ORDER & SHIP TIMES OF COMMUNICATION-ELECTRONIC COMPONENTS UNDER LEAN LOGISTICS AND CONVENTIONAL AIR FORCE REPARABLE PIPELINE: A COMPARATIVE STUDY

THESIS

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Presented to the Faculty of the Graduate School of Logistics

and Acquisition Management of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Transportation Management

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September 1995

Acknowledgments

I would like to thank Dr. William Cunningham, my advisor who provided me the academic freedom to pursue the study as I saw it and Captain Joni Lee, my reader and sponsor. Without her assistance and understanding of lean logistics principles, this study would not have been possible. I also would like to thank Mr. Rick Reed and his staff who provided the data I needed to conduct the study and Dr. Panna Nagarsenker whose statistical expertise was invaluable in selecting an appropriate methodology.

Most of all I want to thank my wife Kim and my children Pearson and Mackenzie. They have been my support through this time at AFIT and a source of joy that always brought things into perspective. They have been truly understanding and have consistently placed my work ahead of their own wishes. The sacrifices they have made during the past fifteen months will never be forgotten. I look forward to our next assignment to begin making up for lost time.

Clifford G. Altizer

Table of Contents

Page

Page

List of Figures

List of Tables

AFIT/GTM/LAL/95S-1

Abstract

Lean logistics (LL) is a new logistics system that applies state-of-the-art business practices utilized in private industry to Air Force logistics processes. Several LL demonstrations have been initiated to develop the best way to implement these new practices in the operational arena. This study focused on the Command, Control, Communications, and Computers (C4) lean logistics demonstration. The reparables in this demonstration differ from aircraft reparables in that they are highly reliable and high-value items. This research determines that the use of LL principles results in shorter order and ship times for the customer. As a follow-on to this finding, the study presents a methodology for comparing the cost of carrying inventory under LL and the traditional pipeline and demonstrates how LL principles result in considerably lower carrying costs.

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I. Introduction

General Issue

The beginning of the 1990s brought a considerable amount of change to the international political arena. The fall of the Berlin Wall and the demise of the Soviet Union have forced defense planners in the United States to reassess the threats to U.S. interests world-wide and formulate a way to counter these threats within increasing budgetary constraints.

Demand uncertainties, force downsizing, and cost reductions will continue to be areas of significant constraints for defense planners. The ability of future logistics processes to meet each of these challenges will be critical in providing support for the Defense Planning Guidance's requirement of fighting two major regional conflicts (MRCs) nearly simultaneously. The Department of Defense (DoD) Logistics Strategic Plan outlines the logistics mission as "To provide responsive support to ensure readiness and sustainability for the Total Force in both peace and war" (Office of the Deputy Under Secretary of Defense, 1994:3). To meet this objective, the logistics function in all of the services must reduce logistics response times, develop a seamless logistics system, and streamline the logistics infrastructure (Office of the Deputy Under Secretary of Defense, 1994:3). Searching for solutions for each of these areas, the Air Force has looked to the commercial sector to find ways of managing its assets more effectively.

The Air Force has introduced the concept of Lean Logistics (LL) which is based on state-of-the-art business techniques. Lean logistics is in various phases of testing and development throughout the Air Force. The purpose of this study is to examine the effectiveness of LL in a real-world environment by considering its application in the Command, Control, Communications, and Computers (C4) demonstration involving the depot at Sacramento Air Logistics Center (SM-ALC).

Background

The instability that has developed as a result of the vacuum created by the unraveling of the Soviet Union has forced the United States to accept a broader range of roles for its military; roles that include humanitarian actions like the operations in Somalia, Bosnia, and Rwanda, as well as international policing actions like the recent operation in Haiti. According to Pyles and Cohen, these additional taskings:

> will combine with the demand unpredictability experienced in contingencies like Desert Storm to require a logistics system that can rapidly readjust its operations to deliver both the kinds and amounts of goods and services needed by the forces in increasingly unpredictable venues and missions. (Pyles and Cohen, 1993:1)

The expansion of mission roles for the U.S. military reduces the excess capacity or "surge" capacity of the DoD which enables a quick response to contingencies world-wide. The current logistics system is not capable of responding quickly enough to the demand uncertainties of a peacetime environment, let alone the demand in a wartime environment especially when humanitarian missions or "operations other than war" are considered (Ramey and Pyles, 1993:1). Defense Planning Guidance calls for the support of two MRCs (HQ USAF/LGM-2,1995:10). If the DoD is to provide a force that can simultaneously fight a major regional conflict on two fronts and carry out these "operations other than war" with ever-decreasing budgets, then the leaders of each branch of service will have to develop and implement new logistics techniques that will be capable of supporting an extremely versatile combat force.

Attention has focused on the logistics pipeline as an area where significant savings in time and money may be realized. The current pipeline is a long support process that utilizes slow transportation, has an internal production focus rather than a customer focus, and uses outdated information systems. This has resulted in numerous resources and assets making their way to the wrong place, creating unfilled inventory levels and grounding aircraft. In addition, the requirements determination process is slow and unable to react to changing demands (HQ USAF Slide Package, 1995). Pyles and Cohen suggest that the Air Force needs a new logistics system that will better meet the demands of today's dynamic environment (Pyles and Cohen, 1993:1). As bases are realigned or closed, and the forward presence of the U.S. in other countries is reduced, it remains necessary for the U.S. to be able to provide a credible deterrent to any potential aggressor.

In order for the Air Force to maintain itself as a credible deterrent, it must continue to develop new techniques to manage its assets and people more efficiently and continue to advance its technological information base. It has been suggested that, in light of new innovations in business practices and increasing budgetary constraints, what is needed is a transformation rather than a continuation of the same concepts. (Pyles and Cohen, 1993:2). It requires a long-term prediction of demand that is not possible with any level of accuracy. Pyles and Cohen claim that this inevitably will "move the wrong material to the wrong places to meet outdated needs that no longer reflect the operational situation" (Pyles and Cohen, 1993:4). From this, it is determined that a new logistics system that can respond quickly, provide the flexibility to adjust for rapid changes in the operational environment, and be robust enough to function in a wide variety of scenarios is essential for mission readiness (Pyles and Cohen, 1993:4). The proposed lean logistics pipeline will afford a better response to the customer while allowing for lower inventory levels and shorter cycle times.

The LL Baseline Road Map has estimated a reduction in average cycle times from 63 days to 5-12 days (HQ USAF/LGM-2, 1995:8). This dramatic reduction will be accomplished by fully utilizing expedited transportation and improved repair processes at the depot and base. Improved technologies, commercial transportation infrastructure, and declining transit costs have paved the way to improved efficiencies and better quality in the logistics system.

Logistics Definitions

To better understand the concepts discussed in this study, it is useful to have a good grasp of the definition of logistics. Several definitions exist that are worth mentioning. The first is called the seven Rs. It addresses the activities of logistics and has a customer focus. It defines logistics as "ensuring the availability of the right product, in the right quantity and the right condition, at the right place, at the right time, for the right customer, at the right cost" (Coyle and others, 1992:6). This is often referred to as the layman's definition of logistics.

Another way to define logistics is through the inventory perspective. This perspective defines logistics as "the effective management and control of inventory (raw materials, goods in process, and finished goods) in motion or at rest in some facility" (Coyle and others, 1992:6). Some argue that this definition only partially defines logistics because it emphasizes the role of inventory in logistics rather than considering the overall systems perspective.

The Council of Logistics Management (CLM) is a professional logistics organization that defines logistics as:

> the process of planning, implementing and controlling the efficient, effective flow and storage of raw materials, in-process inventory, finished goods, services, and related information from point of origin to point of consumption (including inbound, outbound, internal, and external movements) for the purpose of conforming to customer requirements. (Coyle and others, 1992:6)

This definition focuses on the basic activities of movement and storage. These are fundamental activities of the logistics process. The use of the terms "planning," "implementing," and "controlling" implies a managerial focus of this definition as well. Effective logistics systems today require superior customer service and thus necessitate each of these actions (Coyle and others, 1992:7).

The Society of Logistics Engineers (SOLE) is another group whose interest is logistics processes. SOLE defines logistics as:

> the area of support management used throughout the life of the product or system to efficiently utilize resources assuring the adequate consideration of logistics elements during all phases of the life cycle so that timely influence on the system assures an effective approach to resource expenditures. (Coyle and others, 1992:8)

The SOLE definition is most closely associated with the military application of logistics because of its focus on the life-cycle of the system being supported. It ties logistical processes to resource requirements by considering how the logistical processes influence resource expenditures both now and in the future (Coyle and others, 1992:9).

Research Questions

The following are questions regarding LL that this research will address:

1. *How do LL order and ship times compare to the order and ship times of the current reparable pipeline of C4 demonstration NSNs?* Specifically, is the delay from when the customer places an order to when the customer receives the part shorter under LL and if

so, by how much? Order and Ship Time (O&ST) is used as a performance indicator because it directly affects customer service.

2. *How much money, in terms of inventory carrying costs, is saved by using LL principles versus the traditional pipeline model?* Lean logistics is an example of the classic trade-off between inventory costs and transportation costs. The increased cost of utilizing fast transportation is offset by significant reductions in inventory carrying costs. It is the inventory cost reductions that will be considered in this research.

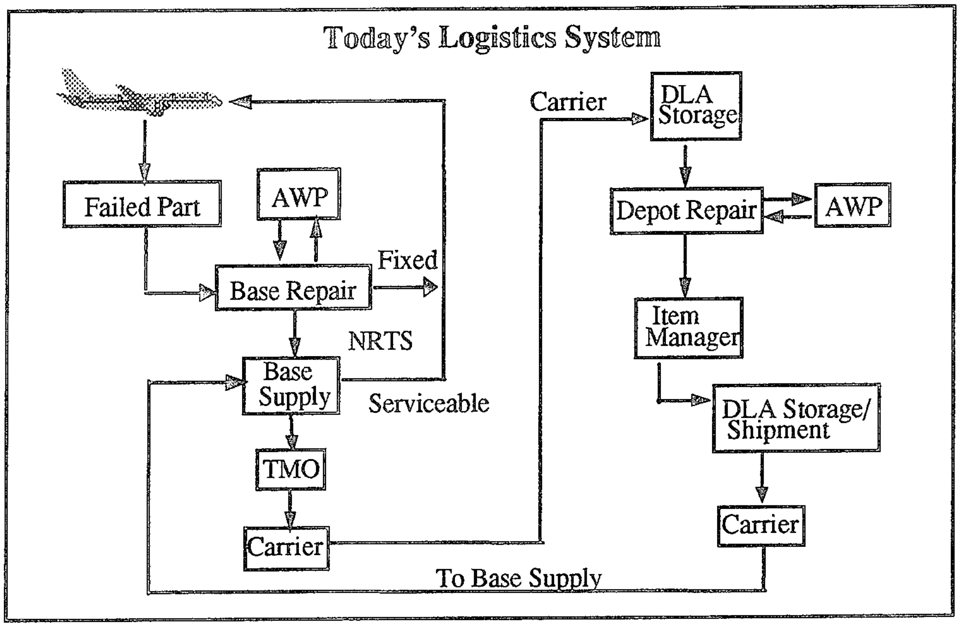
II. Literature Review

Introduction

In this chapter, a review of the concepts that lean logistics is built upon is presented. A brief discussion of the logistics pipeline is given as it currently exists to lay a foundation for understanding how lean logistics is designed to work. This is followed by some of the underlying theories that have led to the development of lean logistics. Specifically, the theory of constraints, just-in-time, and two-level maintenance are discussed. It is at this point that the lean concept is introduced. Its origins and development are considered as the chapter progresses. Next follows a discussion of the vision and tenets of lean logistics. Finally, a brief synopsis of the lean logistics demonstrations being conducted by the Air Force is presented.

The Current Reparable Pipeline

Figure 1 is taken from the USAF Baseline Lean Logistics Master Plan and Road Map, version 3.0. It illustrates the flow of the current logistics pipeline. When a part fails, it is sent to the repair shop to determine if local repair can be accomplished. If the part can be repaired, it is fixed and sent back to the user. If it cannot be repaired locally, then it is labeled Not Repairable This Station (NRTS) and is turned in to base supply who processes the part to the base traffic management office (TMO). From TMO, the part is shipped to DLA storage at the appropriate depot where it must await induction into the depot repair process which operates in batches. Once it has been repaired, it goes back to DLA storage until it is needed for shipment back to a base. Once the part has been returned to base-level, it either goes to the end user or base supply until a demand is placed for it. The average repair cycle time of this system is 63 days (HQ USAF/LGM-2, 1995:8). As a result of this long cycle time, the objective of the pipeline has been to fill it



Source: USAF Baseline Lean Logistics Master Plan and Road Map v. 3.0

Figure 1. Current Logistics Pipeline

up with as much inventory as possible to ensure that an adequate level of spares will be available when needed. One of the problems with this system is that only 10 to 20% of the flow time an asset spends in the pipeline is spent on value-added activity. The remainder represents sunk costs in the form of lost value (Ramey and Pyles, 1993:3).

In the past, transportation costs were expensive so the pipeline had to be structured in such a way as to provide maximum support to flying units around the world while minimizing transportation costs. This resulted in excessive inventory levels and slow response to changing demands (Pyles and Cohen, 1993:2). The deregulation of the transportation industry has contributed to a steady decline of transportation costs and increased accountability that have paid off for firms using just-in-time (JIT) techniques in the commercial sector. These techniques have received a considerable amount of attention by defense planners in the Air Force.

Just-in-Time

Just-in-Time is a production process that minimizes inventory by scheduling the arrival of components "just in time" for production. It is a customer driven system that "pulls" a product through the production process so that only the number of items needed are produced. Some of the benefits of JIT include the minimization of waste, establishment of a partnership relationship between the buyer and suppliers where both work together to produce a better item at a lower overall cost, a reduced number of vendors, and increased product quality (Ramey and Pyles, 1993:2).

Push vs. pull. In a "push" system, the manufacturer attempts to forecast what the demand will be and produces according to that forecast. The production output is then "pushed" through the production system to the end user. To illustrate this, Coyle uses the example of a caterer. Here, the number of people at a catered event is used to produce all the food needed at one time. The food is then taken to the event to be consumed by the end users (Coyle and others, 1992:219).

A "pull" system is one where the demand drives the production of the product. For instance, in a JIT system, when a part is withdrawn from the system by the customer, a demand is placed on the preceding activity of that production process to produce another part. This demand is then transferred to that activity's preceding operation which then performs its operation. The resulting chain reaction throughout the production process is driven ultimately by the initial withdrawal of one end-item by the customer. Coyle uses the example of a fast food restaurant to illustrate this concept. When a customer places a demand for a hamburger, the production process begins to fill this demand. Only the number of hamburgers demanded are produced (Coyle and others, 1992:218-219).

Lean logistics implies a utilization of the concepts of JIT in the reparable pipeline. Some of these concepts are: increased responsiveness to the customer while reducing inventory, eliminating non-value added activities, reducing batch sizes and machine setup times and using recent, local information to guide logistics processes (Ramey and Pyles, 1992:2). This will require the Air Force logistics community to move from the traditional pipeline which utilized a push system to the pull system utilized by JIT systems.

The Theory of Constraints

The intensification of global competition in the past twenty years has forced businesses to consider new manufacturing systems to remain competitive. In the early 1980s, a system called optimized production technology (OPT) was introduced by Eli Goldratt and was later called the theory of constraints (TOC) (Fawcett and Pearson, 1991:46). In their article, "The Evolution of the Theory of Constraints," Stanley Gardiner, John Blackstone, and Lorraine Gardiner state,

> TOC asserts that constraints determine the performance of a system and that any system contains only a few constraints. A constraint is anything that limits a system's performance relative to its goal. To improve the strength of the system one would first find the weakest link (constraint) in the chain and strengthen it. (Gardiner, Blackstone, Gardiner, 1994:13)

This approach to production allows a firm to identify its weakest links and produce according to their limitations. It also provides a starting point for management to increase production capacity. As long as the constraint is operating at 100% capacity, any improvement to any other process will not increase the production capacity of the system. The constraints must be addressed for the system's performance to improve.

Lean logistics uses this concept to address the constraints inherent in the logistics reparable pipeline (AFMC Slide Package presented to LtGen Farrell , 1995). Fiscal limitations as well as process shortfalls in the repair process require constant management to improve the overall system. The streamlining of depot processes will result in better system performance leading to reduced pipeline times.

Two-Level Maintenance

The Air Force maintenance program for reparables in the past involved three levels of maintenance: organizational, intermediate, and depot. At the organizational level, if a part needed maintenance, it was performed by flightline personnel. If flightline personnel were not able to perform the repairs, the part was then removed from the end item and sent to a backshop where the intermediate level repair was done. The backshop was usually located on the base but was part of another organization. If the intermediate level maintenance was not capable of performing the maintenance, the part was then shipped to the depot where it would be overhauled or condemned (James, 1992:6-7).

In Two-Level Maintenance (2LM), the intermediate repair function for avionics and engines is moved primarily to the depot (Slide Package, 1995). Figure 2 illustrates how the responsibilities have been distributed.

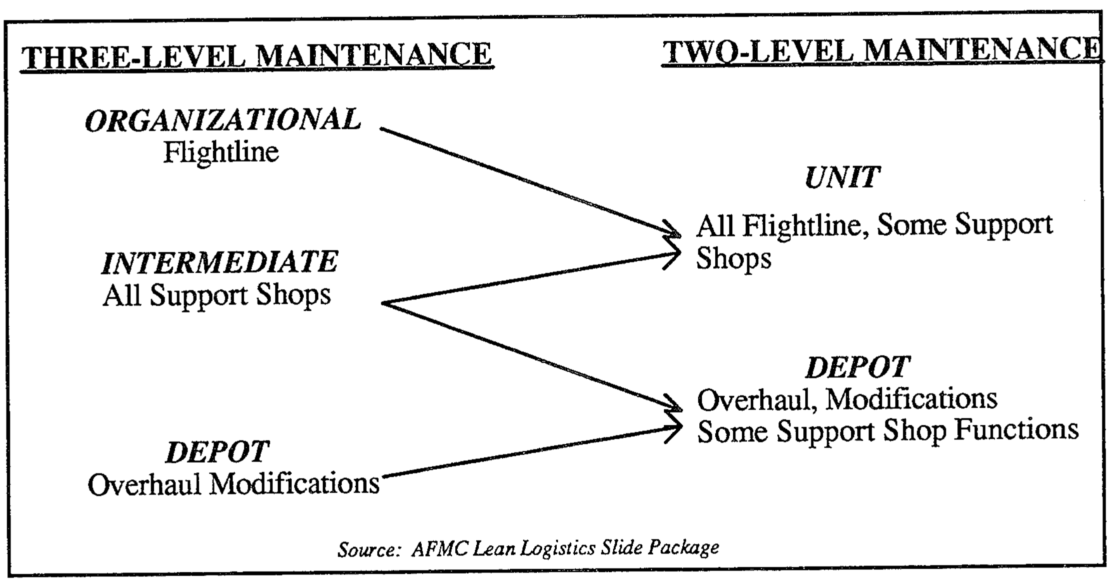


Figure 2. Two-Level Maintenance

When a part fails, if the flightline personnel cannot repair it, the part is sent to the depot for repair. This process utilizes a smaller mobility footprint in terms of personnel and equipment but stops short of the goal of reparable inventory reduction.

In July, 1991, the Air Force conducted a series of tests called CORONET DEUCE and CORAL THRUST/CORAL STAR for avionics and engines respectively. These tests resulted in significant reductions of pipeline times for avionics while those of engines met with mixed results (HQ USAF/LGM-2, 1995:22). The organizations using two-level maintenance have found that the operations tempo responsiveness provided equal or better customer support and shorter pipeline times than that of three-level maintenance (HQ USAF Slide Package, 1995). The demonstration proved that buffer stocks could be replaced by fast transportation at an affordable cost and that current inventory levels could consequently be reduced.

The Lean Concept

As a result of the successes realized by two-level maintenance, many believe that the idea of just-in-time can be applied to the Air Force logistics pipeline to reduce cycle times and inventories while enhancing the responsiveness of the system. The Air Force has been studying a manufacturing system based on JIT principles and used by Japanese automakers and being implemented by U.S. automakers. In their book, The Machine That Changed the World, James P. Womack, Daniel T. Jones, and Daniel Roos coin the term "lean production" to describe this system which has enabled Japanese automakers to acquire a larger market share of the U.S. auto market by offering high quality cars and trucks. This system was developed to adjust to a changing auto market that included expansion into a global arena (Womack and others, 1990:13).

In the auto industry, the use of lean production has the following primary goals: continually declining costs, zero defects, and zero inventories (Womack and others, 1990:15). This marks a significant departure from mass production principles utilized by Henry Ford early in this century. Womack suggests that the most striking difference between lean production and mass production lies in their ultimate objectives. "Mass producers set a limited goal for themselves-'good enough,' which translates into an acceptable number of defects and a maximum level of inventories." Lean producers, on the other hand, continually work to reduce their inventory levels and strive for perfection in the form of zero defects (Womack and others, 1990:15). Since the late 1970's, lean production concepts have been adopted by an increasing number of U.S. automakers as well as firms in other industries. For firms to remain competitive in today's economic environment, they must adopt business behaviors that improve responsiveness to customers' needs and reduce their costs (Ramey and Pyles, 1992:2).

Cohen and Pyles suggest the following about lean production and the Air Force logistics system:

> A logistics system based on lean production concepts would lessen the dependence on long-term predictions of buy and repair actions based on long-term historical data. Instead, it would seek ways to learn the users' new needs more quickly to adjust product mix rapidly, and to shorten production and delivery times dramatically (Cohen and Pyles, 1992:2).

Lean production is capable of providing greater responsiveness to meet variable demand while increasing quality by empowering the worker to control his or her output. Its continuous improvement processes allow for a smaller scale and result in lower cost (Cohen and Pyles, 1992:1).

Whether or not this lean production system of logistics would work in a wartime environment is a matter of considerable debate because it has never been attempted. It is generally agreed that what is needed is a system that incorporates the best qualities of lean production and is robust enough to function in a wartime environment (Pyles and Cohen, 1993:1). The objective of the logistics system will not change. It must continue to provide effective mission performance and aircraft availability while minimizing costs (HQ USAF/LGM-2, 1995:13).

Process Reengineering

Reengineering is a concept that is being widely implemented by firms in the commercial sector and by the U.S. government. It is the process of rethinking the way business is conducted. In their book, Reengieering the Corporation. A Manifesto for Business Revolution, Michael Hammer and James Champy define reengineering as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service and speed" (Hammer and Champy, 1993:32). Hammer points out four key words of this definition in his book, The Reengineering Revolution, a Handbook. The first is "dramatic." In the past, firms have tried to improve performance by 5 or 10 percent by improving or correcting a process. Reengineering attempts to make huge strides in improving the performance of some aspect of the organization (Hammer and Stanton, 1995:3).

The next key word is "radical." Radical implies throwing away the old way of doing business and getting to the root of a problem. This means tearing down the current processes and rebuilding them. Hammer cites the question posed by Edwin Artzt, the CEO of Procter & Gamble (P&G), when P&G implemented a reengineering campaign in 1993. He asked, "If Procter & Gamble did not exist today, how would we create it?" He then followed that question with the comment, "We are going to take this place apart brick by brick and put it back together again" (Hammer and Stanton, 1995:4). For the Air Force, this means looking at every aspect of the reparable pipeline process and determining how it can be done better, faster, cheaper, more efficiently, and more accurately.

The third key term in the definition is "process." Too often the symptoms of a bad process are addressed rather than the process needing repair. A process should be a collection of activities that create value to the customer (ALC-Reengineering Overview slide package, 1995). Those processes that do not meet the parameters of this definition by not adding value to the customer should be eliminated.

The last key word discussed by Hammer is "redesign." Reengineering deals with the design of processes a firm uses to accomplish work. A poor process design will result in poor results regardless of the motivation of the personnel carrying out the tasks. These processes should be redesigned so as to maximize the value added to the customer and to eliminate those activities that add nothing (Hammer and Stanton, 1995:5).

One of the problems in implementing reengineering campaigns is that often, reengineering is considered to be a "code word" for reorganizing, restructuring, or downsizing. Consequently, employees are wary of it and do not support its premise. This is where management's role enters into the process. Management should be careful to ensure that reengineering does not become a simple exercise in revising organizational charts. Also, employees should understand that reengineering is not a tool that exists primarily to eliminate jobs. While it is true that some jobs may be eliminated as a result of reengineering, it is also true that new types of jobs are created to support reengineered processes.

In the Air Force, reengineering is the methodology that allows logisticians to move from the concept of lean production to the lean vision of Air Force logistics. It has guided planners to a better way of managing the reparable pipeline. This new concept is discussed below.

Lean Logistics Vision

LL requires a total reengineering of current processes to meet changing demands. It encompasses all logistics activities and requires that all processes be redesigned to maximize the efficiency of the entire logistics process. The Air Force has defined the lean logistics concept as: "Maximize operational capability by using high velocity, just-in-time processes to manage mission and logistics uncertainty in-lieu of large inventory levels" (AFMC Slide Package, 1995). The vision of LL is based on two overarching principles: keep the part moving and reinventory the Air Force (AFMC Slide Package, 1995). Keeping the part moving will require the use of fast transportation from one point in the pipeline to the next. This will reduce the waiting time in all segments of the pipeline allowing for the next principle of the lean logistics vision, reinventory the Air Force. This principle involves leaning the inventory levels of the Air Force logistics system resulting in reductions in procurement and holding costs. The use of a consolidated serviceable inventory (CSI) located at the source of repair will significantly reduce the inventory costs at the base level (AFMC Slide Package, 1995).

The Tenets of Lean Logistics

In order to realize the vision of LL, the Air Force has identified several tenets or "keys" to LL. These tenets are the necessary parts of the LL system. Each tenet is briefly discussed below.

User in control. The first tenet is "user in control." Operational units already have control of intermediate and flightline level logistics processes. They do not control the distribution of the assets after repair is completed. Pyles and Cohen argue that "the operational units need more direct control of the distribution of equipment and material to maintain and adjust the balance of logistics resources across operational units in the field" (Pyles and Cohen, 1993:4).

One of the problems with the pipeline is that too often the wrong assets were received by the user at the wrong time. LL addresses this problem by placing the control of the demand requirements into the users' hands. With the user in control, only those parts that are needed are placed into the pipeline. This focuses the utilization of repair processes on those activities and assets that are required for mission readiness (AFMC Slide Package, 1995).

Consolidated inventory. The next tenet is the consolidated inventory. In an effort to maximize readiness in the past, Air Force units have ordered in excess of what their requirements actually were. This practice resulted in redundancy in the inventory and unnecessary expenditures. The consolidated inventory will reduce the inventory at the base level thereby reducing the costs associated with holding that inventory. The use of fast transportation will allow for the sustainment of mission readiness. It has already been shown that the savings afforded by the inventory consolidation will offset the increased costs of express transportation (AFMC Slide Package, 1995).

Customer driven repair. Customer driven repair is the next tenet to be discussed. Because LL is based on just-in-time concepts, it is classified as a pull system that is driven by the demands placed on the system. This concept makes sense because the function of the support units and depots is to keep the operational organizations mission-ready. To do this, the needs of the operational units must be met and no organization can better identify the needs of these organizations than the operational units themselves (AFMC Slide Package, 1995).

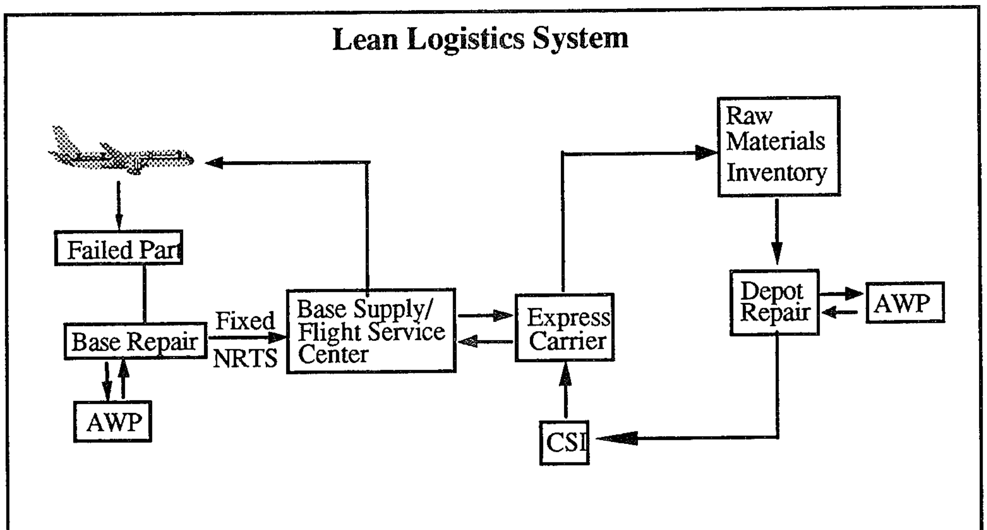
Innovation in contracting. DoD contracting practices have emphasized cost minimization in an environment of free and open competition. There are many who think that DoD contracting policies should move away from this free and open competition to a philosophy of managed competition. Frank Camm cites the "Great Engine Competition" as an example. The Air Force funded General Electric and Pratt and Whitney to develop engines for the F-16 and the F-15 and split its annual purchases of engines between the two manufacturers depending on the relative terms that they offered. This resulted in the Air Force receiving "remarkable responsiveness" by both contractors as well as a continuing improvement in the prices of the engines (Camm, 1993:2). Competition improves a buyer's leverage and this example clearly demonstrates what can happen if the DoD were to shift to a managed competition way of doing business.

Another innovation that is required in contracting is the inclusion of fast transportation to and from shippers. Currently, transportation is slow and delays the O&ST pipeline. Establishing a consolidated serviceable inventory (CSI) and contracting to move parts from there to the bases will be necessary for LL to be successful.

Tightened repair and manufacturing process. This would simplify the management of the logistics system by eliminating non-valued added processes. As stated above, only 10-20% of the time an asset spends in the pipeline is used on value-added operations. That represents an area where significant strides in efficiency may be made. The use of just-in-time principles will alleviate this issue by only inducting those carcasses needed by the operational units. This will reduce the number of items in the repair segment and allow for quicker turnaround times (Ramey and Pyles, 1993:3).

Fast transportation everywhere. In LL, fast transportation refers to the amount of time time required by the asset to get from the base to the depot and back again will be on the order of one to three days depending on the location of the base. Current standards state that CONUS bases will receive the asset in one to two days while OCONUS will need up to three days (Hill and Walker, 1994:30). If the pipeline can move the assets at this speed, the number of assets in the pipeline will be reduced because of the ability of the smaller number of assets required to maintain availability (Hill and Walker, 1994:30).

The lean logistics system is presented in figure 3. Using this system, a failed part proceeds through a similar process at the base level as under three-level maintenance. In LL, a failed part is processed for immediate shipment to the depot for repair via express carrier and a serviceable part is received from the consolidated serviceable inventory (CSI) maintained at the source of repair. Once the part arrives at the depot, it is inducted into repair based on shortages in the CSI. The batch size is extremely small or nonexistent under lean logistics. After the part has been fixed, it is sent to the CSI. The CSI is a buffer stock for all bases while the safety stocks at the individual bases are reduced. The only stock on-hand at the base is the leaned level that supports the basic requirements of the base.



Source: USAF Baseline Lean Logistics Master Plan and Road Map, V. 3.0

Figure 3. Lean Logistics Pipeline

As previously mentioned, the cycle time will be significantly reduced which in turn will allow for the smaller inventories of spares and provide substantial savings in reduced holding costs. The trade-off for this system is increased transportation costs but the deregulation of the transportation industry and technological improvements have resulted in significant reductions in the cost of transportation to the point that it is now more economical to replace safety stock with fast transportation (HQ USAF/LGM-2, 1995:36).

The Air Force has implemented the testing of lean logistics principles in several demonstrations. Each demonstration considers a different aspect of LL so that a solid understanding of the use of these techniques in the operational arena may be gained. Each of the demonstrations is briefly discussed below.

Lean Logistics Demonstrations

C-5 Demonstration. The C-5 lean logistics demonstration was the first demonstration conducted to test LL principles. It was composed of two phases. Phase I was designed to consider the concept of operating a central storage facility and command supply center to monitor 24 NSNs at six C-5 bases (HQ USAF/LGM-2, 1995:23). It demonstrated that the use of fast transportation and user involvement in repair priorities can effectively reduce the number of days an item spends in the repair cycle which in turn leads to reduced inventories. Decreased pipeline times and increased issue effectiveness for the 24 NSNs were the success criteria.

Lessons learned. This phase of the C-5 demonstration identified the need to collocate the CSI and the SOR and eliminate the CSF. This action would eliminate the additional transit time required to move the asset from the depot to the consolidated storage facility (CSF). There should also be a savings in the form of reduced second destination charges while adding one to two more assets into the total pipeline per NSN (HQ USAF/LGM-2, 1995b:5).

Lean logistics must be applied to an entire shop. Items involved with the LL demonstration have to be processed by the system if the test is to effectively represent how LL would work for the whole inventory. Hand-massaging a few of the items in the demonstration is expected but a better measure is taken if the whole shop operates from LL procedures (HQ USAF/LGM-2, 1995b:11).

Manual tracking of assets was excessive. Tools need to be developed to handle the tracking of assets and metrics. AFMC has already contracted with SYNERGY to produce better metrics and provide data analysis (HQ USAF/LGM-2, 1995b:11).

The second phase of this demonstration is the implementation phase. It implements the lessons learned from phase I and has a dual focus on critical item support and whole shop implementation. This phase began in January 1995 with 33 problem NSNs. The metrics for this demonstration are increased issue effectiveness at both the base and the CSI, reduced MICAP hours, reduced MICAP incidents, reduced MICAP cause codes, and increased RSP fill rates. SYNERGY will collect the data for AFMC. The goal for this demonstration is to develop system-wide/policy changes rather than specialized treatment (HQ USAF/LGM-2, 1995b:11).

Radar-Navigation Shop Demonstration. The Radar-Navigation shop demonstration uses 74 NSNs to demonstrate the potential of the LL concept. The primary objective of the Radar-Navigation shop demonstration is to illustrate the effectiveness of the LL concept by giving MAJCOMs input to the repair and distribution process, establishing lean base stock levels that will be supported by a CSI, streamlining pipeline segment processes, improving depot repair responsiveness to customers' demands, and decreasing transportation time by using priority shipment modes (HQ USAF/LGM-2, 1995:24). The metric for this demonstration is the CSI issue effectiveness. This will measure the ability of the depot to fill a demand from the CSI immediately (HQ USAF/LGM-2, 1995:24).

Oxygen Systems Shop Demonstration. This demonstration uses 23 master NSNs and 69 actual NSNs to determine the practicality of LL concepts for the oxygen shop at the Oklahoma City Air Logistics Center (OC-ALC). Priority shipment modes are utilized to allow for reduced inventories resulting from leaned base stock levels. Once again, the success criteria is the issue effectiveness of the CSI (HQ USAF/LGM-2, 1995:24-25).

F-16 Avionics Consolidation Demonstration. A multi-phased approach is used for this demonstration. Phase I implements a CSI at Ogden ALC and utilizes fast transportation to examine the impacts of LL on the pipeline. Distribution and Repair in a Variable Environment (DRIVE) is used to determine which LRUs (Line Replaceable Units) will be repaired and how distribution is scheduled. Phase II will attempt to develop and implement process improvements and validate the DRIVE data utilized in Phase I. Process improvements will center on stopping batch processes in favor of repair-on-demand, revisions to shop layouts to facilitate routing improvements, prepositioning, and floating stock availability. In Phase III, the interfaces between DRIVE, DMMIS, and the contractor will be developed. Success criteria include the ability to support the customer while reducing inventories, and realizing savings (HQ USAF/LGM-2, 1995:25).

Electronic Engine Controls Demonstration. This demonstration includes 25 NSNs that use extensive back shop support in the repair of components. Process improvements are direct induction into repair, fast movement of items from shops to DLA, and in-shop process improvements. Success criteria include improved customer support, issue effectiveness, and depot repair and response time. Pipeline reduction, inventory reduction, and visibility of CSI levels are also focal points of interest (HQ USAF/LGM-2, 1995:25).

E-3 Weapon System Conversion. This demonstration is another approach to the evaluation of LL. It focuses on "reducing MICAP drivers, implementing repair on demand, expediting distribution, using express transportation for the movement of critical items to and from the source of repair, and improved contractor support for specific items" (HQ USAF/LGM-2, 1995:26). This allows for reduced programmed depot maintenance (PDM) cycles and thereby reduces the number of aircraft in PDM at one time. The planning for this demonstration began in December 1994 and currently, the demonstration is underway.

Communications-Electronics Lean Logistics Demonstration. The C4 demonstration plan is included in Appendix A. Its primary purpose is to establish an approach to convert other systems into a lean operations mode. There are several distinguishing points in this study. First, it is the first demonstration of LL principles on non-aircraft reparables. These parts are low demand, high value parts that have a high mean time between failure. Second, it highlights the actual reduction of C4 inventory levels. One of the problems that had to be addressed in the preparation for this demonstration was what to do about the excess inventory. Because of the high mean time between failure rates of these parts, establishment of the new CSI levels resulted in an excessive level of inventory. The serviceable excess was placed in condition code "B" and the unserviceable excess was placed in condition code "J". For purposes of the demonstration, all of these assets were then considered to be unusable. This allowed the depots and bases to test the adequacy of the CSI levels in terms of operations.

The demonstration is divided into two separate parts. The first part is an evaluation of the total pipeline for 109 Air Traffic Control and Landing System (ATCALS) components. It sets up a CSI at the Source of Repair (SOR) and utilizes express transportation to move the parts from the bases to the depot and from the depot back to the bases. It focuses on depot repair shop process improvements. The second part of the demonstration uses a CSI and express transportation but does not employ changes to depot repair priorities. The major difference between the two demonstrations is in the partial demonstration, not all items in the depot repair shop are LL items.

These demonstrations are important for the implementation of LL in the Air Force as they will identify the areas where LL will need to be improved and those areas where LL is an improvement over current processes. There is a sufficient level of difference in the parts being used to provide a fairly generalizeable application of LL across the Air Force.

III. Methodology

Introduction

This study considers the effectiveness of LL concepts in a real-world application by evaluating the performance of the C4 depot conversion demonstration conducted by SM-ALC. The demonstration plan is included in appendix A. It was selected for study for two reasons: 1) because it provides an opportunity to observe the performance of LL on assets that are widely distributed (there is comm equipment of some type at every base that has a runway); and 2) because of the large number of national stock numbers (NSN) relative to the other demonstrations currently under way. In this demonstration, assets are broken into two categories: Total Pipeline Demonstration; and Partial Pipeline Demonstration. The total pipeline demonstration will track assets through the repair process as well as transportation times. The partial pipeline demonstration will involve tracking only the transportation times of selected items (HQ USAF/LGM-2, 1995:23). This study examines only the total pipeline demonstration in order to allow for depot processes in establishing order and shipping times (O&ST) and to limit the number of NSNs to a manageable amount. Appendix D presents a list of the NSNs that were used in this study.

Data

The pipeline times for this study were obtained from the Air Force Logistics Information File (AFLIF) maintained by Air Force Materiel Command (AFMC). AFLIF provides the number of days an asset spends in the retrograde (base to depot) and replenishment (depot to base) segments of the pipeline and allows each item to be tracked by National Stock Number (NSN), Transportation Control Number (TCN), or Requisition Number. AFLIF captures supply transaction records (D6 records) every fifteen minutes and airlift and sealift movement information every hour (AFLIF User's Guide, 1995:6). By searching the on-line pile of D6 records for matches to the NSNs used in the C4 demonstration, the data for this study was extracted and sorted. The script for this operation is given in Appendix B. The data were collected over a twelve-month period beginning May 1994 and ending April 1995. This allows for the collection of pipeline performance measures for five months prior to the demonstration start date on 1 October 1994 and the collection of pipeline performance measures for seven months during which LL procedures were used. By collecting order & ship time (O & ST) data from the LL demonstration and O & ST data from the traditional pipeline from AFLIF, a comparison of the LL system and the current pipeline system is possible. The primary variable is O & ST under each system. If a significant reduction in O & ST is noted, then the potential exists for inventory reductions to occur that would eliminate many of the costs associated with holding inventory.

The use of a simple database that is capable of sorting records and processing queries on those records allows for easy analysis of the data. In this study, the data from AFLIF was entered into a Microsoft Works 3.0 database for storage and processing. Queries were run on this database to group the data according to three categories: aggregate O & ST; CONUS and overseas O & ST; and MAJCOM O & ST. This arrangement of the data allows for the evaluation of O & ST under the current pipeline system and under LL on an aggregate basis, according to location (overseas vs. CONUS), and by MAJCOM. It should be noted that only the MAJCOMs that were involved in the data sample are included in this study. Those MAJCOMs that are not included did not have any transactions in the C4 demonstration during the twelve month period.

LL vs. Current Pipeline

The first part of this study requires that the means of two populations (LL O&ST and current pipeline O&ST) be compared to determine if there is a significant difference between them. Several statistical tests exist that compare the means of two populations. The preferred test is the Large-Sample Test of Hypothesis for (μ_1-μ_2). The assumptions for this test are that the two sample sizes are randomly selected in an independent manner from the two populations and that the sample sizes are large enough so that the O&ST of the current pipeline sample (μ_1) and LL sample (μ_2) each have approximately normal sampling distributions and so that the variance for each sample (s_1^2 and s_2^2) provides a good approximation to the variance of the data population (σ_1^2 and σ_2^2). According to McClave and Benson, this will be true if the number of observations is large. They define large as being n_1 and $n_2 \geq 30$ (McClave and Benson, 1994:393). Because the sample sizes involved are both greater than 30, this test is used to compare the aggregate means of the data.

Variables: μ_1 = Current Pipeline O & ST
μ_2 = Lean Logistics O & ST

Hypothesis: H_0: $(\mu_1 - \mu_2) = D_0$
H_a: $(\mu_1 - \mu_2) > D_0$

where D_0 = hypothesized difference between the means (0).

Test statistic: $$z = \frac{(\bar{x}_1 - \bar{x}_2) - D_0}{\sigma_{(\bar{x}_1 - \bar{x}_2)}} \text{ and } \sigma_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

Rejection Region: $z > z_{.05}$

The same procedure is used to compare the populations for the CONUS O&ST.

The other subsets of data to be analyzed are that of the overseas O&ST and MAJCOMs. These data sets are composed of several small groups of data that do not meet the assumptions of the large-sample test of hypothesis. Due to the nature of the data, a nonparametric test is required to compare the means of the two samples for each group.

The Kruskal-Wallis H Test

The Kruskal-Wallis H test is a nonparametric test that allows a comparison of *p* populations without assumptions concerning the population probability distributions. It uses an H statistic to measure the extent to which the *p* samples differ with respect to their relative ranks (McClave and Benson, 1994:945). The H statistic is calculated as follows:

$$\text{Test Statistic: } H = \frac{12}{n(n+1)}\sum_{j=1}^{p}\frac{R_j^2}{n_j} - 3(n+1) \tag{1}$$

where

n_j = Number of measurement in sample j
R_j = Rank sum for sample j, where the rank of each measurement is computed according to its relative magnitude in the totality of data for the p samples
n = Total sample size = $n_1 + n_2 + \ldots + n_p$

Rejection Region: $H \rangle \chi_{\alpha}^{a}$ with $(p-1)\ df$

Assumptions:
1. The p samples are random and independent.
2. There are 5 or more measurements in each sample.
3. The p probability distributions from which the samples are drawn are continuous.

Ties: Assign tied measurements the average of the ranks they would receive if they were unequal but occurred in successive order. For example, if the third and fourth-ranked measurements tie, rank both (3 + 4)/2 = 3.5. The number of ties should be small relative to the total number of observations. (McClave and Benson, 1994:947)

The results of this test are included in chapter IV.

Cost Assessment of LL vs. Traditional Pipeline

The cost of the pipeline is difficult if not impossible to determine. Due to the dynamic nature of real-world demands, no standard model has emerged that can accurately quantify the savings of a one-day reduction of pipeline length. It was decided that the best measure of this characteristic of LL was to compare the inventory carrying costs under each system. Inventory carrying costs are those costs that vary with the level of inventory stored. They are made up of capital costs, inventory service costs, storage costs, and inventory risk costs (LaLonde and Lambert, 1976:21).

Capital Cost. Capital costs are the largest part of inventory carrying costs. They are sometimes referred to as the opportunity cost of inventory investment. It is the cost of having money tied up in inventory rather than in some other money-making investment (Coyle, Bardi, and Langley, 1992:200).

Storage Space Cost. Storage space cost is the cost associated with moving the inventory into and out of storage and the cost of storage such as heating, electricity, and rent. These costs experience a significant degree of variation because the storage requirements for different commodities will differ. For example, some items require refrigeration while others can be stored outside (Coyle, Bardi, and Langley, 1992:200).

Inventory Service Cost. Inventory service costs include insurance premiums and taxes. As with the storage space cost, the nature of the commodity being stored will drive this cost. As the value of the commodity increases, so will the cost to insure the assets (Coyle, Bardi, and Langley, 1992:201).

Inventory Risk Cost. This cost encompasses risk and obsolescence of the product being stored. These are the costs that the firm cannot control. Usually, these costs are driven by events that render the product useless or out of style. Agricultural commodities that spoil in storage are an example of an inventory risk cost (Coyle, Bardi, and Langley, 1992:201).

All of the above costs are considered when a firm calculates its holding costs. Each one is calculated as a percentage of product value and then the percentages are added together to get a total inventory carrying cost percentage of product value. This figure is then multiplied by the inventory cost to arrive at an annual cost of carrying the inventory (Coyle, Bardi, and Langley, 1992:201-202). Table 1 illustrates how the inventory carrying costs are calculated.

TABLE 1. Example Calculation of Annual Inventory Carrying Cost

Unit Price	$100.00
Total inventory	10
Capital cost*	15
Storage space cost*	3
Inventory risk*	2
Inventory service*	5
Total*	25
Inventory Carrying Cost	$250.00/year

* Expressed as a percentage of product value.
Source: The Management of Business Logistics *5th edition*

If a firm held only one product whose unit price was $100 and the firm had 10 in inventory with the inventory carrying costs specified in table 4, the total carrying cost is 25% of the inventory cost which is $1000.00. That is,

$$\$1000 * 25\% = \$250 \text{ per year} \tag{2}$$

Thus, the inventory carrying cost on an annual basis would be $250.00.

There is no generally accepted procedure for establishing what holding costs are for a firm although LaLonde states, "a number of authors have addressed the types of costs that should be considered and have estimated that such costs range from 12% to

35%" (LaLonde and Lambert, 1976:16). Currently, data does not exist to determine the inventory carrying costs for the Air Force. For purposes of this study, a sensitivity analysis will be performed using a range of percentages to develop a better understanding of how a reduction of O&ST will impact the Air Force in terms of dollars saved through reduced inventory carrying costs. Using LaLonde and Lambert's work as a reference, the figures used here are 15%, 20%, 25%, 30%, and 35% to determine the inventory carrying costs at each level.

The inputs required for this analysis are price per unit of each NSN in the C4 demonstration and the quantity of each of those NSNs. The unit cost of each NSN in the study was obtained from the Air Force Master Item Identification Database (D043A) and the quantity of each NSN in the Air Force inventory was obtained by querying the D035A Item Manager System for each NSN involved in the C4 demonstration. Once completed, the inventory carrying costs were computed at each of the above percentages using the formula and then that result was divided by 365 to get a daily inventory carrying cost. From these computations, the savings realized by reduced O&ST that result from LL principles were calculated. The results are included in chapter IV.

IV. Results and Analysis

Introduction

This chapter presents the results and analysis of the data collected using the methodology described in chapter III. First, the results of the large-sample test of hypothesis are presented and discussed. This is followed by a discussion and presentation of the results of the Kruskal-Wallis H test. Once the comparison of O&ST populations is complete, the chapter moves into the impacts of LL principles on inventory costs. A sensitivity analysis is performed using the methodology described in chapter III to develop a better understanding of the effect of reduced O&ST on daily holding costs. Finally, the chapter concludes with a brief summary of the two research questions that this study has addressed.

Comparison of Order & Ship Times

Large-Sample Test of Hypothesis. Using Excel version 4.0, a large-sample test of hypothesis was performed on the aggregate sample and the CONUS sample. The results strongly indicate a significant difference in the O&ST of LL and the traditional pipeline. The test is given in tables 2 and 3.

Excel requires a known variance for each variable as an input to calculate the test. By invoking the Central Limit Theorem, the variance of the sample is a good estimate of the actual population variance because $n > 30$ (McClave and Benson, 1994:282). Consequently, the variance of the data sample was used in this test. Based on the data, there is clearly a significant difference between the two population means as evidenced by the fact that the z-statistic is 6.62 for the aggregate data set and 5.36 for the CONUS data set with rejection regions of 1.64 for both sets of data. The p-values generated suggest that the probability of the test failing to reject the null hypothesis is extremely small.

TABLE 2. Large Sample Test of Hypothesis for Aggregate Data		
	Traditional Pipeline	Lean Logistics Pipeline
Mean	39.36882129	14.38095238
Known Variance	*3186.333	*223.6804
Observations	263	105
z	6.620464762	
P(Z<=z) one-tail	1.79982E-11	
z Critical one-tail	1.644853	
* Variance was calculated from data sample		
** Test was based on a .05 level of confidence		

TABLE 3. Large Sample Test of Hypothesis for CONUS Data		
	Traditional	Lean Logistics Pipeline
Mean	36.3559322	11.37662338
Known Variance	*3603.594	*100.4747
Observations	177	77
z	5.366727529	
P(Z<=z) one-tail	4.01775E-08	
z Critical one-tail	1.644853	
* Variance was calculated from data sample		
** Test was based on a .05 level of confidence		

Kruskal-Wallis H Test. The remaining data sets were analyzed using the nonparametric Kruskal-Wallis H test as set forth in chapter III. This study utilized an analytical software package called Statistix version 4.0 to run this series of tests. The results of these tests are summarized in table 4 below.

TABLE 4. Kruskal-Wallis One-Way AOV Results		
Data Set	H Statistic	P-Value Using Chi-Squared Approximation
Overseas	8.5033	0.0035
ACC	0.4498	0.5024
AETC	1.4518	0.2282
AFMC	3.1850	0.0743
AMC	1.3212	0.2504
ANG	7.8630	0.0050
PACAF	6.7234	0.0095
USAFE	5.0368	0.0248

From this test it is fair to say that the mean O&ST for LL is significantly shorter than the mean O&ST under the traditional pipeline at practically every level of usage. The statistical analysis for these tests can be seen in Appendix C. The results of the above tests clearly indicate that LL principles result in shorter O&ST than the traditional system.

Impacts on Holding Costs

The focus now turns to research question #2: How much money is saved by using LL principles versus the traditional pipeline model? To address this question, the inventory costs were used as a way to compare the two systems and identify what the savings gained in are in LL. The data for this analysis was collected by querying the D035A Item Manager system to obtain the number of line items for each NSN in the inventory and the unit cost for each NSN. By multiplying the unit price by the number of units for each NSN and then summing these products for all NSNs in the demonstration, a total inventory investment for the C4 demonstration can be determined. This investment is presented in tables 5 and 6 for each system under the heading "Inventory Investment." The annual cost of holding inventory was calculated by multiplying the inventory investment by each percentage factor of the analysis. This factor is found under the "Inventory Costs" heading in tables 5 and 6. The results of this computation are shown in the tables under the column labeled "Annual Inventory Carrying Cost." This product was then divided by 365 to obtain a daily cost of holding inventory. It should be noted that the reduced LL inventory level of the CSI has the effect of further reducing this cost. Once these calculations were completed, the average length of the pipeline under each system was used to find the average daily carrying cost of each pipeline. This was done by multiplying the daily inventory carrying costs by the average length of the pipeline. Tables 5 and 6 present the results of these calculations.

TABLE 5. Inventory Carrying Cost of Traditional Pipeline

Inventory Costs	Inventory Investment	Annual Inventory Carrying Cost	Daily Inventory Carrying Cost	Average Length of Pipeline in Days	Average Annual Inventory Carrying Cost of Pipeline
15%	$14,377,783.55	$2,156,667.53	$5,908.68	39.37	$232,624.66
20%	$14,377,783.55	$2,875,556.71	$7,878.24	39.37	$310,166.21
25%	$14,377,783.55	$3,594,445.89	$9,847.80	39.37	$387,707.77
30%	$14,377,783.55	$4,313,335.07	$11,817.36	39.37	$465,249.32
35%	$14,377,783.55	$5,032,224.24	$13,786.92	39.37	$542,790.87

TABLE 6. Inventory Carrying Cost of Lean Logistics Pipeline

Inventory Costs	Inventory Investment	Annual Inventory Carrying Cost	Daily Inventory Carrying Cost	Average Length of Pipeline in Days	Average Annual Inventory Carrying Cost of Pipeline
15%	$2,572,707.43	$385,906.11	$1,057.28	14.38	$15,203.64
20%	$2,572,707.43	$514,541.49	$1,409.70	14.38	$20,271.52
25%	$2,572,707.43	$643,176.86	$1,762.13	14.38	$25,339.41
30%	$2,572,707.43	$771,812.23	$2,114.55	14.38	$30,407.29
35%	$2,572,707.43	$900,447.60	$2,466.98	14.38	$35,475.17

To bring these results into perspective, table 7 illustrates a comparison of the costs for each system and gives an indication of the savings that can be gained by the utilization of LL principles.

TABLE 7. Comparison of LL Pipeline and Traditional Pipeline Inventory Costs

Inventory Carrying Costs	Traditional Pipeline	Lean Logistics Pipeline	Savings	Percent Savings
15%	$232,624.66	$15,203.64	$217,421.02	93%
20%	$310,166.21	$20,271.52	$289,894.69	93%
25%	$387,707.77	$25,339.41	$362,368.36	93%
30%	$465,249.32	$30,407.29	$434,842.03	93%
35%	$542,790.87	$35,475.17	$507,315.70	93%

This data clearly indicated that the use of LL principles can save a significant amount of money that may be used for other operations. The rationale of this reseach is that each day an item spends in the pipeline, inventory costs are increased by the amount shown in the daily inventory carrying cost columns of tables 5 and 6 for each method, depending on which percentage factor is used. According to the data obtained in this research, a reduction of the O&ST pipeline equates to the amount of dollars saved in table 7 multiplied by the length of the pipeline in days. At each percentage level, there is an annual reduction in the inventory carrying costs of 93% for the reparable pipeline. This is clearly a significant savings that the Air Force stands to gain from the utilization of LL principles.

Conclusion

This chapter has presented the results of the tests performed to determine if lean logistics principles result in shorter pipeline times and how those reductions equate to dollars saved for the Air Force. The results showed that there is a significant difference in the means of the O&ST of LL and the traditional pipeline at every level of analysis.

V. Recommendations and Conclusions

Introduction

This chapter begins by discussing the limitations of the study. This is followed by the findings of this research and explains the conclusions that may be drawn from them. The research questions are restated and then each is addressed in terms of the results of this research. Finally, recommendations for further research are presented.

Limitations of the Study

This research is designed to examine the performance of LL principles in the C4 depot conversion demonstration. It evaluates the effects of these principles on the time an asset spends in the repair cycle as well as LL's ability to respond to customer demands quickly. Listed below are the limitations that defined the scope of this research.

1. *A peacetime environment was assumed.* The demands of a wartime environment are significantly different and an accurate assessment of LL's performance in a wartime scenario cannot be made until there is a test of LL concepts during an exercise or deployment.

2. *The components considered are only C4 components.* These are usually high value, low demand items that have a low failure rate. Other demonstrations are examining LL performance with aircraft components that have a high failure rate, may be high or low valued items, and may be high or low demand items. The purpose of this demonstration is to evaluate LL with C4 components to determine the viability of applying LL principles to parts other than aircraft parts.

3. *An in depth analysis of all demonstrations is not practical due to time constraints.* Recently, there have been eight LL demonstrations conducted in various geographical locations. Each demonstration is examining a separate characteristic of LL. To attempt

to consider each demonstration in detail would force the focus of this study from the demonstration of interest.

Revisiting the Research Questions

This research set out to examine the viability of the Air Force logistics system to function under LL principles for non-aircraft reparables. The C4 demonstration conducted by AFMC presented an opportunity to examine the effectiveness of LL for these parts over a set period of time. The first question to be considered was: *How do LL order and ship times compare to the order and ship times of the current reparable pipeline of C4 demonstration NSNs?* It was hypothesized that the O&ST for LL would be smaller than for the traditional pipeline. The data strongly supported this hypothesis at nearly every level of implementation. This was believed to be the starting point for this research because if a difference did not exist, it would not be practical for the Air Force to pursue LL principles for these types of components. Also, O&ST were selected as a performance indicator because of the bearing it has on customer service. The whole idea of LL is to be more responsive to the end-user. If that end-user has to wait more than a few days for the part, it should not be assumed that LL is more responsive.

The next question that was considered was: *How much money is saved by using LL principles versus the traditional pipeline model?* As stated in earlier chapters, there is no hard and fast way to measure the impact of a one-day reduction of the O&ST pipeline. Inventory costs were used as a way to measure the performance of LL and make a comparison to the current pipeline. The methodology used to address this question is similar to that used by the private sector and its performance is directly driven by the O&ST pipeline. This research clearly indicates that substantial savings will be realized by the Air Force as it implements LL principles into the logistics pipeline.

Recommendations for Further Research

As the research progressed, many questions arose that were beyond the scope of this study. The possibilities for further research are abundant in this area as lean logistics is in the early stages of implementation. A few suggestions are given below.

This study only considered how much money could be saved by reduced inventory carrying costs. It did not consider the increased expenditures necessary for fast transportation. A study could be performed that would identify how much more was being spent for transportation so that a more complete understanding of the net effect of LL principles would be obtained.

One of the problems with the cost assessment portion of this research was that there were no inventory holding cost data available. This resulted in the arbitrary assigning of five percentage "factors" to get an estimate of the savings resulting from LL. Research could be done that would identify each of the costs associated with holding inventory for the Air Force and develop a model for determining what these costs are. If actual data were available in this area, the impact of implementing LL could be better illustrated in terms of dollars saved.

Another option would be to examine the effect of implementing LL on inventory levels. The current LL demonstrations have generated some data in this respect. Perhaps a study with a slightly broader focus could investigate what the impacts are of lower inventory levels to aircraft availability. Fewer parts mean that utilization rates will increase. As parts get older, their mean time between failures will decrease requiring the procurement of replacement components. This will place a demand on the acquisition system to keep replacement parts available within a relatively short period of time from manufacturers.

The research conducted in this study was narrowly focused on a single LL demonstration and for a certain type of reparable. Other studies similar to this one could be performed for other demonstrations of LL to develop a broader understanding of the effectiveness and efficiency of LL.

Conclusion

This research has proved that lean logistics saves money and improves customer support throught shorter order and ship times. In a time when fiscal realities dictate that logistics processes become more efficient, lean logistics demonstrates that the Air Force can meet the challenges of future operational requirements by using improved logistics processes. The most important aspect of any military system is that it be effective while efficiency receives a secondary consideration. Lean logistics has proved that it can improve the efficiency of the logistics pipeline while maintaining operational effectiveness.

APPENDIX A

- DRAFT ONLY -

AF C4 LEAN LOGISTICS PLAN

(Third Edition Supercedes the 1 February 1995 Plan)

1 JULY 95

This Plan is intended to transmit instructions for the Lean Logistics Demonstration that will be conducted in the Communications - Electronics community.

AF C4 LEAN LOGISTICS PLAN

1. Purpose. This plan is a "living document" that establishes actions, goals, and timelines associated with Lean Logistics implementation for the Communications-Electronics community. Participants include: MAJCOMS/FOA LG/SC, HQ USAF/LG/SC/XO,HQ AFC4A/SY, HQ AFMC/ LG/DO/XR/CI, AFLMA/LG, HQ AFFSA/XR, AWS/PM, SM-ALC/LH/FM, (appropriate SPDs/SSMs) SM-ALC/LGS, and Defense Logistics Agency (DLA), Base Supply and Communications personnel.

2. Objective. The primary objective of this effort is to demonstrate the premise of the Lean Logistics concept for AF C4 and establish an approach to convert other systems into a lean operations mode by:

a. Involving the customer in determining base and Consolidated Stockage inventory lean levels and mission essential items.

b. Reducing spares levels at each retail and wholesale level.

c. Decreasing transit times for repair cycle assets moving to and from depot repair.

d. Streamlining base and depot repair processes.

e. Streamlining depot procurement processes.

f. Improving support to the field.

Note: The first phase will be comprised of two concurrent plansnstrations in the ATCALS area. The first stage will be the Total Pipeline effort which will involve items worked in the Navigational Aid shops. In this stage, a selected number of NSNs will be monitored from the time the user's request is received until the reparable is repaired and takes its place in the supply system. This will include tracking the asset throughout the entire pipeline and repair shop process.

The second part in the ATCALS area will be a Partial Pipeline effort which will regionalize selected NSNs for various ATCALS systems. This effortnstration will measure asset movement through the pipeline and does not include any internal shop tracking. This portion of the LL effort may expand to additional items/systems as the effort progresses.

3. Definitions.

a. Awaiting Part (AWP) Time. Elapsed time a reparable spends awaiting parts while in the repair cycle.

b. **Base Lean Level.** Quantity authorized for stock by either a base demand level or fixed level. The base level is influenced by the base daily demand rate, base repair cycle time, percent of base repair, and order and ship time (OS&T) from the Consolidated Serviceable Inventory (CSI). These levels may fluctuate based upon use at the bases. Total quantities authorized may be fixed, lower or higher, based upon consumption. (Communication System/Mission Essentiality will apply)

c. **Consolidated Inventory Location (CIL)**
Serviceable and reparable assets for this commodity, associated with the partial pipeline effort is located at the Source of Repair (SOR). The serviceable items in the CSI plus the reparable assets equal the CSI level for the partial pipeline.

d. **Consolidated Serviceable Inventory (CSI).** The centralized serviceable asset inventory, that will provide rapid (CONUS - 1 day for processing, CONUS -1 day for transportation, OCONUS - 2 days for transportation) distribution to an organization where a requirement exists to fill a base or depot request.

e. **Consolidated Serviceable Inventory (CSI) Level.** The quantity of serviceable inventory maintained necessary to accommodate all of the user requirements including Foreign Military Sales, depot overhaul, and non -AF users. This level may fluctuate based upon use at the bases. Total quantities authorized may be fixed, lower or higher, based upon consumption. Safety levels will not be considered when computing insurance items.

f. **Express Table.** A file in the Stock Control and Distribution (SC&D) system that identifies items to be issued to maintenance upon receipt in Central Receiving (Direct induction of reparables).

g. **Express Transportation.** The express transportation concept (expedites the flow of Lean Logistics reparables from the base to the repair source and serviceable from the CSI to the user. Features could include express carrier terminals in the dedicated support element, and daily (excluding Sunday) pick-up and delivery by the express carrier. The base reparable evacuation process is streamlined by eliminating transportation management office processing and placing reparables in express transportation channels. Note: For this effort the express transportation process is R2P.

h. **Ineligible Stock.** Assets above the authorized base lean levels or CSI levels. These assets, for the purpose of the AF C4 LL effort, will be considered stock not usable either by the bases or the PDM line unless a MICAP situation exists. This stock is considered excess to the requirement based upon new OS&T and depot repair times. At the depots, the item managers will place the serviceable assets in Ownership Purpose (OP) code "B" and unserviceable in condition code "J." The bases will also be required to identify stock at the base as excess when the total number available exceeds the authorized lean quantity, identify them as suspended stock and placed them in supply condition code "J" for base level and supply condition code " B" for depot.

i. USAF Lean Logistics - Lean Logistics is an umbrella concept that describes the application and adaptation of the most successful public and private business practices to the USAF Logistics system. These technological and management innovations that have been proven by other organizations facing turbulent market demand can be adapted in many cases to USAF logistics processes. The resulting logistics system will be more effective, i.e. more robust and flexible, and affordable.

j. AF C4 Lean Logistics - Total Pipeline Effort. This Lean Logistics premise involves a limited number of systems and assets to be reviewed over a 6-month period. Unlike the Partial Pipeline effort, this portion will track assets through the repair process. (See Table 1 for NSN listing)

k. AF C4 Lean Logistics - Partial Pipeline Effort. This effort will involve consolidated inventory and express transportation from and to the CIL of selected items not in the Total Pipeline Effort. (See Table 1 for NSN listing)

l. Readiness Spares Package (RSP) Authorization. A level authorized to sustain planned contingency operations (without resupply) for a specified period of time.

m. Order and Ship Time (OS&T). Represents the expected number of days between initiation of a requisition and receipt of the stock by the user including the backorder time.

n. Reparable Inventory. A centralized reparable asset inventory location of carcasses pending repair. In this particular plan, SM-ALC has been designated as the repair facility.

o. Reparable Item Movement Control System Code (RIMCS). The Repairable Item Movement Control System is designed to ensure items in need of repair are sent to the nearest appropriate repair activity.

p. R2P (Return and Repair Packaging). R2P moves eligible reparables at high velocity to and from the bases and depots, door to door. Criteria for R2P is predicated on the part's being non-hazardous/classified, weighs 150 lbs or less and has simple packaging/preservation requirements.

4. Responsibilities.

a. SM-ALC Staff is responsible for:

(1) Identifying and analyzing the AF C4 Lean Logistics total pipeline effort candidate systems/items and make recommendations to the working group (See Table 1 for selected NSNs).

(2) Computing, recommending and coordinating with the users the total pipeline effort will lean levels for each base and the CSI.

(3) Reviewing and controlling asset distribution and direct appropriate actions.

(4) Collecting and analyzing metrics data.

(5) Negotiating delivery times with the users for each item in the plan covered by R2P.

(6) Identifying depot process improvement goals.

(7) Ensuring Total Pipeline items are immediately inducted to the repair line based on actual demand.

(8) Ensuring items are repaired within standard shop repair time and delivered to the CSI.

(9) Using express transportation (R2P).

(10) Performing periodic reviews of depot lean levels.

(11) Replacing assets required for non-Air Force users to the CSI.

(12) Establishing and operating the Consolidated Serviceable location.

(13) Holding excess disposal action in abeyance for 180 days after the plan starts on affected NSNs.

b. MAJCOM/Base Users are responsible for:

(1) Identifying and analyzing the AF C4 Lean Logistics Partial Pipeline candidate systems/items and make recommendations to the working group.

(2) Collecting and analyzing metric data.

(3) Negotiating delivery times with the depot for each item not covered by R2P.

(4) Monitoring ineligible stockage document withdrawals. (Exclude HQ PACAF)

(5) Validating fixed lean levels for the plan.

(6) Adjusting base levels as outlined in plan.

(7) Rapidly evacuating reparables to the reparable shipping destination using R2P. (Exclude HQ PACAF)

(8) Identifying and implementing process improvements at the base level to support the goals of the AF C4 Lean Logistics plan.

(9) Analyzing shortages of Lean Logistics items in Readiness Spares Packages and identify to SM-ALC any impacts.

5. Concept of Operations.

a. Requirements Determination. Under a Lean logistics concept, every requisition represents an immediate requirement for fill action, either from the CSI, critical base supply stock, or the source of repair. When a base requisitions an asset from the CSI, CSI level generates a repair requirement for the depot shop. A shortage in the CSI level generates a repair requirement for the depot shop. Assets returned to serviceable condition will be stored at CSI. or shipped to fill backorders. (Partial Pipeline effort doesn't include immediate induction into repair.).

b. Ineligible Stock Withdrawal.

1. Requests for withdrawal of AF C4 Lean Logistics ineligible stock will require an FCC action to change the condition code from "J" to "A". Do not issue the items to maintenance for a determination of condition.

2. Automated program will Identify AF C4 Lean Logistics ineligible stocks by loading “LLL” , RIC Code, to the R920 details. D23 unserviceable report will print LL in the RI* field to identify those items. Do not ship, report, or request disposition on these items. Change the condition code to the original condition "A" prior to all disposition of these assets by processing an FCC. Maintain a log of withdrawal actions with at least the following information.

NSN	QTY	DATE	REASON	DATE STK REPL REQN
5820006276641	1	5031	MICAP	NA
5825008400176	1	5033	PIPELINE EXCEEDED	5026
5825010475917	1	5040	SURGE DEMAND	5039

c. **Waiver For Inspection and Storage of AF C4 Lean Logistics Plan Ineligible Assets.**

1. A waiver has been approved by HQ USAF/LGSP, for the duration of the AF C4 Lean Logistics Plan, to allow chief of supply's the option whether to retag and relocate suspended condition code "J" (paperwork only transactions) ineligible assets. Allowing the chief of supply this option will reduce the number of man-hours and reduce storage space requirements when the actual physical condition of the property does not change (will still be serviceable).

2. Withdrawals from ineligible will be require processing an FCC to change the condition code back to "A". Inspection will not issue assets to maintenance for condition code evaluation for determining serviceability. Assets will appear as LL in the CODE RI* column on the D23 Unserviceable DIFM Details listing. This identification will alert stock control not to request disposition or report assets.

3. Condition Change (FCC) Document Flow, for above.

a. AFM 67-1, Volume II, Part two, Chapter 14, Attachment B-1, paragraphs 1b and 4a.

b. AFM67-1, Volume I, Part one, Chapter 4, paragraph 7b and 21a.

d. **Adjusted Stock Levels (AF Form 1996) for Lean Logistics Critical Items.** Preapproved Critical items for the AF C4 Lean Logistics Plan do not require an AF Form 1996. These are AFMC Directed Levels using the AF C4 Lean Logistics Plan in justification field. Request for additional adjusted levels on "Critical" items (System off the air) will be submitted on a AF Form 1996. There are no adjusted levels for Non-Critical items.

e. **Requisition Processing.** Every requisition represents an immediate requirement for distribution of an asset from the CSI to the customer. DRIVE does not contain the non-airborne items and will not be able to assist in this plan. The following procedures will be accomplished to support customers requests.

(1) Bases will place a requisition to the CSI when the serviceable plus due-in from maintenance balance falls below the base lean level or a requirement exists.

(2) The source of repair will provide serviceable assets to satisfy base lean level requirements from the CSI.

(3) Assets condemned at the depot will be replaced in the system by withdrawal of ineligible stock. Ineligible stock consists of assets over and above the Lean Logistics assets set aside at the start of the effort. Ineligible stock will be used to replace condemned assets or to fill critical shortages upon approval of MAJCOM/Unit Commander and notify the SSM/SPD Item Manager after the fact. SM-ALC/LHZR will document each such use of ineligible stock. Note: The unit's commander/staff retains the authority to determine mission criticality and authorize the ineligible stock withdrawal. Units must rely on the established spares levels and the express transportation system to the greatest extent possible to validate the Lean Logistics concepts.

f. Reparable Asset Processing. The reparable pipeline is the lifeline of the system. In order to survive in a lean environment, maintenance, supply, and transportation must give special attention to prompt reparable processing.

(1) Base level maintenance activities will expedite reparables through the shops and base supply. Processes vary by MAJCOMs so refer to your MAJCOMS individual instructions for reparable turn-in and express transportation .

(2) The time standard for base reparable evacuation is 2 days (1 day for processing and 1 day for transportation) for direct NRTS items and 4 days (1 day for processing 2 for AWP/repair and 1 day for transportation) for all other reparables. Bases should give strong consideration for NRTS action on items awaiting parts. A serviceable replacement will normally be 2 days away at the CSI; bases would have to receive AWP parts and fix the end item within 2 days to match the same level of service. Keep in mind that a replacement asset (in support of base lean levels) will not be shipped from the CSI as long as the base owned asset is in AWP status. Holding on to end items in AWP status delays replenishment to the base and causes the base to exceed the Repair Cycle Time standard.

(3) Time standards for depot reparable processing are as follows:

(a) Receipt and flow to repair shop: 1 day

(b) Shop repair time: negotiated/standard by NSN

(c) Repair shop to DLA to express carrier: 1 day

(d) Total depot processing time: (shop repair time + 2 days)

g. Levels. The AF C4 Lean Logistics support system consists of two types of levels: base lean levels and CSI levels. The AF C4 Lean Logistics SC/LG Work Group is responsible for setting, reviewing, and adjusting levels for Lean Logistics items. The working group participants are outlined in paragraph 1 of the plan. The pipeline standards used in deriving lean levels can be seen in Figure 1.

Direct NRTS Items

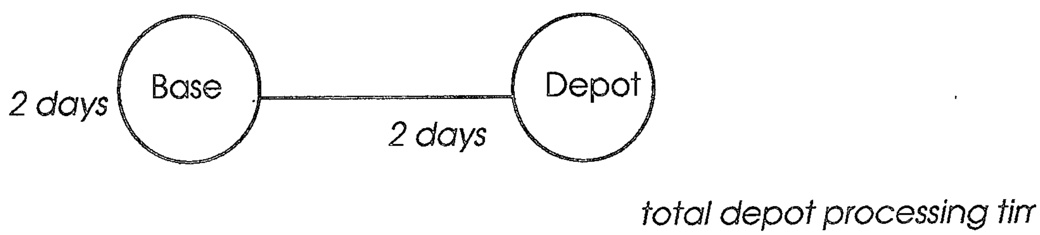


Figure 1

(1) Base lean levels are derived using the least consumption base repair capability, percent of base repair, base repair cycle time, processing time (pipeline from the CSI to the base), a unit cost adjustment factor, a safety level and mission/system essentially.

(2) The CSI lean level is derived by multiplying the system-wide leveling factors with the depot repair time, which will vary by item due to shop repair time variability. The depot repair time represents the reparable pipeline from the base to the depot, the actual repair time, and the serviceable pipeline back to the CSI.

(3) The working group MAJCOM representative will pass base lean levels to each base chief of supply, who will load fixed levels in the SBSS. Any primary operating stock (POS) on-hand above the lean level will be set aside and will be considered ineligible stock. Bases will request use of ineligible stock from their unit's commander/staff to satisfy not mission capable requirements; MAJCOMs will also coordinate this action with SM-ALC/LHZR. This information will be compiled monthly and reported along with other metrics in this plan.

6. Metrics. Several metrics will be used to determine progress of the plan and where changes need to be made during the AF C4 Lean Logistics Plan. There are three

categories of metrics that will be monitored during the performance of this plan. They include pipeline metrics, effectiveness and performance metrics, and cost/savings metrics. Metrics in each of these areas are further defined below.

Pipeline Metrics:

a. Depot Awaiting Parts (AWP) Time (Source: EPS OPR: SM-ALC/LHA-2 -depot, Base D23) - Elapsed time a reparable asset spends awaiting (depot - both "F" & "G" condition) parts while in the repair cycle. Incidents of each occurrence will be noted.

b. Base repair time (Source: ATAC-AF OPR: Users/AFC4A) - The time the reparable asset sits in base maintenance; e.g., awaiting parts, in work, etc. In most cases, this time should be less than 2 days because of the required asset release after receipt of a serviceable asset.

Pipeline Process & Metrics

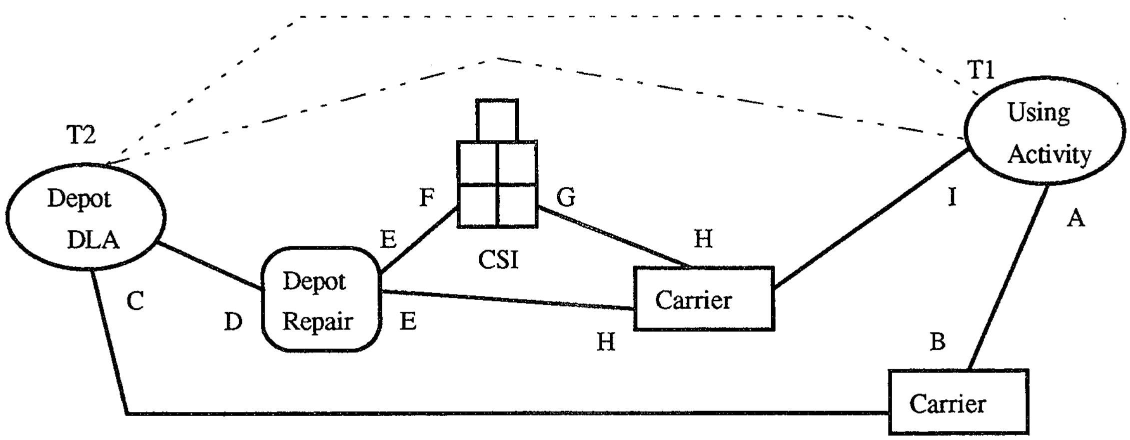


Figure 2

c. Base Shipment Processing Time (Source: ATAC-AF/LMA program OPR: USERS) - Elapsed time from Not Reparable This Station (NRTS) turn-in to supply until shipment processing off base with express carrier. Reference Figure 2 (A=>B)

d. Reparable Transit Time (Source: ATAC-AF/LMA program OPR: SM-ALC/LHA-2) - The time it takes for a reparable asset to get from the using activity's base to depot receiving and then from receiving to the repair shop. Reference Figure 2 (B=>C).

e. **CSI Shipping Time (Source: LMA program OPR: SM-ALC/LHA-2)** - Elapsed time to process item from the CSI warehouse storage to express shipping. Reference Figure 2 (G=>H)

f. **Depot Processing & Depacking Time (Source: LMA program OPR: SM-ALC/LHA-2)** - The time between depot receipt of the asset until the asset is received in the repair shop. Reference Figure 2 (C=>D)

g. **Packing to CSI Time (Source: ATAC-AF OPR: SM-ALC/LHA-2)** - Elapsed time from repair shop turn-in of a serviceable asset to DLA until this asset is warehoused in the CSI. Reference Figure 2 (E=>F)

h. **Packing to Shipping Time (Source: ATAC-AF OPR: SM-ALC/LHA-2)** - Elapsed time from repair shop turn-in of a serviceable asset to DLA for shipment to customer until the asset is actually shipped. Reference Figure 2 (E=>H)

i. **Request to Fill Time (Source: LMA Program OPR: SM-ALC/LHA-2)** - Elapsed time from receipt of customer requirement at depot until the serviceable asset is received back at the base level supply. (T2=>I)

j. **Serviceable Transportation Time (Source: LMA program OPR: SM-ALC/LHA-2)** - Elapsed time from shipment of serviceable from CSI until asset is received at base level or R2P receipt point. Reference Figure 2 (H=>I)

k. **Shop Repair Time (Source: LMA program OPR: SM-ALC/LHA-2)** - The elapsed time from receipt of a reparable at the depot repair shop until the item is procured to the DLA distribution function as a serviceable asset. This pipeline segment represents actual shop flow time (repair plus processing time). Reference Figure 2 (D=>E)

l. **Transaction Communication Time (Source: ATAC-AF OPR: SM-ALC/LHA-2)** - Elapsed time for a requirement transaction to pass system to system, from using activity supply system to depot (D035). Reference Figure 2 (T1=>T2)

<u>Effectiveness / Performance Metrics:</u>

a. **Base Lean Level Issue Effectiveness (Source: R15, OPR: Users)** - Issue effectiveness at the base indicates the fill rate based on customer demands issued from the customers' local base supply stock. Issue effectiveness should be compared to the number of customer demands placed against the base supply and the total issues made from it. The metric indicates Base Supply Issue Effectivness.

b. **CSI issue effectiveness (Local tracking OPR: SM-ALC/LHA-2)** - Issue effectiveness is the ability of the CSI to fill a customer requirement with a serviceable asset once a demand is made. Divide the number of customer demands placed against the CSI by the total issues made from it. The metric shows the percentage of time the CSI can immediately fill a customers requirement.

c. Ineligible withdrawals (local tracking OPR: MAJCOMs OCR: SM-ALC/LHZ) - Ineligible withdrawals will be tracked in order to provide lessons learned and adjust CSI levels. and future computations. Each occurrence will be documented by NSN, Qty, SRD, reason why.

d. Inventory Level - (local tracking OPR: SM-ALC/AFC4A/AFLMA) Track the change in the data elements used to compute the CSI and base lean levels; the number of levels changes and the impact of the on dollars required/saved, quantity reduced/increased and why. Bottom line : What is the minimum number of resources needed with the best system performance.

e. MDR/PQDR incidents (local tracking OPR: SM-ALC/LHAQ-4/LHA-2). - Any MDRs/PQDRs generated for the plan period will be tracked. History of prior MDRs/PQDRs will be reviewed for potential trends.

f. Negotiated vs. Actual Repairs -(D041 OPR: SM-ALC/LHZ) Shows D041 computed negotiated requirements vs. what was actually repaired for each stock number. (Leaseline information)

g. NMCS hours/incidents/cause/delete codes (Source WSMIS) (AFC4A) - -Capture will be number of NMCS hours the a piece of equipment was out of commission for supply.

- The number of NMCS occurrences for a particular piece of equipment. The NMCS time begins when a MICAP is generated and ends when the MICAP is satisfied.

- In addition, the cause code and number of occurrences on each asset in NMCS will be tracked and used to analyze impacts on CSI levels. Cause codes are listed in AFM 67-1.

h. RSP fill rate (User) - The RSP fill rate is computed by dividing the total of on hand stock items by the authorized requirement.

i. RSP issue (User) - The number of times items have been removed from RSPs. Note: MAJCOMs will track NSN, Qty, SRD, and reason why.

Cost Metrics:

a. DLA handling costs - (OPR: SM-ALC/LHA-2/FMIC) Handling costs associated with Lean Logistics techniques will be computed. Data will be used to project future funding requirements. Number of transactions such as shipments, receipts will be totaled and multiplied against the $29.00 handling and surcharge rate to determine the costs. In addition, cost information will assist in further analysis to determine the impact on DLA handling costs resulting from expedited processes.

b. Transportation costs - (OPR: SM-ALC/LHA-2/FMIC) Express transportation costs will be collected so they can be compared to cost avoidance factors brought about by reduced inventories. Express costs and normal distribution costs will be considered in this computation.

Metric measurements will be tracked as of the first of each month and reported to HQ USAF/LGM-2, SM-ALC, HQ AFMC/LGI, and HQ AFC4A on a monthly basis. Up channel reporting will be accomplished on/about the 10th of the month for the preceding months activity. Weekly reporting will take place during the first 30 days of the effort. Reports will contain analysis and supporting information in a professional format.

7. Timeline. The timeline for AF C4 Lean Logistics Plan is as follows.

Action	OPR	Date
Determine shop repair times	SM-ALC	22 Jul 94
Identify Financial Impacts	SM-ALC	08 Jul 94
Identify Bits & Pieces of Repair Shop	SM-ALC	22 Jul 94
Develop CSI Process	SM-ALC	08 Jul 94
Develop Item / Program Managers Role	SM-ALC	15 Jul 94
Resolve Shop Issues	SM-ALC	20 Jul 94
AF C4 LL Plan, second version	SM-ALC/AFC4A	01 Feb 95
Adjust base supply records	Users	01 Mar 95
Fill lean levels	SM-ALC	XX Mar 95
Start baseline data collection	AFC4A/SM-ALC	XX Apr 95
Compute revised lean levels	SM-ALC/USERS	XX Apr 95
Validate items and CSI levels	All	XX Apr 95
Collect retail usage data	Users	XX Apr 95
Complete baseline data collection	AFC4A/SM-ALC	XX May 95
How goes it meeting	AFC4A	26 Jun 95
AF C4 LL Plan results to USAF	AFC4A/SM-ALC/AFMC	XX Aug 95
Next How Goes It meeting	All	TBD

APPENDIX B

Script used - afit_d6

```
-----------------------------------------------------------------------
HOME=/otis
ISAM=$HOME/isam
D6_1=$ISAM/supply/d6/d6_1
D6_2=$ISAM/supply/d6/d6_2
REPORTS=$HOME/reports/afit/$0
SCRIPTS=$HOME/scripts/reports/afit/$0
NIIN_LIST=$SCRIPTS/$0.niin
EXTRACT_D6AS=/var/tmp/$0.extract_d6s.$1$2_$1$3
EXTRACT_D6Z=/var/tmp/$0.extract_d6z.$1$2_$1$3
D6AS_SORT=/var/tmp/$0.d6as_sort.$1$2_$1$3
D6Z_SORT=/var/tmp/$0.d6z_sort.$1$2_$1$3

echo "Script $0 begin: " `date`
#
# This script searches the data pile for all D6S/A and D6Z records pertaining
# to a set of particular NIINs.
#
#
# Pull the D6S records for the list of NIINs.
#
( cat $NIIN_LIST | iscat $D6_1 -c 12-20 -v - ;
cat $NIIN_LIST | iscat $D6_2 -c 12-20 -v - ) |
nawk '{
#
# Make sure the record is D6S/A or D6Z.
#
      dic = substr($0,1,3)
      if (dic !~ /D6[ASZ]/) {
            next
      }
if (dic ~ /D6[AS]/) {
            print $0 > "'$EXTRACT_D6AS'"
      }
      if (dic == "D6Z") {
            print $0 > "'$EXTRACT_D6Z'"
      }
}' -
cat $EXTRACT_D6AS | sort -t~ +0.11 -0.23 > $D6AS_SORT
cat $EXTRACT_D6Z | sort -t~ +0.11 -0.23 > $D6Z_SORT
echo "Script $0   end: " `date`
-----------------------------------------------------------------------
```

APPENDIX C

STATISTIX 4.0 THESISDA, 07/21/95, 15:36

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
ACCCP	25.0	33
ACCLL	27.8	18
TOTAL	26.4	51

KRUSKAL-WALLIS STATISTIC 0.4498
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.5024

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	99.2760	99.2760	0.44	0.5079
WITHIN	49	10935.8	223.179		
TOTAL	50	11035.0			

TOTAL NUMBER OF VALUES THAT WERE TIED 36
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 51 MISSING CASES 475

STATISTIX 4.0 THESISDA, 07/21/95, 15:42

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
AETCCP	25.0	43
AETCLL	20.1	5
TOTAL	22.6	48

KRUSKAL-WALLIS STATISTIC 1.4518
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.2282

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	289.489	289.489	1.47	0.2321
WITHIN	46	9082.44	197.444		
TOTAL	47	9371.93			

TOTAL NUMBER OF VALUES THAT WERE TIED 33
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 48 MISSING CASES 478

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
AFMCCP	35.5	36
AFMCLL	27.3	27
TOTAL	31.4	63

KRUSKAL-WALLIS STATISTIC 3.1850
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.0743

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	1067.17	1067.17	3.30	0.0741
WITHIN	61	19706.6	323.059		
TOTAL	62	20773.7			

TOTAL NUMBER OF VALUES THAT WERE TIED 51
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 63 MISSING CASES 463

STATISTIX 4.0 THESISDA, 07/21/95, 15:43

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
AFRESCP	3.5	5
AFRESLL	5.3	2
TOTAL	4.4	7

KRUSKAL-WALLIS STATISTIC 1.1491
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.2837

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	5.35937	5.35937	1.18	0.3261
WITHIN	5	22.6250	4.52500		
TOTAL	6	27.9843			

TOTAL NUMBER OF VALUES THAT WERE TIED 4
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 7 MISSING CASES 519

STATISTIX 4.0 THESISDA, 07/21/95, 15:44

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
AMCCP	26.0	32
AMCLL	21.4	16
TOTAL	23.7	48

KRUSKAL-WALLIS STATISTIC 1.3212
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.2504

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	258.424	258.424	1.33	0.2547
WITHIN	46	8934.78	194.234		
TOTAL	47	9193.21			

TOTAL NUMBER OF VALUES THAT WERE TIED 40
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 48 MISSING CASES 478

STATISTIX 4.0 THESISDA, 07/21/95, 15:44

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
ANGCP	28.5	34
ANGLL	17.0	15
TOTAL	22.8	49

KRUSKAL-WALLIS STATISTIC 7.8630
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.0050

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	1641.95	1641.95	9.21	0.0039
WITHIN	47	8381.41	178.328		
TOTAL	48	10023.3			

TOTAL NUMBER OF VALUES THAT WERE TIED 36
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 49 MISSING CASES 477

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
PACAFCP	32.9	48
PACAFLL	21.0	12
TOTAL	26.9	60

KRUSKAL-WALLIS STATISTIC 6.7234
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.0095

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	2133.82	2133.82	7.46	0.0083
WITHIN	58	16591.3	286.057		
TOTAL	59	18725.1			

TOTAL NUMBER OF VALUES THAT WERE TIED 46
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 60 MISSING CASES 466

STATISTIX 4.0 THESISDA, 07/21/95, 15:47

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
USAFECP	23.1	31
USAFELL	14.5	10
TOTAL	18.8	41

KRUSKAL-WALLIS STATISTIC 5.0368
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.0248

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	745.912	745.912	5.62	0.0228
WITHIN	39	5177.77	132.763		
TOTAL	40	5923.68			

TOTAL NUMBER OF VALUES THAT WERE TIED 27
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 41 MISSING CASES 485

STATISTIX 4.0 THESISDA, 07/21/95, 15:45

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
CONUSCP	137.1	177
CONUSLL	105.4	77
TOTAL	121.2	254

KRUSKAL-WALLIS STATISTIC 11.8049
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.0006

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	64077.7	64077.7	12.33	0.0005
WITHIN	252	1.309E+06	5195.34		
TOTAL	253	1.373E+06			

TOTAL NUMBER OF VALUES THAT WERE TIED 234
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 254 MISSING CASES 272

KRUSKAL-WALLIS ONE-WAY NONPARAMETRIC AOV

VARIABLE	MEAN RANK	SAMPLE SIZE
OSCP	62.0	86
OSLL	43.8	28
TOTAL	52.9	114

KRUSKAL-WALLIS STATISTIC 8.5033
P-VALUE, USING CHI-SQUARED APPROXIMATION 0.0035

PARAMETRIC AOV APPLIED TO RANKS

SOURCE	DF	SS	MS	F	P
BETWEEN	1	9468.10	9468.10	9.11	0.0031
WITHIN	112	1.164E+05	1038.86		
TOTAL	113	1.258E+05			

TOTAL NUMBER OF VALUES THAT WERE TIED 96
MAX. DIFF. ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 114 MISSING CASES 412

APPENDIX D

List of NSNs in C4 Demonstration		
5820006156050ZK	5825010124838ZK	5985001565575ZK
5820006276641ZK	5825010321238	5985001595694ZK
58200076868775K	5825010701448ZK	5985001595697
5820008400175ZK	5825010701470ZK	5985001771668
5820010712815	58250107023092K	5985002536676ZK
5825000787612	5825010731182ZK	5985004661015
5825002330928	5825012186063ZK	59980045170022K
5825003583095	5895003585076ZK	5998004777882
5825004777806	5895003585079ZK	5998004779085ZK
5825004777807	5895004203056ZK	59980048397622K
5825004839706	5820008400175ZK	5998004866328ZK
5825004839709	5895004839714ZK	5998010701463ZK
5825004929793	5895004962183ZK	5998010701464ZK
5825004929795	5895004981547ZK	5998010701468ZK
5825004929803	5895005528624ZK	5998010809754ZK
5825004929804	58950061559972K	5998011465507ZK
5825004929806	5895006156085ZK	5998011781103ZK
5825004929811	5895006175779ZK	5998011827316ZK
5825004929812	5895006175789ZK	5998011890327ZK
5825004929814	5895006279705ZK	6110000015365ZK
5825004929815	5895007615370ZK	6110004854166
5825004981472ZK	58950076927672K	6130000526714ZK
5825004981475ZK	58950080899192K	6130000526715ZK
58250049814772K	5895008126181ZK	6130003515731ZK
5825005192202ZK	5895008812822ZK	6130004481081
5825005533925	5895011827351	6130004660699ZK
5825006156084	5895011829834ZK	6130004839766ZK
5825006276639	58950118304262K	61300049298052K
5825006276643	5895012039144ZK	6130004929810ZK
58250064271732K	5895012098859ZK	6130006276644ZK
5825006582792	59150058997092K	6130006276647ZK
5825006704675	59150128119782K	6130007265889ZK
5825007133600	5955004777872ZK	6130007265890ZK
5825007133602	5975004929820ZK	6130010812360ZK
5825007615373ZK	5985001373931ZK	6130011556468ZK
58250084001762K	5985001373932ZK	6625004991872ZK

BIBLIOGRAPHY

AFMC/LG/LL. AF C4 Lean Logistics Plan. 1 July 1995.

Air Force Logistics Information File User's Guide. 1995.

Air Force Materiel Command. "ALC-Reengineering Overview Slide Package." January 13, 1995.

Camm, Frank. "Should DoD Buy More Logistics Activities From Contractors?" Santa Monica CA, Rand Corporation, IP-111. March, 1993.

Cohen, I. K. and R. A. Pyles. "Empowering the Commands to Control Logistics Operations," Rand Corporation, Draft IP-109, 1993.

Coyle, John J., Edward J. Bardi, and C. John Langley, Jr. The Management of Business Logistics. 5th ed. West Publishing Company, New York. 1992.

Fawcett, Stanley E. and John N. Pearson. "Understanding and Applying Constraint Management in Today's Manufacturing Environments," Production and Inventory Management Journal. Third Quarter, pp. 46-55 1991.

Gardiner, Stanley C, John H. Blackstone, and Lorraine R. Gardiner. "The Evolution of the Theory of Constraints." Industrial Management. Vol. 36, Iss 3. May/June 1994. Pp. 13-16

Hammer, Michael and James Champy. Reengineering the Corporation: A Manifesto for Business Revolution. 1993.

Hammer, Michael and Steven A. Stanton. The Reengineering Revolution: A Handbook. Harper Business. New York, 1995.

Hill, Tracey L. and William N. Walker. An Analysis of the Effects of Lean Logistics on the Current Air Force Reparable Pipeline: A Simulation Study. MS thesis, AFIT/GLM/LAL/94S-22. Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1994 (AD-A285 298).

HQ USAF/LGM-2. "USAF Baseline Lean Logistics Master Plan and Road Map," Version 3.0. 31 January 1995.

HQ USAF/LGM-2. "USAF Baseline Lean Logistics Master Plan and Road Map Supplement Lessons Learned and Checklist of Required Actions," Version 3.0. 31 January 1995.

LaLonde, Bernard J. and Douglas M. Lambert. "Inventory Carrying Costs: Significance, Components, Means, Functions." Managerial Finance Vol. 3, No. 1, 1977. Pp. 16-28.

McClave, James T. and P. George Benson. Statistics for Business and Economics. 6th ed. Macmillan College Publishing Company, New York. 1994.

Office of the Deputy Under Secretary of Defense (Logistics). Department of Defense Logistics Strategic Plan. 1994.

Pyles, Raymond A. and I. K. Cohen. "Using Emerging Business Practices to Meet New Logistics Challenges," Santa Monica CA, Rand Corporation, Draft IP-108, September 1993.

Ramey, Timothy L. and Raymond A. Pyles. "Would 'Just in Time' Improve Logistics Responsiveness and Cost?" Santa Monica CA, Rand Corporation, Draft IP-110, September 1992.

Slide Package, ALC-Reengineering Overview. HQ AFMC, Wright-Patterson AFB OH, January 1995.

Slide Package, Lean Logistics. HQ AFMC, Wright-Patterson AFB OH, February 1995.

Slide Package, Lean Logistics. HQ AFMC, Wright-Patterson AFB OH, May 1995.

Slide Package, Lean Logistics. HQ AFMC, Wright-Patterson AFB OH, Presented to LtGen Farrell 17 May 1995.

Womack, James P., Daniel T. Jones, and Daniel Roos. The Machine That Changed the World. Harper Perennial, 1990.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE
ORDER & SHIP TIMES OF COMMUNICATION-ELECTRONIC COMPONENTS UNDER LEAN LOGISTICS AND CONVENTIONAL AIR FORCE REPARABLE PIPELINE: A COMPARATIVE STUDY

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology,
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GTM/LAL/95S-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQ USAF/LGMM
Washington DC 20330

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Lean logistics (LL) is a new logistics system that applies state-of-the-art business practices utilized in private industry to Air Force logistics processes. Several LL demonstrations have been initiated to develop the best way to implement these new practices in the operational arena. This study focused on the Command, Control, Communications, and Computers (C4) lean logistics demonstration. The reparables in this demonstration differ from aircraft reparables in that they are highly reliable and high-value items. This research determines that the use of LL principles results in shorter order and ship times for the customer. As a follow-on to this finding, the study presents a methodology for comparing the cost of carrying inventory under LL and the traditional pipeline and demonstrates how LL principles result in considerably lower carrying costs.

14. SUBJECT TERMS
Centralization, Communications-Electronics, Lean Logistics, Logistics Pipeline, Maintenance Management, Reengineering Logistics, Two-Level Maintenance.

15. NUMBER OF PAGES
69

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL