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ESTIMATING DEPLOYED AIRLIFT AND EQUIPMENT REQUIREMENTS FOR F-16 AIRCRAFT IN SUPPORT OF THE ADVANCED LOGISTICS PROJECT

THESIS

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AFIT/GLM/ENS/01M-11

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ESTIMATING DEPLOYED AIRLIFT AND EQUIPMENT REQUIREMENTS FOR F-16 AIRCRAFT IN SUPPORT OF THE ADVANCED LOGISTICS PROJECT

THESIS

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Matthew W. Goddard

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Abstract

The Advanced Logistics Project (ALP) is a 5-year DARPA effort to investigate automated architectures to increase the efficiency of logistics support for deploying combat forces. The Mission-Resource Value Assessment Tool (M-R VAT) is a joint AFIT/AFRL adjunct processor to the ALP. The purpose of the M-R VAT is to select optimal force packages to meet the needs of theater commanders, considering both weapon system capability and the logistics package required to support them. This research supports the development of the M-R VAT's capability in two fundamental ways: first, through the development of an airlift estimation function; and second, by defining and justifying equipment requirements rule-sets. The airlift estimation function is a critical component of the force package optimization algorithm research being conducted in a parallel effort. This airlift estimation function will allow the M-R VAT optimization algorithms to constrain the selection of the optimal force package based upon the airlift estimator's output versus available airlift. The rule-sets are used in support of the M-R VAT Time Phased Force Deployment list generator. Justification of existing rule-sets for equipment determination will allow for their use in the M-R VAT existing software structure. This will give M-R VAT the capability to determine logistics needs for a given force package. Major findings include 1) the determination of a useful "best fit" function for aggregate lift requirements, 2) validation and demonstration of the utility of a family of rule-sets for equipment.

ESTIMATING DEPLOYED AIRLIFT AND EQUIPMENT REQUIREMENTS FOR F-16 AIRCRAFT IN SUPPORT OF THE ADVANCED LOGISTICS PROJECT

I. INTRODUCTION

Background

The Advanced Logistics Project (ALP) is a unique computer based logistics system that accesses information in equipment and manpower databases worldwide. The ultimate goal of the ALP program is to utilize information in these databases to coordinate United States military forces and equipment for sustainable deployment in a much quicker, more efficient manner than current methods (Carrico, 1999).

Agile Combat Support (AGS) is the driving factor for the ALP initiative. A RAND essay on support of expeditionary aerospace forces summarizes the need for Agile Combat Support: "Because of the demand to respond quickly to contingencies by deploying from CONUS, the new concept presents significant support challenges. The requirement to deploy quickly places pressures on the deploying units to minimize the amount of support they deploy; the demanding employment scenarios place counterbalancing pressures on the support system to ensure that there are sufficient resources to sustain combat operations" (Tripp, 1999:xiii).

The Air Force currently relies on a force-packaging concept known as the Unit Type Code (UTC). UTCs are detailed standardized lists of equipment, parts, and people created during deliberate planning in preparation for a specific anticipated mission need. When a unit deploys for an AEF rotation, exercise, or crisis situation, standard UTCs are pared and tailored by functional area experts. Paring and tailoring ensures the amount and type of equipment deployed is properly suited to the specific needs of the supported deployment, based on the deploying unit's expert experience and reasoning.

A UTC is pared and tailored by eliminating or adding the equipment the deploying unit deems necessary given the expected location, duration, operating environment, sortie rate and other factors. This research seeks to identify rule-sets from existing and developing computer tools that capture the logic used by combat units to deploy equipment. Rule-sets, as applicable to this research, are logical mathematical expressions that can be used to determine quantities of support equipment based on the number of aircraft deployed and a few other input factors.

Problem Statement

In order for ALP designers and software engineers to test the true capabilities of the ALP system there must be a realistic input comprised of a desired force mix and an accompanying list of required equipment and spare aircraft parts. AFIT's role is to design an architecture to translate the desires of a theater commander into the optimal force mix. This tool, currently under construction by AFIT faculty and students, is called the Mission-Resource Value Assessment Tool (M-R VAT). The M-R VAT is also designed to utilize rule-sets for calculation of the needed support equipment to sustain this optimal force mix for the required time frame.

To properly support the ALP framework, the M-R VAT needs valid rule-sets to build, from the ground up, the proper list of needed equipment and spare parts to sustain any conceived optimal force package. Thus, instead of starting with a previously conceived list of equipment and parts, known as the UTC, the ALP structure requires the M-R VAT to custom-build the list of needed support equipment and parts.

This need leads to the two objectives of this research, in support of the ALP AFIT M-R VAT tool. To re-iterate, these two objectives are to a) identify an airlift footprint estimation function and b) justify existing rule-sets for use in the M-R VAT tool.

Research Questions

Key questions arise which must be addressed in the forthcoming literature review and methodology. The proposed rule-sets attempt to build equipment requirements automatically, a task normally accomplished by experienced military personnel. Deployed logistics requirements are based on an ever-changing and unpredictable set of driving forces (Bloker, 2000). On what inputs would we base an accurate airlift estimation function? Are the outputs of existing equipment determination rule-sets reasonable when compared to historical data?

Methodology

The methodology of this research will attack the two stated objectives in order. First, an existing predictive tool called the Minmxfl6cj model, standard UTC data, and historical deployments will be used to construct an airlift estimation function. Secondly, the equipment detail output of two existing predictive tools will be compared to historical data to justify their rule-sets for use in the M-R VAT. Also as part of the second objective, the automated generation of spare parts requirements with the Aircraft Sustainability Model (ASM) will be compared to current authorized Mission Readiness Spares Package (MRSP) spare parts quantities.

Assumptions

This research focuses on F-16 fighter aircraft. In order to systematically examine and justify the proposed rule-sets for determination of equipment it is necessary to narrow the focus to one specific weapon system. Examining multiple weapon platforms is beyond the scope and goal of this research.

The focus of this research is to build a bottom-up tool. Its emphasis will be on aircraft that currently have the greatest need for deployment planning reform in the UTC process. Fighter aircraft of the Air Combat Command fit this requirement because most UTCs now used by ACC are Major Theater (MTW) UTCs, designed for large-scale wars. UTCs for small numbers of aircraft do exist, but are basically pre-pared and tailored larger packages (Broardt, 2000).

Currently, when a fighter unit deploys a certain number of aircraft, that unit pares and tailors an off-the-shelf UTC. For deployments of fewer than 6 aircraft, (for which no UTCs currently exist), a large amount of paring and tailoring must be accomplished. With the exception of bomber aircraft, the other main categories of deployable aircraft are tankers and transports that exist primarily to support the work of the fighter units. While bombers comprise an important category of combat aircraft, it makes the best sense to focus on fighters because of their wide versatility and flexibility. Fighter aircraft are indeed the central focus of most contingency operations.

Transport and Tanker aircraft could also benefit from a tool that custom builds spares and equipment packages. However, Air Mobility Command (AMC) UTCs are currently already more adaptable to the AEF concept than are ACC UTCs, because of their smaller, more modular size (Bryant, 2000).

It also makes sense to further narrow the study to a combat weapon system that is deployed often by the U.S. Air Force. Therefore, because of its widespread use and excellent versatility, this research has selected the F-16 fighter aircraft. Because of its versatility there is a wide range of standard F-16 force packages. These UTCs will be important in the justification of rule-sets for determination of airlift footprint and equipment. Finally, F-16 aircraft have been the focus of much of the research already accomplished regarding equipment rule-sets (Crowley, 2000). Additional assumptions will be stated in the course of this research.

Summary

This research supports the Advanced Logistics Project (ALP). Specifically, it seeks to enhance the capabilities of the ALP M-R VAT tool by providing an airlift estimation function, and justifying the use of equipment determination rule-sets. To achieve these goals, we start with a review of three important current logistics tools in the Literature Review.

II. LITERATURE REVIEW

Introduction

The goals of this literature review are to describe the U.S. Air Force deployment process and explain three tools that will aid us in accomplishing our stated research objectives. These tools are the Minmxf16cj model, the Unit Type Code Development and Tailoring tool (UTC-DT) (both are equipment tools), and the Aircraft Sustainability Model (ASM) (a spares tool). From the two equipment tools we obtain rule-sets which can be used in the ALP M-R VAT architecture. The Aircraft Sustainability Model (ASM), already in use by Air Force Major Commands (MAJCOMs), will also be described. In Chapter III we justify the equipment rule-sets by comparing their outputs to real-world deployments and compare current MRSP quantities to ASM determined quantities for real-world scenarios.

The central goal of this research is to support the ALP M-R VAT tool's capability to determine force packages and logistics support requirements for those force packages. The following review of existing deployment computer tools prepares the reader for Chapter III, where the tools' (and accompanying rule-sets') outputs are examined. The reader should understand why the M-R VAT needs an automated logistics requirements determination capability. To facilitate this understanding we first describe the U.S. Air Force deployment process. This gives the reader a picture of how logistics support packages are currently built for real-world deployments. This review of current deployment requirements determination methods will expose the usefulness of automated (i.e. M-R VAT) determination of support packages for deploying combat aircraft.

This literature review will consist of three main sections. The first section is a synopsis of the current Air Force deployment process. The M-R VAT architecture, supported by this research, will be a tool that can help improve deployment processes. Also in section one is a detailed enumeration of key assumptions which bound the scope and focus the objectives of this research.

The second part of the literature review describes two tools containing useful rule-sets for equipment requirements determination. These are the Minmxf16cj and UTC-DT models.

The final part of the literature review provides an overview of the Aircraft Sustainability Model (ASM) and a description of its basic working logic. An understanding of ASM is important because in Chapter Three we compare the output of the ASM model to current spares quantities.

The U.S. Air Force Deployment Process

"Strange as it may seem, the Air Force, except in the air, is the least mobile of all the services. A squadron can reach its destination in a few hours, but its establishment, depots, fuel, spare parts, and workshops take many weeks, and even months to develop" (Tripp, 1999:7). Winston Churchill's statement above, as quoted in the Air Force Journal of Logistics by Robert Tripp, is still applicable today. It summarizes the dilemma of all deployable Air Force units. This dilemma has become increasingly pertinent for the U.S. Air Force in today's world of multiple annual deployments.

Under official Air Force Contract, The RAND Corporation has completed detailed analyses of the logistics aspects of U.S. Air Force deployments. A recent RAND report from this research is titled Supporting Expeditionary Aerospace Forces: An Integrated Strategic Agile Combat Support Planning Framework. It is an excellent summary of the deployment challenges facing the U.S. Air Force today, and serves to set the stage (see Figure 1) for our look at support equipment and spare parts (Killingsworth et al., 1999:8).

RANDMR1113-1.3

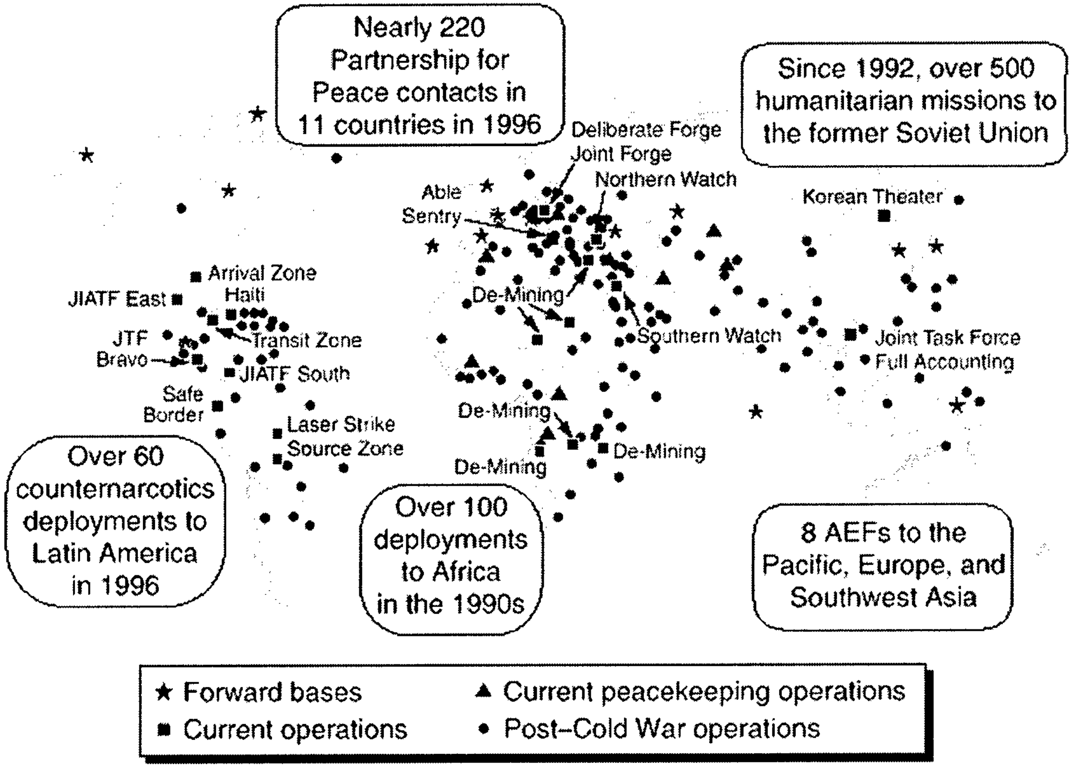


Figure 1. USAF deployments in the 1990s

> With the end of the Cold War, symbolized by the destruction of the Berlin Wall in 1989, the United States has entered an entirely new security environment. In the course of a decade, that environment has changed from a bipolar world where two superpowers confronted each other around the globe to a multipolar world where the United States is the only superpower in a world of many regional powers. The result has been a number of deployments ranging in size from Operation Desert Storm through Northern/Southern Watch and Preserve Democracy, to smaller humanitarian relief and noncombatant evacuation operations. In all of these operations, the Air Force has played a significant role. The pace of operations has not abated...Not only are these operations far-flung, but many were initiated with a short lead-time in response to a potential crisis.
> ...Because of planned force reductions, the deployments in the latter half of the 1990s are being carried out by a substantially smaller force than existed in the 1980s or even during operation Desert Storm...Because the security environment has changed, the Air Force

> leadership has formulated a major change in Air Force organization and employment: the Expeditionary Aerospace Force (EAF). (Tripp et al., 1999:1-2)

The Air Force was recently re-organized into 10 AEF elements. Each element contains fighters, bombers, and tankers. Each AEF element has 12 months when it cannot be tapped for crisis or rotational deployments. After this period, the subject AEF element then serves a 90-day rotation where all personnel are either deployed or on-call for crisis deployments (Tripp et al., 1999:4).

> The core of the new concept is that the on-call AEF would provide highly capable force packages that could be deployed from the continental United States (CONUS) quickly, travel to deployed sites with a minimum of in-place infrastructure, be employed as soon as they arrived in theater, and sustain the required level of operations. Such a capability would deter an aggressor from an attack in the absence of permanent in-theater U.S. forces, as long as the threat was credible. To make the threat credible, therefore, the Air Force has to be able to move aircraft and support activities to any location, with a wide range of infrastructure, in a very compressed timeline. (Tripp et al., 1999:4)

The United States Air Force has transformed into a lighter, more mobile organization. The mobility needs of our more versatile Air Force have placed new demands on the logistics methods used to support combat operations. The current ACC standard sets a goal of " ...48 hours from execute order to full deployment and full operation, after a 24-hour strategic warning" (Tripp et al., 1999:5).

Faster deployment of combat aircraft means the logistics support package for an initial sustainment period must be determined and in-place in time to ensure that operations can begin within Air Combat Command time standards. This established need for faster, more efficient logistics support of combat operations is commonly referred to as Agile Combat Support or ACS (Galway et al., 2000:iii).

The Advanced Logistics Project seeks to speed the placement of logistics support requirements by coordinating sources of logistics assets and transportation methods all over the world. This is accomplished through real-time computer knowledge of available equipment, parts, munitions, and all support related items possessed by combat units around the globe (Carrico, 1999).

The M-R VAT effort seeks to determine the optimal aircraft force package for a given U.S. military need anywhere in the world. This research supports the ALP M-R VAT architecture by constructing an airlift footprint estimation function that can provide instant airlift estimations. M-R VAT will utilize this function to constrain its optimization of the ideal force package. Airlift is a key constraint in the logic of the M-R VAT tool. But why does the Air Force need the M-R VAT architecture? What is lacking in the current method of determining logistical support for short-notice deployments?

The following paragraphs answer these questions by describing the current methods of determining and deploying logistics support. Additionally, the specific assumptions used in this research will be presented.

The UTC Concept. In order to understand why the M-R VAT architecture should have a logistics requirements determination capability, it is necessary to understand how the U.S. Air Force deploys combat forces. "The basic building block the Air Force uses to deploy forces is the UTC. Everything that is initially deployed with a unit is listed in the UTC. UTCs are five character identifiers that uniquely specify a force or support package" (Leftwich et al., 1997:2).

Air Force Instruction (AFI) 10-403 provides basic guidance for deployment planning. AFI 10-403 defines a UTC as "a five-character alphanumeric designator uniquely identifying each Armed Forces unit" (AFI 10-403, 1998:34).

A UTC is a listing of all the personnel and equipment needed to deploy a certain force package, for example, a 6-ship package of F-16s.

> The majority of the UTC consists of the manpower/logistics detail, contained in the Manpower Force Element Listing (MFEL) and the Logistics Detail (LOGDET). The MFEL is broken down by Air Force Specialty Code (AFSC) type and quantity of personnel, and a code specifying where each person will be working. The LOGDET specifies a list of all the equipment needed, including weight, size, shipping characteristics, national stock numbers, and the increment number for each item. (Leftwich et al., 1997:2)

"Standard UTCs are developed by Pilot Units as benchmarks for other units. A Pilot Unit is a unit tasked to develop a standard UTC for use by all units equipped with a specific number and type weapon system. The Pilot Unit acts as a single point of contact for development and maintenance of a standard UTC" (Leftwich et al., 1997:2).

With an understanding of the Unit Type Code (UTC) we can describe how an Air Force Combat unit receives a tasking and deploys to a Forward Operating Location (FOL). Automated control of the entire deployment process is maintained by a system know as the Integrated Deployment System (IDS).

> The IDS is the automated tool used for wing level deployments and contingency operations. It includes the following component systems: DeMS, MANPER-B, LOGMOD, CMOS, and CALM. The IDS provides the interfaces necessary for the flow of information throughout the deployment process and can operate on either disk to disk or via the LAN. (AFI 10-403, 1998:17)

The focus of our deployment process description will be the Logistics Module (LOGMOD) portion of the IDS system defined above. Within LOGMOD, unit level deployment managers (UDMs) and experts from various maintenance and other logistics specialties accomplish the UTC paring and tailoring function (Taylor, 2000).

All standard UTCs are kept on file in the Logistics Force Module (LOGFOR) portion of the LOGMOD (Taylor, 2000). "All units (active and gained) will maintain in LOGFOR the standard UTCs for which they are tasked to deploy or have been designated as the Pilot Unit" (AFI 10-403, 1998:17).

When a combat unit receives a tasking, the tasking usually includes the standard UTC to deploy. The unit then accesses this UTC in the LOGFOR database (subset of LOGMOD) (Bryant, 2000). Unit Logistics Planners then work with Unit Deployment Managers and shop-level experts to transform the standardized UTC listing of equipment and personnel into a customized listing known as the LOGPLAN (Taylor, 2000). The LOGPLAN is built using software contained in the LOGMOD system, accessible by each deployable combat unit (Taylor, 2000).

The process described above is known as paring and tailoring. Paring and tailoring transforms the standard UTC into the customized LOGPLAN. The completed LOGPLAN contains the list of the exact equipment (and people) to be deployed.

> The need for tailoring can be caused by numerous events including changes in the bed down location, number of aircraft, personnel requirements, equipment requirements, mode of transportation (type or size), collocation with other units, reduction in airlift allocation, seasonal factors, and even political factors. Political factors have at times included restrictions on the number of aircraft, personnel, equipment and major spares. Whether these changes or restrictions occur in a deliberate planning or short-notice crisis situation, they can and usually do require a significant amount of research, coordination, and UTC data manipulation to be accomplished. (Leftwich et al., 1997:16)

Thus the key objective of the paring and tailoring process which must be accomplished by all deploying combat units is to adjust the standard UTC for logistics support to fit the specific crisis or other deployment situation.

> However, there are times when the changes required are so drastic that no existing UTC is even close to the required force package. When this occurs the "closest match" is chosen for use of the given formats in facilitating rapid building of listings to be distributed to the units/shops. They then pass them via disk or hard copy to the unit functionals such as; operations, maintenance, supply, and personnel for the actual tailoring.
>
> If the tasking received is for an assigned UTC(s) to be used in the planned environment, and pre-loaded in a Logistics Planning Subsystem (LOGPLAN), then normally minimal tailoring is necessary. However, if the tasking is "non-standard" (for example: fewer aircraft or people in to an unplanned environment/location, or in an otherwise constrained situation that doesn't already exist in a LOGPLAN), tailoring becomes a major workload requiring a significant increase in validation, coordination, and computer input activities.

> Again, numerous hours can be spent in refining the logistics and manpower files. (Leftwich et al., 1997:17-21)

The paring and tailoring process can be relatively easy and quick or extremely long and difficult, depending upon how close the specific needs happen to match the tasked UTC. This research has determined that paring and tailoring will always need to be accomplished to some degree because the specific needs will never exactly match the standardized UTC list of equipment (Milikan, 2000).

Why should the Air Force pursue and utilize an ALP M-R VAT automated requirements determination capability such as this research supports? The answer is two-fold: speed and flexibility. The paring and tailoring process described above requires careful thought and consideration, and this requires substantial amounts of time. What is needed is a tool that can imitate basic requirements determination in the paring and tailoring process, in less time than currently required. Recall that paring and tailoring of UTCs are crucial steps in the deployment process. Without it, we might waste valuable airlift assets or sacrifice mission capabilities due to a lack of needed tools, equipment or parts.

Every deployment of a combat aircraft unit, even of the same unit, presents a new and different combination of challenges. Every hour required for paring and tailoring a support package is an hour that could be spent actually loading and delivering that package to the deployed location.

What If. What if there was a way to capture the basic human experiential decision elements and logic used in the task of paring and tailoring support packages? What if a tool (i.e. M-R VAT) could capture and utilize the basic decision making rules used by experienced technicians well enough that a substantial time savings would result?

While rule-sets can never account for all the factors that affect tailoring needs, they could be used to generate a baseline UTC that is closer to the actual needs than any standard UTC.

These questions center on the concept of the UTC. To answer these "what if" questions, we must first outline the critical assumptions of this research necessary in relation to the deployment process. This is the goal of the following paragraphs.

Defining Assumptions

Here we enumerate in detail the specific assumptions necessary to accomplish the goals of this research. With our assumptions we define the limits within which we will demonstrate and compare the equipment rule-sets.

Clearly there are numerous factors which influence the UTC paring and tailoring process. It is beyond the scope of this exploratory research to suggest rule-sets to properly account for all these factors and possible combinations of factors.

However, by limiting our goals with carefully selected defensible assumptions, we can show the feasibility of automated tools to determine equipment needs from the ground up. Since, of course, in the real world we cannot count on any of these assumptions being true (although it is a possibility), the assumptions must be chosen very carefully and in a way that makes plausible the demonstrated capabilities of the automated tools and rule-sets. The rule-sets chosen for the M-R VAT tool could be expanded in future research to eliminate the need for certain assumptions, perhaps one by one, as more comprehensive research is conducted and more extensive data collected.

The following four assumptions limit the scope of this research, and each will be explained in greater detail in the upcoming paragraphs:

1. The output focus of automated tools examined is on determination of equipment and spares, and ignores personnel, fuel, and munitions requirements.
2. Deployment is of a single combat unit of one MDS (F-16s).
3. Deployment is to a single FOL of category 1.
4. Rule-sets in the automated tools examined will consider numbers of deployed aircraft, and to a limited degree, deployment duration, sortie- rates and mission types. However, location of the FOL as well as Forward Support Locations (FSL) or other support options are beyond the scope of this research.

Assumption #1. The focus of this research is on determination of equipment and spares, and ignores personnel, fuel, and munitions requirements. The reason for the focus on equipment and spares is that equipment takes up approximately 70 percent, on average, of the airlift space required for deployment (Galway et al., 1999:5). Spares are an important subset of these equipment packages. Additionally, focusing on equipment and spares narrows the research scope and makes more reasonable the goal of justifying rules-sets for support requirements.

Therefore, not addressed in this research are the other three key logistics support links for deployment -- munitions, personnel, and fuel. Figure 2 on page 16 depicts a result of PROJECT AIR FORCE research from the RAND Corporation and shows the emphasis on support equipment as the major player in the total short tons that are actually moved for a deploying combat unit (Killingsworth et al., 2000:33).

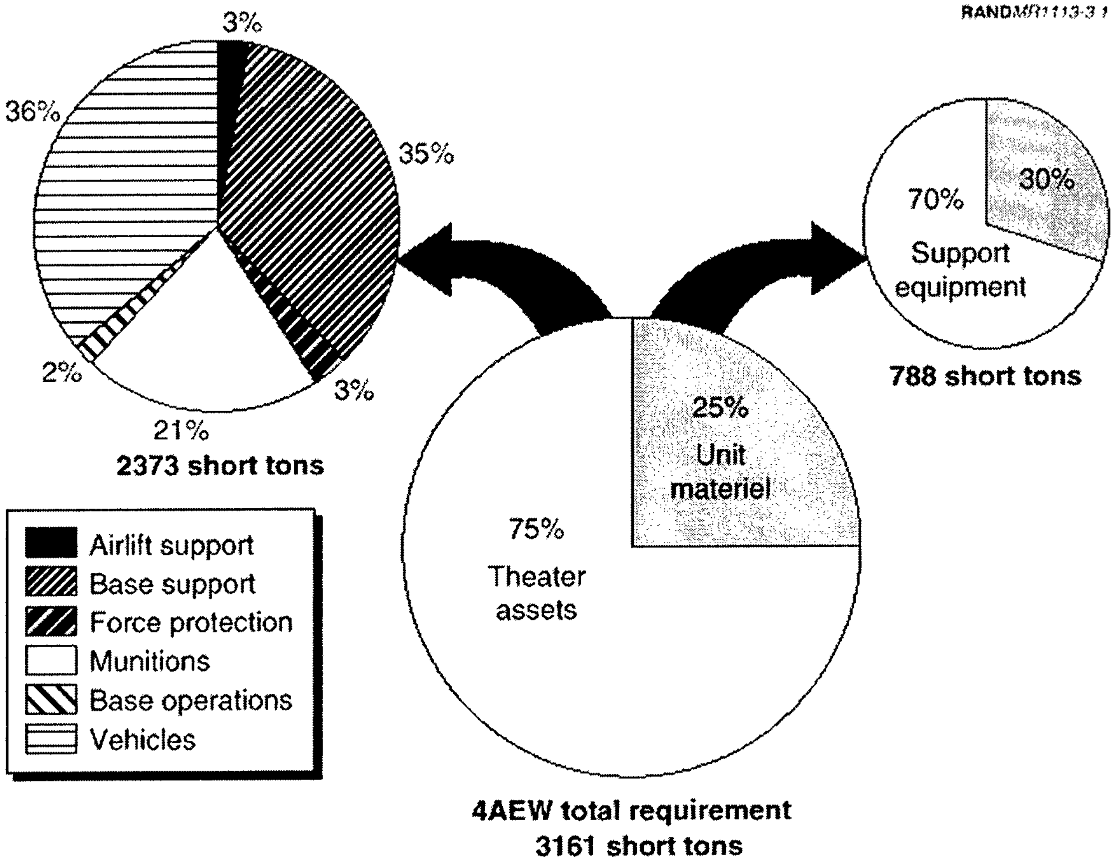


Figure 2. Footprint Breakout

Assumption #2. We assume deployment is of a single combat unit of one MDS (F-16s). The concept of deploying multiple combat units and multiple MDSs to a single location is a topic too advanced to fit the scope of this research. However, demonstration of the capability to determine equipment for a single deploying unit will show key features necessary to be applied to multiple units.

Assumption #3. Deployment is to a single FOL of category 1. RAND's PROJECT AIR FORCE research was highlighted in a series of four articles in the Air Force Journal of Logistics. The following excerpt is the central conclusion of the first of this series of articles, and defends assumption number three.

> To get close to the execution order plus 48-hour deadline for placing the first bombs on target, AEWs must deploy to category-1 bases. Further, given that a flight halfway around the world takes approximately 20 hours, pushing the timeline below 48 hours will require either having people deployed or materiel at an advanced state of preparation at the FOL or both. (Galway et al., 1999:38)

Table 1 summarizes the differences between Category 1, 2 and 3 FOLs, so the reader has a better understanding of the implications of assumption #3 (Killingsworth et al., 2000:24).

Table 1. FOL Categories

Category 3	Category 2	Category 1
Runway	Category 3+	Category 2+
Ramp space	Fuel Storage/Distribution	Arresting System
Fuel	Vehicles	Communications
Water	Medical Facilities	Munitions (3days)

Assumption #4. Rule-sets will not consider the FOL location, FSL or other support options. In order for any existing rule-sets to perfectly size a UTC, whether by automated tailoring or building from the ground up, the inputs to the model must include some information about the deployed location. However, this capability is not yet fully developed in any of the available tools. Instead we must rely on the rule-sets constructed from interviews with personnel in the actual combat units. So while our rule-sets may recommend requirements generally the way, say, the 27th Fighter Wing would, there is currently no provision for incorporating the considerations of base-specific FOL assets into the rule-sets' recommendations. The UTC-DT model is designed to incorporate this capability however the capability was never fully developed (Sjoquist, 2001).

UTC-DT does make use of a few inputs when something is known about the forward location, such as lighting and the number of aircraft UKES or tugs available.

The RAND AFLMA Minmxf16cj model makes no consideration for FOL location in its rule-sets.

Selecting Rule-Sets

The selection of existing tools with built-in rule-sets that could be justified for use in the M-R VAT structure will be based on a few key criteria. First, many computer architectures and systems designed for modeling and or predicting deployment-related information were considered. As a first pass, all currently operating and developing systems were examined to determine if they calculate equipment and/or spares for deployment. Only a handful of tools remained after applying this first selection criterion. Finally, selecting only those that were based upon rule-sets from actual field interviews further narrowed the list. This literature review first describes the two tools selected for their equipment determination rule-sets for F-16 combat aircraft. We then describe the current system used by the USAF to determine spare parts kits for wartime.

Tools for determination of equipment will be described first. The reason for this is that spare aircraft parts are really a subset, albeit an important subset, of the list of equipment that is deployed for a specific scenario. This is evident when reviewing cargo loading manifests and deployment LOGPLANS. The spares kits themselves are considered a piece of equipment to be included in the overall LOGPLAN and subsequent Load Plan for the cargo aircraft. Therefore our first focus is on finding a tool that can build custom UTCs of maintenance support equipment for F-16 aircraft. The next focus is on how the existing ASM system determines the actual contents of the spare parts kits.

This research seeks tools that, within the boundaries of our stated assumptions, capture the logic used by experienced aircraft maintenance planners. That logic is usually in the form of rule-sets for specific combat units deploying specific aircraft, in our case, the F-16.

While not yet fielded or in use by active Air Force units, such a tool does exist and is currently in the evaluation phase. This tool is called the Unit Type Code Development and Tailoring Tool (UTC-DT) (Crowley, 2000).

Another tool was also selected to aid in the goals of this research. This tool is called the RAND AFLMA Minmxf16cj requirements determination tool. It is a Microsoft EXCEL-based model written by CMSGt John G. Drew of the Air Force Logistics Management Agency (AFLMA).

The following sections will describe these two equipment tools and how they can affect the UTC process.

Equipment

For the issue of equipment it was determined that no models are *currently* in use by operational units or command headquarters to determine equipment requirements. Equipment is determined during UTC review meetings that are generally held on an annual basis. Here we describe two experimental tools that use rule-sets to determine equipment. The first to be reviewed is the RAND AFLMA Minmxf16cj requirements determination tool.

RAND/AFLMA Requirements Determination Tools. The Air Force Journal of Logistics recently highlighted RAND and the Air Force Logistics Management Agency's (AFLMA) research in a series of four articles on Expeditionary Airpower. These four articles enumerate RAND and AFLMA conclusions regarding logistics support of deploying USAF forces. The titles of the four articles are: “Global Infrastructure”, “Strategic EAF Planning”, “F-15 support analysis”, and “A Vision For Agile Combat Support”. The three key themes of all these articles are: Mission Requirements Determination, Support Requirements Determination, and Support Options Analysis. The key theme dominating the discussion in the series is Support Options Analysis. Support Options Analysis consists of examining the trade-offs between different ways of meeting the logistics needs of a deployed combat unit. The key mechanisms for meeting logistics needs are the Forward Operating Location (FOL), Forward Support Locations (FSL), and CONUS Support Locations (CSL).

The primary conclusion of the series of articles is that judicious use of these three support options, or combinations thereof, will be absolutely necessary to meet the current ACC goal of bombs on target in 48 hours. The articles further conclude that these Global Infrastructure options are absolutely essential because the logistics requirements of deploying AEF forces are simply too heavy to be met in the required time frame by airlift assets alone (Galway et al., 1999:38).

One of the reports performs a Support Options Analysis for a sample F-15 deployment scenario. The RAND and AFLMA authored articles stress that before support options can be explored, we need to know what the support requirements are.

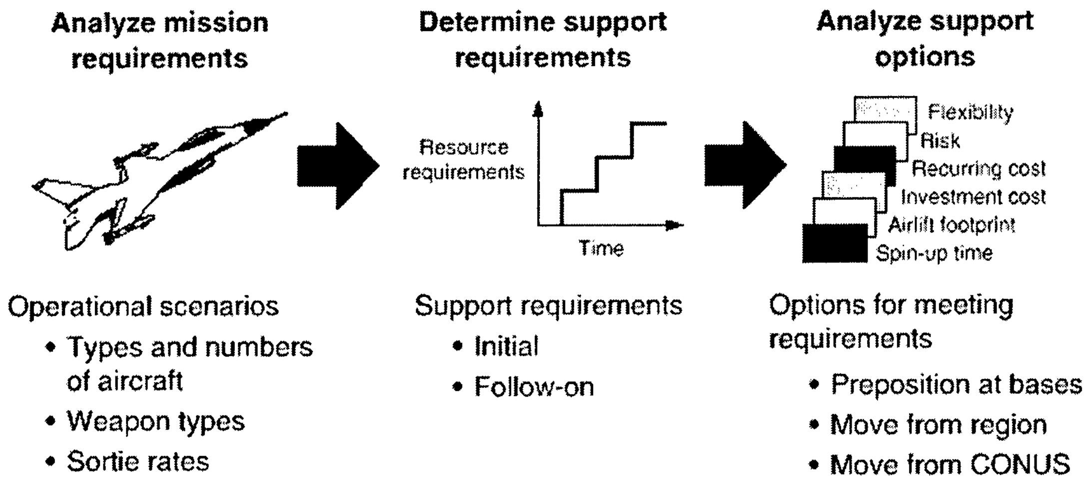


Figure 3. Three-Step RAND Approach

Support Requirements Determination is the second key theme of the series (see Figure 3 above) (Galway et al., 1999:5). RAND and AFLMA have developed some simple EXCEL spreadsheet tools to estimate support requirements for five major resource categories including "munitions, fuels support, unit maintenance equipment (the bulk of unit support equipment), vehicles, and shelter" (Galway et al., 1999:5).

This research will utilize the unit maintenance equipment models developed by RAND and AFLMA as an aid in developing an airlift estimation function and as one source of rule-sets for equipment determination for F-16 aircraft. CMSgt John G. Drew of AFLMA authored these maintenance equipment requirements models and produced versions for B-52, F-15, and F16 aircraft. In this research we borrow the F-16 model, as our focus is F-16 aircraft. The models for the other aircraft operate in a similar manner to the F-16 model. We will now take a brief look at the RAND AFLMA Minmxf16cj requirements determination model.

Basic Model Structure.

> Primary maintenance activities to support combat sortie generation include: launch (including end of runway (EOR) and electronic countermeasure flow through inspections), recovery and inspection, refueling, and munitions uploading and downloading. Secondary functions include troubleshooting and repair of inoperative aircraft systems. Tertiary functions include avionics component repair, jet engine intermediate maintenance (JEIM), and major aircraft (phase) inspections.
>
> The minimum maintenance personnel and support equipment model (an EXCEL spreadsheet) determines requirements for the primary maintenance activities described above. The model determines aviation support package requirements by deriving maintenance personnel and equipment capabilities from the number of Primary Assigned Aircraft (PAA) tasked for deployment and other important parameters. (Tripp et al., 1999:89)

These minimum maintenance personnel and support equipment models calculate both equipment and personnel requirements. In this research, we are focused specifically on the equipment requirements determination portion of the models. "The model is designed to produce requirements for a seven-day operation in a highly tasked environment" (Tripp et al., 1999:92). The equipment determination portion of the model is based upon number of tasked aircraft, and does not appear to be affected by sortie rate changes in the model-input section. "Once the tasked number of aircraft has been determined, the model will compute requirements" (Tripp et al., 1999:95). These models generate requirements on the pallet level, or increment level. "We have not explored reducing single items inside of individual pallets because of the anticipated negligible gains" (Tripp et al., 1999:95). "A large percentage of the support equipment is classified as AGE, and this is where we concentrated our efforts" (Tripp et al., 1999:95).

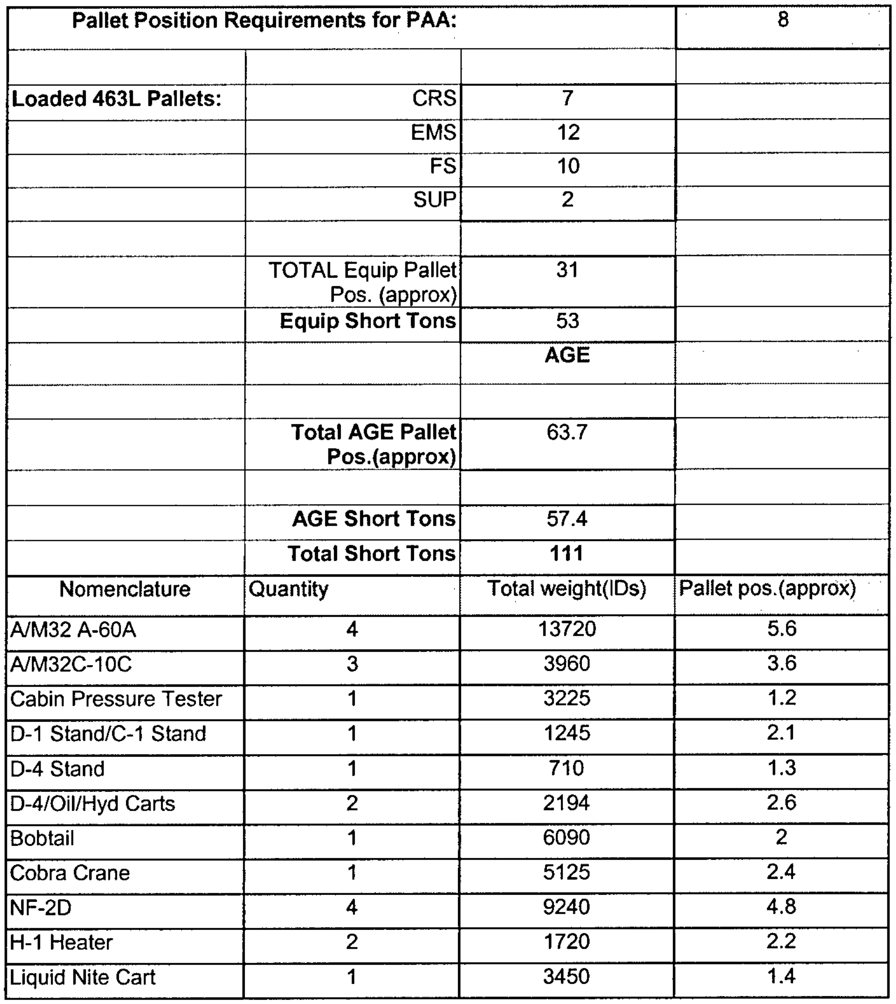
> The rules in this model, as in our other models, were developed from a number of sources: review of written documentation such as regulations and pamphlets that specify resource relationships, observation of unit preparation activities, and discussion with experts in the field. Unit-, MAJCOM-, and USAF-level functional experts have validated our rules and models. (Tripp et al., 1999:92)

Table 2 shows a portion of data for AGE equipment from the model and the accompanying rule-sets for each item (Tripp et al., 1999:97).

Table 2. AGE Rule-Sets

Nomenclature	Description	Weight	Pallet Pos. (approx)	Rule-Base
A/M32 A-60A	Generator	3430	1.4	1 per 2 Acft - deploy with A/M32C-10C
A/M32C-10C	Air Conditioner	1320	1.2	5 per 12 Acft - deploy with A/M32A-60A
Cabin Pressure Tester		3225	1.2	1 per deployment
B-1 Stand/C-1 Stand	Maintenance Stand	1245	2.1	1 per 12 Acft
B-4 Stand	Maintenance Stand	710	1.3	1 per deployment
B-4/Oil/Hyd Carts	Servicing Carts	1097	1.3	1 per 6 Acft
Bobtail		6090	2	1 per 12 Acft
Cobra Crane		5125	2.4	1 per deployment
NF-2D	Light Cart	2310	1.2	1 per 2 PAA unless good lighting, then 1 per 6PAA
H-1 Heater	Heater	860	1.1	1 per 6 Acft
Liquid Nite Cart		3450	1.4	1 per 12 Acft
Liquid Oxygen Cart		1110	1	1 per 12 Acft
MB-4 Coleman		10650	1.9	1 per 12 Acft
MC-2A Lo-Pac	Air Compressor	860	1	1 per 4 Acft
MC-7	Air Compressor, 100 PSI	2400	1.4	2 per 12 Acft
Towbar		500	3.3	1 per Coleman & 1 per 12 Acft
-86 Generator Set	Generator	6050	1.1	1 per deployment
MJ-4	Bomblift	6750	2	1 per deployment & 2 per 12 Acft
MJ-1B	Bomblift	3880	1.7	1 per deployment & 2 per 6 Acft
MJ-2A Hts		5980	1.4	1 per deployment & 2 per 12 Acft
Tank Dolly		430	1.5	2 per deployment
Trl MHU-141		5098	1.6	1 per deployment
Wash Cart		1260	1	1 per deployment

Figure 4 below is a picture of the model output for AGE equipment, which gives total AGE pallet positions required and total AGE short tons required (Tripp et al., 1999:97). Also shown are the total short tons for all equipment.



Pallet Position Requirements for PAA:			8
Loaded 463L Pallets:	CRS	7	
	EMS	12	
	FS	10	
	SUP	2	
	TOTAL Equip Pallet Pos. (approx)	31	
	Equip Short Tons	53	
		AGE	
	Total AGE Pallet Pos.(approx)	63.7	
	AGE Short Tons	57.4	
	Total Short Tons	**111**	
Nomenclature	Quantity	Total weight(lDs)	Pallet pos.(approx)
A/M32 A-60A	4	13720	5.6
A/M32C-10C	3	3960	3.6
Cabin Pressure Tester	1	3225	1.2
D-1 Stand/C-1 Stand	1	1245	2.1
D-4 Stand	1	710	1.3
D-4/Oil/Hyd Carts	2	2194	2.6
Bobtail	1	6090	2
Cobra Crane	1	5125	2.4
NF-2D	4	9240	4.8
H-1 Heater	2	1720	2.2
Liquid Nite Cart	1	3450	1.4

Figure 4. Sample AGE Requirements Output

While no output of total short tons is given in the original model for other than AGE equipment, the model was easily modified to generate this output, using the equipment weight data included in the spreadsheet's data tables. Thus, with minor modification, we were able to adapt the RAND-AFLMA Minmxf16cj requirements model to estimate total equipment short tons, for both AGE and other than AGE maintenance support equipment. This total short ton estimation feature will serve as an aid in Chapter III where we construct an airlift estimation function.

Now we move on to discuss another tool, referred to in RAND and AFLMA PROJECT AIR FORCE reports. "Armstrong Laboratory is developing a UTC tailoring tool for the Air Force, and we believe many of the ideas discussed here will be applicable to Armstrong's effort" (Tripp et al., 1999:97).

Unit Type Code Development and Tailoring tool. The Unit Type Code Development and Tailoring Tool (UTC-DT) is an initiative of the Armstrong Laboratory designed to improve the efficiency of Air Force Deployment processes, especially as related to the UTC concept. UTC-DT is a part of the Logisticians Contingency Assessment (LOGCAT) suite of tools (Crowley, 2000). "LOGCAT is intended to demonstrate how advanced technologies can improve the timeliness and efficiency of wing logistics planning for short notice contingencies" (Leftwich et al., 1997:1). The Synergy Corporation's Dayton Ohio office developed the UTC-DT tool for Armstrong Laboratories (Sjoquist, 1997:1).

UTC-DT Purpose. "Rapid rule based force package development and tailoring in a collaborative environment capable of supporting any contingency: right size vs. downsize" (SSG, 2000). The basic scope of the UTC-DT model is the automatic tailoring and development of combat UTCs for aviation units. The model recommends types and numbers of support equipment using rule-sets that have been developed from allowance standards and interviews with actual combat units. The UTC-DT model applies these rule-sets along with user inputs to the model such as date, MDS, PAA, sortie rate, mission type, duration of deployment and other items.

UTC-DT Capabilities.

> UTC-DT will improve the development and tailoring process currently employed by the Air Force by quickly providing recommendations for cargo and personnel, and allowing multiple users at different levels the ability to work together in refining the detail to best fit the mission requirements. (Leftwich et al, 1997:25)

Now we will look more closely at the current capabilities of the UTC-DT tool.

> The current version of UTC-DT will develop a list of logistics detail and recommended quantities based on the mission parameters supplied. These parameters include the MDS, PAA, mission duration, sortie rate, and others using ASCs, STEP auto, BCAT Assessment, Rules Base, etc. The result is a list of NSNs for each individual FAC (functional account code) that may then be further refined by an individual with the appropriate access, or by a group of individuals working collaboratively. (Leftwich et al., 1997:26)

The UTC-DT model has four user-access levels, including flight, squadron, wing, and MAJCOM levels. All these levels have different authority for input concerning the UTC being tailored or developed. We will focus on the wing user access level because this is the level that allows us to create new UTCs (Leftwich et al., 1997:27).

UTC-DT was designed to be utilized in a client/server architecture, allowing inputs from multiple authorities from multiple locations. This allows real-time crosscheck functionality when paring and tailoring an existing UTC. "The client/server architecture facilitates the execution of an application on one computer while accessing data residing on another computer" (Leftwich et al., 1997:4).

> The application of this technology to UTC-DT will allow users from different organizations at different levels to access, modify, review, and comment on the detail being developed for a given UTC. This will apply to both developing new UTCs and tailoring existing ones. This can happen in an on-line, 'real time', fashion where each of multiple participants can make changes and recommendations to the detail with the other participants being able to see and comment on their work, and off-line where individuals may make changes and recommendations that the others may see later. The on-line,

collaborative work will allow the organizations involved to reach a consensus about the appropriate detail to include, and in conjunction with the host base determine any use of War Reserve Material (WRM), existing support equipment, and facility sharing at the reception base. (Leftwich et al., 1997:6)

Figure 5 below shows the potential interface capabilities of UTC-DT (Leftwich et al., 1997:9).

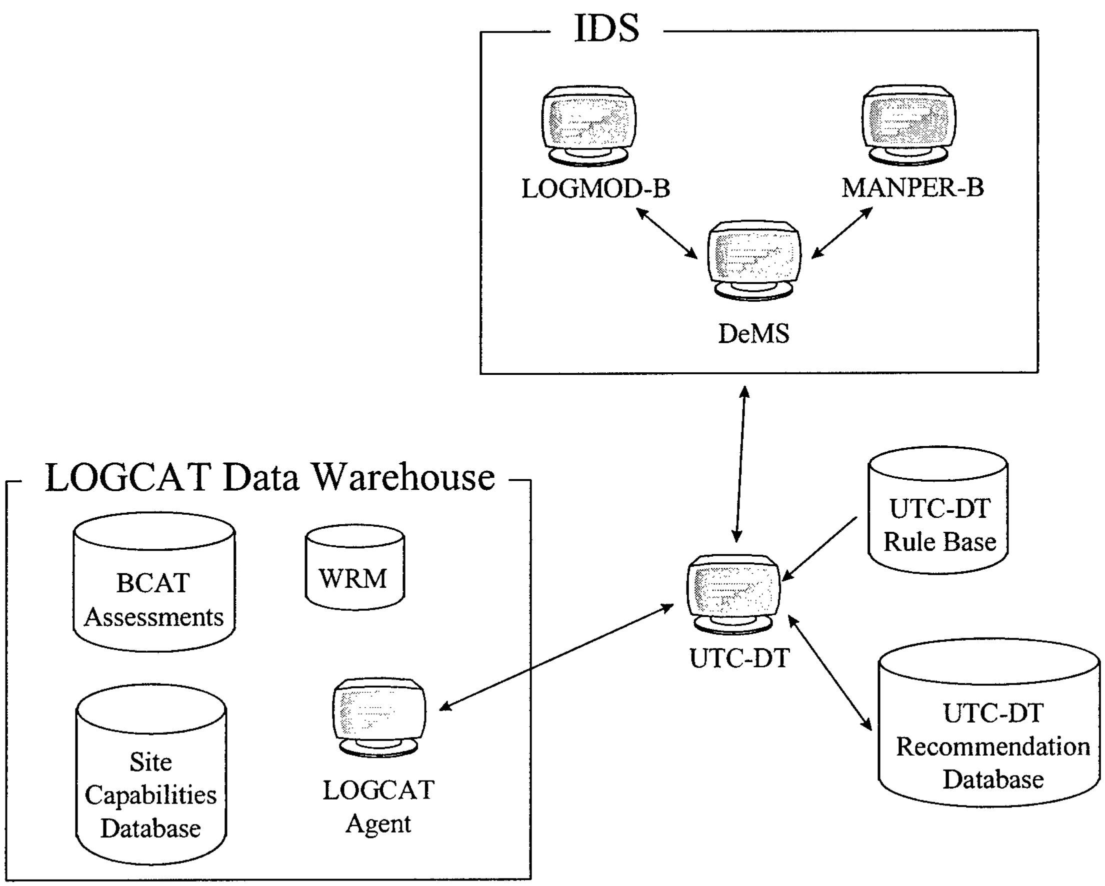


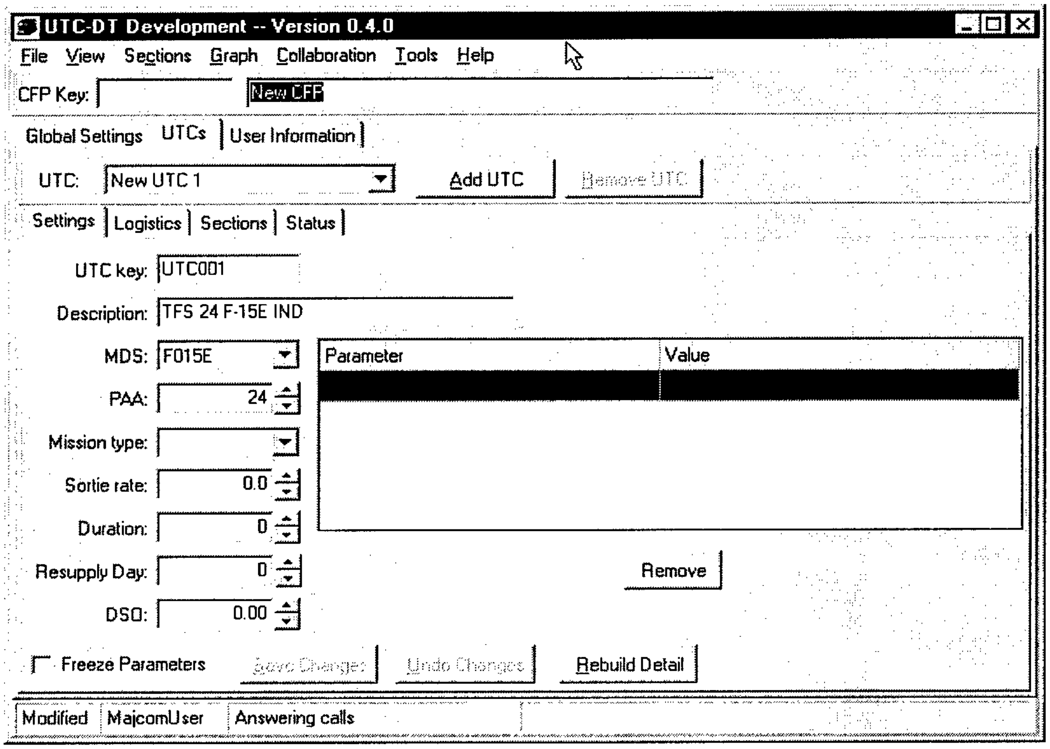
Figure 5. UTC-DT Connectivity

The information obtained from the different systems would be provided to UTC-DT. This will give the planner rapid access to all site survey information, lessons learned on previous deployments, logistic detail information, and manpower requirements. This information would be accessed by selecting either specific locations (airfields) or regions. (Leftwich et al., 1997:9)

UTC Paring and Tailoring. The key capability gleaned from the above enumerated features is that of the automated paring and tailoring of existing UTCs and the creation of new UTCs from the ground up. The primary rules driving the paring and tailoring "engine" are the User Knowledge Base (Leftwich et al., 1997).

Detailed Description of UTC-DT Operational Structure. In this section we will describe the key inputs and outputs of UTC-DT. Then we will explain the mechanism and data used to produce those outputs.

The UTC-DT tool takes as its input the key parameters for a specific deployment scenario. These parameters are the deployment site, date of deployment, type of aircraft, number of aircraft, sortie rate, mission type, deployment duration and others. When using the software, these inputs are entered on the following screen (Figure 6) (Sjoquist, 1997:18).



CFP Key: New CFP

UTC: New UTC 1

UTC key: UTC001

Description: TFS 24 F-15E IND

MDS: F015E

PAA: 24

Mission type:

Sortie rate: 0.0

Duration: 0

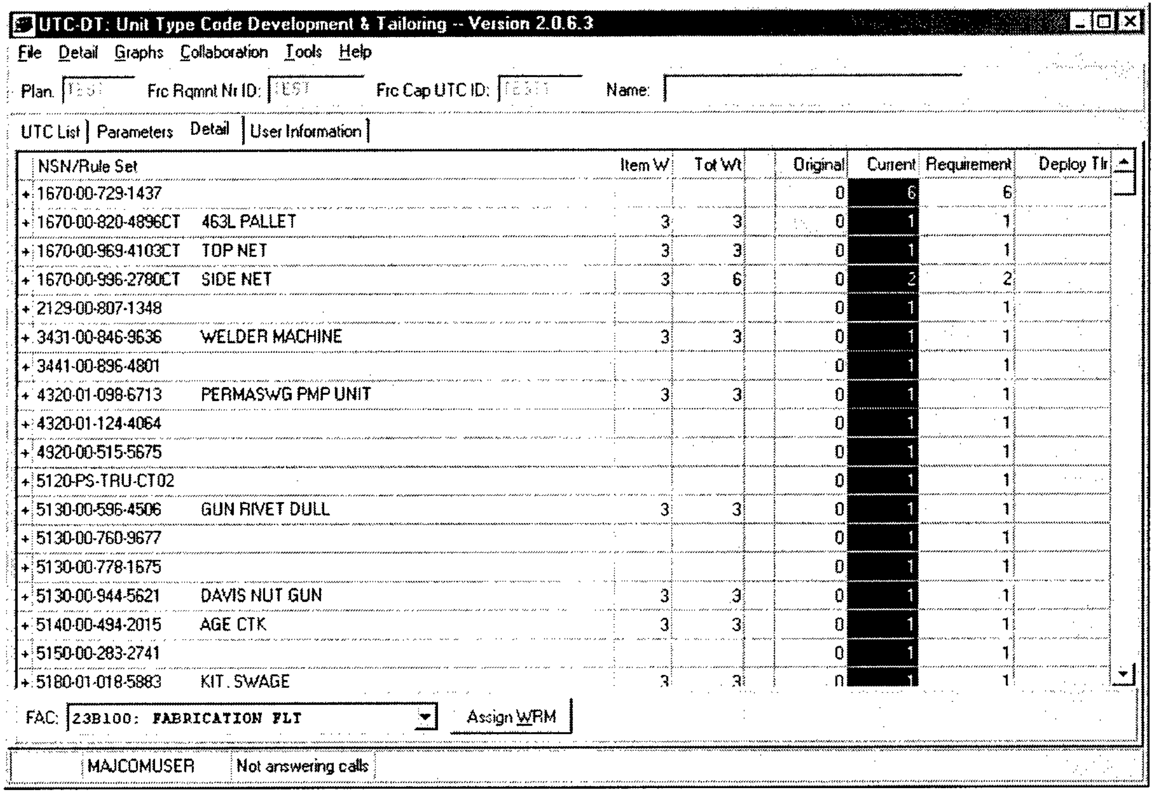
Resupply Day: 0

DSO: 0.00

Modified | MajcomUser | Answering calls

Figure 6. UTC-DT Input Screen

The output of the UTC-DT model is an automatically pared and tailored UTC or a new UTC built for the inputs given. This output is stored by UTC-DT as the equipment detail of the specific existing or created UTC. The user accesses this output according to each specific Functional Area Code (FAC). An example of equipment detail (a portion of it as visible on the screen) for the Fabrication FAC code is displayed in Figure 7.



NSN/Rule Set		Item W	Tot Wt	Original	Current	Requirement	Deploy Thr
1670-00-729-1437				0	6	6	
1670-00-820-4896CT	463L PALLET	3	3	0	1	1	
1670-00-969-4103CT	TOP NET	3	3	0	1	1	
1670-00-996-2780CT	SIDE NET	3	6	0	2	2	
2129-00-807-1348				0	1	1	
3431-00-846-9636	WELDER MACHINE	3	3	0	1	1	
3441-00-896-4801				0	1	1	
4320-01-098-6713	PERMASWG PMP UNIT	3	3	0	1	1	
4320-01-124-4064				0	1	1	
4920-00-515-5675				0	1	1	
5120-PS-TRU-CT02				0	1	1	
5130-00-596-4506	GUN RIVET DULL	3	3	0	1	1	
5130-00-760-9677				0	1	1	
5130-00-778-1675				0	1	1	
5130-00-944-5621	DAVIS NUT GUN	3	3	0	1	1	
5140-00-494-2015	AGE CTK	3	3	0	1	1	
5150-00-283-2741				0	1	1	
5180-01-018-5883	KIT . SWAGE	3	3	0	1	1	

FAC: 23B100: FABRICATION FLT

MAJCOMUSER | Not answering calls

Figure 7. UTC-DT Output

As can be seen in Figure 7 above, the equipment detail screen for each FAC gives recommended quantities in the "Current" column. Since this was a UTC that we created, the "Original" column will contain all zeros. Other FAC details can be accessed for the UTC such as: AGE, Sortie Support, Maintenance Supervision, etc. Currently, no correct weight information is loaded into the latest version of UTC-DT. Also, notably missing from the UTC-DT model are the Propulsion, Accessories, and Avionics FAC codes.

The recommendations for equipment quantities are based upon one of seven different types of rule-sets or sources of information. Each recommendation made by the software can be traced to a specific recommendation type, depending upon which rule-set was the overriding factor in determining the amount of the particular piece of equipment in question. For this research, we will be concerned with the *Automatic* recommendation types, which include the User-Knowledge Base, and the Allowance Standard Codes (ASC) (Sjoquist, 1997:8). Since it is attempting to show the non-human capabilities of an automated UTC development tool, this research focuses exclusively on the *automatic* recommendations.

UTC-DT uses a knowledge base containing rule-sets derived from actual combat units. These rule-sets are the recorded, quantified recommendations of field experts as discovered by several hundred interviews conducted by UTC-DT authors at Cannon AFB and Mountain Home AFB (Crowley, 2000).

In the upcoming methodology chapter, we will use the automated capabilities of the UTC-DT tool to build UTC equipment detail for some specific deployment scenarios. The goal will be to show the feasibility of an automated tool to get "in the ballpark" with a near-real-time constructed UTC of equipment and to show that these outputs can be considered valid enough to include their driving rule-sets in the M-R VAT structure.

The Aircraft Sustainability Model (ASM)

What we seek to show in this research regarding aircraft spare parts (spares) requirements is similar but different than our goals for equipment. As discussed earlier, we consider spares an important subset of equipment. However, once UTC-DT or the RAND AFLMA model indicates that a spares kit must be included in the logistics detail, it does not tell us specifically what spare parts are to be included in those kits. That is the job of the Aircraft Sustainability (ASM) model. The ASM model is used at Major Command level to determine stock levels for aircraft parts, including Mission Readiness Spares (MRSP) kits (Meyenburg, 2000). MRSP kits are designed for 30 days of support and are ready to load on an aircraft as is (Johns, 2000). A form of the ASM model, called the Dyna-Metric Analysis System (DMAS), is currently in use by unit level supply personnel to build custom made kits, referred to as Readiness Spares Kits (RSK), for CONUS deployments of under 30 days (Johnson, 2001).

The goal regarding UTC-DT and RAND AFLMA models, in this research, is to justify their rule-sets for automated generation of equipment UTCs. However, the goal regarding the ASM model will be to describe and define an accepted capability that is already being utilized by combat units. We will start our description and definition of existing ASM capabilities with the following overview of the ASM model.

ASM Overview. The Aircraft Sustainability Model (ASM), developed by the Logistics Management Institute (LMI) has been in use by the United States Air Force since 1989 for determining the number and types of spare parts that comprise Readiness Spares Kits for Aircraft (Slay, 2000). The ASM can be used to calculate spares requirements for both peacetime and wartime scenarios. The ASM model uses a marginal analysis approach identical to that found in the DMAS or Dyna Metric Model, also in use by Air Force Bases at the unit level. In addition, the ASM uses several key input parameters to calculate needed spares. ASM recommendations are based on weapon system availability (Slay et al., 1996:2-2). The ASM model decides which spares to buy based upon a spare's impact to the overall weapon system availability. Weapon system availability is defined as (1-NMCS rate)/total number of aircraft. For any wartime deployment operation, a specified NMCS rate constrains the ASM spares optimization.

> The ASM is used by the USAF to determine spares kits to support squadron-deployments in wartime and has been specially enhanced for the initial provisioning process. It is in use by the USAF for initial provisioning for the F-22 Advanced Tactical Fighter and the E-8 Joint Surveillance, Target Attack Radar System (JSTARS); it has been proposed as a Department of Defense standard. The ASM uses the typical component data-demand rates, repair times, unit cost, and so on-in concert with any of a wide range of operating scenarios-number of aircraft, time phasing of aircraft procurement, and operating tempo. The ASM then uses a marginal analysis approach, ranking possible additions to the inventory in terms of their probable benefit to aircraft availability divided by their procurement cost. Spares that have the greatest benefit per dollar appear at the top of this "shopping list". Accumulated costs and resulting aircraft availability are tracked as the shopping list is formed to provide a curve relating overall funding and projected availability. (Slay et al., 1996:iv)

Aircraft Sustainability Model (ASM) capabilities. The aircraft sustainability model has two key capabilities. One is to build an aircraft spares kit from a given set of input parameters and a baseline kit as a starting point. These are the kinds of parameters which would be pre-determined by the M-R VAT tool, including number of aircraft, daily sortie rate, and the desired aircraft availability rate, expressed as a non mission capable rate. The weapon system availability rate is also referred to as the Desired Support Objective, or DSO (Meyenburg, 2000). Secondly, the ASM model will evaluate a given spares kit for its impact on mission success, given certain input parameters.

The capability most applicable to this research is the first ability mentioned, that of building an aircraft spares kit given certain distinct parameters.

Detailed Description of Aircraft Sustainability Model Function. It is beyond the scope and purpose of this research to provide an in-depth exposition and discussion of the mathematical formulas that are the basis for the ASM model. However, a brief discussion of the basic logic, including the elementary mathematical expressions that describe that logic will be included in the following paragraphs as part of the overall description of the ASM. The following description will focus primarily on the key inputs and outputs of the model and the specific operation of the model as it relates to the goal of this research. Therefore, we focus our operational discussion of the model on its capability to determine spares kits for deployments (wartime). But we start with a discussion of the key assumptions for this research as related to the ASM model.

Of the wide range of capabilities of the ASM model, we will focus on only a few. As stated before our goal is to show the capability to determine custom built kits of spares for deployments of F-16 combat units. For the spares issue, we make the following assumptions:

- Deployment of a single combat unit of one MDS (F-16s)
- Deployment is to a single FOL of category 1

In addition, we will assume that cannibalization (of parts) is authorized and practiced during the wartime scenario.

Basic Driving Logic. Now we provide a general description of the logic behind the ASM model, and more specifically, the logic for the kinds of calculations our research requires. As discussed and defined earlier, the concept of weapon system availability is the driving concept of the ASM model. For steady state flying conditions without cannibalization, aircraft availability is directly dependent upon the number of backorders for a given aircraft part.

For such peacetime conditions, the ASM calculates spares requirements based on minimizing expected backorders (EBOs), shown in the below equation (Slay et al., 1996: 2-5).

$$EBO = \sum_{x \succ s} (x - s) p(x)$$

where s equals the number of items in stock and x is the number of demands on that item in a day. Thus by minimizing the expected backorders for each aircraft part, the ASM model maximizes aircraft availability. Availability in terms of EBOs is given by the equation below (Slay et al, 1996:2-13).

$$availability = \prod_{l} \left(1 - \frac{EBO_l}{NAC} \right)$$

for LRU l, where NAC = Number of Aircraft.

But many parts occur more than once per aircraft so the expression becomes the following (Slay et al., 1996:2-13),

$$availability = \prod_{l} \left(1 - \frac{EBO_l}{TI_l} \right)^{QPA_l}$$

where QPA is Quantity Per Aircraft and TI is total installed on all aircraft.

However, for our research, we are concerned *not* with steady state flying conditions, but rather with *dynamic* flying conditions. We also must consider cannibalization, since it is highly likely that cannibalization will be occurring during wartime conditions (Slay et al., 1996:3-5).

> We introduce one further complication: under dynamic conditions, we allow for a demand at the base to be satisfied by using a part from a grounded aircraft (cannibalization)-this is a policy likely to be used in war. Availability under cannibalization must be computed from the distribution of the number of aircraft NMCS for each item, rather than from each item's expected backorders. (Slay et al., 1996:3-5)

To illustrate the power of cannibalization for boosting aircraft availability, consider a simple scenario where we have 10 aircraft and each aircraft has only two different components (Slay et al., 1996:4-1).

> Consider the case where two aircraft are NMCS for the first component and one aircraft is NMCS for the second component. Maintenance can restore one aircraft to service by taking a unit of the second component from one of the two planes that are NMCS for the first component and installing it in the aircraft that is down for the second component; this process is called cannibalization. Consolidating the holes onto the fewest possible aircraft in this way raises the availability from 72 percent to 80 percent. (Slay et al., 1996:4-1)

The equation representing aircraft availability in the case of cannibalization is the following (Slay et al., 1996:4-2).

$$availability = 1 - \frac{ENMCS}{NAC}$$

where ENMCS is the expected number of aircraft that are not-mission-capable (NMC) due to lack of a spare part. ENMCS is defined as follows (Slay et al., 1996:4-3).

$$ENMCS = \sum_{D=0}^{\infty} \Pr(NMCS \geq D)$$

As stated earlier, the flying hour scenario will usually be dynamic and not steady state as in peacetime.

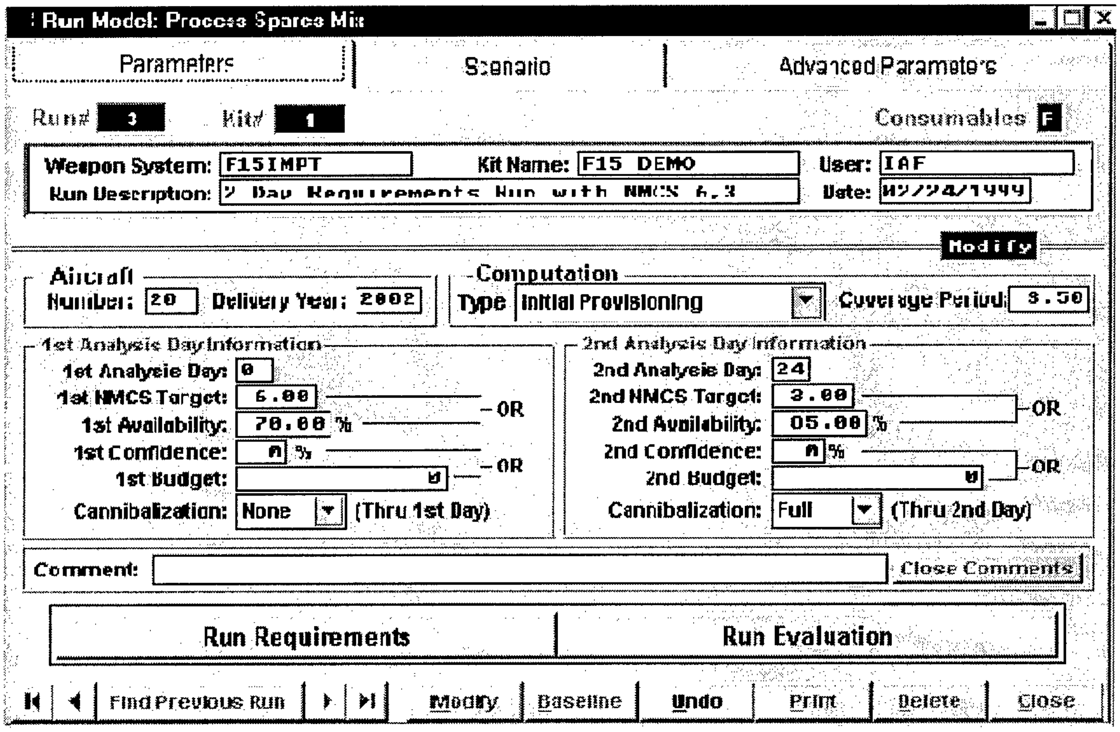
> One situation that leads us to consider dynamic conditions is planning for wartime, when the use of aircraft (i.e., the flying hours, sorties, or other measures of activity) changes rapidly from day to day, and thus so does the component demand process. In the transition from peace to war, resupply times may shorten or lengthen; resupply may even be suspended. (Slay et al., 1996:3-1)

ASM Model Inputs. The key input parameter for the ASM model, whether looking at steady state conditions, or the dynamic wartime conditions this research seeks to examine, is the average daily demand, or λ (Slay et al., 1996:2-6).

> The mean daily demand, λ, is a critical model input. In accordance with the USAF policy in effect when the ASM was developed, λ is estimated as the product of the failure factor (FF)-the historical demands per flying hour-and the total daily flying-hour program (FHP). (Slay et al., 1996:2-6)

From a user's perspective, we are concerned with the programmed flying hours for each day of the war. ASM will use these flying hour estimates to determine a λ value for each applicable part, based upon historical information that is captured in computer files known as item data. To use the ASM to generate spares kits, we import the historical part usage (item) data from a computer disk, and then set the flying hours and other key input parameters such as: number of days of wartime scenario, base repair capability (on or off), aircraft availability target, and desired confidence level for that target.

When using the ASM software tool, this information would be entered in the Model Parameters screen and the Scenario screen. The Model Parameters Screen is shown in Figure 8 on page 37 (Slay et al., 1996:1-12).



Run# 3
Kit# 1
Consumables F

Weapon System: F15IMPT
Kit Name: F15 DEMO
User: IAF
Run Description: 2 Day Requirements Run with NMCS 6.3
Date: 02/24/1999

Aircraft
Number: 20
Delivery Year: 2002

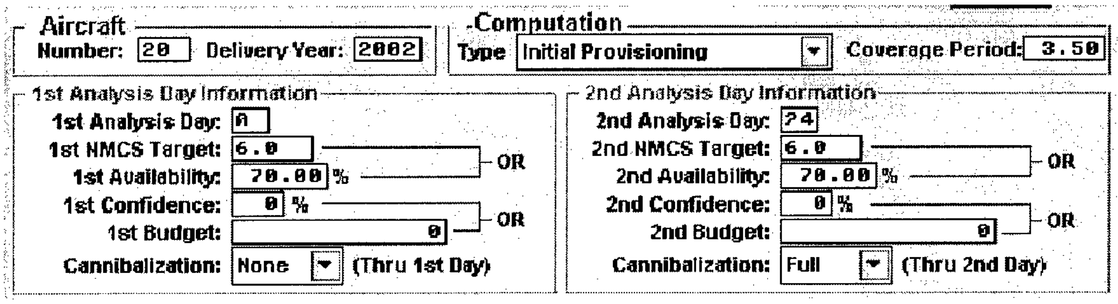
Computation
Type: Initial Provisioning
Coverage Period: 3.50

1st Analysis Day Information
1st Analysis Day: 0
1st NMCS Target: 6.00
1st Availability: 70.00 %
1st Confidence: 0 %
1st Budget: 0
Cannibalization: None (Thru 1st Day)

2nd Analysis Day Information
2nd Analysis Day: 24
2nd NMCS Target: 3.00
2nd Availability: 05.00 %
2nd Confidence: 0 %
2nd Budget: 0
Cannibalization: Full (Thru 2nd Day)

Figure 8. ASM Input Parameters

The model input parameters screen is critical to the ASM model operation. Therefore we will now examine each section of this screen in more detail. Figure 9 is a close up view of the primary system parameters section of the parameters page (Kline et al., 1999:1-15).



Aircraft
Number: 20
Delivery Year: 2002

Computation
Type: Initial Provisioning
Coverage Period: 3.50

1st Analysis Day Information
1st Analysis Day: 0
1st NMCS Target: 6.0
1st Availability: 70.00 %
1st Confidence: 0 %
1st Budget: 0
Cannibalization: None (Thru 1st Day)

2nd Analysis Day Information
2nd Analysis Day: 24
2nd NMCS Target: 6.0
2nd Availability: 70.00 %
2nd Confidence: 0 %
2nd Budget: 0
Cannibalization: Full (Thru 2nd Day)

Figure 9. ASM Primary System Parameters Section

Across the top of the screen shown in Figure 9 on page 37 we enter the number of aircraft to be supported and if the calculation is for initial provisioning the delivery year as well. The computation type for our research purposes will be set at "current", with the other available options being "replenishment" and "initial provisioning". Coverage period applies only to the initial provisioning option (Kline et al., 1999:1-15).

In the next section we enter the critical information for each analysis day. The ASM model computes spares requirements based upon a one or two day analysis of the wartime period. The user enters the first day on which to conduct analysis and then the second day on which to conduct analysis. Below each analysis day we enter the NMCS target, or availability target for that day. Next we enter either a confidence level for that availability target, or a budget constraint. Finally, for each analysis day, we enter the status of cannibalization (on or off) *through* that day (Kline et al., 1999:1-19).

At this time the reader may need a more detailed understanding of the analysis days and exactly how they are used by the ASM model as reference points for calculation of wartime spares requirements. Figure 10 below shows a sample flying hour profile for three aircraft, A, B, and C (Slay et al., 1996:5-3).

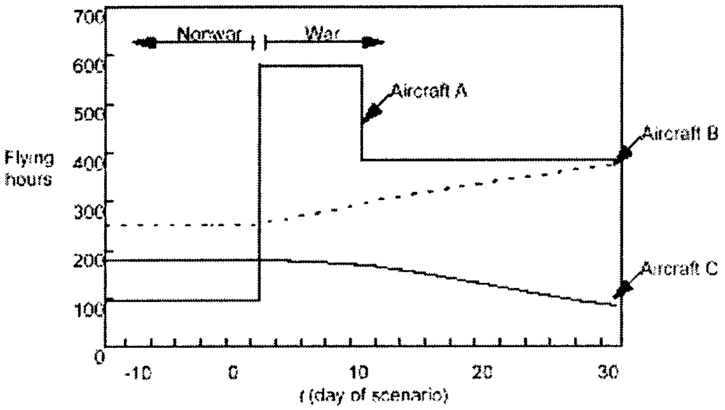


Figure 10. Flying Hour Scenario Example

> The ASM can generate and analyze requirements for one or two days specified by the user. While it is the availabilities on these specified analysis days that explicitly drive the requirements calculation, the model considers activity over the entire period, since this activity contributes to the pipelines on the analysis days. For a one-day analysis, the ASM computes the spares requirements to meet a user-specified availability or budget target on that day.
>
> For a two-day analysis, the ASM requires availability or budget targets for each analysis day. The model first purchases enough spares to meet the target on the first analysis day or — if constrained by the budget — purchases the spares that yield the best performance without exceeding the budget constraint. For the second analysis day, the model includes those spares already computed in support of the first day in the inventory, and it also considers any changes the maintenance system may undergo between the two days (e.g., a transition from a no-cannibalization mode to a "cannibalize-when-necessary" mode). It then computes the additional spares required to meet the specified second-day target or second day incremental budget constraint. After processing both days, the model assesses performance on both days with the total quantity of spares. Often the availability on the first analysis day will then exceed its target because the model typically purchases additional spares to meet the second day's target over and above the spares required to meet the first day's target. Whether the model is performing a one-day or two-day analysis, it produces curves of performance versus cost.
>
> Analysis of typical scenarios requires a judicious choice of analysis days. Often a choice of day zero as the first analysis day is indicated, since this would give the requirement for peacetime operations. One would like to identify the "worst" or most demanding day for the second analysis day so that spares sufficient to support that day are also adequate to maintain the required availability rate throughout the 30-day wartime support period. From an activity-level perspective, day 10 might be a good choice for analysis of Aircraft A, since its flying hours drop after that, while day 30 might be appropriate for Aircraft B. But, if the scenario involves maintenance and resupply disruption until day 15, that day might be the best choice for all three types of aircraft. Trial and error is sometimes the only way to make the choice of an analysis day.
> (Slay et al., 1996:5-3)

So then we have the option of computing spares requirements for our wartime period using a single-day analysis or a two-day analysis. Under the single-day analysis option there are three configurations to choose from depending upon the given need. These are: *steady-state conditions* (primarily for peacetime), *dynamic conditions* (for wartime only), and *dynamic conditions linked with steady state* (assumes peacetime pipelines are present at start of war) (Slay et al., 1996:5-4).

Under the two-day analysis there are also three possibilities. These are: *steady-state and dynamic conditions* (peace followed by war), *two dynamic analysis days* (typical USAF mode of operation when calculating deployment kits), and *two dynamic* *analysis days linked with steady-state* (similar to preceding except that peacetime pipelines are present at the start of the war) (Slay et al., 1996:5-5).

For our research we will use the *two dynamic analysis days* approach to calculating spares requirements. Refer to Figure 10 on page 38:

> Two dynamic analysis days. This is the typical USAF mode of operation when the ASM is used to calculate requirements for deployment kits, or mobility readiness spares packages (MRSPs). The model computes the spares required for two different days in a single wartime scenario — for instance, the last day of the surge and the end of the war (for Aircraft A this corresponds to day 10 and day 30). The model assumes that spares are required only for the wartime support period and that all spares and aircraft are available on day 1. A fleet flying-hour program for each day of the war is specified, and the steady-state flying hours are set to zero. There are two analysis days, and the model computes the requirement to meet both of those days' targets. (Slay et al., 1996:5-5)

Because the choice of analysis days is critical to the proper operation of the ASM Model, their selection should be based on a careful analysis of the dynamic flying hour program that is to constitute the wartime effort (Slay et al., 1996:5-17).

The following excerpt refers to Figure 11 on page 41.

> To determine requirements or evaluate support for a dynamic scenario such as war, the analysis should focus on the logistically most demanding day. Usually that is the last day of the wartime support period; however, for scenarios with an initial surge or a significant drop in flying hours over time, the best analysis day is less certain. To demonstrate that point, we ran the model under a typical scenario with our demonstration database. The flying-hour profile started with steady-state conditions of 10 hours a day, moved to a surge period of 60 flying hours a day, and then leveled off at 40 hours a day after day 5. ENMCS worsened over the surge period and then improved (dropped) once the surge ended. With this scenario, the lowest availability was projected to occur at the end of the surge period (day 5), making that day a good choice for the analysis day; even with flying hours dropping by a third, the ENMCS results varied only by half an aircraft or a few percent in availability after the fifth day. (Slay et al., 1996:5-17)

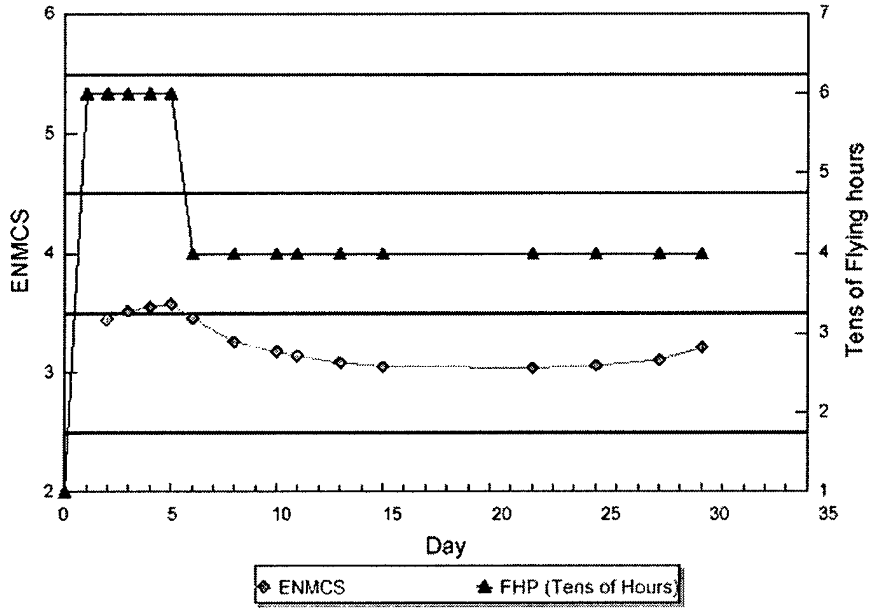
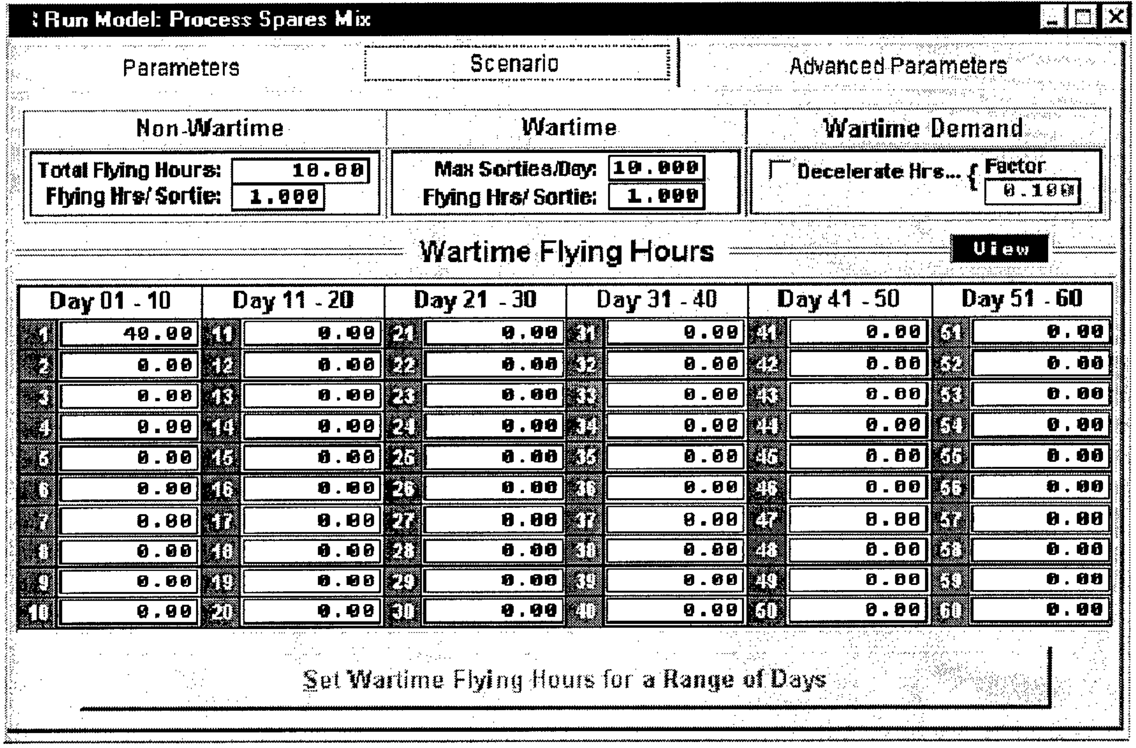


Figure 11. Choosing Analysis Days

Now we move on to explain the second important option in the model's input screen, the "Scenario" section. This is where we specify the aircraft flying hours for each day of the conflict. Refer to Figure 12 on page 42 (Kline et al., 1999:2-13).



Non-Wartime

Total Flying Hours: 10.00
Flying Hrs/ Sortie: 1.000

Wartime

Max Sorties/Day: 10.000
Flying Hrs/ Sortie: 1.000

Wartime Demand

☐ Decelerate Hrs... Factor 0.100

Wartime Flying Hours

Day 01 - 10		Day 11 - 20		Day 21 - 30		Day 31 - 40		Day 41 - 50		Day 51 - 60	
1	40.00	11	0.00	21	0.00	31	0.00	41	0.00	51	0.00
2	0.00	12	0.00	22	0.00	32	0.00	42	0.00	52	0.00
3	0.00	13	0.00	23	0.00	33	0.00	43	0.00	53	0.00
4	0.00	14	0.00	24	0.00	34	0.00	44	0.00	54	0.00
5	0.00	15	0.00	25	0.00	35	0.00	45	0.00	55	0.00
6	0.00	16	0.00	26	0.00	36	0.00	46	0.00	56	0.00
7	0.00	17	0.00	27	0.00	37	0.00	47	0.00	57	0.00
8	0.00	18	0.00	28	0.00	38	0.00	48	0.00	58	0.00
9	0.00	19	0.00	29	0.00	39	0.00	49	0.00	59	0.00
10	0.00	20	0.00	30	0.00	40	0.00	50	0.00	60	0.00

Figure 12. ASM Flying Hours Scenario Input

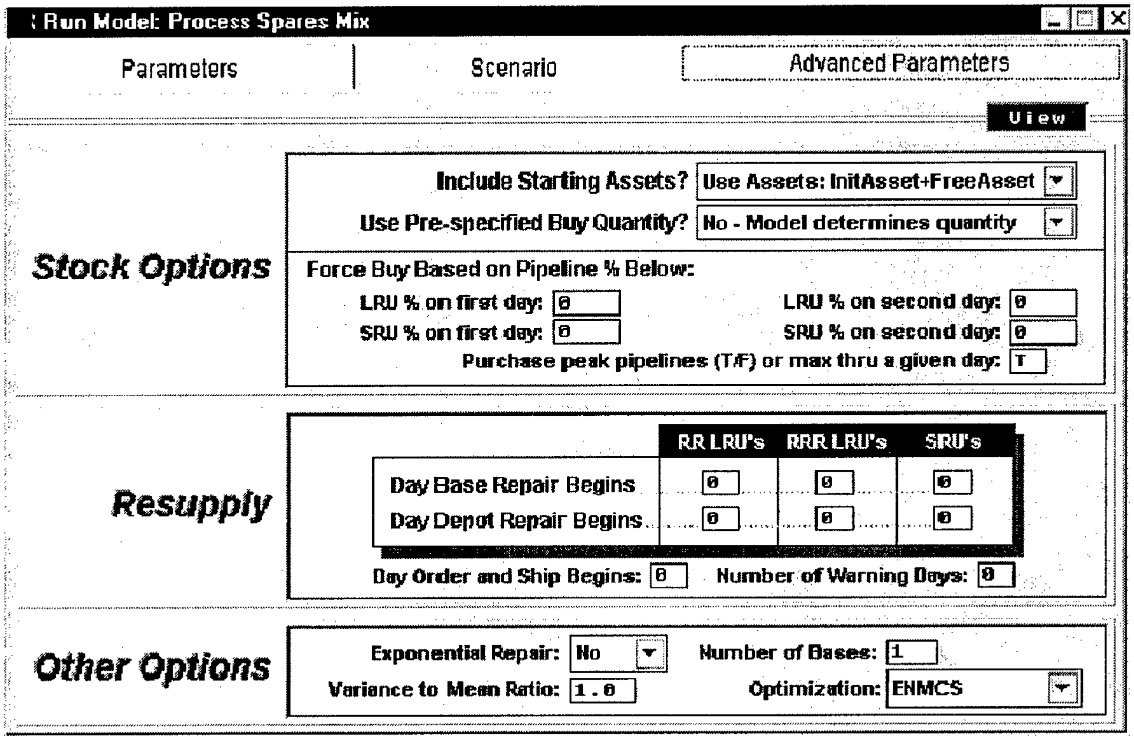
> Flying hours are the combined number of flying hours all the aircraft fly in a day. The Model multiplies that number by the demands per flying hour and the quantity of the item per aircraft (item data) to obtain the total demands for an item for each day.
> (Kline et al., 1999:2-13)

This screen is where we enter the daily flying hour program for our scenario. The ASM USER Manual provides an excellent detailed description of each compartment of this screen, except that we leave out the description of the "Non Wartime" compartment, since we are concerned in our research only with wartime conditions:

> **Max Sorties/Day.** The maximum number of sorties per aircraft per day in wartime (user input entered on the Scenario Page). It is also referred to as the *turn rate*. This value is required if you want to perform a multi-day evaluation
>
> **Flying Hours/Sortie.** The wartime flying hours per sortie. This value is required if you want to decelerate wartime flying hours or perform a multi-day evaluation.
>
> **Decelerate Hrs**. This field must be activated in order to use the decelerated flying-hour capability of the Model to better translate non-wartime demand into wartime demand. When this field is selected, the **Factor** text box field is activated.

> **Day 01—60.** These fields contain the total flying hours for day 01 through day 60 for wartime conditions. You are required to enter the flying hours for each day through the day, after which the flying hours remain constant until the end of the war. If the flying hours remain the same throughout the entire war, you are required only to enter a value on day 01. The Model is programmed to treat the flying hours as constant from the last non-zero value entered. The Model will accept a break in the flying hours (i.e., one or more days with 0 flying hours in between two or more days with flying hours greater than 0).
>
> **Set Wartime Flying Hours for a Range of Days Button.** This button is used to set the flying hours as a constant over a range of days in wartime. When you click on it, the dialog box shown in Figure 2–7 appears. (Kline et al., 1999:2-13)

The third and final portion of the model inputs screen is the advanced parameters setting tab. Figure 13 shows the Advanced Parameters Screen (Kline, et al., 1999:3-2).



Include Starting Assets? Use Assets: InitAsset+FreeAsset

Use Pre-specified Buy Quantity? No - Model determines quantity

Force Buy Based on Pipeline % Below:

LRU % on first day: 0

LRU % on second day: 0

SRU % on first day: 0

SRU % on second day: 0

Purchase peak pipelines (T/F) or max thru a given day: T

	RR LRU's	RRR LRU's	SRU's
Day Base Repair Begins	0	0	0
Day Depot Repair Begins	0	0	0

Day Order and Ship Begins: 0

Number of Warning Days: 0

Exponential Repair: No

Number of Bases: 1

Variance to Mean Ratio: 1.0

Optimization: ENMCS

Figure 13. ASM Advanced Parameters Screen

For our research, we are concerned with only the last two sections of this screen, “Resupply” and “Other Options”, since “Stock Options” settings are for peacetime base level scenarios. The first excerpt from the ASM user manual gives a detailed explanation of the "Resupply" block seen in Figure 13 on page 43.

> **Resupply** options are accessible via the middle section of the Advanced Parameters Page. This Resupply section enables you to adjust run-time parameters that affect when base and depot repair begin in wartime for RR (remove and replace) LRUs, RRR (remove, repair, and replace) LRUs, and SRUs. You specify in the item's maintenance concept (**Maint Con**) field whether an LRU is remove and repair (RR) or RRR. The standard use of those categories assumes that RRR items have repair start early in the war, while RR items have no repair until later in the war. However, you may designate LRUs as either RR or RRR on the basis of your own categorization separating them into any two groups differentiated by having their repair start on different days of the war.
>
> **Day Base or Depot Repair Begins**
> These three values indicate the day when base repair (top row) or depot repair starts for each type of item during wartime. In each case, a value greater than the analysis day denotes no repair of that category (e.g., for a day 30 run, '**3**' indicates that repair will start on day 03, while '**31**' indicates that no repair will be performed).
> **RR LRU's.** First day of repair for RR LRUs.
> **RRR LRU's.** First day of repair for RRR LRUs.
> **SRU's.** First day of repair for SRUs.
>
> **Day Order and Ship Begins**
> The day that forward transportation from the depot starts. As an example, an air force may assume that at the start of the war trucks will not be available to ship spares from the depot to the base because they will be in use for higher priority missions. If those trucks will not be available until day 5 of the war, then this parameter is set to '**5**'.
>
> **Number of Warning Days**
> The number of days of warning before the start of the wartime scenario (normally set to 0). In a model run that includes peacetime (day 0), this field indicates how long the Model will use wartime resupply values before the wartime scenario actually begins. For instance, with '**3**' days of warning, the model assumes war re-supply times for day–2, day–1, and day 0. Thus, the Model results for the analysis day (scenario day = 0) now represent the transitional characteristics on day 0 (immediately prior to the war beginning) and no longer represent the steady-state characteristics we assumed in the rest of this document. (Kline et al., 1999:3-11)

The "other options" section of the screen also contains some key input information and is fairly self-explanatory.

This concludes our discussion of the key input settings for use of the ASM model to calculate wartime spares requirements. Now we will take a brief look at the outputs we obtain from ASM "model runs" based on specific flying scenarios and imported item data and for a specific aircraft, in our case, the F-16.

Outputs and Output Parameters. A few key concepts must be understood in order to understand the outputs available from the ASM Model. The first of these is the term *kit*. The software developers at LMI derived this term and concept in order to keep all input parameters and item-data together in one package to prevent confusion or mixing of parameters from one model-run to another. "We link the parameters and item information into a kit to help ensure model output consistency. Each kit contains all the required model input necessary to run the Model" (Kline et al., 1999:4-3).

The other key concept for the reader to grasp is termed *model run*. A model run is when we actually run the ASM model for a certain kit (input parameters and item data), and generate recommendations and analysis outputs. These outputs can be accessed through various reports as the following paragraphs describe.

A primary output report resulting from the running of the ASM is called the Performance Report Page Frame. It contains the summary information for the latest model run. It can also be accessed to view summary information for any historical model run (each model run is saved with its own ID number) (Kline et al., 1999:2-19).

Many comparison and analysis reports are available from the system pull down menu (Kline et al., 1999:2-23). But the most important output available for the purposes of this research is the item information. This is where we can access the actual detail of the spare parts that have been recommended for the specific wartime scenario. The key value of several available here is the "Shopping List Data". The shopping list gives the item by item (part by part) requirements needed to meet the NMCS target (Kline et al., 1999:2-24).

Applicability of the ASM Model to the ALP PreProcessor Task. The spare parts aspect of this research focuses on the ASM's capability to build spares packages given certain input scenarios. As mentioned previously, the ASM uses a marginal analysis approach to selecting parts for procurement. The ASM system is designed to select parts based upon the ratio of that part's contribution to aircraft availability to the cost of that part in dollars. With a limited budget, then, the ASM will select the optimal buy list of spare parts for the given input scenario. Or with an unlimited budget, the ASM will optimize the parts package for the least possible dollar cost to obtain the desired support objective (DSO) (Slay et al., 1996).

During the methodology chapter of this research (Chapter III), we will take actual combat scenarios and use the ASM model to build spares kits for them and compare the results to current MRSP levels for 25 selected parts.

Summary

In this literature review we have looked at the U.S. Air Force deployment process and the determination of equipment support packages for F-16 units. We have also examined two tools selected for their equipment requirements determination rule-sets. The USAF's currently operating Aircraft Sustainability Model (ASM) was presented, to gain an understanding of its logic. In the next chapter, we use the tools described under the stated assumptions to show the capability of automated generation of logistics support packages. We also justify their outputs by comparison to actual historical deployments.

III. Methodology and Results

Introduction

In this chapter we use the tools discussed in Chapter II to produce an airlift footprint function for F-16 aircraft. Additionally, we attempt to justify the rule-sets contained in the Minmxf16cj and UTC-DT models by comparing their outputs to historical amounts of deployed equipment. Finally, we demonstrate the capability of the Aircraft Sustainability Model (ASM) to determine wartime spare parts requirements. To do so, we accomplish ASM model runs for a few specific historical scenarios and compare the outputs to current MRSP kits.

Our first goal is to determine an airlift footprint estimation function. To do this we map data for deployed equipment versus deployed aircraft. Next, we identify an equation that describes this mapping, using simple linear regression. This will show the weight data as a function of deployed aircraft. We build an initial map of weight data using the RAND Minimum Maintenance F-16CJ (Minmxf16cj) EXCEL tool for various numbers of deployed aircraft. To verify the approximate accuracy of this weight estimator, we build a regression line from standard UTC data found in the Logistics Force Packaging (LOGFOR) database. We also compare the Minmxf16cj regression to a regression of actual pared and tailored UTC (historical) data.

Recall that our second research goal is to justify rule-sets to be used in the M-R VAT architecture for detailed equipment and parts deployment requirements determination. We justify the use of RAND and UTC-DT deployed equipment rule-sets by comparing their outputs to actual deployed UTCs. For actual historical deployment scenarios of F-16 combat units, we input the sortie and other parameters into Minmxf16cj, and UTC-DT models and generate recommended quantities and types of equipment. Next, we carefully choose a sample of 29 equipment NSNs and compare the model outputs for those sample NSNs to the actual numbers in the historical tailored LOGPLANS. We also analyze and explain how these differences confirm or deny the accuracy and usefulness of the UTC-DT and RAND rule-sets.

Next we review and analyze the results of comparisons and draw conclusions. Specifically we analyze both the Aggregate Footprint Estimator (AFE) and the detailed equipment rule-sets justification. Observations and conclusions will be discussed, first for the AFE results and then for the detailed equipment rule-sets. Also, we discuss any research assumptions that need more explanation given the results of the methodology. Here we address and explain their effects on both the AFE and the detailed equipment rule-sets. Finally, all results and conclusions are summarized.

Building the Aggregate Footprint Estimator (AFE)

RAND AFLMA Minmxf16cj Estimates. As described in Chapter II, the RAND Minmxf16cj tool is part of the requirements generation portion (step 2) of the three step RAND and AFLMA approach to overall deployment logistics support planning (Galway et al., 2000:14). This particular tool includes the capability to generate estimates of total short tons and pallet positions for specific scenarios. In this the first part of the methodology, we use the Minmxf16cj tool to generate (estimate) and map the weight of equipment requirements versus number of deployed aircraft.

As discussed in the literature review, the Minmxfl6cj model originally compiled a total weight for only AGE, and not other types of equipment. However, the weight data for other than AGE maintenance equipment was included in the model's data sheet. The model output was easily modified to include the weight of all other maintenance support equipment, in addition to AGE.

Figure 14 below shows the mapping of the output of the Minmxfl6cj model. It displays required total short tons of equipment per number of deployed F-16 aircraft.

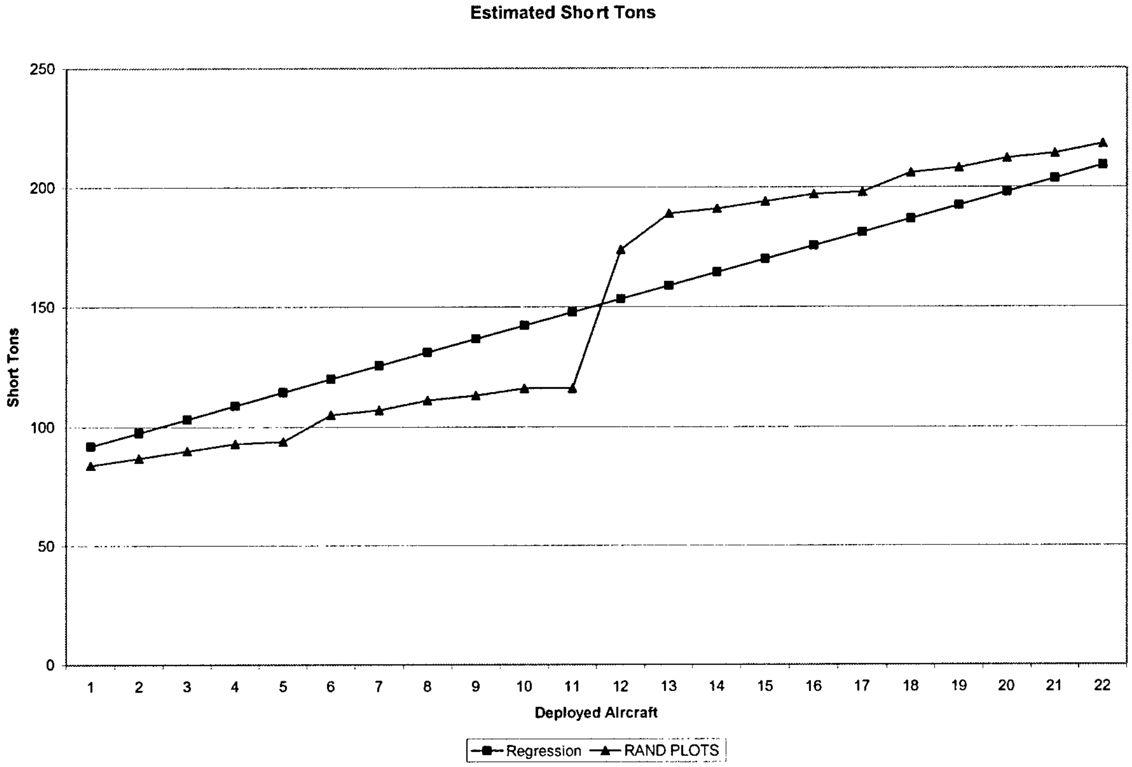


Figure 14. Estimated Short Tons

Observations and Conclusions. The results of the best-fit linear regression can be seen in Figure 14. The coefficient and intercept for this straight-line representation of the footprint versus deployed aircraft data was obtained using Microsoft EXCEL's built in data analysis function.

However, this single straight-line representation is not a very close fit for any of the data points in particular. Therefore a stepped linear-fit was tried with two separate straight-line functions (see Figure 15 below).

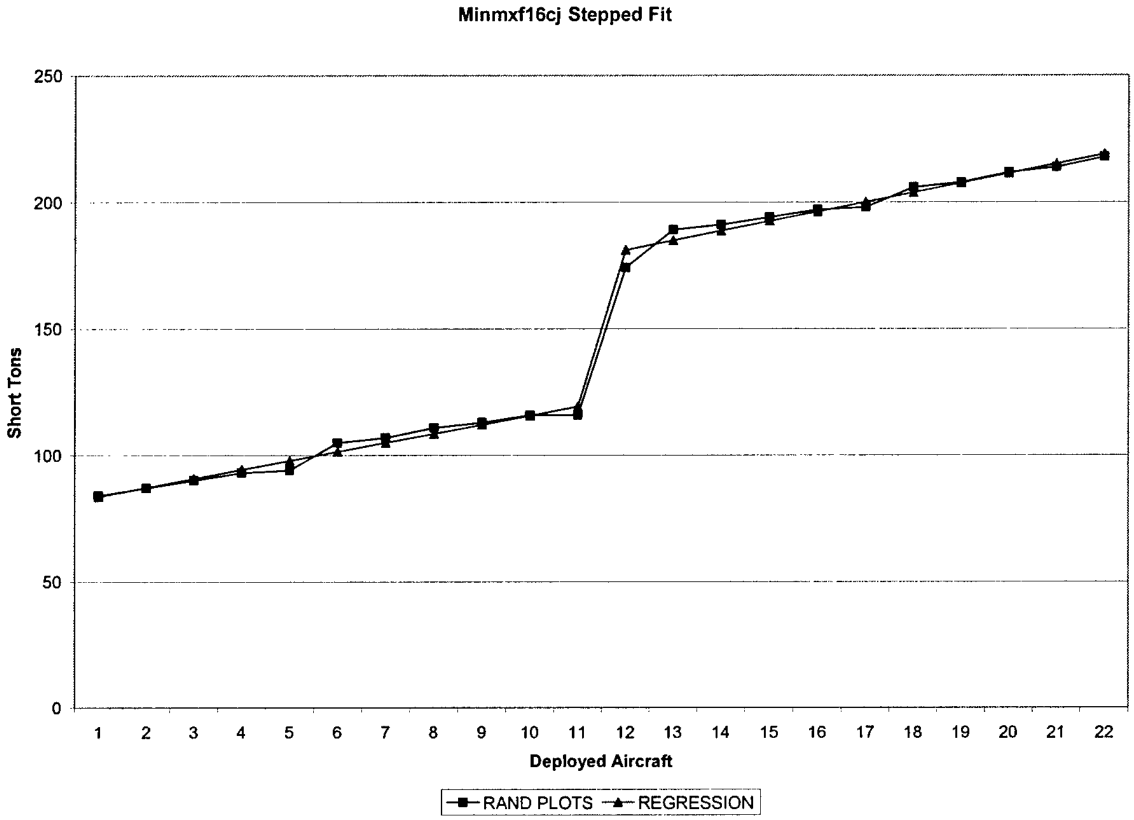


Figure 15. Minmxf16cj Stepped Fit

Observations and Conclusions. The break in the step function is at 12 deployed aircraft, the point where the short tons appear to spike upward. This upward spike is due to the increased equipment requirements prescribed by the rule-sets for 12 aircraft and above. As seen in Figure 15 above, this stepped linear approximation is a much closer fit to the plotted weight estimate data. Therefore, we adopt this stepped linear regression to quickly approximate the output of the Minmxf16cj model in terms of total short tons per number of deployed F-16 aircraft. From 1 to 11 aircraft, the function is $y = 3.6x + 80$ and from 12 to 24 aircraft the function is $y = 3.8x + 135.2$, rounded to nearest tenths, where y = number of short tons deployed and x = number of aircraft deployed.

LOGFOR Plots. Now we take standard UTCs and construct a similar mapping chart. Data was obtained for total required short tons of standard F-16 UTCs from the Manpower and Equipment Force Packaging (MEFPAK) list (MEFPAK, 2000:Sep). The MEFPAK list contains all official USAF UTCs. This data was crosschecked with the actual LOGFOR UTC weight data downloaded from the LOGMOD database, to ensure accuracy. See Appendix A for a summary of F-16 standard LOGFOR UTC data.

Figure 16 on page 52 shows the plotted short tons of equipment requirements versus deployed aircraft for the 27 standard F-16 Aviation Package UTCs found in the LOGMOD LOGFOR database. All but three of the UTCs are for F-16 C and D model aircraft of different block production numbers. Three of the UTCs are for the older F-16 A and B model aircraft.

The data points shown as solid black squares in Figure 16 on page 52 each represent an average of several UTCs for each number of deployed acft. The only numbers of deployed acft for which standard F-16 UTCs exist are 6, 12, 15, 18 and 24. There are 6 six-ship UTCs, 5 twelve-ship UTCS, 6 fifteen-ship UTCs, 7 eighteen-ship UTCs and 3 twenty-four-ship UTCs.

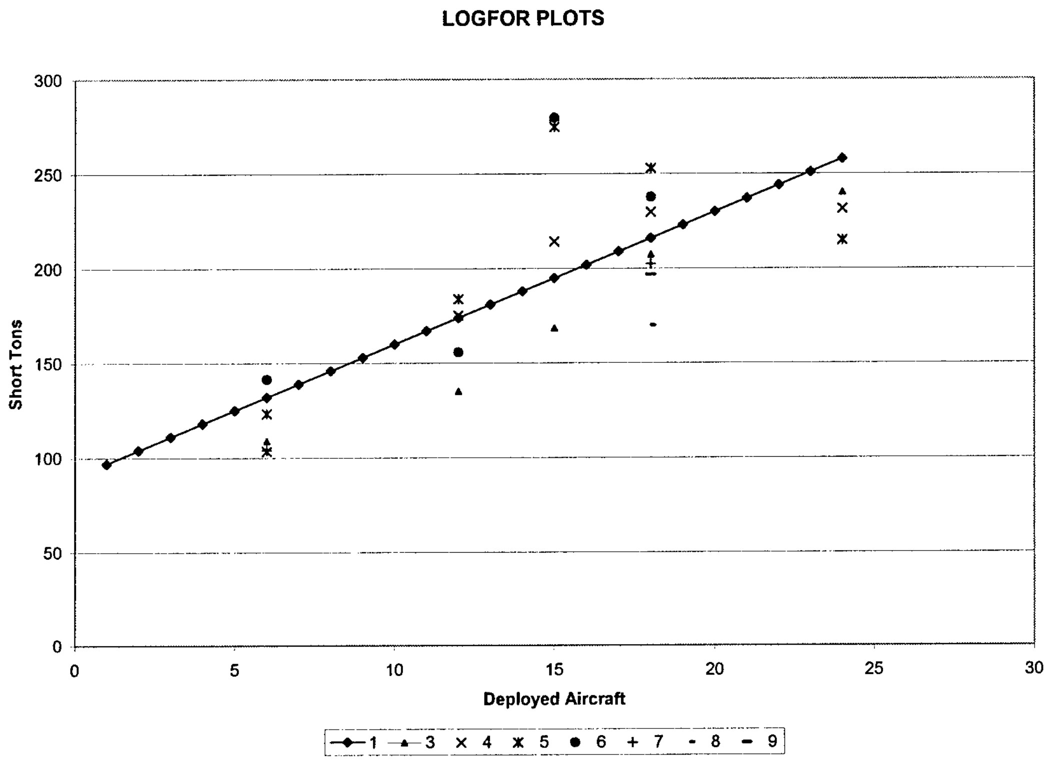


Figure 16. LOGFOR Plots

Observations and Conclusions. The best linear fit of the LOGFOR short ton data is a straight linear fit. The slope of this line appears very similar to the slopes of the stepped linear fit for the Minmxf16cj short ton estimate plots. Several interesting observations resulted from the mapping of short tons for standard LOGFOR deployment packages. One is the fact that the average standard short ton requirements (maximum authorized), as shown in the MEFPAK summary, are higher for 15-ship packages than for 18 and 24-ship packages? This runs counter to common sense logic that tends to suggest that the more airplanes you deploy, the more equipment you will need and accordingly the more weight required to be airlifted.

A closer look at the MEFPAK and the included LOGFOR UTC packages reveals that all of the 15-ship package pilot units are Air National Guard Units. SMSgt Larry

Briggs, ACC Command Maintenance Plans Manager, agreed this is the best explanation for this observation, since Air National Guard units generally deploy substantially heavier than active duty units (Briggs, 2001).

Figure 17 below shows the comparison of the Minmxf16cj stepped linear regression and the LOGFOR linear regression. The similarity of the slopes indicates a corresponding similarity in the relationship each predictive regression line has between deployed aircraft and deployed short tons.

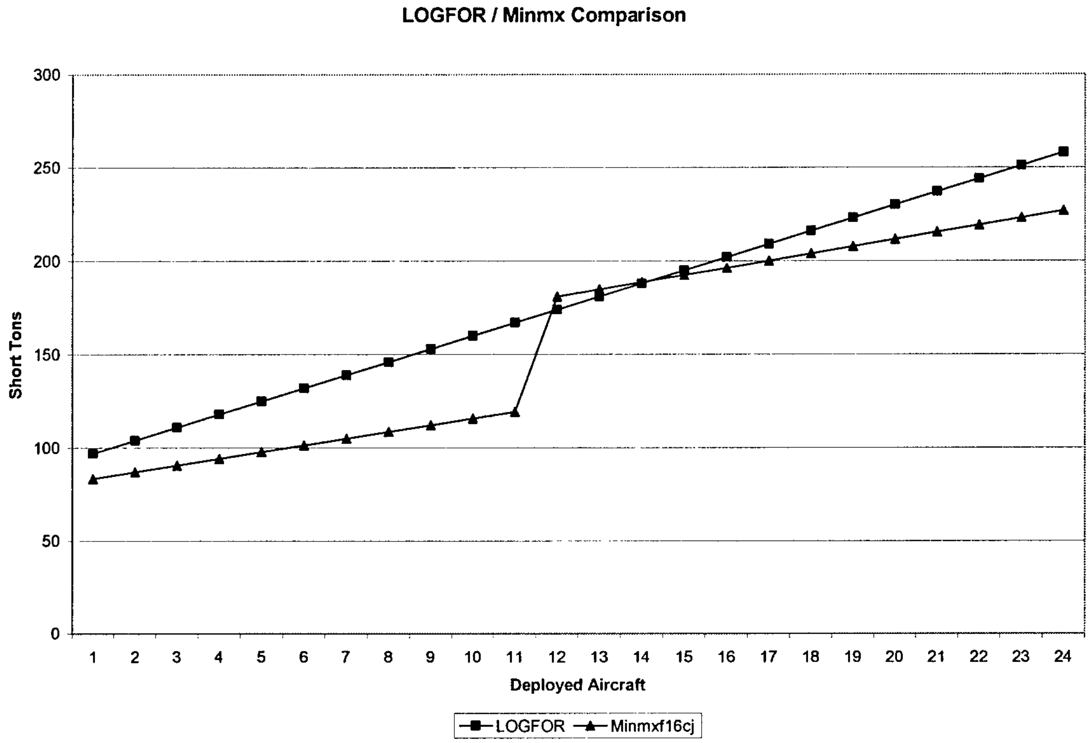


Figure 17. LOGFOR / Minmx Comparison

Observations and Conclusions. The similarity of the LOGFOR and Minmxf16cj regression line slopes, seen in Figure 17, tends to generally re-enforce the validity of the RAND AFLMA Minmxf16cj short ton estimates. The LOGFOR line plots short ton requirements that are an average of 20 short tons higher than the Minmxf16cj estimates. This difference is as expected, since the LOGFOR averages are obtained from standard UTCs whose total short tons reflect the maximum authorized by Air Combat Command (ACC). Also, RAND and AFLMA compiled the rule-sets driving the Minmxf16cj model from extensive interviews of experienced maintenance personnel at Shaw AFB, NC. We would expect rule-sets derived from such interviews to reflect some tailoring considerations, despite the fact that the rule-sets are not FOL specific.

Now we add the comparison of actual historical deployed weight data. Figure 18 below is the plot of the actual short tons deployed for several deployments each of 5, 6, 8, 10, 12, 18 and 24-ship force packages. Note that the 5, 8 and 10-ship packages do not exist in the LOGFOR listing, and the deploying unit must tailor the closest existing UTC to obtain appropriate requirements. These weight values were taken from 57 actual F-16 overseas deployments.

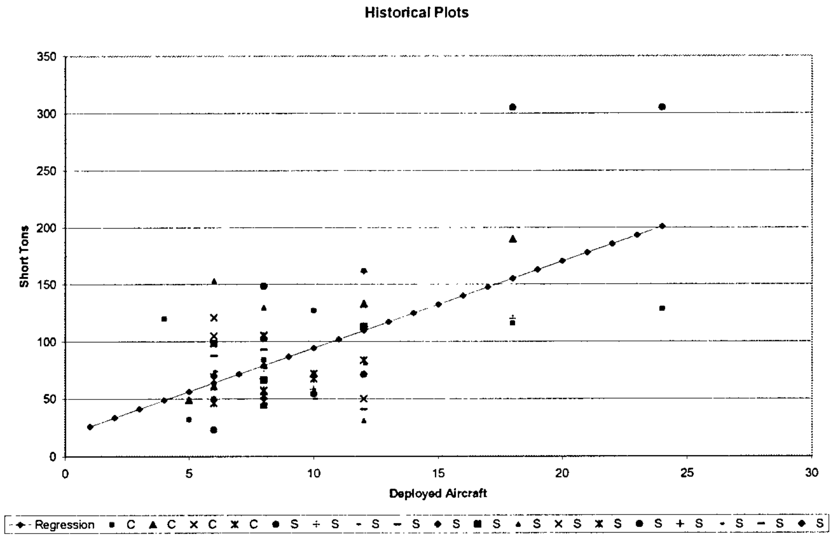


Figure 18. Historical Plots

Observations and Conclusions. Noteworthy in Figure 18 above is the fact that the 8-ship package has the most data points, followed by the 6 and then 12-ship packages.

The legend for Figure 18 shows the datapoints labeled with a C or an S, indicating either Cannon or Shaw AFB as the source for the data point.

The first data point outlier that needs explanation is the single 4-ship deployment package which appears very heavy compared to the 5, 6 or 8-ship packages. Very little information was available for this particular deployment, which was over 5 years ago. The most likely explanation for the heaviness of the package is that the FOL, Fairford England, normally supports heavier aircraft such as bombers and likely did not have many of the fighter-specific assets needed.

The average short tons for 6 through 10-ship packages appear to decrease by about 10 short tons as we move from 6 to 10 aircraft, rather than increasing, as logically expected. This phenomenon is explained by the existence of one large outlier in the 6-ship data set and one large outlier in the 8-ship data set. One of these outliers was a deployment to a classified location, which may well have had less pre-positioned assets available. Another was to Al Jafra Air Base, which does not have the infrastructure of other Southwest Asia bases. Additionally, there were a smaller number of 10-ship deployments and several of these were to "well stocked" bases in terms of pre-positioned assets. Also shown in Figure 19 is a 12-ship deployment (the lightest 12-ship package at only 31 short tons) that appears much lighter than nearly all of the 6 or 8-ship deployments. The FOL for this deployment was Incirlik Air Base, which has a large amount of in-place assets for F-16 fighter aircraft. This explains the very light weight of this particular 12-ship package when compared to the heaviest 6 and 8-ship packages, which appear heavier.

Moving across the x-axis, we make other important observations about data points that appear to be outliers and require further explanation. The highest weighted 12-ship package was a 27th FW deployment to an air base in Southwest Asia (specific location not given). This 12-ship package appears much heavier than the two lightest 18-ship packages to Dahran Air Base and an unmentioned air base in Saudi Arabia. Further investigation revealed that this 12-ship package contained a special "AEF Initial Link" component accounting for the unusual heaviness of the deployment.

Finally, the heaviest 18-ship and 24-ship packages appear to be outliers and require explanation. Both of these deployments were in support of ALLIED FORCE, a real world contingency operation. Real world contingency operations generally deploy heavier than routine on-going rotations such as Northern/Southern Watch.

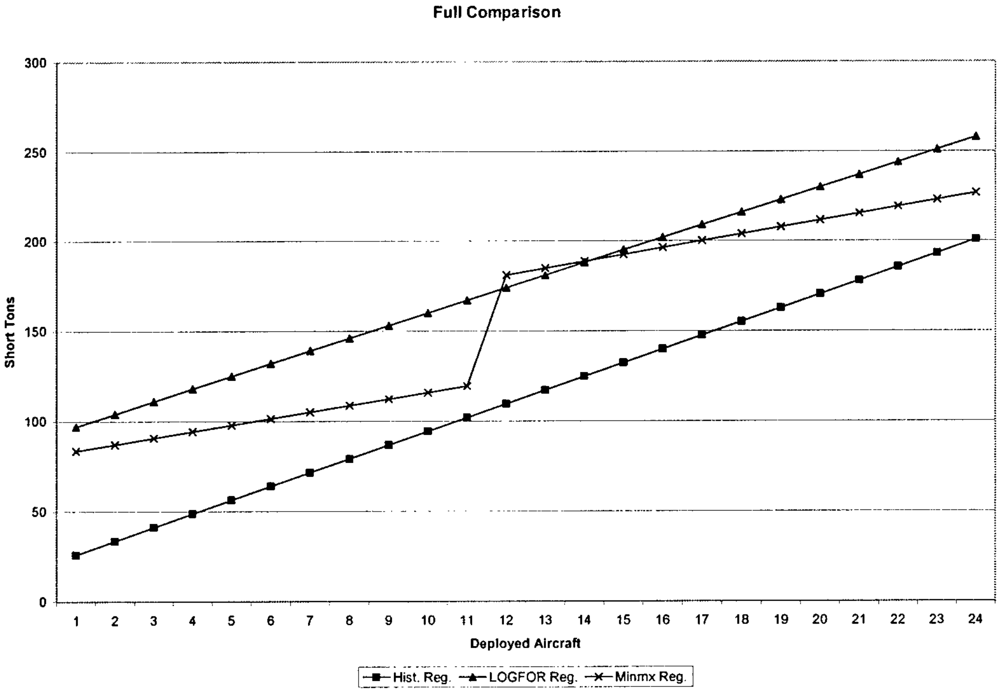


Figure 19. Full Comparison

Figure 19 on page 56 shows the linear regression of the historical data as compared with the linear regressions of the LOGFOR data and Minmxf16cj estimates Note the substantial difference between the historical and LOGFOR short ton values at each point along the x-axis (deployed aircraft). The short ton values represented by the historical regression line are 60 short tons less than the values on the LOGFOR regression line. This is because historical weights are of pared and tailored UTCs; reduced to the level of equipment needed for the specific deployed location. A large amount of this is due to pre-positioning of AGE equipment at the specific FOL. Note however that the slopes of the lines are nearly identical. This similarity supports the claim that the historical regression line does reflect a valid relationship between deployed aircraft and deployed short tons. Figure 20 below shows the same chart with a 95% confidence interval applied to the historical regression line.

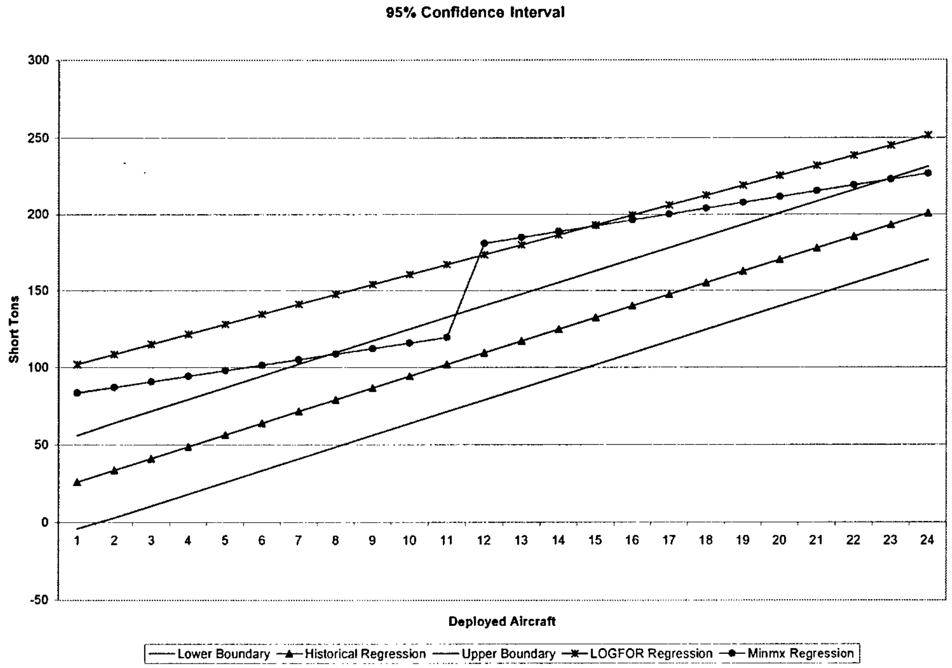


Figure 20. 95% Confidence Interval

Having examined data regressions for the EXCEL-based Minmxf16cj tool, tailored UTCs, and untailored LOGFOR UTCs, the task remains to select an equation which best estimates required airlift short tons for deployed F-16 aircraft. Here we briefly address each option and then make the best selection that will be called the Aggregate Footprint Estimator (AFE) function.

The first option would be to use the regression of the untailored LOGFOR UTCS. This has the obvious disadvantage of generating "untailored" short ton estimates. For the M-R VAT tool to successfully use the AFE output as a constraint to force selection, the estimate must be as close as possible to actual airlift requirements. This need eliminates this first option as the optimal choice.

Another option would be to select the Minmxf16cj stepped linear function. Its main disadvantage is that it appears to provide very heavy estimates when compared to the regression of actual operational deployments. We could possibly apply a correction factor, by measuring the difference between the two lines over the range where the slopes are similar. However, there is no way to be confident this correction factor will apply for all situations and scenarios.

It was decided that an extended version of the actual historical plots would be the best choice. A simple 95% confidence interval was constructed using Microsoft EXCEL's data analysis function. The upper and lower bounds of this interval are seen as solid black lines in Figure 20 on page 56. If we select the upper bound as a "worst case" scenario for any deploying F-16 unit, we can use it as an estimating linear function. This allows us to be 95% certain that the number of short tons deployed for any deployed F-16 unit will not exceed the amount represented by this line. Yet this line will still give us a significant tailoring affect, as it is approximately 40 short tons lighter than the maximum authorized amounts represented by the LOGFOR regression line. Increased numbers of data points could substantially decrease the size of the confidence interval and allow us to assume an even greater tailoring affect. In summary then, the final recommended AFE function is:

$$\mathbf{y = 7.6x + 48.1} \tag{1}$$

where y = required short tons

x = number of deployed F-16 aircraft.

Detailed Requirements Determination

The objective here is to justify based upon specifically set forth criteria, the Minmxf16cj and UTC-DT equipment determination tools' rule-sets so that these rule-sets may be confidently used in the M-R VAT architecture. The process used will be to generate output from the RAND and UTC-DT tools for three specific historical scenarios and compare this output to the pared and tailored equipment listings from the actual LOGPLANs from those specific historical scenarios. The reasoning used when comparing the outputs will be based upon the following hypothesis:

Hypothesis. The primary hypothesis regarding the UTC-DT and Mimmxf16cj rule-sets is that, based upon the fact that the rule-sets were determined through detailed interviews with actual field experts, they are reasonable approximations of actual equipment needs or requirements for deployment of F-16 aircraft.

Since potentially thousands of different pieces of support equipment could be selected for any one-deployment scenario, we select a sample of deployable equipment on which to base our comparisons.

Enumeration of Sample Equipment. Based upon careful scrutiny of several LOGPLANS from actual F-16 active duty combat units, we selected a list of sample equipment to use for justification of the Minmxf16cj and UTC-DT rule-bases. This list is shown in Table 3 below.

Table 3. Original Sample Equipment

Nomenclature	**AEF1 421FS**	UTC-DT	Minmx
Folding Tables	14		
STORES LOADER	6		
TANK DOLLY	7		2
GENERATOR M32A-60	4	4	5
LOX CART/VENT KIT	2		
JACK HYD TRIPOD	12	3	
UALS UNLOADED	6		
NF2D LIGHT CART	10	2	5
MJ1			4
MHU 83			
NIT CART LIQUID	3		1
LAUNCH BAG	42		
CTK APG	42		
TANK, FUEL 370 GAL	9		
STEP LADDER, 4FT	12	1	
TIRE INFLATOR KIT	9		
DOG, CTK	42		
CTK, AVIONICS	10		
H-70 CASKET	5		
TRAILER, ACFT ENGINE	10		
GE-F110-100 ENGINE	6		
ENG SUP AY P40064	7		
ECM CASKET (with 184 and E	12		
TARGET POD IN CASKET	14		
ADAPTER M10 TREE	8		
TER 9A RACK ASSY	36	12	
WING WEAPON PYLON	12		

Any time a sample of a population is selected, it is important to understand the logic driving the selection of those items. When examining F-16 LOGPLANS to select equipment for our sample, we examined equipment items in each of the key aircraft maintenance functional areas. Many items in a typical LOGPLAN occur only once per increment and some only once per entire LOGPLAN. When selecting equipment for our sample, pieces that occurred only once were generally avoided because such an item would have less opportunity to vary in number over different scenarios, making output comparisons difficult. Therefore, items were selected that occurred 2 or more times per increment and/or 2 or more times per LOGPLAN.

If a piece of equipment met the *occurred multiple times* criterion, the next "cut" was based upon perceived pertinence to aircraft generation. This decision was based upon general knowledge of aircraft maintenance equipment and aircraft maintenance operations. Thus, critically important equipment items were "singled out".

Also, heavier items were favored over lighter ones, because heavier items would be more likely to show up on an aircraft load plan as a single cargo increment. This makes more efficient the task of comparing tailored packages to UTC-DT and RAND model outputs.

Table 3 on page 60 shows the original selected sample equipment items. Initial comparisons indicated, as can be seen, that many of the selected items were lacking from the UTC-DT rule-sets. Therefore it was decided that the sample list should come directly from the rule-sets of the UTC-DT model. In this way, we are able to justify the rule-sets that do exist, instead of merely highlighting the fact that many items do not appear in UTC-DT.

Comparison. The next step was to choose three actual historical deployment scenarios for which we had detailed lists of deployed equipment. These three historical scenarios are as follows:

1. AEF 1, 421 FS Deployment to Al Jaber 1999: 388 FW, Hill AFB, UT: 10 F-16C/D
2. AEF 9, 524 FS Deployment to Al Jaber 2000: 27 FW, Cannon AFB, NM: 10 F-16C/D
3. AEF 10, 522 FS Deployment to Incirlik 2000: 27 FW, Cannon AFB, NM: 8 F-16C/D

Next, we used the input parameters (# aircraft deployed, sortie rates, deployment duration, mission types) for each of the three scenarios as inputs to UTC-DT and Minmxf16cj models. The results were output lists of recommended numbers of deployed equipment for the specific scenario. The UTC-DT recommendations for the selected sample equipment were tabulated and recorded. Then we compiled the numbers of items deployed in the actual historical scenarios and constructed comparison tables for each scenario. An example of one of these three tables, for AEF 9 data, is shown in Table 4 on page 63. Comparison tables for the other two scenarios AEF 1 and AEF 10 can be seen in Appendix B and Appendix C.

In Table 4 on page 63 shaded and bolded rows show items whose predicted values match the historical values exactly, or very close given consideration of the specific item. Bolded only are items which were very close or whose UTC-DT recommendation matched closely the Minmxf16cj recommendation. Next, we combined the comparison data for all three AEF scenarios into one summary table as seen in Table 5 on page 64.

Table 4. AEF 9 Comparisons

NSN	Nomenclature	AEF 9	UTC-DT	Minmxf16cj
1095012293821	TER-9/A	28	12	
1440011856632	LAU-117 LAUNCHERS	12	6	
1440013154103	**LAU-129 LAUNCHER**	**4**	**4**	
1730000012278	ADAPTER AFT PYLON	4	1	
1730002943695	WOOD CHOCKS	24	2	
1730002948883	**B4 STAND**	**0**	**2**	**1**
1730003905618	**B1 STAND**	**0**	**1**	**1**
1730003952781	**C1 STAND**	**1**	**1**	**1**
1730005162019	JACK HYD 10 TON	6	3	
1730006408080	TOWBAR	0	1	3
1730008542237	JACK ACFT 15 TON	1	2	
1730008576819	ADAPTER WING PYLO	3	2	
1730009438306	MHU-83 FORKS	0	2	
1740005807990	**MB-4 COLEMAN**	**0**	**2**	**1**
1740007135908	**TRAILER ACFT ENG**	**2**	**2**	
1740010315868	**MHU141 TRL (CKC)**	**4**	**1**	**1**
3431008469636	WELDER MACHINE	0	1	
3950010933721	COBRA CRANE	0	1	
4120003033064	**A/M32C-10C A/C**	**0**	**4**	**4**
4310011732826	COMPRESSOR MC2A	0	2	
4520007200175	H-1 HEATER	0	5	2
4910008955394	**HYD CART**	**2**	**2**	**2**
4930006202406	**OIL CART**	**2**	**2**	**2**
4933012302374	AMMO LOADER	0	2	
5140004942015	AGE CTK	0	1	
6115004208486	**AM32A-60 GEN SET**	**0**	**4**	**5**
6230012240938	**FLOODLIGHT NF2D**	**0**	**5**	**5**
7195009731961	**PAR PACKING TABLES**	**4**	**5**	
1740011187669Y	WBOBTAIL DODGE	0	3	1

In Table 5 on page 64 a dash indicates UTC-DT or Minmxf16cj gave no recommendation for this piece of equipment for the particular scenario. An asterix indicates items that did not appear on the actual deployment list. A 0% indicates a perfect match between the recommended and actual values. All other percentages indicate the deviation of the recommended from the actual values.

Table 5. Comparison Summary

Scenario:	**AEF 1**		**AEF 9**		**AEF 10**	
Nomenclature	UTC-DT	Minmx	UTC-DT	Minmx	UTC-DT	Minmx
TER-9/A	-67%	-	-57%	-	-33%	-
LAU-117 LAUNCHERS	*	*	-50%	-	*	*
LAU-129 LAUNCHER	*	*	**0%**	-	-33%	-
ADAPTER AFT PYLON	*	*	-75%	-	-75%	-
WOOD CHOCKS	*	*	-92%	-	*	*
B4 STAND	*	*	*	*	*	*
B1 STAND	*	*	*	*	*	*
C1 STAND	*	*	**0%**	0%	*	*
JACK HYD 10 TON	-75%	-	-50%	-	**0%**	-
TOWBAR	-50%	50%	*	*	**0%**	200%
JACK ACFT 15 TON	*	*	100%	-	*	*
ADAPTER WING PYLO	**0%**	-	-33%	-	-83%	-
MHU-83 FORKS	-50%	-	*	*	**0%**	-
MB-4 COLEMAN	*	*	*	*	*	*
TRAILER ACFT ENG	-80%	-	**0%**	-	-50%	-
MHU141 TRL (CKC)	*	*	-75%	-75%	**0%**	0%
WELDER MACHINE	-50%	-	*	*	*	*
COBRA CRANE	-50%	-	*	*	*	*
A/M32C-10C A/C	**0%**	**0%**	*	*	*	*
COMPRESSOR MC2A	*	*	*	*	*	*
H-1 HEATER	*	*	*	*	*	*
HYD CART	*	*	**0%**	0%	**0%**	0%
OIL CART	*	*	**0%**	0%	**0%**	0%
AMMO LOADER	*	*	*	*	*	*
AGE CTK	*	*	*	*	*	*
AM32A-60 GEN SET	**0%**	25%	*	*	*	*
FLOODLIGHT NF2D	-80%	-50%	*	*	*	*
PAR PACKING TABLES	-64%	-	25%	-	*	*
WBOBTAIL DODGE	*	*	*	*	*	*

Observations and Conclusions. When comparing detailed equipment requirements numbers, it was quietly assumed that the actual historical deployed amount of equipment should be the standard against which the predictive rule-sets should be judged. To defend this point of view, we must consider what the rule-sets are meant to accomplish. The rule-sets appear to fall somewhere between full tailored and full-authorized quantities. They reflect the views of field experts regarding needed quantities of equipment but do not account for FOL pre-positioned assets.

Before launching the discussion of the logic behind our rule-set justification, some key terms need to be defined. In the following paragraphs, three types of equipment quantities will be referred to. These are *required quantities*, *actual deployed quantities*, and *recommended quantities*. Required quantities refer to the amount of equipment that is actually needed to perform the operational missions, given the specific sortie rate and mission type. Stated another way, required quantities are what is actually needed at the site of operations to perform the mission.

Actual deployed quantities refer to the actual number of a particular equipment item that is airlifted (deployed) by the deploying unit to the site of operations. There are two types of actual deployed quantities, *tailored* and *untailored*. A tailored actual deployed quantity refers to an item whose deployed quantity is less than the required quantity due to FOL pre-positioning of the item. An untailored actual deployed quantity is theoretically equal to the required quantity, since no tailoring assumes no FOL pre-positioning of the particular item.

Finally, the recommended quantity refers to the number of a particular item that the UTC-DT or Minmxf16cj rule-sets *recommend* as the required quantity.

The central dilemma in making these comparisons is the fact that we cannot know exactly how many of an equipment item were pre-positioned at the FOL at the time of deployment or whether the many functional area experts whose inputs produced the LOGPLAN were in fact aware of these numbers. That is to say, not without intensive and lengthy research beyond the scope of this paper.

However, we can still make some logical observations. If an item from our sample equipment list appeared in one of the three actual historical LOGPLANs used for comparison, then there exists one of two possibilities regarding FOL pre-positioning of that item. First, a certain quantity of the item may have existed at the FOL location at the time of the deployment and, assuming this quantity was known to the LOGPLAN authors, the number of items in the deployed LOGPLAN equipment listing is a tailored actual deployed number. The second possibility is that none of the particular item in question was present at the FOL location or equivalently that it was perceived by the LOGPLAN authors that none of the particular item was present at the FOL in which case the number of items in the deployed LOGPLAN is an untailored actual deployed quantity or *required* quantity.

The problem is we do not know for certain which of the two possibilities is the true case for any particular deployed item. For a particular equipment item, if the first possibility were true and the actual deployed quantity was a tailored quantity, we could reasonably expect the number of items recommended by the rule-sets (UTC-DT or Minmxf16cj) to be at least roughly equal to or more than the tailored actual deployed number (if in fact the primary hypothesis is true regarding that particular rule). If the recommended quantity is roughly equal to or more than a tailored deployed quantity then we fail to disprove the primary hypothesis regarding that particular rule. If the second possibility were true, that is the actual deployed quantity was an *untailored* quantity then we would still reasonably expect the recommended quantity to be roughly equal to or more (but not substantially more) than the actual deployed quantity.

Therefore, regardless of whether the actual deployed quantity is a tailored quantity (possibility one) or an untailored quantity (possibility two), we should expect that the recommended quantity *never* be *substantially less than* the actual deployed quantity. If we find that the recommended quantity is substantially less than the actual deployed quantity, based upon careful consideration of the actual equipment item and its intended use and basic knowledge of aircraft maintenance equipment and operations, then we call into question the particular equipment rule and refuse to justify it. This does not mean that we have fully disproven the primary hypothesis regarding this rule. The rule may in fact be valid because it is possible that the deploying unit has over-deployed the item in question. What it does mean is that, based on the logic described earlier, we find the rule questionable enough regarding the primary hypothesis not to justify the rule.

If an item from our sample list was not deployed at all by the deploying unit then there was either no requirement at all by the unit for the item, or the item existed pre-positioned at the FOL in sufficient quantities that none of the particular item needed to be airlifted (deployed). In the case where an item was not deployed and it is known that this kind of item is pre-positioned at the particular FOL, as is the case with AGE equipment and Al Jaber Air Base, the rule would not be called into question because there is no deployed quantity to compare with the recommended quantities. In this case, we compare the UTC-DT recommended quantity to the Mimnxf16cj recommended quantity if available for that particular item. If roughly equal then we fail to disprove the hypothesis about the particular rule and consider the rule justified, as was the case with several pieces of AGE. If the Minmxf16cj rule did not exist for that item then no negative conclusions could be drawn about the item and we still consider the rule justified.

Where disagreement between the three historical scenario comparisons was encountered, agreement between comparisons for two of the three scenarios was considered sufficient to be considered failure to disprove or conversely to call into question the hypothesis for that rule.

Therefore, based upon this reasoning, we examined in detail the results of the scenario comparisons. Table 6 below shows the results of the comparisons for each of the 29 sample equipment items.

Table 6. Sample Equipment Rules' Status

Nomenclature	Status
TER-9/A	N
LAU-117 LAUNCHERS	J
LAU-129 LAUNCHER	J
ADAPTER AFT PYLON	N
WOOD CHOCKS	N
B4 STAND	J
B1 STAND	J
C1 STAND	J
JACK HYD 10 TON	J
TOWBAR	J
JACK ACFT 15 TON	J
ADAPTER WING PYLO	J
MHU-83 FORKS	J
MB-4 COLEMAN	J
WBOBTAIL DODGE	J
TRAILER ACFT ENG	J
MHU141 TRL (CKC)	J
WELDER MACHINE	J
COBRA CRANE	J
A/M32C-10C A/C	J
COMPRESSOR MC2A	J
H-1 HEATER	N
HYD CART	J
OIL CART	J
AMMO LOADER	J
AGE CTK	J
AM32A-60 GEN SET	J
FLOODLIGHT NF2D	J
PAR PACKING TABLES	N

Only 5 of 29 sample equipment items' rules were not justified (indicated by an N) based upon the general criteria described in this chapter. Based upon this outcome it is recommended that the entire UTC-DT rule-set, and the Minmxf16cj rule-set where applicable, be utilized in the M-R VAT tool as a solid starting point and that non-justified items be investigated in future research. In Chapter IV we discuss more options for justification of rule-sets.

The single most outstanding initial research assumption regarding detailed equipment requirements determination is that of not considering the FOL location. It is clear from the results of both the AFE research and the detailed equipment comparisons that the influence on the amount of equipment deployed of the particular forward operating location is tremendous. Clearly an FOL-driven paring and tailoring capability is not incorporated into the equipment rule-sets themselves. However, this fact is not damaging to the requirements rule-sets. This simply makes clear the role of any justified equipment requirements rule-sets used in the M-R VAT structure. This role is one of total requirements determination and not tailored requirements determination. The role of automated tailoring based upon equipment assets pre-positioned at the selected FOL belongs to the overall ALP structure.

The second assumption that needs additional comment is that of deployment of a single combat unit and single MDS. Both of these are closely related to the FOL location assumption, because the coordination of multiple sets of requirements (that is for multiple units and multiple MDS) will necessarily hinge on the recommendations of the ALP architecture. For instance, if 6 F-16s are deployed with 12 F-15s and 3 bombers to the same FOL, the automated equipment requirements rule-sets (such as the ones in UTC-DT) will produce lists that will have many overlapping required items. It will be the job of the ALP information network to decide what assets are in place at the FOL and what assets are otherwise available at FSLs, etc. Nevertheless, ALP may require some specific engineered rules for how to allocate available FOL assets to the multiple deploying units.

ASM Demonstration and Comparisons

The goal regarding spares will be slightly different than for the equipment comparisons. As shown in Chapter II, during the Aircraft Sustainability Model (ASM) discussion, the portion of the model which custom-builds RSK kits for wartime deployments is already in use by combat units in the form of the DMAS system. DMAS uses the same methodology incorporated in the ASM model. DMAS is currently used by combat units to build custom spares packages for deployments of fewer than 30 days. However, deployments of fewer than 30 days are almost exclusively to CONUS FOLs where a parts infrastructure normally exists for F-16 aircraft. Recall that deployments of over thirty days will cause a unit to automatically bring their entire MRSP kits, since they are designed by headquarters ACC using the ASM model. When an overseas deployment occurs, possession of the combat unit's MRSP kit is automatically transferred to the theater gaining command (Johnson, 2001). The deploying unit will automatically attempt to fill the MRSP kit to the authorized levels for any overseas deployment (Johnson, 2001). Shown in Table 7 on page 71 are comparisons of ASM determined requirements to actual MRSP levels for two specific 27th Fighter Wing TDY deployments, for the top 25 spare parts in terms of non mission capable (NMC) aircraft downtime. The input parameters for the specific deployments input to ASM are specific daily flying hours for each flying day.

Table 7. ASM Comparisons

Rank	NSN	Nomenclature	Auth.	On Hand	524 Saudi/Jordan	522 Keflavik
1	6115012368434	GENERATOR, AC	1	0	0	0
2	6115012465622	GENERATOR, AC	2	2	2	1
3	4320000620511	PUMP, AXIAL PISTONS	1	2	2	2
4	1270012330011	RECEIVER-GENERATOR	2	2	2	1
5	1680010553451	ACTUATOR, ELECTRO-ME	NL	0	0	0
6	6130012099062	POWER SUPPLY	0	0	0	1
7	6605010182184	INDICATOR, HORIZONTAL	3	1	0	0
8	1560014107004	STABILIZER, VERTICAL	0	0	0	0
9	6140010606855	BATTERY, STORAGE	0	0	0	0
10	5865013247734	RECEIVER, COUNTERMEASURES	1	1	1	1
11	1660012512549	CONTROL BOX, ELECTRICAL	2	2	0	0
12	6130013861430	CHARGER, BATTERY	0	0	1	1
13	1650010586259	MOTOR, HYDRAULIC	0	0	0	0
14	2835012080169	GEARBOX, ACCESSORY DRIVE	1	1	1	1
15	1650011508939	CYLINDER ASSEMBLY, ACTUATOR	1	1	2	1
16	6605010580975	INDICATOR, HORIZONTAL	3	1	0	0
17	1270013571351	MONITOR, HEAD-UP DISPLAY	0	0	0	0
18	1660013836734	REGULATOR, OXYGEN, DI	1	0	3	2
19	1560013274955	SLAT, AIRCRAFT	0	0	0	0
20	1270012383662	TRANSMITTER SUBASSEMBLY	1	0	1	1
21	4810000618893	VALVE, BUTTERFLY	0	0	0	0
22	4810012257171	VALVE, REGULATING, FL	0	0	1	1
23	5985012122950	ANTENNA	5	5	1	1
24	2915011472644	PROPORTIONER SUBASSEMBLY	0	0	0	0
25	4810010549843	VALVE, REGULATING, FL	0	0	1	1

Observations and Conclusions. The "NL" seen in Table 7 above indicates an item that was not loaded in the supply system at Cannon AFB. For authorized items, the ASM numbers matched fairly well for a majority of items although some of these were not on hand to be deployed. This comparison confirms the ability of the ASM to generate custom built war-time spares packages, should it prove useful in the future for wartime deployments of very short duration.

Summary

To summarize the methodology, we recommended Equation (1) as an airlift estimation function (see page 59). Also, we ran comparisons to be used for examination of the performance of the UTC-DT and Minmxf16cj equipment requirements rule-sets, for three specific historical scenarios. Finally, we showed the wartime spares determination capability of the ASM model.

Effects of assumptions on the detailed equipment comparisons were discussed as well as the logic used for justification of rule-sets. The resulting justified rules from the sample items were presented and recommendations made for utilization of the UTC-DT and Minmxf16cj rule-sets in the M-R VAT structure. Anomalies in the collected weight data were also explained.

The detailed equipment rule-sets will be used to provide equipment recommendations that are the total required amount of equipment, not the tailored amount of equipment for the specific FOL location.

IV. Discussion

Airlift Footprint Estimator (AFE) Summary

The first objective of this research was the determination of an airlift estimation function for F-16 Aircraft. This objective was completed with the recommendation of Equation (1) as seen on page 59.

Recommendations for Future Research. Future research in this area should focus on the tightening of the confidence interval presented in Chapter III. This can be accomplished by collecting additional actual historical weight data for the larger force packages such as 18, 22, and especially 24-ship deployments. With the confidence interval tightened, the AFE function taken from the "worst case" upper boundary of the 95% confidence interval will estimate weight values that are closer to actual deployed values and thereby loosen the airlift constraint on the M-R VAT tool.

In addition, a cube estimator could be pursued. One suggested method is to use the pallet positions predicted by the Minmxf16cj along with total pallet positions for various historical deployments and produce a function that estimates pallet positions. This function could be combined with an average cube value for a single pallet position to estimate the overall required cube of a support package, based upon number of deployed aircraft.

Detailed Equipment Requirements Rule-Sets

The second objective of the research was to justify the use of existing equipment requirements determination rule-sets. This objective was accomplished based upon the comparisons and logical reasoning performed in Chapter III. It was recommended that based upon the results of these comparisons, the entire UTC-DT and Minmxf16cj rule-sets be utilized in the M-R VAT as a good starting point for equipment requirements determination.

Recommendations for Future Research. Additional research in this area should focus first on collection of additional rule-sets to supplement those lacking in the UTC-DT an Minmxf16cj models. Since these models were built primarily to show the capability to determine equipment requirements, many critical items are lacking from the rule-sets. These include: Avionics, Accessories, Propulsion, and other maintenance related equipment items.

Once a more complete rule-set is compiled, further means of justification and validation should be pursued. One suggestion is the comparison of the output of the rule-sets to the recommendations of panels of field experts from various F-16 combat units.

Research Summary

To summarize the impact of this research, we determined an airlift estimation function and justified equipment rule-sets that may be used by the M-R VAT tool. This will result in valid inputs of force package requirements for testing of the ALP architecture.

Appendix A: F-16 LOGFOR UTC Data

UTC	Unit Type Name	Pilot Unit	Auth. Personnel	Total Short Tons
3EHA1	15 F-16A/B	148th FW	353	168
3EHA3	06 F-16A/B	148th FW	165	108
3FKAA	24 F-16C/D Block 50 SEAD	20th FW	342	240
3FKAB	18 F-16C/D Block 50 SEAD Dependent	20th FW	324	207
3FKAH	06 F-16C/D Block 30	27th FW	275	175
3FKAR	06 F-16C/D Block 50 SEAD	20th FW	122	103
3FKAS	12 F-16C/D Block 50 SEAD	20th FW	171	135
3FKAT	12 F-16C/D Block 30	27th FW	275	175
3FKJE	12 F-16C/D ADC AUGMENTATION	56th FW	148	76
3FKJF	06 F-16C/D ADC AUGMENTATION	57th WG	122	90
3JKJH	15 F-16C/D	944th FW	336	214
3FKJJ	15 F-16A/B ECM	188th FW	388	275
3FKL6	06 F-16C/D Block 50 CW A	366th WG	112	141
3FKL7	12 F-16C/D Block 50 CW B	366th WG	179	184
3FKL8	18 F-16C/D Block 50 CW C	366th WG	315	230
3FKLZ	15 F-16C/D Block 40 PGM	150th FW	337	280
3FKM3	18 F-16C/D Block 40 PGM	388th FW	348	253
3FKM4	18 F-16C/D Block 40 PGM Dependent	388th FW	341	238
3FKM6	24 F-16C/D Block 40 PGM	27th FW	331	231
3FKM7	18 F-16C/D Block 50 SEAD	20th FW	343	202
3FKM8	18 F-16C/D Block 30 GP Dependent	27th FW	282	170
3FKM9	24 F-16C/D Block 30 GP Dependent	27th FW	367	215
3FKMP	15 F-16C/D	114th FW	390	278
3FKMR	06 F-16C/D Block 40 GP PGM	388th FW	105	104
3FKMS	12 F-16C/D Block 40 GP PGM	388th FW	165	156
3FKMT	18 F-16C/D Block 30 GP	27th FW	274	197

Appendix B: AEF 1 Comparison Table

NSN	Nomenclature	AEF1	UTC-DT	Minmxf16cj
1095012293821	TER-9/A	36	12	
1440011856632	LAU-117 LAUNCHERS		6	
1440013154103	LAU-129 LAUNCHER		4	
1730000012278	ADAPTER AFT PYLON		1	
1730002943695	WOOD CHOCKS		2	
1730002948883	**B4 STAND**		**2**	**1**
1730003905618	**B1 STAND**		**1**	**1**
1730003952781	**C1 STAND**		**1**	**1**
1730005162019	JACK HYD 10 TON	12	3	
1730006408080	**TOWBAR**	**2**	**1**	**3**
1730008542237	JACK ACFT 15 TON		2	
1730008576819	**ADAPTER WING PYLO**	**1**	**1**	
1730009438306	MHU-83 FORKS	4	2	
1740005807990	**MB-4 COLEMAN**		**2**	**1**
1740007135908	TRAILER ACFT ENG	10	2	
1740010315868	**MHU141 TRL (CKC)**		**1**	**1**
3431008469636	**WELDER MACHINE**	**2**	**1**	
3950010933721	**COBRA CRANE**	**2**	**1**	
4120003033064	**A/M32C-10C A/C**	**4**	**4**	**4**
4310011732826	COMPRESSOR MC2A		2	
4520007200175	H-1 HEATER		10	2
4910008955394	**HYD CART**		**2**	**2**
4930006202406	**OIL CART**		**2**	**2**
4933012302374	AMMO LOADER		2	
5140004942015	AGE CTK		1	
6115004208486	**AM32A-60 GEN SET**	**4**	**4**	**5**
6230012240938	FLOODLIGHT NF2D	10	2	5
7195009731961	PAR PACKING TABLES	14	5	
1740011187669Y	WBOBTAIL DODGE		3	1

Appendix C: AEF 10 Comparison Table

Nomenclature	AEF 10	UTC-DT	Minmxf16cj
TER-9/A	18	12	
LAU-117 LAUNCHERS	0	6	
LAU-129 LAUNCHER	**6**	**4**	
ADAPTER AFT PYLON	4	1	
WOOD CHOCKS	0	1	
B4 STAND	**0**	**2**	**1**
B1 STAND	**0**	**1**	**1**
C1 STAND	**0**	**1**	**1**
JACK HYD 10 TON	**3**	**3**	
TOWBAR	**1**	**1**	**3**
JACK ACFT 15 TON	0	1	
ADAPTER WING PYLO	6	1	
MHU-83 FORKS	**2**	**2**	
MB-4 COLEMAN	0	1	1
TRAILER ACFT ENG	4	2	
MHU141 TRL (CKC)	**1**	**1**	**1**
WELDER MACHINE	0	1	
COBRA CRANE	0	1	
A/M32C-10C A/C	**0**	**3**	**3**
COMPRESSOR MC2A	**0**	**2**	**2**
H-1 HEATER	0	4	
HYD CART	**2**	**2**	**2**
OIL CART	**2**	**2**	**2**
AMMO LOADER	0	2	
AGE CTK	0	1	
AM32A-60 GEN SET	**0**	**3**	**4**
FLOODLIGHT NF2D	**0**	**4**	**4**
PAR PACKING TABLES	0	5	
WBOBTAIL DODGE	0	1	

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14. ABSTRACT The Advanced Logistics Project (ALP) is a 5-year DARPA effort to investigate automated architectures to increase the efficiency of logistics support for deploying combat forces. The Mission-Resource Value Assessment Tool (M-R VAT) is a joint AFIT/AFRL adjunct processor to the ALP. The purpose of the M-R VAT is to select optimal force packages to meet the needs of theater commanders. This research supports the development of the M-R VAT's capability through the development of an airlift estimation function and validating equipment requirement rule-sets. This airlift estimation function will allow the M-R VAT optimization algorithms to constrain the selection of the optimal force package based upon the airlift estimator's output versus available airlift. The rule-sets are used in support of the M-R VAT Time Phased Force Deployment list generator. Justification of existing rule-sets for equipment determination will allow for their use in the M-R VAT existing software structure. This will give M-R VAT the capability to determine logistics needs for a given force package. Major findings include 1) the determination of a useful "best fit" function for aggregate lift requirements; 2) validation and demonstration of the utility of a family of rule-sets for equipment.

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