93	0	1	28	2.93103448
32258	7H	1	EXPO(0.881)	0.91	7	1	21	1.20454545
32259	7H	1	LOGN(1.23, 3.51)	0.98	5	0	24	1.17916667
32450	7H	1	EXPO(3.36)	2.9	4	0	25	3.364
32500	7H	2	LOGN(0.226, 0.2)	0.43	5	1	24	0.525
32504	7H	2	LOGN(0.0773, 0.066)	0.11	7	0	22	0.14545455
32675	7H	1	LOGN(1.33, 3.37)	0.97	5	0	24	1.17083333
32676	7H	1	LOGN(2.3, 7.03)	1.71	3	0	26	1.90384615
32683	7H	1	LOGN(1.69, 4.8)	1.13	7	0	22	1.49545455
32687	7H	1	LOGN(1.56, 4.55)	1.13	5	0	24	1.37083333
32688	7H	1	LOGN(2.1, 8.02)	1.39	6	0	23	1.75652174

32689	7H	1	LOGN(1.41, 4.87)	1.14	6	0	23	1.43913043
32694	7H	1	LOGN(1.27, 4.43)	1.21	6	0	23	1.53043478
32695	7H	1	LOGN(1.99, 9.06)	1.83	8	0	21	2.52857143
32696	7H	1	LOGN(0.872, 2.44)	0.79	9	0	20	1.14
32701	ah or as	1	LOGN(5.27, 22.9)	3.39	2	0	25	3.656
32741	AH	1	EXPO(0.582)	0.58	0	0	22	0.58181818
32881	7H	1	LOGN(0.424, 0.731)	0.43	5	0	24	0.525
32882	7H	1	LOGN(0.847, 2.38)	0.93	4	0	25	1.076
42110	ag or as	3	1 + EXPO(9.57)	10.57	0	0	29	10.5724138
52741	AS	1	LOGN(4.21, 7.26)	3.57	0	0	26	3.56538462
52743	AS	1	LOGN(3.45, 13.3)	2.82	1	0	25	2.928
64070	as or ba	1	EXPO(1.6)	1.8	0	1	28	1.80344828
64090	AS	1	LOGN(1.46, 4.36)	1.2	4	0	25	1.396
66018	AS	1	EXPO(1.58)	1.44	2	0	20	1.58
68194	7H	1	LOGN(0.46, 0.861)	0.61	1	0	28	0.63214286

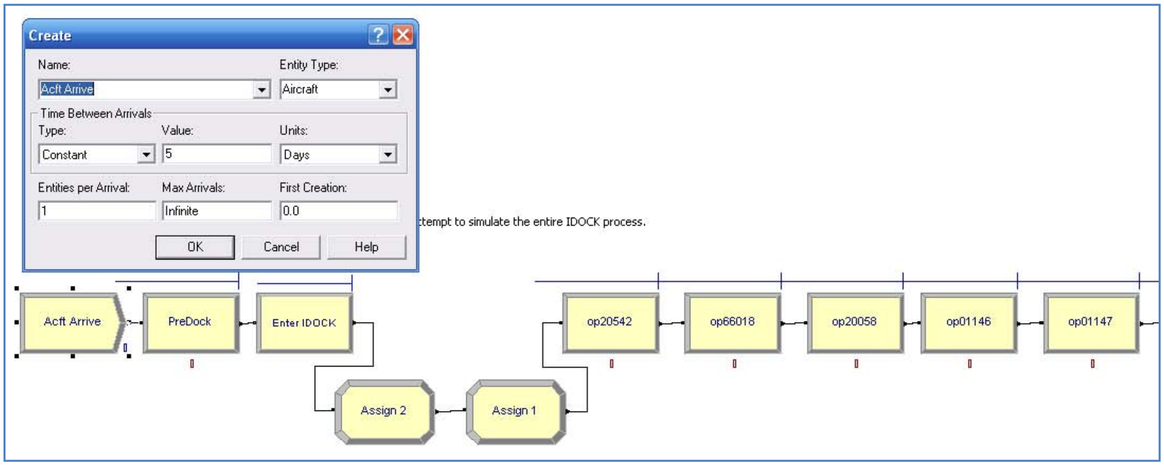
Appendix D: Data of Task Complexity from Tinker AFB Visit

Data Points from Visit to Tinker AFB

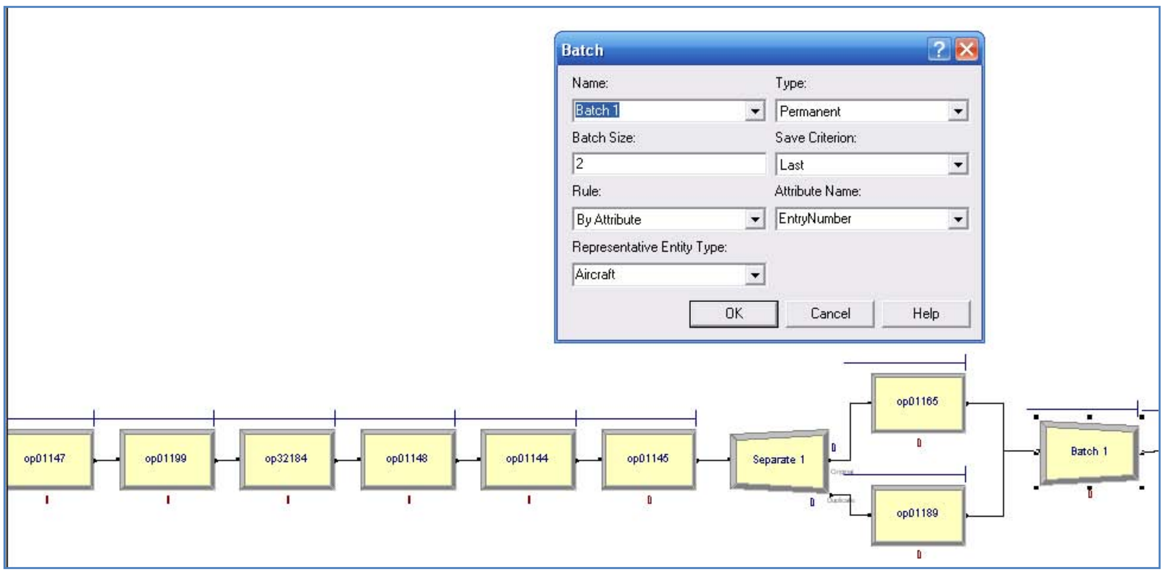
Operation #	Certainty of Occurance	Prerequisite Tasks	Task Priority	Duration	# of People	Other OSs	Complexity to Perform	Difficulty to Train	Training Required
01144	all	no	5	3 hrs	2	as	1	1	ojt
01145	all	no	5	3 hrs	2	as	1	1	ojt
01146	all	no	5	15 min	1	as	3	2	ojt
01147	all	no	5	5-30 min	1	7H (ssq)	4	3	ojt
01148	all	no	5	14 hrs	2	as	1	1	ojt
01158	all	jacked	5	8	5	as	5	5	ojt
01165	all	jacked	5	8	5	as	5	5	ojt
01189	all	jacked	5	8	5	as	5	5	ojt
01199	all	no	5	30 min	2	7h	1	2	ojt
20058	all	no	5	5 min	1	all	1	1	ojt
20542	all	no	5	30 min	1	ah or 8852	1	1	ojt
32030	all	jacked	5	2 hr	1	7h	3	2	ojt
32040	all	strut jack	5	1 hr	7	7h	5	5	ojt
32043	all	jacked	5	10 hrs	2	7h	4	4	ojt
32044	all	insp c/w	5	30 min	1	7h	2	2	ojt
32045	all	insp c/w	5	30 min	1	7h	2	2	ojt
32060	all	no	4	2 hr	1	7h	4	4	ojt
32061	all	no	4	2 hr	1	7h	4	4	ojt
32067	all	gear out	5	1 hr	1	7h	4	3	ojt
32083	all	gear out	2	10 min	1	7h	1	1	ojt
32084	all	gear out	2	10 min	1	7h	1	1	ojt
32157	all	gear out	5	2 hr	1	7h	5	5	ojt
32184	all	cog	5	3 hrs	7	7h (3 ssq)	5	5	ojt/school
32201	all	jacked	5	2 hr	2	7h	4	4	ojt
32202	all	jacked	5	2 hr	2	7h	4	4	ojt
32203	all	jacked	5	2 hr	2	7h	4	3	ojt
32204	all	jacked	5	2 hr	2	7h	4	3	ojt
32205	all	gear out	5	4 hr	2	7h	4	4	ojt
32206	all	gear out	5	4 hr	2	7h	4	4	ojt
32253	all	gear out/clean	5	1.5 hr	1	7h or AS	4	4	ojt
32254	all	gear out/clean	5	1.5 hr	1	7h or AS	4	4	ojt
32256	all	gear out	4	4 hr	1	7h	4	4	ojt
32257	all	gear out	4	4 hr	1	7h	4	4	ojt
32258	all	gear out/clean	4	1 hr	1	7h or AS	4	4	ojt
32259	all	gear out/clean	4	1 hr	1	7h or AS	4	4	ojt
32450	all	gear out/bolt rem	4	4 hr	1	7h or as or ah	3	3	ojt
32500	all	gear out	5	15 min	1	7h	1	1	ojt
32504	all	gear out	5	15 min	2	7h	1	1	ojt
32675	all	gear out	3	1	2	7h	1	2	ojt
32676	all	gear out	3	1	2	7h	1	2	ojt

32683	all	gear out	3	1	2	7h	1	2	ojt
32687	all	gear out	3	1	2	7h	1	2	ojt
32688	all	gear out	3	1	2	7h	1	2	ojt
32689	all	gear out	3	1	2	7h	1	2	ojt
32694	all	gear out	3	1	2	7h	1	2	ojt
32695	all	gear out	3	1	2	7h	1	2	ojt
32696	all	gear out	3	1	2	7h	1	2	ojt
32701	DID NOT GATHER DATA: Told it was not done in this major job.								
32741	all	no	2	30 min	1	ah	1	1	ojt
32881	all	no	2	1 hr	1	7h or aa	1	1	ojt
32882	all	no	2	1 hr	1	7h or aa	1	1	ojt
42110	all	no	5	1 hr	1	as	5	5	ojt
52741	all	trunion rem	5	4-16 hrs	1	as	4	5	ojt
52743	all	trunion rem	5	4-16 hrs	1	as	4	5	ojt
64070	DID NOT GATHER DATA: Told it was not done in this major job.								
64090	DID NOT GATHER DATA: Told it was not done in this major job.								
66018	DID NOT GATHER DATA: Told it was not done in this major job.								
68194	all	uplock act rem	2	1 hr	1	7h	2	1	ojt

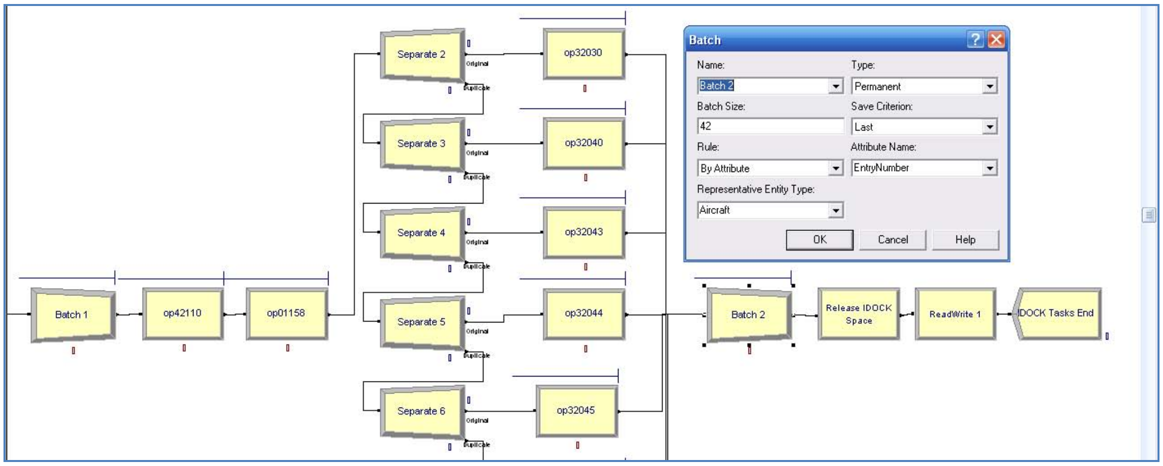
Appendix E: "As-Is" Arena Model



Page 1 of Model with "Acft Arrive" Process Expanded

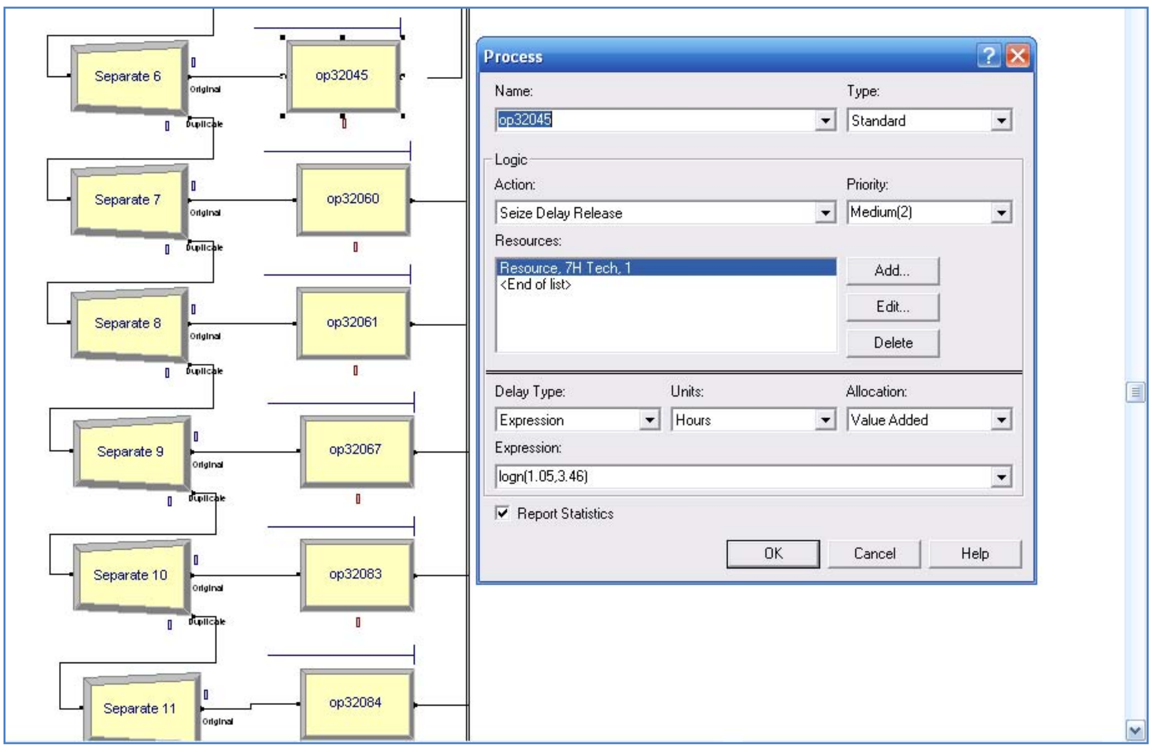


Page 2 of Model with "Batch" Process Expanded

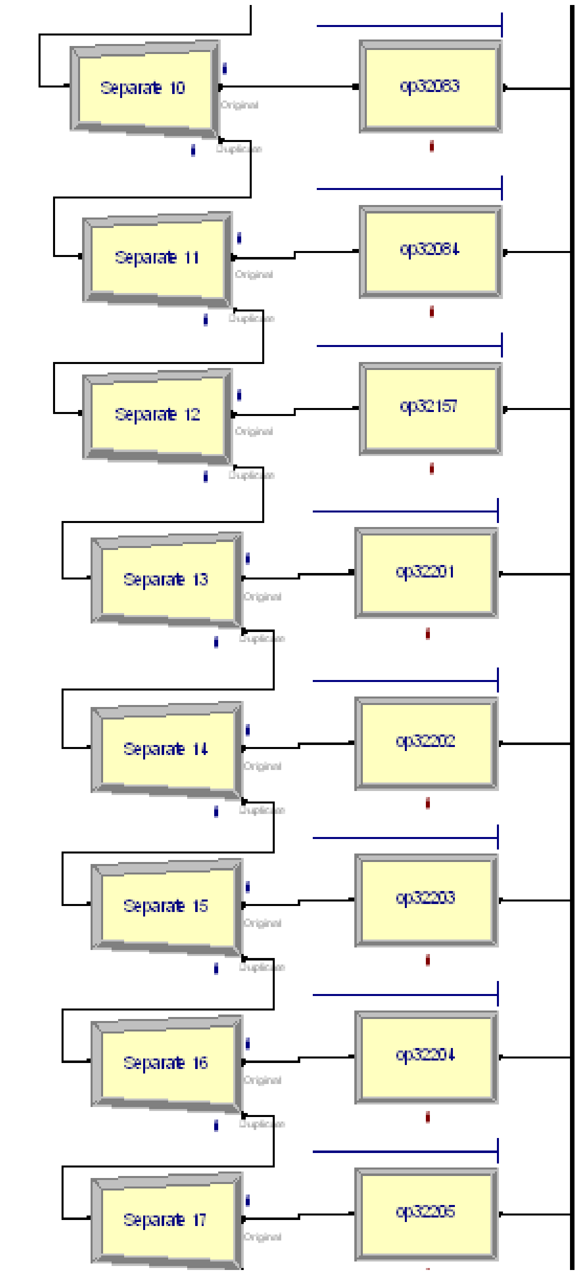


Page 3a of Model with "Batch 2" Process Expanded

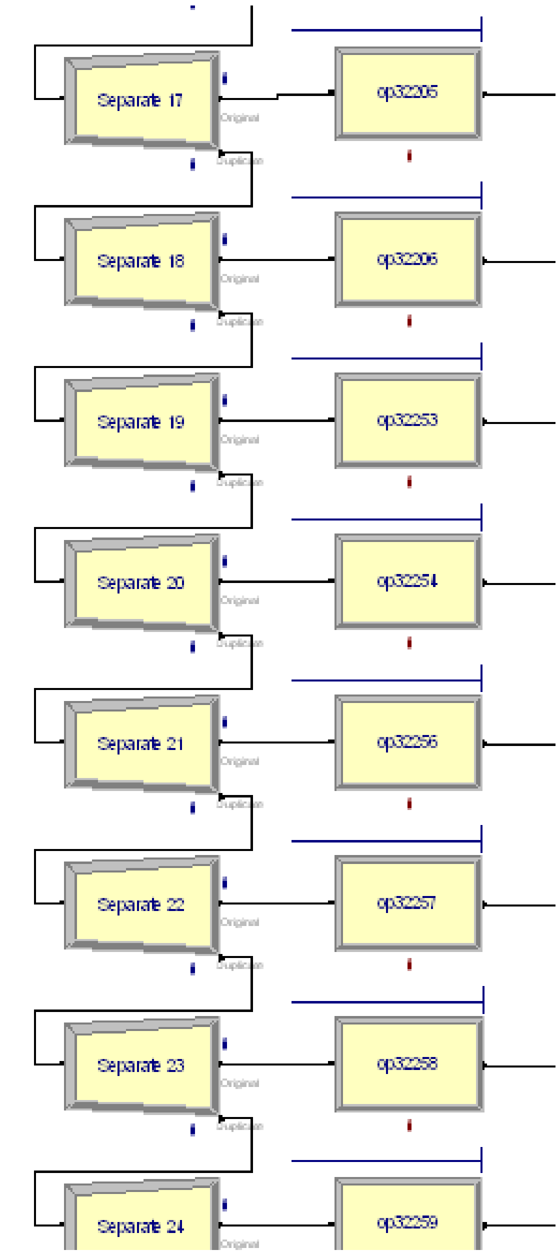
Page 3b through 3g below are in parallel to page 3a.



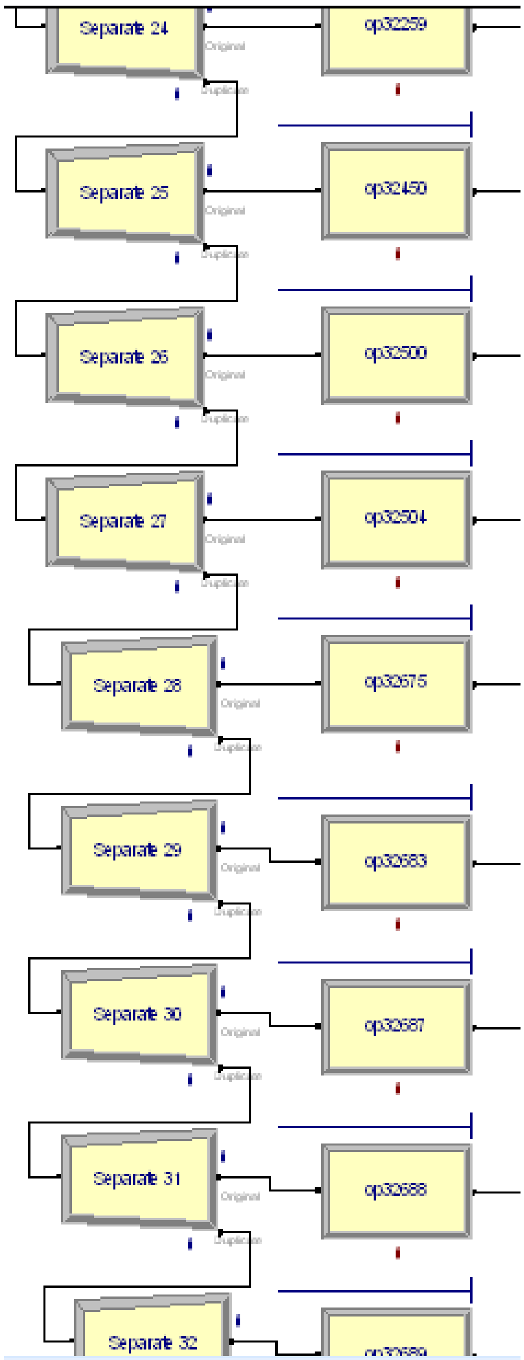
Page 3b of Model with "Op32045" Process Expanded



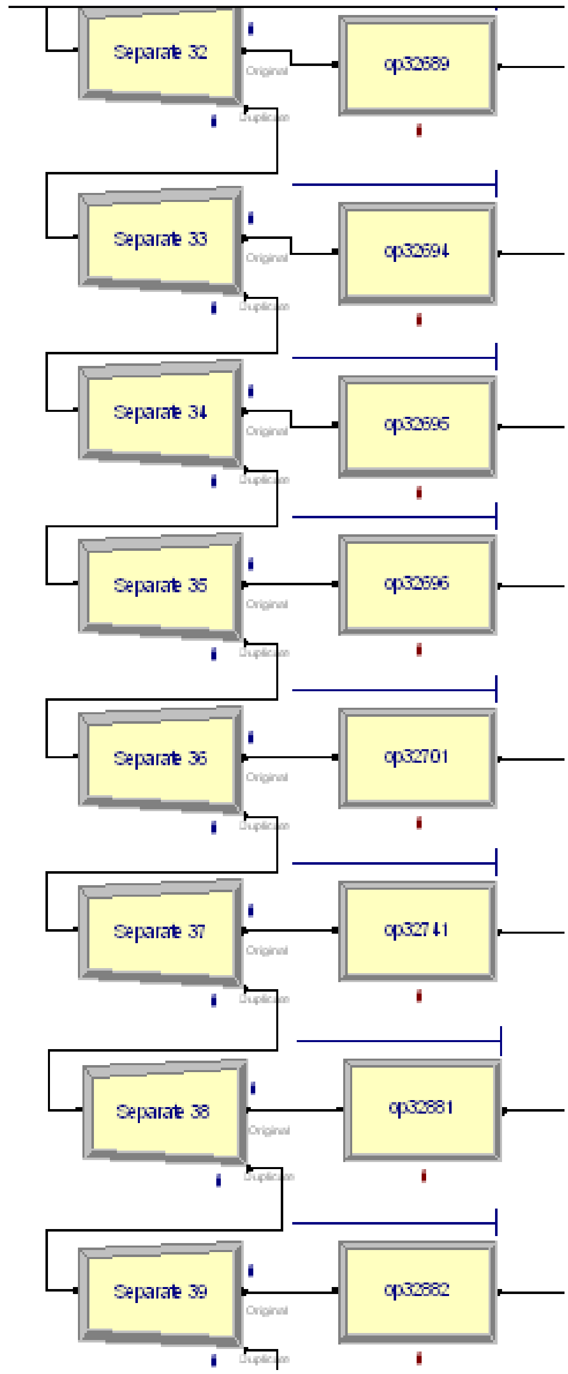
Page 3c of Model



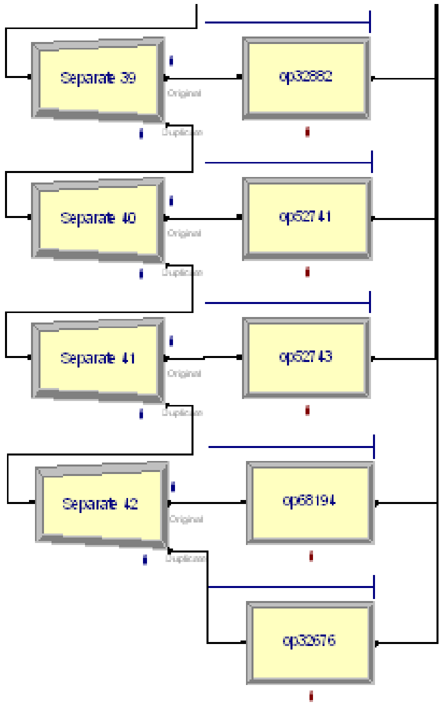
Page 3d of Model



Page 3e of Model



Page 3f of Model



Page 3g of Model

Appendix F: Current State Model Summary Stats

Statistic Name	Database Data Type	Average
7H Tech.NumberSeized	Total Number Seized	8114.36
7H Tech.ScheduledUtilization	Scheduled Utilization	0.491632
AH Tech.NumberSeized	Total Number Seized	314.89
AH Tech.ScheduledUtilization	Scheduled Utilization	0.01458
Aircraft.NumberIn	Number In	6499.14
Aircraft.NumberOut	Number Out	6489.9
AS Tech.NumberSeized	Total Number Seized	5731.68
AS Tech.ScheduledUtilization	Scheduled Utilization	0.574103
IDOCK Space.NumberSeized	Total Number Seized	145.21
IDOCK Space.ScheduledUtilization	Scheduled Utilization	0.826289
PreDockSpace.NumberSeized	Total Number Seized	147
System.NumberOut	Number Out	144.22
7H Tech.NumberBusy	Number Busy	1.474897
7H Tech.NumberScheduled	Number Scheduled	3
7H Tech.Utilization	Instantaneous Utilization	0.491632
AH Tech.NumberBusy	Number Busy	0.02916
AH Tech.NumberScheduled	Number Scheduled	2
AH Tech.Utilization	Instantaneous Utilization	0.01458
Aircraft.NVATime	NVA Time	0
Aircraft.OtherTime	Other Time	0
Aircraft.TotalTime	Total Time	765.2779
Aircraft.TranTime	Transfer Time	0
Aircraft.VATime	VA Time	553.8152
Aircraft.WaitTime	Wait Time	3058.284
Aircraft.WIP	WIP	31.69165
AS Tech.NumberBusy	Number Busy	3.444617
AS Tech.NumberScheduled	Number Scheduled	6
AS Tech.Utilization	Instantaneous Utilization	0.574103
Batch 1.Queue.NumberInQueue	Number Waiting	0.077442
Batch 1.Queue.WaitingTime	Waiting Time	4.692734
Batch 2.Queue.NumberInQueue	Number Waiting	15.90973
Batch 2.Queue.WaitingTime	Waiting Time	45.97884
Enter IDOCK.Queue.NumberInQueue	Number Waiting	0.815802
Enter IDOCK.Queue.WaitingTime	Waiting Time	98.0176
IDOCK Space.NumberBusy	Number Busy	2.478868
IDOCK Space.NumberScheduled	Number Scheduled	3
IDOCK Space.Utilization	Instantaneous Utilization	0.826289
op01144.Queue.NumberInQueue	Number Waiting	0.029865

op01144.Queue.WaitingTime	Waiting Time	3.609819
op01145.Queue.NumberInQueue	Number Waiting	0.015182
op01145.Queue.WaitingTime	Waiting Time	1.838709
op01146.Queue.NumberInQueue	Number Waiting	0.011553
op01146.Queue.WaitingTime	Waiting Time	1.396179
op01147.Queue.NumberInQueue	Number Waiting	9.15E-06
op01147.Queue.WaitingTime	Waiting Time	0.001106
op01148.Queue.NumberInQueue	Number Waiting	0.093376
op01148.Queue.WaitingTime	Waiting Time	11.30664
op01158.Queue.NumberInQueue	Number Waiting	0.058252
op01158.Queue.WaitingTime	Waiting Time	7.054331
op01165.Queue.NumberInQueue	Number Waiting	0.057057
op01165.Queue.WaitingTime	Waiting Time	6.908234
op01189.Queue.NumberInQueue	Number Waiting	0.14402
op01189.Queue.WaitingTime	Waiting Time	17.43624
op01199.Queue.NumberInQueue	Number Waiting	0.151881
op01199.Queue.WaitingTime	Waiting Time	18.34471
op20058.Queue.NumberInQueue	Number Waiting	0.016326
op20058.Queue.WaitingTime	Waiting Time	1.969692
op20542.Queue.NumberInQueue	Number Waiting	1.32E-06
op20542.Queue.WaitingTime	Waiting Time	0.000159
op32030.Queue.NumberInQueue	Number Waiting	0.086003
op32030.Queue.WaitingTime	Waiting Time	10.44063
op32040.Queue.NumberInQueue	Number Waiting	0.091501
op32040.Queue.WaitingTime	Waiting Time	11.10824
op32043.Queue.NumberInQueue	Number Waiting	0.123442
op32043.Queue.WaitingTime	Waiting Time	14.97754
op32044.Queue.NumberInQueue	Number Waiting	0.019499
op32044.Queue.WaitingTime	Waiting Time	2.367902
op32045.Queue.NumberInQueue	Number Waiting	0.02383
op32045.Queue.WaitingTime	Waiting Time	2.89364
op32060.Queue.NumberInQueue	Number Waiting	0.030375
op32060.Queue.WaitingTime	Waiting Time	3.688034
op32061.Queue.NumberInQueue	Number Waiting	0.041533
op32061.Queue.WaitingTime	Waiting Time	5.041998
op32067.Queue.NumberInQueue	Number Waiting	0.052891
op32067.Queue.WaitingTime	Waiting Time	6.419704
op32083.Queue.NumberInQueue	Number Waiting	0.055274
op32083.Queue.WaitingTime	Waiting Time	6.709574
op32084.Queue.NumberInQueue	Number Waiting	0.057915

op32084.Queue.WaitingTime	Waiting Time	7.030063
op32157.Queue.NumberInQueue	Number Waiting	0.061178
op32157.Queue.WaitingTime	Waiting Time	7.426283
op32184.Queue.NumberInQueue	Number Waiting	0.588227
op32184.Queue.WaitingTime	Waiting Time	71.0373
op32201.Queue.NumberInQueue	Number Waiting	0.206902
op32201.Queue.WaitingTime	Waiting Time	25.07506
op32202.Queue.NumberInQueue	Number Waiting	0.278997
op32202.Queue.WaitingTime	Waiting Time	33.81878
op32203.Queue.NumberInQueue	Number Waiting	0.323358
op32203.Queue.WaitingTime	Waiting Time	39.20387
op32204.Queue.NumberInQueue	Number Waiting	0.365902
op32204.Queue.WaitingTime	Waiting Time	44.36692
op32205.Queue.NumberInQueue	Number Waiting	0.391766
op32205.Queue.WaitingTime	Waiting Time	47.50852
op32206.Queue.NumberInQueue	Number Waiting	0.423485
op32206.Queue.WaitingTime	Waiting Time	51.35901
op32253.Queue.NumberInQueue	Number Waiting	0.071696
op32253.Queue.WaitingTime	Waiting Time	8.701814
op32254.Queue.NumberInQueue	Number Waiting	0.08378
op32254.Queue.WaitingTime	Waiting Time	10.16773
op32256.Queue.NumberInQueue	Number Waiting	0.464322
op32256.Queue.WaitingTime	Waiting Time	56.31926
op32257.Queue.NumberInQueue	Number Waiting	0.504384
op32257.Queue.WaitingTime	Waiting Time	61.20232
op32258.Queue.NumberInQueue	Number Waiting	0.094737
op32258.Queue.WaitingTime	Waiting Time	11.49749
op32259.Queue.NumberInQueue	Number Waiting	0.100788
op32259.Queue.WaitingTime	Waiting Time	12.23136
op32450.Queue.NumberInQueue	Number Waiting	0.107817
op32450.Queue.WaitingTime	Waiting Time	13.08406
op32500.Queue.NumberInQueue	Number Waiting	0.529971
op32500.Queue.WaitingTime	Waiting Time	64.30496
op32504.Queue.NumberInQueue	Number Waiting	0.532237
op32504.Queue.WaitingTime	Waiting Time	64.58376
op32675.Queue.NumberInQueue	Number Waiting	0.127454
op32675.Queue.WaitingTime	Waiting Time	15.46668
op32676.Queue.NumberInQueue	Number Waiting	0.198938
op32676.Queue.WaitingTime	Waiting Time	24.14217
op32683.Queue.NumberInQueue	Number Waiting	0.135474

op32683.Queue.WaitingTime	Waiting Time	16.43985
op32687.Queue.NumberInQueue	Number Waiting	0.14481
op32687.Queue.WaitingTime	Waiting Time	17.57498
op32688.Queue.NumberInQueue	Number Waiting	0.15309
op32688.Queue.WaitingTime	Waiting Time	18.57945
op32689.Queue.NumberInQueue	Number Waiting	0.162699
op32689.Queue.WaitingTime	Waiting Time	19.74535
op32694.Queue.NumberInQueue	Number Waiting	0.1696
op32694.Queue.WaitingTime	Waiting Time	20.58257
op32695.Queue.NumberInQueue	Number Waiting	0.17582
op32695.Queue.WaitingTime	Waiting Time	21.33612
op32696.Queue.NumberInQueue	Number Waiting	0.184031
op32696.Queue.WaitingTime	Waiting Time	22.33179
op32701.Queue.NumberInQueue	Number Waiting	0
op32701.Queue.WaitingTime	Waiting Time	0
op32741.Queue.NumberInQueue	Number Waiting	1.98E-05
op32741.Queue.WaitingTime	Waiting Time	0.002406
op32881.Queue.NumberInQueue	Number Waiting	0.18878
op32881.Queue.WaitingTime	Waiting Time	22.90826
op32882.Queue.NumberInQueue	Number Waiting	0.191569
op32882.Queue.WaitingTime	Waiting Time	23.24677
op42110.Queue.NumberInQueue	Number Waiting	0.053658
op42110.Queue.WaitingTime	Waiting Time	6.499888
op52741.Queue.NumberInQueue	Number Waiting	0.004704
op52741.Queue.WaitingTime	Waiting Time	0.570326
op52743.Queue.NumberInQueue	Number Waiting	0.008965
op52743.Queue.WaitingTime	Waiting Time	1.087826
op66018.Queue.NumberInQueue	Number Waiting	0.042188
op66018.Queue.WaitingTime	Waiting Time	5.08851
op68194.Queue.NumberInQueue	Number Waiting	0.196087
op68194.Queue.WaitingTime	Waiting Time	23.79513
PreDock.Queue.NumberInQueue	Number Waiting	0
PreDock.Queue.WaitingTime	Waiting Time	0
PreDockSpace.NumberBusy	Number Busy	3.074643

Appendix G: Model 2 Summary Stats

Statistic Name	Database Data Type	Average
7H Tech.NumberSeized	Total Number Seized	7528.23
7H Tech.ScheduledUtilization	Scheduled Utilization	0.491287
AH Tech.NumberSeized	Total Number Seized	626.42
AH Tech.ScheduledUtilization	Scheduled Utilization	0.013951
Aircraft.NumberIn	Number In	6494.74
Aircraft.NumberOut	Number Out	6486.3
AS Tech.NumberSeized	Total Number Seized	5992.18
AS Tech.ScheduledUtilization	Scheduled Utilization	0.575758
IDOCK Space.NumberSeized	Total Number Seized	144.92
IDOCK Space.ScheduledUtilization	Scheduled Utilization	0.825734
PreDockSpace.NumberSeized	Total Number Seized	147
System.NumberOut	Number Out	144.14
7H Tech.NumberBusy	Number Busy	1.473862
7H Tech.NumberScheduled	Number Scheduled	3
7H Tech.Utilization	Instantaneous Utilization	0.491287
AH Tech.NumberBusy	Number Busy	0.027902
AH Tech.NumberScheduled	Number Scheduled	2
AH Tech.Utilization	Instantaneous Utilization	0.013951
Aircraft.NVATime	NVA Time	0
Aircraft.OtherTime	Other Time	0
Aircraft.TotalTime	Total Time	777.5648
Aircraft.TranTime	Transfer Time	0
Aircraft.VATime	VA Time	552.8673
Aircraft.WaitTime	Wait Time	3047.034
Aircraft.WIP	WIP	31.52931
AS Tech.NumberBusy	Number Busy	3.454549
AS Tech.NumberScheduled	Number Scheduled	6
AS Tech.Utilization	Instantaneous Utilization	0.575758
Batch 1.Queue.NumberInQueue	Number Waiting	0.07738
Batch 1.Queue.WaitingTime	Waiting Time	4.691042
Batch 2.Queue.NumberInQueue	Number Waiting	16.78801
Batch 2.Queue.WaitingTime	Waiting Time	48.61924
Enter IDOCK.Queue.NumberInQueue	Number Waiting	0.928788
Enter IDOCK.Queue.WaitingTime	Waiting Time	111.7505
IDOCK Space.NumberBusy	Number Busy	2.477202
IDOCK Space.NumberScheduled	Number Scheduled	3
IDOCK Space.Utilization	Instantaneous Utilization	0.825734
op01144.Queue.NumberInQueue	Number Waiting	0.030107

op01144.Queue.WaitingTime	Waiting Time	3.648623
op01145.Queue.NumberInQueue	Number Waiting	0.015991
op01145.Queue.WaitingTime	Waiting Time	1.937383
op01146.Queue.NumberInQueue	Number Waiting	0.010118
op01146.Queue.WaitingTime	Waiting Time	1.222385
op01147.Queue.NumberInQueue	Number Waiting	2.01E-05
op01147.Queue.WaitingTime	Waiting Time	0.00243
op01148.Queue.NumberInQueue	Number Waiting	0.094993
op01148.Queue.WaitingTime	Waiting Time	11.52506
op01158.Queue.NumberInQueue	Number Waiting	0.057567
op01158.Queue.WaitingTime	Waiting Time	6.987464
op01165.Queue.NumberInQueue	Number Waiting	0.056855
op01165.Queue.WaitingTime	Waiting Time	6.889684
op01189.Queue.NumberInQueue	Number Waiting	0.144388
op01189.Queue.WaitingTime	Waiting Time	17.50828
op01199.Queue.NumberInQueue	Number Waiting	0.153247
op01199.Queue.WaitingTime	Waiting Time	18.54402
op20058.Queue.NumberInQueue	Number Waiting	0.01585
op20058.Queue.WaitingTime	Waiting Time	1.918492
op20542.Queue.NumberInQueue	Number Waiting	3.63E-06
op20542.Queue.WaitingTime	Waiting Time	0.00044
op32030.Queue.NumberInQueue	Number Waiting	0.08338
op32030.Queue.WaitingTime	Waiting Time	10.15587
op32040.Queue.NumberInQueue	Number Waiting	0.08869
op32040.Queue.WaitingTime	Waiting Time	10.80164
op32043.Queue.NumberInQueue	Number Waiting	0.120127
op32043.Queue.WaitingTime	Waiting Time	14.62181
op32044.Queue.NumberInQueue	Number Waiting	0.017877
op32044.Queue.WaitingTime	Waiting Time	2.17147
op32045.Queue.NumberInQueue	Number Waiting	0.02226
op32045.Queue.WaitingTime	Waiting Time	2.70398
op32060.Queue.NumberInQueue	Number Waiting	0.028952
op32060.Queue.WaitingTime	Waiting Time	3.516353
op32061.Queue.NumberInQueue	Number Waiting	0.040299
op32061.Queue.WaitingTime	Waiting Time	4.894441
op32067.Queue.NumberInQueue	Number Waiting	0.051535
op32067.Queue.WaitingTime	Waiting Time	6.259044
op32083.Queue.NumberInQueue	Number Waiting	0.053948
op32083.Queue.WaitingTime	Waiting Time	6.552193
op32084.Queue.NumberInQueue	Number Waiting	0.056552

op32084.Queue.WaitingTime	Waiting Time	6.868404
op32157.Queue.NumberInQueue	Number Waiting	0.059837
op32157.Queue.WaitingTime	Waiting Time	7.267185
op32184.Queue.NumberInQueue	Number Waiting	0.595581
op32184.Queue.WaitingTime	Waiting Time	72.09714
op32201.Queue.NumberInQueue	Number Waiting	0.205168
op32201.Queue.WaitingTime	Waiting Time	24.92441
op32202.Queue.NumberInQueue	Number Waiting	0.277244
op32202.Queue.WaitingTime	Waiting Time	33.68573
op32203.Queue.NumberInQueue	Number Waiting	0.321507
op32203.Queue.WaitingTime	Waiting Time	39.06326
op32204.Queue.NumberInQueue	Number Waiting	0.364437
op32204.Queue.WaitingTime	Waiting Time	44.28848
op32205.Queue.NumberInQueue	Number Waiting	0.390303
op32205.Queue.WaitingTime	Waiting Time	47.44264
op32206.Queue.NumberInQueue	Number Waiting	0.422195
op32206.Queue.WaitingTime	Waiting Time	51.3167
op32253.Queue.NumberInQueue	Number Waiting	0.069735
op32253.Queue.WaitingTime	Waiting Time	8.470841
op32254.Queue.NumberInQueue	Number Waiting	0.081209
op32254.Queue.WaitingTime	Waiting Time	9.865315
op32256.Queue.NumberInQueue	Number Waiting	0.462698
op32256.Queue.WaitingTime	Waiting Time	56.24683
op32257.Queue.NumberInQueue	Number Waiting	0.50422
op32257.Queue.WaitingTime	Waiting Time	61.30875
op32258.Queue.NumberInQueue	Number Waiting	0.091948
op32258.Queue.WaitingTime	Waiting Time	11.16947
op32259.Queue.NumberInQueue	Number Waiting	0.097968
op32259.Queue.WaitingTime	Waiting Time	11.90029
op32450.Queue.NumberInQueue	Number Waiting	0.105359
op32450.Queue.WaitingTime	Waiting Time	12.79766
op32500.Queue.NumberInQueue	Number Waiting	2.88E-05
op32500.Queue.WaitingTime	Waiting Time	0.003496
op32504.Queue.NumberInQueue	Number Waiting	0.002048
op32504.Queue.WaitingTime	Waiting Time	0.248798
op32675.Queue.NumberInQueue	Number Waiting	0.124759
op32675.Queue.WaitingTime	Waiting Time	15.15525
op32676.Queue.NumberInQueue	Number Waiting	0.195734
op32676.Queue.WaitingTime	Waiting Time	23.78213
op32683.Queue.NumberInQueue	Number Waiting	0.132579

op32683.Queue.WaitingTime	Waiting Time	16.10533
op32687.Queue.NumberInQueue	Number Waiting	0.141515
op32687.Queue.WaitingTime	Waiting Time	17.19125
op32688.Queue.NumberInQueue	Number Waiting	0.149796
op32688.Queue.WaitingTime	Waiting Time	18.19848
op32689.Queue.NumberInQueue	Number Waiting	0.159371
op32689.Queue.WaitingTime	Waiting Time	19.36294
op32694.Queue.NumberInQueue	Number Waiting	0.166502
op32694.Queue.WaitingTime	Waiting Time	20.2297
op32695.Queue.NumberInQueue	Number Waiting	0.172958
op32695.Queue.WaitingTime	Waiting Time	21.01421
op32696.Queue.NumberInQueue	Number Waiting	0.181094
op32696.Queue.WaitingTime	Waiting Time	22.0028
op32701.Queue.NumberInQueue	Number Waiting	7.83E-05
op32701.Queue.WaitingTime	Waiting Time	0.009499
op32741.Queue.NumberInQueue	Number Waiting	0.00222
op32741.Queue.WaitingTime	Waiting Time	0.269719
op32881.Queue.NumberInQueue	Number Waiting	0.185692
op32881.Queue.WaitingTime	Waiting Time	22.562
op32882.Queue.NumberInQueue	Number Waiting	0.188428
op32882.Queue.WaitingTime	Waiting Time	22.89439
op42110.Queue.NumberInQueue	Number Waiting	0.052286
op42110.Queue.WaitingTime	Waiting Time	6.34087
op52741.Queue.NumberInQueue	Number Waiting	0.008067
op52741.Queue.WaitingTime	Waiting Time	0.980794
op52743.Queue.NumberInQueue	Number Waiting	0.011936
op52743.Queue.WaitingTime	Waiting Time	1.451594
op66018.Queue.NumberInQueue	Number Waiting	0.03946
op66018.Queue.WaitingTime	Waiting Time	4.771249
op68194.Queue.NumberInQueue	Number Waiting	0.192943
op68194.Queue.WaitingTime	Waiting Time	23.44292
PreDock.Queue.NumberInQueue	Number Waiting	0
PreDock.Queue.WaitingTime	Waiting Time	0
PreDockSpace.NumberBusy	Number Busy	3.064157

Appendix H: Model 3 Summary Stats

Statistic Name	Database Data Type	Average
7H Tech.NumberSeized	Total Number Seized	5800.62
7H Tech.ScheduledUtilization	Scheduled Utilization	0.448265
AH Tech.NumberSeized	Total Number Seized	1294.07
AH Tech.ScheduledUtilization	Scheduled Utilization	0.062313
Aircraft.NumberIn	Number In	6546.42
Aircraft.NumberOut	Number Out	6536.7
AS Tech.NumberSeized	Total Number Seized	7162.1
AS Tech.ScheduledUtilization	Scheduled Utilization	0.590188
IDOCK Space.NumberSeized	Total Number Seized	145.83
IDOCK Space.ScheduledUtilization	Scheduled Utilization	0.699076
PreDockSpace.NumberSeized	Total Number Seized	147
System.NumberOut	Number Out	145.26
7H Tech.NumberBusy	Number Busy	1.344795
7H Tech.NumberScheduled	Number Scheduled	3
7H Tech.Utilization	Instantaneous Utilization	0.448265
AH Tech.NumberBusy	Number Busy	0.124625
AH Tech.NumberScheduled	Number Scheduled	2
AH Tech.Utilization	Instantaneous Utilization	0.062313
Aircraft.NVATime	NVA Time	0
Aircraft.OtherTime	Other Time	0
Aircraft.TotalTime	Total Time	650.0961
Aircraft.TranTime	Transfer Time	0
Aircraft.VATime	VA Time	556.7697
Aircraft.WaitTime	Wait Time	2739.863
Aircraft.WIP	WIP	29.13928
AS Tech.NumberBusy	Number Busy	3.541129
AS Tech.NumberScheduled	Number Scheduled	6
AS Tech.Utilization	Instantaneous Utilization	0.590188
Batch 1.Queue.NumberInQueue	Number Waiting	0.077731
Batch 1.Queue.WaitingTime	Waiting Time	4.675877
Batch 2.Queue.NumberInQueue	Number Waiting	17.58623
Batch 2.Queue.WaitingTime	Waiting Time	50.45961
Enter IDOCK.Queue.NumberInQueue	Number Waiting	0.249633
Enter IDOCK.Queue.WaitingTime	Waiting Time	29.89458
IDOCK Space.NumberBusy	Number Busy	2.097229
IDOCK Space.NumberScheduled	Number Scheduled	3
IDOCK Space.Utilization	Instantaneous Utilization	0.699076

op01144.Queue.NumberInQueue	Number Waiting	2.53E-05
op01144.Queue.WaitingTime	Waiting Time	0.003039
op01145.Queue.NumberInQueue	Number Waiting	0
op01145.Queue.WaitingTime	Waiting Time	0
op01146.Queue.NumberInQueue	Number Waiting	0.017739
op01146.Queue.WaitingTime	Waiting Time	2.132684
op01147.Queue.NumberInQueue	Number Waiting	2.81E-05
op01147.Queue.WaitingTime	Waiting Time	0.003371
op01148.Queue.NumberInQueue	Number Waiting	0.079684
op01148.Queue.WaitingTime	Waiting Time	9.589353
op01158.Queue.NumberInQueue	Number Waiting	0.051998
op01158.Queue.WaitingTime	Waiting Time	6.263114
op01165.Queue.NumberInQueue	Number Waiting	0.064091
op01165.Queue.WaitingTime	Waiting Time	7.711075
op01189.Queue.NumberInQueue	Number Waiting	0.151264
op01189.Queue.WaitingTime	Waiting Time	18.19921
op01199.Queue.NumberInQueue	Number Waiting	0.000356
op01199.Queue.WaitingTime	Waiting Time	0.043048
op20058.Queue.NumberInQueue	Number Waiting	7.3E-05
op20058.Queue.WaitingTime	Waiting Time	0.008761
op20542.Queue.NumberInQueue	Number Waiting	0.000141
op20542.Queue.WaitingTime	Waiting Time	0.016994
op32030.Queue.NumberInQueue	Number Waiting	0.074565
op32030.Queue.WaitingTime	Waiting Time	8.971644
op32040.Queue.NumberInQueue	Number Waiting	0.079635
op32040.Queue.WaitingTime	Waiting Time	9.583092
op32043.Queue.NumberInQueue	Number Waiting	0.114135
op32043.Queue.WaitingTime	Waiting Time	13.74546
op32044.Queue.NumberInQueue	Number Waiting	0.007456
op32044.Queue.WaitingTime	Waiting Time	0.897968
op32045.Queue.NumberInQueue	Number Waiting	0.011976
op32045.Queue.WaitingTime	Waiting Time	1.442537
op32060.Queue.NumberInQueue	Number Waiting	0.019075
op32060.Queue.WaitingTime	Waiting Time	2.297809
op32061.Queue.NumberInQueue	Number Waiting	0.03087
op32061.Queue.WaitingTime	Waiting Time	3.719112
op32067.Queue.NumberInQueue	Number Waiting	0.042705
op32067.Queue.WaitingTime	Waiting Time	5.144357
op32083.Queue.NumberInQueue	Number Waiting	0.000445
op32083.Queue.WaitingTime	Waiting Time	0.053563

op32084.Queue.NumberInQueue	Number Waiting	0.000506
op32084.Queue.WaitingTime	Waiting Time	0.060948
op32157.Queue.NumberInQueue	Number Waiting	0.045108
op32157.Queue.WaitingTime	Waiting Time	5.433878
op32184.Queue.NumberInQueue	Number Waiting	0.467115
op32184.Queue.WaitingTime	Waiting Time	56.1092
op32201.Queue.NumberInQueue	Number Waiting	0.196074
op32201.Queue.WaitingTime	Waiting Time	23.61947
op32202.Queue.NumberInQueue	Number Waiting	0.267924
op32202.Queue.WaitingTime	Waiting Time	32.28095
op32203.Queue.NumberInQueue	Number Waiting	0.313746
op32203.Queue.WaitingTime	Waiting Time	37.80341
op32204.Queue.NumberInQueue	Number Waiting	0.351679
op32204.Queue.WaitingTime	Waiting Time	42.37203
op32205.Queue.NumberInQueue	Number Waiting	0.37616
op32205.Queue.WaitingTime	Waiting Time	45.32989
op32206.Queue.NumberInQueue	Number Waiting	0.405733
op32206.Queue.WaitingTime	Waiting Time	48.89195
op32253.Queue.NumberInQueue	Number Waiting	0.056088
op32253.Queue.WaitingTime	Waiting Time	6.758013
op32254.Queue.NumberInQueue	Number Waiting	0.068894
op32254.Queue.WaitingTime	Waiting Time	8.300852
op32256.Queue.NumberInQueue	Number Waiting	0.443611
op32256.Queue.WaitingTime	Waiting Time	53.4492
op32257.Queue.NumberInQueue	Number Waiting	0.480988
op32257.Queue.WaitingTime	Waiting Time	57.95019
op32258.Queue.NumberInQueue	Number Waiting	0.080519
op32258.Queue.WaitingTime	Waiting Time	9.701291
op32259.Queue.NumberInQueue	Number Waiting	0.086933
op32259.Queue.WaitingTime	Waiting Time	10.47366
op32450.Queue.NumberInQueue	Number Waiting	0.094841
op32450.Queue.WaitingTime	Waiting Time	11.42628
op32500.Queue.NumberInQueue	Number Waiting	0.01439
op32500.Queue.WaitingTime	Waiting Time	1.732594
op32504.Queue.NumberInQueue	Number Waiting	0.016185
op32504.Queue.WaitingTime	Waiting Time	1.948868
op32675.Queue.NumberInQueue	Number Waiting	0.000667
op32675.Queue.WaitingTime	Waiting Time	0.080311
op32676.Queue.NumberInQueue	Number Waiting	0.015235
op32676.Queue.WaitingTime	Waiting Time	1.834595

op32683.Queue.NumberInQueue	Number Waiting	0.001899
op32683.Queue.WaitingTime	Waiting Time	0.228722
op32687.Queue.NumberInQueue	Number Waiting	0.003918
op32687.Queue.WaitingTime	Waiting Time	0.471948
op32688.Queue.NumberInQueue	Number Waiting	0.005329
op32688.Queue.WaitingTime	Waiting Time	0.642293
op32689.Queue.NumberInQueue	Number Waiting	0.006877
op32689.Queue.WaitingTime	Waiting Time	0.828667
op32694.Queue.NumberInQueue	Number Waiting	0.00836
op32694.Queue.WaitingTime	Waiting Time	1.007439
op32695.Queue.NumberInQueue	Number Waiting	0.009805
op32695.Queue.WaitingTime	Waiting Time	1.181395
op32696.Queue.NumberInQueue	Number Waiting	0.011387
op32696.Queue.WaitingTime	Waiting Time	1.372056
op32701.Queue.NumberInQueue	Number Waiting	0.001393
op32701.Queue.WaitingTime	Waiting Time	0.167789
op32741.Queue.NumberInQueue	Number Waiting	0.01691
op32741.Queue.WaitingTime	Waiting Time	2.036356
op32881.Queue.NumberInQueue	Number Waiting	0.012802
op32881.Queue.WaitingTime	Waiting Time	1.542431
op32882.Queue.NumberInQueue	Number Waiting	0.013988
op32882.Queue.WaitingTime	Waiting Time	1.685266
op42110.Queue.NumberInQueue	Number Waiting	0.041294
op42110.Queue.WaitingTime	Waiting Time	4.96643
op52741.Queue.NumberInQueue	Number Waiting	0.004331
op52741.Queue.WaitingTime	Waiting Time	0.521979
op52743.Queue.NumberInQueue	Number Waiting	0.008793
op52743.Queue.WaitingTime	Waiting Time	1.057715
op66018.Queue.NumberInQueue	Number Waiting	0.041854
op66018.Queue.WaitingTime	Waiting Time	5.026512
op68194.Queue.NumberInQueue	Number Waiting	0.116179
op68194.Queue.WaitingTime	Waiting Time	13.99663
PreDock.Queue.NumberInQueue	Number Waiting	0
PreDock.Queue.WaitingTime	Waiting Time	0
PreDockSpace.NumberBusy	Number Busy	3.070331

Appendix I: Model 4 Simulation Results

Statistic Name	Database Data Type	Average
7H Tech.NumberSeized	Total Number Seized	8766.93
AH Tech.NumberSeized	Total Number Seized	462.58
Aircraft.NumberIn	Number In	6573.95
Aircraft.NumberOut	Number Out	6568.65
AS Tech.NumberSeized	Total Number Seized	5083.2
IDOCK Space.NumberSeized	Total Number Seized	145.99
IDOCK Space.ScheduledUtilization	Scheduled Utilization	0.321525
PreDockSpace.NumberSeized	Total Number Seized	147
System.NumberOut	Number Out	145.97
7H Tech.NumberBusy	Number Busy	2.021995
AH Tech.NumberBusy	Number Busy	0.172902
Aircraft.NVATime	NVA Time	0
Aircraft.OtherTime	Other Time	0
Aircraft.TotalTime	Total Time	484.9375
Aircraft.TranTime	Transfer Time	0
Aircraft.VATime	VA Time	553.1313
Aircraft.WaitTime	Wait Time	982.7678
Aircraft.WIP	WIP	13.77321
AS Tech.NumberBusy	Number Busy	2.795573
Batch 1.Queue.NumberInQueue	Number Waiting	0.06943
Batch 1.Queue.WaitingTime	Waiting Time	4.164117
Batch 2.Queue.NumberInQueue	Number Waiting	8.153757
Batch 2.Queue.WaitingTime	Waiting Time	23.19356
Enter IDOCK.Queue.NumberInQueue	Number Waiting	0.002575
Enter IDOCK.Queue.WaitingTime	Waiting Time	0.30859
IDOCK Space.NumberBusy	Number Busy	0.964574
IDOCK Space.NumberScheduled	Number Scheduled	3
IDOCK Space.Utilization	Instantaneous Utilization	0.321525

Appendix J: Blue Dart

Blue Dart Submission Form

First Name: ___Andrew______________ Last Name: ___Levien_________________

Rank (Military, AD, etc.): __Major_________ Designator #__AFIT/ILS/ENS/10J-03_

Student's Involved in Research for Blue Dart:__None_____________________________
____

Position/Title:
__Student____

Phone Number: __302-943-1428____ E-mail: __andrew.levien@afit.edu__________

School/Organization: ___AFIT/ENS______________________________________

Status: [X] Student [ ] Faculty [ ] Staff [ ] Other

Optimal Media Outlet (optional): ____

Optimal Time of Publication (optional): ____________________________________

General Category / Classification:

[ ] core values	[ ] command	[ ] strategy
[ ] war on terror	[ ] culture & language	[ ] leadership & ethics
[ ] warfighting	[ ] international security	[ ] doctrine

[X] other (specify): _Workforce Composition_________________________________

Suggested Headline: _Flexibility Key to Dynamic Work Environments____________

Keywords: __Cross-Training, Workforce Flexibility, Work Flow Simulation, Depot Workforce__

Blue Dart

This research addresses Air Force Material Command's desire to develop a flexible depot workforce to meet the demands of maintaining an ever-changing and aging aircraft fleet. Air Force depot maintenance personnel are currently (and have been for quite some time) categorized in very narrow occupational specialties, resulting in the approximately 23,000 personnel to be spread over 171 different occupational specialties. Much of the depot work maintenance workload has decreased in volume but increased in velocity, thereby demanding a more flexible workforce that can perform skills from multiple occupational specialties in support of Lean strategies for production.

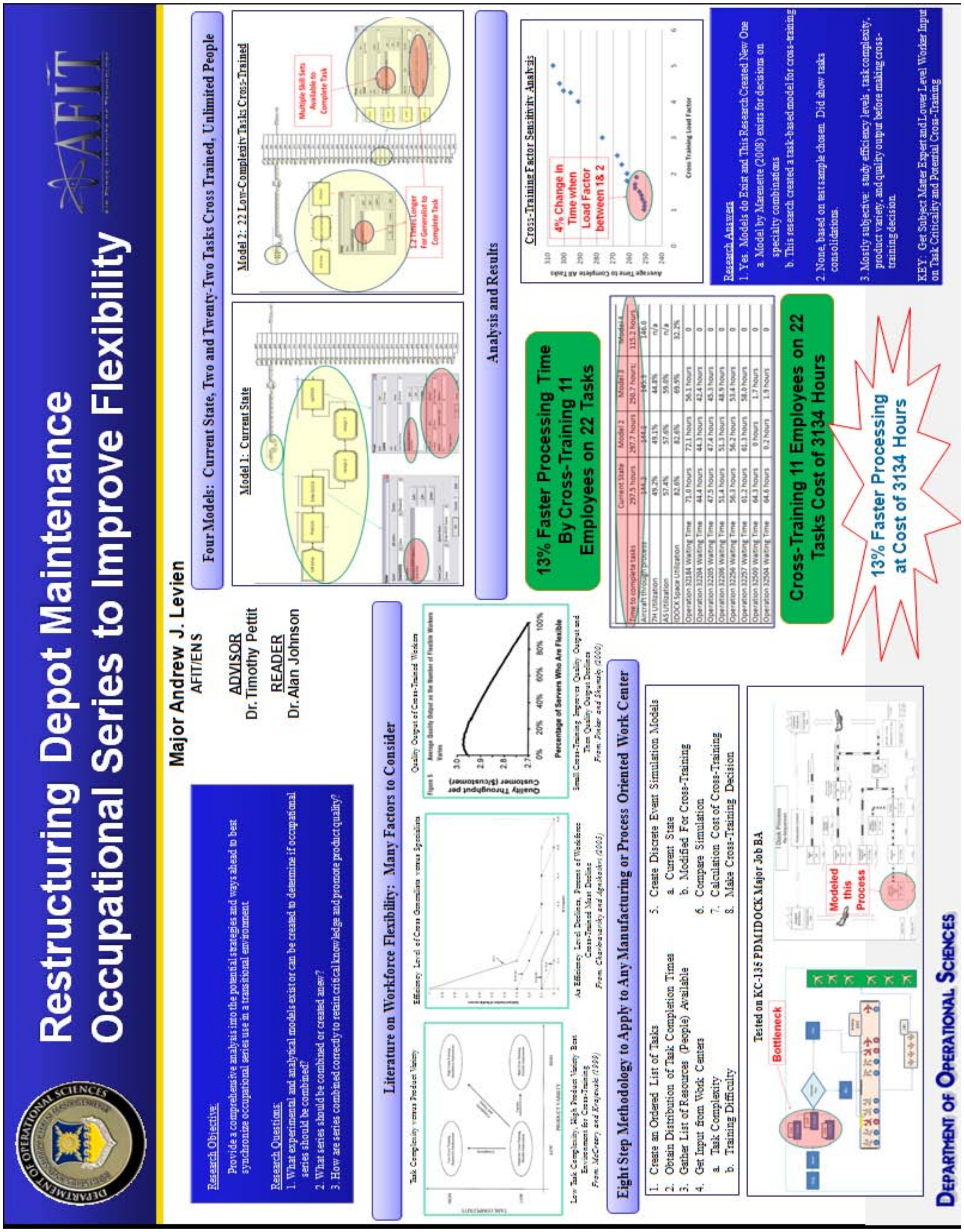
This study provides a comprehensive analysis into the potential strategies and ways ahead to best synchronize occupational series use in a transitional environment. This research addresses several questions: (1) what experimental and analytical models exist or can be created to determine if occupational series should be combined; (2) what series should be combined or created anew; and (3) how are series combined correctly to retain critical knowledge and promote product quality. A methodology is developed that can be applied to any production work environment to see the effects on production time as a result of cross-training. The methodology was tested on the KC-135 PDM line at Tinker AFB—showing a 13.3% gain in throughput time at a cost of 3134 man-hours.

The research questions were answer through the thorough literature review and application of the methodology on the KC-135 PDM line. 1) The literature review addressed this at length. Several models have been created, but only one (Marentette K. A., 2008) discussed which jobs to combine. The rest of the models were more about what roles to combine, leaving the manager to ascertain what actual positions could be combined. Some of the models were role specific and some were task specific. Besides Marentette's model, the problem with most of these models is that they were very specific to the system or industry they were researching. In order to apply it to AFMC's research question, they would need to be adapted significantly. There is no one model that can be created to determine if occupational series should be combined. However, the methodology created in this research is a basic process that can be followed to determine which tasks should be combined with others. This methodology explains how a task-based discrete simulation model can be developed to show were production gains can be made with cross-training. 2) This research was unable to ascertain which occupational series should be combined or created anew because the production line selected to test the methodology only had a few occupational series. A method was created that can be used to look at work areas that have a large diversity of similar occupational series, but such areas may not exist. It appears that there is much specialization within in each occupational series, so reducing the number of occupational series may not be a realistic goal. 3) Based on the literature, this is almost purely subjective. Most of the literature does suggest that some flexibility is good, but an organization must maintain a certain level of expertise (i.e. specialization). The proper degree of flexibility is a factor of the complexity of the tasks, the quality concerns of the final product, and level of utilization of current specialists. One way to overcome this might be to create a cross-trained team, as suggested by Molleman and Slomp (1999)—a team that consists of at least one expert for each task with all other team members being cross-trained on some of the other tasks. This creates a depth of knowledge, but also a breadth of some team members to help out when their utilization is low. The key to this research paper's methodology working is having an accurate opinion from the subject matter experts. If a consensus can be reached that the benefits of a flexible workforce outweighs the potential loss in depth, then a manager should feel confident in the cross-training decision. The decision cannot be made without first-level leadership and worker involvement.

Using the proposed methodology, determining which tasks should be shared with other occupational series is pretty clear. A cut in production time was seen when low complexity tasks were cross-trained, but the cost of cross-training might be very high in terms of time to train the new technicians. A delicate balance needs to be drawn, based on expert opinion, about which career fields can cross-train. A more flexible workforce can be obtained if the right team is put together to study it.

Apr 07

Appendix K: Quad Chart



Appendix L: Form 298

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 074-0188
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to an penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**			
1. REPORT DATE *(DD-MM-YYYY)* 06-17-2010	**2. REPORT TYPE** **Master's Graduate Research Paper**		**3. DATES COVERED** *(From – To)* May 2009 - Jun 2010
4. TITLE AND SUBTITLE RESTRUCTURING DEPOT MAINTENANCE OCCUPATIONAL SERIES TO IMPROVE FLEXIBILITY			**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Levien, Andrew J., Major, USAF			**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Street, Building 642 WPAFB OH 45433-7765			**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT/ILS/ENS/10J-03
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFMC/A4DI Attn: Mr. Steve McBride 4375 Chidlaw Rd Bldg 262, Rm C109 DSN: 787-3271 WPAFB OH 45433-5006 e-mail: steve.mcbride@wpafb.af.mil			**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
12. DISTRIBUTION/AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT This research addresses Air Force Material Command's desire to develop a flexible depot workforce to meet the demands of maintaining an ever-changing and aging aircraft fleet. Air Force depot maintenance personnel are currently (and have been for quite some time) categorized in very narrow occupational specialties, resulting in the approximately 23,000 personnel to be spread over 171 different occupational specialties. Much of the depot work maintenance workload has decreased in volume but increased in velocity, thereby demanding a more flexible workforce that can perform skills from multiple occupational specialties in support of Lean strategies for production. This study provides a comprehensive analysis into the potential strategies and ways ahead to best synchronize occupational series use in a transitional environment. This research addresses several questions: (1) what experimental and analytical models exist or can be created to determine if occupational series should be combined; (2) what series should be combined or created anew; and (3) how are series combined correctly to retain critical knowledge and promote product quality. A methodology is developed that can be applied to any production work environment to see the effects on production time as a result of cross-training.			
15. SUBJECT TERMS Cross-Training, Multi-tasking, Workforce Flexibility			

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Timothy Pettit, Lt Col, USAF (ENS)
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
U	**U**	**U**	**UU**	86	(937) 255-6565, ext xxxx; e-mail: timothy.pettit@afit.edu

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18