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Estimating Resource Requirements to Support Multi-Echelon F-15E Deployments

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ESTIMATING RESOURCE REQUIREMENTS TO SUPPORT MULTI-ECHELON F-15E DEPLOYMENTS

THESIS

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Abstract

Since the end of the Cold War, the United States has become focused on developing the capability to rapidly respond to emerging crises. Strategic and operation planning play key roles in order to effectively implement this concept. During the planning process, separate courses of action (COAs) are developed. These COAs are evaluated based upon their operational effect, resource availability, nuclear and transportation feasibility.

Currently, transportation feasibility assessments are based on the resources contained within a full Unit Type Code (UTC). Some COAs are eliminated based on these factors. However, most deployments occur at reduced levels. Situational factors, such as the number of aircraft, type of deployment, duration of the deployment, and availability of resources from other locations, can significantly reduce the logistics footprint of a deploying base.

Additionally, full-UTC planning factors reduce the planner's knowledge of airlift requirements until information regarding tailoring is returned from the base. As a result, precious time is consumed, and potentially favorable COAs may be eliminated erroneously.

By developing a forecasting tool to identify the critical factors in tailoring, and their effect on the size of the package deployed, planners can quickly evaluate deployment scenarios, providing more accurate assessments regarding plan feasibility and transportation supportability.

Acknowledgments

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David R. Maxwell

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I. Introduction

Background

During the Cold War, the United States military planning philosophy was centered on large conflicts with significant build up time. However, with the fall of the Soviet Union and with instability in many areas of the world, the United States has become focused on developing the capability to rapidly respond to emerging crises.

Efficient strategic and operational planning are key factors in developing the ability to rapidly respond to emerging crises. To foster rapid deployment, many planning tools and processes have been developed. However, Air Force planners do not have a tool to estimate the amount of cargo and the number of personnel required to support different quantities and types of given weapons systems.

Currently, planners are forced to tailor generic Unit Type Codes (UTC) to meet the requirements of the mission at hand. When weapon systems are tasked at sub-UTC levels, support planners do not have the tools required to estimate the cargo and passengers that they need to support the tasked package. The result is a lack of predictability regarding the amount of resources during the operation. This lack of predictability hinders the ability to effectively plan in short periods of time.

Models proposed by the Rand Corporation produced cargo packages for F-15 deployments based on decision rule processes. These decision rules attempted to accomplish UTC tailoring automatically, based on various input factors. However, these models have methodological issues that hinder their use in developing resource estimations.

In order to understand the contents of a deployment package, a model must be developed to accurately describe historical deployment requirements. This model can provide resource estimations, and can also serve as a baseline for future endeavors into automated resource estimation tools.

Problem Statement

Decision makers at all levels need to have access to realistic support requirements, tailored to the quantity of weapon systems required by the current mission. There is a large quantity of data regarding what was actually deployed to support an array of weapon systems. These data can be used to create a model that provides near-instantaneous support estimates, facilitating the planning process. The purpose of this research is to collect and analyze this data to develop a model to estimate the resources required to support a given number, of a given type of airframe.

Research Question

Can deployment processes be improved by providing a model to predict the resources required to support F-15E deployments under different scenarios?

Investigative Questions

In order to meet the goals of this research, it is necessary to answer the following questions:

1) What are the significant factors determining the number of passengers and amount of cargo required to support a deployment?

2) How effective have previous models been in estimating real-world deployment requirements?

A) What are the models underlying assumptions?

B) Do the models' outputs properly predict the composition of actual deployments?

3) Can a model be constructed that is more robust than existing models?

4) What factors must future models account for to produce effective estimates?

5) What precision and significance can a regression model provide regarding resource estimations?

Research Methodology

The methodology used in the research was a two-level investigation based on data collected from the 1St Logistics Readiness Squadron, Langley, Virginia and the 48th Logistics Readiness Squadron, RAF Lakenheath, United Kingdom. The data was collected form historical deployment files, and was coded by the number of deploying aircraft, the short tons of cargo deployed, the number of passengers deployed, whether the deployment was for Air Expeditionary Force or other activities, the composition of the deployed location (aggregating with other aircraft versus not aggregating), and the planned duration of the deployment.

The data gathered in the original data collection period (32 points) was then used to develop two regression models. The first measured the effect of the number of deploying aircraft, the type of location, and the type of deployment on the number of passengers deployed. The second regression model measured the effect of the number of deploying aircraft, the type of location, and the type of deployment on the short tons of cargo deployed.

Finally, the models were validated for their ability to significantly predict resource requirements, and the precision with which their predictions actually reflect real requirements. This validation occurred with 15 data points gathered during a secondary data collection.

Scope and Limitations

This research only deals with F-15 aircraft, and does not apply to other airframes. Rather, this investigation attempts to establish a methodology that could be applied to other necessary combat platforms (tanks, airframes, hospitals, depots, etc). Additionally, this model does not account for items deployed from another location to support an F-15 package (barriers, Major Command support, etc.) As a result, this model will not, by itself, provide a robust tool to facilitate planning of a diverse deployment package.

This research does not specifically account for items that are available at the deployed site, such as water, fuel, vehicles, etc. However, this model’s scope is to predict the resources required to move from the deploying location. The model is able to perform despite this limitation.

This methodology does not give exact resource estimations, but provides a flexible range for planners to use when planning to mobilize forces. As a result, the model does not provide specifics regarding what resources will be deployed, only an aggregate estimation regarding how much is required.

Finally, this research investigates the resources required from the deploying location, and does not assess the resources required to support downrange operations. For example, if fuel is purchased locally, it is not a resource required from the deploying location, however, it is still a resource required at the deployed location. Thus this model as developed would have to be combined with other information to estimate the resources required to support an F-15 deployment.

II. Literature Review

Chapter Overview

This chapter provides a review of the literature relevant to this research effort. It begins with an explanation of the different types of joint planning: Deliberate and Crisis Action. The Department of Defense's Joint Planning Model follows, which explains the merging of the two types of joint planning into a single process. A description of Air Force planning follows, explaining manpower and equipment force packages, included within the Manpower and Equipment Force Packaging System (MEFPAK). The process of tailoring UTCs during Deliberate and Crisis Action Planning is described, including key variables considered in the tailoring process. Finally, a description of previous attempts to estimate deployment resource requirements is provided. An investigation of these models establishes the need to describe historical deployment resource requirements.

Background

As the Air Force transitions to capabilities-based planning, the need for rapid, accurate planning increases. In order to compare multiple scenarios for logistics feasibility, rapid forecasts for operational packages must be available. These forecasts allow for rapid selection of a feasible course of action when responding to arising crises.

There are numerous factors that impact the composition of resource packages required to support an operational package. These factors are considered when a joint plan is developed, and affect the size and selection for a resource package.

Many attempts have been made to automate and hasten the planning process. These attempts have had limited success, limiting their applicability when trying to estimate resource requirements tailored to a specific scenario. These efforts will be detailed in the literature review.

Joint Planning

The task of planning and mobilizing the four military services in response to an arising crisis is critical to the defense of our national interests. To guide the process, the Department of Defense has created a complex architecture designed to facilitate planning for a wide range of scenarios with varying planning horizons. Two types of plans are central to joint planning, deliberate and crisis action plans. They provide a means to respond to immediate crises, and plan for anticipated crises that may arise in the future. The joint planning process provides a framework to consider the output of each type of planning into an executable plan.

Deliberate Planning

Deliberate Planning involves speculation of the nature and location of a threat that may develop. Deliberate Planning is conducted principally in peacetime to develop joint operation plans for contingencies in accordance with national strategic policy (Logistics Readiness Officer Logistics Plans Module, 2003:20).

The Deliberate Planning process is initiated when the Joint Chiefs of Staff (JCS) issue the Joint Strategic Capabilities Plan (JCSP). This plan assigns tasks and resources, identifies broad scenarios for planning, and guides the strategic planning effort (Logistics Readiness Officer Logistics Plans Module, 2003:24).

The planning process continues by assigning a supported commander, that is, a commander who will be required to implement the plan should the need arise. The supported commander issues a Letter of Intent (LOI) which identifies the agencies involved in the planning process.

After the LOI is issued, a Time Phased Force Deployment Data (TPFDD) is developed based on guidance and requirements identified by the supported commander. The TPFDD identifies forces that supporting commanders must provide to successfully implement the plan. These force capabilities are represented by Unit Type Codes, a five letter alphanumeric code that contains a mission description and the resources required to accomplish that mission. Additionally, the TPFDD identifies which units will provide the required forces and the timeline that must be followed. The TPFDD is a living document that is refined continually during the planning process. (see Figure 1)

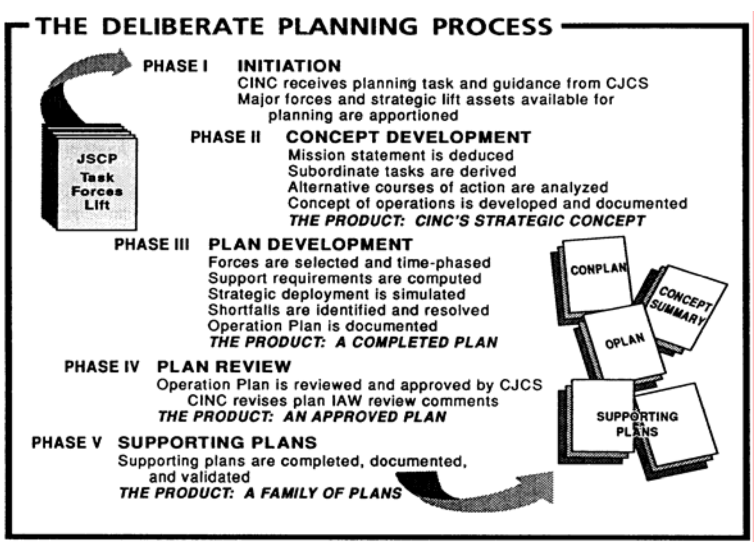

Figure 1- Deliberate Planning Process (LRO Log Plans Course, 2003:21)

Once the resources required to support a plan are determined, transportation feasibility is assessed to identify constraints which may affect the plan. After a plan is determined to be transportable, supporting commanders identify limitations, to be either resolved by utilizing resources from another supporting commander, or identified as shortfalls, which will be reported to the JCS. Once the limitations have been resolved, the plan is submitted to the JCS for final review.

The two most frequent outputs of the Deliberate Planning process are Operations Plans (Oplans) and Concept Plans (ConPlans). Oplans are plans that direct the conduct of military operations. They contain a complete listing of supporting plans and appendices, and also have a supporting Time-Phased Force Deployment Data (TPFDD) listing. Oplans are more specific and detailed than ConPlans.

A ConPlan contains fully developed statements of mission, situation, assumptions, and concepts of operations. ConPlans tend to contain well defined statements of mission, situation, assumptions, and concepts of operations. However, they usually do not contain detailed support requirements or detailed flow of resources.

The goal of Deliberate Planning is to identify resources required to accomplish our National Strategic Objective, and to hasten response planning when actual contingencies arise. However, it is important to note that in Deliberate Planning, time is not a restrictive factor, and most plans are developed in 18 to 24 months.

Crisis Action Planning

Crisis Action Planning occurs when military intervention is required due to an emerging crisis. A crisis is defined in Joint Pub 5-03.1 as

> "an incident or situation involving a threat to the United States' vital interests that develops rapidly and creates a condition of such diplomatic, economic, political, or

> military importance that commitment of US military forces and resources is contemplated to achieve national objectives." (Joint Pub 5-03.1, 1997:21)

Crisis Action Planning occurs when a situation arises that requires immediate military intervention. During the initial stages of the plan, the Chairman of the Joint Chiefs of Staff (CJCS) assesses the situation. The CJCS then discusses the situation with the National Security Council (NSC), which is composed of the President, the Vice President, the Secretary of State and the Secretary of Defense. Together they decide whether or not military intervention may be required, and in what capacity it would be used.

Once the CJCS and NSC identify potential courses of action (COAs) that require analysis, the CJCS issues a Warning Order that contains a description of the threat and the potential COAs. The resources and requirements of each COA are then assessed. Due to time restrictions, this assessment may not entail the development of complete TPFDDs and transportation feasibility studies of actual resource requirements. The supported commander consolidates inputs from all of the involved agencies and determines the best course of action. The consolidated plan is submitted to the NSC for review, and becomes executable when the NSC issues an Execution Order.

The nature of Crisis Action Planning is a response posture. In contrast with Deliberate Planning, time is a critical factor in Crisis Action Planning. In response to unexpected contingencies, multiple courses of action must be developed and analyzed within hours or days. This need for accurate planning within a small timeframe requires accurate tools to rapidly estimate deployment support requirements in a short amount of time.

Joint Planning Process

As contingencies arise, they may or may not have been anticipated or planned for. Thus, during the development of potential courses of action, a suitable deliberate plan may or may not be present. The result is a requirement to have a consolidated joint planning process that allows for planning to occur either by modifying a Deliberate Plan or by creating a new plan through Crisis Action Planning.

Figure 2 shows the consolidated planning process that the Department of Defenses uses during contingency response.

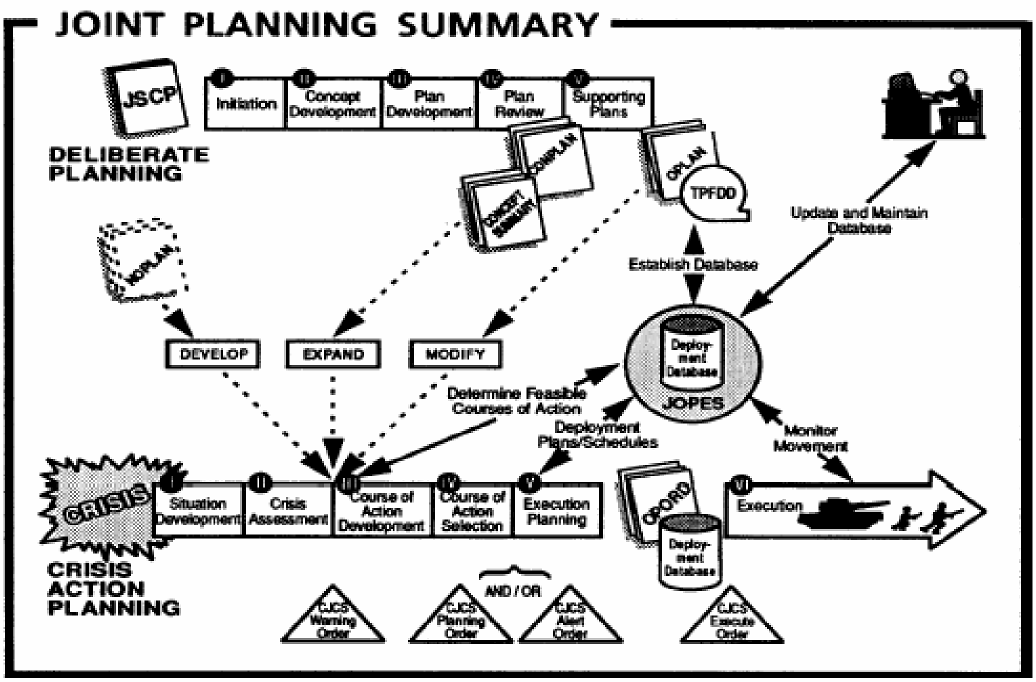

Figure 2. Joint Planning Process (AFMAN 10-403, 2003:9)

Figure 2 details the relationship between Crisis Action Planning and Deliberate Planning. Oplans and ConPlans, if available, developed in the Deliberate Planning process are expanded or modified to generate particular courses of action. If no Oplans or ConPlans exist in relation to the crisis, then Crisis Action Planning occurs to generate courses of action. In either case, once the proper course of action has been selected, an Execution Order is issued.

An important system that serves as an enabler for the entire planning and execution system is the Joint Operating Planning and Execution System (JOPES). "JOPES is a combination of joint policies and procedures (guidance), and Automated Data Procedures (ADP) support used to plan and execute joint military operations (User's Guide, 1995:3)." According to the User's Guide for JOPES (1995), the system standardizes the terminology and operating procedures used by each service into one standard multifaceted system. JOPES is used in both Deliberate and Crisis Action Planning processes to ensure that service capabilities and requirements are all accounted for in a standardized fashion. This effort integrates each service's efforts into a single system used to execute multi-Service exercises and operations.

In addition, JOPES serves as an Automated Data Processing tool. It supports the planning process by integrating a network of systems that enable planners to estimate potential deployment requirements based on Unit Type Code (UTC) taskings, to track items during the duration of the deployment and to manage redeployment operations as well. According to the JOPES User's Guide,

> "JOPES uses a set of command and control techniques and processes, supported by a computerized information system, to ensure the right amount of timely support gets to the war fighter to ensure a decisive victory (User's Guide; 1995:3)."

The UTCs contained in JOPES are not tailored. That is, they contain the largest resource level that could possibly be developed to support a deployment. Thus when the planning factors are identified during the construction of COAs, planners tend to overstate the movement requirement. This presents a skewed transportation feasibility analysis.

Air Force Planning

As Joint Planning directives move down the chain of command, the Air Force implements its own specific planning process in order to fulfill supported commander requirements. This section begins with the Air Force Planning Process. This is the process that the Air Force uses to translate Joint Planning Process output into a plan that is service-specific.

Air Force Planning Process

The Air Force War and Mobilization Plan (WMP) is the tool used to translate JSCP requirements into Air Force plans and capabilities. The WMP is composed of five volumes (Logistics' Readiness Officer Course, 2003:26).

The first WMP volume provides planners with general policies and guidance for the development of war plans and the support of combat forces during wartime. This section addresses the nature of the mission, the concept of operations, and execution tasks for Air Forces throughout the world.

The second volume identifies all of the joint plans which require Air Force participation. This serves as a master listing of all possible taskings that the Air Force could receive in the bodies of existing plans.

The third volume serves as a master listing of all Unit Type Codes (UTCs) and their associated Mission Capability Statements (MISCAPs). All of the UTCs listed in the

MEFPAK are also listed in this chapter. This provides planners with an accessible listing of options that can be used when developing new plans or reviewing existing plans.

The fourth volume of the WMP details the current state of MAJCOM planning, positioning, and employment activity of aviation forces tasked in support of Oplans. This provides a picture the current location of forces, and what missions they are serving.

The fifth volume provides wartime sortie and attrition rates and sortie duration for each type of aircraft and potential mission. Additionally, it provides consumption rates for items such as fuel, oil, lubricants, rations and other mission critical logistics support.

The WMP provides planners with visibility of the planning process, the current resources available to the Air Force, the taskings that currently engage our forces, and the amount of support required to sustain operations for a given period of time. This information plays an important part in enabling the Air Force to provide planning in accordance with JOPES procedures and JSCP requirements.

Manpower and Equipment Force Packaging System

According to Air Force Manual 10-401 the MEFPAK "is the process for developing and describing standard, predefined manpower and equipment force packages and determining the deployment characteristics of these packages in support of JOPES" (AFMAN 10-401, 2003: 93).

The MEFPAK was designed to provide planners with standardized descriptions of unit capabilities. These descriptions facilitate the deliberate and crisis action planning processes by blending the capability of a unit's resources with a plan requirement. Force capability packages are identified in MEFPAK using unit type codes (UTCs). The terms force package and UTC are often used synonymously.

UTCs are comprised of two major components. The first is called the Manpower Force Packaging System (MANFOR). This contains a listing of all of the personnel required to satisfy the force capability. The second major component of a UTC is the Logistics Force Packaging System (LOGFOR). This is a listing of all of the equipment required to successfully support a given force capability. While some UTCs do not have associated MANFOR or LOGFOR components, all UTCs are a blend of resources required to provide a specified force capability. They are registered in the MEFPAK listing and become a standard component for use in Air Force planning.

F-15E MEFPAK Descriptions

The MEFPAK provides a listing of all deployable UTCs owned by the Air Force. This listing shows that planners deploy Air Force F-15E aircraft using a three-increment methodology. In addition to the core F-15E packages, other UTCs are often tasked as supporting UTCs.

The first increment of an F-15E deployment is a 12 ship UTC (3FQL1 or 3FQM1 depending on the engine type). This package provides 12 deploying F-15E aircraft, and the associated standard support UTCs required to support them.

Since aircraft requirements are not linear in nature, an initial follow-on 6 ship (3FQL2 or 3FQM2) is used, along with additional standard support UTCs. This package contains the resources that must be added to support six additional aircraft, creating a package of 18, versus 12 aircraft. Since, some required support for the initial follow-on

6-ship is contained in the 12-ship support UTCs, resulting in a package that is proportionally smaller than the initial 12-ship package.

Finally, a second follow-on 6 ship package (3FQL3 of 3FQM3) and associated support is designed to raise the force numbers from 18 to 24 ships. This package contains mostly pilots and crews, since there is very little additional support equipment required.

Many of the supporting UTCs are standard, identified as such in volume 3 of the WMP. Standard support packages include the maintenance and support necessary for sustaining operations. However, many support UTCs are not standard. Non-standard support UTCs are added to a package based on local factors (i.e. the experience of the planner or unique mission needs). The size and number of UTCs selected to deploy varies depending on the size and nature of the deployment (Snyder and Mills, 2004:6).

Expeditionary Air Forces (EAF)

During the Cold War, the USAF was "primarily poised to respond to conflict in the most volatile arenas of the time: Europe or the Korean Peninsula "(Galway et al, 2001:7). With the fall of the Soviet Union, however, a change in readiness was required. Planning became focused on rapid deployments with global reach, enabling forces to respond to emerging threats and smaller conflicts (Vo, 1997:12). This led to the creation of the Expeditionary Air Forces in 1994.

> The EAF "concept is how the Air Force organizes, trains, equips, and sustains itself by creating a mindset and cultural state that embraces the unique characteristics of aerospace power – range, speed, flexibility, and precision – to meet the national security challenges of the 21st Century. The concept has two fundamental principles: first, to provide trained and ready aerospace forces for national defense, and second, to meet national commitments." (AFI 10-400, 2002:6)

The EAF represents the entire Air Force inventory, and is divided into ten Air Expeditionary Forces (AEFs). AEFs contain "Fighter, Bomber, Airlift, Tanker, Intelligence, Surveillance, and Reconnaissance units (that) are on-call or deployed for one

4-month rotation during each 20-month cycle" (AEF Course, 2003) (see Figure 3).

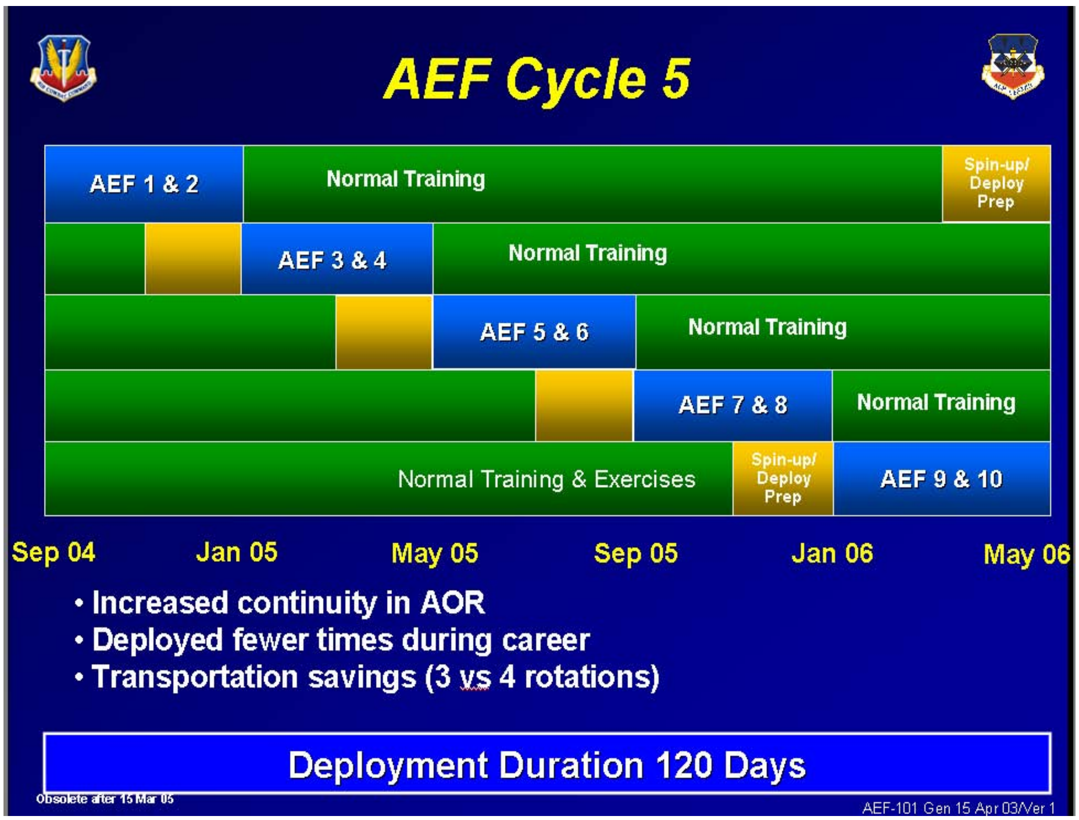

Figure 3. An Example AEF Cycle- Cycle 5 (AEF Course, 2003)

Each rotation is composed of two AEFs, postured to deploy to two separate locations in support of the NSAs multi-theatre war doctrine. One cycle is composed of a 20 months period where all AEFs have been postured to deploy.

Since the AEF is a response mechanism with a long planning horizon (typically 14-months), it lies somewhere between Deliberate and Crisis Action Planning. Like the Deliberate Planning Process, AEF planning has a long planning horizon, but is used to respond to a contingency without the revisions common to the Joint Planning Process. Additionally, the long lead time results in a higher level of airlift planning. By enabling airlift to be programmed far in advance, it has a higher probability of receiving airlift support.

UTC Tailoring in the Joint Planning Process

UTCs are generic packages designed to represent the maximum package size required to support a given force capability. Resources are often trimmed from the package to meet the needs of the mission at hand. This activity is known as tailoring.

Tailoring cannot begin until UTCs have been selected based on operational requirements. However, equipment and personnel cannot be prepared for deployment until unit planners have tailored their UTCs, and in cooperation with MAJCOM and USTRANSCOM, acquired sufficient transportation to mobilize their package.

During the execution phase of the Joint Planning Process, multiple possible Courses of Action (COAs) are developed. Within each COA, force capabilities required to successfully achieve the goals (established by the NSC) are identified in terms of untailored UTCs. Each plan is then evaluated for force strength and transportation feasibility. Once feasibility has been ascertained for each plan, a favorable plan is selected to begin implementation.

After a plan is selected, a TPFDD is created in JOPES. This TPFDD identifies not only the force capabilities required, but the units tasked to supply those capabilities. Unit planners work with Major Command (MAJCOM) planners to garner information regarding the nature of the scenario. This information is used to determine which equipment or personnel contained in the UTC are actually needed to accomplish the mission. Once this is accomplished, unit level planners determine feasibility of their plan. If sufficient resources are available, they notify MAJCOM planners who source transportation through United States Transportation Command (HQ USTRANSCOM).

HQ USTRANSCOM sources airlift using the tailored deployment data developed by the units, and coordinated through the MAJCOMs. If insufficient airlift is available, TRANSCOM notifies the MAJCOM that further tailoring is required. This iterative process occurs until airlift is sourced for the deploying unit. This process occurs late in the planning window, close to the point of execution.

During most deployment scenarios, the force capability provided within a UTC contains resources not required to accomplish the mission at hand. In these cases, resources are removed (tailored) from the package. If the support provided by the UTC closely matches the resources required by the scenario, then tailoring may be minimal, or not required.

> 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 Logistics Plan (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).

During Crisis Action Planning, these additional planning hours are precious when a scenario emerges requiring mobilization within 48 hours. The importance of rapid estimations during execution becomes magnified because mobility operations cannot begin until tailoring is completed. Additionally, "the amount of airlift available is relatively constant (and very limited), so the size of the deployment package determines how many units can be moved at once" (Griffis and Martin, 1996:9). As a result, plans using a full-UTC planning factor overestimate the required airlift. A plan may be dismissed as unfeasible if HQ USTRANSCOM or Air Mobility Command determine that there is insufficient airlift to move the appropriate units in a timely manner.

"An analytical methodology to shorten this time frame would…expedite crisis action planning, reducing the response time to exigencies" (Snyder and Mills, 2004:2). By creating a rapid estimation tool, different potential COAs can be quickly analyzed for feasibility, reducing the time required for planning and increasing the time allowed for execution.

An estimation tool could also improve the Deliberate Planning Process. Precise resource forecasts during Deliberate Planning would create more accurate TPFDDs. If a crisis emerged requiring activation of an Oplan, an accurate TPFDD would reduce the time required to modify the existing plan into an actionable plan. Snyder concurs with the notion that a planning estimator can enhance the Deliberate Planning Process.

> "operational planners could explore candidate deployment plans to estimate the manpower and material needed across all deployment sites. A comparison might be used to dismiss one plan in favor of another based on logistical efficiencies" (Snyder and Mills, 2004:41).

Since transportation feasibility assessments are negatively impacted by full-UTC estimations, a tool that could more accurately predict resource requirements would improve the ability to rapidly plan effective responses. By predicting resource requirements early in the process, feasible COAs and airlift requirements could be developed at USTRANSCOM before TPFDD data were sent to the MAJCOMs and to the affected bases. This would allow more time for airlift sourcing by ensuring that early iterations of the TPFDD accurately estimate the package after tailoring occurs at the MAJCOM and the base.

Relevant Variables in UTC Tailoring

UTCs are resource listings that include the maximum amount of resources required to support a given package. However, there are many factors that may reduce the logistics resources required to support a mission. This creates dissonance between the resources required to support a mission and the resources contained within the untailored UTCs. This dissonance creates the need for tailoring, and guides the composition of the final deployment package.

One critical factor that results in tailoring is the availability of airlift. Even as the Air Force has transitioned to a unit with an expeditionary mission, numerous studies have indicated that there may be insufficient airlift available to meet mobility requirements (e.g., Quadrennial Defense Review, 2001:8; General Accounting Office Report, 2000:5). The shortage of airlift requires that deploying units tailor their UTCs. Indeed, it can be argued that with unconstrained airlift capacity, tailoring UTCs would be unnecessary.

A second factor that impacts the size of a deploying UTC is the characteristics of the destination base. Since UTCs are generic packages and are established as the maximum required supporting a wartime capability, it is assumed that there are no resources available at the deployed location. However, a wide range of availability of lodging, sustenance, infrastructure, supplies and vehicles may be available, either through pre-positioning or through local businesses (Snyder and Mills, 2004: xviii). The availability of resources at the deployed location determines which resources can be left out of the deployment package.

The third variable that impacts the size of the deployment package is the number of aircraft that are scheduled to deploy (Snyder and Mills, 2004:10). As previously described, the Air Force deploys F-15E model aircraft using a series of three UTCs. The first provides support for a 12 ship package. The second provides additional resources required to support 18 ships. The final provides the additional resources required to support 24 ships. However, F-15Es are often deployed in quantities other than 12, 18 or 24 ships. When the Air Force decides to deploy F-15Es in other quantities, tailoring must occur. The result may be a significant modification of untailored UTCs to derive the actual deployment package.

The fourth variable that may result in UTC tailoring is whether the receiving base will serve as a composite location. A composite location is “an Air Force Wing with several different types of aircraft assigned to the same base.” (O’Fearna, 1999:12). If multiple aircraft types are assigned to a deployed location, a reduction in resources may be available by eliminating redundancy. This has been identified as a significant footprint reduction strategy (O’Fearna, 1999:11).

The duration of the deployment is a fifth variable that can affect deployment resource requirements. Initial Preplanned Supply Kits, estimated fuel support and hospital kit requirements are built to provide a 30 day supply (Logistic's Readiness Officer's Supply Module, 2002:27). However, planners may reduce these requirements if services are available locally, or other plans can lessen the need for airlift (Galway et al, 2002: 17).

Individual experiences of deployment planners also can effect the UTC selection and tailoring process. "Which UTCs are deployed will vary somewhat depending on the judgment of the planner" (Snyder and Mills, 2004:13). Thus, variation may occur even in deployments under near-identical circumstances. In this regard, a stochastic model will likely be required to properly estimate potential deployment sizes since it captures the variance associated with deployment data.

The availability of prepositioned assets that are deployed from a third location is another important variable in determining final package size, as well. The first source of assets deployed from a third location is assets from War Readiness Materials (WRM) stocks. According to Air Force Instruction 25-101:

> "WRM is Service-owned resources positioned as either starter or swing stock, or a combination of both, to maximize worldwide war fighting capability…Starter stocks are those assets required at or near the point of intended use until air and sea lines of communications (LOCs) are capable of sustaining operations…The AF prepositions to support starter requirements. Swing stocks are positioned to maximize flexibility to support multiple theaters… WRM is based on wartime additive requirements sufficient to accomplish the Two-MTW (Multi-Theatre War) strategy" (AFI 25-101, 2000:15).

Thus, WRM, as defined, are materials that are available for deployment to the deployed location. These assets are not required to be shipped from the deploying locations and reduce the size of the deployment package.

A second type of asset available from a third location is MAJCOM supporting resources. Bare-base support kits are often available at the MAJCOM level to provide support. Harvest Falcon and Harvest Eagle kits are examples of MAJCOM support resource. Harvest Falcon and Harvest Eagle kit provide billeting, kitchen, hygiene facilities, industrial operations and flight line support for units deploying to a base that provides little or no support (Snyder and Mills; 2004:25). This reduces the number of resources that the deploying base must provide to be self-sufficient.

The third type of third location support is resources that are available from a unit in another wing. In the AEF construct, support and operations resources are sometimes deployed from different bases. Since the deploying unit is the base supplying the aircraft, their required resources to support their flying operations are reduced. This occurs during many AEF rotations. An example is the AEF support given by RAF Lakenheath, an F-15 fighter wing. At Lakenheath, the F-15s are tasked to support AEFs 4 and 7 (see Appendix 1). However, support forces are provided in other AEFs. The result is that some support functions deploying from Lakenheath do not deploy to support the Lakenheath F-15s, but rather support operational activities initiating from other bases. Additionally, when the F-15s deploy from Lakenheath, units deploy from other locations to provide certain types and levels of support. The end result is and understanding that there are variables that affect the quantity of support deploying from a base to support a given mission.

Automated Resource Estimation Tools

As the Air Force transitioned to an expeditionary force, focus on the ability to rapidly respond to crises intensified. The expeditionary mindset requires a faster and more streamlined planning process to enable sufficient force identification in short planning horizons (Snyder and Mills, 2004:XV).

Air Combat Command (ACC) establishes the planning horizon for crisis response as “48 hours from execute order to full deployment and full operation, after a 24-hour strategic warning” (Tripp et al., 1998:5). The resulting planning window established by ACC is a total of 72 hours from the time of the emergence of the crisis, to the time of response. The need for faster, more efficient logistics support of combat operations is described as Agile Combat Support or ACS (Galway et al., 2002:iii). Numerous tools have been developed to estimate the deployment forces required to support a given deployment scenario.

UTC-Development Tool (UTC-DT)

The UTC-DT is a tool that is intended to increase the efficiency of Air Force mobility operations.

> “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)

UTC-DT is a decision tool model that recommends types and numbers of support equipment using rule-sets that have been developed from allowance standards and interviews with actual combat units (Goddard, 2001:35). 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

(Goddard, 2001: 36). These decision rules correlate the level of support with the number of aircraft that are tasked to deploy.

Information regarding personnel (from MANPER-B) and equipment (from LOGMOD-B) requirements are consolidated and enter the UTC-DT system. The system is also consolidated with information from the Beddown Capability Assessment Tool (BCAT). The BCAT provides automated details of the resources available at the deployed location. The detail of WRM availability is also consolidated within the UTC-DT database. The rule-sets are then modified by subtracting the resources available at the deployed location (BCAT) and the assets available from WRM. (see Figure 4)

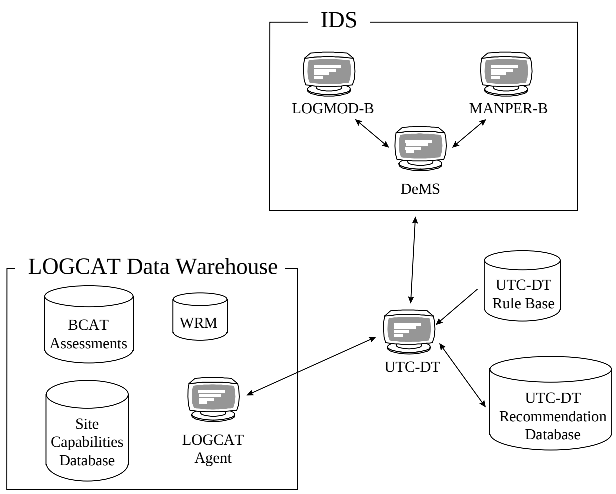

Figure 4. UTC-DT Proposed Connectivity (Sjoquist, 1997:18)

The UTC-DT user inputs required information into the model such as date, Mission Designation Series, number of aircraft, sortie rate, mission type, duration of deployment and other items.

The output of the UTC-DT is a tailored list of equipment and personnel needed to support a deployment under the circumstances described by the user. This output is stored by UTC-DT as the equipment detail of the specific existing or created UTC.

There are key assumptions that may limit the applicability of the UTC-DT model as a significant planning tool. Since much of the planning process is based on personal experiences, different planners from different places may produce a variety of listings of required resources. Since the UTC-DT rule-sets are based on the inputs from planners from Cannon AFB and Mountain Home AFB, they are derived from a limited set of philosophies and experiences. The sets may not generalize to other planners or to other bases.

A second weakness of the model is its precision. The UTC-DT provides a deterministic list of resources, leaving no flexibility for situations where commanders may opt to take non-traditional equipment.

A third weakness is the reliance on BCAT data regarding base support. The data in the BCAT is often inadequate and out of date (Leftwich et al, 1997:39). Additionally, much of the problem with determining base support "lies in the stochastic nature of the quantities and availabilities of the many resources required to support air mobility operations" (Randall, 2004:16).

The reliance upon input from BCAT and WRM systems significantly reduces it usefulness in Deliberate Planning. Deliberate Planning usually occurs in absence of detail regarding deployed location and theatre of operations. The lack of knowledge about the future location of military operations requires a model that is flexible, providing a range of potential resource requirements.

A fourth weakness associated with the UTC-DT model is that it includes only maintenance packages that are directly associated with the F-15E UTC. Logistics and support functions not directly associated with maintenance activities were not included in the resource determination. UTC-DT does not account for these resources.

RAND/AFLMA Requirements Determination Tools.

The RAND Corporation and the Air Force Logistics Management Agency (AFLMA) teamed to create a different model for estimating resource requirements. Their efforts focused on the relationship between the areas that require and provide logistics support: Forward Operating Locations (FOL), Forward Support Locations (FSL), and CONUS Support Locations (CSL).

The ability to support a deployment requires optimal use of each potential source of support. (Galway et al., 1999:38). Additionally, in order to optimize the mobility process, three crucial determinations must be made (see Figure 5).

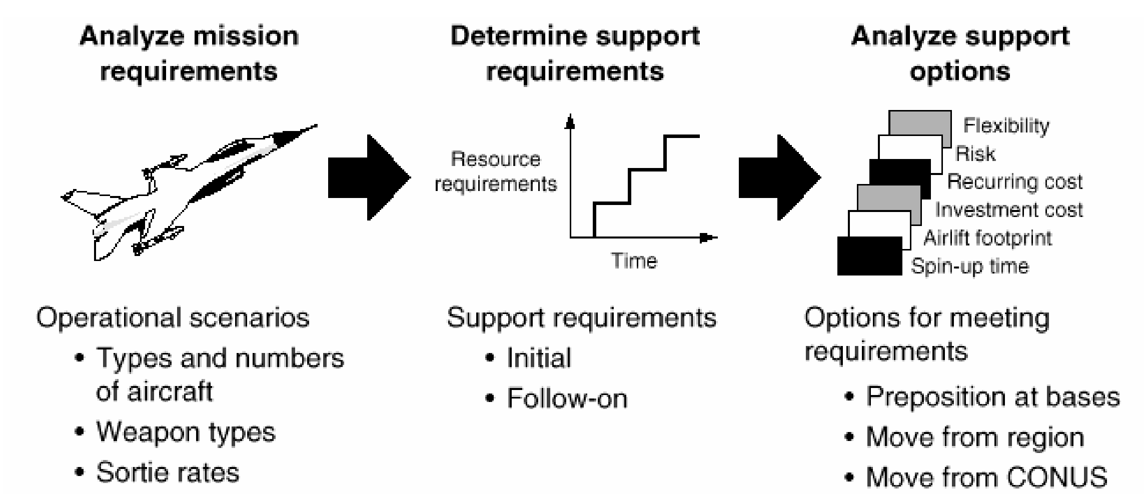

Figure 5. Three-Step RAND Approach (Galway et al, 1999:36)

The initial step is to identify the requirements of the mission. This provides the nature of the deployment. Once this has been decided, planners must identify the support required to satisfy the mission requirements. Third, trade-offs and resource-reducing opportunities must be addressed.

The deployment of aircraft falls within the second phase. Specifically, it is during the initial support requirements determination that mobility package size is identified. RAND and AFLMA have captured their decision rule sets within EXCEL spreadsheets, which allow for rapid resource determinations for five resource categories: “munitions, fuels support, unit maintenance equipment (the bulk of unit support equipment), vehicles, and shelter” (Galway et al., 1999:5).

The models for the other aircraft operate in a similar manner to the F-15E model, but will not be examined, as they are outside the scope of this research. Since the scope of this research is to investigate the resources required to support F-15E deployments, it is necessary to analyze the RAND/AFLMA Minmxf15e requirements determination model.

The Minmxf15e is an optimization model geared at minimizing the resources required to deploy in support of an F15E deployment.

> 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)

One of the key assumptions is that the deployed units are tasked for a “seven-day operation in a highly tasked environment” (Tripp et al., 1999:92). Additionally, it focuses solely on the number of aircraft to derive the resources required to support the package. (Tripp et al., 1999:95).

The rule sets that establish the base of the model were developed mostly through "discussion with experts in the field. Unit-, MAJCOM-, and USAF-level functional experts have validated our rules and models" (Tripp et al., 1999:92). There may be issues with the validity of these rule-sets, since there was no effort to ensure that the experiences, knowledge and capability were representative of other deployment planners. Thus the rule-sets may not be generalizable.

Table 1 shows a portion of data for Air Ground Equipment (AGE) equipment from the model and the accompanying rule-sets for each item (Tripp et al., 1999:97). Thus, resources are selected to deploy based on the number of aircraft required for the mission. For example, two TTU-228 hydraulic test stands will be deployed to support 12 F-15E's. That number would remain unless 24 aircraft were deployed, in which case, four would be deployed. This is representative of the other rule-set procedures discussed in this chapter.

Table 1. Rule Sets Employed by Minmxf15e Model

Nomenclature	Description	Rule-Base
TTU-228	Hydraulic Test Stand, 3 Phase, 5000 PSIG, 15 GPM	2 per 12 Acft, 4 per 24
MHU-83	Munitions Lift Truck	2 per 12 Acft, 4 per 24
M32A-86D	Generator, 3 Phase, 115/200V or 230/400V, 400Hz	2 per 12 Acft
MEP-105	Generator	Req. 5 for Avionics support
Data Pod Trailer		Req. for GBU-15 capability
MHU-110		Included with MunMaster input
Engine Trailer		1 per 12 Acft, plus 1 for ESTA

The model also initially included other resource characteristics, such as the number of short tons of AGE equipment required, and was later modified to include weight and dimensions of all associated cargo (Goddard, 2001:38).

There are a few potential weaknesses in this model as well. First, it only considers the number of deploying aircraft. Since it ignores the potentially significant factors that were previously discussed, such as third location capabilities, its applicability may be limited.

Similar to the UTC-DT model, the Minmxf153 model considers only associated UTCs, and may miss required UTCs that are not listed in the AFWUS. Finally, its product is a deterministic listing of resources, providing no flexibility for different planning philosophies.

Airlift Footprint Estimator (AFE)

A joint venture between the Air Force Institute of Technology and the Air Force Research Laboratory was initiated to develop the Advanced Logistics Project. A key component of this project was the Mission-Resource Value Assessment Tool (M-R VAT); a tool designed to utilize rule-sets for calculation of the needed support equipment to sustain an optimal force mix for the required time frame. This tool was intended to validate the rule-sets created by the RAND model.

The goal of this project was to produce a tool to automatically build custom UTCs. Rather than tailor current UTCs, the M-R VAT used 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 (Goddard, 2001:12). The research conducted by

Goddard had two stated goals: identify an airlift footprint estimation function and justify existing rule-sets for use in the M-R VAT tool (Goddard, 2001:13).

In order to develop an airlift footprint estimate, the data from actual deployments of F-16 aircraft was collected. A best fit line was calculated through linear regression to demonstrate the relationship between the number of aircraft deploying and the number of tons of equipment deployed.

The final estimation model proposed by Goddard (2001) was:

$$\mathbf{y = 7.6x + 48.1} \quad (1)$$

where y = required short tons

x = number of deployed F-16 aircraft

Once this equation, called the Airlift Footprint Estimator (AFE), was developed, it was used as a baseline to compare the performance of the decision rule sets used by the UTC-DT and the RAND/AFLMA Minmxf16cj model.

The resulting evaluation of the AFE validation was that the rule sets in both the UTC-DT and the Minmaxf16cj should be implemented within the M-R VAT tool (Goddard, 2001:74). That is their combined output was more successful in determining the final output of actual deployment requirement. However, the model failed to combine the rule-sets to ensure that the models were not tasking redundant resources. This lack of information limits the applicability of the research conclusion.

There are a number of limitations regarding the validity of the AFE and its use as a basis for verifying rule-sets. The first is that it only uses one predictor; the number of aircraft. Since numerous factors were identified in the literature, an enumeration of the percentage of explained variance would determine the strength of the model. Additionally, the model was not tested for the assumptions of regression, and R-squared value was provided.

Another potential limitation of the study is the exclusion of a statistical model to estimate personnel requirements. This is significant for planning purposes, since personnel consume 30% of the airlift required during deployments (Galway et al., 1999:5).

RAND's Strategic Tool for the Analysis of Required Transportation (START)

In 2004, the RAND Corporation published the new START resource estimator. This effort attempted to implement the military's direction to Capability Based Planning (CBP). CBP is a transformation initiative, directed by then Secretary of the Air Force, Donald Rumsfeld (Quadrennial Defense Review, 2001). The new approach to planning is to create a "portfolio of capabilities that is robust across the spectrum of possible force requirements, both functional and geographical (Quadrennial Defense Review, 2001:17). This new way of planning will "require the United States military to develop a new analytic architecture" (Snyder and Mills, 2004:2).

The START model determines the feasibility of a list of UTCs required to support a given deployment and estimates the movement requirements. Similar to previous models, START tailors UTCs using decision rules developed through interviews with functional experts and through Air Force Publication information. Actual deployment data was not considered.

> "We have not used historical deployment data as a significant input for three reasons. First, for most deployed sites, the nature and quantity of existing infrastructure, manpower, and equipment at the site are poorly documented. Because these resources are needed, yet are not on the TPFDD, the TPFDD underestimates the requirements. Likewise, some material is not at the site and also not listed on the TPFDD, because it was readily available locally (for example, leasing of general-purpose vehicles). Second, a large fraction of deployed UTCs are listed in the TPFDD as "**Z99" and, as such, contain insufficient detail for our needs. Third, in historical deployments, the desired operational capability of a site may change with time, making it difficult to correlate a specific capability with material on the TPFDD." (Snyder and Mills 2004:12)

The model addressed inadequate BCAT information by designating the deployed location as either a bare-base or a non-bare base. While the authors concede that these terms are loosely defined, given the lack of current base information, topography, and geography, an estimation is required (Snyder and Mills 2004:6).

The model input screen allows for parameters to be entered into the system including base description (Bare or Established), operating requirement (Initial or Full), and a variety of potentially important support factors (see Figure 6)

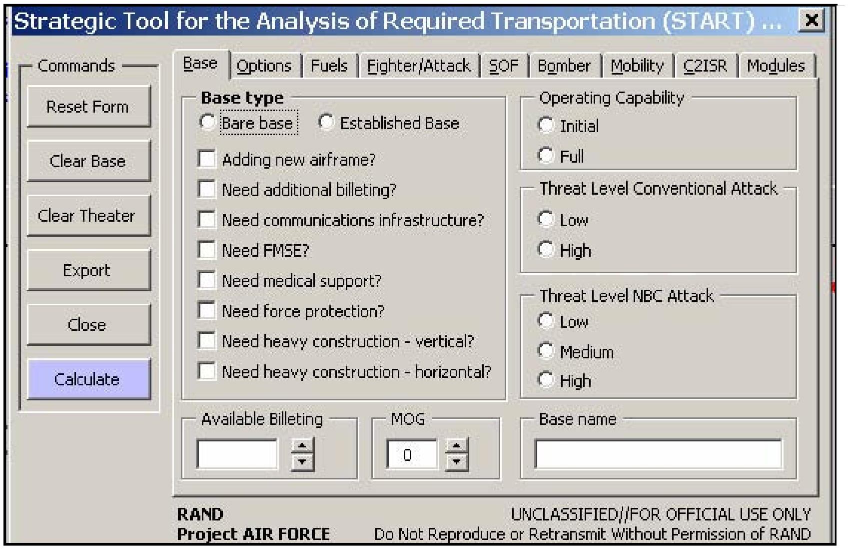

Figure 6. START Model Input Screen

Given a set of input parameters, START automatically compiles a listing of UTCs resembling a TPFDD. (see Table 2)

Table 2. Abbreviated START Output – 24-Ship Tasked to Established Base

UNCLASSIFIED//FOR OFFICIAL USE ONLY						
UL N	DESCRIPTION	UTC	UNIT NAME	PAX	AUTH PAX	TOTAL WT
	24 F 15E -220	3FQK1		509	509	390.6
	PB FL SP THREAT RESP LIT TM	4F9DB		2	2	6.4
	PB FL SP THREAT RESP AUG TM	4F9DC		2	2	0
	PB FL SP THREAT RESP AUG TM	4F9DC		2	2	0
	PB FL SP THREAT RESP AUG TM	4F9DC		2	2	0
	PRIME BEEF EOD LEAD TEAM	4F9X1		6	6	11.8
	PRIME BEEF EOD FOLLOW TEAM	4F9X2		4	4	5.9
	PRIME BEEF EOD BASE SUPT TM	4F9X3		2	2	3.6
	24 F 15E	HGHQ1		70	70	159.3
	SECURITY FORCES SQUAD	QFEB2		13	13	5.3
	SECURITY FORCES SQUAD	QFEB2		13	13	5.3
	SECURITY FORCES SQUAD	QFEB2		13	13	5.3

Essentially, the model selects the proper UTCs given a certain set of deployment parameters. This listing is compiled using standard UTCs adopted directly from the MEFPAK. Additionally, the tool allows for planning many combinations of fighter, cargo, special operations and reconnaissance airframes at a given location. In fact by combining options for the base, mission and airframes involved in the tasking, the START model provides an excellent tool for UTC identification, allowing for rapid construction of the TPFDD.

However, the model considers UTCs whole, that is, it does not assist in tailoring UTCs. While this can assist in rapidly developing the TPFDD during mobility operations, it does not solve the problems encountered in the process.

First, it calculates only standard UTCs. During mobility operations, UTC selection is an inexact endeavor. That is, many different UTCs may be selected to satisfy a resource requirement. For example, if four Vehicle Operators, Air Force Specialty

Code (AFSC 2T1XX) are needed for support, then numerous UTCs can be combined or tailored to meet this need. Table 3 shows the UTCs that contain 2T1XX personnel.

Table 3. UTCs Containing 2T1XX Personnel (Vehicle Operators)

UNCLASSIFIED//FOR OFFICIAL USE ONLY					
UTC	**UNI T**	**TYPE NAME**	**AUTH PERS**	**NO. PAX**	**No. 2T1XX**
UFTSA	TRN	BASE SUPPORT PKG RF	33	33	9
UFTSB	TRN	WG TRANSPORTATION ELE	17	17	5
UFTSE	TRN	VEHICLE OPERATIONS MANAGER	1	1	1
UFTSK	TRN	VEHICLE OPS SUPPORT PKG	5	5	5
UFTSL	TRN	VEHICLE OPS SUPERVISOR	1	1	1
UFTSM	TRN	VEHICLE OPS SUPERINTENDENT	1	1	1

As can be seen in Table 3, four 2T1XXs could be tasked by tailoring UFTSA, UFTSB, or UFTSK. Additionally, they could be tasked by combining UFTSE, UFTSL or UFTSM. Thus, the selection of the UTC is not as important as defining the actual requirement for the deployment. In reality, it is the identification of resource requirements that consumes the majority of planning time, which the START model does not do.

Another issue with the applicability of the START model is that it only tasks aircraft packages at full-UTC levels. (see Figure 7)

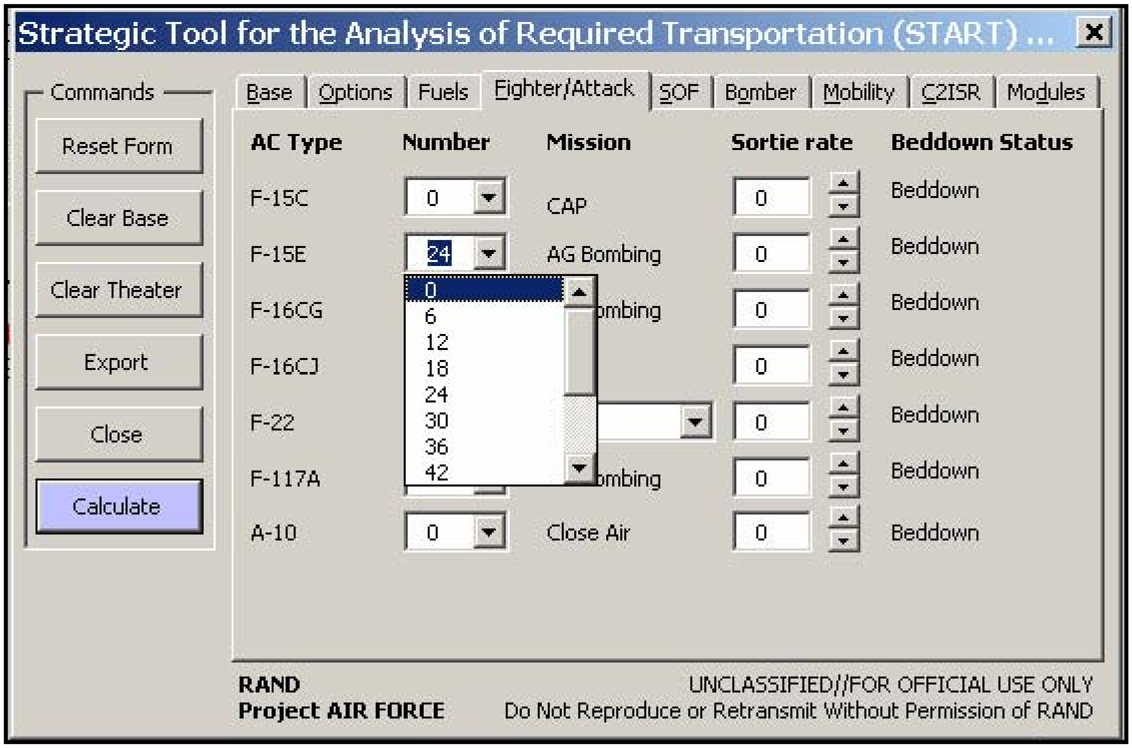

Figure 7. START Aircraft Selection Tab

As is shown in Figure 7, F-15Es can only be tasked in increments of 6. This does not allow for planning deployments that are in increments other than 6.

Additionally, when viewing the composition of a 6-ship tasking, it selects the UTC 3FQKR, which is a six ship tasking that no longer exists. It was deleted during the transitioned to the current, right-sized UTCs previously described.

Upon examination it was discovered that the MEFPAK used by the START model was published in December of 2001. Additionally, attempts to update the model with a current AFWUS were unsuccessful. This is probably because the EXCEL MACROS were designed specifically using the MEFPAK used to develop the model. As a result, the model would have to be updated each time a new MEFPAK is published, and the MACROs would have to be calibrated to the new data set. Failure to update as needed would result in the model tasking invalid or non-existent UTCs.

The START model provides the foundation for a rapid UTC selection tool that could be used to rapidly develop a TPFDD. However, it is not a tool that could rapidly determine resource requirements and it could not forecast deployment resource requirements.

Summary

With a basic understanding of the military's Joint Planning Process, and the tools used to mobilize our forces, it is apparent that a tool to estimate resource requirements can increase the speed and accuracy in which we respond to arising crises. Additionally, flexibility and the ability to compare, evaluate and select multiple scenarios will improve the quality of plans that we use to go to war. Chapter III provides a description of the approach used to create a stochastic resource estimator, based on historical deployment scenarios. It also provides a methodology for analyzing the ability to predict resource requirements, and to determine the accuracy of those predictions.

III. Methodology

Chapter Overview

The purpose of this chapter is to establish the basis for creating an explanatory model of resources used to support an F-15E deployment, and its use as a forecasting tool for improving transportation feasibility analysis. First, a justification for using a regression model will be provided. Second, the specific factors to be used in the construction of the model will be discussed, including their expected effect on the dependent variables. Third, a detailed explanation will characterize the process of constructing the model, including the process of checking for the underlying assumptions of a regression model. Finally, a detailed explanation of methodology used to test the validity and the accuracy of the model will be provided.

Model Selection

This research design calls for a quantified relationship between several independent variables and a dependent variable. A regression model accomplished this by quantifying the deterministic portion of a data set, and providing an interval of allowable error (McClave et al, 2001:458). Additionally, since it is assumed that deployment planning has an error component involved, the ability to include a prediction interval provides a better estimate than deterministic models.

Regression models attempt to fit a straight line through a data set, minimizing the cumulative distance between the line and each data point (called a residual). This is accomplished by analyzing the variance in the dependent variable related to each independent variable. The amount of error that occurs that cannot be explained by the independent variable, are considered to be random error.

In this model, a best fit line will be fit through the data set, based on significant variables. This best fit line with a corresponding confidence interval will serve as a tool to define the explanatory power of the model. Additionally, if the model successfully explains a large amount of the variance, a prediction interval can be used to forecast resource requirements of future deployments, given certain parameters.

Factor selection

There are numerous variables that can impact the number of resources required to support an F-15E deployment. These factors can increase or decrease the number of resources required to deploy, which requires that a robust model identify and account for them.

The first factor used in the construction of an estimation tool is the number of aircraft that are scheduled to deploy. Since F-15s can deploy in varying numbers, it is important to relate the size of the package to the number of aircraft that it is required to support. It is anticipated that the coefficient of this variable will be positive, as each adding aircraft will increase the required support. This variable will be quantified using whole number integers corresponding to the number of aircraft.

The presence of other airframes at the deployed location has been identified as a potential factor. Collocating different airframes at a single location, called composite basing, reduces the amount of resources required to support operations (O’Fearna 1999:11). As a result, base level planners will collaborate to determine which UTC package will contain shared resources, and which UTC will have resources tailored out. A dummy variable is used to capture this phenomenon, where zero indicates that there are no other airframes present, and a one indicates composite basing. This coefficient is expected to be negative, as composite basing reduces the amount of supporting resources by eliminating redundancies.

A third factor affecting the amount of resources is the characteristics of the deployed locations. Following the logic employed by the RAND START model, a base will be identified as either a bare base, or a non-bare base, depending on the presence of housing, fuel, vehicles and runway equipment (Snyder and Mills, 2004:17). Basing will be addressed using a dummy variable where a zero indicates a bare base and a one indicates a non-bare base. This coefficient is expected to be negative, as deploying to a base with resources present (a non-bare base) will reduce the size of the package.

The duration of the deployment will also be investigated. Many of the resources required to support a deployment provide support for 30 days with no resupply (Logistics Readiness Officer Supply Module, 2002: 27). Following this logic, a dummy variable will be used to identify whether or not the deployment will last for 30 days or more. This variable has a value of zero if the deployment is less than 30 days, and a value of 1 of the deployment is 30 days or longer. The coefficient relating to this variable is expected to be positive, since a longer deployment would require more support.

Finally, information was collected regarding the title, type, date, and location of each deployment. This additional data serves as reference to the complexity of the deployment, and can help serve as a reference if more detailed information is required to explain non-representative data points and outliers during evaluation of the collected data.

There will be two models; one for passengers and one for equipment. The models representing the resources required to support an F-15 deployment is expected to take the form:

$$\mathbf{y = B_1 + B_2X_1 - B_3X_2 - B_4X_3 + \varepsilon} \quad (2)$$

where y = number of passenger or short tons of equipment

X_1 = number of deployed F-15 aircraft

X_2 = 0 if no other aircraft are present, 1 if others are present

X_3 = 0 if deployment is under 30 days, 1 if over 30 days

X_4 = 0 if the deployed location bare, 1 if it is not

ε = Random error, normally distributed with a mean of zero

In order to perform a regression, five or more observations are required to account for the degrees of freedom lost by using four independent variables.

Building the Estimators

Data will be extracted from historical data files from Langley AFB, and from RAF Lakenheath. Files with incomplete data were ignored.

Once the data iss collected, a regression determined the best fit line. The model will be evaluated to ensure that it meets the underlying assumptions of regression. If a model cannot meet the assumptions, then the confidence in its results is diminished. These four key assumptions are detailed by McClave et al (2001:498).

The first assumption of a regression model is that errors are normally distributed with a mean of zero. Residuals that are not normally distributed occur because there are non-random factors in the data set that are unaccounted for. This can be resolved by transforming the data, or by identifying the additional factors.

The second assumption of regression is that variance of the residual's probability distribution is the same for all levels of each of the independent variables. If the variance of residuals is not consistent at different levels, the beta weights cannot be interpreted with confidence.

The third assumption is that the errors are independent. If the value of a residual error is determined by other errors in the vicinity, then by definition it is not random error. The measure of residual independence is serial correlation. Serial correlation tests for correlation between neighboring residuals (McClave et al, 2001:797). The test for serial correlation is the Durbin-Watson test.

The Durbin Watson test examines the hypothesis that there is no first order serial correlation in the data. The exact sampling distribution of the Durbin-Watson test statistic "d" is difficult to derive. Thus, there is no unique critical value that will lead to accepting or rejecting the null hypothesis (McClave et al, 2001:798). Instead of a critical value, a range of values is provided. In the case of the Durbin-Watson test, a value of 2 means that there is no serial correlation present. However, some degree of serial correlation can be present and not negatively impact the performance of the model (see Figure 8).

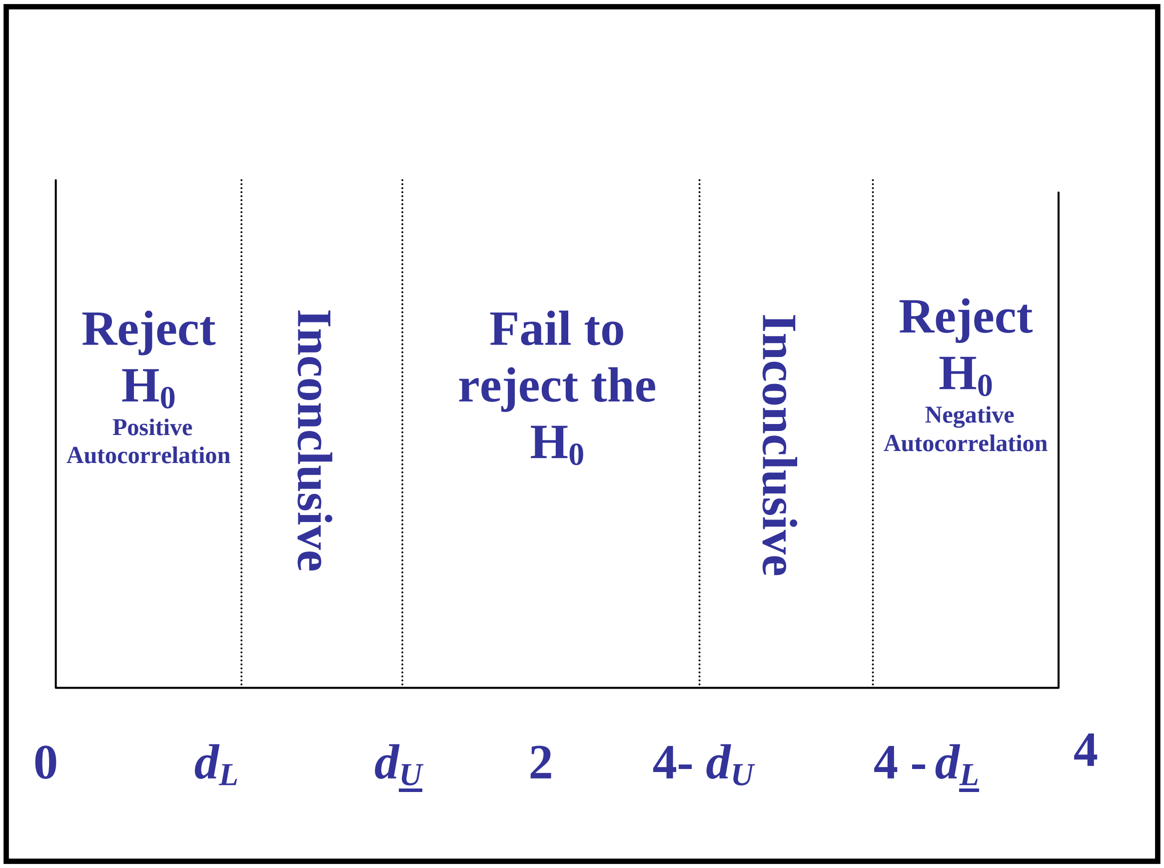

Figure 8. Durbin-Watson Critical Value Range

The final key assumption of a regression model is that the independent variables convey unique information (McClave et al, 2001:650). That is, the variance described by an independent variable is unique from the variance described by other independent variables. This potential redundancy in independent variables is called multicollinearity. A common symptom of high multicollinearity is when the overall F-test for the model shows a high degree of significance, but there are no significant effects. This is because the independent variables combine to provide a high degree of explanation of the same part of the data set.

Multicollinearity can be tested by examining the shared covariance between each independent variable, with every other independent variable in the model. While there is no key statistic to determine when there is an unsatisfactory level of multicollinearity, a high measure of covariance, coupled with one or more factors being insignificant, indicates that multiple variables describe the same construct. The solution is to remove one of the factors from the model and run the model with the reduced factor set.

In order to validate the model and compare the relative success in estimating resources, a 15 data points test set will be collected, using the same factors as described above. These points will be entered into the models, and an assessment will be made regarding the effectiveness of the model's to predict, with 95% confidence, the number of passengers and short tons used to support the deployment. This will provide confirmation as to the power and effectiveness of the model.

Analysis of AFE using Cargo and Passenger Models

Once the data has been shown to sufficiently support the assumptions of regression, a comparison will be made to the first generation of regressive estimator, proposed by Goddard (2001). That model was constructed using a similar regression methodology, but used only one predictor: the number of aircraft. Additionally, it only described the equipment requirements, foregoing passenger estimations. If the cargo and passenger models are more effective than the AFE, it should be able to describe a significantly higher amount of variance.

Since the F-16CJ formed the basis for the exact AFE model, the methodology will be reapplied to the F-15E. In this case, a regression model will be constructed using the number of aircraft as the sole predictor using F15E data. If there is not a significant increase in the explained variance, then using the less complicated model would be preferred.

Validation of the Cargo and Passenger Models as a Forecasting Tool

If the cargo and passenger models satisfy the underlying assumptions of a regression model, that it outperforms the simple regression model presented in the AFE, and that it explains a large portion of the variance in resource requirements, a validation of the effectiveness of the model will occur.

This validation will be conducted using 15 additional data points collected from RAF Lakenheath and Langley AFB during a second data collection effort. The parameters for each of these deployments will be entered into both AFE-II equations, and the predicted requirements will be recorded.

The predicted requirements will be inspected first to determine if they are within a calculated prediction interval. This interval is used to determine a threshold of performance for the regression model.

> The basic idea of a prediction interval is thus to choose a range in the distribution of Y wherein most of the observations will fall, and then to declare that the next observation will fall in this range. The usefulness of the prediction interval depends, as always, on the width of the interval and the needs for precision by the user. (Neter et al, 1996:63)

The measure of precision required in the prediction is represented by alpha (α). In this case, since forecasting requirements should be precise, and since a small sample size was used, an alpha of .05 will be used. Conceptually, this means that out of 100 predictions, 95 will fall within the prediction interval. If more than 5 are outside of the prediction interval, then the hypothesis that the model successfully predicts resource estimate with 95% confidence must be rejected.

The equation used in calculating a prediction interval is:

$$\mathbf{Y_h \pm t(1\text{-}\alpha/2;\ n\text{-}2)s} \quad (3)$$

where $E(Y_h)$ = The mean value of Y at point h

t = The value derived from the t-Distribution

α = The precision required in the prediction

n = The number of data points in the sample

s = An estimation of the population's standard deviation, σ

This model allows the calculation of a prediction interval when using a sample where the population parameter σ, representing the standard deviation, is unknown.

The output from this equation, along with the mean regression line, will be used to determine whether the model is able to successfully predict, with 95% confidence, the resources required to support a deployment with a given set of parameters.

Finally, the model will be tested for the proximity of its prediction to actual deployment data. Since the sample size is relatively small, a wide prediction interval will result. This is because as the sample size increases, the value of the t-score decreases, moving the upper and lower bounds of the distribution closer to the mean line.

The specific methods of proximity evaluation will be the mean percentage error (MPE) and the mean absolute percentage error (MAPE) of the predicted actual value. These provide a measure of the degree of variation between the predicted point and the actual value by providing a quantification of the error as a percentage of the actual.

The MPE is calculated by differencing the actual and predicted amount, then dividing the difference by the actual. These values are summed across predictions for that resource, and then averaged. A mathematical representation of the MPE derivation is:

$$MPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{X_i - \hat{X}_i}{\hat{X}_i}\right) \qquad (4)$$

where X_i = The predicted value for point i

$\hat{X}_i$ = The actual value of point i

i = Successive deployments from the validation set of data

n = The number of data points in the sample

The MPE provides an analytical tool to determine the ability of the model to predict the actual data over time. Values of the MPE can be positive or negative. Negative numbers indicate a situation where the prediction understated the actual, while a positive number indicates that the prediction overstated the actual. Numbers closer to zero indicate a small error in the prediction, while numbers farther from zero indicate a large error in the prediction.

However, since predictions that are over the actual are canceled out by similar predictions that understate the actual, another tool must be used to identify the absolute or total error created by the prediction model. In order to determine the total average error created by the prediction model, a MAPE analysis will be conducted. The MAPE is similar to the calculation used for the MPE. However, a key distinction comes from taking the absolute value when differencing. By accomplishing this all errors are determined to be positive. This allows a determination of the total error of the model since over and understated errors do not cancel out. A representation of the calculation methodology is:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{\left|X_i - \hat{X}_i\right|}{\hat{X}_i}\right) \tag{5}$$

where X_i = The predicted value for point i

$\hat{X}_i$ = The actual value of point i

i = Successive deployments from the validation set of data

n = The number of data points in the sample

A high MAPE score means that the model is susceptible to high error in its prediction, but provides no information regarding its tendency to over or under estimate actual values. Low MAPE scores indicate a model that closely estimates actual values.

Since the MPE provides little information regarding the scale of the absolute error, and the MAPE provides little information regarding the direction of the estimation error, both measures will be used in unison to determine model effectiveness. Table 4 provides a description of the logic used to interpret MAPE and MPE values.

Table 4. 2 X 2 Interpretation Matrix for MAPE and MPE

		MAPE	
		Low	**High**
MPE	**Low**	Low Error Model	High errors/cancel out
	High	Not Possible	Over/Under Estimates

A low MPE and a low MAPE is the result of a good model. The error in prediction is low, and the model tends to slightly over and under estimate in equal proportions.

A low MPE and a high MAPE results from a model that creates high errors, but the errors tend to equally over and under estimate the actual value.

A high MPE and a low MAPE does not exist because a high MPE suggests that a model creates high errors in one direction, and a low MAPE suggests low errors. These cannot exist simultaneously.

Finally, a model that produces high MPE and high MAPE is a model that creates large error, systematically under or over estimating the actual value.

IV. Analysis

Chapter Overview

This research began with the intention of creating a deployment resource estimation tool, capable of providing quick and accurate assessments of the resources required to support different F-15E deployments.

Previous chapters have provided justification of the need for rapid resource estimations, and have provided a context for research in this area. Further, an investigation into the ability of rule-set models to predict deployment requirements has been addressed.

This chapter reports the results of the methodology introduced in Chapter III. This methodology works to develop a robust regression model for use in explaining the factors involved in determining deployment requirements that can also be used to forecast the composition of future deployment packages given a specific scenario.

Finally, an evaluation of the model is outlined using a comparison of the mean percentage error (MPE) and the mean absolute percentage error (MAPE), and an evaluation of the Mean Squared Error (MSE) is provided to assess the presence of large errors in the cargo model's prediction.

Data Collection

In all, 47 data points were collected; 32 were used in the creation of the model, and 15 were used during the validation of the model. However, one of the data points from the set used to create the model was excluded. It was a deployment during 2001 in support of OPERATION ENDURING FREEDOM from Langley, AFB. This movement occurred during an intensely short planning period. During the movement, no TPFDD or UTC data was used to drive deployment requirements. Additionally, no information was available on the duration or nature of the mission. As a result of these factors, the package that was deployed was larger than a full UTC movement. Since this was an atypical movement that was not impacted by usual planning constraints, it was dismissed as an outlier. Since the scope of this research is to estimate deployments utilizing the Joint Planning Process, this point was consciously omitted.

Identification of Significant Factors

As the data were collected, information about the number of aircraft, the duration of the deployment and whether other airframes were collocated at the deployed site were readily available. However, neither location was able to provide data from a base that fit the START definition of a bare base. Thus, the bare base factor was dropped due to insufficient data.

Additionally, after examining successive outliers, another factor was identified. During the initial test, a succession of outliers was removed and analyzed. In each case, the deployment was supporting an AEF. After collaboration with planners at Langley AFB, it was determined that the AEF deployment planning process is indeed different from the process for planning training or wartime deployments. First, the planning horizon is long, typically 14 months. This allows for more time to consider package requirements. Additionally, since the AEF movements are programmed far in advance, and have a very high priority, they are more likely to receive airlift support in quantities requested. This scenario differs greatly from the 72-hour implementation of a plan created using the Joint Planning Process.

Since the AEF planning process is conducted on a 16 month time scale, comparable to the deliberate planning time scale, and is executed almost exactly as planned, a factor to assess the significance of the AEF's long term planning horizon was included. This factor was added to the process of passenger and cargo model development. To account for this factor, a dummy variable was designed, such that a zero meant the deployment was an AEF deployment, and a 1 meant that the deployment was not due to an AEF. The coefficient of this variable was expected to be positive for two reasons.

For personnel, an AEF package was expected to be smaller because of the window available for training personnel. Given a 14 month training window, personnel could learn to perform more tasks specific to the mission. Additionally, since all personnel requirements were validated through MAJCOMs, the force numbers within UTCs, once tailored, are fairly stable. This would indicate that an AEF deployment would reduce passenger requirements. Finally, non-AEF deployments are often used for training personnel in their war time competency. Thus, non-AEFs would theoretically have more personnel in them to maximize the training opportunity. As a result, it is hypothesized that in an AEF deployment, less personnel would be deployed than in a non-AEF deployment.

For cargo, it was assumed that more time for planning, meant a more deliberate consideration of the equipment required to support a given package. This time allows for planners to identify redundant or unnecessary equipment items. Thus, it was hypothesized that an AEF deployment would have less cargo than a similar deployment that was not in support of an AEF.

Developing the Passenger Model

Based on the data, a regression equation was tested using the number of passengers as a dependent variable that responds to the values of the four independent variables.

A best fit line was determined using linear regression.

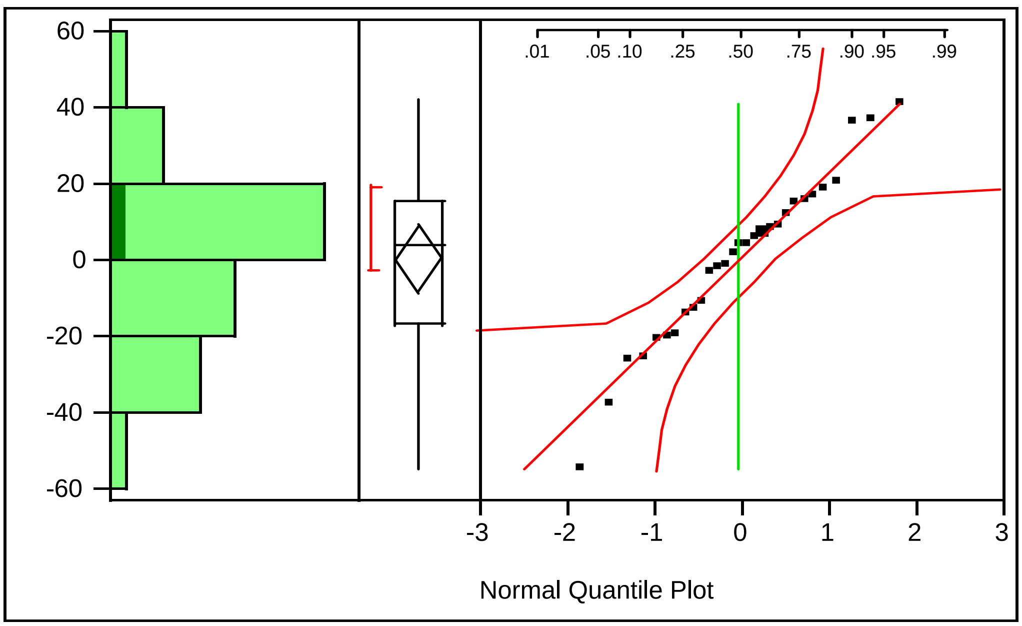

Figure 9. Normal Quantile Plot of Passenger Model Residuals

The first check to satisfy the underlying assumptions of regression is to ensure the residuals are normally distributed. The normal quantile plot (see Figure 9) shows that the distribution is roughly normal, with a proportionally higher concentration of points in the middle, and no points falling outside of the 95% confidence interval. The Shapiro-Wilk test statistic was used to determine the fit of the residuals to a normal distribution. The Shapiro-Wilk tests the hypothesis that the distribution in question and a normal distribution are the same. Thus, a Shapiro-Wilk test score with a P-value of less than .05 will result in rejecting the null hypothesis that the distribution is normal, and results in the model violating the regressive assumption of normality. The Shapiro-Wilk test statistic for the passenger model is .978 with a p-value of .7950. Thus the null hypothesis is not rejected, and the distribution is considered normal.

Second, a scatter plot of residuals is used to examine the equivariance of the residuals. The second assumption of regression is that the variance of the residual's probability distribution is the same for all levels of the independent variable. (see Figure 10)

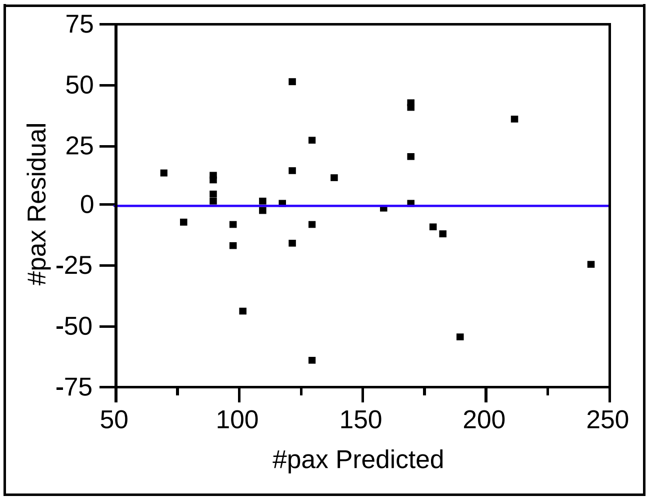

Figure 10. Residual by Predicted Plot for Passenger Model

The scatter plot of residuals based on the number of passengers predicted provides a visual evaluation of equivariance. Since the residuals seem to fall evenly around the mean, with not significant increasing or decreasing trends, the model seems to produce equivariant residuals. This satisfies the second assumption of a regression model

With evidence supporting sufficient equivariance and normal residuals, an investigation of serial correlation must be conducted. Serial correlation is a measure of dependence among neighboring data points, and was tested using the Durbin-Watson test for first order serial correlation.

The Durbin Watson test examines the hypothesis that there is no first order serial correlation in the data. The Durbin-Watson test statistic and the relative critical values are shown in Table 5.

Table 5. Serial Correlation for Passenger Model

Model	Durbin	d_u	d_l

	Watson		
Passenger	1.77	1.64987	1.198

Since the test statistic falls between d_u and two, the null is not rejected, and the assumption of no significant serial correlation is maintained.

The final check in ensuring a sound regression model is the check for multicollinearity. As discussed in Chapter III, multicollinearity is a measure of the relationship between two or more independent variables; that is, do they measure the same thing? A quantified assessment of shared covariance is used to determine the amount of shared variance between predictors. (see Table 6)

Table 6. Shared Covariance of Passenger and Cargo Predictors

	# AC	**Planning Dummy**	**Duration Dummy**	**Co-located Dummy**
# AC	1	0.1639	0.1669	0.2006
Planning Dummy	0.1639	1	-0.5078	-0.1679
Duration Dummy	0.1669	-0.5078	1	0.0486
Co-located Dummy	0.2006	-0.1679	0.0486	1

As was the case in serial correlation, there are no critical thresholds to determine the amount of shared variance between independent variables; a visual assessment determines whether the presence of multicollinearity threatens the performance of the model.

In this analysis, larger numbers represent a greater amount of covariance. The shared variance between the Duration Dummy variable and the Planning Dummy variable is high. However, considering that both of the variables are significant in the model, it isn't high enough to determine that the variables are measuring the same thing. Thus, the model appears relatively free from significant covariance. Additionally, the cargo formulation uses the same data, with no additional factors; the multicollinearity test is identical for both cases.

Finally, with the underlying assumption of a regression model successfully fulfilled, the effects of the regression equation can be investigated.

An investigation into the significance of each of the four independent variables shows that all are statistically significant contributors to the number of passengers deployed. (see Table 7)

Table 7. Parameter Estimates for Passenger Model

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	68.30149	16.60618	4.11	0.0004
# AC	8.903698	1.182325	7.53	<.0001
Planning Dummy (0= AEF, 1= not AEF)	-29.6854	13.01406	-2.28	0.0317
Co-located Dummy (0=no,1=yes)	-24.7644	10.47851	-2.36	0.0266
Duration Dummy (0<30, 1 >=30)	35.10655	11.06773	3.17	0.0041

Finally, an assessment of the performance is conducted by determining the ability of the regression model to explain variation within the data. (see Table 8)

Table 8. Summary of Fit for Passenger Model

R-Square	0.80709
R-Square Adj	0.774938
Root Mean Square Error	23.99245
Mean of Response	134.4828
Observations (or Sum Wgts)	29

The passenger model explains approximately 77% of the variance in the number of passengers deployed. This suggests that the four independent variables are critical to providing an estimate of the number of passengers required to support a deployment. However, approximately 23% of the variance is not explained. Since the 23% of unexplained variance in the model is considered to be randomly distributed error, a prediction interval will be calculated. The prediction interval will provide a more robust prediction of the resources required by acknowledging an expected level of error about the mean.

The model representing the number of passengers required to support an F-15 deployment is:

$$\mathbf{y = 68.30 + 8.90X_1 - 29.81X_2 - 24.76X_3 + 35.11X_4} \qquad (3)$$

where y = number of passengers

X_1 = number of deployed F-15 aircraft

X_2 = 0 if no other aircraft are present, 1 if others are present

X_3 = 0 if deployment is less30 days, 1 if 30 days or more

X_4 = 0 if the deployment is AEF, 1 if it is not AEF

Developing the Cargo Module

As with the passenger model the independent variables were used to fit a line through the data, minimizing the sum of the squared error terms. An initial investigation into the significance of the variables indicates that one of the identified variables is non-significant in predicting cargo requirements (see Table 9).

Table 9. Preliminary Parameter Estimates – Cargo Model

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	80.85807	14.24198	5.68	<.0001
# AC	3.981304	1.013999	3.93	0.0006
Planning Dummy (0= AEF, 1=	-64.9918	11.16127	-5.82	<.0001

not AEF)				
Duration Dummy (0<30, 1 >=30)	10.3413	9.492031	1.09	0.2868
Co-located Dummy (0=no,1=yes)	-25.493	8.986697	-2.84	0.0091

An examination of the significance of these variables highlights the fact that the duration of a deployment is not a significant factor in determining the amount of cargo required to support a mission. Other factors may impact this phenomenon. For example, some cargo may be transported at a later date as resupply. In any case,, the effect of the duration of a deployment will not be included in the cargo model.

The first check to satisfy the underlying assumptions of regression is ensure the residuals are normally distributed. The normal quantile plot (see Figure 11) shows that the distribution is roughly normal, with a proportionally higher concentration of points in the middle, and no points falling outside f the 95% confidence interval.

Using the significant variables, normality of residuals was addressed. The normality of the cargo data residuals was not as well defined as it was for passengers (see Figure 11).

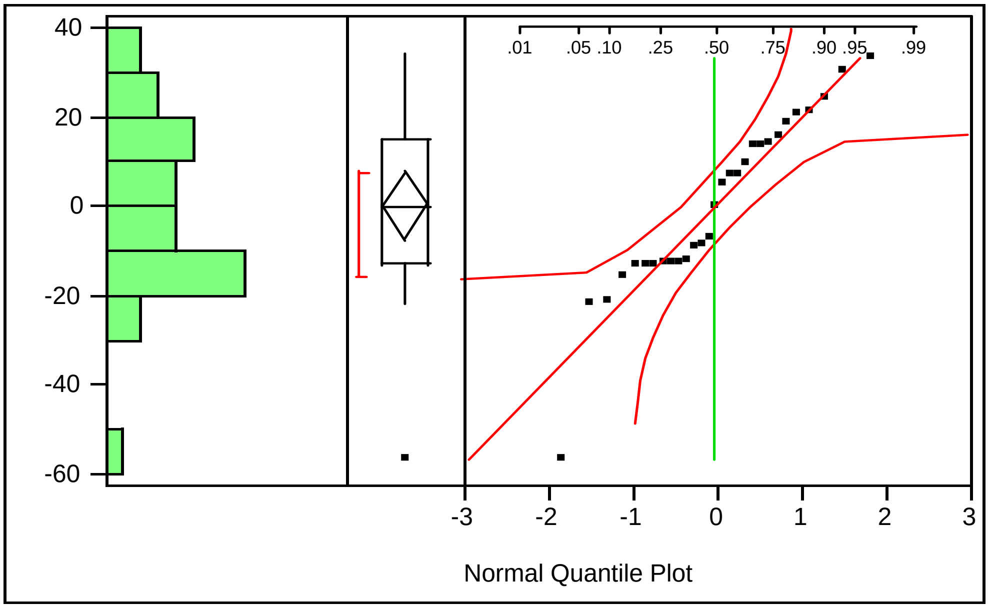

Figure 11. Normal Quantile Plot of Cargo Model Residuals

In the distribution displayed in Figure 11, all points stayed within the 95% confidence intervals, fulfilling the underlying requirements for normally distributed residuals. Additionally, the Shapiro –Wilk score is .936 and the p-value is .077. Since the Shapiro-Wilk assumes similarity between distributions, a P-value above .05 results in accepting the hypothesis that the distribution is normal.

Second, a scatter plot of residuals is used to examine the equivariance of the residuals. The second assumption of regression is that variance of the residual's distribution is near equal (see Figure 12).

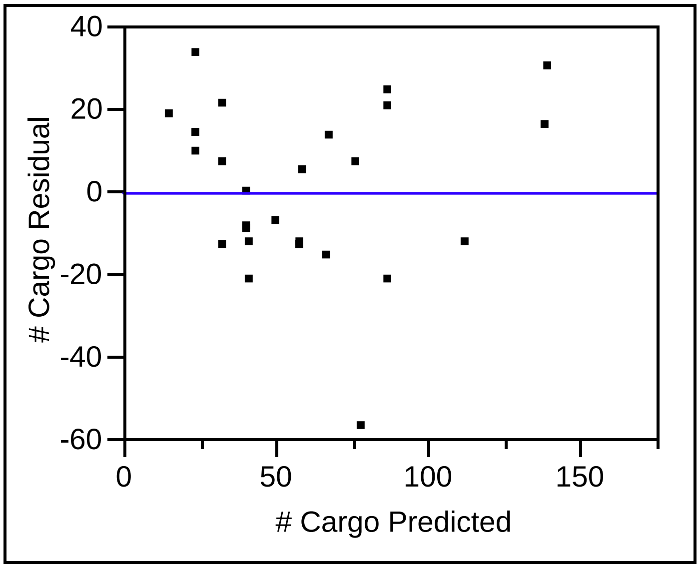

Figure 12. Residual for Predicted Plot for Cargo Model

One data point appears to defy the equivariance of the set. Unfortunately, the deployment occurred in 2001, and no one in the organization remembers the deployment, or why it was so small comparatively. However, regression is a robust modeling technique that can withstand a single point deviating from the assumption. There does not appear to be a systematic variation, so the regression model beta weights are still acceptable.

The third check is for serial correlation using the Durbin Watson test. The Durbin-Watson test statistics and the relative critical values are shown in Table 10.

Table 10. Serial Correlation for Cargo Model

Model	**Durbin-Watson**	d_u	d_l
Cargo	1.4384025	1.64987	1.198

Since the test statistic is greater than d_l the assumption that the null hypothesis assuming no serial correlation is accepted. However, since there is no absolute threshold dividing a high and low serial correlation, the analysis includes values between d_u and d_l. This range includes values that indicate the need to exercise caution. That is, while the null is accepted, meaning that the model doesn't have serial correlation, the model shows a higher level than expected. This indicates that more information may reverse the finding that serial correlation is present (McClave et al, 2001:799). While this isn't optimum, it does not prevent the use of the results for prediciton.

With assumptions necessary to apply a regression equation satisfied, the results of the regression equation can be investigated. An investigation into the significance of each of the three remaining independent variables shows that each is a significant contributor to the short tons of cargo deployed. (see Table 11)

Table 11. Parameter Estimates for Cargo Model

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	87.56963	12.88862	6.79	<.0001
# AC	4.327508	0.966513	4.48	0.0001
Planning Dummy (0= AEF, 1= not AEF)	-71.7911	9.287884	-7.73	<.0001
Co-located Dummy (0=no,1=yes)	-26.6747	8.954293	-2.98	0.0064

Finally, an assessment of the performance is conducted by determining the ability of the regression model to explain variation within the data. (see Table 12)

Table 12. Summary of Fit for Cargo Model

R-Square	0.73457
R-Square Adj	0.702719
Root Mean Square Error	20.65347
Mean of Response	58.55862
Observations (or Sum Wgts)	29

The cargo model explains approximately 70% of the variance in the number of passengers deployed. This suggests that the three independent variables are critical to providing an estimate of the short tons of cargo required to support a deployment. However, as in the passenger model, approximately 30% of the variance is not explained. As a result, a model will be used to determine the mean number of short tons of equipment that will be deployed to support a mission, and a 95% prediction interval will allow for significant predictions in the midst of potential error.

The model for the tons of cargo required to support an F-15 deployment is:

$$\mathbf{y = 87.57 + 4.33X_1 - 71.79X_2 - 26.67X_3} \quad (4)$$

where y = Short tons of cargo

X_1 = number of deployed F-15 aircraft

X_2 = 0 if no other aircraft are present, 1 if others are present

X_3 = 0 if the deployment is AEF, 1 if it is not AEF

AFE Evaluation

Since the AFE model proposed by Goddard (2001) was constructed using only one factor, it has is limited in its predictive ability. The AFE model significantly underperforms the more robust cargo and passenger models when tested usind the present data ser. This phenomena occurs even without the AEF data that did not exist at the time of the AFE construction, even when it is constructed without any data from AEF deployments. Its ability to explain the variance is significantly lower (.248 adjusted R-squared) leaving a very significant amount of unexplained variance (see Table 13). As a result, the model will not be investigated further, on the grounds that it does not explain a significant level of variance.

Table 13. Summary Table for AFE

R-Square	0.287791

R-Square Adj	0.248224
Root Mean Square Error	12.12925
Mean of Response	41.17
Observations (or Sum Wgts)	25

The increase in explained variance provides a significant argument to the cargo and passenger models serving as a better estimator for the resources required to support an F-15 deployment. It's inclusion of more factors provides a more flexible planning tool when certain parameters of the deployment may be known or when multiple scenarios are compared. Finally, the passenger model provides more information critical to planning.

Passenger and Cargo Model Validation

In order to evaluate the models developed in the first part of this study, a second set of data were collected. These data was used to test the predictive power of the statistical models. While the first part validated the ability of the models to explain the factors and their contributions to resource requirements, the models still needed to be evaluated for their performance against actual deployment data. This validation was a multi-step process, testing statistically significant predictions, and the errors in the forecast.

A validation set of data was used in this step of the analysis. The data test set was collected independently of the original data set. The coded values of this set are provided in Table 14.

Table 14. Values of the Test Data Set

Cargo	Pax	#AC	Aggregate	Duration	AEF
76.2	141	6	0	1	1
110.1	117	6	0	0	0
111.2	152	8	0	0	0

65.7	90	8	1	1	0
121.3	94	4	0	0	0
61.1	77	4	1	0	0
79.6	137	12	1	1	1
79.2	133	12	1	1	0
129.7	149	8	0	0	0
134.3	157	12	0	1	0
73.3	176	12	1	1	0
59.9	79	4	1	0	0
92.1	131	16	1	1	0
76.2	182	16	1	1	1
84.2	196	18	1	1	1

Assessment of Statistical Significance

To further test that the model works properly, the validation set will be used. In this case the actual deployment resources will be evaluated to see if they are within the bounds of the models prediction interval. Given a 95% prediction interval, a successful model will be able to contain the actual resource quantity within the associated interval 95% of the time. This assessment determines the ability of the model to perform under circumstances with different parameters. That is, the model was developed using 32 data points, but can the model predict the actual deployment requirements using 15 data points from independent deployments?

The passenger module was able to successfully capture the actual number of passengers deploying in all 15 cases. That is, in every case the actual deployment requirement was between the upper confidence interval (UCI) and the lower confidence interval (LCI). (see Table 15)

Table 15. Passenger Model Significance

Predicted	Actual	#AC	AEF	Duration	Co-located	LCI	UCI	Actual Within Prediction

								Interval?
92.0	141	6	1	1	0	38.7	145.3	Yes
121.7	117	6	0	0	0	62.5	181.0	Yes
139.5	152	8	0	0	0	79.8	199.2	Yes
114.8	90	8	0	1	1	58.6	171.0	Yes
103.9	94	4	0	0	0	44.8	163.1	Yes
79.2	77	4	0	0	1	22.5	135.8	Yes
120.7	137	12	1	1	1	69.2	172.2	Yes
150.4	133	12	0	1	1	92.9	207.9	Yes
139.5	149	8	0	0	0	79.8	199.2	Yes
175.1	157	12	0	1	0	113.4	236.9	Yes
150.4	176	12	0	1	1	92.9	207.9	Yes
79.2	79	4	0	0	1	22.5	135.8	Yes
186.0	131	16	0	1	1	125.7	246.3	Yes
156.3	182	16	1	1	1	103.3	209.3	Yes
174.1	196	18	1	1	1	119.7	228.5	Yes

This analysis shows that the prediction interval was very effective in capturing the actual resource requirements. However, the meaningfulness of this test is somewhat limited. For example, for the first data point, the number of passengers that would have been captured in the prediction interval ranged from 39 to 145. This is a wide range that would not provide enough information to effectively assess transportation requirements.

The cargo module was also able to predict, with 95% confidence, the number of short tons of cargo that would be required to deploy to support and F-15 deployment. This indicates the success of the model in predicting resources requirements. Additionally, the model was provided a confidence interval that captured the actual resource requirement 100% of the time. However, the results were similar to those produced by the passenger estimation model. This analysis is described in Table 16.

Table 16. Cargo Module Significance

Predicted	Actual	#AC	AEF	Duration	Aggregate	LCI	UCI	Actual Within Predictio n

								Interval?
39.75	76.2	6	1	1	0	0.0	85.5	Yes
104.75	110.1	6	0	0	0	53.9	155.5	Yes
112.71	111.2	8	0	0	0	61.5	163.9	Yes
87.22	65.7	8	0	1	1	39.0	135.4	Yes
96.78	121.3	4	0	0	0	46.0	147.5	Yes
71.29	61.1	4	0	0	1	22.7	119.8	Yes
38.15	79.6	12	1	1	1	0.0	82.3	Yes
103.14	79.2	12	0	1	1	53.8	152.4	Yes
112.71	129.7	8	0	0	0	61.5	163.9	Yes
128.63	134.3	12	0	1	0	75.6	181.6	Yes
103.14	73.3	12	0	1	1	53.8	152.4	Yes
71.29	59.9	4	0	0	1	22.7	119.8	Yes
119.07	92.1	16	0	1	1	67.3	170.8	Yes
54.07	76.2	16	1	1	1	8.6	99.5	Yes
62.04	84.2	18	1	1	1	15.4	108.7	Yes

One concern regarding the significance of these predictions must be identified. While the supplementary data and the corresponding significance analysis provide a basis for the models use and applicability, the small sample size used in the original data set results in wide intervals.

For example, in the first case, the prediction interval spans from zero to eighty-five short tons. This is a wide margin, leaving room for potentially large errors. While this margin serves to evaluate the statistical significance of the models predictions, it does little to evaluate the practical significance of the predictions. Satisfying the statistical significance serves as an important foundation for forecasting, the ability to accurately predict resource requirements is what planners need. As a result, the model will be evaluated for its ability to precisely predict requirements.

Examination of Mean Percentage Error and the Mean Absolute Error Percentage

The second approach used to assess the performance of the model will be conducted using the mean percentage error (MPE) and the mean absolute percentage error (MAPE).

For this analysis, a value of 20% was selected to serve as the threshold between moderate and low error. The threshold for high error was determined to be 30%.

These thresholds were selected in order to provide a very conservative evaluation of acceptable error in the prediction term. Scores greater than 30%, or less and -20% are considered high, meaning that there is a significant amount of difference between the predicted and the actual resource requirements. A score between 20% and 30% is considered moderate. Scores closer to zero are considered low error. These thresholds will allow for an assessment of the relative accuracy and reliability of the models to produce resource estimates.

Table 17. MPE and MAPE Calculation for the Passenger Module

Pax-Actual	Pax-Predicted	PE	APE
141	92.0	-34.72	34.72
117	121.7	4.04	4.04
152	139.5	-8.20	8.20
90	114.8	27.52	27.52
94	103.9	10.55	10.55
77	79.2	2.79	2.79
137	120.7	-11.90	11.90
133	150.4	13.07	13.07
149	139.5	-6.35	6.35
157	175.1	11.56	11.56
176	150.4	-14.56	14.56
79	79.2	0.19	0.19

131	186.0	41.98	41.98
182	156.3	-14.11	14.11
196	174.1	-11.16	11.16
	MPE	**0.71%**	
	MAPE		**14.18%**

As indicated in Table 17, both scores were considered low for the passenger module estimations, indicating a relatively high level of precision and accuracy in the models prediction of passenger requirements. The model makes low errors in total (measured by the MAPE), and tends to over and under estimate actual requirements equally (measured by the MPE). The result is a model that should prove very effective in predicting passenger requirements required to support and F-15 deployment in a given scenario.

With the passenger model successfully providing predictions with low errors, a similar exercise was conducted regarding the number of tons of cargo. The MAPE/MPE analysis of the predictions provided by the cargo model can be seen in Table 18.

Table 18. MPE and MAPE Calculation for the Cargo Module

Cargo-Actual	Cargo-Predicted	PE	APE
76.2	39.75	-47.83	47.83
110.1	104.75	-4.86	4.86
111.2	112.71	1.36	1.36
65.7	87.22	32.75	32.75
121.3	96.78	-20.21	20.21
61.1	71.29	16.68	16.68
79.6	38.15	-52.07	52.07
79.2	103.14	30.23	30.23
129.7	112.71	-13.10	13.10
134.3	128.63	-4.22	4.22
73.3	103.14	40.71	40.71
59.9	71.29	19.02	19.02

92.1	119.07	29.28	29.28
76.2	54.07	-29.04	29.04
84.2	62.04	-26.32	26.32
	MPE	**-1.84%**	
	MAPE		**24.51%**

This model produces a very low MPE, but a moderate MAPE. This means that the model has moderate estimation errors, but they tend to equally over and underestimate the actual values. As such, the model successfully predicts the cargo requirements to support a deployment within 24 percent. Given a moderate level of error, it is necessary to analyze the composition of the error between the predicted and actual cargo requirements. While the MAPE/MPE analysis provided a view of the average errors, it did not provide enough analysis regarding the characteristics of individual error. To conduct this analysis, the error terms are plotted in a distribution. The errors between the prediction and actual cargo requirements are shown in Figure 13.

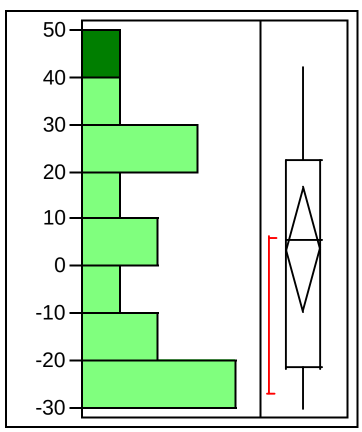

Figure 13. Cargo Prediction Errors

These error terms indicate that most of the error terms are between -30 and 30; which is relatively close to the predicted quantity. However, a few of the terms are located far from the predicted quantity, both above and below the predicted level. These values are magnified by plotting the distribution of the squared errors (see Figure 14). This may indicate the absence of another significant factor in the models.

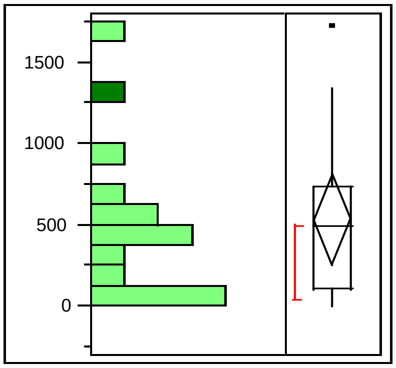

Figure 14. Squared Cargo Prediction Errors

The squared errors indicate that most of the predictions are close to the actual requirements. However, one outlier and another point call far outside the distribution. This means that two errors are significantly increasing the error, inflating the MAPE. Removing these two points significantly reduces the MAPE (see Table 19).

Table 19. Cargo Error Evaluation Without Two Large Error Terms

Cargo-Actual	Cargo-Predicted	PE	APE
110.1	104.75	-4.86	4.86
111.2	112.71	1.36	1.36
65.7	87.22	32.75	32.75
121.3	96.78	-20.21	20.21
61.1	71.29	16.68	16.68
79.2	103.14	30.23	30.23
129.7	112.71	-13.10	13.10
134.3	128.63	-4.22	4.22
73.3	103.14	40.71	40.71
59.9	71.29	19.02	19.02
92.1	119.07	29.28	29.28
76.2	54.07	-29.04	29.04

84.2	62.04	-26.32	26.32
	MPE	4.817551	
	MAPE		17.85127

Removing the two data points further reduces the MAPE, resulting in a model that produces low error. These two errors were created by deployments that occurred in 1999 and 2001 respectively. This analysis may indicate that another factor has a significant impact on deployment resource requirements. Details regarding the logistics planning leading up to the deployment were not available, so an analysis as to the reason for a large departure from other deployment data was not feasible. Additionally, these data points cannot be dropped from the analysis, as they cannot be identified as non-routine, as was the case with the non-TPFDD data point that was eliminated. While they cannot be dropped, this analysis reinforces the fact that the model generally is accurate in predicting deployment requirements with low error.

V. Conclusions and Recommendations

Chapter Overview

The purpose of this chapter is to summarize the findings of the research. Each of the investigative questions developed for this effort are addressed and supported. Limitations of the research are addressed, followed by an evaluation of the results. Finally, topics for recommended future research are presented.

Investigative Question One

What are the significant factors determining the number of passengers and amount of cargo required to support a deployment?

The analysis was able to identify multiple factors that had a significant impact on the size of the final deployment package. The number of deploying aircraft, the presence of other aircraft at the deployed location, and whether the deployment was in support of an AEF were significant factors for both the Cargo and Passenger Models. Additionally, the duration of the deployment was a significant factor in determining the number of passengers that were required to deploy.

Investigative Question Two

How effective have previous models been in estimating real-world deployment requirements?

Due to the approach used, previous models have been largely unsuccessful in determining the resources that actually deploy in support of an F-15 mobility operation. The decision rule-sets utilized by the UTC-DT effort did not account for potential differences that occur between different planners. Additionally, its reliance on information from WRM and BCAT information reduces its ability to assist in deliberate planning. During deliberate planning, information regarding theatre and location are often not specific. Third, it does not provide predictions regarding the number of passengers required, missing 30% of our deployment resources required. Finally, it only includes maintenance UTCs in its calculation. As a result, it does not provide predictions regarding the size of the entire package, missing many of the resources required to support the deployment (i.e. services, transportation, civil engineering).

The RAND Minmx series also utilizes decision rules to predict resource requirements. It also is based on the opinions of a few individuals, creating the same questions of whether their planning factors are representative of all planners. Additionally, the plan only accounts for maintenance equipment and does not provide passenger predictions. Finally, it utilizes only the number of aircraft deploying as its planning factor. This greatly limits its potential, as there are other significant factors that affect the size of the deployment.

The AFE developed by Goddard (2001) utilized a similar methodology as this research, however, its inclusion of only one significant factor results in an inferior model.

Finally, the RAND START model attempts to selected UTCs at the beginning of the planning process, speeding the time required for planning. While it does compile non-maintenance UTCs, it does not provide tailoring estimates, but rather identifies full UTCs that may be selected for deployment. Additionally, it only allows for fighters to be tasked in increments of six. Since fighters may be tasked to deploy in intervals other than six, the ability to properly estimate deployment requirements is significantly impaired. Finally, the rule-sets employed by the model were based on antiquated MEFPAK dated from December 2001. In fact, the F-15E packages that the tool selected are no longer in the inventory, having been replaced by ACC Right-Sized UTCs. As a result, the START does not provide accurate resource estimates.

Investigative Question Three

Can a model be constructed that is more robust that existing models?

Utilizing a methodology that analyzes actual deployment data using a best-fit regression line, a more accurate prediction tool was developed. The tool performed very well in its validation phase, producing low to moderate error in prediction. While the passenger module is very effective in its predictions, the cargo is not as successful. Based on the analysis of error, it is possible that another factor may be involved that occasionally creates large differences in the resources required.

The presence of relatively low prediction errors, though, and provides a much more effective prediction tool than other models produced with this goal in mind. While it is far from the final solution in deployment planning, it provides a vast improvement, and can contribute to more efficient planning.

Investigative Question Four

What factors must future models account for to produce effective estimates?

Future models must be developed to consider all of the factors identified in the first question. In addition, decision-rule sets should be created to allow for flexibility and individual differences planning. Another critical factor is that future models include all of the resources required to support a deployment, and not focus solely on maintenance. A prediction that ignores portions of the package will not produce usable results.

Investigative Question Five

What precision and significance can a regression model provide regarding resource estimations?

It seems that regression may be a helpful tool to use for resource estimation. Using the factors that were identified, it was able to produce statistically significant predictions in 100% of the validation data set. Additionally, it was able to provide estimations regarding the amount of resources required that were either low or moderate in error. In the case of passengers, the model was able to predict with 85.82% accuracy the number of people required to deploy. With respect to cargo, predictions were 75.49% accurate in deployment requirements. A thorough review of the literature did not uncover another tool that provided estimates of this precision.

Limitations

The conclusions in this study have limitations that may affect the performance of the model. First, this research only deals with F-15 aircraft, and does not apply to other airframes. This investigation attempts to establish a methodology that could be applied to other necessary combat platforms (tanks, airframes, hospitals, depots, etc). In order to predict the required airlift, or to hasten planning, tools would be required for each potential platform. Without information regarding all other platforms, this tool is of little use.

Second, this model does not account for items deployed from other locations to support an F-15 package (barriers, TALCE, etc). This study is taken from the perspective of the deploying location, not from the deployed location. As such, the estimations provided give information about the resources that needs to be moved to a location, but no information regarding the resources needed for support at that location. This methodology fails to give exact resource estimation, but provides a flexible range for planners to use when planning to mobilize forces. As a result, the model does not provide specifics regarding what resources will be deployed, only an aggregate estimation regarding how much is required.

Third, this model was developed using a very small sample size. While it meets the minimum size required for the number of variables tested and predicts well given a set of test data, the beta values of the variables may be significantly changed if a larger data set was collected. In a similar fashion, the data was collected from two bases over the last five years. It is possible that local policy or ingrained organizational habits have a significant effect on the results. It is possible that the data collected is not representative of other F-15E bases. Additionally, since data were not included for all aircraft quantities (e.g. 1, 3, 5 or 25 aircraft deployed) extreme caution must be exercised when using the model to predict deployments in these quantities.

Finally, this model does not attempt to reduce, direct or optimize the deployment package. The scope of this research was to explain what actually happens. As a result, inefficient planning may be accepted as the norm. This model made no attempt to change the tailoring process, only to quantify it and use that analysis to streamline planning.

Implications

This research shows that accurate planning factors can be developed using statistical methods. In turn, this methodology can be used to improve the Joint Planning Process. First, rapid COA comparisons can occur. This allows for more accurate transportation feasibility assessments to occur early in the planning process. As a result, feasible COAs will not be dismissed as a result of poor planning factors.

Additionally, accurate airlift requirements can be developed early in the planning process. This would allow for HQ USTRANSCOM to begin scheduling early in the process, before tailoring occurred at the base and MAJCOM level. By using planning factors that closely match actual deployment requirements, the planning process will be more accurate, quick, and will better support our expeditionary posture.

Future Research

Future research is required to develop and architecture for making transportation feasibility analysis more accurate and rapid. In order to develop this architecture, other deployable platforms will have to be identified and quantified if an accurate picture of all of the airlift requirements is to be developed. While it is beneficial to have accurate information regarding the F-15E, it does little to determine the feasibility of plans that contain other capabilities.

Additionally, other significant factors could be identified and added to the regression models as independent variables. While this research provided a large explanation of the variance in deployment resources, an additional factor or two may reduce the error in prediction that these models produce.

Similarly, future research could seek to reproduce these results using ordinal, discrete or continuous variables, rater than dummy variables. By elaborating the duration, type of deployment, or type of platform that is collocated, a more robust explanation of variance may be found.

Finally, future research could be developed to combine the decision rule-set approach with the regression results. By combining these methodologies, it is possible to provide both a prediction tool, and an automated tailoring tool that closely estimates the actual resource requirements. By combining these approaches, efficiency would be gained by combining the planning at the Joint level, and the time to tailor UTCs that occurs at the base level.

Appendix A: RAF Lakenheath AFWUS

UTC	UNIT	ORIGIN	PAX	Cycle 5
6KDB4	0048FTRWG	LAKENHEATH	1	AEF01
6KDB4	0048FTRWG	LAKENHEATH	1	AEF01
6KDB4	0048FTRWG	LAKENHEATH	1	AEF01
6KDB4	0048FTRWG	LAKENHEATH	1	AEF01
9ACP5	0048FTRWG	LAKENHEATH	3	AEF01
9ACZZ	0048FTRWG	LAKENHEATH	2	AEF01
6KDB4	0048FTRWG	LAKENHEATH	1	AEF03
9ACP1	0048FTRWG	LAKENHEATH	3	AEF03
9ACP4	0048FTRWG	LAKENHEATH	2	AEF03
9ACP7	0048FTRWG	LAKENHEATH	0	AEF03
6KAAE	0048FTRWG	LAKENHEATH	1	AEF04
6KDB4	0048FTRWG	LAKENHEATH	1	AEF04
6KDB4	0048FTRWG	LAKENHEATH	1	AEF04
6KDB4	0048FTRWG	LAKENHEATH	1	AEF04
6KDB4	0048FTRWG	LAKENHEATH	1	AEF04
6KDB4	0048FTRWG	LAKENHEATH	1	AEF04
6KTD0	0048FTRWG	LAKENHEATH	1	AEF04
9AAGG	0048FTRWG	LAKENHEATH	5	AEF04
9AEMP	0048FTRWG	LAKENHEATH	10	AEF04
9AEMP	0048FTRWG	LAKENHEATH	10	AEF04
9AEMP	0048FTRWG	LAKENHEATH	10	AEF04
9AEMQ	0048FTRWG	LAKENHEATH	5	AEF04
9AMEA	0048FTRWG	LAKENHEATH	1	AEF04
CSFAL	0048FTRWG	LAKENHEATH	1	AEF04
CSFAN	0048FTRWG	LAKENHEATH	0	AEF04

CSFAP	0048FTRWG	LAKENHEATH	3	AEF04
HFZZZ	0048FTRWG	LAKENHEATH	4	AEF04
RFGAE	0048FTRWG	LAKENHEATH	1	AEF04
XFFC1	0048FTRWG	LAKENHEATH	1	AEF04
XFFC1	0048FTRWG	LAKENHEATH	1	AEF04
XFFC2	0048FTRWG	LAKENHEATH	1	AEF04
XFFC2	0048FTRWG	LAKENHEATH	1	AEF04
XFFC4	0048FTRWG	LAKENHEATH	2	AEF04
XFFG1	0048FTRWG	LAKENHEATH	1	AEF04
XFFG2	0048FTRWG	LAKENHEATH	1	AEF04
XFFG2	0048FTRWG	LAKENHEATH	1	AEF04
XFFG7	0048FTRWG	LAKENHEATH	1	AEF04
XFFGZ	0048FTRWG	LAKENHEATH	1	AEF04
XFFJ3	0048FTRWG	LAKENHEATH	2	AEF04
XFFJ3	0048FTRWG	LAKENHEATH	2	AEF04
XFFJ3	0048FTRWG	LAKENHEATH	2	AEF04
XFFJ8	0048FTRWG	LAKENHEATH	2	AEF04
XFFJP	0048FTRWG	LAKENHEATH	1	AEF04
XFFJP	0048FTRWG	LAKENHEATH	1	AEF04
XSMA1	0048FTRWG	LAKENHEATH	1	AEF04
XSMA2	0048FTRWG	LAKENHEATH	1	AEF04
UTC	**UNIT**	**ORIGIN**	**PAX**	**EAFC5**
XSMA3	0048FTRWG	LAKENHEATH	1	AEF04
XSMA3	0048FTRWG	LAKENHEATH	1	AEF04
XSMA3	0048FTRWG	LAKENHEATH	1	AEF04
XSMA4	0048FTRWG	LAKENHEATH	1	AEF04
XSMA6	0048FTRWG	LAKENHEATH	1	AEF04
9ACP5	0048FTRWG	LAKENHEAT	3	AEF05

		H		
6KAAE	0048FTRWG	LAKENHEATH	1	AEF07
6KAAE	0048FTRWG	LAKENHEATH	1	AEF07
9ACP5	0048FTRWG	LAKENHEATH	3	AEF07
9AEMP	0048FTRWG	LAKENHEATH	10	AEF07
9AEMP	0048FTRWG	LAKENHEATH	10	AEF07
9AEMP	0048FTRWG	LAKENHEATH	10	AEF07
9AEMQ	0048FTRWG	LAKENHEATH	5	AEF07
CSFAK	0048FTRWG	LAKENHEATH	1	AEF07
CSFAL	0048FTRWG	LAKENHEATH	1	AEF07
CSFAL	0048FTRWG	LAKENHEATH	1	AEF07
CSFAL	0048FTRWG	LAKENHEATH	1	AEF07
HFZZZ	0048FTRWG	LAKENHEATH	4	AEF07
RFBZZ	0048FTRWG	LAKENHEATH	1	AEF07
RFGAE	0048FTRWG	LAKENHEATH	1	AEF07
XFFC1	0048FTRWG	LAKENHEATH	1	AEF07
XFFC1	0048FTRWG	LAKENHEATH	1	AEF07
XFFC2	0048FTRWG	LAKENHEATH	1	AEF07
XFFC2	0048FTRWG	LAKENHEATH	1	AEF07
XFFC3	0048FTRWG	LAKENHEATH	1	AEF07
XFFG2	0048FTRWG	LAKENHEATH	1	AEF07
XFFG2	0048FTRWG	LAKENHEATH	1	AEF07
XFFG6	0048FTRWG	LAKENHEATH	1	AEF07
XFFGZ	0048FTRWG	LAKENHEATH	1	AEF07
XFFJ3	0048FTRWG	LAKENHEATH	2	AEF07
XFFJ3	0048FTRWG	LAKENHEATH	2	AEF07
XFFJ3	0048FTRWG	LAKENHEATH	2	AEF07
XFFJJ	0048FTRWG	LAKENHEAT	1	AEF07

		H		
XFFJP	0048FTRWG	LAKENHEAT H	1	AEF07
XFFJP	0048FTRWG	LAKENHEAT H	1	AEF07
XFFJP	0048FTRWG	LAKENHEAT H	1	AEF07
XFFJZ	0048FTRWG	LAKENHEAT H	1	AEF07
XSMA2	0048FTRWG	LAKENHEAT H	1	AEF07
XSMA3	0048FTRWG	LAKENHEAT H	1	AEF07
XSMA3	0048FTRWG	LAKENHEAT H	1	AEF07
9ACP2	0048FTRWG	LAKENHEAT H	3	AEF09
6KDB4	0048FTRWG	LAKENHEAT H	1	AEF10
6KDB4	0048FTRWG	LAKENHEAT H	1	AEF10
6KDB4	0048FTRWG	LAKENHEAT H	1	AEF10
6KDB4	0048FTRWG	LAKENHEAT H	1	AEF10

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14. ABSTRACT

Since the end of the Cold War, the United States has become focused on developing the capability to rapidly respond to emerging crises. Strategic and operation planning play key roles in order to effectively implement this concept. During the planning process, separate courses of action (COAs) are developed. These COAs are evaluated based upon their operational effect, resource availability, nuclear and transportation feasibility.

Currently, transportation feasibility assessments are based on the resources contained within a full Unit Type Code (UTC). Some COAs are eliminated based on these factors. However, most deployments occur at reduced levels. Situational factors, such as the number of aircraft, type of deployment, duration of the deployment, and availability of resources from other locations, can significantly reduce the logistics footprint of a deploying base.

Additionally, full-UTC planning factors reduce the planner's knowledge of airlift requirements until information regarding tailoring is returned from the base. As a result, precious time is consumed, and potentially favorable COAs may be eliminated erroneously.

By developing a forecasting tool to identify the critical factors in tailoring, and their effect on the size of the package deployed, planners can quickly evaluate deployment scenarios, providing more accurate assessments regarding plan feasibility and transportation supportability.

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