THE EFFECT OF IMPROVING THE LOGISTICS PIPELINE ON SUPPLY SUPPORT OF AEROSPACE EXPEDITIONARY FORCES

THESIS

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AFIT/GLM/ENS/01M-16

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THESIS

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Steve Martinez

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Abstract

One of the biggest considerations for an Aerospace Expeditionary Force (AEF), in terms of cost and airlift requirement, is the use of aircraft spares kits to support combat operations. To date, these kits are built on the assumption that there would be no resupply for the first 30 days of a contingency. However, with more efficient transportation and information resources available today, it seems logical that resupply would occur much more quickly. If so, the Air Force should be able to trim its wartime stocks of aircraft spares.

This thesis investigated the effect of improving the logistics pipeline on the size and cost of Air Force mobility readiness spares packages (MRSPs). By using the Aircraft Sustainability Model (ASM), it was shown that order and ship time was the most significant determinant of kit size and cost. Also, through an innovative use of the Forward Support Location (FSL) Option, a potential for significant savings in both airlift requirement and spares costs was identified. In addition, evidence to support the efficacy of the "pipeline on the fly" concept was presented. Under this model, aircraft spares would flow simultaneously from a depot as well as in a spares kit with a deploying unit.

THE EFFECT OF IMPROVING THE LOGISTICS PIPELINE ON SUPPLY SUPPORT OF AEROSPACE EXPEDITIONARY FORCES

I. Introduction

Background

The fall of the Berlin Wall, breakup of the Soviet Union, and dissolution of the Warsaw Pact in the late 1980s changed the environment in which the United States armed forces operates. The most likely military threats subsequent to these dramatic events include smaller-scale conflicts virtually anywhere on the globe. Our national security strategy is now centered on the concept of engagement, rather than attempting to contain communism. (Barrett, 2000) In order to meet the challenge of being able to respond to a wider range of operations, the United States Air Force has developed the Aerospace Expeditionary Force (AEF) concept. "An AEF consists of aircraft wings, groups, or squadrons attached to a USAF numbered air force deployed under the command of a U.S. Military Joint Commander-in-Chief (CINC) of a geographic region, during a period of increased operations tempo" (Davis, 1998). The main objective of this reengineering effort is to allow the U.S. to replace its forward-based aerospace power with a force package that can be employed anywhere on the earth from the continental United States (CONUS).

In Joint Vision 2020, the Joint Chiefs of Staff outlined imperatives for the U.S. military of the 21st century. One of the key concepts was Focused Logistics, which is "the ability to provide the joint force the right personnel, equipment, and supplies in the right place, at the right time, and in the right quantity, across the full range of military operations." (JCS, 2000) Accordingly, the Air Force identified two core competencies—Rapid Global Mobility and Agile Combat Support—that support this tenet. The term "Rapid Global Mobility" is used to describe "the timely movement, positioning, and sustainment of military forces and capabilities through air and space, across the range of military operations," while "Agile Combat Support" encompasses base support functions such as maintenance, supply, transportation, services, and civil engineering that "form a seamless, agile, and responsive combat support system of systems." (AFDC, 1999)

Because the speed at which information is processed and combat operations are conducted continues to increase substantially, an AEF must be able to react quickly upon changes in the global situation. "By taking advantage of the intrinsic strengths of air power—speed, range, and flexibility—the AEF provides a logistically lean, flexible, tailored, quick-response force to the CINC." (Davis, 1998) During Operation DESERT SHIELD in 1990, the U.S. needed 6 months to move forces to the Persian Gulf area and prepare them to conduct offensive operations in support of Operation DESERT STORM. For Operation ALLIED FORCE in 1998, the first offensive aerial missions were launched within about 7 weeks of NATO's approval for the deployment of forces to the area. (DoD, 2000)

It is now apparent that 21st-century U.S. military contingencies will require a much more rapid deployment capability to counter aggression and defeat our enemies. It is imperative that we reduce the logistics "footprint," or support personnel and equipment, required to operate an AEF unit. The Air Force hopes to "...streamline what we take with us, reducing our forward support footprint by 50 percent." (Ryan, 2000) By doing this, units can deploy much more quickly and critical lift forces (usually airlift) required to move them can be used for only the most urgent requirements. The popular catchphrase to describe this characteristic is "Light, Lean, and Lethal." In fact, the goal of the Air Force is to be able to deploy an AEF within 48 hours, and up to five AEFs in 15 days. (Ryan, 2000) This will be done through improvements generated by leveraging "...information technology, rapid transportation, and the strengths of both the organic and industrial logistics base to ensure responsive, dependable, precise support." (Ryan, 2000)

Within the realm of supply support, the movement of spare parts and key consumable items, normally contained in a Readiness Spares Package (RSP) is a major consideration for planning the deployment of a combat unit. As such, methods to reduce the size of Mobility RSPs (MRSPs) must be investigated. A key tenet of "Agile Combat Support (ACS)" is the concept of "reachback," which is the use of distributed information systems to enable deployed personnel to source data residing in the CONUS, without the need to deploy entire data networks from their homestations. For supply operations, this translates to the use of real-time information systems to communicate requirements to regionalized supply operations, who then pass the requests to the source of supply. Again, this reduces the number of personnel and equipment required at the forward operating location (FOL). Applying reachback, in conjunction with rapid mobility, should allow forces to decrease the number of assets that are normally deployed with a unit to hedge against variations in the resupply pipeline time.

Currently, MRSP requirements are computed based on 30 days of support for a contingency with the assumption that there will be no resupply. The amount of spares authorizations allotted to each base for every weapon system comprises the assets needed to support the most taxing scenario involving the greatest number of aircraft that would deploy from that location. In practice, supply and sortie generation personnel coordinate with each other to tailor each kit, based on the expected number of sorties and duration of each sortie for the contingency. However, it seems as though there is no situation, except for a 30-day or greater contingency, for which it is necessary to keep 30 days' worth of spares on hand day to day. Therefore, it seems logical, for cost and airlift requirement reduction purposes, to only stock the minimum number of spares at the home station that is required to support a deployment, up to the point at which the resupply pipeline can deliver an asset to the FOL.

Also, it is probable that the Defense Transportation System (DTS), through which aircraft parts are moved, can be improved so that the assets needed for an entire military operation do not have to be deployed at the outset of a contingency. In contrast, by reducing the total shipment time and the variability in these times, holding spares that are planned to be needed after the time required to ship them to the deployed location at the depot may be a viable way to reduce the initial lift requirement. (See Figure 1 on the next page)

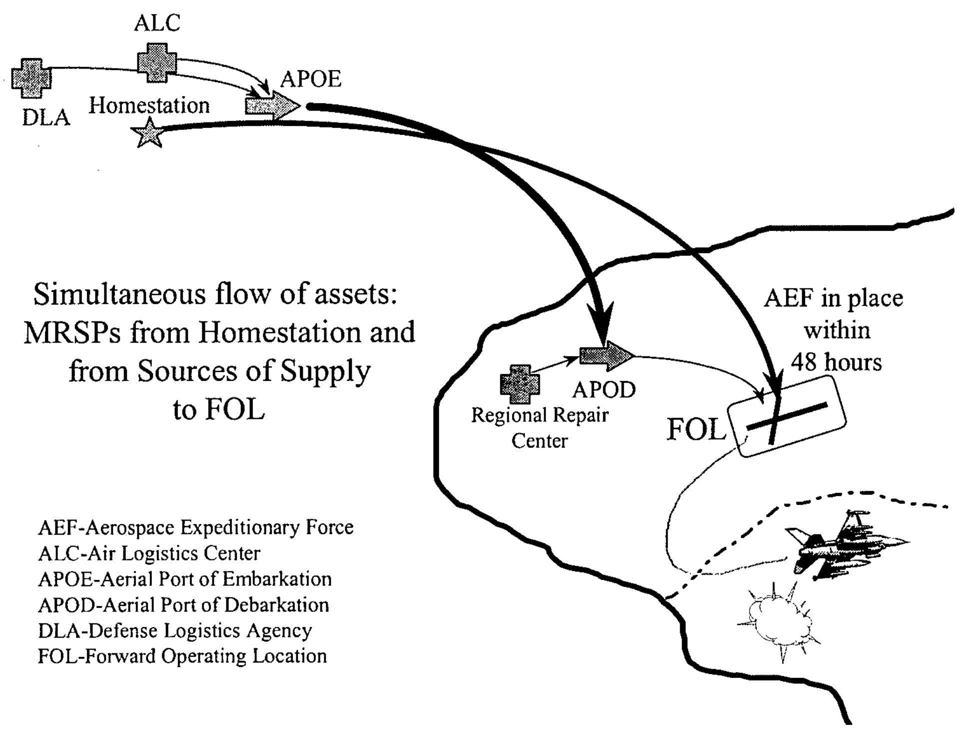


Figure 1. Simultaneous Movement of Parts from Sources of Supply to Point of Use

The parts that are needed after the first few days of the conflict could be shipped from the depot at the same time as the deployment from homestation, and those parts would be available as the spares from the kit began to deplete. This concept is known as the "pipeline on the fly." An added benefit from this technique is that the parts flowed to the FOL later in the contingency only consist of items specifically requested by the deployed unit, rather than continuing to be comprised of parts that were estimated to be needed in the deliberate planning process. (See Figure 2 on the next page)

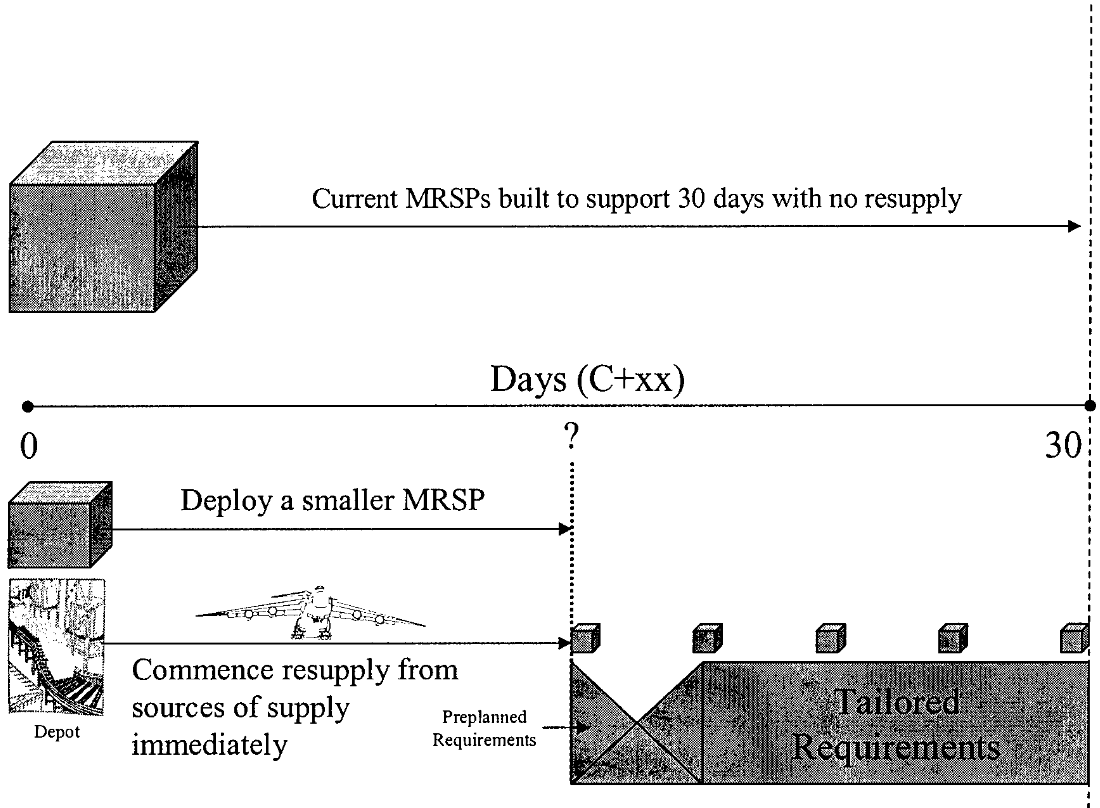


Figure 2. "Pipeline on the Fly"

The Air Force could maintain smaller spare parts kits, and hold some of the assets that are no longer stored in the base-level MRSPs at a higher-echelon inventory point—centralizing the inventory. This would allow a lower overall level of inventory Air Force wide to attain the same service level as can be achieved with the current decentralized spare parts kits.

Reduction of the size of RSPs is of critical importance, and would likely help the Air Force achieve its objective of minimizing its logistics footprint. Recently, concerns over the U.S. military's ability to execute two, nearly simultaneous major regional contingencies (MRCs) have arisen from senior level leaders in the DoD, such as General

Anthony Zinni, USMC (Ret), the former Commander-in-Chief of U.S. Central Command. (McIntyre, 2000) Also, the General Accounting Office stated in a June 2000 report to the House Committee on Armed Services that

> The Department of Defense (DoD) does not have sufficient airlift and aerial refueling capability to initially meet the two major theater war requirements. Its military airlift capability is over 29 percent short of the wartime requirement…" (GAO, 2000)

By minimizing the amount of spare parts that needs to be moved in an initial deployment of an air expeditionary force, the Air Force can help alleviate this problem.

Problem Statement

With the need to trim down our support requirements in mind, the leadership of the Air Force must develop the most efficient ways in which to support AEF deployments and aerospace combat operations without sacrificing mission capability. In order to meet the objectives of ACS, one of the key areas for improvement in logistics is determining the most effective way to deploy and sustain supplies in support of future AEF deployments across the spectrum of conflict. The Air Force is in need of a method by which its investment in spares and the subsequent airlift requirement for deployment of these spares is reduced, without degrading mission support.

Research Objective & Investigative Questions

The main focus of this research was to determine the effect of improving the resupply pipeline so that it can provide an asset to a deployed location more quickly, and consequently effect a significant reduction in MRSP sizes and costs. By understanding the impact of changes that can be made to the logistics pipeline, we can ascertain the possible reduction in wartime spares requirements, in both funding and lift. Subsequently, we can focus on improvement efforts to achieve a specific enhancement. To come to such a conclusion, several investigative questions had to be answered, for they provided valuable insight to the overall research problem.

In order to determine an answer to the overall research question, several other issues had to be understood. First, the current logistics infrastructure that translates parts requirements in the field and moves assets through the transportation system to the user had to be identified. This was done by reviewing previous works that discussed the idea of a "logistics pipeline" and comparing the ideas presented therein with current Joint Chiefs of Staff publications.

Then, the time required to establish the logistics pipeline in order to achieve time-definite delivery (TDD) of spares to an FOL rapidly had to be determined. Although aircraft can reach a location in a matter of hours, express shipment of parts does no good without the ability to unload aircraft and receive items into a supply account, such as that provided by an aerial port operation. In a practical sense, this time represents the lower bound of the possible range of times for which the analysis of the current process was conducted.

The amount of time it takes to place an order for an item from the FOL and receive the item at that FOL had to be calculated. This provided the frame of reference for determining what range of resupply times is probable in future contingencies. Sample data taken from Operation NOBLE ANVIL (ONA), the U.S. air campaign in support of Operation ALLIED FORCE (OAF), the United States' and the North Atlantic Treaty

Organization's action to bring an end to Serbian atrocities in Kosovo, were analyzed statistically to construct the feasible region of times to consider.

Given a specified Direct Support Objective (DSO), the impact of the reduction of MRSP sizes to satisfy demands only until resupply is established was studied. Specifically, the amount of spares investment cost and airlift requirement that could be eliminated by assuming the logistics pipeline could react more quickly than currently possible was calculated.

Lastly, a determination as to whether the "pipeline on the fly" approach would yield any significant reduction in the MRSP requirements had to be made. By modeling the effects of this adjustment to the current process, the resultant improvement was calculated and analyzed for its significance.

Methodology

The research involved gathering current data from ONA, since the rapid deployment and subsequent employment of aerospace forces during this conflict resemble the AEF concept better than any other engagement the U.S. Air Force has undertaken. The main measurement that was examined was the Logistics Response Time (LRT) for various items of supply moved in support of ONA.

LRT is a measurement reflecting the amount of time that elapses for processing a part request and moving the asset to the user. The process starts when a supply technician inputs a requisition for an item into the Standard Base Supply System (SBSS) computer. The order is then electronically transmitted to the Source of Supply (SOS) for the item, which in turn reviews the request and takes appropriate actions to satisfy the requirement.

This is done in one of two ways: if the item is stocked, the depot immediately prepares the item for shipment and inputs it into the transportation system; if the item is not in stock, the asset must either be manufactured or purchased, and then shipped to the requester. Finally, the item is moved through the Defense Transportation System (DTS) from the SOS to the FOL. (HQ AFMC/LGI, 2000)

In order to obtain the data required to answer the research question, it was necessary to collect LRTs for a representative array of supplies moved during ONA. For this research, LRTs for assets used to sustain F-15s, F-16s, KC-135s, and B-52s were analyzed, representing "typical" requirements for a fighter, air mobility, and bomber unit, respectively. With this data, an average LRT was computed, along with a confidence interval that was used to determine the probability that the average LRT would occur between determined upper and lower bounds. Once this confidence interval was established, a sensitivity analysis was conducted by varying LRT and the day parts begin to move from depots (Day Order & Ship Begins, DO&SB) as the independent variables while maintaining a minimum desired aircraft availability rate (AAR). The resultant cost of assets required in the MRSP to attain that AAR, and the number of aircraft pallet positions such a kit would require were computed. Finally, a cost/benefit trade-off curve with which a decision regarding the optimal solution can be made was created by comparing cost or airlift requirement against LRT and DO&SB.

A surrogate value for LRT known as Order & Ship Time (O&ST) was used to allow for the use of the Aircraft Sustainability Model (ASM) in this research effort. Within this software model, the values for O&ST, which represented the majority of

LRT, were reduced for each item in a kit so that the overall average O&ST for the entire kit were reduced. As well, the DO&SB was lowered to represent the "pipeline on the fly." Then, these variables were analyzed through regression to determine which dependent variable significantly affected the independent variables of kit size or cost.

Lastly, an analysis was accomplished using the Forward Support Location (FSL) Option of ASM. This function provided insight as to the amount of aircraft spares that could be pooled at a centralized inventory point, such as a depot, as well as the amount of spares that would be required in spare parts kits forwarded to the contingency.

Assumptions/Limitations

It was assumed that connectivity through the SBSS to either a Regional Supply Squadron (RSS) within the area of responsibility (AOR) or the Air Force Contingency Supply Squadron (AFCSS) to place orders for parts from the FOL is accomplished within 48 hours after the Deployment Order is issued. Also, the capability to receive assets at the FOL is in place within 72 hours after the Deployment Order. Lastly, there is an unimpeded flow of data and information from the FOL to the SOS, and materiel from the SOS to the FOL.

A limitation of using ONA data is that the U.S. Army played a very small role in that contingency. Therefore, the LRT data may reflect more rapid times than normal since there were fewer items in the DTS from the Army that competed for limited airlift resources. A future operation may or may not encounter such a situation.

Implications

The results of this research, as well as future analyses of alternatives utilizing this methodology, can be used to significantly change how the Air Force provisions its aircraft spares and deploys its supplies to support EAF combat operations. If the number of combat capable aircraft available can be kept the same or increased, this research will provide two main benefits. First, the amount of spares the Air Force purchases and maintains to support contingency operations can be reduced, saving valuable funding and minimizing the use of airlift to move spare parts in the critical early phases of a deployment. Second, if a significant reduction in spares package size can be attained when using an average LRT that is too low to be met with the current transportation system, this research highlighted that an opportunity exists for a reengineering of the logistics pipeline. In fact, priority should be placed on various subprocesses so that the savings identified in this research can be realized. On the other hand, if the reduction of DO&SB translates to a reduction in the spares required, the USAF may benefit from implementing the "pipeline on the fly" concept.

Summary

This chapter provided an introduction to the research endeavor that was undertaken, by discussing the environment in which the Air Force exists today, as well as the logistical challenges that are being encountered. It then described basic terms and concepts that are key components for the entire thesis. Then, the research objective and investigative questions were listed to illustrate the overall structure of the study. Next, the methodology used was outlined, and the assumptions and limitations of this procedure were introduced. Finally, the expected consequences of the results were discussed. At this point, it is necessary to survey existing literature to gain a better understanding of the problem at hand and the issues that surround it.

II. Literature Review

Introduction

The process of ordering, providing, and moving supplies is a classic problem in the logistics profession. Since the days of Napoleon, military forces have understood the criticality of the ability to get the right parts to the right place at the right time. This literature review will discuss the rationale behind trying to improve the performance of the logistics pipeline, by describing "just-in-time" inventory and distribution practices that have succeeded in the past. Also, the concept of "risk pooling" is explained, and its relevance to this research is illustrated. Then, it will define the complex system known as the "logistics pipeline" and provide the context in which it is the key consideration. The concept of a "logistics pipeline" must be understood: the components that comprise it, how they interface, and the systems that enable it. The logistics pipeline, as with any other system, must be measurable in order for people to effect changes to it. This review discusses logistics response time (LRT), which is the current measurement used in the Air Force logistics community. As a result of making changes to the logistics pipeline, costs and benefits to the system will be experienced. This review will provide various models with which to conduct a cost-benefit tradeoff. Next, analysis models that are in use currently for calculating spares requirements will be described. Then, the ability to quickly set up a logistics pipeline in combat will be discussed. Lastly, previous studies that included a similar analysis of the logistics pipeline will be introduced and examined.

Just-In-Time (JIT) Inventory and Distribution

One of the purposes for this research is to analyze an opportunity to reduce the amount of materiel necessary for the deployment of an AEF. A principle concept that can be applied to this effort is JIT. In its purest sense, JIT is a philosophy that guides improvement in all aspects of a production-oriented firm. Ohno (1988) explains that JIT's overarching purpose is to totally eliminate waste throughout a company's operations.

However, there are numerous connotations of JIT and ways in which it is practiced. This research focuses on its use relative to inventory and distribution operations. In this context, JIT can be thought of as "...having the needed goods arrive in the needed amount at the needed time." (Ohno, 1988: 9) Because the Air Force is production-oriented in its maintenance activities—depot, off-equipment and on-equipment—it is appropriate to seek the elimination of waste within these areas by applying JIT principles. This includes the case of fixing aircraft at a deployed location, which is the focus of this research.

Langford (1995) describes JIT as a system in which shipments of materiel arrive for production just prior (or "just in time") to when they are needed, with a goal of "...minimizing inventories of production materials, either purchased or manufactured in other company plants." (Langford, 1995: 382) This is accomplished through instantaneous replenishment of materiel using express ordering and transportation services. (Langford, 1995: 372) However, his discussion recommended a cautious approach to implementing JIT techniques in production situations. "JIT means exercising stringent control over suppliers and carriers to produce a continuous flow of small quantities into the production plant so as to minimize the amount of working inventory on hand." (Langford, 1995: 382) In the context of this research, a spare parts kit can be thought of as a level of working inventory that is deployed to offset a delay in resupply. He explained that controlling the performance of external suppliers and transporters can be difficult. Therefore, Langford suggested a list of questions logistics managers should consider before adopting JIT improvements:

- Does the production plant have access to rapid, responsive, and efficient transportation?
- Are the carriers reliable?
- Do the carriers schedule frequent deliveries?
- Is there a high potential for labor stability among the network of suppliers (e.g., a low probability of strikes or work stoppages)?
- Is high-speed communications technology which provides links with the suppliers available in the plant? (Langford, 1995: 383)

With this list of questions, a cost-benefit tradeoff can be accomplished to evaluate the effect of any changes in the inventory management policies upon the firm's performance.

Risk Pooling

The concept of risk pooling demonstrates the benefits that can be derived from transforming an inventory system from a decentralized structure to a more centralized network.

> Risk pooling suggests that demand variability is reduced if one aggregates demand across locations because, as we aggregate demand across different locations, it becomes more likely that high demand from one customer will be offset by low demand from another. This reduction in variability allows us to reduce safety stock and therefore reduce average inventory. (Simchi-Levi, 2000: 59)

The key factor in this approach is the understanding that the standard deviation of demand or the coefficient of variation for a centralized inventory of a particular number of items is less than the sum of the individual standard deviations or coefficients of variation of those same items in when they are placed in multiple locations. (See Simchi-Levi, 2000: 56-60)

The critical aspects of risk pooling can be summarized as follows:

> 1. Centralizing inventory reduces both safety stock and average inventory in the system.
> 2. The higher the coefficient of variation, the greater the benefit obtained from centralized systems; that is, the greater the benefit from risk pooling.
> 3. The benefits from risk pooling depend on the behavior of demand from one market relative to demand from another...the benefit from risk pooling decreases as the correlation between demand from the two markets becomes more positive.
>
> (Simchi-Levi, 2000: 60)

As for the correlation of different markets' demands, it seems that, intuitively, the Air Force typically experiences uncorrelated demands. For instance, the demand for aircraft spares during wartime would probably increase for those units that deploy, while the demands from units that do not deploy either stay the same or decrease. If this is the case, the Air Force stands to benefit from risk pooling as it can be applied to the management of spare parts kits.

Logistics Pipeline

The term "logistics pipeline" was coined to effectively describe the flow of materiel, for it is analogous with the movement of water through pipes. In fact, the U.S.

Army used the diagram in Figure 3 that consisted of pools and pipes filled with water to describe its logistics process for the American Expeditionary Forces of World War I.

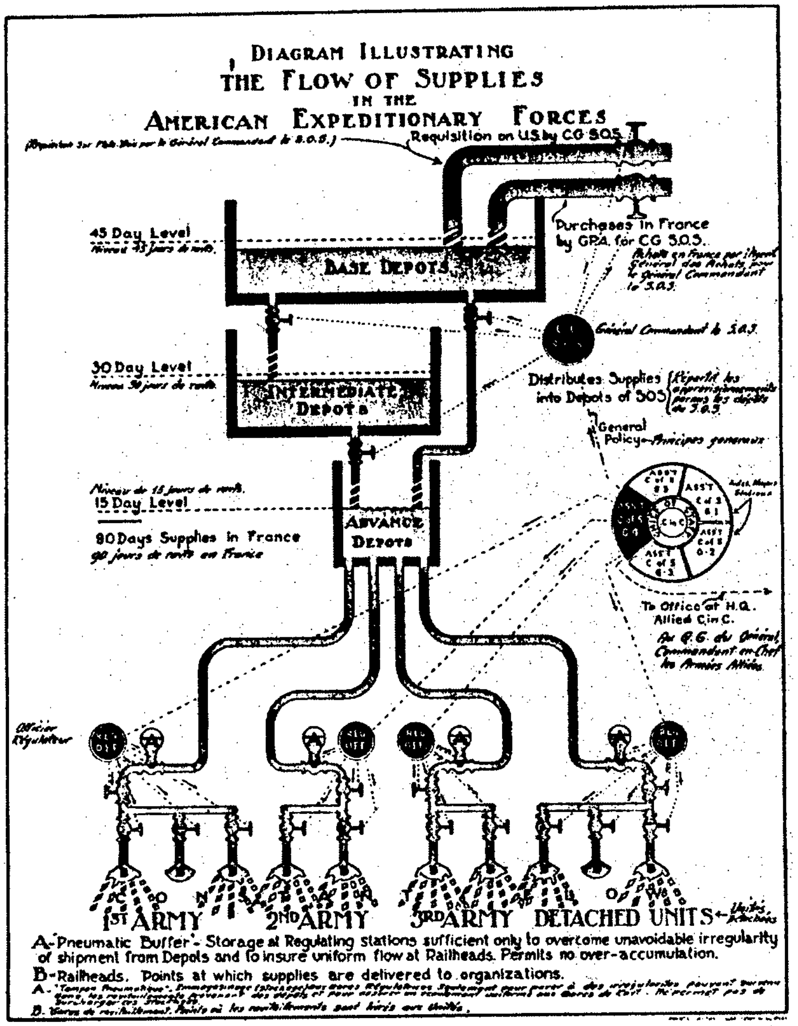


Figure 3. Logistics Pipeline in World War I (Rutenberg, 1987: 67)

Since that time, many descriptions of this pipeline have been used, each one incorporating improvements in technology and refinements of the necessary actions involved. Bond and Ruth (1989) provided one such iteration of the pipeline (Figure 4) when they described a pipeline consisting of various subsystems, such as acquisition, depot, base, and disposal, with transportation and information linkages connecting them.

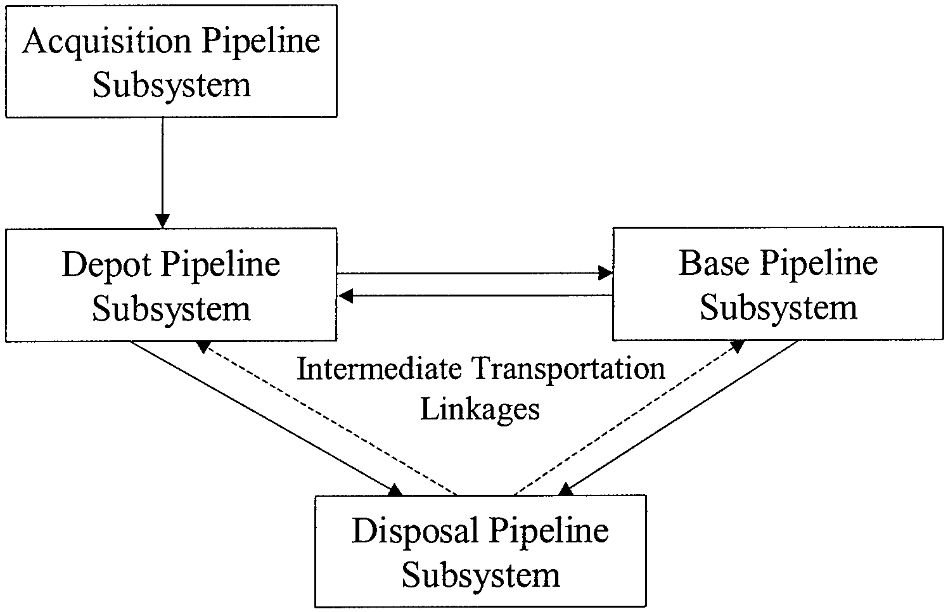


Figure 4. The Overall Logistics Pipeline (Bond & Ruth, 1989: 169)

While the model they presented is insightful, the authors' intent seems to have been to describe the logistics pipeline in enough detail to allow further research, such as a simulation, to be accomplished. In fact, they stated that studies that followed their work should focus on describing the process in more detail than what they offered (Bond & Ruth, 1989: 213). For the purposes of this thesis, the model is at a level of detail that makes it difficult to analyze the entire process of ordering a part to receiving a part. Rather than trying to pinpoint the specific actions within the system that cause significant delays, this thesis analyzed the performance of the entire logistics pipeline in whole.

A more practical model of the logistics pipeline was presented by Gordon (1989). Here, the author offered a broader view of the process:

> The supply pipeline provides a system through which products and information flow between suppliers and customers. Many sub-systems or functions make-up the pipeline including: order processing,

> transportation, warehousing, inventory control, distribution communications, and procurement. But, as products and information move through the pipeline, the traditional boundaries between functions are transcended and each individual function becomes part of a smooth, efficient, and effective process for meeting customer requests. (Gordon, 1989: 13)

Gordon used the graphic shown in Figure 5 to illustrate this view:

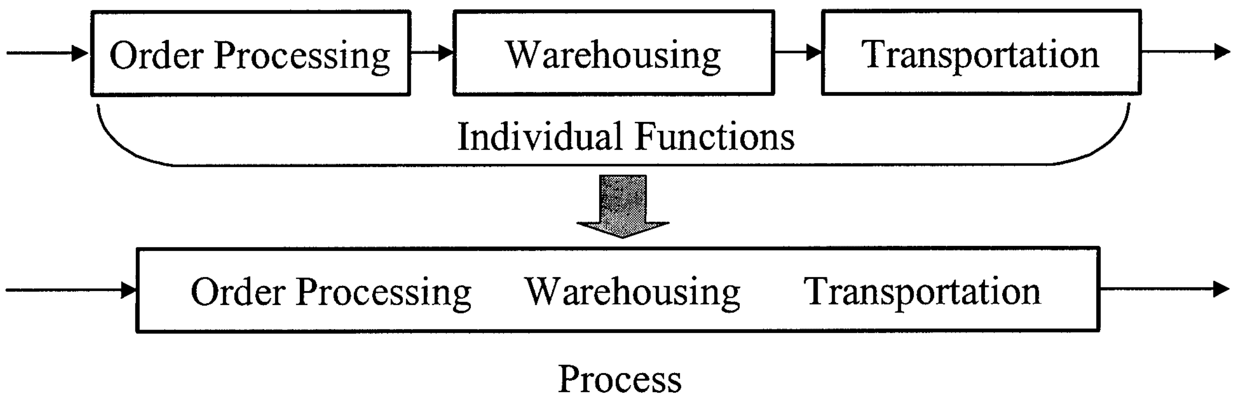


Figure 5. Pipeline Flow Process (Gordon, 1989: 13)

This model is more useful in this research since it presents the pipeline as an integrated set of actions that must act in concert to enable the movement of assets, from the providing source to the point of demand. However, it treats "Transportation" as a single entity rather than an essential function that occurs throughout the process. In fact, one can think of the transportation of data from the order point to the source of supply through the information system as the first step in the entire logistics pipeline. Also, transportation occurs when assets are moved from the source, to an assembly point, and eventually to the unit that placed a request. Therefore, transportation occurs in discrete portions in several phases of the logistics pipeline.

The Joint Chiefs of Staff (JCS) described the logistics pipeline (also called the Distribution Pipeline) as "…the end-to-end flow of resources from supplier to point of consumption" (JCS (b), 2000: I-1) in Joint Publication 4-01.4, Joint Tactics, Techniques, and Procedures for Joint Theater Distribution. This concept is further depicted in Figure 6 as comprising two portions: strategic and in-theater.

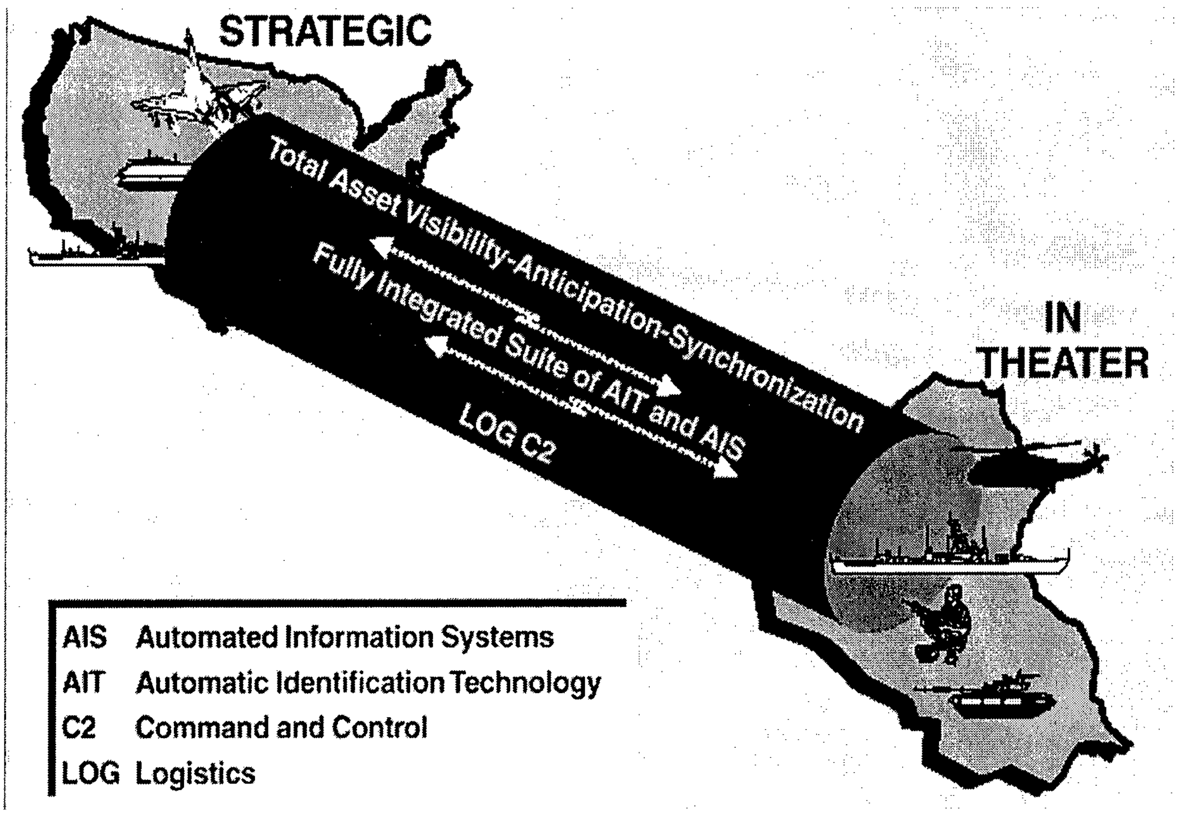


Figure 6. The Distribution Pipeline (JCS (b), 2000: I-2)

The strategic segment entails the acquisition, storage, allocation, and distribution of items, as well as their movement and shipping status until they reach the theater commander's area of responsibility (AOR). The theater portion consists of the movement of materiel from the point of entry into the AOR until arrival at the unit that requested the item (JCS (b), 2000: I-2). Both parts are connected by automated information systems to maintain total asset visibility (TAV) and sharing of vital data used in ordering, preparing, and tracking assets throughout the pipeline.

Further, the JCS divided this pipeline into three distinct distribution segments, based on the agency or unit of responsibility: Defense Logistics Agency (DLA), Defense Transportation System (DTS), and Theater (JCS (b), 2000: IV-2). (See Figure 7 on the next page) In the first segment, the DLA acquires materiel from suppliers, stores assets until needed, and prepares them for shipment by the DTS. The DLA segment does not include assets acquired by each Service. In such cases, the Service depots replace DLA to acquire and provide items to the DTS for movement. The DTS is responsible for moving units and materiel from the origin (or source) to the Port of Embarkation (POE), normally the point through which materiel exits the U.S., and on to the Port of Debarkation (POD), normally the point of entry into a foreign country. United States Transportation Command (USTRANSCOM) is the agency charged with moving materiel through the DTS. Lastly, the theater Commander-in-Chief (CINC), through his logistics staff, is tasked with managing the movement of items from the POD to the final destination.

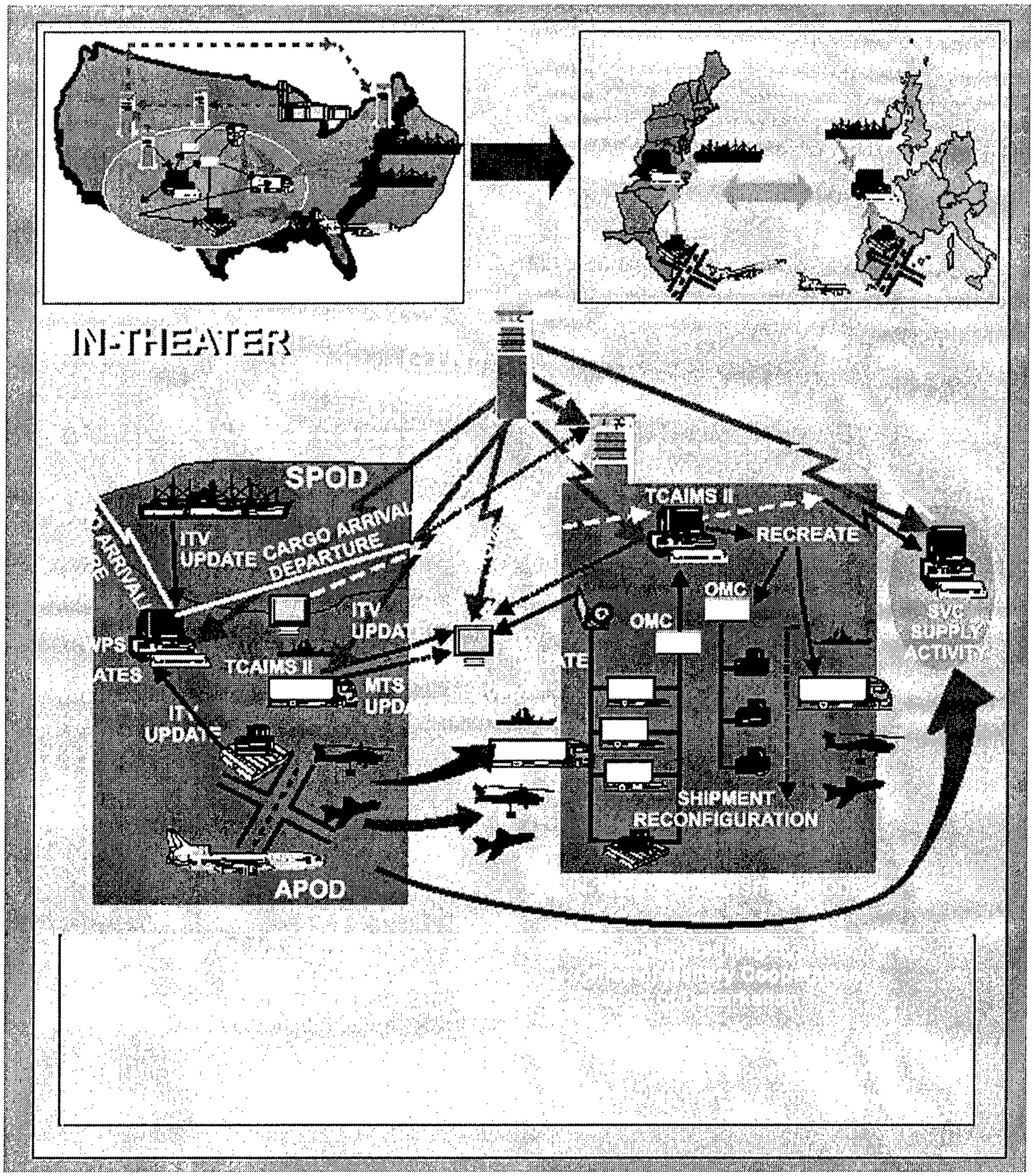


Figure 7. Distribution Pipeline Segments (JCS (b), 2000: IV-5)

This representation of the logistics pipeline is the most suitable for this research effort, for it captures the most important steps of the distribution process as it relates to the movement of assets to the intended user. However, it does not depict the information system link between the requesting activity (user) and the source of supply (depot). It is this essential step, which transfers critical information—item descriptions, priorities, shipping addresses, required delivery dates, and others—to the agencies responsible for providing the item that initiates the entire logistics pipeline. Without a materiel need, there is no reason for a logistics pipeline. Therefore, the transmission of a requisition from the ordering activity to the source of supply was added to the distribution pipeline suggested by the JCS for this research effort, in order to provide a complete picture of the logistics pipeline. (See Figure 8 below)

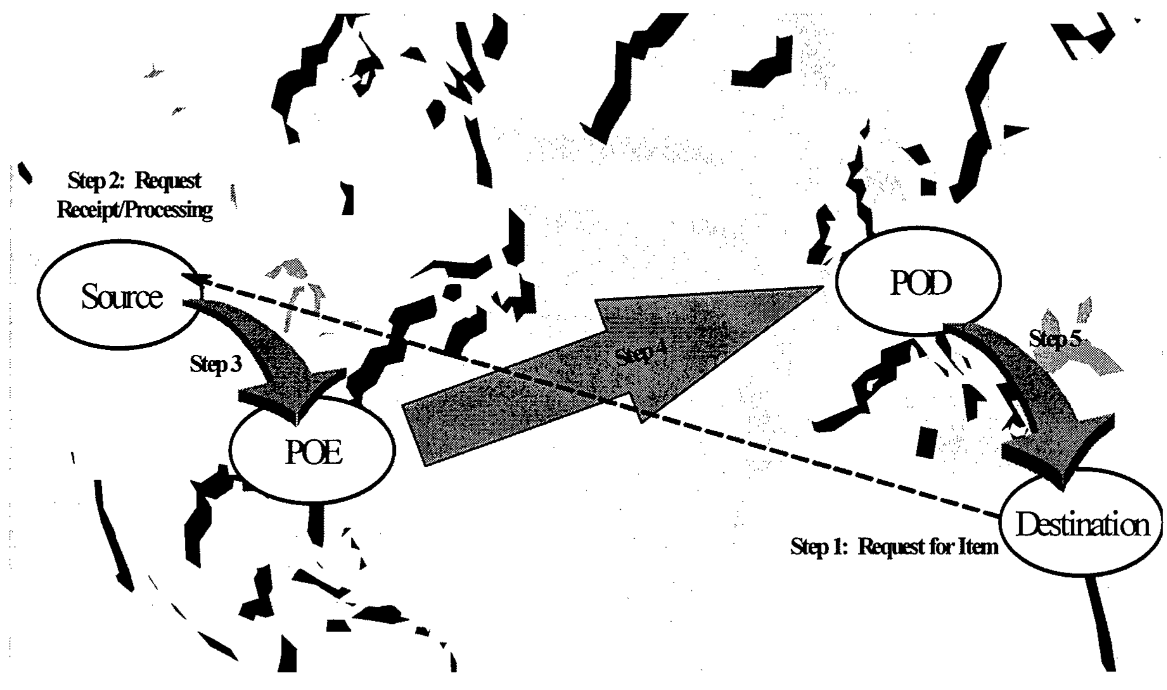


Figure 8. The Logistics Pipeline

In Figure 8, the dotted line represents the transmission of the requisition from the user to the source of supply (Step 1). Although the dotted line is unbroken, representing an essentially linear event, the reader should understand that there are intermediate collection and transfer points for the requisition data. Subsequent events include the receipt of the requisition and all actions necessary to acquire the part and place it in the DTS (Step 2), collection at the source of supply and movement to the POE (Step 3), shipment from the POE to the POD (Step 4), and transshipment from the POD to the final destination (Step 5). Of note, Steps 2 through 5 involve both the movement of materiel and the transfer of data to maintain ITV.

Logistics Response Time

In order to analyze the logistics pipeline, there must exist a useful way in which to measure it. The process of transforming a need into an asset in hand has been assessed in numerous ways in the recent past. The following is a discussion of the two most recent measurements that have been used by the U.S. Air Force: Order & Shipping Time (O&ST) and Logistics Response Time (LRT).

According to Air Force Manual 23-110, The USAF Supply Manual, O&ST is defined as "the time interval in days between the initiation of stock replenishment action by a specific activity and the receipt by the base of the materiel resulting from such action" (SSG, 2000: 3-131). Unfortunately, this is a single value that represents a very complex process consisting of various differing steps as shown in Figure 6. It is an aggregate value, so it has distinct advantages and disadvantages. It is a useful metric in that it is simple to use in forecasting computations. However, it can prove to be a difficult measure to use when attempting to pinpoint a specific area for improvement.

A step forward from this measure is the use of LRT, which is the elapsed time from the submission of an order (requisition) by a customer until the asset ordered is received. It consists of the following components:

1. Requisition Submission Time
2. Defense Automated Addressing System (DAAS) Processing Time
3. Inventory Control Point (ICP) Processing Time
4. Distribution Depot Processing Time
5. In-Transit to Container Consolidation Control Point Time
6. Container Consolidation Processing Time
7. In-Transit to Port of Embarkation Time
8. Port of Embarkation Processing Time
9. In-Transit to Theater Time
10. Port of Debarkation Processing Time
11. In-Transit, In-Theater Time
12. Receipt Take-Up Time (DLA, 2000: A-2, 3)

The Air Force Materiel Command (AFMC), charged with overseeing the Air Force's logistics systems, consolidated many of these time categories into four groupings: Base Requisition, ICP Process, DLA Process, and Transit Time. The differences between the two measurements can be seen in Table 1:

Table 1. AFMC LRT versus DoD LRT (AFMC/LGI, 2000: 1)

<table>
<tr><th colspan="2">AFMC SEGMENTS</th><th colspan="2">DoD LMARS COMMITTEE SEGMENTS</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Base Requisition</td><td>1</td><td>Requisition Submission Time</td></tr>
<tr><td>2</td><td>DAAS Processing Time</td></tr>
<tr><td>2</td><td>ICP Process</td><td>3</td><td>Initial Source Processing Time</td></tr>
<tr><td>3</td><td>DLA Process</td><td>4</td><td>Depot Processing Time</td></tr>
<tr><td rowspan="8">4</td><td rowspan="8">Transit Time</td><td>5</td><td>Depot to Containerization Point Transportation Time</td></tr>
<tr><td>6</td><td>Containerization Point Processing Time</td></tr>
<tr><td>7</td><td>CONUS In Transit Time</td></tr>
<tr><td>8</td><td>Port of Embarkation Processing Time</td></tr>
<tr><td>9</td><td>In Transit to Theater Time</td></tr>
<tr><td>10</td><td>Port of Debarkation Processing Time</td></tr>
<tr><td>11</td><td>In Transit In Theater Time</td></tr>
<tr><td>12</td><td>Receipt Take-Up Time</td></tr>
</table>

In effect, both measurements capture the same data and represent values that can be analyzed for the same purpose.

Finally, it is important to understand how the AFMC LRT metric ties into the logistics pipeline model. Each segment can be aligned with a step in the pipeline, as shown in Figure 9 below. The Base Requisition time reflects Step 1, the time required to transmit an order from the requestor to the source of supply. Both the ICP (order receipt) and DLA (acquisition or order picking) processes occur at the depot, in Step 2. The Transit Time reflects the rest of the logistics pipeline, from the time the depot inputs an item into the transportation system until the item is received by the user and status is updated to reflect the asset arrived.

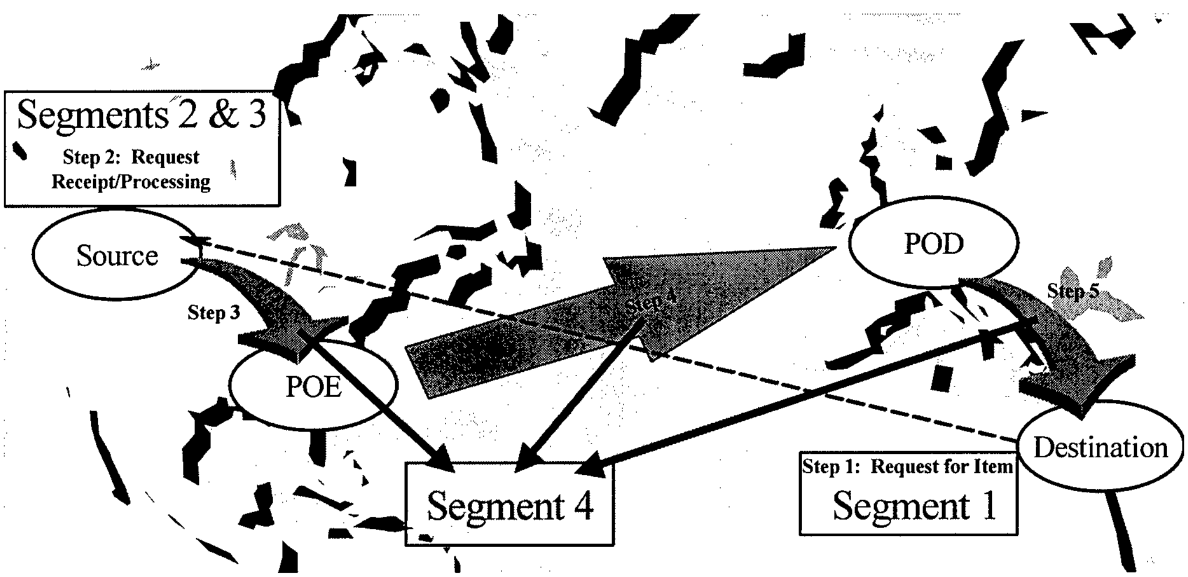


Figure 9. Relationship of AFMC LRT Segments to the Logistics Pipeline

Tradeoff Framework

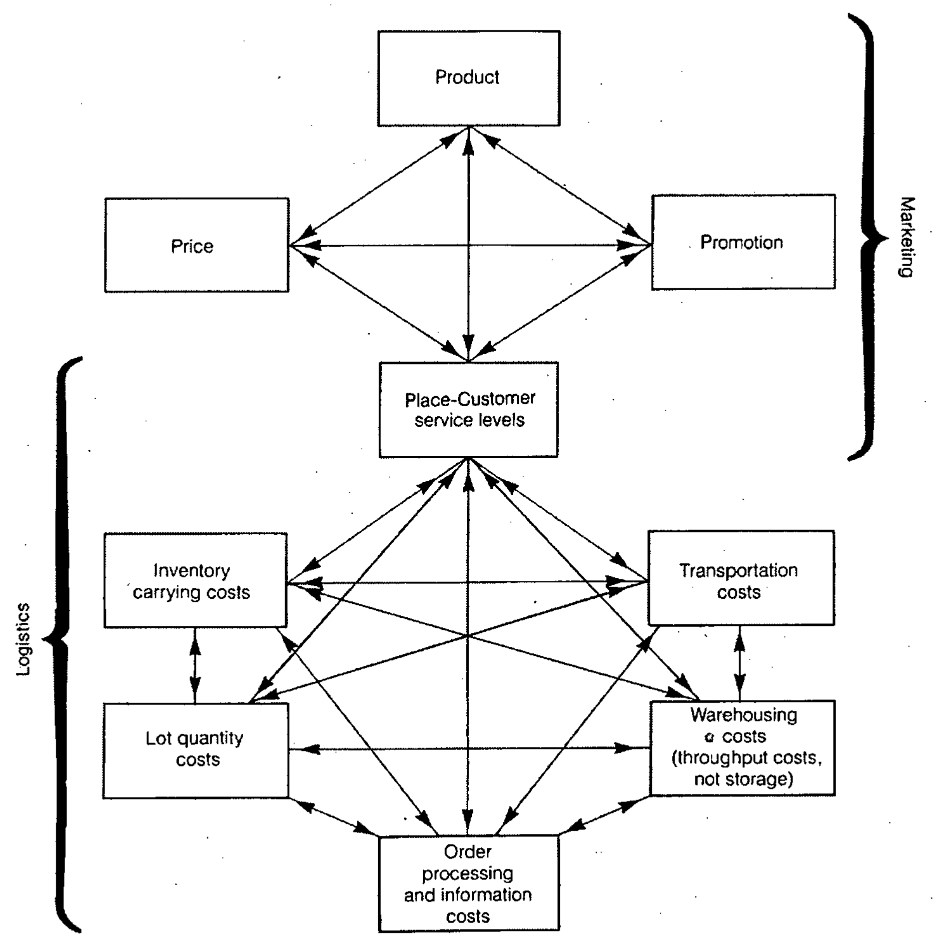
As with any decision, the resultant costs must be compared to the expected benefits to determine the suitability of the change. When a company chooses to implement JIT techniques for its inventory and distribution activities, there are a number of operational elements that can be affected. Langford offered the following factors to consider:

- Order placement or setup costs
  - Generated at a distribution center and plant purchasing activity
- Inventory investment
  - Purchase price or manufacturing cost, plus transportation cost
- Warehousing costs
  - Storage (facility), property tax, and insurance costs
- Inventory risk
  - Costs of spoilage, damage, obsolescence, and pilferage
- Stock-out costs
  - "Hard": Duplicate ordering, extra communications, and premium transportation costs
  - "Soft": Lost selling time, lost goodwill, and lost sales

(Langford, 1995: 390)

With increased use of electronic communications, the cost of placing an order in the DoD's supply system is probably negligible when compared to the overall cost of the logistics system. This is because the cost of electronically transmitting requisition information can often be 10 times cheaper than using paper methods (Liu & Zhang, 1997: 3). In fact, studies indicated that the increased use of automation and electronic data interchanges (EDI), and corresponding decreases in manual processes, in business transactions will continue to decrease the cost of ordering (Turbyfill, 1999: 4, 8). Assets that support a flying unit in a deployment, such as aircraft spares, engines, and avionics components, are not typically subject to inventory risk as described by Langford. These items do not spoil, and have a small chance of being damaged, stolen, or becoming obsolete while in the Mobility Readiness Spares Packages (MRSPs). Lastly, the cost of a stock-out when dealing with items that directly support AEF aircraft operations normally result in the incapability to perform a combat sortie. It is very difficult to apply a specific cost factor to the inability to perform a specific combat mission, for the range of detriment probably extends from lost training time to loss of life. For these reasons, the most important factors to consider for this research effort are the impact of changes on inventory investment and warehousing costs. Assuming there is a net reduction in total costs, the effect of implementing JIT on warehousing costs seems rather intuitive. If JIT allows a firm to reduce the amount of inventory kept on hand, then it follows that less warehousing space and infrastructure is necessary, equating to lower warehousing costs. Therefore, the remaining consideration, the inventory investment, became the prime consideration.

While there are numerous considerations to make when incurring costs in a business enterprise, there must exist a method by which these costs are categorized and compared. Stock and Lambert (1987) provided an illustration of what they thought to be the relevant costs that must be weighed in a logistics system, shown in Figure 10. Stock and Lambert stated that an analysis using this framework should include "...only those costs that will change with the system change." (Stock & Lambert, 1987: 529). With the objective of supporting a given level of customer service, the effect of implementing JIT in the case of formulating MRSPs will not directly impact lot quantity sizes (most reparable aircraft spares are ordered one at a time) or warehousing costs (change is subsequent to change in inventory levels). Since the order processing and information costs are very small, the only remaining factors to consider are the inventory carrying and transportation costs.



Marketing objective: Allocate resources to the marketing mix in such a manner as to maximize the long-run profitability of the firm.

Logistics objective: Minimize total costs given the customer service objective.

Where total costs equal: Transportation costs + warehousing costs + order processing and information costs + lot quantity costs + inventory carrying costs.

SOURCE: Adapted from Douglas M. Lambert, *The Development of an Inventory Costing Methodology: A Study of the Cost Associated with Holding Inventory* (Chicago, Illinois: National Council of Physical Distribution Management, 1976), p. 7.

Figure 10. Cost Trade-Offs Required in a Logistics System (Stock & Lambert, 1987: 530)

A classic methodology used in the study of logistics to decide on the implementation of JIT is to compare costs using the inventory-transportation tradeoff (Bowersox & Closs, 1996: 509-512). (See Figure 11 below)

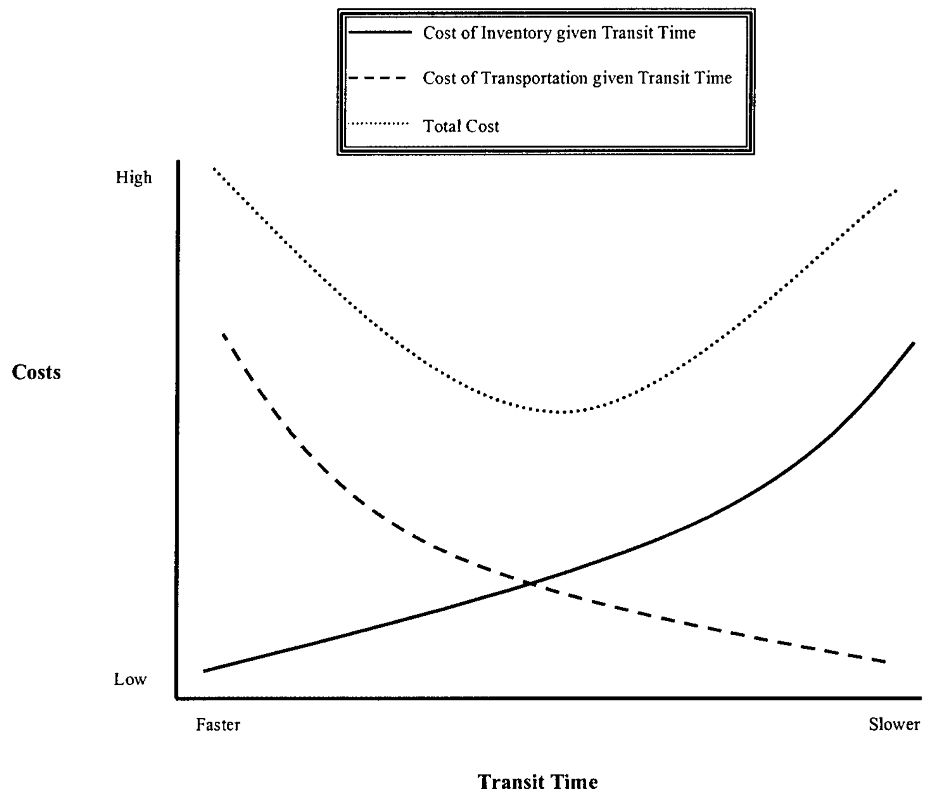


Figure 11. Inventory-Transportation Tradeoff (Adapted from Taylor, 1998: 4)

In this type of analysis, it is given that a firm desires to decrease total operating costs, and is weighing decreases in on-hand inventory costs (e.g., purchasing, warehousing, and personnel) from carrying less material against increases from using premium transportation to move items quickly and consistently through the logistics network.

It is important to stress here that it is much more important to reduce the variability of the transportation than it is to speed it up. A process that is reliable and consistent allows for more effective planning and forecasting of demands. A key tenet to JIT is the reduction of safety stock at all levels of the supply chain, due to the decrease in shipment variability. In this research, an MRSP can be thought of as safety stock that is moved forward in the supply chain to buffer the initial resupply delay. A slow transportation system that is unvarying will only encounter delay for the first delivery, and all subsequent deliveries will occur as anticipated. If a very quick transportation is inconsistent, the logistics system will still rely on inaccurate forecasts and have to react inefficiently to satisfy requirements.

This practice is in line with the JIT philosophy, since items are purchased and delivered immediately prior to the need for a particular unit. In performing such an analysis, the decrease in inventory cost and the increase in transportation cost (more frequent deliveries, higher cost per delivery) are calculated. Given that the same or higher level of customer service is achieved, if the decrease in inventory cost is greater than the increase in transportation cost, the change should be implemented. In such a case, the substitution of express transportation for on-hand inventory makes sense since it reduces the total cost to the firm, and given all else remains the same, increases profit. "...the identification of the least-total-cost system design is the goal of logistics integration." (Bowersox & Closs, 1996: 509).

The inventory-transportation tradeoff is just one area that could be analyzed in order to reduce the order cycle time, which is the total amount of time from when an order is placed until the item is received by the requestor. In effect, the LRT represents order cycle time, and is used as such in this research. The focus of this research is much larger than just the inventory-transportation tradeoff. In fact, it is directed at determining, based on the reduction in LRT, the corresponding reduction in inventory carrying cost for parts in MRSPs.

Parts Requirements Models

Several models that incrementally produce better results mark the evolution of Air Force spares calculations. Since the 1960s, the Air Force and partners such as the Rand Corporation (RAND) and the Logistics Management Institute (LMI) have developed the mathematical tools to determine the right amount of aircraft spares to purchase, store, and deploy. It is appropriate at this point to discuss the enhancements provided by the two most current models in use, the Dyna-METRIC and the Aircraft Sustainability Model (ASM).

RAND developed the Dyna-METRIC (Dynamic, Multi-Echelon Technique for Recoverable Item Control) model in the late 1980s to better reflect the realities of Air Force combat operations. Prior to this model, other methods only calculated the spares requirements and resultant effects on the ability to generate combat sorties on the last day of the hypothetical contingency (normally Day 30) (Arostegui, 2000: 12). The objective was to determine a spares mix that would minimize the expected number of backorders, or parts shortages, at the end of the support period. The main improvement attained by the Dyna-METRIC model was the ability to represent changes in key parameters, such as number of sorties flown and sortie duration, throughout the period under consideration

(Arostegui, 2000: 12). Through experience, it was noted that many combat scenarios involved surge operations near the beginning of the contingency. Therefore, there was a high level of sorties that occurred at the outset, and a lower number in the later periods. Due to this uneven distribution of sorties, the spares requirement was much higher just after the deployment of a combat unit to the AOR. In addition, expanded maintenance capabilities in the AOR and the establishment of resupply channels allowed failed components to be replaced after the first portion of a deployment. Neither of these characteristics was represented in the static models prior to Dyna-METRIC (Arostegui, 2000: 12). With the use of Dyna-METRIC, the Air Force was able to more accurately assess its parts requirements through a model that was more representative of an actual combat operation.

LMI built upon the work done by RAND and developed a marginal analysis methodology known as ASM. This advancement

> computes optimal spares mixes to support a wide range of possible operating scenarios. In contrast to the typical practice, the ASM sizes the spares inventory based explicitly on desired weapon system readiness levels, such as aircraft availability—the percentage of the fleet ready to fly a mission—rather than supply-oriented measures, such as stock on the shelf or percentage of demands filled. (Slay, 1996: iii, iv)

This model can be used in two ways: 1) for a given funding level, it will calculate the spares mix that will maximize aircraft availability (AA), or 2) for a given AA goal, it will calculate a least cost spares mix to attain the goal. (Slay, 1996 iv) Because of its robust capabilities, ASM was incorporated into the Air Force's Requirements Execution Availability Logistics Module (REALM) system in the 1990s to calculate spares requirements for MRSPs worldwide (Arostegui, 2000: 12).

Capability to Quickly Establish the Logistics Pipeline

As mentioned previously in Chapter I, the goal of the U.S. Air Force under the Expeditionary Aerospace Force (EAF) concept is to have base support in place at a deployed location within 48 hours after the order is given to deploy. Therefore, the desired capability under EAF is to have the personnel and equipment needed to employ a logistics pipeline at the Forward Operating Location (FOL) in 2 days.

In the recent past, there have been numerous deployments involving Air Force personnel and equipment to all parts of the world. One documented case that highlighted the possible challenges to creating a logistics pipeline involved the deployment of F-117 fighter aircraft from Holloman Air Force Base, New Mexico, to Ahmed Al Jaber Air Base, Kuwait. Although thorough planning was conducted prior to the deployment to ensure effective procedures were being utilized, "[i]t took base communication personnel almost a week to get the MRSP personnel online with the AFCSS [Air Force Contingency Supply Squadron] in the hangar." (Allen, 1999: 36) The Squadron Maintenance Officer at Al Jaber noted, "Fortunately, a Standard Base Supply System (SBSS) terminal was available in the A/OA-10 hangar across the flight line to order parts until we were connected with the base LAN [Local Area Network]." (Allen, 1999: 36) Without the ability to communicate to vital process nodes such as the Air Force Contingency Supply Squadron, who typically coordinates orders from and shipments to deployed locations, it is very difficult to commence an effective resupply effort.

This observation pointed out just one of the many factors that can impact the establishment of a logistics pipeline. Other functions such as security, aerial port (handling incoming and outgoing materiel), and civil engineering, plus many others, must be present to ensure supply personnel can perform their duties.

Previous Works in this Subject Area

While the idea of improving transportation capability to allow for a reduction in inventory is not a new idea, there seems to be very little research that exists for applying this concept to military operations. In the course of this literature review, three relevant efforts were uncovered. The first is a master's thesis from a student at Virginia Tech, the second a research project published by the RAND, and the third a research project by the Air Force Materiel Command.

In his graduate thesis titled "Economic Tradeoffs of Substituting Transportation for Inventory in the Department of Defense: A Case Study of Pipeline Reduction," H. Don Taylor provided a measure of the cost tradeoff between inventory and transportation for supporting various parts that the U.S. Army uses. He also conducted a sensitivity analysis to see which variables affected the levels of inventory the most. The data used was collected over 9 months and represent over 200 locations of stock across the United States. (Taylor, 1998: 1) By using a conservative average of 3 days assumed to be attained by using express air carriers (FedEx, UPS, etc.), the study resulted in a reduction of costs from $18,635,391 to $8,498,425, a savings of $10,136,966, for the 10 items that produced the greatest cost reductions. (Taylor, 1998: 33)

This work presented valuable cost models for calculating the total cost of holding inventory and transportation, as well as a benefit-to-cost ratio to measure the impact of reductions in inventory against the increase in transportation costs. However, this study was conducted using stateside, non-combat unit data in a static environment. In fact, Taylor notes in his introduction that the data used in his thesis "...represent investments for routine training purposes, as contrasted to 'go to war inventory'" (Taylor, 1998: 1). Therefore, it does not completely depict the results that can be expected from an analysis of parts purchased to support units in dynamic combat situations.

The Rand Corporation conducted a study of the support structure for the C-5 airlifter and analyzed the impact of improving various aspects of the logistics process. In his report, "Lean Logistics: High-Velocity Logistics and the C-5 Galaxy," Timothy L. Ramey modeled the current logistics pipeline that supports Air Mobility Command's (AMC) C-5 aircraft world wide. In addition, he used the same model to approximate the results of enhancing such components as depot repair and parts distribution times. Ramey modeled a "high-velocity" logistics process by decreasing shipping times to 1 to 2 days versus 17 days, and reducing depot flow times from 54 days to 7 days. Using the Dyna-METRIC version 6 (simulation) for calculations, he determined that using this high-velocity system would result in a reduction of by as much as $32 million per year under the support process that existed at the time of the study. (Ramey, 1999: xiii)

This research identified the significant amount of inventory investment that could be avoided, and probably better spent elsewhere, as a result of improvements in the Air Force's logistics pipeline. The results are specific to the C-5 aircraft and its specialized role as the largest cargo aircraft in the U.S. Air Force inventory. The missions it performs and the unique en-route support structure operated by AMC to ensure downrange parts availability make the analyses done in this study too narrow to extend to other weapon systems. Also, the support concept required to operate a C-5 varies significantly from that which would be needed to sustain a combat oriented AEF deployment. Ramey stated in the study that "[g]eneralizing specific results of this study to other weapon systems may be problematic." (Ramey, 1999: xiv)

A research effort that was similar to the analysis accomplished in this thesis was the "White Paper on Examining the Readiness Spares Package for the AEF" accomplished by Mike Niklas of the Air Force Materiel Command's Studies and Analysis Office (AFMC/SAO). This study asserted that the previous assumption of no resupply of combat forces within the first 30 days of conflict was no longer applicable with the implementation of the AEF concept. (Niklas, 2000: 1) Therefore, an MRSP no longer needs to be calculated for 30 days' worth of support. The author first determined what a reasonable range of LRTs was for this analysis (based on results from Operations NORTHERN/SOUTHERN WATCH and ALLIED FORCE). Next, he calculated MRSP sizes based on the number of parts required to support various aircraft packages (6-, 12-, 18-, and 24-ship) assuming parts were shipped within the range of LRTs determined previously (specifically, 10, 14, 20, and 30 days). After analyzing various sized packages of F-16s, F-15s, KC-135s, and B-52s, the results of this study were mixed. While reducing the size of MRSPs did reduce the number of spares required to support aircraft while maintaining similar levels of mission performance, some kits actually remained the same no matter how many days it takes for an asset to arrive at the deployed location. (Niklas, 2000: 8)

This project was a very helpful tool in conducting the research for this thesis. The assumptions and methodology used are still valid, and were used in this effort as well. However, the range of the LRTs in AFMC's White Paper was limited to that which was currently attainable based on recent experience. It did not provide insight as to what will be possible in the near future, as the DoD continues to expand its use of commercial express carriers and improves the performance of organic transportation systems. A more "forward-looking approach" can better highlight the potential benefits of improvements to the logistics pipeline today that will be enjoyed several years in the future.

The last work that addressed this area of research was a study conducted by the Dynamics Research Corporation (DRC) (1999) for the Director of Supply, Headquarters United States Air Force. In this report, DRC attempted to determine if it was advantageous to collocate inventories of spare parts at a commercial express transportation hub. To do so, DRC analyzed readiness spares package costs when the order and ship time was reduced to 3 days, representing an estimate of the delivery times achieved through the use of an express carrier. However, they did not explore a range of order and ship times, just one value. So, while the results indicated that a benefit could be obtained by collocating spares at express carrier hubs, the study neglected the possibility that there may be significant savings from improving the current logistics pipeline. It did not address whether streamlining organic airlift processes would yield substantial reductions in spares costs or airlift requirement, perhaps at a much lower cost to the Air Force. As such, the scope was too narrow to facilitate an array of improvement options. Thus, research with a broader scope was needed.

Summary

This literature review presented information that explains the background of the analysis that was conducted in this research effort. First, it illustrated why it is important to the U.S. Air Force to implement JIT improvements that will allow it to decrease its inventory holding costs. Then, the term "logistics pipeline" was defined and illustrated in order to understand the object of the analysis conducted herein. A defined and useful metric known as Logistics Response Time was introduced and outlined. Methods by which cost-benefit analyses could be accomplished were discussed, for they underlie the focus of the analysis. The most current models in use today were outlined and the relevance of these to the thesis was explained. Finally, other works that provided similar reviews and results to this effort were described to identify the shift in analysis that this research provides to the subject area.

III. Methodology

Introduction

It is important at this time to discuss the framework of the analysis conducted in this research effort. By doing so, the methods used in this study and their relevance can be understood, setting the stage for the presentation of the results. First, the sources of data used and the methods of retrieval employed will be introduced. After that, a description of the Aircraft Sustainability Model (ASM), its characteristics, and its capabilities is offered. Then, the design of the experiment used in this study is described. In addition, the elements used to organize the analytical results, derived from the outputs of ASM and statistical procedures, are described. Specifically, an explanation of the regression analysis used is provided. Lastly, the use of the Forward Support Location (FSL) Option of the ASM is illustrated.

Data Retrieval

The information utilized in this research consisted mainly of values for Logistics Response Time (LRT). As described previously, the LRT is the time period between the input of an order and the receipt of that order by the requester. These data reside on the Headquarters Air Force Materiel Command's (AFMC) Logistics Support Office, Cargo Movement Division web site (AFMC/LSO, 2000). Within this site, a link to the LRT data is provided. The LRTs are categorized by fiscal year and month, and reside in separate database files.

The population of interest is LRTs for all requisitions in support of Air Force operations. It is not difficult to understand the enormity of gathering data from this population, with thousands of aircraft each comprised of thousands of parts. Therefore, this study concentrates on data taken from a sample. Because the intent of this thesis is to analyze the wartime effect of changes in practice, it was important to use data from the most current Air Force combat operation. Thus, LRTs from Operation NOBLE ANVIL (ONA), the U.S. Air Force's combat missions in support of Operation ALLIED FORCE (OAF), were collected. This more narrow scope still presented a formidable amount of data with which to do an analysis, for there were several weapons systems that participated in ONA. Therefore, the sample was limited even further to include only requisitions with a Required Delivery Date (RDD) code of "999" or "777." These requisitions represent the items that received the highest priority for action throughout the logistics pipeline. As such, using shipments with RDD 999 and 777 correspond to the logistics pipeline operating at its highest level of performance. The last filter applied to this data was limiting the analysis to parts ordered and shipped to locations in the European theater. In order to do this, a list of Stock Record Account Numbers (SRAN), each one unique to the supply account against which a part was ordered, that operated in Europe during ONA was obtained from the Supply Division at Headquarters, United States Air Forces in Europe. (See Appendix A) This allowed for the exclusion of requisitions that may have been placed in support of ONA, but did not go to a unit physically in the European theater at that time. Otherwise, the values for LRT could have been underestimated through the analysis of shipments destined to locations within the United States.

The relevant time period to observe parts movement in support of ONA had to be determined. The Chairman of the Joint Chiefs of Staff authorized the use of a requisition Project Code of 9FS to expedite actions for items in support of ONA. Since the databases contained data on all requisitions to AFMC, those requests with Project Code 9FS were extracted. While the official commencement of OAF, and concurrent strike operations of ONA, occurred on 24 March 1999 (DoD, 2000: A-7), the movement of supplies in preparation for the initial missions more than likely began prior to this date. Therefore, LRT data for the months prior to March 1999 were reviewed for Project Code 9FS. In fact, there were requisitions using 9FS in the first month of available data, October 1998. There were data related to support of this contingency from that point until OAF officially terminated on 20 June 1999 (DoD, 2000: A-11).

Once all of the pertinent LRT data was collected, an analysis was conducted to determine what random distribution would most closely model the range of actual values. This allowed for a subsequent examination of the data to ascertain the central tendency of the values as well as any relationships or associations that would influence them (See Appendix A).

Aircraft Sustainability Model (ASM)

As stated earlier, the ASM is used by the U.S. Air Force to calculate the number of spares required to be maintained in an MRSP. The logic of the program ensures that the spares mix producing the highest aircraft availability given a level of funds is created

(Slay, 1996: 1-1). The model requires data elements provided by either the Dyna-Metric Microcomputer Analysis System (DMAS) or the D087 report from Headquarters, AFMC, known also as the Requirements Execution Availability Logistics Module (REALM). The REALM contains information pertaining to items such as demands (failures) per flying hour, base and depot repair times, probability of repair at a given location, condemnation rates, shipping times, unit cost, quantity per application (QPA), and procurement lead time (Slay, 1996: 1-2).

Once this data is imported into the model, the program initiates a three-step process as described below:

- The first step involves characterizing the probability distribution of the number of items in various stages of the resupply process (or "pipeline")—unserviceables in repair at bases or depot and serviceables/unserviceables in transit. The relationship between these quantities and the number and location of spares in the system determines the probability of a backorder.
- The second step is to relate that item information to weapon-system performance; specifically, to determine the expected number of item backorders, the expected number of aircraft NMCS [Not Mission Capable Supply], and several other weapon-system-oriented measures of supply performance.
- The third step is to produce the availability-versus-cost curve and the associated optimal spares mix for a specified availability or budget target. The model uses a marginal analysis technique that determines the best mixes of spares for a wide range of targets. (Slay, 1996: 1-3)

This technique is illustrated in Figure 12 on the next page. In the first step, the user inputs information based on either a steady-state (peacetime) or dynamic (wartime) flying hour scenario into the model. Since this research analyzed support of combat operations, dynamic flying hour data was used. The second step actually calculates an expected aircraft availability based on the cannibalization option chosen in Step 1. Then, the third step allots an optimal spares mix through marginal analysis, recommending the purchase of items that have the highest benefit-to-cost ratio first.

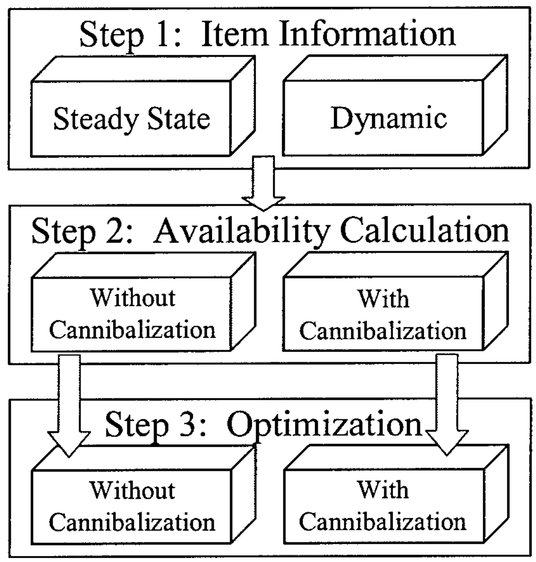


Figure 12. Basic Model Methodology (Slay, 1996: 1-4)

It creates a "shopping list" of spares, and "purchases" each one in order until either all of the spares are allocated or the specified funding level for spares is exhausted (Slay, 1996: 1-4). Because of the importance of generating every sortie in wartime operations, cannibalization, or the removal of a working item from a non-functional aircraft to another aircraft, is a normal practice. Therefore, the full cannibalization option was used throughout this research.

To evaluate the effect of changes to the LRT on spares requirements, it was necessary to adjust the data within the kit files from D087 to reflect various average Order & Ship Times (O&ST). Although LRT is comprised of more than just O&ST, the only other repair time values in the kit file were "Base Repair Time" and "Depot Repair

Time." There was no point in considering "Base Repair Time" since it was assumed that no base repair would be available. This assumption is discussed later when the values for "Base Repair Time" of components is explained. Also, "Depot Repair Time" values include more data than does the LRT. Therefore, including this number in the analysis could have injected more error. So, the simplest and most accurate proxy for LRT was O&ST.

The adjustment of O&ST values was accomplished by exporting the kit data into an Excel spreadsheet, and modifying the values listed under the column labeled "iostw." (See Table 2 below) These numbers represented the expected wartime O&STs for each item in the kit.

Table 2. Sample Solver Calculations

NSN	0.784	0.568	0.352	0.136	0.000	0.000	% Reduction
1560007242853FL	13	19	26	30	30	30	
1560008601911FL	13	19	26	30	30	30	
1560008601912FL	13	19	26	30	30	30	
1560011273340FL	6	8	11	13	13	13	
1620010639477	13	19	26	30	30	30	
1630004927144	13	19	26	30	30	30	
///	///	///	///	///	///	///	
6620005573023	13	19	26	30	30	30	
6620005619380	7	11	15	17	17	17	
6620011404405	7	11	15	17	17	17	
6620011450265	13	19	26	30	17	17	
6620011519590	13	19	26	30	14	14	
6620012471816	13	19	26	30	30	30	
Average	4.806	9.982	14.783	20.083	23.138	23.138	
Goal	5	10	15	20	25	30	

Utilizing the Solver add-in, these values were adjusted to provide overall average O&STs of 5, 10, 15, and 20 days for the entire kit of each aircraft type. In Table 2, the row corresponding to the percent sign represents the percentage decrease applied to the original values that result in an average ("Average") that is equal to the target ("Goal") value. The spares packages for all four aircraft had average O&STs less than 25 days, so there was no need to create higher adjusted average values. These new item O&STs had to be rounded to the nearest integer, put back into the Excel spreadsheet, and input into ASM (See Appendix B).

In order to observe the effects essential for this analysis, it was necessary to adjust some of the parameters used by the ASM. From the "Parameters" screen, "2nd Analysis Day" was adjusted to correspond to the average O&ST for the kit being evaluated. By doing so, the ASM calculated a spares kit that met the aircraft availability goal at the end of the period of coverage that the kit would provide. For example, a kit with an average O&ST of 5 days would need only enough items to cover 5 days of operations. Therefore, setting the "2nd Analysis Day" to Day 5 forced the model to calculate the number of items needed to support Days 0 through 5 of the operation. The "1st Analysis Day" was set at Day 0 for runs that analyzed non-fighter aircraft kits (B-52 & KC-135), as well as fighter kits with an average O&ST of 5 days. For the rest of the kits, it was set at Day 5 to represent the point at which a planned surge ended and sustainment operations began. At this point, the Direct Sortie Objective (DSO), which was represented by the Aircraft Availability (AA) goal on the "Parameters" page, changed for F-15Es and F-16Cs (HQ USAF/XOP, 2000). Using different aircraft flying data for two concurrent periods allowed for the simulation of a surge during a deployment in which the first several days' flying is much more intense in frequency and duration than later days. Lastly, the DSO used for all analyses, except for those under a sustainment phase for F-15s and F-16s, was

83%. This value was input in the “Availability” fields of the “Parameters” screen (see Figure 13 below).

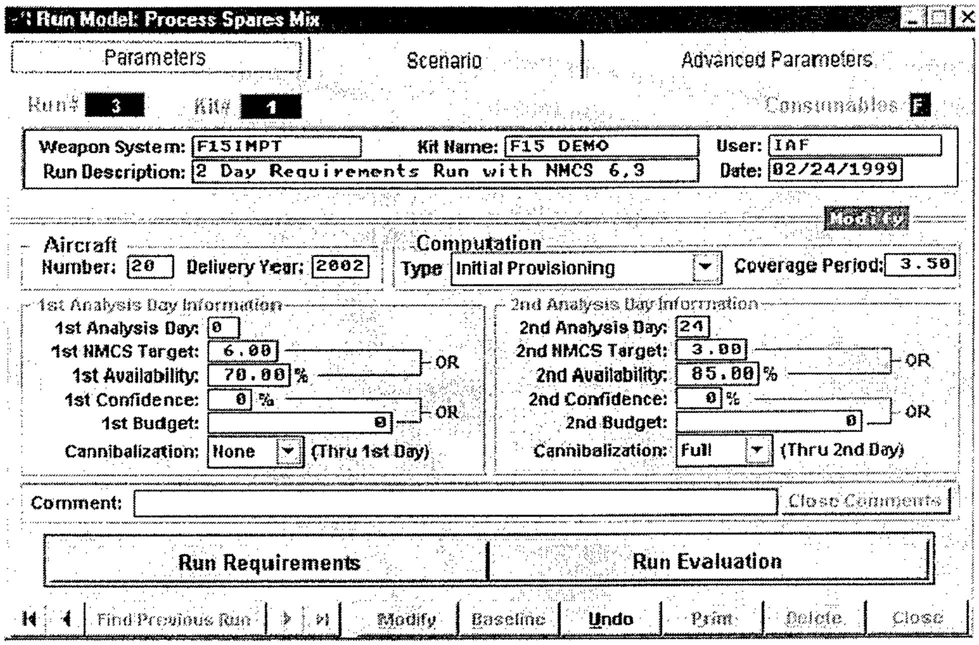


Figure 13. Model Parameters Screen with the Parameters Page Displayed (Kline, 1999: 2-5)

All of the flying hour data is found on the “Scenario” screen, shown on the next page in Figure 14. The Non-Wartime, Wartime, and daily Wartime Flying Hour data used were provided by the Studies & Analysis Office at Headquarters, AFMC, based on data residing in the Weapon System Management Information System database. These values were reasonable, and, therefore, were not changed.

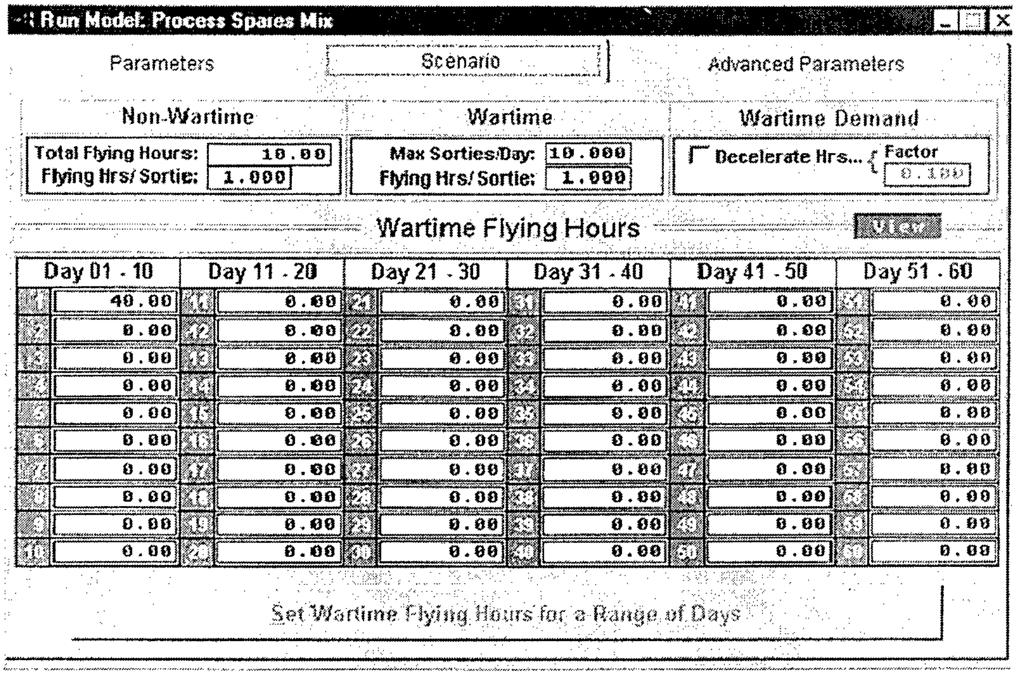


Figure 14. Scenario Page (Kline, 1999: 2-13)

Next, the "Advanced Parameters" page, shown in Figure 15 on the next page, contained three vital factors that had to be manipulated. Here, the values for "Day Base Repair Begins," "Day Depot Repair Begins," and "Day Order and Ship Begins" were adjusted. For the first two parameters, separate consideration was given to remove and replace (RR) and remove, repair, and replace (RRR) items. RR assets are those items that, when they fail, are taken off of the aircraft and replaced with a serviceable unit.

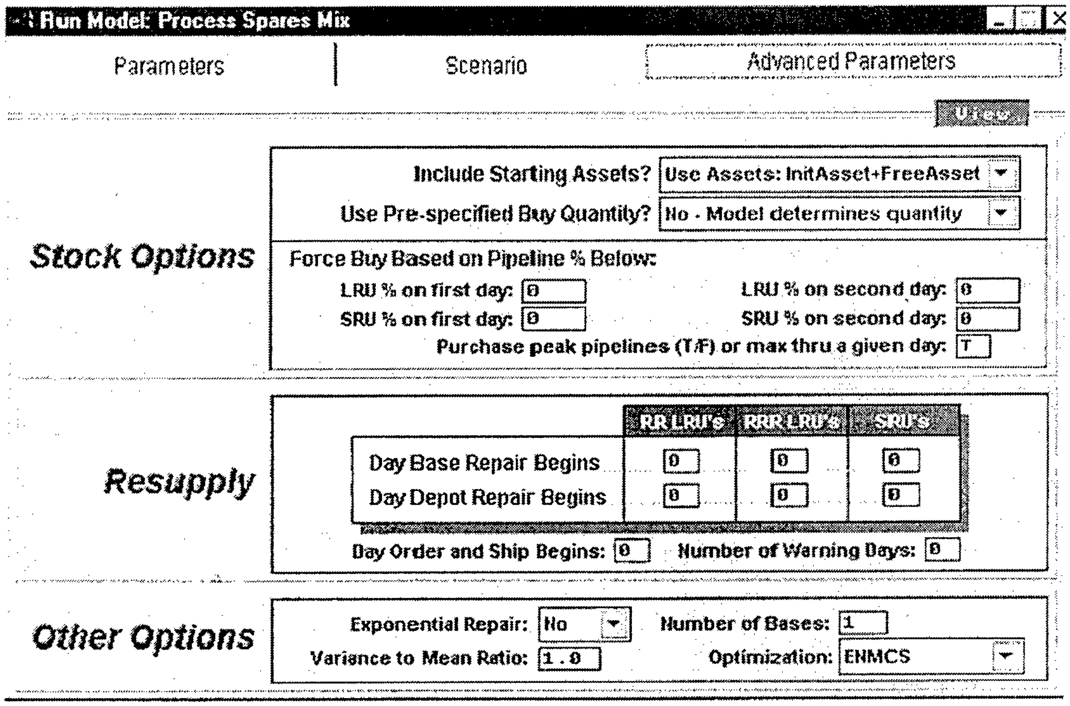


Figure 15. Advanced Parameters Page of the Parameters Screen (Kline, 1999: 3-2)

The failed unit is then shipped back to the repair facility to be fixed. In contrast, RRR items are taken off the aircraft when they fail, moved to a repair center at the same location, and then placed into the serviceable stock after they are fixed. Also, an LRU is a Line-Replaceable Unit, meaning that the item is a "black box" that is dealt with as a complete component. Thus, it can be placed in or removed from the weapon system on the line, or flight line. In contrast, a Shop-Replaceable Unit (SRU) is a subcomponent of an LRU that can only be repaired in a repair facility, or back shop.

For the purposes of this research, a worst-case assumption of no repair was made for base repair of assets. For RR and RRR LRUs, and SRUs at the base level, a value of 99 was placed in the appropriate box. This forces the program to not include any base repair of items, since the maximum number of days that was analyzed was 30. Although the goal under the Aerospace Expeditionary Forces (AEF) concept is to have support forces in place at the deployed location within 48 hours, a more conservative approach was used to allow for the possibility of delays and the possibility that repair capability is never deployed to the front line. This scenario could occur if the Air Force implements a regionalized repair and inventory concept for AEF support, and uses a strict 2-level maintenance philosophy for aircraft spares (Killingsworth, 2000: 24).

The value for "Day Depot Repair Begins" was set at 0 for RR and RRR LRUs as well as SRUs. Doing this allowed the ASM to assume that any item that arrived at the depot from the outset of the contingency could be repaired immediately. Although this would probably not be the case in reality, it allowed the research to focus on the impact of reducing the "Day Order & Ship Begins" (DO&SB) without being affected by slow depot repair times. For instance, there would be no benefit to reduce the DO&SB to Day 0 if the depot did not start repairs until Day 10 since there would be no serviceable asset to move.

The value for DO&SB was one of the dependent variables in the analysis. It represents "[t]he day that forward transportation from the depot starts." (Kline, 1999: 3-12) This value is a constraint that can be set to whatever day in the scenario that transportation, be it trucks or airplanes, will be available to ship assets from the depot to the requester. In the experiments, this number was set at Days 0, 7, and 15 to gauge the effect of starting the resupply pipeline more quickly. In essence, it represented the effect of the "pipeline on the fly" approach. For previous spares kit calculations, it was always assumed that there would be no resupply within 30 days.

Design of the Experiment

The analysis conducted for this research consisted of an experiment comprising two independent variables, "Day Order and Ship Begins" and "Logistics Response Time," and a dependent variable of either "Kit Cost" or "Kit Size." (See Figure 16 below)

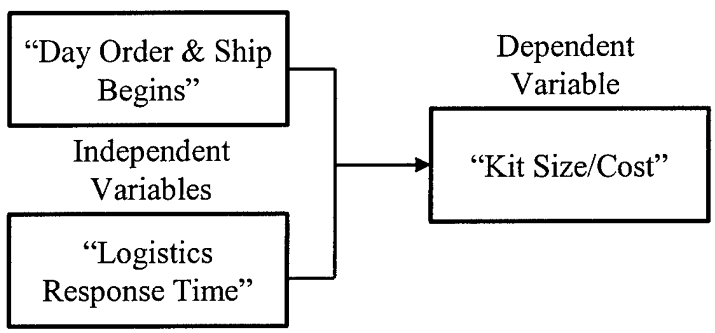


Figure 16. Experimental Design

As explained earlier, the adjusted O&ST values actually used in the analysis represented the variations in Logistics Response Time (LRT). Combinations of these values and those for "Day Order & Ship Begins" produced various responses in the dependent variable "Kit Size/Cost."

Output and Results

The values of the independent variable "Day Order & Ship Begins" were set at 0, 7, and 15, and values for "O&ST" were set at 5, 10, 15, and 20 days. ASM took these inputs and calculated a cost for an entire MRSP that attains the target aircraft availability rate. It also specified which items should be purchased and recommended quantities of those parts. These quantities were multiplied with a volume and weight per unit, obtained from The Packaging, Transportation, and Regulated Material report (D035T), to obtain the corresponding kit size.

Based on these calculations, a matrix was developed that allows the reader to compare the values of the independent variables—"Day Order & Ship Begins" and "Order & Ship Time"—to the dependent variable "Kit Size/Cost." Also, a response surface graph was created for each weapon system analyzed, which makes it easy to visually ascertain the relationships between the independent and dependent variables.

To further gain an understanding of the effects of each variable upon the kit sizes and costs, a regression analysis was conducted for each weapon system. By using the kit sizes and costs as the dependent variable "Y" and the O&ST and DO&SB as the independent variables "X_1" and "X_2," it was possible to determine which factor significantly influenced the output values for kit size and cost.

This was accomplished by using an Analysis of Variance (ANOVA) F-test. Testing the significance of a multiple regression model in this manner involves a test of hypotheses, using the F test statistic, and determining if the calculated value of the F statistic occurs within an established rejection region.

The process is summarized below:

Null and Alternate Hypotheses:

H_0: $\beta_1 = \beta_2 = \ldots = \beta_k = 0$ (All model terms are unimportant for predicting y)

H_a: At least one $\beta_i \neq 0$ (At least one model term is useful for predicting y)

Test Statistic:

$$F = \frac{(SS_{yy} - SSE) \div k}{SSE \div [n-(k+1)]} = \frac{R^2 \div k}{(1-R^2) \div [n-(k+1)]} = \frac{MeanSquare(Model)}{MeanSquare(Error)}$$

where n is the sample size and k is the number of terms in the model

Rejection Region:

$F > F_\alpha$, with k numerator degrees of freedom and [n – (k + 1)] denominator degrees of freedom

Assumptions:

1. For any given set of values $x_1, x_2, \ldots, x_k$, the random error $\in$ has a normal probability distribution with mean equal to 0 and variance equal to σ^2.
2. The random errors are independent.

(McClave, 1998: 505, 520)

With this procedure, if the calculated value of the F statistic is greater than the F statistic value for a given level of significance (α), the null hypothesis is rejected and one can conclude that at least one variable contributes to the prediction of the dependent variable, y. Once it is established that the model contains at least one significant variable, the individual F statistic values for each variable can be assessed to ascertain which specific independent variable contributes significantly to the prediction of y.

Forward Support Location (FSL) Option of the ASM

In order to evaluate the "pipeline on the fly" concept better, the Forward Support Location (FSL) Option of the ASM was employed.

> This option models a theater where multiple squadrons at various locations are supported by a single Consolidated Support (or Queen Bee) activity called a Forward Support Location (FSL). The model computes stock both at the aircraft locations (called Forward Operating Locations-FOLs) and at the FSL...This option properly aggregates the demand at the FSL and estimates the total spares requirements based upon the NSN's [National Stock Number's] commonality. (Kline, 1999)

The relationship modeled by the FSL Option is illustrated below in Figure 17.

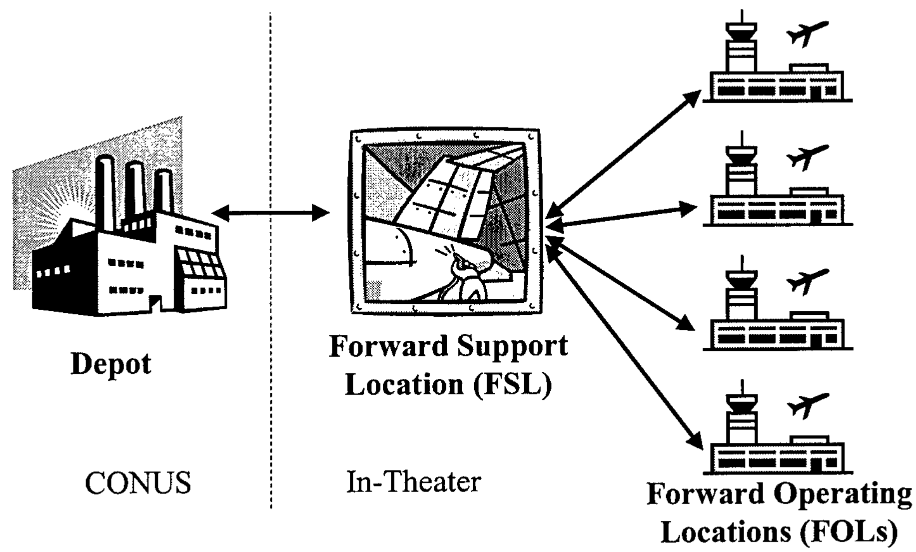


Figure 17. Forward Support Location (FSL) Option

In its basic form, the FSL Option allows the user to analyze the spare levels required when using a central inventory point that is in the same geographic area as the spare parts kits at the FOLs. The FSL, then, is an intermediate storage location between the end user and the depot.

The FSL Option requires input parameters that are different from the standard ASM settings (see Figure 18 below).

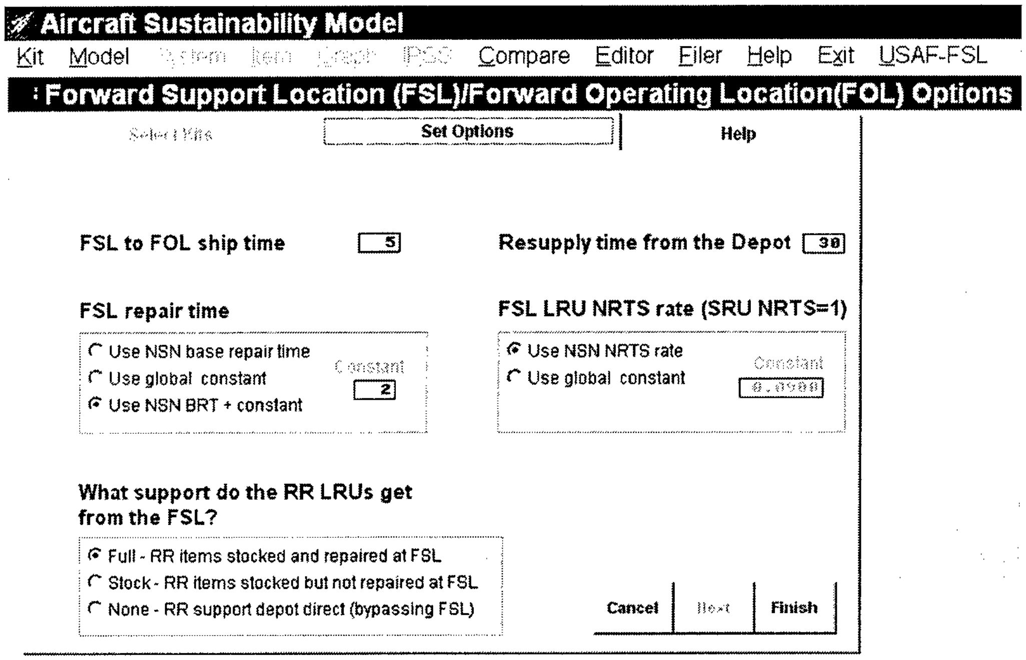


Figure 18. FSL Option Input Parameters

The "FSL to FOL ship time" is the O&ST between the FSL and the FOLs, while "Resupply time from the Depot" is the O&ST when the request must be satisfied from the depot. Both of these values are constant for all items, which is a departure from the ASM methodology. The "FSL Repair Time" represents the time period between an order for a part at the FSL placed by the FOL, until that part is ready to be shipped to the FOL. It includes the time needed to move the unserviceable asset from the FOL to the FSL (retrograde), as well as the repair time. Since typical values for base repair times (BRT) do not include the retrograde shipment time, the FSL Option allows the user to add a constant value to the BRT to represent this movement. The "FSL LRU NRTS rate" input corresponds to the probability that an LRU will be Not Reparable This Station (NRTS) and will have to be moved further to the depot for repair. This adaptation assumes the SRU NRTS rate is 100 percent for simplicity. Lastly, the input for "What support do the RR LRUs get from the FSL?" allows the user to specify whether parts are only stored, or both stored and repaired, at the FSL. It also has the flexibility to model no support for RR LRUs at the FSL (i.e. unserviceable parts would go straight to the depot from the FOLs). The assumptions used in the FSL Option are listed below:

- All aircraft are located at the FOLs.
- The FOLs are supported by a single FSL.
- The FSL is supported by the depot.
- No component repair is performed at the FOLs; all parts are immediately retrograded back to the FSL where they are either repaired or declared Not Repairable This Station (NRTS) and sent back to the Depot.
- Only LRUs are repaired at the FSL; all SRUs are sent to the depot for repair (100% NRTS).
- The model automatically sets [ASM] parameters to no exponential repair, no order and ship delay, no evaluation runs, and no 2 day analyses (only Analysis Day 1 is used). (Kline, 1999)

In this research, the objective was to understand the feasibility of the "pipeline on the fly" concept. Therefore, the FSL Option was used in a modified manner, so that it would model the stockage of aircraft spares at a depot and FOLs only. (See Figure 19 on the next page)

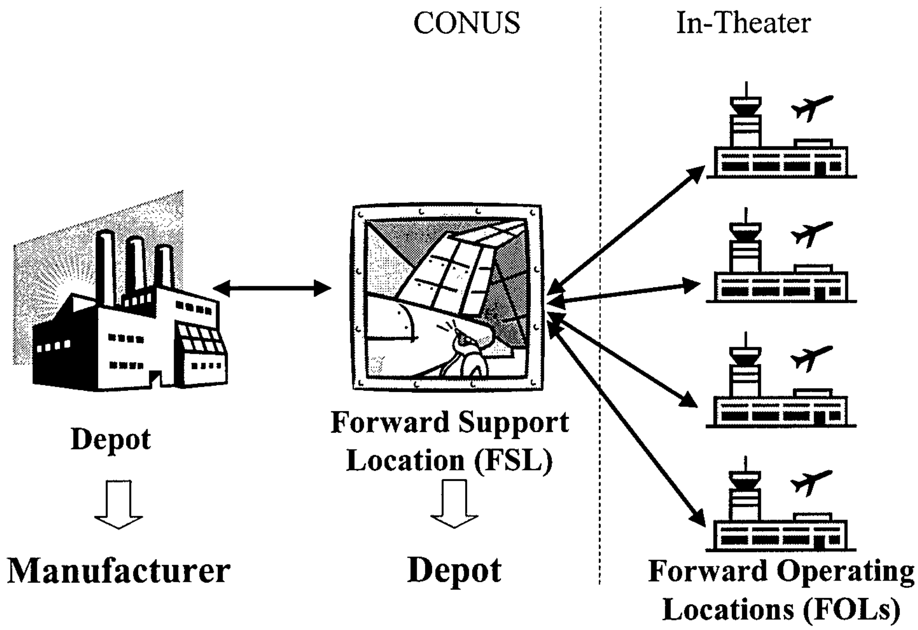


Figure 19. Modified FSL Option

By setting the "Resupply time from the depot" parameter at a value of 99, the model effectively stocked at only two echelons, the FSL and at the FOLs. Assuming there was a requirement to stock an asset at either the FSL, with a "reasonable" O&ST, or the depot, with an O&ST of 99 days, the model always chose to place it at the FSL. Henceforth, the FSL can be thought of as the depot, and the depot can be thought of as the manufacturer. When this was done, the model was, in effect, forced to stock an asset either at the depot or at one of the FOLs.

The other parameters were set as follows:

- FSL to FOL ship time: 5, 10, 15, 20 days (21 and 23 days were used to determine the effect on the baseline 30-day kits)
- FSL repair time: "Use NSN BRT + Constant" with Constant = 2
- FSL LRU NRTS rate: "Use NSN NRTS rate"
- What support do the RR LRUs get from the FSL?: "Full"

Summary

In this chapter, the process used to conduct the analyses required was described in detail. First, the process for collecting LRT data and how they were examined were discussed. The capabilities of ASM and its use in this research were explained next. After that, the way in which output data were examined and analyzed, through graphing and regression, were described. Lastly, the use of the FSL Option to gain insight on the benefits of pooling assets was outlined. Now that the process utilized in this thesis is understood, this paper will now shift its focus to the analysis of the empirical results.

IV. Results

Introduction

This chapter summarizes the numerical output derived from the process accomplished as described in Chapter III. In addition, it describes the statistical tests that were used to identify whether the changes in parameters produced a statistically significant improvement. The knowledge gained by sifting through the output data and analyzing them allowed for the resolution of the research questions presented in Chapter I. To review, those questions were:

1. What is the "logistics pipeline?"
2. How quickly can the logistics pipeline be established?
3. How long does it take to place an order and receive a part in the logistics pipeline?
4. How much airlift and funding can be saved by reducing kits to support operations when a logistics pipeline that can respond more quickly than currently possible exists?
5. Does the "pipeline on the fly" concept yield a significant improvement in logistics pipeline performance?

Questions 1 and 2 have been addressed in the previous chapters. Questions 3 through 5 will be answered in the subsequent paragraphs.

Current Logistics Pipeline Performance

In order to gauge how well the current logistics pipeline supports parts requests during wartime, data was gathered from Operation NOBLE ANVIL (ONA), the most recent Air Force contingency. This was accomplished by downloading Logistics Response Time (LRT) values from the Air Force Materiel Command's LRT web page, as expressed in Chapter III. The data tended to follow a lognormal distribution, as ascertained through the use of a distribution analysis software program. (See Appendix A) Because the values follow such a distribution (see Figure 20 below), it is more valid to view the median or mode as a measure of central tendency than the mean or average LRT.

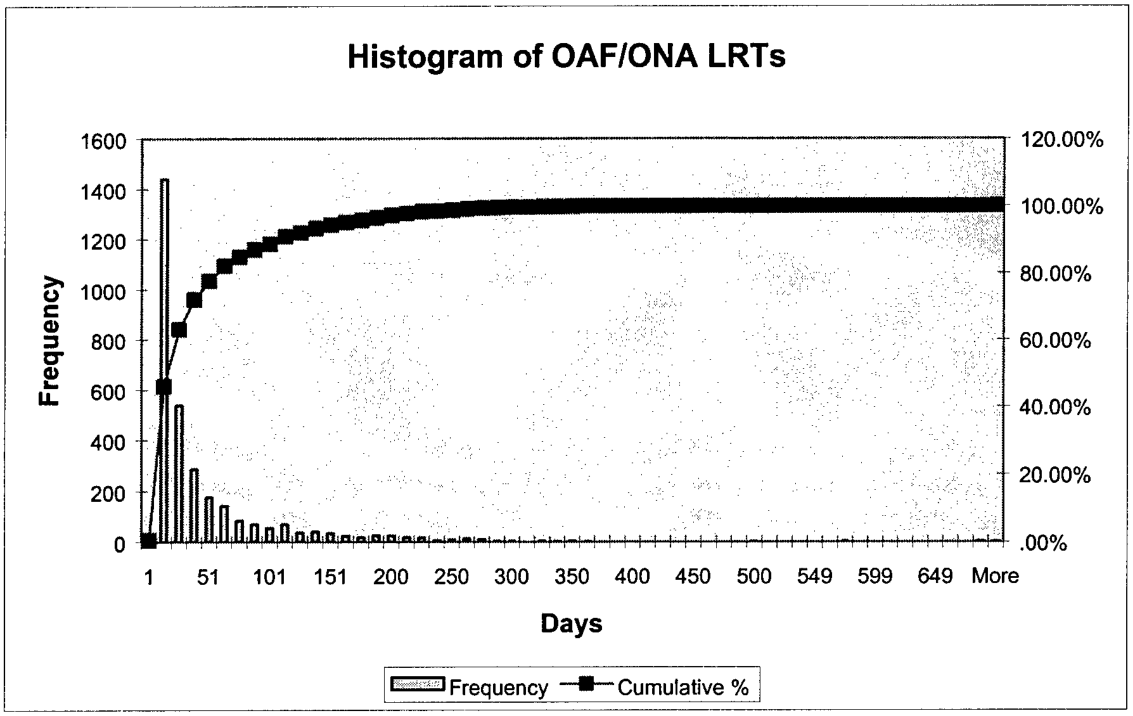


Figure 20. Histogram of Logistics Response Times from Operation ALLIED FORCE/NOBLE ANVIL (HQ AFMC/LSO, 2000)

The median is "...the middle number when the measurements are arranged in ascending (descending) order" (McClave, 1998: 55). Another way to describe the significance of this statistic is to note that 50 percent of the area under a graph of the distribution of values lies to the left of the median, and 50% of the area lies to the right. This statistic is a more valid measure of central tendency than the mean since it is less susceptible to the effects of very large or very small data values (McClave, 1998: 56). In addition, the mode was considered in this research since it "...is the measurement that occurs most frequently in the data set." (McClave, 1998: 58) This statistic is especially useful in cases when it is important to ascertain the section of the quantitative data set in which most of the observations occur (McClave, 1998: 58). As shown previously in Figure 20, the skewness of the data results in a mean value that is much higher than the median. So, consideration of the median and mode was appropriate. (See Table 3 below)

Table 3. Excel Descriptive Statistics Output for OAF/ONA LRTs

OAF/ONA LRTs	
Mean	**39.41511224**
Standard Error	1.050801383
Median	**15**
Mode	**6**
Standard Deviation	59.09765275
Sample Variance	3492.532561
Kurtosis	22.57363628
Skewness	3.674828978
Range	698
Minimum	1
Maximum	699
Sum	124670
Count	3163
Confidence Level(95.0%)	2.060323046

The results shown in Table 3 indicate that the current logistics pipeline—tested in our most recent combat situation—performs rather well, since most of the time a part arrived where it needed to be in 6 days. However, it seemed that the process includes a large amount of variance, and hence makes it less than reliable. Compared to the descriptive statistics for the O&ST values used in calculating the kit spare parts requirements, the current pipeline seemed to perform better.

Based on the source data for the items currently stocked in each kit, the wartime order & ship time (O&ST) for each aircraft averaged around 22 days. (See Table 4 below)

Table 4. Descriptive Statistics for Kit File O&STs, All Weapon Systems

MDS	*B-52H*	*F-15E*	*F-16C*	*KC-135*
Mean	20.62651	21.3702	22.90674	23.13825
Standard Error	0.682023	0.446071	0.716063	0.588329
Median	29	29	30	30
Mode	30	30	30	30
Standard Deviation	10.76214	9.388701	9.947864	8.666627
Sample Variance	115.8236	88.14771	98.96001	75.11043
Kurtosis	-1.64477	-1.55301	-1.23344	-0.8263
Skewness	-0.42705	-0.38524	-0.79902	-0.80503
Range	28	27	26	27
Minimum	2	3	4	3
Maximum	30	30	30	30
Sum	5136	9467	4421	5021
Count	249	443	193	217
Confidence Level(95.0%)	1.343295	0.876683	1.412358	1.159601

But when the medians and modes are compared, the actual pipeline seemed to move assets more rapidly during ONA than estimated during the process used to determine how many parts should go into the kit.

A more in-depth analysis of the LRTs was accomplished by identifying quantiles within the original distribution, and eliminating values that occurred in the highest sections. These occurrences are known as outliers, and typically are anomalies, or random errors, that can be found in any process. By removing these values that may not be representative of the true performance of the system, one can gain better insight on the factors influencing its operation.

The following three outputs in Table 5 below represent the elimination of the highest 5 percent ("95%"), 10 percent ("90%"), and 25 percent ("75%") of the LRT values, respectively.

Table 5. Descriptive Statistics Without Outliers

	95%	90%	75%
Mean	29.1464226	24.18042494	14.16814159
Standard Error	0.61789871	0.471770283	0.212868542
Median	14	13	11
Mode	6	6	6
Standard Deviation	33.8718977	25.27826007	10.36956061
Sample Variance	1147.30545	638.990432	107.5277873
Kurtosis	3.02132817	2.275747393	0.570876308
Skewness	1.89318719	1.708228682	1.181650125
Range	161	112	45
Minimum	1	1	1
Maximum	162	113	46
Sum	87585	69422	33621
Count	3005	2871	2373
Confidence Level(95.0%)	1.21154635	0.925041851	0.417427989

The first statistic that shows a distinct reduction is the mean, going from 29.146 after eliminating the highest 5 percent of values down to 14.168 when the highest 25 percent are taken out. Even though the mean is not as good a measure of central tendency in a lognormal distribution, it does highlight the fact that the skewness was reduced. This is validated by the "skewness" statistic that decreased as well. Further, the mean, median, and mode approach the same value as more outliers are reduced. In spite of the significant reduction in the mean, the lower three quartiles still have a large amount of variance. In fact, the maximum value is still 46 days, well above the 30 days used as the assumption when stocking parts for a spare parts kit. The next logical line of questioning would be to determine whether there is any indication that the high values observed are due to a unique aspect of a part or problems occurring in the logistics pipeline.

To gain this insight, four items that accounted for 106 of the 790 (13.4%) shipments in the uppermost quartile in the above analysis were selected for review. The spares that included the highest LRT (699 days) and the lowest LRT of the upper quartile (46 days), a value in between the two (96 days), and a "random" value of 199 days were selected for analysis. These parts are listed in Table 6 below:

Table 6. Items Selected for Further Analysis

LRT	National Stock Number (NSN)	Nomenclature
699 days	1270013732769	ROLL SECTION, TARGET
199 days	2910011426707	FUEL CONTROL, MAIN, T
96 days	6620008344265	TRANSMITTER, RATE OF
46 days	6610013195039	ALTIMETER, PRESSURE

For each of these items, all of the LRTs within the relevant period were collected and reviewed. If the times were consistently large, that would probably indicate a characteristic of the item that caused the system to take longer to ship it (e.g. very long, very heavy, or hazardous material). If times ranged from very low to very high, there probably was no hindrance caused by the physical features of the spare, but rather variability in the process. For all four items, there were LRT values ranging from very low to very high. For example, the ROLL SECTION, TARGET had one value of 7 days, as well as a value of 175 days. Since the mode of shipment and order priority were the same for both requisitions, this may indicate that process fluctuation was experienced rather than difficulty in handling the item. This evidence tended to strengthen the conclusion that there were process variations in the logistics pipeline, rather than a stable process that had problems handling unique assets. Although this sample only represented 13.4 percent of all shipments in ONA, it may indicate a need for further research and analysis to more fully understand the cause of the variability of the logistics pipeline.

Airlift and Cost Savings as a Result of a More Rapid Logistics Pipeline

Experimental data runs in the Aircraft Sustainability Model (ASM) were accomplished for each aircraft—B-52H, F-15E, F-16C, and KC-135—with various combinations of O&ST and Day Order & Ship Begins (DO&SB). (See Table 7 below) For each weapon system, the number of aircraft the kit was designed to support (PAA, or Primary Aircraft Authorized) was matched with various values of O&ST and DO&SB.

Table 7. Sample of Experimental Runs in ASM

A/C	PAA	O&ST	DO&SB
B-52H	6	5	0
B-52H	6	5	7
B-52H	6	5	15
B-52H	6	10	0
B-52H	6	10	7
B-52H	6	10	15
B-52H	6	15	0
B-52H	6	15	7
B-52H	6	15	15
B-52H	6	20	0
B-52H	6	20	7
B-52H	6	20	15

Similar combinations of values were used for each of the weapon systems in this analysis, with the value for PAA based on the size of actual spares kits used in the Air Force. (See Appendix D) Once the total cost of the kit was calculated, it was compared with the cost of the current 30-day kit. A percentage difference was computed to show the degree of decrease that results from the changes in O&ST and DO&SB. An example of the results attained in this analysis is at Table 8 below. The results of all the data runs are listed in Appendix C.

Table 8. Sample of Results from ASM Experimental Runs, B-52H Kit Cost

A/C	PAA	O&ST	DO&SB	Kit Cost ($M)	% Diff *
B-52H	6	5	0	15.56	61.55
B-52H	6	5	7	16.65	58.86
B-52H	6	5	15	16.65	58.86
B-52H	6	10	0	23.57	41.76
B-52H	6	10	7	24.19	40.23
B-52H	6	10	15	24.71	38.95
B-52H	6	15	0	30.58	24.44
B-52H	6	15	7	30.92	23.60
B-52H	6	15	15	32.10	20.69
B-52H	6	20	0	37.35	7.71
B-52H	6	20	7	37.68	6.90
B-52H	6	20	15	38.80	4.13

* vs. 30-day kit cost of $40.47M

The results of all these analyses indicate that there may be significant cost savings that can be achieved by either reducing the O&ST or the DO&SB, or both. Further, these reductions can be attained while still maintaining the minimum level of support (target Aircraft Availability Rate, or AAR) used to compute spares requirements.

Just as compelling were the reductions in the Kit Size realized through the changes in O&ST and DO&SB. Again, a sample of the resulting reductions in kit size is shown on the next page in Table 9 (see Appendix D for all others). Just as was seen in the values for Kit Cost, there were significant reductions in Kit Size when the O&ST and the DO&SB were decreased.

Table 9. Sample of Results from ASM Experimental Runs, B-52H Kit Size

A/C	PAA	O&ST	DO&SB	Kit Size (Pallets)	% Diff *
B-52H	6	5	0	7.84	67.05
B-52H	6	5	7	9.95	58.20
B-52H	6	5	15	9.95	58.20
B-52H	6	10	0	12.33	48.19
B-52H	6	10	7	13.10	44.98
B-52H	6	10	15	13.57	42.98
B-52H	6	15	0	14.74	38.07
B-52H	6	15	7	14.81	37.76
B-52H	6	15	15	16.26	31.69
B-52H	6	20	0	17.75	25.42
B-52H	6	20	7	17.88	24.86
B-52H	6	20	15	20.59	13.48

* vs. 30-day kit size of 23.8 pallets

The Effect of "Pipeline on the Fly"

One of the key investigative questions in this research effort was to determine whether the "pipeline on the fly" concept would yield any significant reductions in spare kit sizes or costs. The following response surface graph (see Figure 21 on the next page) is an example of the illustrations created to give an indication of the relative strengths of both independent variables in producing the value for Kit Cost and Kit Size.

For the B-52H, there was a distinct linear decrease that corresponded with the decrease in O&ST. Also, there was almost no variation in the axis that represents the values for DO&SB.

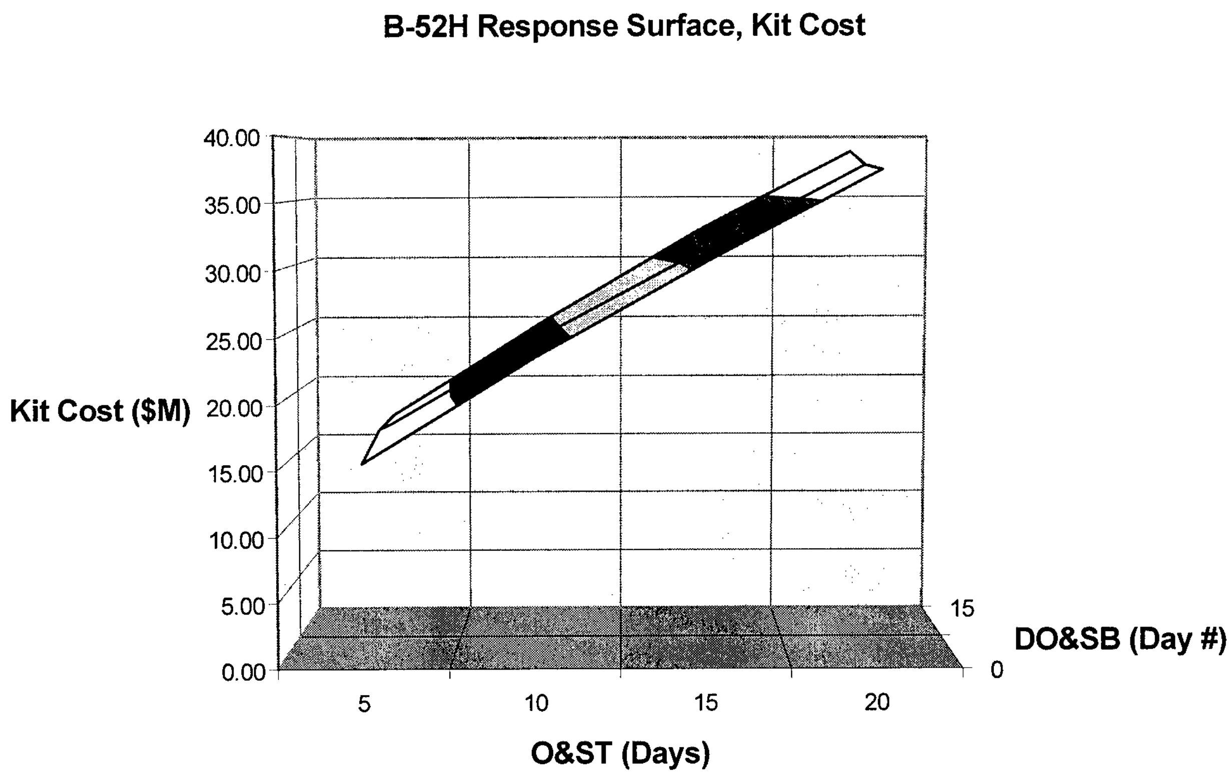


Figure 21. Sample Response Surface for Kit Cost, B-52H

In fact, the response surfaces for the F-15E, F-16C, and KC-135 indicated the same relationships. (See Appendix C) All showed a decline in the Kit Cost/Kit Size values that match the trend in O&ST, and very little changed in relation to the decrease in the variable DO&SB. Visually, it was apparent that O&ST had a significant impact on the kit cost, while it seemed that DO&SB had very little influence on the reductions that occurred. The response surfaces for Kit Size also illustrated this relationship, an example of which can be seen in Figure 22 on the next page.

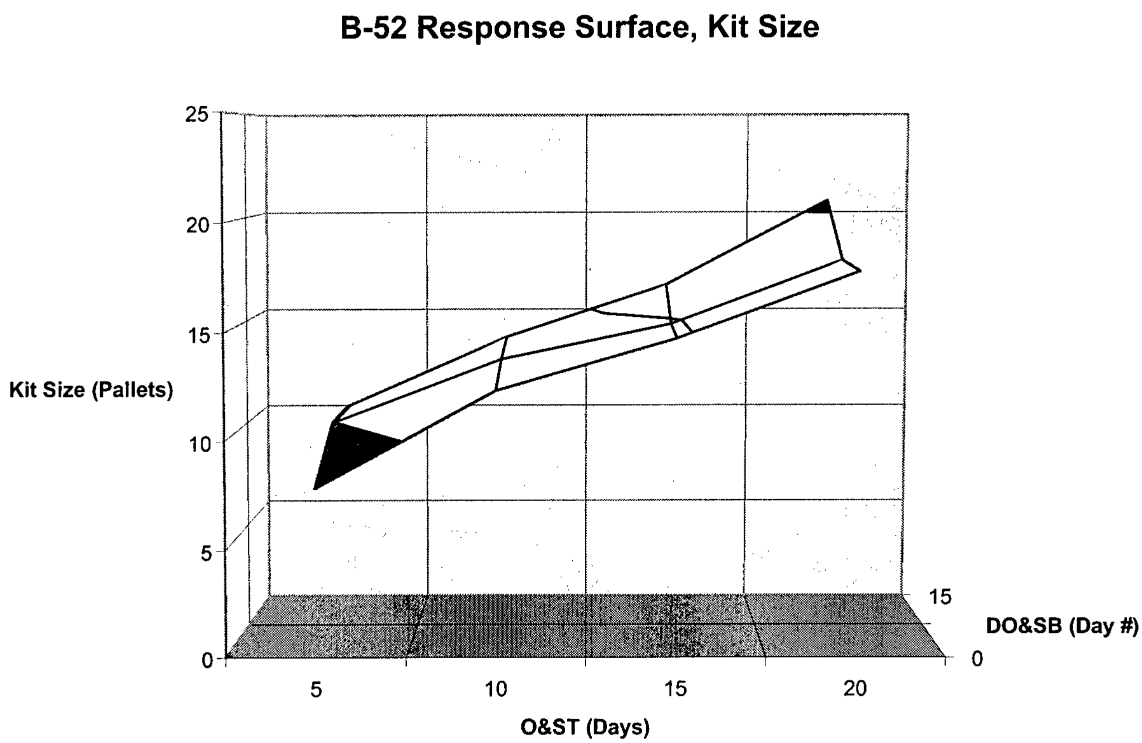


Figure 22. Sample Response Surface for Kit Size, B-52H

Once again, the response surfaces for the other weapon systems are at Appendix C.

Regression analyses were accomplished in order to better understand the effects of the two independent variables, O&ST and DO&SB. To review, the null hypothesis for this experiment was that there was no difference in the coefficients of all regression terms, while the alternate hypothesis was that there was at least one regression coefficient that was different.

For the equation

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \varepsilon,$$

where y = kit cost/kit size, x_1 = O&ST and x_2 = DO&SB, then

$$H_0: \ \beta_1 = \beta_2 = 0$$
$$H_a: \ \beta_1 \neq 0 \text{ or } \beta_2 \neq 0$$

The results (shown below in Figure 23) indicated that the variable O&ST was the only significant contributor to the value of Kit Cost for F-15Es.

Response: F-15E Kit Cost

Summary of Fit

RSquare	0.958523
RSquare Adj	0.949306
Root Mean Square Error	0.204555
Mean of Response	0.9675
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	8.7020417	207.9702	<.0001
DO&SB	1	1	0.0007988	0.0191	0.8931

Figure 23. Sample Regression Analysis Results from JMP, F-15E Kit Cost

The change in DO&SB did not have a significant impact on the dependent variable "Kit Cost." The same was true for all kit sizes and costs, except for the B-52H (both kit size and cost) and the KC-135 (kit size). It can be concluded, then, that when only these two variables were considered together in a model, O&ST was a significant predictor of the output results while the effect of DO&SB was not clear. The regression analyses for all of the weapon systems under review are at Appendix D.

One note of caution deserves to be mentioned here. These calculations did not consider any of the risk pooling effect envisioned with the use of the "pipeline on the fly." If assets are no longer kept in base-level MRSPs but are pooled at the depot, the remaining spare parts kits at each base would need to maintain enough items to cover demands during the O&ST ("O&ST quantity"). However, the stocks at the central location now cover the demand for more than one base, which allows each individual kit at these bases to be reduced ("risk pooling"). The analysis runs conducted in ASM were for one location only, so they did not account for the effect of pooling assets at a centralized point such as a depot. Therefore, another approach that could model the "pipeline on the fly" was needed in order to gain an understanding of the risk pooling effects.

When the FSL Option was used, it seemed that the "pipeline on the fly" concept was more aptly modeled. In contrast to the use of the DO&SB in ASM, the FSL Option provided results that could be used to illustrate the impact upon the logistics pipeline from implementing a change in the process. An example of the results obtained from the FSL Option is shown in Table 10 on the next page.

Table 10. Sample FSL Option Results, F-15E

F-15E	# of Kits	3			
O&ST	Kit Cost	% Reduction	Kit Sum Cost	Depot Cost	Overall Cost
5	$349,725.54	97.49%	$1,049,176.62	$3,286,395.21	$4,335,571.83
10	$2,744,519.97	80.28%	$8,233,559.91	$3,286,395.21	$11,519,955.12
15	$5,011,562.15	63.99%	$15,034,686.45	$3,286,395.21	$18,321,081.66
20	$7,430,842.24	46.61%	$22,292,526.72	$3,286,395.21	$25,578,921.93
21	$7,787,953.55	44.04%	$23,363,860.65	$3,606,465.48	$26,970,326.13

30-day Kit Cost	$13,917,843.06	Overall 30-day Kit Cost	$41,753,529.18

O&ST	Kit Size	% Reduction	Kit Sum Size	Depot Size	Overall Size
5	0.23	94.18%	0.68	1.70	2.37
10	1.20	68.96%	3.60	1.70	5.30
15	1.71	55.74%	5.14	1.70	6.84
20	3.33	14.00%	9.99	1.70	11.68
21	3.43	11.39%	10.29	1.74	12.03

30-day Kit Size	3.87	Overall 30-day Kit Size	11.62

Note: Kit Sizes are in Pallets

In the table above, "% Reduction" was the difference between the 30-day value (either cost or size) and the value obtained at the various O&STs. Then, "Kit Sum Cost/Size" were the individual kit sizes or costs multiplied by the number of spare parts kits that exist in the USAF today. The "Depot Cost/Size" represented the amount of spares that the FSL Option recommended for stockage at the depot, and when added to the "Kit Sum Cost/Size" became the "Overall Cost/Size." Finally, the "30-day Kit Cost/Size" reflected the cost and size of a standard spares kit analyzed in ASM with the same sortie data (number of sorties per aircraft, hours per sortie, and total hours per day), and that standard kit multiplied by the number of kits is the "Overall 30-day Kit Cost/Size." Similar results for the other weapon systems used in this research are at Appendix E.

At this point, using a graphical depiction of the results helps to appreciate the magnitude of the savings that are possible by using this type of analysis. The Air Force's newest airlifter, the C-17 Globemaster III, is capable of carrying a maximum payload equal to 18 pallets. (HQ USAF, 1999) Assuming that a typical Aerospace Expeditionary Force deployment consists of at least one mobility readiness spares package (MRSP) from each of the four weapon systems analyzed in this research, such a movement would require 66 pallets' worth of parts and cost $85,510,862.33 (HQ ACC/LGSWW & HQ AMC/LGSWC, 2001). In order to move this load, the Air Force would need to use 3.67 C-17 aircraft (see Figure 24 below).

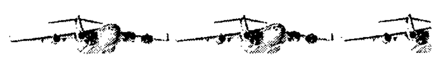
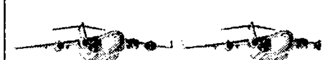
Airlift Requirement in a Single Deployment with:	
30-day kits (66.00 pallets or 3.67 C-17s)	
O&ST = Baselines (50.29 pallets or 2.79 C-17s)	
O&ST = 20 days (44.49 pallets or 2.47 C-17s)	
O&ST = 15 days (32.29 pallets or 1.79 C-17s)	
O&ST = 10 days (24.02 pallets or 1.33 C-17s)	
O&ST = 5 days (10.61 pallets or 0.59 C-17s)	
	Note: 1 C-17 = 18 pallet positions (HQ USAF, 2001)

Figure 24. Airlift Requirement in a Single Deployment

In contrast, simply using the FSL Option with no reduction in O&ST (O&ST = Baselines) lowered the single-deployment airlift requirement by nearly 24%. The airlift requirement gradually slimmed to .59 C-17s when the O&ST was cut to 5 days. When the size of each spares package was multiplied by the number of kits the USAF maintains, and added to the size of spares stocked at the depot, an overall kit size was the result. (See Figure 25 below)

Overall Kit Sizes for MRSPs with:	
30-day kits (573.00 pallets or 31.83 C-17s)	
O&ST = Baselines (418.68 pallets or 23.26 C-17s)	
O&ST = 20 days (362.83 pallets or 20.16 C-17s)	
O&ST = 15 days (267.83 pallets or 14.88 C-17s)	
O&ST = 10 days (194.65 pallets or 10.81 C-17s)	
O&ST = 5 days (84.70 pallets or 4.71 C-17s)	
	Note: 1 C-17 = 18 pallet positions (HQ USAF, 2001)

Figure 25. Overall Kit Sizes

Again, the current 30-day kits, when analyzed with the FSL Option, were immediately reduced by almost 27 percent to 418.68 pallets. The amount of spares continued to decline until it was the equivalent of 4.71 C-17 loads when the O&ST was 5 days, an 85 percent reduction from the current kit levels.

While these results are significant with respect to the Air Force's objective of reducing its deployment "footprint," the cost savings attained through the use of the FSL Option analyses are perhaps more amazing. When compared to the cost of a single deployment of current 30-day kits, using the FSL Option without adjusting the O&ST lowered the cost by over 28 percent to $61,279,584.88, for a savings of $24,231,584.45. (See Figure 26 below)

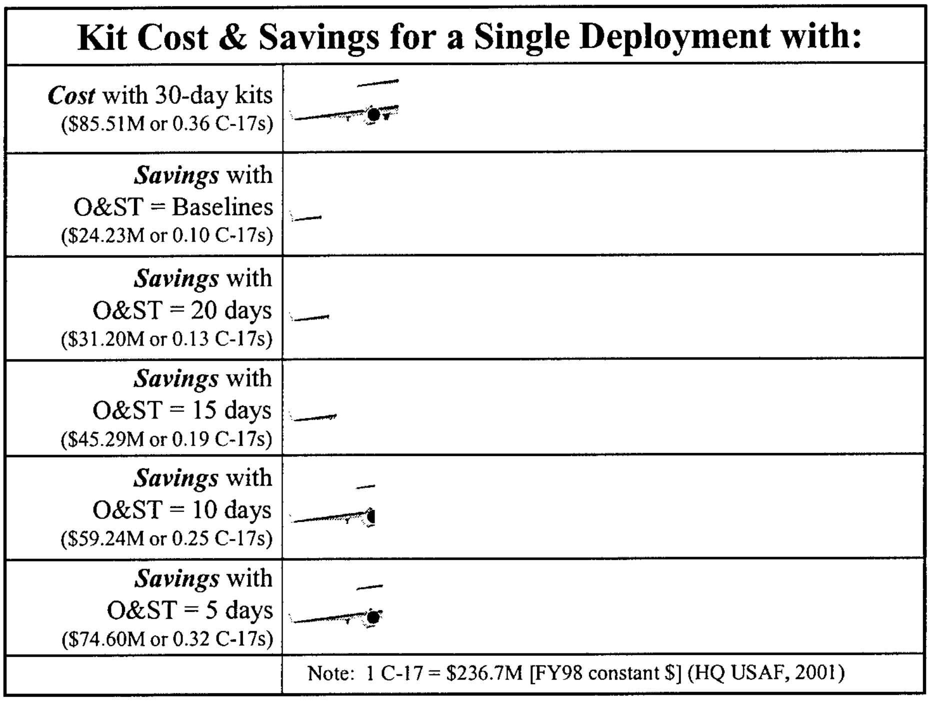


Figure 26. Kit Cost & Savings for a Single Deployment

Incredibly, the savings achieved by using the FSL Option and reducing the O&ST to 5 days nearly equaled the cost of a single deployment of current 30-day MRSPs.

In a similar fashion to overall kit size, the cost of each kit was multiplied by the number of kits in possession by the Air Force, and added to the spares stocked at the depot to calculate an overall kit cost. Again, merely utilizing the FSL Option with the baseline kit data resulted in almost a 27 percent reduction in the cost of aircraft spares, from $714,862,875.61 to $512,163,811.78. This saving was the same amount needed to purchase almost one C-17 aircraft. (See Figure 27 below)

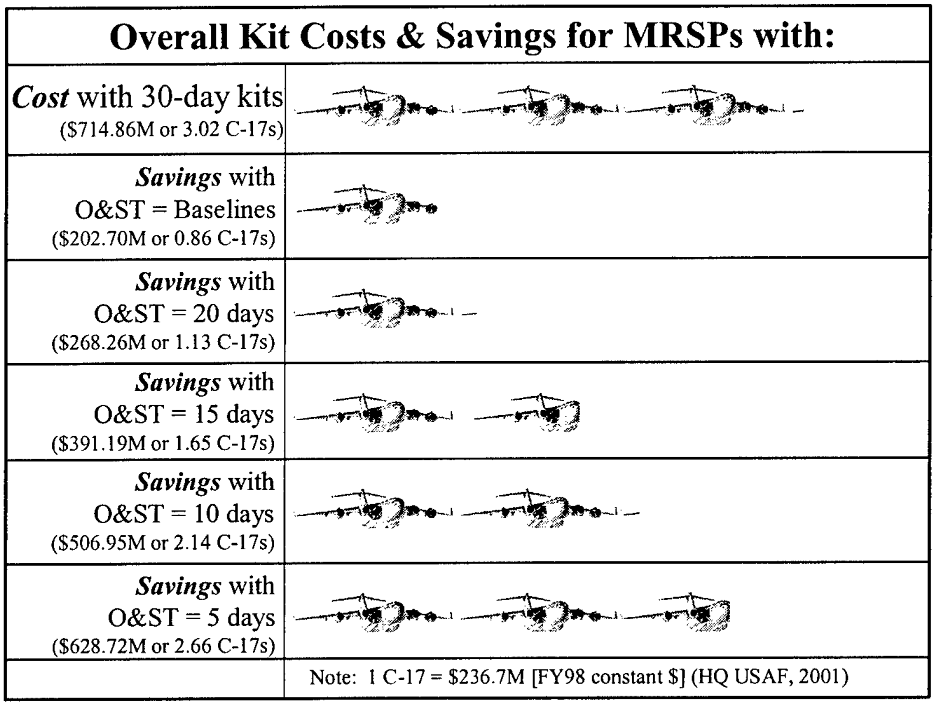


Figure 27. Overall Kit Cost & Savings

Lowering the O&ST to 5 days further increased the savings to $628,719,490.99, or the cost of 2.66 C-17 aircraft.

Summary

The results of the experiments conducted in this research effort were presented in this chapter. First, the performance of the current logistics pipeline in a wartime environment was measured. Next, the Aircraft Sustainability Model was utilized to analyze the effect decreasing the order and ship times for parts moving through the logistics pipeline, as well as commencing resupply from the depot earlier in a contingency, had on the size and cost of mobility readiness spares packages. Also, regression analyses were accomplished to determine whether decreasing the value of the independent variables "Order & Ship Time" and "Day Order & Ship Begins" had any significant impact on the dependent variable, "Kit Size/Cost." Lastly, the results obtained through the use of the FSL Option were examined to calculate the amount of savings in airlift requirement and costs possible through the implementation of the "pipeline on the fly" concept.

V. Conclusions/Recommendations

Recapitulation

This thesis research effort was conducted to gain an understanding of the effect improving the logistics pipeline has on the way the Air Force supplies aircraft spares in combat operations. Through various improvement efforts, the U.S. Air Force is attempting to streamline its logistics functions. This will enable future Aerospace Expeditionary Forces (AEF) to be employed as a "light, lean, and lethal" combat power. Two main focus areas in this endeavor are reducing the cost of support and trimming down the size of the materiel needed for this support. Assessed in this research were the effects of reducing the Logistics Response Time (LRT) and implementing a "pipeline on the fly" technique. In order to fully comprehend the impact of both of these efforts, this research was structured to answer five main investigative questions:

1. What is the "logistics pipeline?"
2. How quickly can the logistics pipeline be established?
3. How long does it take to place an order and receive a part in the logistics pipeline?
4. How much airlift and funding can be saved by reducing kits to support an operation when a logistics pipeline that can respond more quickly than currently possible exists?
5. Does the "pipeline on the fly" concept yield a significant improvement in logistics pipeline performance?

The remainder of this paper will answer these questions, discuss any conclusions that can be drawn from this analysis, and recommend future research efforts that would continue to add insight to this area of logistics.

What is the "logistics pipeline?"

The logistics process has been described as a "pipeline" for many years, but the specific measurements that are used to measure it have been adjusted several times during this period. Today, it encompasses the entire order cycle, from identifying the need to satisfying that need. It begins with the input of a requisition for a particular item by a specific unit, now mostly done through an on-line computer system. Then, that order is transmitted to the respective source of supply, where it is analyzed and processed. Once an asset is available to fulfill that requirement, it is shipped to the requesting organization.

A measurement that is currently being used by the Department of Defense and the U.S. Air Force is the Logistics Response Time (LRT). To date, it is the metric that is most representative of the various segments that comprise the logistics pipeline. As such, the LRT is the key concept around which this research was conducted, and its reduction and its effect on Mobility Readiness Spares Packages (MRSP) was one of the main objectives of this thesis effort.

How quickly can the logistics pipeline be established?

While the assumption was made that base support for an AEF would be in place within 48 hours after the Deployment Order is given, the literature pointed to several issues that have kept that goal from becoming reality. However, the example cited in Chapter II was a sample of only one event that occurred in 1997. Therefore, it is likely that, through various subsequent exercises and simulations, functions required to enable supply functions at a bare base could now be in place earlier than 1 week after the deployment commences. Just what that number of days is cannot be ascertained at this point. However, it appears safe to conclude that it would occur much earlier than the minimum reasonable order and ship time, now or in the near future. Even if a part was shipped on Day 0 of a contingency, the order and ship time required to move that asset to the forward operating location would exceed the number of days needed to set up supply operations. Therefore, it does not appear that the time needed to make a deployed location fully operational would be of great concern in relation to the time required to establish a viable logistics pipeline.

How long does it take to place an order and receive a part in the logistics pipeline?

Based on logistics response time (LRT) data collected from Operation NOBLE ANVIL, the United States' aerial operations during Operation ALLIED FORCE, the mean time to order and receive a part was 36 days. However, the distribution of times was not normal; rather, it was best modeled by a lognormal distribution. Therefore, more valid indicators of the central tendency of the LRTs were the median and the mode. These values were 15 and 6 days, respectively. Therefore, it was highly probable during this contingency that an asset would require between 1 to 2 weeks for delivery. As such, the current logistics pipeline is not very far from being able to perform well enough to produce average order and ship times (O&STs) like those used in this research. It may not require much more effort or resources to achieve an average O&ST of 10 or even 5 days, since the pipeline can most often move assets within times ranging between 6 and 15 days currently.

These promising data probably came about due to increased attention and focused management, for they represented materiel being moved in support of actual combat operations. So, it can be presumed that any future conflict will enjoy a similar level of support from all agencies and functions that comprise the logistics pipeline. Such an assumption may not be prudent from a military planning standpoint, though.

How much airlift and funding can be saved by reducing kits to support a logistics pipeline that can respond more quickly than currently possible?

The experiments conducted utilizing the Aircraft Sustainability Model (ASM) resulted in tremendous cost and size savings for mobility readiness spares packages when both "order and ship time" (O&ST) and "day order and ship begins" (DO&SB) were reduced. All weapon systems considered—B-52H, F-15E, F-16C, and KC-135—experienced reductions in both cost and size from approximately 4% to 90% and above. In fact, when the average O&ST is 5 days, the model recommended no kit at all for the KC-135. Clearly, there is much to be gained, both in saving scarce funding and minimizing the logistics "footprint" when deploying forces, by endeavoring to reduce O&ST and DO&SB. Again, these results were not exact since notional sortie data had to be used. However, they did give an indication of the magnitude of savings that could be achieved by improving the logistics pipeline.

On a particular deployment, units already reduce their spares kits ("paring and tailoring") to take only those items required for a specific scenario. The savings described here would be obtained by decreasing the number of spares kept on hand on a day-to-day basis, since we would not be stocking with the 30-day, no-resupply assumption for every weapon system at every base. However, a key question remained as to which variable would produce the more significant reductions in kit sizes and costs.

Does the "pipeline on the fly" concept yield a significant improvement in logistics pipeline performance?

Based on the regression analysis conducted to determine the significance of O&ST and DO&SB on the value of the independent variables "Kit Cost" and "Kit Size," it was evident that DO&SB was almost completely insignificant. The resultant values of Kit Cost/Size were affected almost completely by the O&ST. By this result alone, it seems that efforts to reduce the cost and the size of Air Force mobility readiness spares package should focus on ways to reduce O&ST rather than DO&SB. However, the results obtained through the use of the Forward Support Location (FSL) Option of the ASM indicated that there may be significant benefits, namely savings in cost and airlift requirement, that could be achieved through the implementation of the "pipeline on the fly" technique. In fact, the unique adaptation of the FSL Option created during this research pointed to the possibility that the Air Force could save over 80 percent in both spares cost and cargo movement needs when the "pipeline on the fly" approach is combined with a reduction of the O&ST to 5 days.

Recommendations for Future Research

This research effort was fruitful in that it identified a significant amount of spares funding and airlift requirement that can be saved by improving the logistics pipeline. Specifically, it demonstrated the impact of reducing the order and ship times experienced when moving parts from the source of supply to the requesting organization. In addition, it illustrated the effect of using the FSL Option as a valid means to model the "pipeline on the fly" concept. Three areas of further study would complement the results obtained from this study, and enhance our understanding of the logistics pipeline as it relates to supply support of combat operations.

First, a more in-depth analysis of the various components that are represented by the segments within LRT is needed. Dividing the overall LRT into its subcomponents, and assessing their individual impact on the total LRT, could do this. Perhaps a regression analysis could also uncover which segments affect the LRT more significantly than others, further narrowing the search for improvement opportunities. Now that a savings in both cost and size of MRSPs has been identified, a cost/benefit analysis of the specific improvements required to reduce LRT (or O&ST) to achieve these reductions should be accomplished. By doing so, we can assess the utility of the adjustments in the logistics pipeline and determine whether the benefits outweigh the costs.

Second, a further look into the behavior of the Aircraft Sustainability Model (ASM) with regard to the manipulation of the variable "Day Order and Ship Begins" to represent the "pipeline on the fly" concept should be accomplished. Intuitively, starting the resupply pipeline earlier in a combat scenario seems as if it should result in a reduction of the number of items needed in an MRSP. However, the results obtained through this research seem to indicate that there is no clear significant relationship between DO&SB and the Kit Size or Kit Cost. A review of the model formulations and discussions with the model author (Slay, 2001) uncovered no obvious errors in the operation of ASM in this study. However, that does not conclusively eliminate the possibility that DO&SB is not the right parameter to use for representing the "pipeline on the fly" within ASM. Either the model behaved as it should and modifications are needed to better represent this new concept, or there is a more valid parameter to use instead of DO&SB.

Lastly, the FSL Option should be expanded in order for it to be more robust and flexible. It should be adjusted to allow for the use of each item's individual O&ST, rather than using a constant average O&ST for all items contained in a kit. Also, it may provide better insight if the model could accommodate various start days for the resupply, rather than assuming that it starts on Day 0. While it does seem to model the "pipeline on the fly" concept well, it could be utilized even more for analyses of near-term improvements if these parameter inputs were allowed.

Appendix A: Logistics Response Time Analysis

Table 11. Stock Record Account Numbers (SRANs) for Operation NOBLE ANVIL (HQ USAFE/LGSP, 2000)

SRAN	Losing Sys Des.	MRSP ORG	MRSP MSI ORG	Inclusive Dates	Gaining Sys Des. (homestation)	Unit Designation
RAF Lakenheath UK						
FB5437	A1	753	N/A	1-28 Jun 99	Seymour Johnson	4th Supply Sq
FB5587	01	454	456	13 Apr - 1 Jul 99	Elmendorf AFB, Alaska	3rd Supply Sq (54th FS)
Ramstein AB GE						
FB5612	O1	695	704	Transferred to:1 Jun 99/Transferred from: 1 Jul 99	O1	726 ACS MT. HOME
FB5612	O1	697	704	Transferred to: 9 Jun 99/Transferred from: 1 Jul 99	O1	388 FW HILL
FB5612	O1	685	674	Transferred to: 21 May 99/ Transferred from:	O1	94 AW DOBBINS
FB5612	O1	563	563	Transferred to: 7 Apr 99/Transferred from: 7 Jul 99	A4	193 SOW HARRISBURG IAP
FB5612	O1	542	544	Transferred to: 1 Apr 99/Transferred to Scott: 22 Apr 99	O1	22 AW MCCONNELL
FB5440	A2	200	201	Transferred to: 17 May 99/ Transferred from:	A5	171 ARW PITTSBURGH ANG
FB5440	A2	202	203	Transferred to: 28 May 99/ Transferred from:	A5	171 ARW PITTSBURGH ANG
FB5440	A2	102	106	Transferred to: 5 Jun 99/ Transferred from: 1 Jul 99	O1	96 ABW EGLIN
FB5440	A2	103	106	Transferred to: 9 Jun 99/ Transferred from: 1 Jul 99	O1	1 FW LANGLEY
FB5471	A5	463		Transferred to: 1 May 99/ Transferred from: 19 May 99	O1	436 AW DOVER
FB5471	A5	536	101,901	Transferred to: 11 May 99/ Transferred from:	O1	4ASOS HEIDELBERG
FB5471	A5	317	100	Transferred to: 9 Jun 99/ Transferred from:	O1	1CCSQ
FB5471	A5	260	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	322	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	325	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	329	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	352	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	364	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	281	100	Transferred to: 11 May 99/ Transferred from:	O1	1CCSQ
FB5471	A5	500	502	Transferred to: 15 Jun 99/Transferred from:	A1	232 COMBAT COMM ALABAMA
FB5471	A5	503	502	Transferred to: 15 Jun 99/Transferred from:	A1	232 COMBAT COMM ALABAMA
FB5471	A5		573	FOR PURCHASING SUPPLIES		621 AMSG/FM
FB5471	A5		683	FOR PURCHASING SUPPLIES		JTF SHINING HOPE 86 CPTS/FMA
FB5462	A6	100	101	Transferred to: 27 May 99/ Transferred from: 6 Jul 99	A2	190 ARW KANSAS ANG
FB5463	A7	358	349	Transferred to: 8 Jun 99/ Transferred from:	A1	161 ARW PHEONIX ANG
FB5463	A7	360	347	Transferred to: 7 Jun 99/ Transferred from:	A2	434 ARW GRISSOM ARB
FB5463	A7	567		Transferred to: 9 Apr 99/ Transferred from:	O1	108 ARW MCGUIRE
FB5463	A7	574	349	Transferred to: 9 Apr 99/ Transferred to Turkey:4 May 99	O1	121 ST ARW RICKENBACKER IAP
FB5463	A7	640	349	Transferred to: 7 Jun 99/ Transferred from:	A5	121 ST ARW RICKENBACKER IAP
Aviano AB IT						
FB5677	A2	147	413	22 Feb 99 - 2 Jul 99	01	493rd Lakenheath
FB5677	A2	201	416	22 Feb 99 - 2 Jul 99	01	493rd Lakenheath
FB5498	A6	403	866	9 Feb 99 - 2 Jul 99	01	494th Lakenheath
FB5498	A6	146	347-335	21 Feb 99 - 2 Jul 99	01	23FS Spangdahlem
FB5498	A6	287	295	15 Apr 99 - 2 Jul 99	01	78th Shaw
FB5498	A6	N/A	340	See Note; 21 Jun 99	n/a	41st Davis Monthan
FB5498	A6	283	334	See Note; arrived for DG	n/a	42nd Davis Monthan
FB5498	A6	392	489	See Note; 24 Feb 99	n/a	43rd Davis Monthan
FB5498	A6	188	188	20 Jan 99 - 15 April 99	A2	81st Spangdahlem
FB5498	A6	608	534	21 Feb 99 - 4 Jun 99	01	49th Holloman
FB5677	A2	n/a	123	22 Feb 99 - 2 Jul 99	n/a	1st Comm Ramstein
Incirlik AB TU						
FB5461	A7	142	139	03 MAY- 01 JUL 99	O1	0079FTR70000
FB5461	A7	323	205	03 MAY- 01 JUL 99	O1	0054CCS60000
FB5460	A8	460	321	03 MAY- 01 JUL 99	O1	00336FTR7000
RAF Mildenhall UK						
FB5518	01	294	294	2 MAY 99--1 JUL 99	01	77TH BOMB SQ
FB5518	01	284	284	2 MAY 99--1 JUL 99	01	2ND BOMB SQ
FB5518	01	119	119	2 MAY 99--1 JUL 99	01	22ND ARS
FB5518	01	685	685	2 MAY 99--TBT	01	22ND SUPS
FB5518	01	124	685	2 MAY 99--TBT	01	22ND SUPS
FB5441	A5	116	116	2 MAY 99--TBT	01	106 EARS
FB5441	A5	138	138	2 MAY 99--TBT	01	106 EARS
Spangdahlem AB GE						
FB5428	A1	419	101,201	1 APR-2 JUL	01, transferred 2July 99	8/9 FS, Holloman AFB
FB5450	A2	188	401,450	1 APR-PRESENT	01	81 FS, Spangdahlem
FB5450	A2	399	401,450	1 APR-2 JUL	01, transferred 2 July 99	23 FG, Pope AFB
FB5450	A2	195	180	1 APR-PRESENT	01	52 COMM, Spangdahlem
FB5450	A2	389	120	1 APR-7JUL	01	606 ACS, Spangdahlem
FB5439	A3	299	201,250	18 MAY-PRESENT	01	110 FW, Selfridge ANG
FB5439	A3	199	101,150	18 MAY-PRESENT	01	104 WG, Barnes ANG
FB5439	A3	499	401,450	18 MAY-2 JUL	01, transferred 2 July 99	3 COMBAT COMM
FB5439	A3	399	301,350	18 MAY-PRESENT	01	124 FW, Boise ANG

Table 12. Best Fit Results, ONA LRTs

Best Fit Results	
Function	**Chi-Square**
Lognormal(50.13,87.51)	1.17E-03
Lognormal2(2.94,1.18)	2.30E-03
Gamma(0.44,88.61)	3.79E-03
Weibull(0.73,61.89)	4.83E-03
Erlang(1.00,1.18e+2)	9.21E-03
Triang(1.00,1.00,6.99e+2)	3.95E-02
NegBin(1.00,2.47e-2)	0.136886076
Geomet(2.47e-2)	0.137375234
Expon(39.42)	0.164760578
Pareto(1.01,1.00)	0.200683723
Logistic(39.42,32.37)	1.518934519
Beta(0.39,8.11) * 6.98e+2 + 1.00	126.9275687
Erf(1.07e-2)	2.36462E+14
Normal(39.42,59.10)	5.01E+16
Poisson(39.42)	1.00E+34
HyperGeo(6.99e+2,6.99e+2,2.10e+3)	1.00E+34
Chisq(39.00)	1.00E+34
Binomial(6.99e+2,5.64e-2)	1.00E+34

Table 13. Frequency Distribution for ONA LRTs

Bin	Frequency	Cum%	Bin	Frequency	Cum%
1	15	.47%	362.4642857	1	99.81%
13.46428571	1440	46.00%	374.9285714	0	99.81%
25.92857143	538	63.01%	387.3928571	0	99.81%
38.39285714	285	72.02%	399.8571429	0	99.81%
50.85714286	176	77.58%	412.3214286	0	99.81%
63.32142857	141	82.04%	424.7857143	0	99.81%
75.78571429	83	84.67%	437.25	0	99.81%
88.25	69	86.85%	449.7142857	0	99.81%
100.7142857	54	88.56%	462.1785714	0	99.81%
113.1785714	70	90.77%	474.6428571	0	99.81%
125.6428571	37	91.94%	487.1071429	0	99.81%
138.1071429	40	93.20%	499.5714286	1	99.84%
150.5714286	34	94.28%	512.0357143	0	99.84%
163.0357143	23	95.00%	524.5	0	99.84%
175.5	18	95.57%	536.9642857	0	99.84%
187.9642857	25	96.36%	549.4285714	0	99.84%
200.4285714	24	97.12%	561.8928571	0	99.84%
212.8928571	18	97.69%	574.3571429	2	99.91%
225.3571429	16	98.20%	586.8214286	0	99.91%
237.8214286	5	98.36%	599.2857143	0	99.91%
250.2857143	8	98.61%	611.75	0	99.91%
262.75	13	99.02%	624.2142857	0	99.91%
275.2142857	9	99.30%	636.6785714	0	99.91%
287.6785714	3	99.40%	649.1428571	0	99.91%
300.1428571	3	99.49%	661.6071429	0	99.91%
312.6071429	0	99.49%	674.0714286	0	99.91%
325.0714286	4	99.62%	686.5357143	2	99.97%
337.5357143	1	99.65%	More	1	100.00%
350	4	99.78%			

Table 14. Values and Descriptive Statistics: Roll Section, Target

1270 013732769		
	Row #	Value
Oct-98	664	162
Nov-98	98	699
Apr-99	570	11
Apr-99	571	160
Apr-99	572	22
Apr-99	4876	16
May-99	4905	23
May-99	5796	15
May-99	5797	15
May-99	5820	7
Jun-99	4087	6
Jun-99	4088	24
Jun-99	4941	59
Jun-99	4942	58
Jun-99	4943	60
Jun-99	4944	175

1270013732769	
Mean	94.5
Standard Error	42.87249
Median	23.5
Mode	15
Standard Deviation	171.4899
Sample Variance	29408.8
Kurtosis	11.726
Skewness	3.283426
Range	693
Minimum	6
Maximum	699
Sum	1512
Count	16
Confidence Level(95.0%)	91.3806

Table 15. Values and Descriptive Statistics: Altimeter, Pressure

6610 013195039		
	Row #	Value
Nov-98	83	6
Nov-98	84	96
Nov-98	834	92
May-99	147	5
May-99	4572	37
Jun-99	3804	5
Jun-99	3805	15
Jun-99	3806	14
Jun-99	3807	6
Jun-99	3808	3
Jun-99	3809	6

6610013195039	
Mean	25.90909
Standard Error	10.55415
Median	6
Mode	6
Standard Deviation	35.00416
Sample Variance	1225.291
Kurtosis	1.2543
Skewness	1.645446
Range	93
Minimum	3
Maximum	96
Sum	285
Count	11
Confidence Level(95.0%)	23.51612

Table 16. Values and Descriptive Statistics: Transmitter, Rate of

6620 008344265	Row #	Value
Oct-98	255	8
Oct-98	256	19
Oct-98	257	19
Oct-98	258	22
Oct-98	259	31
Oct-98	260	31
Oct-98	261	32
Oct-98	262	34
Oct-98	263	34
Oct-98	264	46
Oct-98	265	46
Oct-98	266	46
Oct-98	267	46
Oct-98	268	46
Nov-98	369	3
Nov-98	370	54
May-99	2131	12
May-99	2132	12
May-99	2133	10
May-99	2134	10
May-99	2135	14
May-99	2136	6
May-99	2137	86
May-99	2138	124
May-99	2139	7
May-99	2140	8
May-99	2141	10
May-99	2142	12
May-99	2143	12
May-99	2144	39
May-99	2145	128
Jun-99	1818	2
Jun-99	1819	9
Jun-99	1820	4
Jun-99	1821	14
Jun-99	1822	9
Jun-99	1823	28

6620008344265	
Mean	29
Standard Error	4.899592
Median	19
Mode	46
Standard Deviation	29.80306
Sample Variance	888.2222
Kurtosis	4.733963
Skewness	2.101907
Range	126
Minimum	2
Maximum	128
Sum	1073
Count	37
Confidence Level(95.0%)	9.936821

Table 17. Values and Descriptive Statistics: Fuel Control, Main, T

2910 011426707	Row #	Value
Nov-98	581	121
Nov-98	582	149
Nov-98	583	199
Nov-98	584	212
Nov-98	585	218
Nov-98	586	237
Nov-98	587	238
May-99	3366	263
May-99	3367	304
May-99	3368	305
May-99	3369	300
May-99	3370	299
May-99	3371	351
May-99	3372	359
May-99	3373	331
Jun-99	2829	37
Jun-99	2830	39
Jun-99	2831	42
Jun-99	2832	42
Jun-99	2833	2
Jun-99	2834	7
Jun-99	2835	94
Jun-99	2836	89
Jun-99	2837	103
Jun-99	2838	116
Jun-99	2839	119
Jun-99	2840	119
Jun-99	2841	144
Jun-99	2842	145
Jun-99	2843	149
Jun-99	2844	165
Jun-99	2845	2
Jun-99	2846	10
Jun-99	2847	35
Jun-99	2848	94
Jun-99	2849	91
Jun-99	2850	96
Jun-99	2851	182
Jun-99	2852	191
Jun-99	2853	267
Jun-99	2854	288
Jun-99	2855	232

2910011426707	
Mean	161.5714
Standard Error	16.22075
Median	147
Mode	149
Standard Deviation	105.1225
Sample Variance	11050.74
Kurtosis	-1.0475
Skewness	0.211936
Range	357
Minimum	2
Maximum	359
Sum	6786
Count	42
Confidence Level(95.0%)	32.75849

Appendix B: Adjusted Order and Ship Times (O&STs)

Table 18. Adjusted O&STs: B-52H

NSN	0.784	0.568	0.352	0.136	0.000	0.000	% Reduction
1560007242853FL	6	13	19	26	30	30	
1560008601911FL	6	13	19	26	30	30	
1560008601912FL	6	13	19	26	30	30	
1560011273340FL	3	6	8	11	13	13	
1620010639477	6	13	19	26	30	30	
1630004927144	6	13	19	26	30	30	
1630006107199	1	2	3	3	4	4	
1630006792558	6	13	19	26	30	30	
1630011401949	4	7	11	15	17	17	
1630012293669	4	7	11	15	17	17	
1630012947958	6	13	19	26	30	30	
1630014114854	6	13	19	26	30	30	
1650004485560	6	13	19	26	30	30	
1650005343889	6	13	19	26	30	30	
1650005345904	6	13	19	26	30	30	
1650005355878	6	13	19	26	30	30	
1650005400164AZ	6	13	19	26	30	30	
1650005548102	6	13	19	26	30	30	
1650005708397	6	13	19	26	30	30	
1650005899026	6	13	19	26	30	30	
1650005918287	6	13	19	26	30	30	
1650006009224	6	13	19	26	30	30	
1650006098372	2	3	5	6	7	7	
1650006098373	6	13	19	26	30	30	
1650006107200	4	9	13	17	20	20	
1650006123748	6	13	19	26	30	30	
1650006133488	6	13	19	26	30	30	
1650006408489	6	11	17	22	26	26	
1650006584832	4	7	11	15	17	17	
1650006763892	6	13	19	26	30	30	
1650007412996	4	7	11	15	17	17	
1650007659187LE	3	6	9	12	14	14	
1650008159387	6	13	19	26	30	30	
1650008635141	2	4	6	8	9	9	
1650008635142	5	9	14	18	21	21	
1650010080644	5	9	14	18	21	21	
1650010833837	4	8	12	16	19	19	
1650011360549	4	7	11	15	17	17	
1650011428094HS	6	13	19	26	30	30	
1650011449294	5	9	14	18	21	21	
1650011636398	4	7	11	15	17	17	
1660001952729BO	6	13	19	26	30	30	
1660003252746	5	9	14	18	21	21	
1660005628335	6	13	19	26	30	30	

1660005889200	6	13	19	26	30	30
1660007662630	6	13	19	26	30	30
1660009271996BO	3	6	10	13	15	15
1660012409042	6	13	19	26	30	30
1680000682535FL	1	2	3	4	5	5
1680001095725FL	6	13	19	26	30	30
1680002499370FL	6	13	19	26	30	30
1680003367412FL	2	3	5	7	8	8
1680006566170FL	4	8	12	16	18	18
1680008394111	6	13	19	26	30	30
1680009637503	1	2	3	3	4	4
1680013959994FL	2	5	7	10	11	11
1680013976026	4	7	11	15	17	17
2620001370262	4	8	12	16	19	19
2620005758893	6	13	19	26	30	30
2835007940610	1	2	3	3	4	4
2835007990148	3	6	9	12	14	14
2835012412308	4	7	11	15	17	17
2840013016329RV	4	7	11	15	17	17
2910009108455YP	4	7	11	15	17	17
2910010132741YP	4	7	11	15	17	17
2915003492159	6	13	19	25	29	29
2915006794272	6	13	19	26	30	30
2915007588152AZ	6	13	19	26	30	30
2915011605502RV	4	7	11	15	17	17
2915011611650RV	4	7	11	15	17	17
2915013023388	6	13	19	26	30	30
2915013026355	6	13	19	25	29	29
2920000600057YP	4	7	11	15	17	17
2920006407547YP	2	3	5	7	8	8
2920010139867YP	6	13	19	26	30	30
2925011615596RV	4	7	11	15	17	17
2925012213247	4	7	11	15	17	17
2995009914153RV	4	7	11	15	17	17
2995011334670	5	10	14	19	22	22
2995012316132RV	6	13	19	26	30	30
2995012779247	4	7	11	15	17	17
3010005675873	6	13	19	26	30	30
4310005094781HS	2	4	6	8	9	9
4320007686345HS	6	13	19	26	30	30
4320009334698HS	5	10	15	20	23	23
4810003250646FG	6	13	19	26	30	30
4810004389890RV	5	10	15	20	23	23
4810005115267HS	6	13	19	26	30	30
4810005291029HS	2	3	5	6	7	7
4810005550700TP	6	13	19	26	30	30
4810005889201TP	6	13	19	26	30	30
4810006011884HS	5	10	15	20	23	23
4810006701388HS	4	7	11	15	17	17
4810006901656HS	6	13	19	26	30	30
4810006928253HS	4	7	11	15	17	17
4810007133144	6	13	19	26	30	30

4810008180440HS	6	13	19	26	30	30
4810010052741HS	6	13	19	26	30	30
4810011273382HS	4	7	11	15	17	17
4810011610476RV	4	7	11	15	17	17
4810012293584YP	6	13	19	25	29	29
4810012542836YQ	4	7	11	15	17	17
4810012987502	4	7	11	15	17	17
4810013995317RV	6	13	19	26	30	30
4820004045866YK	6	13	19	25	29	29
4820005282836HS	4	7	11	15	17	17
4820006927483AZ	1	1	2	3	3	3
4820007172679HS	6	13	19	26	30	30
4820008171939TP	1	2	3	4	5	5
4820009948785YQ	2	3	5	6	7	7
4820012513530RV	2	4	6	9	10	10
5810010508115CA	4	7	11	15	17	17
5810012737820CS	4	7	11	15	17	17
5821010621019	6	13	19	26	30	30
5821010772503	4	8	12	16	19	19
5821010979133	3	6	9	12	14	14
5821011038155	6	13	19	26	30	30
5821012287058	6	13	19	26	30	30
5821013115105	6	13	19	26	30	30
5821013925718	2	4	6	8	9	9
5826001345968	6	13	19	26	30	30
5826001345970	6	13	19	26	30	30
5826001345971	6	13	19	26	30	30
5826001345973	6	13	19	26	30	30
5826001345974	2	4	6	8	9	9
5826001345976	6	13	19	26	30	30
5826001345977	6	13	19	26	30	30
5826001345978	2	3	5	7	8	8
5826001345979	6	13	19	26	30	30
5826001345981	6	13	19	26	30	30
5826001345982	6	13	19	26	30	30
5826001345984	6	13	19	26	30	30
5826001345985	6	13	19	26	30	30
5826002755781	6	13	19	26	30	30
5826004445276	2	3	5	6	7	7
5826005053094	6	13	19	26	30	30
5826010121938	6	13	19	26	30	30
5826010124864	6	13	19	26	30	30
5826011244793	6	13	19	26	30	30
5826012481750	2	5	7	10	11	11
5826013512143	6	13	19	25	29	29
5831005195883	6	13	19	26	30	30
5841001345975CX	6	13	19	26	30	30
5841008454243	6	13	19	26	30	30
5841010781344	6	13	19	26	30	30
5841012827090	4	8	12	16	18	18
5841012827091	6	13	19	26	30	30
5841012827093	6	13	19	26	30	30

5841012830065	6	13	19	26	30	30
5841013373505	6	13	19	25	29	29
5895004713174CX	2	4	6	8	9	9
5895014195604CX	2	4	6	8	9	9
5895014563702CA	6	13	19	25	29	29
5895014594866	2	4	6	8	9	9
5985011041424BY	6	13	19	26	30	30
5985011515848BY	6	13	19	26	30	30
5985012827891CW	2	4	6	8	9	9
5996003215418TP	6	13	19	26	30	30
5996005578206NT	6	13	19	26	30	30
5996007178111NT	6	13	19	26	30	30
5996008985597NT	6	13	19	26	30	30
5996010537839CW	6	13	19	26	30	30
5998012253744NT	6	13	19	26	30	30
5998012253745NT	6	13	19	26	30	30
5998012258214NT	6	13	19	26	30	30
6110004884189	5	10	15	20	23	23
6110011322442	4	8	12	16	19	19
6110011638496	2	3	5	6	7	7
6115000065331UH	5	10	14	19	22	22
6115000891405	5	11	16	22	25	25
6115008188189UH	6	13	19	26	30	30
6115012006843	2	4	6	8	9	9
6130006297069	6	13	19	26	30	30
6130006789897	2	4	6	8	9	9
6130007728562NT	2	5	7	10	11	11
6130008048800	6	13	19	26	30	30
6130010568665CW	2	4	6	8	9	9
6320002365143CX	6	13	19	26	30	30
6340003474713	1	2	3	4	5	5
6605005570349	6	13	19	26	30	30
6605006320667	2	4	6	8	9	9
6605006719631	6	13	19	26	30	30
6605008329691	6	13	19	26	30	30
6605010182181	6	13	19	26	30	30
6605010352009	6	13	19	26	30	30
6605010846834	6	13	19	26	30	30
6605011326795	6	13	19	26	30	30
6605011336139	4	7	11	15	17	17
6605011375957	6	13	19	26	30	30
6610002365139CX	6	13	19	26	30	30
6610005300026	6	13	19	26	30	30
6610005300028	6	13	19	26	30	30
6610005303064	6	13	19	26	30	30
6610006334334	6	13	19	26	30	30
6610006334338	6	13	19	26	30	30
6610008720454	2	3	5	7	8	8
6610011519454	6	13	19	26	30	30
6610011710849	6	11	17	22	26	26
6610012551433	3	6	9	12	14	14
6610014352935	2	4	6	8	9	9

6610991263875	2	4	6	8	9	9
6615005506628	6	13	19	26	30	30
6615005568510	6	13	19	26	30	30
6615005570298	6	13	19	26	30	30
6615005704966	6	13	19	26	30	30
6615011343127CX	6	13	19	26	30	30
6615011689718	3	6	10	13	15	15
6615012258139	6	13	19	26	30	30
6615012258241	6	13	19	26	30	30
6615012261012	6	13	19	26	30	30
6615013264636	1	1	2	3	3	3
6620005573023	6	13	19	26	30	30
6620005619380	4	7	11	15	17	17
6620011404405	4	7	11	15	17	17
6620011450265	4	7	11	15	17	17
6620011519590	3	6	9	12	14	14
6620012471816	6	13	19	26	30	30
Average	4.806	9.982	14.783	20.083	23.138	23.138
Goal	5	10	15	20	25	30

Table 19. Adjusted O&STs: F-15E

NSN	0.766	0.532	0.298	0.064	0	0	% Reduction
1005000566753	6	12	18	24	26	26	
1005001886968	7	14	21	28	30	30	
1005001886969	7	14	21	28	30	30	
1005003268701	7	14	21	28	30	30	
1005010086283	7	14	21	28	30	30	
1005010932225	7	14	21	28	30	30	
1005011055476	7	14	21	28	30	30	
1005012982522	4	8	12	16	17	17	
1240012507258	2	4	6	8	9	9	
1270012308578FX	7	14	21	28	30	30	
1270012368438FX	7	14	21	28	30	30	
1270012396562FX	7	14	21	28	30	30	
1270012446118FX	7	14	21	28	30	30	
1270012507263	2	4	6	8	9	9	
1270012684611	2	4	6	8	9	9	
1270013174719	2	4	6	8	9	9	
1270013554495	2	4	6	8	9	9	
1270013562583	2	4	6	8	9	9	
1270013619240FX	7	14	21	28	30	30	
1270013643118	2	4	6	8	9	9	
1270013659471	2	4	6	8	9	9	
1270013732769	2	4	6	8	9	9	
1270013841108FX	7	14	21	28	30	30	
1270014171826	2	4	6	8	9	9	
1270014174143	2	4	6	8	9	9	
1270014187633	2	4	6	8	9	9	
1270014225778FX	7	14	20	27	29	29	
1270014367588FX	7	14	20	27	29	29	
1270014590687FX	7	14	20	27	29	29	
1285011513178NM	2	4	6	8	9	9	
1290013459798FX	7	14	20	27	29	29	
1290013459799FX	7	14	20	27	29	29	
1290013594751	2	4	6	8	9	9	
1290013952696FX	4	8	12	16	17	17	
1560010037178FX	2	4	6	7	8	8	
1560012713545FX	7	14	21	28	30	30	
1560012912590FX	2	4	6	8	9	9	
1560013725909FX	3	6	9	12	13	13	
1560013725910FX	2	4	6	7	8	8	
1560013814941FX	2	4	6	8	9	9	
1560013843372FX	3	5	8	10	11	11	
1560013876118FX	1	2	4	5	5	5	
1560013877289FX	1	2	3	4	4	4	
1560014114818FX	2	4	6	8	9	9	
1560014492052FX	7	14	20	27	29	29	
1620002671046	7	14	21	28	30	30	
1620012403571	4	8	12	16	17	17	

1620012409687	7	14	21	28	30	30
1620012418033	4	8	12	16	17	17
1630010182004	4	8	12	16	17	17
1630010645005	4	8	12	16	17	17
1630012251877	7	14	21	28	30	30
1630012257451	7	14	21	28	30	30
1630014080315	7	14	21	28	30	30
1650002886044	7	14	21	28	30	30
1650003337185	7	14	21	28	30	30
1650003715854	7	14	21	28	30	30
1650004330145	7	14	21	28	30	30
1650005357662	2	4	6	7	8	8
1650010157858	7	14	21	28	30	30
1650010181073	7	14	21	28	30	30
1650010189089	7	14	21	28	30	30
1650010206212	1	3	4	6	6	6
1650010503491	4	9	13	18	19	19
1650010657768	7	14	21	28	30	30
1650010912313	7	14	21	28	30	30
1650011216981	7	14	21	28	30	30
1650011226948	2	5	7	9	10	10
1650011438536	4	8	12	16	17	17
1650012288118FS	2	4	6	8	9	9
1650012511153	7	14	21	28	30	30
1650012934346	7	14	21	28	30	30
1650013134227	7	14	21	28	30	30
1650013466328	7	14	21	28	30	30
1650014460599	4	8	12	16	17	17
1660001239587	7	14	21	28	30	30
1660002738669	7	14	21	28	30	30
1660002929104	3	6	8	11	12	12
1660003277052	7	14	21	28	30	30
1660010215625	7	14	21	28	30	30
1660010631213	7	14	21	28	30	30
1660012267959	1	3	4	6	6	6
1660012276608	2	4	6	7	8	8
1660012830970	1	3	4	6	6	6
1660013387046BO	7	14	20	27	29	29
1660013387129BO	7	14	20	27	29	29
1680010530071LS	1	2	3	4	4	4
1680011390166	4	8	12	16	17	17
1680011417358	7	14	21	28	30	30
1680011595332YQ	7	14	21	28	30	30
1680011596742YQ	7	14	21	28	30	30
1680011625850FX	7	14	21	28	30	30
1680012283821	4	8	12	16	17	17
1680012283822	4	8	12	16	17	17
1680012375871	7	14	21	28	30	30
2835003901884	7	14	21	28	30	30
2835010346948	7	14	21	28	30	30
2835012180143	7	14	21	28	30	30

2835012188080	7	14	21	28	30	30
2835012428063	3	6	8	11	12	12
2835013801364	7	14	20	27	29	29
2840011802941PT	2	4	6	8	9	9
2840012403591PT	4	8	12	16	17	17
2840013084465PT	7	14	20	27	29	29
2840013084467PT	7	14	20	27	29	29
2840013084469PT	7	14	20	27	29	29
2840013094147PT	2	4	6	8	9	9
2840013206432PT	4	8	12	16	17	17
2840014369105PT	7	14	20	27	29	29
2910010092822YP	7	14	21	28	30	30
2910010378565	7	14	21	28	30	30
2915005370336	4	8	12	16	17	17
2915010562716	7	14	21	28	30	30
2915010653149	7	14	21	28	30	30
2915010658525	4	8	12	16	17	17
2915010970518	5	9	14	19	20	20
2915010972423	4	8	12	16	17	17
2915011160968	7	14	21	28	30	30
2915011396643	4	8	12	16	17	17
2915011405874	4	8	12	16	17	17
2915012147281PT	1	2	4	5	5	5
2915013094143PT	7	14	20	27	29	29
2920010139867YP	7	14	21	28	30	30
2925012067723PT	4	8	12	16	17	17
2925014081480PT	7	14	21	28	30	30
2930011638153YP	4	8	12	16	17	17
2995013895136PT	7	14	21	28	30	30
2995014336462PT	4	8	12	16	17	17
2995014455335PT	7	14	20	27	29	29
3040003550211FX	7	14	21	28	30	30
3040003550213FX	7	14	21	28	30	30
3040013249088PT	4	8	12	16	17	17
3040013249089PT	2	4	6	7	8	8
4120013637072AY	2	4	6	8	9	9
4120013656743AY	2	4	6	8	9	9
4210003141930AZ	7	14	21	28	30	30
4320012513549AY	3	5	8	10	11	11
4320012855844HS	7	14	21	28	30	30
4320012863686HS	7	14	21	28	30	30
4320013327069YP	7	14	21	28	30	30
4320013327070YP	7	14	21	28	30	30
4320014398143TP	7	14	21	28	30	30
4810003035851HS	4	8	12	16	17	17
4810010070536	7	14	21	28	30	30
4810010175072	1	3	4	6	6	6
4810010208093HS	6	12	18	23	25	25
4810010214822TP	7	14	21	28	30	30
4810010505228HS	4	8	12	16	17	17
4810010898900	4	8	12	16	17	17

4810010911930	4	8	12	16	17	17
4810010944568	4	9	13	18	19	19
4810011325907	4	8	12	16	17	17
4810012203996HS	3	6	9	12	13	13
4810012518480HS	1	2	4	5	5	5
4810012679518HS	7	14	21	28	30	30
4810013355940TP	4	8	12	16	17	17
4810013963097HS	2	5	7	9	10	10
4810014126652TP	4	8	12	16	17	17
4820003133307	4	8	12	16	17	17
4820003464324LE	4	8	12	16	17	17
4820003934771LE	1	2	3	4	4	4
4820010524890AZ	4	8	12	16	17	17
4820010736472	4	8	12	16	17	17
4820011751901PT	7	14	21	28	30	30
4820012329856TP	7	14	21	28	30	30
4920010054155DQ	2	4	6	8	9	9
4920010569722DQ	4	9	13	18	19	19
4920010630406DQ	2	3	5	7	7	7
4920011133408DQ	4	9	13	18	19	19
5340001323272AZ	4	8	12	16	17	17
5810010269624CS	3	5	8	10	11	11
5810010508115CA	4	7	11	14	15	15
5810012737819CS	7	14	21	28	30	30
5810012737820CS	7	14	21	28	30	30
5821012287058	7	14	21	28	30	30
5821012483022FX	7	14	21	28	30	30
5826010121938	7	14	21	28	30	30
5826010211744FX	7	14	21	28	30	30
5831013823225FX	4	8	12	16	17	17
5836010512886BY	1	3	4	6	6	6
5836013862964NM	7	14	20	27	29	29
5841010031835FX	7	14	21	28	30	30
5841010475880FX	7	14	21	28	30	30
5841010510385FX	7	14	21	28	30	30
5841012247835FX	7	14	21	28	30	30
5841012261171FX	7	14	21	28	30	30
5841012506200AY	2	4	6	8	9	9
5841012506235AY	2	4	6	8	9	9
5841012508705	2	4	6	8	9	9
5841013014588	1	3	4	6	6	6
5841013030403FX	3	7	10	13	14	14
5841013112851FX	7	14	21	28	30	30
5841013150646FX	7	14	21	28	30	30
5841013288234FX	7	14	21	28	30	30
5841013467924FX	4	8	12	16	17	17
5841013486483FX	4	8	12	16	17	17
5841013656017FX	4	8	12	16	17	17
5841013760002FX	4	8	12	16	17	17
5841013867141FX	2	4	6	8	9	9
5841013882922FX	7	14	21	28	30	30

5855013871928	2	4	6	8	9	9
5855014138962AY	2	4	6	8	9	9
5865004671191EW	7	14	21	28	30	30
5865011799699EW	7	14	21	28	30	30
5865011814318EW	2	3	5	7	7	7
5865011830425EW	7	14	21	28	30	30
5865012112335EW	7	14	21	28	30	30
5865012112336EW	3	5	8	10	11	11
5865012119086EW	7	14	21	28	30	30
5865012876182EW	7	14	21	28	30	30
5865013524168EW	3	5	8	10	11	11
5865014186979EW	4	8	12	16	17	17
5895004671140EW	7	14	21	28	30	30
5895004775704EW	7	14	21	28	30	30
5895010162209FX	7	14	21	28	30	30
5895011126380	7	14	21	28	30	30
5895011736012EW	7	14	21	28	30	30
5895011830228EW	7	14	21	28	30	30
5895011830230EW	7	14	21	28	30	30
5895011830236EW	7	14	21	28	30	30
5895012247827FX	7	14	21	28	30	30
5895012404455EW	7	14	21	28	30	30
5895012677708FX	7	14	21	28	30	30
5895012731990	7	14	21	28	30	30
5895012913073FX	4	8	12	16	17	17
5895012996026EW	2	4	6	8	9	9
5895013062073FX	7	14	21	28	30	30
5895013359716FX	7	14	21	28	30	30
5895013388850EW	7	14	20	27	29	29
5895013732801FX	7	14	21	28	30	30
5895013962183EW	7	14	21	28	30	30
5895014124396EW	2	4	6	8	9	9
5895014139798EW	7	14	20	27	29	29
5895014373071EW	2	4	6	8	9	9
5895014376925NM	7	14	20	27	29	29
5930001688051YP	4	8	12	16	17	17
5930011729448EW	7	14	21	28	30	30
5960012349107FX	7	14	21	28	30	30
5960012361169FX	7	14	21	28	30	30
5960012363884FX	7	14	21	28	30	30
5960012445442FX	1	3	4	6	6	6
5960013552968EW	2	3	5	7	7	7
5960013563490EW	2	4	6	8	9	9
5980014345755FX	7	14	21	28	30	30
5985010030352FX	7	14	21	28	30	30
5985010630856FX	7	14	21	28	30	30
5985010645907DQ	3	6	8	11	12	12
5985012355120EW	7	14	21	28	30	30
5985012355121EW	4	8	12	16	17	17
5985012370128EW	7	14	21	28	30	30
5985012542862EW	3	6	8	11	12	12

5985012778913FX	7	14	21	28	30	30
5985013038121EW	2	4	6	8	9	9
5985013183191AY	3	5	8	10	11	11
5985013870372AY	2	4	6	8	9	9
5985013902368EW	4	8	12	16	17	17
5990012535011FX	7	14	21	28	30	30
5995013564257FX	7	14	21	28	30	30
5995013568639FX	7	14	21	28	30	30
5995013568640FX	7	14	21	28	30	30
5996010513949FX	7	14	21	28	30	30
5996010535732FX	2	4	6	8	9	9
5996011066215YB	7	14	21	28	30	30
5996011814274EW	7	14	21	28	30	30
5996012521167AY	2	4	6	8	9	9
5996012967301EW	4	8	12	16	17	17
5996013022076FX	7	14	21	28	30	30
5996013451134EW	4	8	12	16	17	17
5996013794943AY	2	4	6	8	9	9
5996013982147AY	2	4	6	8	9	9
5996014355547AY	2	4	6	8	9	9
5998001487038FX	2	4	6	7	8	8
5998002988874DQ	7	14	21	28	30	30
5998003466624DQ	2	3	5	7	7	7
5998004438714EW	3	7	10	13	14	14
5998010033911DQ	7	14	21	28	30	30
5998010328095DQ	4	7	11	14	15	15
5998010632787DQ	7	14	21	28	30	30
5998010668994DQ	7	14	21	28	30	30
5998011174571NM	2	4	6	8	9	9
5998011175324NM	4	7	11	14	15	15
5998011259546EW	7	14	21	28	30	30
5998011260430EW	7	14	21	28	30	30
5998011339952EW	7	14	21	28	30	30
5998011339953EW	4	8	12	16	17	17
5998011341082EW	7	14	21	28	30	30
5998011350335FX	7	14	21	28	30	30
5998011585207FX	7	14	21	28	30	30
5998011677893FX	7	14	21	28	30	30
5998011802131EW	4	8	12	16	17	17
5998011919484DQ	6	11	17	22	24	24
5998011922413EW	4	8	12	16	17	17
5998011922416EW	3	6	9	12	13	13
5998011938117EW	7	14	21	28	30	30
5998011944487EW	2	4	6	8	9	9
5998011997534EW	2	4	6	8	9	9
5998012077151FX	7	14	21	28	30	30
5998012113991EW	7	14	21	28	30	30
5998012176746FX	7	14	21	28	30	30
5998012316188FX	7	14	21	28	30	30
5998012374633FX	4	8	12	16	17	17
5998012392971FX	7	14	21	28	30	30

5998012418137FX	7	14	21	28	30	30
5998012418138FX	7	14	21	28	30	30
5998012445541FX	4	8	12	16	17	17
5998012445571FX	7	14	21	28	30	30
5998012498838AY	2	4	6	8	9	9
5998012498839AY	1	2	4	5	5	5
5998012505577AY	1	1	2	3	3	3
5998012505597AY	2	4	6	8	9	9
5998012505620AY	1	3	4	6	6	6
5998012507410AY	2	4	6	8	9	9
5998012507420AY	2	4	6	8	9	9
5998012569620FX	3	6	9	12	13	13
5998012644636AY	2	3	5	7	7	7
5998012686188FX	7	14	21	28	30	30
5998012730901DQ	1	2	3	4	4	4
5998012793555FX	7	14	21	28	30	30
5998012892981EW	2	4	6	8	9	9
5998012945214EW	3	5	8	10	11	11
5998012945217EW	7	14	21	28	30	30
5998012977725DQ	1	2	4	5	5	5
5998012977764FX	7	14	21	28	30	30
5998012998047FX	7	14	21	28	30	30
5998013053350DQ	4	8	12	16	17	17
5998013055056DQ	7	14	20	27	29	29
5998013094203FX	7	14	21	28	30	30
5998013100175FX	4	8	12	16	17	17
5998013100199FX	4	8	12	16	17	17
5998013107478FX	7	14	21	28	30	30
5998013171528FX	3	5	8	10	11	11
5998013191342FX	7	14	21	28	30	30
5998013193884FX	7	14	21	28	30	30
5998013294688FX	4	8	12	16	17	17
5998013314963EW	2	4	6	8	9	9
5998013314965EW	7	14	21	28	30	30
5998013330715FX	4	8	12	16	17	17
5998013462200DQ	4	8	12	16	17	17
5998013585160AY	2	4	6	8	9	9
5998013601841FX	4	8	12	16	17	17
5998013663066AY	2	4	6	8	9	9
5998013732197EW	2	4	6	8	9	9
5998014074425FX	4	8	12	16	17	17
5998014118102EW	2	4	6	8	9	9
5998014209725FX	4	8	12	16	17	17
5998014298008EW	4	8	12	16	17	17
5998014298009EW	2	4	6	8	9	9
5998014312560EW	7	14	20	27	29	29
5998014320361EW	7	14	20	27	29	29
5998014369404NM	7	14	20	27	29	29
5998014369406NM	2	4	6	8	9	9
5999011834251EW	7	14	21	28	30	30
5999013211549AY	2	4	6	8	9	9

6105013904568AY	2	4	6	8	9	9
6110005390411	2	4	6	8	9	9
6110007270792	3	5	8	10	11	11
6110009259954	7	14	21	28	30	30
6110010433894	7	14	21	28	30	30
6110011230868FX	7	14	21	28	30	30
6110012305147	7	14	21	28	30	30
6115000891405	6	12	18	23	25	25
6115011213632UH	7	14	21	28	30	30
6115012345860	7	14	21	28	30	30
6130003328383DQ	7	14	21	28	30	30
6130010213078FX	7	14	21	28	30	30
6130011091640DQ	7	14	21	28	30	30
6130011092466DQ	4	8	12	16	17	17
6130012026607FX	7	14	21	28	30	30
6130012088522FX	7	14	21	28	30	30
6130012261154FX	7	14	21	28	30	30
6130012433062FX	7	14	21	28	30	30
6130012486604AB	4	9	13	18	19	19
6130012508147AY	2	4	6	8	9	9
6130012590623FX	7	14	21	28	30	30
6130012684979FX	7	14	21	28	30	30
6130012828769FX	7	14	21	28	30	30
6130012905835EW	7	14	21	28	30	30
6130012992128EW	4	8	12	16	17	17
6130013100808FX	4	8	12	16	17	17
6130013311438AL	7	14	21	28	30	30
6130013339064FX	7	14	21	28	30	30
6130013339064FX	7	14	21	28	30	30
6130013509124AY	2	4	6	8	9	9
6130013536592EW	4	8	12	16	17	17
6130013542834EW	4	8	12	16	17	17
6130013550070AY	2	4	6	8	9	9
6130013629049AY	2	4	6	8	9	9
6130013642733AY	2	4	6	8	9	9
6130013898225EW	7	14	21	28	30	30
6130013996861EW	4	8	12	16	17	17
6130014203338FX	7	14	21	28	30	30
6130014350879FX	7	14	21	28	30	30
6140010550435WF	2	4	6	8	9	9
6140013220675EW	2	4	6	8	9	9
6150012505539AY	2	4	6	8	9	9
6150013098856PT	7	14	20	27	29	29
6150013106126PT	7	14	20	27	29	29
6150013227666PT	7	14	20	27	29	29
6150013239354PT	7	14	20	27	29	29
6340003327300	7	14	21	28	30	30
6605001491134	7	14	21	28	30	30
6605003142536	7	14	21	28	30	30
6605012400136FX	7	14	21	28	30	30
6605013429775FX	2	4	6	8	9	9

6605013574519	7	14	21	28	30	30
6610001342259	2	3	5	7	7	7
6610001600905	7	14	21	28	30	30
6610002963574	7	14	21	28	30	30
6610003036706	7	14	21	28	30	30
6610005357722	7	14	21	28	30	30
6610010379144	7	14	21	28	30	30
6610010933356	7	14	21	28	30	30
6610013195039	3	5	8	10	11	11
6610013429774	4	8	12	16	17	17
6615003036728	7	14	21	28	30	30
6615003036730	7	14	21	28	30	30
6615010350744	7	14	21	28	30	30
6615012428344	7	14	21	28	30	30
6615012444251	7	14	21	28	30	30
6615012486599	7	14	21	28	30	30
6615013462155	7	14	21	28	30	30
6615014449008	7	14	21	28	30	30
6620010344539	3	6	8	11	12	12
6620011959950PT	4	8	12	16	17	17
6620012320680	7	14	21	28	30	30
6620014450111PT	2	4	6	8	9	9
6625001379077DQ	7	14	21	28	30	30
6625012912759DQ	2	4	6	8	9	9
6625013033735DQ	2	4	6	8	9	9
6625014209520DQ	4	7	11	14	15	15
6680010594638	4	8	12	16	17	17
6680011033419	7	14	21	28	30	30
6685011787635	4	8	12	16	17	17
6685012147238PT	1	2	4	5	5	5
6685013642225AY	2	4	6	8	9	9
6685013643441AY	2	4	6	8	9	9
6685014333057HS	3	6	9	12	13	13
6695012507234NT	7	14	21	28	30	30
6695014320352FX	7	14	21	28	30	30
7025011726541BF	4	8	12	16	17	17
7025012458137DQ	2	4	6	8	9	9
7045014446971FX	7	14	20	27	29	29
7045014450383FX	7	14	20	27	29	29
Average	5	9.986	14.923	19.901	21.370	21.370
Goal	5	10	15	20	25	30

Table 20. Adjusted O&STs: F-16C

NSN	0.782	0.563	0.345	0.127	0.000	0.000
1005000566753	7	13	20	26	30	30
1005007755578	7	13	20	26	30	30
1005010086283	1	3	4	5	6	6
1005010446174	7	13	20	26	30	30
1005010463536	7	13	20	26	30	30
1005010556484	7	13	20	26	30	30
1260014396698WF	2	4	6	8	9	9
1270012330011WF	2	3	5	6	7	7
1270012383662WF	7	13	20	26	30	30
1270013963088WF	7	13	20	26	30	30
1270014209450WF	2	5	7	10	11	11
1270014491574WF	2	4	6	8	9	9
1270014510004WF	7	13	20	26	30	30
1290014204200WF	2	5	7	10	11	11
1290999847192WF	7	13	20	26	30	30
1560013751430WF	2	4	6	8	9	9
1620011365173	7	13	20	26	30	30
1620013471770	7	13	20	26	30	30
1620014503214	7	13	20	26	30	30
1630010454508	2	3	5	7	8	8
1630010848399	7	13	20	26	30	30
1630012173141	7	13	20	26	30	30
1630013302736	7	13	20	26	30	30
1630013304860	7	13	20	26	30	30
1630014171493	6	13	19	25	29	29
1650010394983	3	7	10	14	16	16
1650010568914	7	13	20	26	30	30
1650010586259	7	13	20	26	30	30
1650010872863YP	2	4	6	8	9	9
1650011061594WF	7	13	20	26	30	30
1650011508939	1	3	4	5	6	6
1650011657203WF	7	13	20	26	30	30
1650012289276	7	13	20	26	30	30
1650012631604	1	2	3	4	5	5
1650014178523WF	2	4	6	8	9	9
1650014178525WF	6	13	19	25	29	29
1650014179655LE	2	4	6	8	9	9
1660005678852BO	7	13	20	26	30	30
1660011408406	7	13	20	26	30	30
1660011965999	7	13	20	26	30	30
1660012128889	1	2	3	4	5	5
1660013199517	7	13	20	26	30	30
1660013836734BO	2	3	5	6	7	7
1660014459556	7	13	20	26	30	30
1660014608886	6	13	19	25	29	29
1680010573391	3	6	9	11	13	13
1680010841544	7	13	20	26	30	30
1680011484167WF	7	13	20	26	30	30

% Reduction

1680011689396WF	1	3	4	5	6	6
1680012585608	7	13	20	26	30	30
1680013178385	7	13	20	26	30	30
2815011023172	7	13	20	26	30	30
2835010738989	7	13	20	26	30	30
2835011156111	7	13	20	26	30	30
2835012080169	7	13	20	26	30	30
2835012428063	7	13	20	26	30	30
2835012639440	1	3	4	5	6	6
2835013083769	7	13	20	26	30	30
2840011802935PT	7	13	20	26	30	30
2840011802941PT	7	13	20	26	30	30
2840011906884PR	7	13	20	26	30	30
2840011921067PR	7	13	20	26	30	30
2840013571941PR	4	7	11	15	17	17
2840013823498PR	7	13	20	26	30	30
2910010092822YP	7	13	20	26	30	30
2910011355681	7	13	20	26	30	30
2915011472644	7	13	20	26	30	30
2915013097889PR	4	7	11	15	17	17
2915013102891PR	7	13	20	26	30	30
2915013548333PR	7	13	20	26	30	30
2915014483117PR	7	13	20	26	30	30
2925011150306YP	7	13	20	26	30	30
2925011909213PR	7	13	20	26	30	30
2925012213247	2	4	6	8	9	9
2925013716853PR	7	13	20	26	30	30
2995010608514FS	4	7	11	15	17	17
2995014436888PR	4	7	11	15	17	17
4320000620511HS	7	13	20	26	30	30
4320013783398PR	7	13	20	26	30	30
4810010549843	7	13	20	26	30	30
4810010734200WF	2	4	6	8	9	9
4810010996392WF	7	13	20	26	30	30
4810011237254	7	13	20	26	30	30
4810011307379	7	13	20	26	30	30
4810012257171	3	5	8	10	12	12
4810012590464WF	7	13	20	26	30	30
4810013169850	7	13	20	26	30	30
4810013631952WF	7	13	20	26	30	30
4820011107775FS	1	2	3	3	4	4
5810010508115CA	7	13	20	26	30	30
5810012737820CS	7	13	20	26	30	30
5821010621019	7	13	20	26	30	30
5821013123525	1	2	3	4	5	5
5826010121938	7	13	20	26	30	30
5826010124864	2	3	5	6	7	7
5826010409798	7	13	20	26	30	30
5826010521945NT	1	3	4	5	6	6
5826014331555NS	7	13	20	26	30	30
5831005358123	1	2	3	4	5	5
5841013499175	7	13	20	26	30	30

5865010481589EW	7	13	20	26	30	30
5865013247734EW	7	13	20	26	30	30
5865013565562EW	6	13	19	25	29	29
5865013648983EW	7	13	20	26	30	30
5865013797613EW	4	7	11	15	17	17
5865013812974EW	7	13	20	26	30	30
5865013813278EW	7	13	20	26	30	30
5865014084378EW	7	13	20	26	30	30
5865014416522EW	2	4	6	8	9	9
5865014450613EW	2	4	6	8	9	9
5865014452785EW	2	4	6	8	9	9
5895011074586EW	7	13	20	26	30	30
5895011126380	7	13	20	26	30	30
5895011405901	7	13	20	26	30	30
5895011435443WF	7	13	20	26	30	30
5895012592564CW	7	13	20	26	30	30
5895013310720WF	7	13	20	26	30	30
5895014265318	2	4	6	8	9	9
5895014406544EW	2	4	6	8	9	9
5895014498302EW	6	13	19	25	29	29
5895014500193EW	6	13	19	25	29	29
5915010558592EW	1	3	4	5	6	6
5930001688051YP	7	13	20	26	30	30
5930011839085EW	7	13	20	26	30	30
5945011709363WF	2	5	7	10	11	11
5960011168858EW	2	4	6	8	9	9
5960011168861EW	2	4	6	8	9	9
5975014484899EW	7	13	20	26	30	30
5985011469283WF	7	13	20	26	30	30
5985012122950WF	7	13	20	26	30	30
5985014470682NS	6	13	19	25	29	29
5996006232912CX	7	13	20	26	30	30
5996014415289EW	2	4	6	8	9	9
5998010803978WF	7	13	20	26	30	30
5998011938150EW	1	2	3	4	5	5
5998012047643EW	3	6	9	12	14	14
5998012696978EW	2	4	6	8	9	9
5998012773936EW	1	3	4	5	6	6
5998013100200EW	1	3	4	5	6	6
5998013227746WF	7	13	20	26	30	30
5998013801918EW	2	4	7	9	10	10
6110009259954	7	13	20	26	30	30
6110011640394WF	4	7	11	15	17	17
6110011640395WF	2	4	6	8	9	9
6110011656844	7	13	20	26	30	30
6110013916067	2	3	5	6	7	7
6115012368434	7	13	20	26	30	30
6115012465622	7	13	20	26	30	30
6130010429844EW	2	4	6	8	9	9
6130011408200	7	13	20	26	30	30
6130011498915	7	13	20	26	30	30
6130012099062	7	13	20	26	30	30

6130012486604AB	7	13	20	26	30	30
6130013311438AL	7	13	20	26	30	30
6130013610655EW	2	4	6	8	9	9
6130013861430	7	13	20	26	30	30
6130219142914WF	6	13	19	25	29	29
6150013088498PR	2	4	6	8	9	9
6340011538696	1	3	4	5	6	6
6340013102536HS	7	13	20	26	30	30
6605011190832	7	13	20	26	30	30
6605012562380	7	13	20	26	30	30
6605014557795	6	13	19	25	29	29
6605993708249WF	7	13	20	26	30	30
6610002008832	4	7	11	15	17	17
6610010404430	2	4	6	8	9	9
6610010929846	7	13	20	26	30	30
6610011150131	7	13	20	26	30	30
6610011192298	7	13	20	26	30	30
6610012438003	7	13	20	26	30	30
6610012531448WF	7	13	20	26	30	30
6610012531449WF	7	13	20	26	30	30
6610013081859WF	2	4	6	8	9	9
6610013728170WF	7	13	20	26	30	30
6615007076478	2	3	5	6	7	7
6615010427834WF	7	13	20	26	30	30
6615010784943WF	2	4	6	8	9	9
6615011297445WF	1	2	3	3	4	4
6615014486152WF	6	13	19	25	29	29
6620011670874	7	13	20	26	30	30
6620011805183	7	13	20	26	30	30
6620012788027	7	13	20	26	30	30
6620013587531PR	7	13	20	26	30	30
6625011938861WF	7	13	20	26	30	30
6680009763923	7	13	20	26	30	30
6680010604248	4	8	12	17	19	19
6680010749369	7	13	20	26	30	30
6685011388075JF	5	10	16	21	24	24
6685013080858PR	7	13	20	26	30	30
6695012305978WF	2	5	7	10	11	11
7025011963702WF	2	4	6	8	9	9
7025013558414WF	3	7	10	14	16	16
7045013134223WF	2	4	6	8	9	9
Average	5.254	9.964	15.228	19.870	22.907	22.907
Goal	5	10	15	20	25	30

Table 21. Adjusted O&STs: KC-135

NSN	0.784	0.568	0.352	0.136	0.000	0.000	% Reduction
1560007242853FL	6	13	19	26	30	30	
1560008601911FL	6	13	19	26	30	30	
1560008601912FL	6	13	19	26	30	30	
1560011273340FL	3	6	8	11	13	13	
1620010639477	6	13	19	26	30	30	
1630004927144	6	13	19	26	30	30	
1630006107199	1	2	3	3	4	4	
1630006792558	6	13	19	26	30	30	
1630011401949	4	7	11	15	17	17	
1630012293669	4	7	11	15	17	17	
1630012947958	6	13	19	26	30	30	
1630014114854	6	13	19	26	30	30	
1650004485560	6	13	19	26	30	30	
1650005343889	6	13	19	26	30	30	
1650005345904	6	13	19	26	30	30	
1650005355878	6	13	19	26	30	30	
1650005400164AZ	6	13	19	26	30	30	
1650005548102	6	13	19	26	30	30	
1650005708397	6	13	19	26	30	30	
1650005899026	6	13	19	26	30	30	
1650005918287	6	13	19	26	30	30	
1650006009224	6	13	19	26	30	30	
1650006098372	2	3	5	6	7	7	
1650006098373	6	13	19	26	30	30	
1650006107200	4	9	13	17	20	20	
1650006123748	6	13	19	26	30	30	
1650006133488	6	13	19	26	30	30	
1650006408489	6	11	17	22	26	26	
1650006584832	4	7	11	15	17	17	
1650006763892	6	13	19	26	30	30	
1650007412996	4	7	11	15	17	17	
1650007659187LE	3	6	9	12	14	14	
1650008159387	6	13	19	26	30	30	
1650008635141	2	4	6	8	9	9	
1650008635142	5	9	14	18	21	21	
1650010080644	5	9	14	18	21	21	
1650010833837	4	8	12	16	19	19	
1650011360549	4	7	11	15	17	17	
1650011428094HS	6	13	19	26	30	30	
1650011449294	5	9	14	18	21	21	
1650011636398	4	7	11	15	17	17	
1660001952729BO	6	13	19	26	30	30	
1660003252746	5	9	14	18	21	21	
1660005628335	6	13	19	26	30	30	
1660005889200	6	13	19	26	30	30	
1660007662630	6	13	19	26	30	30	
1660009271996BO	3	6	10	13	15	15	
1660012409042	6	13	19	26	30	30	

1680000682535FL	1	2	3	4	5	5
1680001095725FL	6	13	19	26	30	30
1680002499370FL	6	13	19	26	30	30
1680003367412FL	2	3	5	7	8	8
1680006566170FL	4	8	12	16	18	18
1680008394111	6	13	19	26	30	30
1680009637503	1	2	3	3	4	4
1680013959994FL	2	5	7	10	11	11
1680013976026	4	7	11	15	17	17
2620001370262	4	8	12	16	19	19
2620005758893	6	13	19	26	30	30
2835007940610	1	2	3	3	4	4
2835007990148	3	6	9	12	14	14
2835012412308	4	7	11	15	17	17
2840013016329RV	4	7	11	15	17	17
2910009108455YP	4	7	11	15	17	17
2910010132741YP	4	7	11	15	17	17
2915003492159	6	13	19	25	29	29
2915006794272	6	13	19	26	30	30
2915007588152AZ	6	13	19	26	30	30
2915011605502RV	4	7	11	15	17	17
2915011611650RV	4	7	11	15	17	17
2915013023388	6	13	19	26	30	30
2915013026355	6	13	19	25	29	29
2920000600057YP	4	7	11	15	17	17
2920006407547YP	2	3	5	7	8	8
2920010139867YP	6	13	19	26	30	30
2925011615596RV	4	7	11	15	17	17
2925012213247	4	7	11	15	17	17
2995009914153RV	4	7	11	15	17	17
2995011334670	5	10	14	19	22	22
2995012316132RV	6	13	19	26	30	30
2995012779247	4	7	11	15	17	17
3010005675873	6	13	19	26	30	30
4310005094781HS	2	4	6	8	9	9
4320007686345HS	6	13	19	26	30	30
4320009334698HS	5	10	15	20	23	23
4810003250646FG	6	13	19	26	30	30
4810004389890RV	5	10	15	20	23	23
4810005115267HS	6	13	19	26	30	30
4810005291029HS	2	3	5	6	7	7
4810005550700TP	6	13	19	26	30	30
4810005889201TP	6	13	19	26	30	30
4810006011884HS	5	10	15	20	23	23
4810006701388HS	4	7	11	15	17	17
4810006901656HS	6	13	19	26	30	30
4810006928253HS	4	7	11	15	17	17
4810007133144	6	13	19	26	30	30
4810008180440HS	6	13	19	26	30	30
4810010052741HS	6	13	19	26	30	30
4810011273382HS	4	7	11	15	17	17
4810011610476RV	4	7	11	15	17	17

4810012293584YP	6	13	19	25	29	29
4810012542836YQ	4	7	11	15	17	17
4810012987502	4	7	11	15	17	17
4810013995317RV	6	13	19	26	30	30
4820004045866YK	6	13	19	25	29	29
4820005282836HS	4	7	11	15	17	17
4820006927483AZ	1	1	2	3	3	3
4820007172679HS	6	13	19	26	30	30
4820008171939TP	1	2	3	4	5	5
4820009948785YQ	2	3	5	6	7	7
4820012513530RV	2	4	6	9	10	10
5810010508115CA	4	7	11	15	17	17
5810012737820CS	4	7	11	15	17	17
5821010621019	6	13	19	26	30	30
5821010772503	4	8	12	16	19	19
5821010979133	3	6	9	12	14	14
5821011038155	6	13	19	26	30	30
5821012287058	6	13	19	26	30	30
5821013115105	6	13	19	26	30	30
5821013925718	2	4	6	8	9	9
5826001345968	6	13	19	26	30	30
5826001345970	6	13	19	26	30	30
5826001345971	6	13	19	26	30	30
5826001345973	6	13	19	26	30	30
5826001345974	2	4	6	8	9	9
5826001345976	6	13	19	26	30	30
5826001345977	6	13	19	26	30	30
5826001345978	2	3	5	7	8	8
5826001345979	6	13	19	26	30	30
5826001345981	6	13	19	26	30	30
5826001345982	6	13	19	26	30	30
5826001345984	6	13	19	26	30	30
5826001345985	6	13	19	26	30	30
5826002755781	6	13	19	26	30	30
5826004445276	2	3	5	6	7	7
5826005053094	6	13	19	26	30	30
5826010121938	6	13	19	26	30	30
5826010124864	6	13	19	26	30	30
5826011244793	6	13	19	26	30	30
5826012481750	2	5	7	10	11	11
5826013512143	6	13	19	25	29	29
5831005195883	6	13	19	26	30	30
5841001345975CX	6	13	19	26	30	30
5841008454243	6	13	19	26	30	30
5841010781344	6	13	19	26	30	30
5841012827090	4	8	12	16	18	18
5841012827091	6	13	19	26	30	30
5841012827093	6	13	19	26	30	30
5841012830065	6	13	19	26	30	30
5841013373505	6	13	19	25	29	29
5895004713174CX	2	4	6	8	9	9
5895014195604CX	2	4	6	8	9	9

5895014563702CA	6	13	19	25	29	29
5895014594866	2	4	6	8	9	9
5985011041424BY	6	13	19	26	30	30
5985011515848BY	6	13	19	26	30	30
5985012827891CW	2	4	6	8	9	9
5996003215418TP	6	13	19	26	30	30
5996005578206NT	6	13	19	26	30	30
5996007178111NT	6	13	19	26	30	30
5996008985597NT	6	13	19	26	30	30
5996010537839CW	6	13	19	26	30	30
5998012253744NT	6	13	19	26	30	30
5998012253745NT	6	13	19	26	30	30
5998012258214NT	6	13	19	26	30	30
6110004884189	5	10	15	20	23	23
6110011322442	4	8	12	16	19	19
6110011638496	2	3	5	6	7	7
6115000065331UH	5	10	14	19	22	22
6115000891405	5	11	16	22	25	25
6115008188189UH	6	13	19	26	30	30
6115012006843	2	4	6	8	9	9
6130006297069	6	13	19	26	30	30
6130006789897	2	4	6	8	9	9
6130007728562NT	2	5	7	10	11	11
6130008048800	6	13	19	26	30	30
6130010568665CW	2	4	6	8	9	9
6320002365143CX	6	13	19	26	30	30
6340003474713	1	2	3	4	5	5
6605005570349	6	13	19	26	30	30
6605006320667	2	4	6	8	9	9
6605006719631	6	13	19	26	30	30
6605008329691	6	13	19	26	30	30
6605010182181	6	13	19	26	30	30
6605010352009	6	13	19	26	30	30
6605010846834	6	13	19	26	30	30
6605011326795	6	13	19	26	30	30
6605011336139	4	7	11	15	17	17
6605011375957	6	13	19	26	30	30
6610002365139CX	6	13	19	26	30	30
6610005300026	6	13	19	26	30	30
6610005300028	6	13	19	26	30	30
6610005303064	6	13	19	26	30	30
6610006334334	6	13	19	26	30	30
6610006334338	6	13	19	26	30	30
6610008720454	2	3	5	7	8	8
6610011519454	6	13	19	26	30	30
6610011710849	6	11	17	22	26	26
6610012551433	3	6	9	12	14	14
6610014352935	2	4	6	8	9	9
6610991263875	2	4	6	8	9	9
6615005506628	6	13	19	26	30	30
6615005568510	6	13	19	26	30	30
6615005570298	6	13	19	26	30	30

6615005704966	6	13	19	26	30	30
6615011343127CX	6	13	19	26	30	30
6615011689718	3	6	10	13	15	15
6615012258139	6	13	19	26	30	30
6615012258241	6	13	19	26	30	30
6615012261012	6	13	19	26	30	30
6615013264636	1	1	2	3	3	3
6620005573023	6	13	19	26	30	30
6620005619380	4	7	11	15	17	17
6620011404405	4	7	11	15	17	17
6620011450265	4	7	11	15	17	17
6620011519590	3	6	9	12	14	14
6620012471816	6	13	19	26	30	30
Average	4.806	9.982	14.783	20.083	23.138	23.138
Goal	5	10	15	20	25	30

Appendix C: Aircraft Sustainability Model (ASM) Results

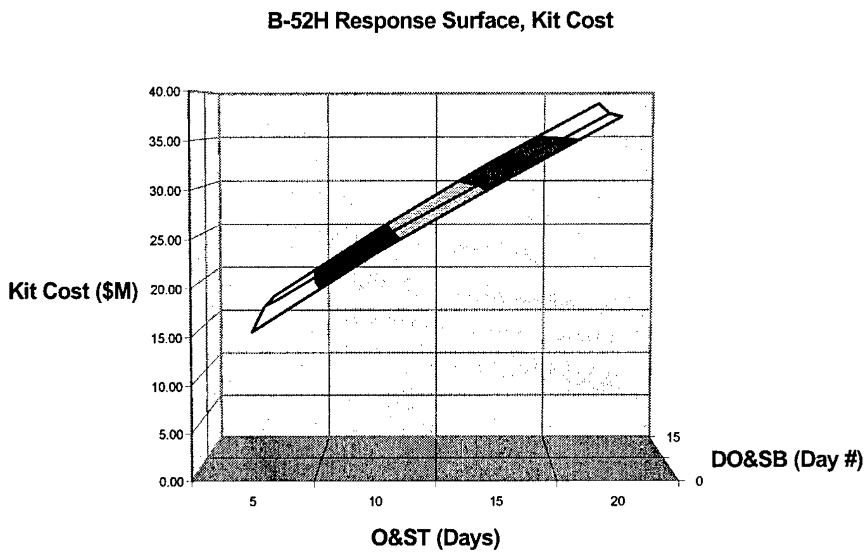


Figure 28. Response Surface, B-52H Kit Cost

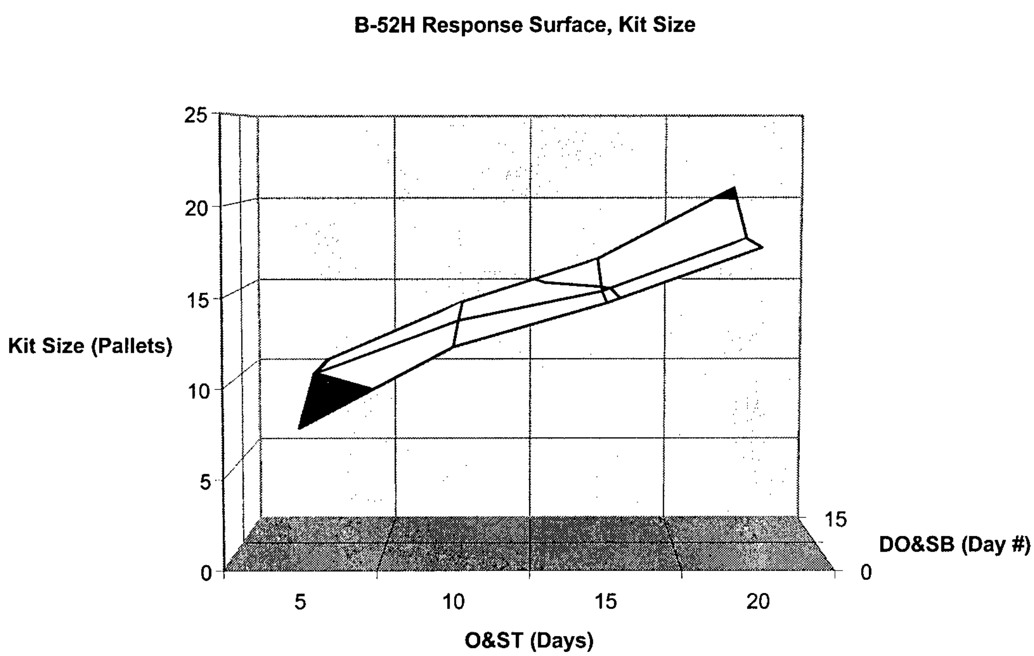


Figure 29. Response Surface, B-52H Kit Size

Table 22. B-52H Results

ID #	A/C	PAA	O&ST	DO&SB	Kit Cost	% Diff	Kit Size	% Diff
52060500	B-52H	6	5	0	15.56	61.55	7.84	67.05
52060507	B-52H	6	5	7	16.65	58.86	9.95	58.20
52060515	B-52H	6	5	15	16.65	58.86	9.95	58.20
52061000	B-52H	6	10	0	23.57	41.76	12.33	48.19
52061007	B-52H	6	10	7	24.19	40.23	13.10	44.98
52061015	B-52H	6	10	15	24.71	38.95	13.57	42.98
52061500	B-52H	6	15	0	30.58	24.44	14.74	38.07
52061507	B-52H	6	15	7	30.92	23.60	14.81	37.76
52061515	B-52H	6	15	15	32.10	20.69	16.26	31.69
52062000	B-52H	6	20	0	37.35	7.71	17.75	25.42
52062007	B-52H	6	20	7	37.68	6.90	17.88	24.86
52062015	B-52H	6	20	15	38.80	4.13	20.59	13.48

Current Cost:	40.47
Current Size:	23.8
# in AF:	7

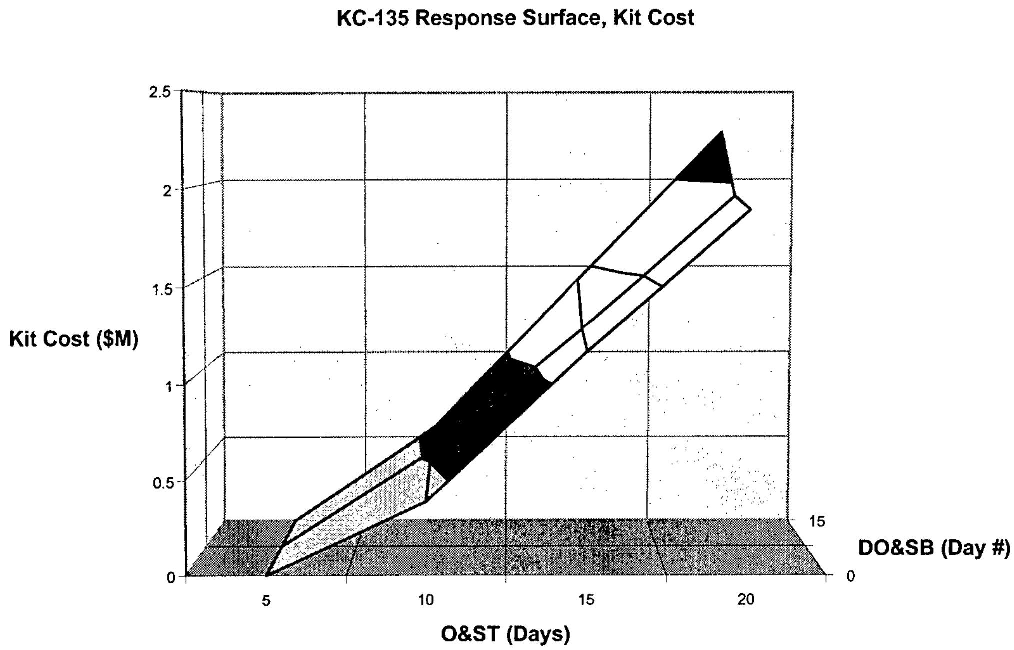


Figure 30. Response Surface, KC-135 Kit Cost

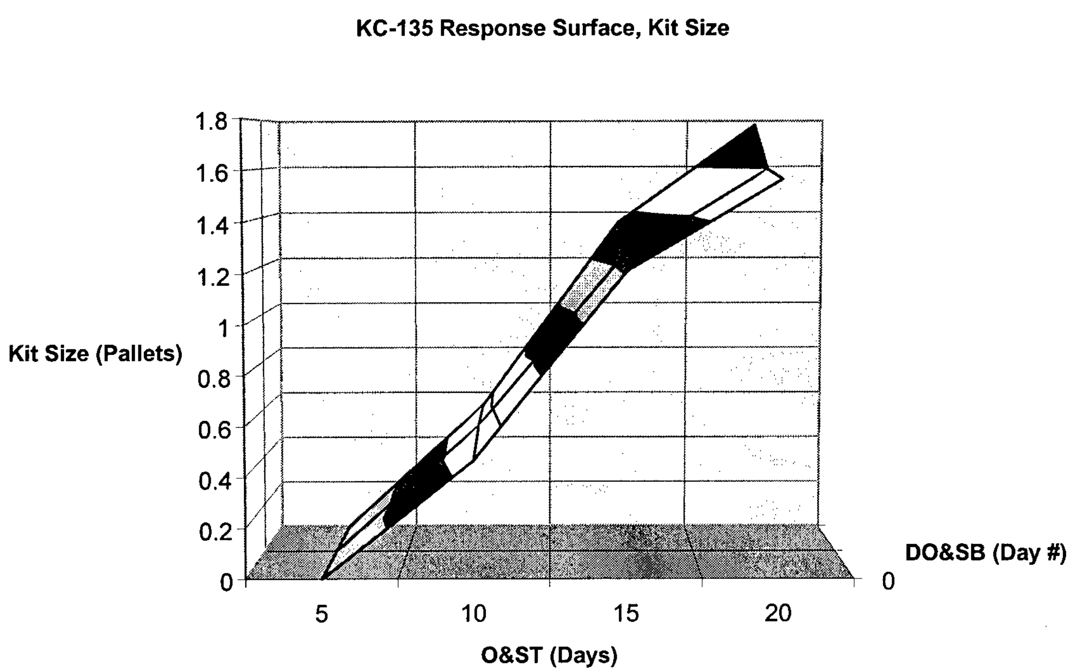


Figure 31. Response Surface, KC-135 Kit Size

Table 23. KC-135 Results

ID #	A/C	PAA	O&ST	DO&SB	Kit Cost	% Diff	Kit Size	% Diff
135120500	KC-135E	12	5	0	0	100.00	0.00	100.00
135120507	KC-135E	12	5	7	0	100.00	0.00	100.00
135120515	KC-135E	12	5	15	0	100.00	0.00	100.00
135121000	KC-135E	12	10	0	0.39	94.88	0.47	92.47
135121007	KC-135E	12	10	7	0.53	93.05	0.53	91.51
135121015	KC-135E	12	10	15	0.56	92.65	0.54	91.29
135121500	KC-135E	12	15	0	1.17	84.65	1.21	80.45
135121507	KC-135E	12	15	7	1.21	84.12	1.23	80.11
135121515	KC-135E	12	15	15	1.42	81.37	1.36	78.13
135122000	KC-135E	12	20	0	1.89	75.20	1.56	74.78
135122007	KC-135E	12	20	7	1.93	74.68	1.59	74.28
135122015	KC-135E	12	20	15	2.27	70.22	1.78	71.27

Current Cost:	7.62
Current Size:	6.2
# in AF:	14

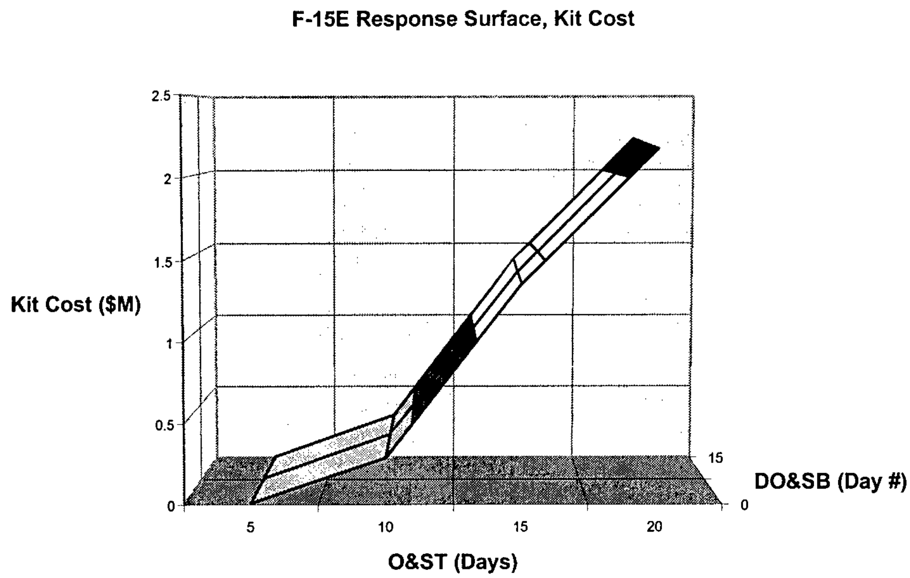


Figure 32. Response Surface, F-15E Kit Cost

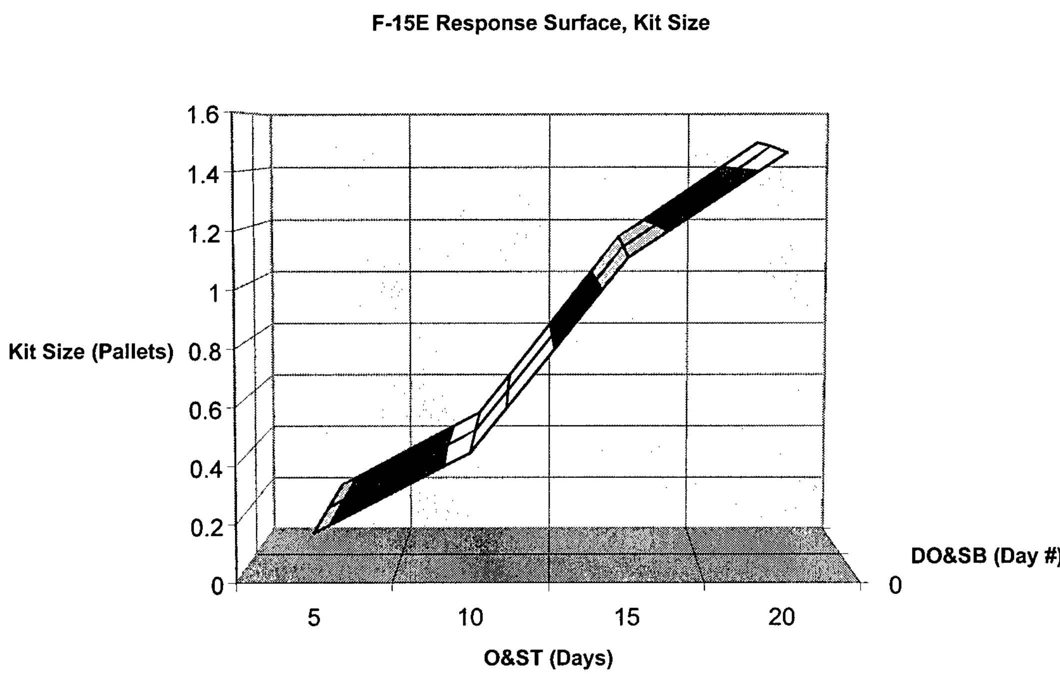


Figure 33. Response Surface, F-15E Kit Size

Table 24. F-15E Results

ID #	A/C	PAA	O&ST	DO&SB	Kit Cost	% Diff	Kit Size	% Diff
15240500	F-15E	24	5	0	0.01	99.90	0.17	91.03
15240507	F-15E	24	5	7	0.01	99.90	0.17	91.03
15240515	F-15E	24	5	15	0.01	99.90	0.17	91.03
15241000	F-15E	24	10	0	0.29	97.88	0.45	76.55
15241007	F-15E	24	10	7	0.30	97.81	0.45	76.17
15241015	F-15E	24	10	15	0.30	97.81	0.45	76.17
15241500	F-15E	24	15	0	1.36	90.06	1.11	41.59
15241507	F-15E	24	15	7	1.37	89.99	1.12	40.99
15241515	F-15E	24	15	15	1.39	89.84	1.13	40.34
15242000	F-15E	24	20	0	2.17	84.14	1.46	23.06
15242007	F-15E	24	20	7	2.19	83.99	1.48	22.07
15242015	F-15E	24	20	15	2.21	83.85	1.49	21.42

Current Cost:	13.12
Current Cost:	13.68
Current Size:	1.9
# in AF:	3

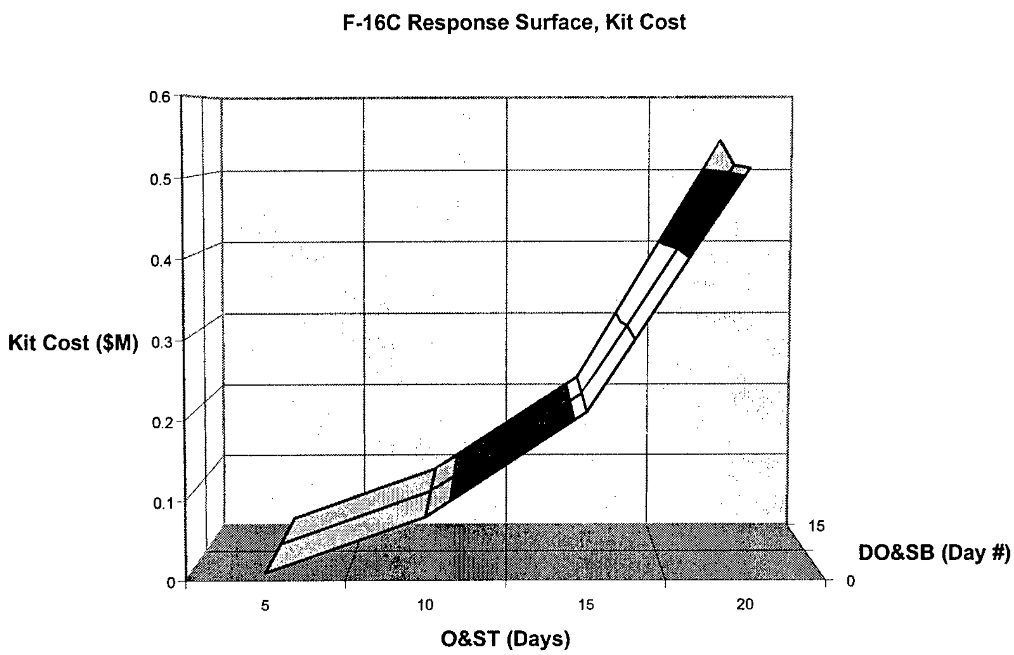


Figure 34. Response Surface, F-16C Kit Cost

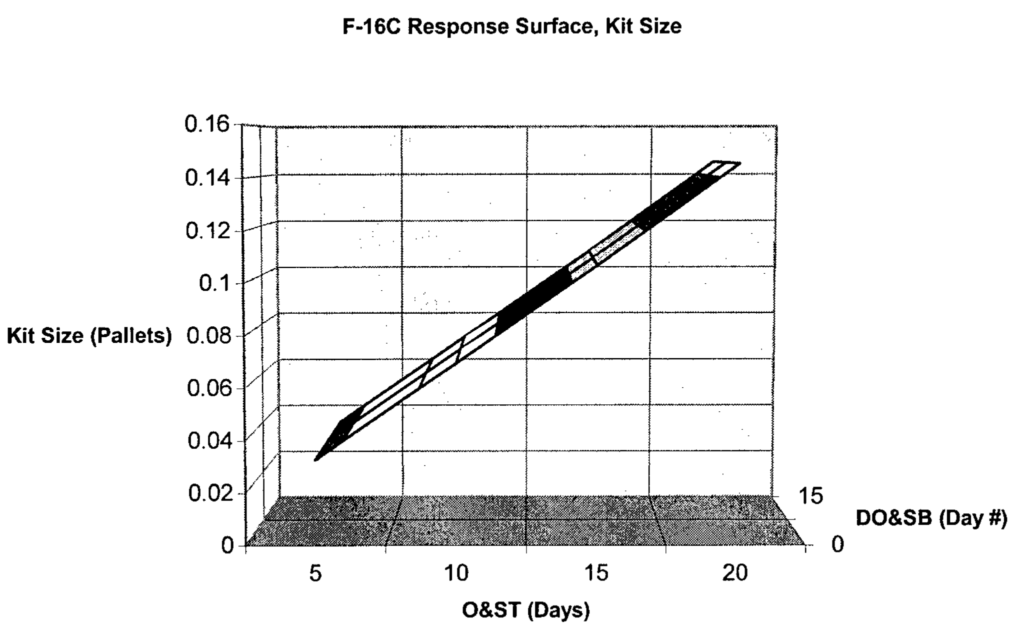


Figure 35. Response Surface, F-16C Kit Size

Table 25. F-16C Results

ID #	A/C	PAA	O&ST	DO&SB	Kit Cost	% Diff	Kit Size	% Diff
16180500	F-16C	18	5	0	0.01	99.25	0.03	94.54
16180507	F-16C	18	5	7	0.01	99.25	0.03	94.54
16180515	F-16C	18	5	15	0.01	99.25	0.03	94.54
16181000	F-16C	18	10	0	0.08	95.93	0.07	88.41
16181007	F-16C	18	10	7	0.08	95.93	0.07	88.41
16181015	F-16C	18	10	15	0.08	95.93	0.07	88.41
16181500	F-16C	18	15	0	0.21	88.76	0.11	82.20
16181507	F-16C	18	15	7	0.21	88.76	0.11	82.20
16181515	F-16C	18	15	15	0.21	88.76	0.11	82.20
16182000	F-16C	18	20	0	0.51	72.70	0.15	75.79
16182007	F-16C	18	20	7	0.51	72.70	0.15	75.79
16182015	F-16C	18	20	15	0.54	71.09	0.15	75.79

Current Cost:	1.87
Current Size:	0.6
# in AF:	17

Appendix D: Regression Analyses

Response: B-52H Kit Cost

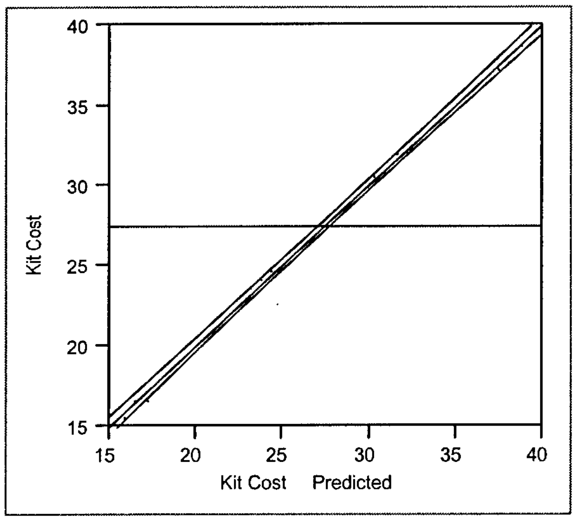
Summary of Fit

RSquare	0.998112
RSquare Adj	0.997693
Root Mean Square Error	0.40518
Mean of Response	27.39667
Observations (or Sum Wgts)	12

Effect Test

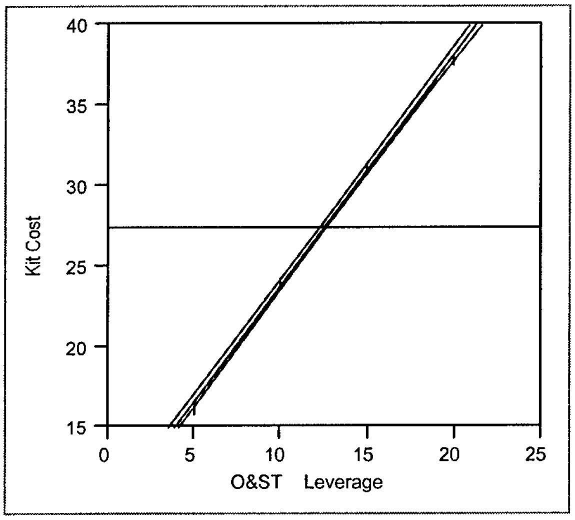
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	777.88803	4738.29	<.0001
DO&SB	1	1	3.38770	20.6353	0.0014

Whole-Model Test



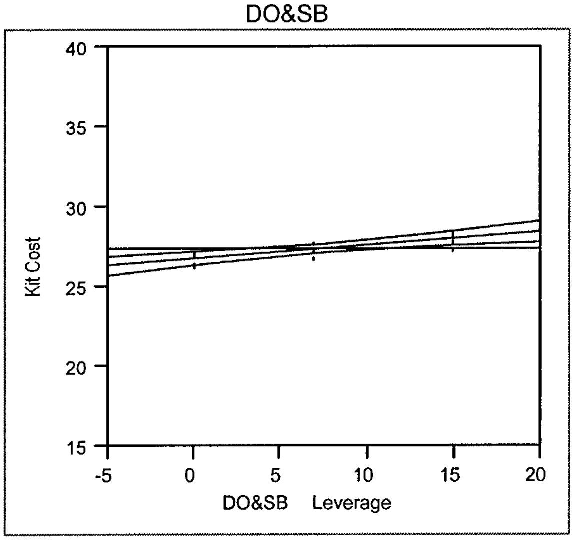
Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	781.27573	390.638	2379.462
Error	9	1.47754	0.164	Prob>F
C Total	11	782.75327		<.0001

O&ST



Effect Test			
Sum of Squares	F Ratio	DF	Prob>F
777.88803	4738.29	1	<.0001

DO&SB



Effect Test			
Sum of Squares	F Ratio	DF	Prob>F
3.3877042	20.6353	1	0.0014

Figure 36. B-52H Kit Cost

Response: B-52H Kit Size

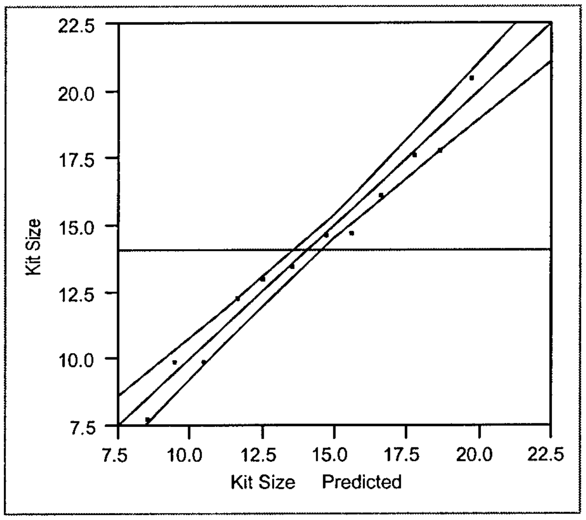
Summary of Fit

RSquare	0.973778
RSquare Adj	0.967951
Root Mean Square Error	0.668411
Mean of Response	14.06417
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	141.83437	317.4643	<.0001
DO&SB	1	1	7.48596	16.7556	0.0027

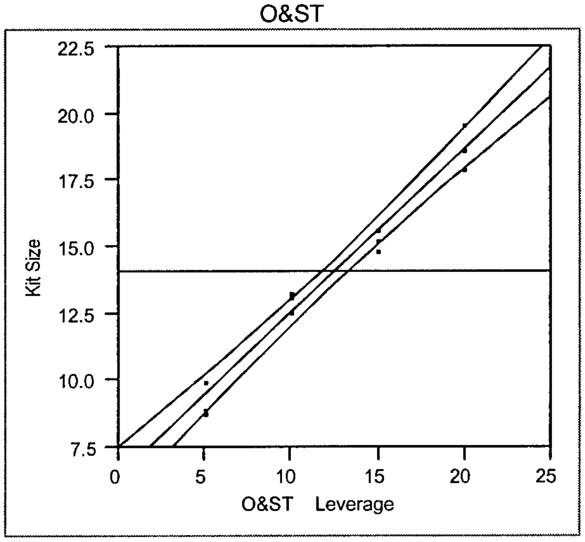
Whole-Model Test



Analysis of Variance

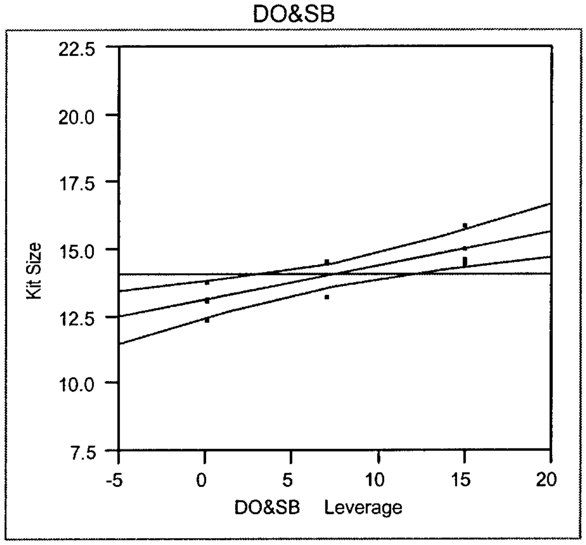
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	149.32034	74.6602	167.1100
Error	9	4.02095	0.4468	Prob>F
C Total	11	153.34129		<.0001

O&ST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
141.83437	317.4643	1	<.0001



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
7.4859622	16.7556	1	0.0027

Figure 37. B-52H, Kit Size

Response: F-15E Kit Cost

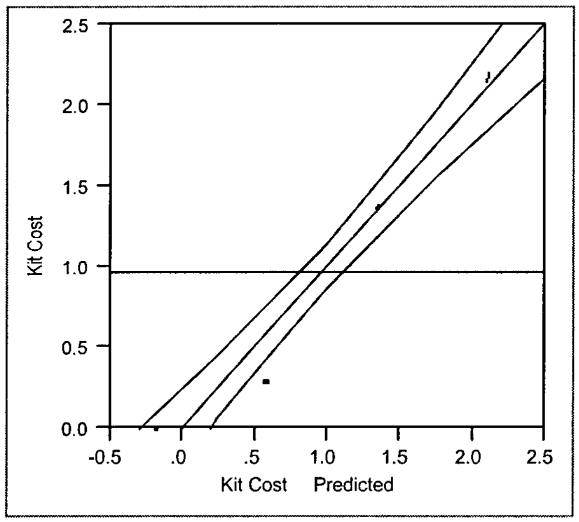
Summary of Fit

RSquare	0.958523
RSquare Adj	0.949306
Root Mean Square Error	0.204555
Mean of Response	0.9675
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	8.7020417	207.9702	<.0001
DO&SB	1	1	0.0007988	0.0191	0.8931

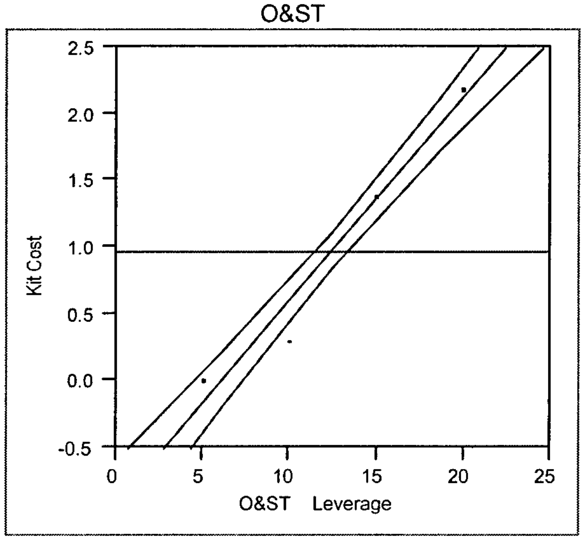
Whole-Model Test



Analysis of Variance

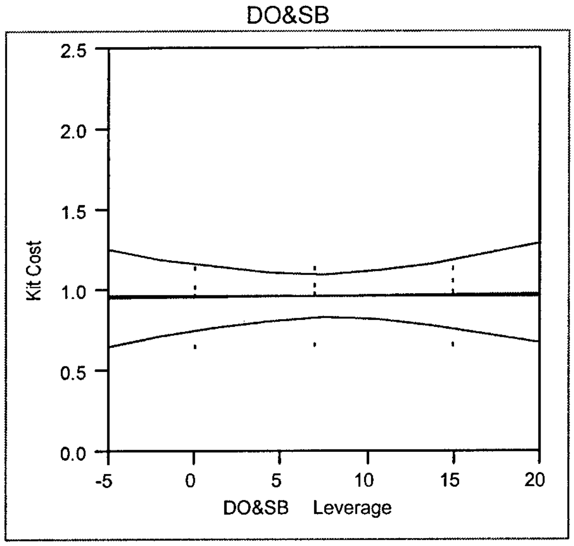
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	8.7028405	4.35142	103.9947
Error	9	0.3765845	0.04184	Prob>F
C Total	11	9.0794250		<.0001

O&ST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
8.7020417	207.9702	1	<.0001



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.00079882	0.0191	1	0.8931

Figure 38. F-15E Kit Cost

Response: F-15E Kit Size

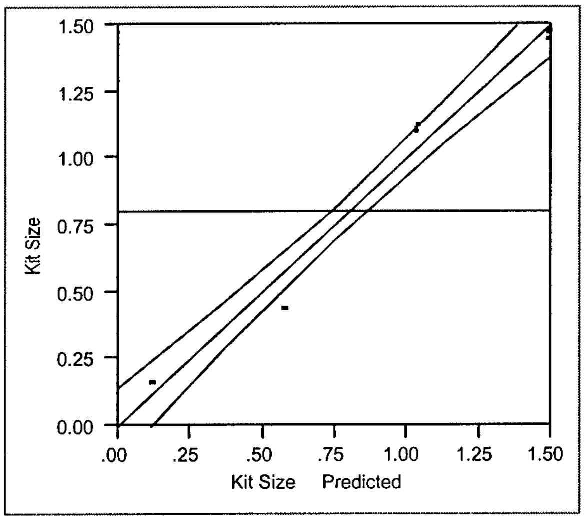
Summary of Fit

RSquare	0.975624
RSquare Adj	0.970207
Root Mean Square Error	0.09367
Mean of Response	0.804167
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	3.1602150	360.1731	<.0001
DO&SB	1	1	0.0003093	0.0352	0.8552

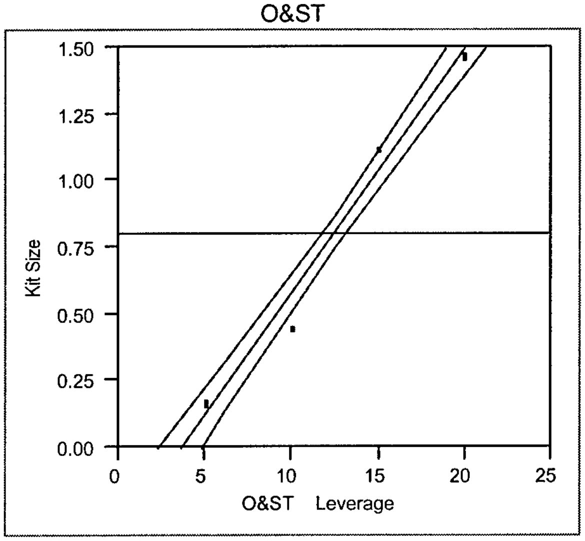
Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	3.1605243	1.58026	180.1042
Error	9	0.0789674	0.00877	Prob>F
C Total	11	3.2394917		<.0001

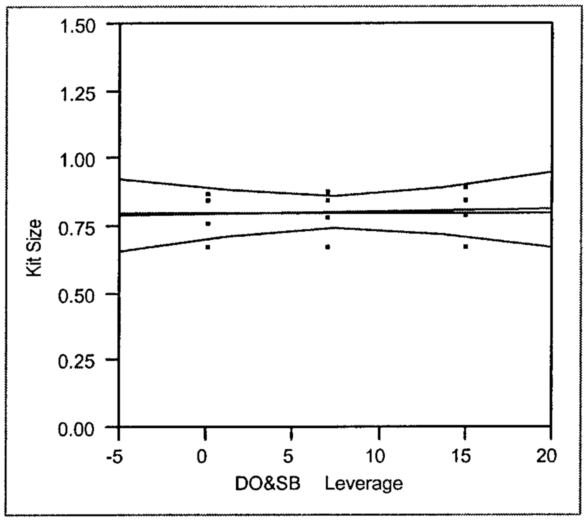
O&ST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
3.1602150	360.1731	1	<.0001

DO&SB



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.00030927	0.0352	1	0.8552

Figure 39. F-15E Kit Size

Response: F-16C Kit Cost

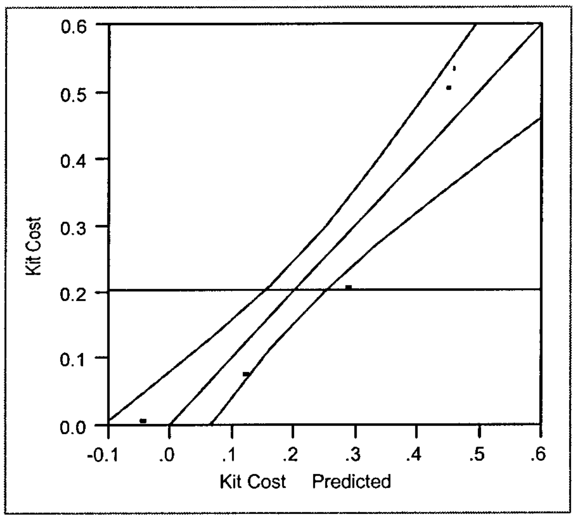
Summary of Fit

RSquare	0.90019
RSquare Adj	0.87801
Root Mean Square Error	0.07137
Mean of Response	0.205
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	0.41334000	81.1485	<.0001
DO&SB	1	1	0.00011738	0.0230	0.8827

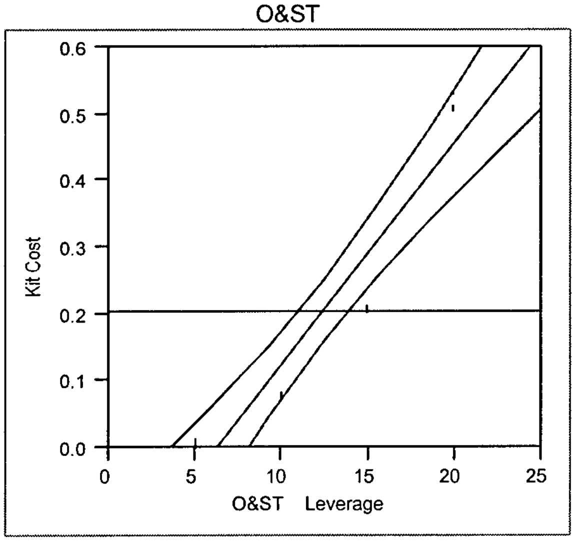
Whole-Model Test



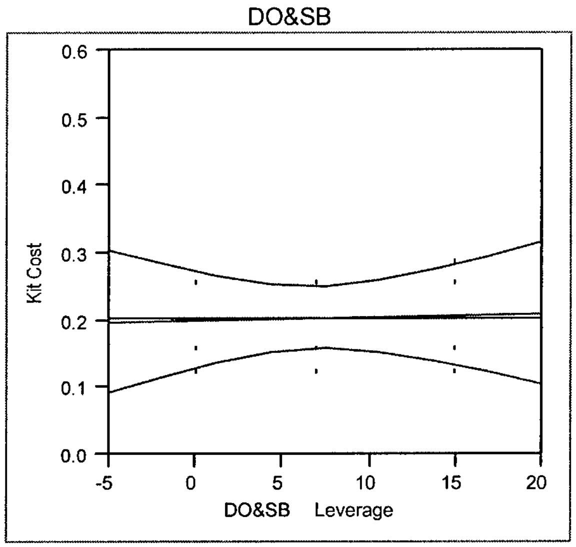
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	0.41345738	0.206729	40.5858
Error	9	0.04584262	0.005094	Prob>F
C Total	11	0.45930000		<.0001

O&ST



Effect Test			
Sum of Squares	F Ratio	DF	Prob>F
0.41334000	81.1485	1	<.0001



Effect Test			
Sum of Squares	F Ratio	DF	Prob>F
0.00011738	0.0230	1	0.8827

Figure 40. F-16C Kit Cost

Response: F-16C Kit Size

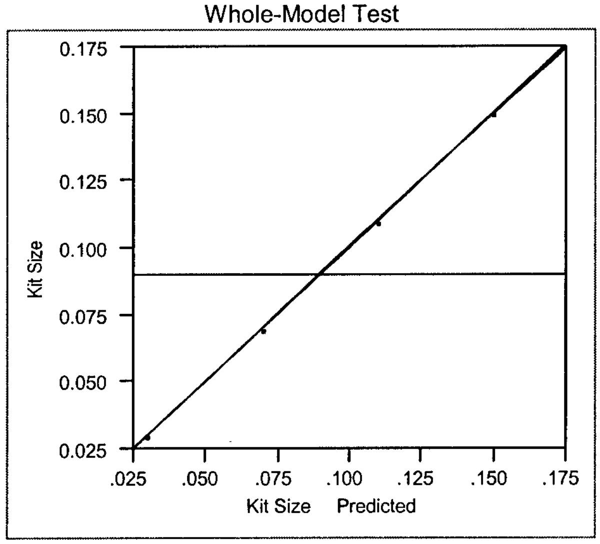
Summary of Fit

RSquare	1
RSquare Adj	1
Root Mean Square Error	1.521e-9
Mean of Response	0.09
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	0.02400000	1.038e16	<.0001
DO&SB	1	1	0.00000000	0.0000	1.0000

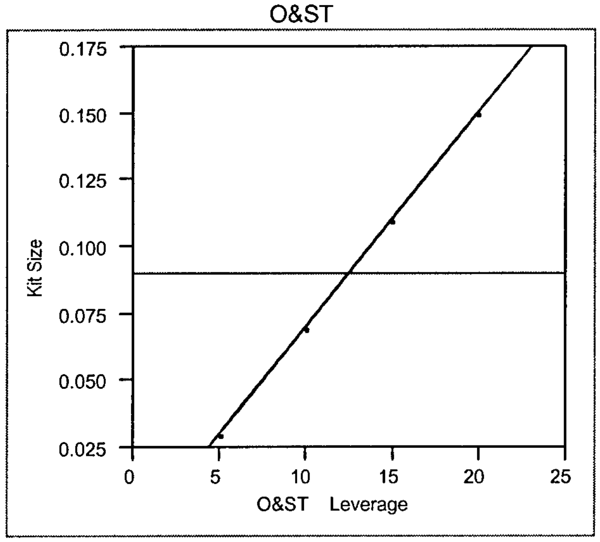
Whole-Model Test



Analysis of Variance

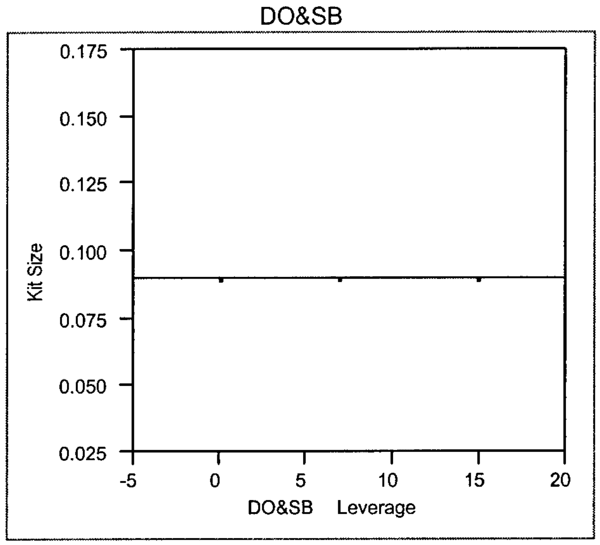
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	0.02400000	0.012000	5.188e15
Error	9	0.00000000	0.000000	Prob>F
C Total	11	0.02400000		<.0001

O&ST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.02400000	1.038e16	1	<.0001



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
8.9089e-33	0.0000	1	1.0000

Figure 41. F-16C Kit Size

Response: KC-135 Kit Cost

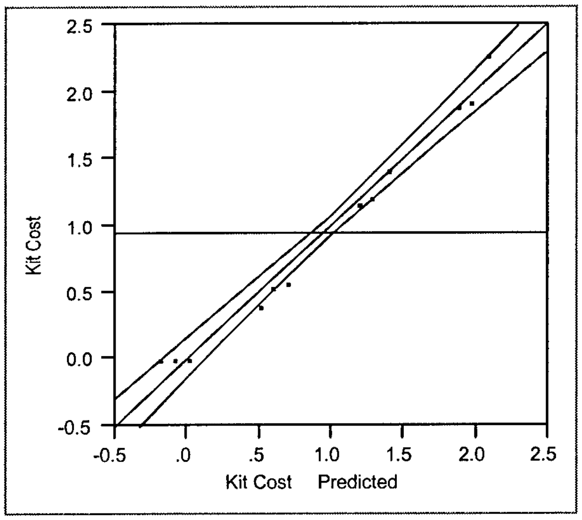
Summary of Fit

RSquare	0.982739
RSquare Adj	0.978903
Root Mean Square Error	0.118104
Mean of Response	0.9475
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	7.0658017	506.5653	<.0001
DO&SB	1	1	0.0814873	5.8420	0.0388

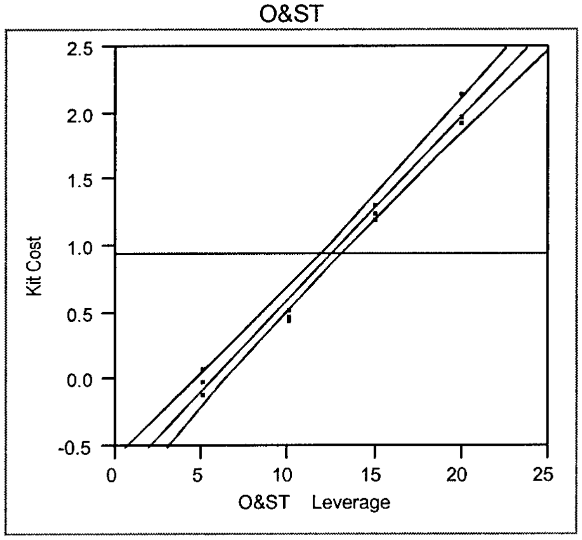
Whole-Model Test



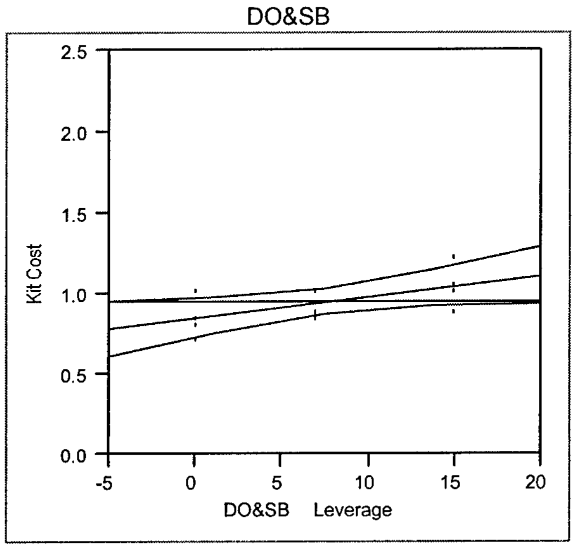
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	7.1472889	3.57364	256.2037
Error	9	0.1255361	0.01395	Prob>F
C Total	11	7.2728250		<.0001

O&ST



Effect Test			
Sum of Squares	F Ratio	DF	Prob>F
7.0658017	506.5653	1	<.0001



Effect Test			
Sum of Squares	F Ratio	DF	Prob>F
0.08148728	5.8420	1	0.0388

Figure 42. KC-135 Kit Cost

Response: KC-135 Kit Size

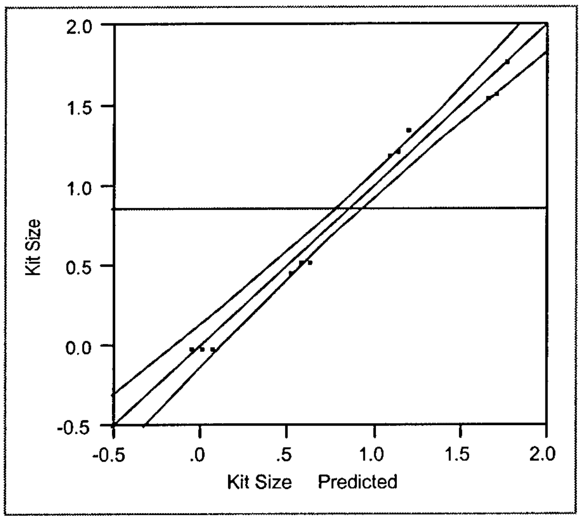
Summary of Fit

RSquare	0.981667
RSquare Adj	0.977593
Root Mean Square Error	0.100524
Mean of Response	0.855833
Observations (or Sum Wgts)	12

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	4.8450417	479.4653	<.0001
DO&SB	1	1	0.0247042	2.4447	0.1524

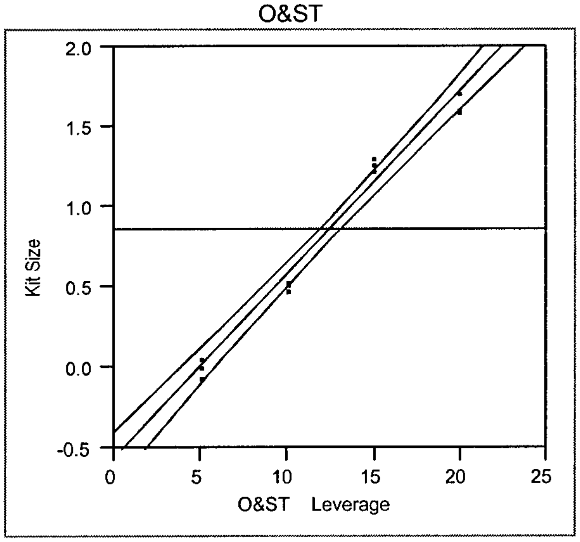
Whole-Model Test



Analysis of Variance

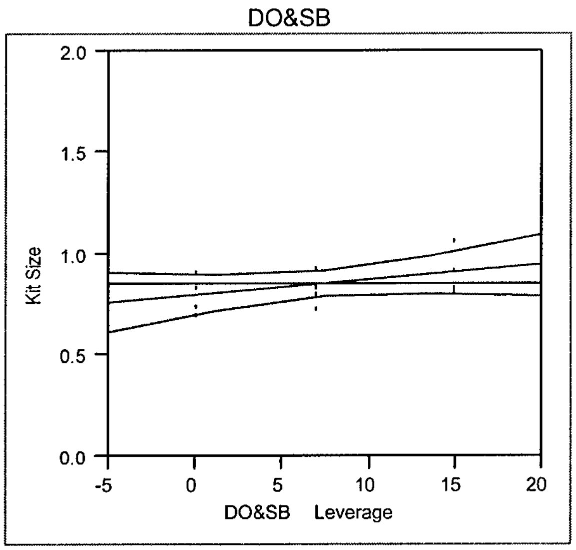
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	4.8697458	2.43487	240.9550
Error	9	0.0909458	0.01011	Prob>F
C Total	11	4.9606917		<.0001

O&ST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
4.8450417	479.4653	1	<.0001



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.02470417	2.4447	1	0.1524

Figure 43. KC-135 Kit Size

Appendix E: FSL Option Results

Table 26. FSL Option Results, B-52H

B-52H	# of Kits	7			
O&ST	Kit Cost	% Reduction	Kit Sum Cost	Depot Cost	Overall Cost
5	$11,502,026.89	82.62%	$80,514,188.23	$0.00	$80,514,188.23
10	$24,175,151.67	63.46%	$169,226,061.69	$0.00	$169,226,061.69
15	$35,005,635.20	47.09%	$245,039,446.40	$0.00	$245,039,446.40
20	$45,119,635.93	31.80%	$315,837,451.51	$0.00	$315,837,451.51
23*	$50,865,392.81	23.12%	$356,057,749.67	$0.00	$356,057,749.67

30-day Cost	$66,160,690.82	Overall 30-day Kit Cost	$463,124,835.74

O&ST	Kit Size	% Reduction	Kit Sum Size	Depot Size	Overall Size
5	6.25	79.43%	43.74	0.00	43.74
10	12.58	58.59%	88.04	0.00	88.04
15	16.19	46.69%	113.35	0.00	113.35
20	21.26	30.01%	148.81	0.00	148.81
23*	23.88	21.40%	167.13	0.00	167.13

30-day Size	30.37	Current Overall Kit Size	212.62

PAA =	8
Fly Hour Data	
1-30	63.6
Sorties/Day	2
Duration/Sortie	4

*Avg O&ST of kit file in D087

Table 27. FSL Option Results, F-15E

F-15E	# of Kits	3			
O&ST	Kit Cost	% Reduction	Kit Sum Cost	Depot Cost	Overall Cost
5	$349,725.54	97.49%	$1,049,176.62	$3,286,395.21	$4,335,571.83
10	$2,744,519.97	80.28%	$8,233,559.91	$3,286,395.21	$11,519,955.12
15	$5,011,562.15	63.99%	$15,034,686.45	$3,286,395.21	$18,321,081.66
20	$7,430,842.24	46.61%	$22,292,526.72	$3,286,395.21	$25,578,921.93
21*	$7,787,953.55	44.04%	$23,363,860.65	$3,606,465.48	$26,970,326.13

30-day Kit Cost	$13,917,843.06	Overall 30-day Kit Cost	$41,753,529.18

O&ST	Kit Size	% Reduction	Kit Sum Size	Depot Size	Overall Size
5	0.23	94.18%	0.68	1.70	2.37
10	1.20	68.96%	3.60	1.70	5.30
15	1.71	55.74%	5.14	1.70	6.84
20	3.33	14.00%	9.99	1.70	11.68
21*	3.43	11.39%	10.29	1.74	12.03

30-day Kit Size	3.87	Overall 30-day Kit Size	11.62

PAA =	24
Fly Hour Data	
1-10	70.25
11-30	48.25
Sorties/Day	2
Duration/Sortie	2

*Avg O&ST of kit file in D087

Table 28. FSL Option Results, F-16C

F-16C	# of Kits	17			
O&ST	Kit Cost	% Reduction	Kit Sum Cost	Depot Cost	Overall Cost
5	$6,671.80	99.91%	$113,420.60	$0.00	$113,420.60
10	$485,246.10	93.32%	$8,249,183.70	$0.00	$8,249,183.70
15	$1,458,352.82	79.94%	$24,791,997.94	$0.00	$24,791,997.94
20	$3,027,506.33	58.35%	$51,467,607.61	$0.00	$51,467,607.61
23*	$4,004,180.65	44.91%	$68,071,071.05	$0.00	$68,071,071.05

30-day Kit Cost	$7,268,632.46	Overall 30-day Kit Cost	$123,566,751.82

O&ST	Kit Size	% Reduction	Kit Sum Size	Depot Size	Overall Size
5	0.016	99.03%	0.27	0.00	0.27
10	0.145	90.93%	2.47	0.00	2.47
15	0.279	82.57%	4.75	0.00	4.75
20	0.494	69.20%	8.39	0.00	8.39
23*	0.668	58.33%	11.36	0.00	11.36

30-day Kit Size	1.60	Overall 30-day Kit Size	27.25

PAA =	18
Fly Hour Data	
1-10	56.2
11-30	38.6
Sorties/Day	2
Duration/Sortie	2

*Avg O&ST of kit file in D087

Table 29. FSL Option Results, KC-135

KC-135	# of Kits	14			
O&ST	Kit Cost	% Reduction	Kit Sum Cost	Depot Cost	Overall Cost
5	$232,220.07	96.86%	$3,251,080.98	$0.00	$3,251,080.98
10	$1,708,619.28	76.91%	$23,920,669.92	$0.00	$23,920,669.92
15	$3,092,886.70	58.21%	$43,300,413.80	$0.00	$43,300,413.80
20	$4,603,737.44	37.79%	$64,452,324.16	$0.00	$64,452,324.16
23*	$5,241,215.99	29.17%	$73,377,023.86	$0.00	$73,377,023.86

30-day Kit Cost	$7,400,212.85	Overall 30-day Kit Cost	$103,602,979.90

O&ST	Kit Size	% Reduction	Kit Sum Size	Depot Size	Overall Size
5	0.16	97.13%	2.22	0.00	2.22
10	1.13	79.47%	15.85	0.00	15.85
15	2.05	62.83%	28.71	0.00	28.71
20	2.80	49.16%	39.26	0.00	39.26
23*	3.55	35.68%	49.67	0.00	49.67

30-day Kit Size	5.52	Overall 30-day Kit Size	77.22

PAA =	12
Fly Hour Data	
1-30	81
Sorties/Day	2
Duration/Sortie	4.5

*Avg O&ST of kit file in D087

Table 30. Kit Size & Cost Comparisons

Single Deployment (1 kit from each weapon system)

O&ST	Kit Size	Delta	% Reduction	Kit Cost	Delta	% Reduction
5	6.65	34.72	83.93%	$12,090,644.30	$82,656,734.89	87.24%
10	15.06	26.31	63.60%	$29,113,537.02	$65,633,842.17	69.27%
15	20.24	21.13	51.08%	$44,568,436.87	$50,178,942.32	52.96%
20	27.89	13.48	32.59%	$60,181,721.94	$34,565,657.25	36.48%
Baseline	31.52	9.84	23.80%	$67,898,743.00	$26,848,636.19	28.34%
30-day	41.36			$94,747,379.19		

AF-wide (Total Costs & Sizes for all weapon systems)

O&ST	Total Size	Delta	% Reduction	Total Cost	Delta	% Reduction
5	48.59	280.11	85.22%	$88,214,261.64	$643,833,835.00	87.95%
10	111.66	217.05	66.03%	$212,915,870.43	$519,132,226.21	70.92%
15	153.64	175.06	53.26%	$331,452,939.80	$400,595,156.84	54.72%
20	208.14	120.57	36.68%	$457,336,305.21	$274,711,791.43	37.53%
Baseline	240.18	88.53	26.93%	$524,476,170.71	$207,571,925.93	28.35%
30-day	328.71			$732,048,096.64		

Actual Kits (FY 2000)

MDS	#	Sizes	Costs	C-17s	
B-52H	7	22	$45,250,000.00		
F-15E	3	19	$18,687,556.00		
F-16C	17	4	$13,341,306.33		
KC-135	14	21	$8,232,000.00		
Total		66	$85,510,862.33	3.67	0.36
Overall		573	$714,862,875.61	31.83	3.02

Applied Reductions

Single Deployment

O&ST	Kit Size	C-17s	Kit Cost	Savings	C-17s
5	10.61	0.59	$10,911,979.09	$74,598,883.24	0.32
10	24.02	1.33	$26,275,382.78	$59,235,479.55	0.25
15	32.29	1.79	$40,223,650.53	$45,287,211.80	0.19
20	44.49	2.47	$54,314,863.20	$31,195,999.13	0.13
Baseline	50.29	2.79	$61,279,584.88	$24,231,277.45	0.10

AF-wide

O&ST	Total Size	C-17s	Total Cost	Savings	C-17s
5	84.70	4.71	$86,143,384.62	$628,719,490.99	2.66
10	194.65	10.81	$207,917,556.37	$506,945,319.24	2.14
15	267.83	14.88	$323,671,904.57	$391,190,971.04	1.65
20	362.83	20.16	$446,600,090.57	$268,262,785.04	1.13
Baseline	418.68	23.26	$512,163,811.78	$202,699,063.83	0.86

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Vita

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His first assignment was Reese Air Force Base, Texas, where he was an Assistant Executive Officer for the Commander, 64th Operations Group, and a Student Pilot. Next, he was assigned to the 60th Supply Squadron, Travis Air Force Base, California, as Officer in Charge, Flightline Dedicated Support Element, and Commander, Supply Policy & Procedures Flight. He was also an Executive Officer for the Commander, 60th Air Mobility Wing. Then he was assigned to the 374th Supply Squadron, Yokota Air Base, Japan, where he was Commander, Combat Operations Support Flight, Commander, Fuels Management Flight, and Commander, Management & Systems Flight. He also served as a Logistics Plans Officer and an Assistant Installation Deployment Officer in the 374th Logistics Support Squadron. He entered the School of Engineering and Management, Air Force Institute of Technology, as a graduate student in August 1999. Upon graduation, he will be a Supply Analyst at the Air Force Logistics Management Agency, Maxwell Air Force Base-Gunter Annex, Alabama.

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14. ABSTRACT
One of the biggest considerations for an Aerospace Expeditionary Force (AEF), in terms of cost and airlift requirement, is the use of aircraft spares kits to support combat operations. To date, these kits are built on the assumption that there would be no resupply for the first 30 days of a contingency. However, with more efficient transportation and information resources available today, it seems logical that resupply would occur much more quickly. If so, the Air Force should be able to trim its wartime stocks of aircraft spares.

This thesis investigated the effect of improving the logistics pipeline on the size and cost of Air Force mobility readiness spares packages (MRSPs). By using the Aircraft Sustainability Model (ASM), it was shown that order and ship time was the most significant determinant of kit size and cost. Also, through an innovative use of the Forward Support Location (FSL) Option, a potential for significant savings in both airlift requirement and spares costs was identified. In addition, evidence to support the efficacy of the "pipeline on the fly" concept was presented. Under this model, aircraft spares would flow simultaneously from a depot as well as in a spares kit with a deploying unit.

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