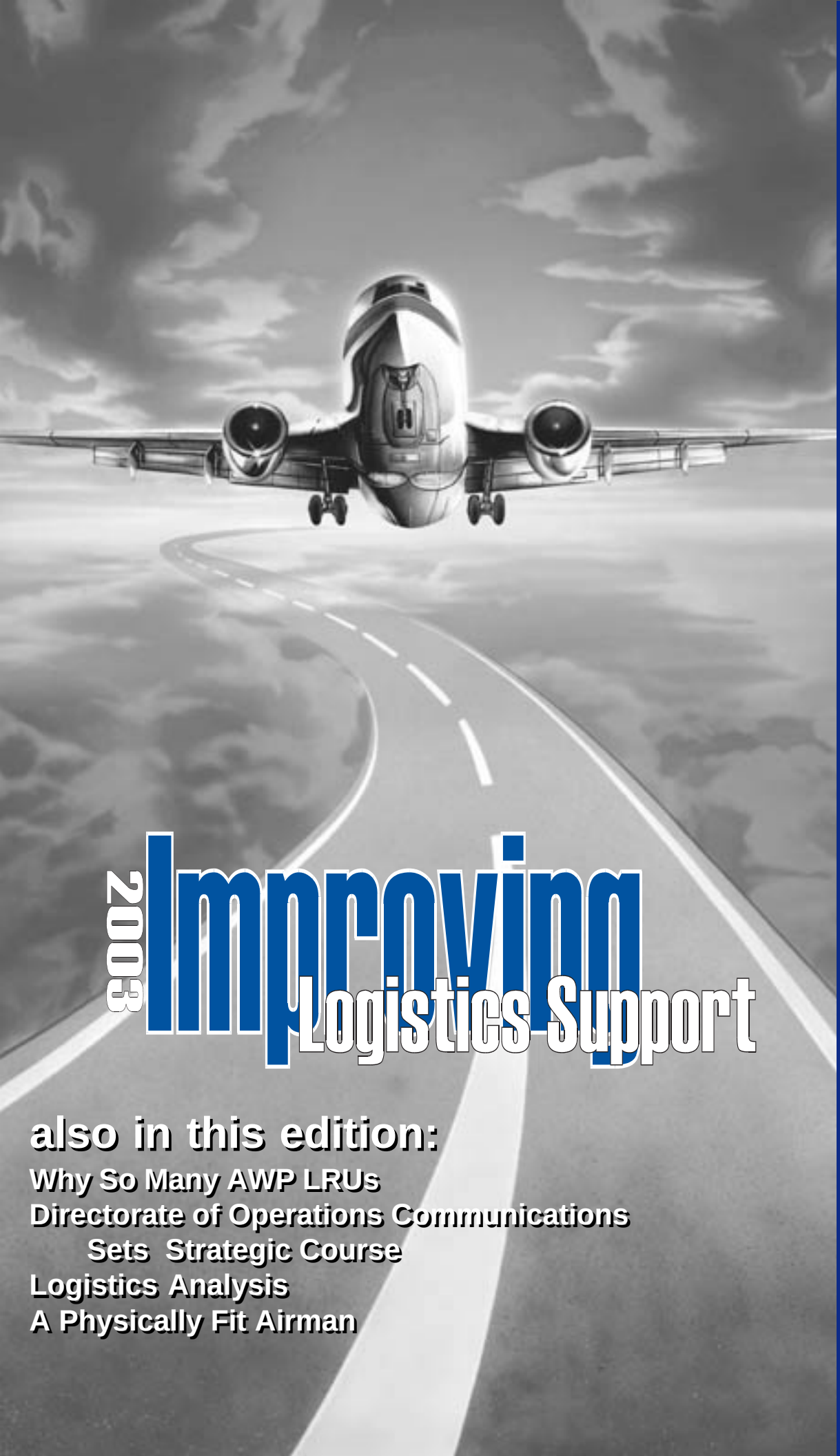


Air Force Journal of Logistics

Volume XXVI,
Number 4
Winter 2002

2003 Improving Logistics Support

also in this edition:

Why So Many AWP LRUs
Directorate of Operations Communications Sets Strategic Course
Logistics Analysis
A Physically Fit Airman

AIR FORCE JOURNAL of LOGISTICS

Volume XXVI, Number 4 **Winter 2002** **AFRP 25-1**

Articles—Improving Logistics Support

3 **Managing Air Force Depot Consumables**
Major Kevin Gaudette, USAF
Douglas Blazer, PhD
H. Kenneth Alcorn

7 **Reparability Forecast Model**
Major Kevin Gaudette, USAF
H. Kenneth Alcorn
Major Matthew Mangan, USAF

13 **Improving the Logistics Pipeline**
Major Steven L. Martinez, USAF
Major Marvin A. Arostegui, USAF
Lieutenant Colonel Stephan P. Brady, USAF

23 **Footprint Configuration: An Essential Element for Agile Combat Support in the EAF**
Lionel Galway, Phd
Mahyar A. Amouzegar, PhD
Don Snyder, PhD
Richard Hillestad, PhD

29 **Focused Logistics and Combat Capability**
Lieutenant Colonel Jon V. Ramer, USAF

DEPARTMENTS

33 **Inside Logistics**
Why So Many AWP LRUs?
Maurice W. Carter
Rick London

36 **Directorate of Communications Operations Sets Strategic Course**
Lieutenant Colonel Kimberly Crider, USAF

37 **Current Logistics Research**
Logistics Analysis
Richard A. Moore

40 **Candid Voices**
A Physically Fit Airman: An Essential Element for Agile Combat Support in the AEF
Lieutenant Colonel Michael W. Alexander,USA

BACK COVER **AFJL Awards**
Most Significant Article to Appear in the *Air Force Journal of Logistics*
Volume XXVI, Number 3

General John P. Jumper
Air Force Chief of Staff

Lieutenant General Michael E. Zettler
Deputy Chief of Staff, Installations and Logistics

Colonel Ronne G. Mercer
Commander
Air Force Logistics Management Agency

Editor-in-Chief
James C. Rainey
Air Force Logistics Management Agency

Editor
Beth F. Scott
Air Force Logistics Management Agency

The *Air Force Journal of Logistics* (*AFJL*), published quarterly, is the professional logistics publication of the United States Air Force. It provides an open forum for presenting research, innovative thinking, and ideas and issues of concern to the entire Air Force logistics community. It is a nondirective publication published under AFI 37-160V4. The views and opinions expressed in the *Journal* are those of the author and do not necessarily represent the established policy of the Department of Defense, Department of the Air Force, the Air Force Logistics Management Agency, or the organization where the author works.

The *Journal* is a refereed journal. Manuscripts are subject to expert and peer review, internally and externally, to ensure technical competence, accuracy, reflection of existing policy, and proper regard for security.

The publication of the *Journal*, as determined by the Secretary of the Air Force, is necessary in the transaction of the public business as required by the law of the department. The Secretary of the Air Force approved the use of funds to print the Journal, 17 July 1986, in accordance with applicable directives.

US Government organizations should contact the *AFJL* editorial staff for ordering information: DSN 596-4087/4088 or Commercial (334) 416-4087/4088. Journal subscriptions are available through the Superintendent of Documents, US Government Printing Office, Washington DC 20402. Annual rates are $15.00 domestic and $18.75 outside the United States. Electronic versions of the *Journal* are available via the World Wide Web at: http://www.aflma.hq.af.mil/lgj/Afjlhome.html. The *Journal* editorial staff maintains a limited supply of back issues.

Unsolicited manuscripts are welcome from any source (civilian or military). They should be from 1,500 to 5,500 words. The preferred method of submission is via electronic mail (e-mail) to: **editor-AFJL@maxwell.af.mil**. Manuscripts can also be submitted in hard copy. They should be addressed to the *Air Force Journal of Logistics*, 501 Ward Street, Maxwell AFB, Gunter Annex AL 36114-3236. If this method is used, a 3.5-inch disk, Zip disk, or compact disk containing an electronic version of the manuscript should accompany the hard copy. Regardless of the method of submission, the basic manuscript should be in Microsoft Word or WordPerfect format, and all supporting tables, figures, graphs, or graphics must be provided in separate files (preferably created in Microsoft Office® products). They should not be embedded in the manuscript. All submissions will be edited in accordance with *AFJL* style guidelines and the *Gregg Reference Manual*, Eighth Edition.

Articles in this edition may be reproduced in whole or in part without permission. If reproduced or reprinted, the courtesy line “Originally published in the *Air Force Journal of Logistics*” should be included.

Managing Air Force Depot Consumables

The Big Picture

Major Kevin Gaudette, USAF
Douglas Blazer, PhD
H. Kenneth Alcorn

Economic Order Quantity Model

Consumable-item management in Air Force depots has evolved over the years, very dramatically in the last 5. The exclusive use of the economic order quantity (EOQ) model, for both leveling and ordering, has given way to more frequent ordering and, recently, to customer service-based leveling. This article documents the major milestones in that evolution, explains the reasons for them, and describes where the various pieces fit into the *big picture*. It presents a top-level description of the theory behind the systems in use and how they interact in the world of consumable inventory management. Before discussing the various pieces of the consumable management pie in more detail, however, a macroview view of the evolution of the whole system will help put the discussion into context. Figure 1 illustrates this evolution graphically from two perspectives. First, it divides the inventory management function into its three primary functions: forecasting, establishing stock levels, and ordering. In this way, the various techniques can be discussed in terms of their specific roles. Second, it provides a chronological time line to help in understanding the order of evolution. The overview that follows explains Figure 1 in more detail.

Until a few years ago, the EOQ model was used to calculate stock levels and place orders, while the forecasts used to calculate the levels and reorder point were based solely on historical demands. In 1998, the Air Force Logistics Management Agency (AFLMA) published the results of a study that recommended more frequent ordering for some consumable items, for reasons that will be discussed later.[1] This led to a

change in policy, and the Air Force Materiel Command (AFMC) began ordering exactly what was used of each item at the end of each day. At about the same time, the Reparability Forecast Model (RFM) was being implemented on a limited basis at the air logistics centers (ALC).[2] RFM was originally developed a few years earlier as a forecasting tool to help identify shortages prior to production and is used to augment the ordering function with more accurate forecasts. Since it works independently of leveling and ordering systems, it complements whatever system is used for those functions. Finally, in 2001, AFMC unveiled the Customer-Oriented Leveling Technique (COLT) to replace EOQ levels. COLT uses a methodology similar to that used by the Aircraft Availability Model (AAM) for reparables, calculating levels to minimize the customer wait time. In this way, it ties levels to a customer-oriented measure of service, just as AAM is tied to aircraft availability.[3] COLT only recently has been tested and is currently being implemented.

The remainder of this article gives a brief overview of EOQ theory, to include some of its assumptions. It also presents a discussion of the effects of violating those assumptions, which provides a framework for the subsequent discussion of solutions the Air Force has implemented over time. Safety levels, daily ordering, the Reparability Forecast Model, and COLT are all included in the discussion.

Economic Order Quantity

Until recently, the Air Force relied primarily on Wilson's EOQ model (via the Wholesale and Retail Receiving and Shipping Program [D035K]) and Standard Base Supply System [SBSS]) to manage its consumable inventory. The model has been widely used for decades, particularly for low-cost items. In fact, it was originally developed by F. W. Harris in 1915, making it one of the oldest inventory models in use today.[4] The fundamental objective of the EOQ model is to minimize total annual inventory cost—purchase cost of the item, cost to stock the item (its *holding cost*), and cost to order the item (its *ordering cost*).[5] Equation 1 presents the mathematical representation of the model.

$$\textit{Total Annual Cost} = DC_U + \frac{D}{Q}C_O + \frac{Q}{2}C_H$$

Where:

D	= *Forecasted annual demand in units*
Q	= *Order quantity per order*
C_U	= *Unit cost (price) of an item*
C_O	= *Ordering cost per order*
C_H	= *Annual holding cost per unit*

Equation 1[6]

Equation 1 can now be differentiated with respect to Q and set equal to zero, which corresponds to the point on the total cost curve where the slope is zero. This point also represents the minimum annual cost, indicated in Figure 2 by a star. The order quantity Q corresponding to this minimum cost is known as the economic order quantity. It is also commonly represented by Q*, to denote that it is the value of Q that provides the minimum total cost shown in Equation 2.

Using the basic EOQ model, up to Q* units are ordered for each consumable item whenever the inventory drops below a level called the *reorder point*. Assuming the lead time is known and constant (a faulty assumption, which will be discussed in more detail later), the reorder point is set at the level of demand during lead time, which ensures adequate stock is on hand while waiting for an order to arrive. As long as the assumptions are met, this technique minimizes the annual cost and ensures a minimum service level. Problems arise, however, when considering the sometimes-unrealistic assumptions of the model. Although there are many assumptions embedded in the EOQ model, five are listed in Table 1 and provide a framework for the remaining discussion of violating the assumptions and solutions the Air Force has implemented to counteract those effects.

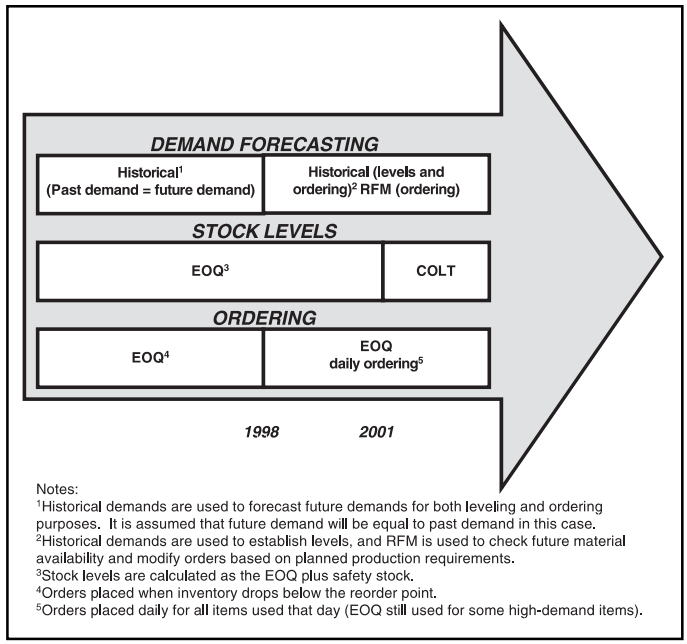


Figure 1. Evolution of Air Force Depot-Consumable Item Management

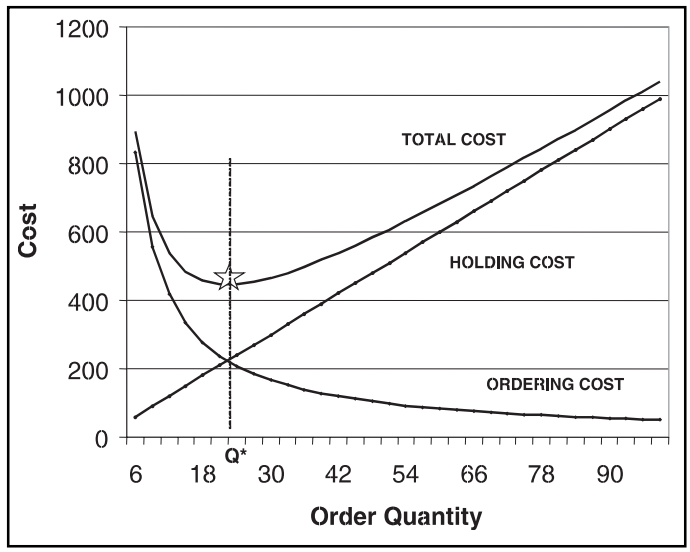


Figure 2. Cost Tradeoff Curve to Determine Economic Order Quantity Q*

$$Q^* = \sqrt{\frac{2DC_O}{C_H}}$$

Equation 2[7]

EOQ Assumption Violations, Their Effects, and Air Force Solutions

Assumption 1: Known and Constant Lead Time (Solution: Safety Stock). Of all the assumptions known and constant, lead time is perhaps the most often violated and most often studied. Consider the *sawtooth* diagram in Figure 3, which shows the steady depletion of inventory over time, the order of quantity Q* when inventory reaches the reorder point, and the subsequent replenishment of inventory up to Q* when the order arrives. As noted in the diagram by the dashed line, a longer lead time than anticipated results in a stockout situation, since the stock goes to zero prior to the order arrival and any demands, therefore, become back orders.[8]

The most common remedy for uncertain and variable lead times, the one that has been used historically by the Air Force, is the use of safety stock.[9] Safety stock is simply a buffer of inventory carried in addition to the normal level, which exists for the sole purpose of reducing the chance of back orders when the lead time or demand, as will be discussed in the next section, is greater than anticipated. In Figure 4, the stockout from Figure 3 is repeated, but in this case, the safety stock is available to meet demands until the order is received.

Assumption 2: Known and Constant Demand (Solutions: Safety Stock and Reparability Forecast Model). Violating the known and constant demand assumption has an effect similar to that of lead time, in that higher-than-anticipated demands during the lead time of an order will deplete stock more quickly than planned. The result, as in the case of variable lead time, is a stockout.[10] Two solutions have been applied to this problem in the Air Force: safety stock and RFM. Safety stock is used for the same reason as lead time—to provide a buffer of inventory to reduce the chance of a back order in the face of variability. RFM is a more recent solution to the problem, having been implemented only over the last 5 years by AFMC in its air logistics centers. It provides materiel managers at the depots with a decision support tool to account for known variations in demand and to adjust orders accordingly.[11] As RFM primarily addresses violations of the independent demand assumption, however, a more detailed discussion is reserved for that section.

Assumption 3: Independent Demand (Solution: Reparability Forecast Model). A third EOQ assumption systematically violated in the Air Force is independent demand. Independent demand is defined as demand "unrelated to the demand for other items."[12] Clearly, this is not the case with many Air Force consumables. For example, demand for turbine blades is directly related to the demand for jet engines. Although this violation is not always a problem, it is enough of a problem that production for many reparables is repeatedly and significantly delayed for want of a small number of consumable items.[13] Violating this assumption, especially its effects on production, led AFMC to develop the RFM.

Reparability Forecast Model

Motivated by production delays caused by stockouts, the San Antonio ALC contracted with CACI to develop RFM to identify those parts that will hold up future production. RFM was subsequently implemented at the Oklahoma City ALC and later chosen by AFMC for inclusion in its standard suite of ALC systems. It has since been implemented, primarily for engines, at all the air logistics centers.

EOQ Level Assumption	Reality	Air Force Solution
Known and constant lead time	Uncertain and variable	Safety levels
Known and constant demand	Highly variable	Safety levels RFM
Independent demand	Some demand dependent	RFM
Single echelon	Multiechelon, with each echelon using EOQ batches	COLT Daily ordering at ALCs
Known ordering and holding costs	Varies by item and is difficult to estimate in practice (see text discussion)	Flat-rate estimates

Table 1. EOQ Assumptions and Corresponding Air Force Solutions

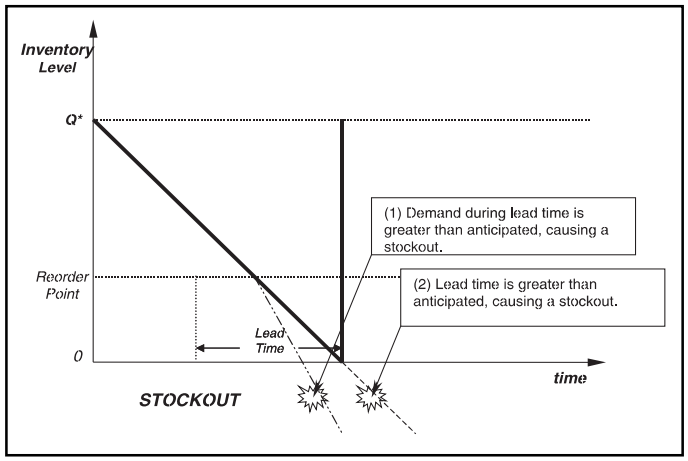


Figure 3. The Effects of Violating Known and Constant Demand and Known and Constant Lead-Time Assumptions

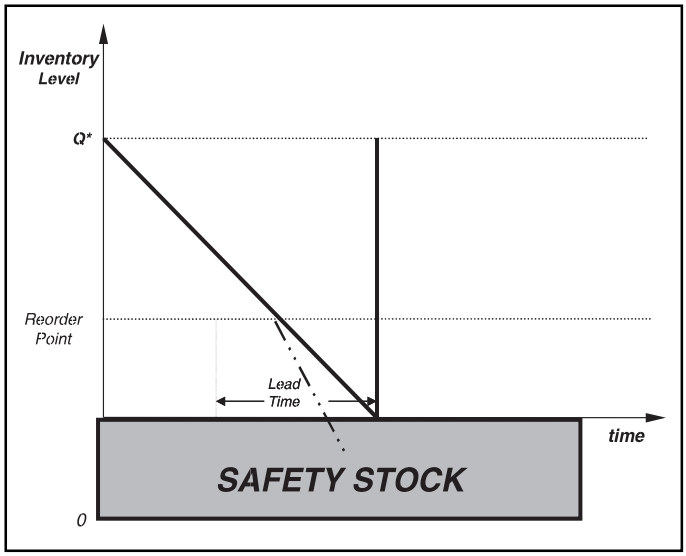
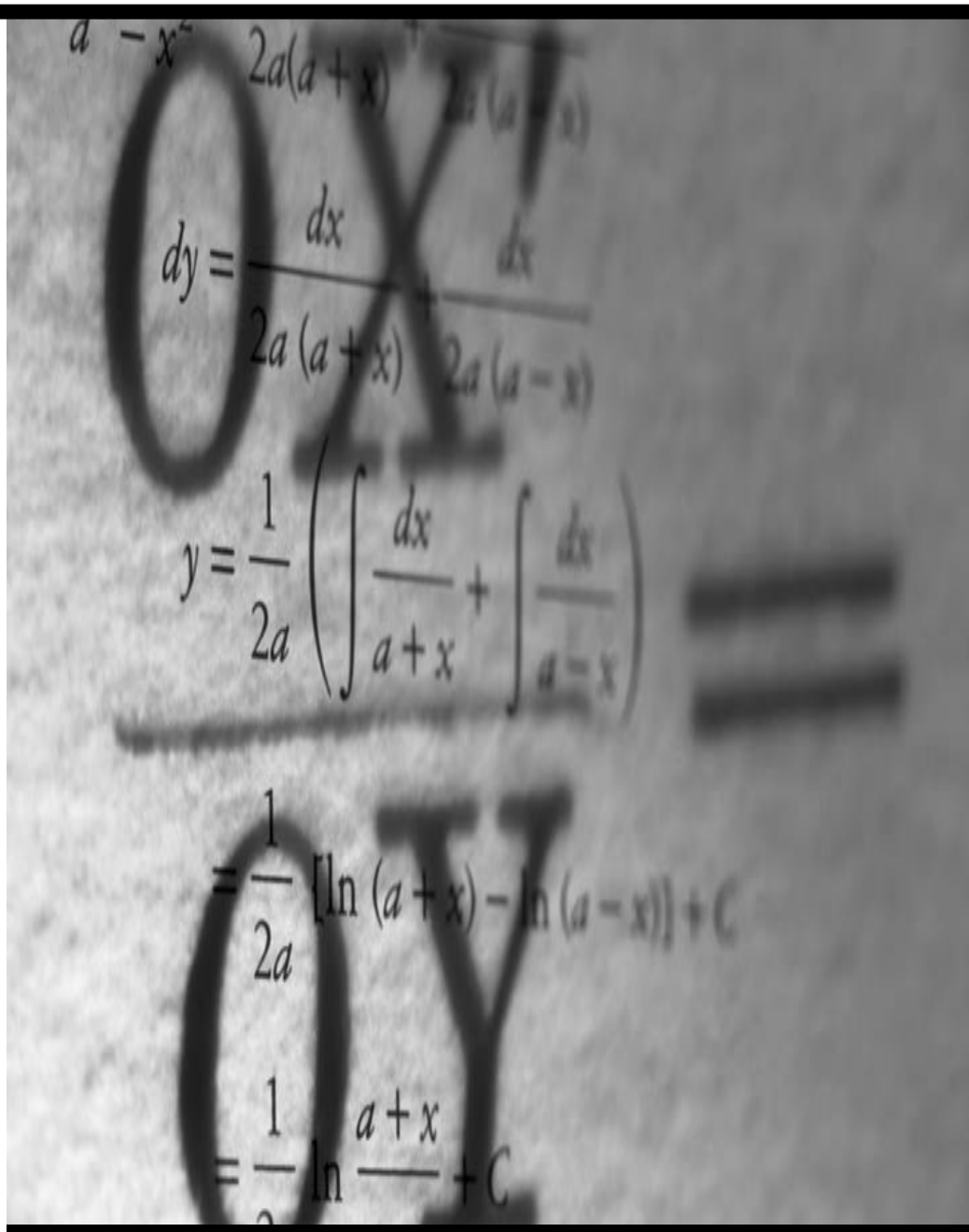


Figure 4. Adding Safety Stock Levels to Preclude Back Orders Due to Lead-Time Variability

(Continued on page 43)

Major Kevin Gaudette, USAF
H. Kenneth Alcorn
Major Matthew Mangan, USAF

Reparabilty Forecast Model



RFM System Logic

With hundreds of logistics systems in use in the Air Force, it is hard to keep them all straight, much less know where they fit into the big picture. As users of these systems, it is important that logisticians understand, at least at the top level, what they do. Perhaps more important, they should understand what the systems do. Unfortunately, this information is not usually openly shared by the developers, leaving most of us to wonder what is going on inside the *black box*. In an earlier article in this publication, the systems that have played a role in the management of depot consumables were discussed.[1] This article delves deeper into one of the newest of those systems, the Reparability Forecast Model (RFM).

RFM has been in use for more than 5 years, having originally been developed by CACI and used by the San Antonio Air Logistics Center (ALC).[2] Now that it has been included in Air Force Materiel Command's (AFMC) standard suite of systems, a comprehensive understanding of both the purpose and logic of the system is needed to ensure its proper use (and avoid its misuse). This article should help users in that understanding. Although RFM's specific role in Air Force depots is uncertain because of the potential transfer of the forecasting function to the Defense Logistics Agency (DLA), its logic must, nevertheless, be understood should it continue to play a role in forecasting at any level.[3]

Before discussing the detailed logic of RFM, it is first helpful, from a macroview, to look at the big picture to understand the role it plays in depot materiel management (Figure 1). Generally speaking, inventory management

Logisticians Must Know Where Logistics Systems Fit into the Overall Picture

involves three primary functions: forecasting, leveling, and ordering. Forecasts are used to establish levels, and levels are then used to trigger orders.[4] Some systems perform all three functions, while others perform only one or two. For example, with depot consumables, the Wholesale and Retail Receiving and Shipping Program (D035K) has historically used past demands as a forecast of future demands and the economic order quantity (EOQ) model to establish levels and place orders.[5] RFM, on the other hand, is strictly a forecasting system. It uses materiel requirements planning (MRP) logic to translate the planned repair requirements in the Secondary Item Requirements System [D200A (replacement for the D041 Recoverable Consumption Item Requirements System)] into a forecast of consumable requirements. In doing so, it identifies potential shortfalls and allows materiel managers to create special requisitions to avoid associated repair delays. It is important to understand two points about RFM. First, it is a system that operates outside the *core process* and provides an external check of the core process, using a different methodology. Second, as its name implies, RFM is primarily a forecasting tool. Although the forecasts can be used to generate special requisitions, its primary purpose is that of forecasting. It does not calculate levels, and it does not generate routine orders to DLA like the Item Manager Wholesale Requisition Process System (D035A).

The remainder of the article provides more details on how RFM performs this function. This includes a detailed look at the system logic of RFM in the context of materiel requirements planning, after which RFM is modeled. Once the logical foundation is established, RFM and MRP are compared and contrasted. This discussion focuses on a few of the most significant similarities and differences, as well as the intended uses of RFM. The final section discusses managerial implications of the purpose and logic of RFM to aid depot materiel managers in its proper use. It also helps illuminate some common pitfalls that might be encountered.

RFM System Logic

Background

Motivated by production delays, the San Antonio ALC contracted with CACI to develop RFM in an effort to identify those parts that would hold up production in the future. RFM was subsequently implemented at Oklahoma City ALC and later chosen by AFMC for inclusion in its standard suite of ALC systems. It has since been implemented at all the air logistics centers, albeit in a limited capacity.

As with any computer system, RFM has an internal logic that defines its strengths and weaknesses. In this case, that basic logic is borrowed from MRP systems. To understand how RFM works, materiel requirements planning is discussed. Throughout the discussion, a simple illustrative example of a company that builds chairs is used. Each chair is comprised of three parts: a back assembly, a seat, and four legs. Although the example is purposely kept simple, the conclusions apply, by extension, to more complex systems as well. In fact, the example is well-suited to the discussion of differences between RFM and MRP, while avoiding an unnecessary level of detail.

Materiel Requirements Planning

MRP systems have three primary inputs: the master production schedule (MPS), the bill of materials (BOM), and inventory records.[6] The master production schedule is comprised of the scheduled end-item production requirements, by date, for each item. An example for the chair is shown in Table 1.

The BOM is a database containing the hierarchy of parts in an assembly. For the chair example, the BOM is presented schematically in Table 2.

The third input, or set of inputs, is inventory records. This is where the MRP system gets data on current inventory levels and projected due-ins, as well as lead times. Together with the master production schedule and BOM, the inventory records allow the MRP system to calculate how much of each part to order and when to order it to meet the MPS requirements. Figure 2 illustrates the basic inputs and outputs of an MRP system.[7]

The goal of materiel requirements planning is to schedule component orders (that is, the back, seat, and legs) so all parts are all available for final assembly in time for the end product (the chair) to be assembled before the due date. In technical terms, a lead-time *offset* is applied to the end item and all its components. For the example, the final assembly of the chair takes 1 week; therefore, it is started 1 week prior to the due date. All three components are then scheduled to arrive just prior to the start

Inventory Management

Inventory management involves three primary functions:

- **Forecasting**
- **Leveling**
- **Ordering**

Forecasts are used to establish levels, and levels are then used to trigger orders.

of final assembly. To accomplish this, they must be ordered to accommodate their various lead times. In this case, the legs and seat must be ordered 1 week prior to final assembly (lead time = 1 week) and the back 2 weeks prior (lead time = 2 weeks). In this way, all components arrive when needed for final assembly, and the due date is met. This process is illustrated in Figure 3.

The primary output of the MRP process is the materials plan, which is simply a time-phased schedule of order releases for each component needed in the end item. Table 3 presents a materials plan for the chair example and shows the lead-time offsets for the various components with shading.[8]

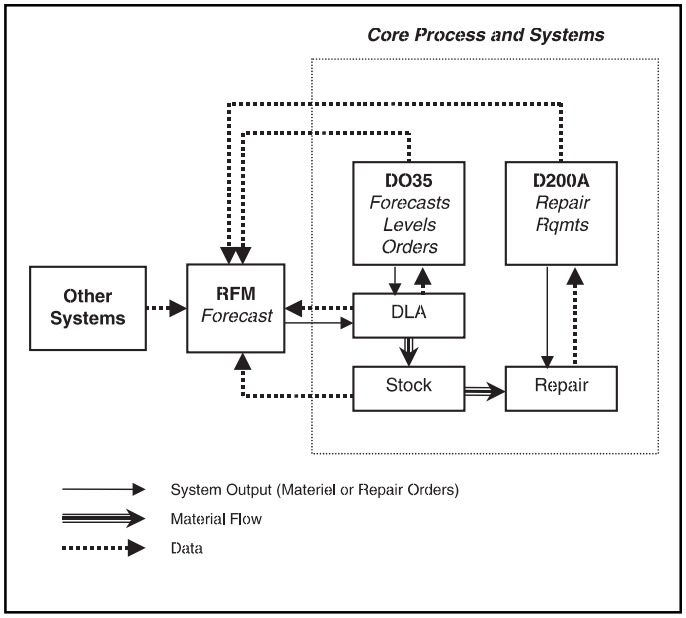


Figure 1. The Reparability Forecast Model and Its Role in Depot-Consumable Management

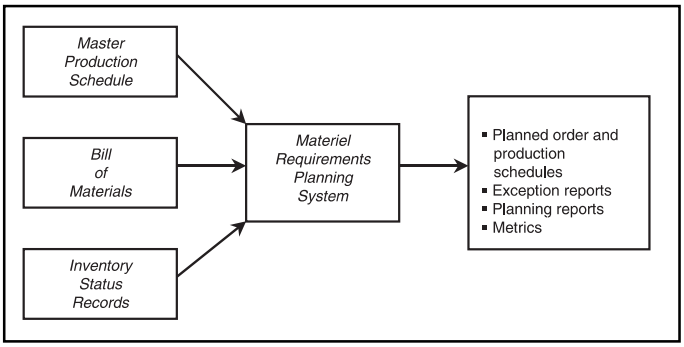


Figure 2: Inputs and Outputs of an MRP System

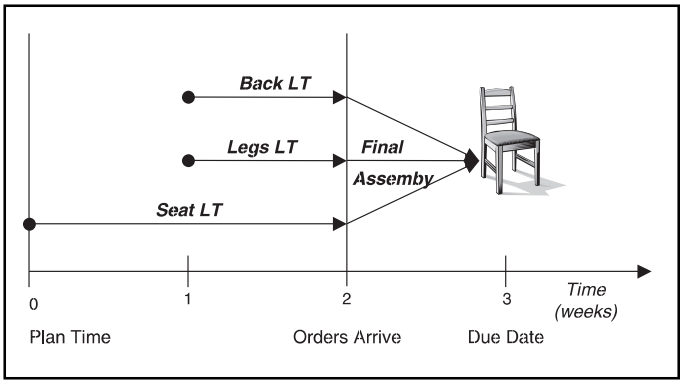


Figure 3: Time-Phased Diagram of Chair Assembly

MRP Versus RFM: Similarities and Differences

Now that the foundation has been laid, the discussion can turn to the subject of interest: the RFM. In the following discussion, MRP conventions laid out thus far are used to identify similarities and differences between MRP and RFM. Additionally, important

Week	1	2	3	4	5	6	7	8	9	10	11	12
Forecasted Chair Rqmts	5	8	12	5	7	10	9	8	3	10	12	6

Table 1. Master Production Schedule for Chair Example

Part No	Noun	BOM Level[1]	Next Higher Assembly[2]	Quantity Per Assembly[3]	Lead Time (weeks)
1	Chair	0			1
2	Leg	1	Chair	4	1
3	Back	1	Chair	1	2
4	Seat	1	Chair	1	1

1. By convention, the end item is generally assigned as level 0, while the direct components making up the end item are assigned as level 1. Parts making up level 1 components would be assigned level 2 and so on. In the Air Force, an end item would be level 0, followed by level 1 line-replaceable units, followed by level 2 shop replaceable units, followed by lower level parts.
2. The next higher assembly is simply the next higher assembly in which the part is consumed.
3. The quantity per assembly refers to the quantity of the part in the next higher assembly.

Table 2. Bill of Materials (Quantity Per Unit Shown in Parentheses)

Week	1	2	3	4	5	6
Chair (End Item, Assembly 1 week)						
Net Requirements	5	8	12	5	7	10
			Lead Time			
Planned Order Releases	8	12	5	7	10	
Legs (Qty 4, Lead Time 1 week)						
Net Requirements	32	48	20	28	40	
		Lead Time				
Planned Order Releases	48	20	28	40		
Seat (Qty 1, Lead Time 2 weeks)						
Net Requirements	8	12	**5**	7	10	
	Lead Time					
Planned Order Releases	**5**	7	10			
Back (Qty 1, Lead Time 1 week)						
Net Requirements	8	12	**5**	7	10	
		Lead Time				
Planned Order Releases	12	5	7	10		

Table 3. MRP Materials Plan for Chair Example

differences are noted between a *traditional* manufacturing environment and that of repair, which has significant implications in terms of system performance.

Similarities

Although there are some important differences between RFM and MRP, they share two major traits: system logic and structure.

Similarity 1: System Logic. MRP systems, as previously discussed, apply a lead-time offset to all components required for production of an end item. This allows the system to automatically order the components at the right times so they all come together for final assembly. Likewise, RFM applies lead-time offsets to all consumable items required for projected end-item repairs, allowing the system to calculate the specific consumable requirements. By comparing those requirements with the items in stock and on order, a report of estimated shortfalls can be generated. Note the distinction between MRP's automatic ordering and RFM's report. This distinction will be discussed in more detail later, but for now, it is important to understand that the underlying system logic is identical.

Similarity 2: System Structure. Recall from Figure 2 the inputs and outputs of a typical MRP system. RFM follows exactly the same structure, but different system names and terminology apply. Figure 4 reproduces Figure 2, with the RFM elements in bold and the corresponding MRP elements in parentheses.[9]

The BOM inputs in Figure 2 come primarily from the Depot Maintenance Materiel Support System (G005M). These include production numbers, quantity per next higher assembly, and replacement percentages, among others.[10] The replacement percentage is an important distinction in a repair environment in that it is an average and will be discussed in more detail as a difference between MRP and RFM.

The MPS inputs come in the form of repair requirements from D200A*. In this case, the MPS and repair requirements are essentially the same from the standpoint of MRP logic. In other words, there is little difference between end-item demand in manufacturing and repair requirements in depot maintenance *from the perspective of the system*. Finally, the inventory data come from a collection of systems, including the D035A, D035K, the Logistics Management Data Bank (D062), Acquisition and Due-In System (J041), DLA systems, and others.[11] As in an MRP system, the inventory data tell RFM how many there are, how many are due in, and when they are due in, in addition to general indicative data. In all, about a dozen systems provide inputs to RFM for processing.

Differences

Although the overall logic and structure of RFM and MRP are equivalent, there are many differences. The three most important to materiel managers, in terms of system performance, are discussed.

Difference 1: Dependent, Semidependent, and Independent Demand. In a traditional manufacturing environment, the quantity of parts required to produce each end item is known. This is referred to as *dependent demand*, since the demands for parts are directly dependent on the demands for the final assembly or product. MRP systems are designed for such environments and are classified as *dependent demand inventory systems*. In repair, however, the quantity required in most cases is unknown until the end item is disassembled, inspected, and tested.

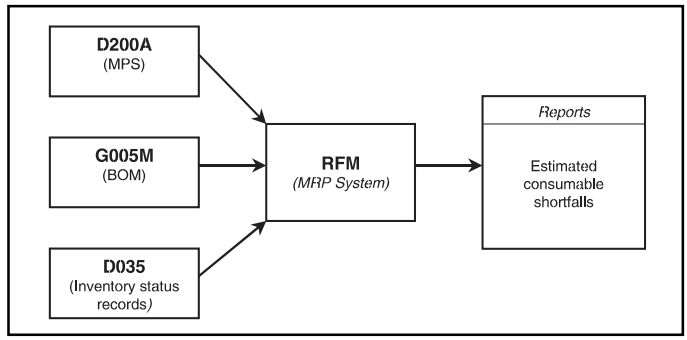


Figure 4: Inputs and Outputs of RFM (MRP Equivalents from Figure 2 Shown in Parentheses)

Although the demand for some parts in repair is certainly directly dependent on the number of end items repaired, almost all can be considered as semidependent or as indirect materiel. Semidependent items are those where the number required for each repair actually varies, although the overall demands over time tend to correlate to end-item repairs. This presents a problem since RFM needs to have a hard quantity to use in the calculation of requirements. This hard quantity comes in the form of a replacement factor. Indirect materiel, by contrast to the first two, experiences independent demand. Such items are typically low-cost, high-demand items that are carried in a bench stock or similar convenient storage area. They also are ordered usually in larger batches, making exact demands difficult to correlate to end-item repairs. Indirect materiel does not lend itself to MRP logic and is better dealt with using *independent demand inventory systems* like EOQ. Obviously, the more dependent the demand, the more appropriate the use of RFM as a forecasting tool.

Difference 2: The Floating Bill of Materials. The most common solution to the problem of unknown requirements (and the one used in RFM) is the use of a replacement factor, which is calculated using historical data.[12] The calculation is simply the number of component issues over a period of time divided by the number of end-item repairs during that same period, which provides a rough estimate of the percentage of time each part is replaced during a repair action. If 1,000 chairs have been repaired over the last year, for example, only 100 seats, 300 back assemblies, and 1,000 legs might have been used. The associated replacement factors would, therefore, be 0.1, 0.3 and 0.25, respectively.[13] The RFM forecast for the next ten chairs, therefore, would be one seat, three back assemblies, and ten legs. Unfortunately, this will almost definitely be wrong, leading to the traditional good news and bad news.

First, the good news: some simple statistics, specifically the Law of Large Numbers, can help us deal with this problem. The law states that a sample mean of size *n* converges to the true mean as *n* gets large, or mathematically:[14]

$$P(M_n \to \mu, n \to \infty) = 1$$

In the context of RFM, the M_n represents the average of the actual requirements (M) for n repairs, while m represents the replacement factor. If the assumption is made that the past demands used in the replacement factor are an accurate predictor of the future, then m is also the future average demand rate per

repair. What this means to RFM users is that, even though forecasted consumable requirements for individual repairs can be expected to be wrong (that is, $M_n ? m$), the more requirements are pooled, the closer it will be (as n gets larger, M approaches m). In other words, RFM assessments can be used to identify shortfalls, but orders should be made in larger lot sizes to smooth out the variability in individual repairs. Forecasting consumables for ten repairs will be more accurate than forecasting for a single repair.

This fact can be easily demonstrated by simulation. Figure 5 shows the results of a simple simulation of 1,000 runs, for an item with a quantity per assembly of ten and a replacement factor of five.[15] Using RFM logic, a quantity of five is, therefore, forecasted for each repair. The horizontal axis in Figure 5 represents the number of repairs, from one to ten, that are *pooled* in a single order. Even ordering for two repairs significantly reduces the resulting deviation from actual requirements, over ordering for a single repair, from 50 to 34 percent. Pooling just four repairs cuts the expected deviation in half. Note also the diminishing returns, suggesting the gains level off beyond some point.

The results of this simple illustrative simulation are consistent with those of a more rigorous simulation of depot engine repair completed in 1998.[16] Ordering for individual repairs led to a modest increase in materiel availability at an extremely high cost in excess inventory. In contrast, ordering the EOQ whenever a shortfall was identified significantly increased materiel availability with a modest increase in inventory.

Now for the bad news: this is precisely the opposite of the current AFMC policy of placing smaller, more frequent orders. So the practice of batching orders must be used with discretion and only for those items that will hold up production. Ideally, the quantity ordered based on RFM forecasts would correspond to the point at which the gains level off. Alternatively, a second potential solution exists in the form of a *modified replacement factor*.

Recall that the replacement factor is an average, meaning that it will be insufficient about 50 percent of the time. It is a simple matter to incorporate service levels into the calculation of the replacement factor, ensuring that parts are on hand with an acceptable probability. This is the equivalent of adding a safety stock level to the replacement factor. For example, if the chair back has a replacement factor of 0.3, three would be needed, on average, for every ten chairs to be repaired. Ordering three for every ten repairs would give a service level of approximately 50 percent, meaning that three would only be enough about half of the time. If, however, 95 percent of the time, five or less are needed, five for every ten to be repaired could be ordered with assurance that there would be enough back assemblies in almost all cases.[17] Using such a *modified replacement factor* is one way to avoid pooling large numbers of requirements for ordering.

Difference 3: The Role of the System. On the output side of Figures 2 and 5, there is another distinction between MRP and RFM. Where materiel requirements planning is a complete production and inventory system (particularly modern MRP and MRP II systems, which consider capacity constraints as well as inventory), RFM is an inventory-only, *decision support system*. MRP actually plans the production and places orders, while RFM simply flags items that may hold up planned production based on a forecast. The logic is the same, but the purpose and outputs are different.

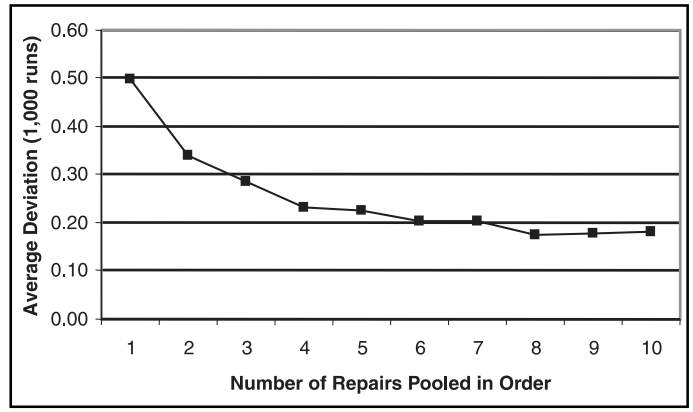


Figure 5. Results of Illustrative Simulation (1,000 Runs, Demands *U~(1,10)*, Orders Based on RFM Calculation Using Replacement Factor of 5)

RFM can provide two types of forecasts for materiel managers:[18]

- An estimate of inventory availability, given the current projection of repairs in D200A
- An estimate of shortfalls if the current projection changes (a *what if* analysis)

In either case, materiel managers can generate special requisitions and expedite existing requisitions to meet consumable demands for repairs. These special requisitions are generated automatically by RFM but are subject to review by depot materiel managers before their release to DLA. They also can use the forecast to justify make-or-buy decisions or adjust the production schedule based on materiel availability.[19]

Conclusions and Management Implications

Up to this point, it has been established that RFM is a forecasting system that uses MRP logic, and MRP has been discussed. In the last section, some major similarities and differences between the two were identified. This concluded with a list of suggestions for users, all based on the preceding discussions. Table 4 summarizes the problems and proposed solutions.

What RFM Is and What RFM Is Not

RFM is a decision support system, meaning it is not the core system that sets levels and orders parts. It is used to create forecasts of consumable demands, which can then be used to generate special requisitions if deemed necessary by materiel managers. It is intended to give materiel managers at the depots the capability to assess parts availability to support current repair projections and conduct *what if* analyses of upcoming changes in the repair projections. Unlike MRP systems, it is not intended to routinely determine parts requirements and automatically place orders.

Dependent Demand

MRP and RFM are designed for items with dependent demand. For items with at least semidependent demand, a floating BOM (replacement factors) can be used, albeit with a full understanding of its implications. For items with independent demand, such as indirect materiel, RFM should not be used to forecast demand.

Two additional item characteristics should also be considered in addition to the dependence issue. First, end items with a fairly constant repair schedule over time will derive little benefit from the use of RFM. Recall that the EOQ model assumes constant, steady demand. If this is the case, RFM will do little to improve existing levels. Second, for consumables that are common to many end items, the variability in repair schedules for each will tend to balance out in aggregate. This will usually mean less variability in consumable demand and, therefore, less benefit from RFM assessments. Users should screen their consumables accordingly rather than using RFM indiscriminately across all items.

Caution: Floating BOM Ahead

Earlier, the issue of the *floating BOM*, which means that the actual quantities used vary from repair to repair, was discussed. Because the replacement factor in the BOM is an average, RFM's forecasts will be either too high or too low almost all the time. Unfortunately, it is not known in advance which. Because MRP logic was not intended for a repair environment with unknown part requirements, extreme care should be exercised in using the output of RFM. Although it can be a useful tool, its output should not be regarded as an exact solution. Materiel managers should balance the need for a large batch order (remember the discussion on the Law of Large Numbers) and the current AFMC policy of daily ordering (which will smooth out the demand that DLA sees). A modified replacement factor incorporating a safety-level quantity is one alternative to batching orders that may avoid unnecessary excess inventory, while maintaining target availability.

Problem	Solution
Parts with semidependent demand	*Floating* Bill of Materials.[1]
Parts with independent demand (indirect materiel)	Exclude from RFM forecasts.
Floating BOM quantities	• Larger orders.[2] • Modified replacement factors.[3]
Parts with constant demand	None. RFM probably will not help, but it will not hurt either. If demand is constant, existing levels should suffice in most cases.
Misdirected metrics	Metrics should focus on forecast accuracy.
Poor coordination	Maintain close coordination. If DLA loses confidence in RFM-initiated forecasts, it will be hesitant to continue honoring them.
Overuse	Use RFM discriminately for only those items that show dependent demand characteristics and are consistently short due to insufficient levels.
1. Floating BOM is also a problem (see Floating BOM quantities, row 3 of table). 2. Larger orders are inconsistent with AFMC policy of daily ordering. 3. Modified replacement factors require more detailed data than currently available.	

Table 4. RFM Problems and Recommended Solutions

Metrics

Metrics need to be carefully developed, measured, and analyzed to determine if RFM is meeting Air Force needs without an unreasonably high inventory investment. Although early metrics were geared toward ensuring the system was interfacing correctly with Air Force and DLA legacy systems, a more important set of metrics is one that shows whether the RFM forecasts are accurate. To do this, the RFM forecasts, the orders they generate to DLA, and the actual demands corresponding to those forecasts and orders must be tracked. In doing so, an assessment of whether RFM is a valid forecasting tool can be made.

Coordination

Coordination between AFMC and DLA has been exemplary throughout the development and implementation of RFM. This coordination must continue so that both sides openly share information and metrics. Only if DLA has faith in RFM forecasts will it continue to use them for its own planning purposes.

Scope of Use

At present, RFM is being used on a very limited basis, primarily for depot engine repair. Increased use will cause a corresponding rise in special requisitions to DLA, which will lead to an increased workload. It remains to be seen whether or not this increase will cause problems on the DLA end. Again, continued coordination will help avoid future problems regarding workload.

RFM's Future Role

The combined effects of the Customer-Oriented Leveling Technique (COLT)[20] and daily ordering at the air logistics centers should, in the near future, improve consumable-item support to depot repair operations.[21] This, in turn, should reduce the dependence on external w*atchdog* forecasts such as those generated by RFM. That said, the *what if* capability of RFM still can prove useful to materiel managers in adjusting to known demand changes. The forecast methodology of RFM can also be incorporated into existing or future leveling and ordering systems, although the cautions set forth in this article will still apply in that case.

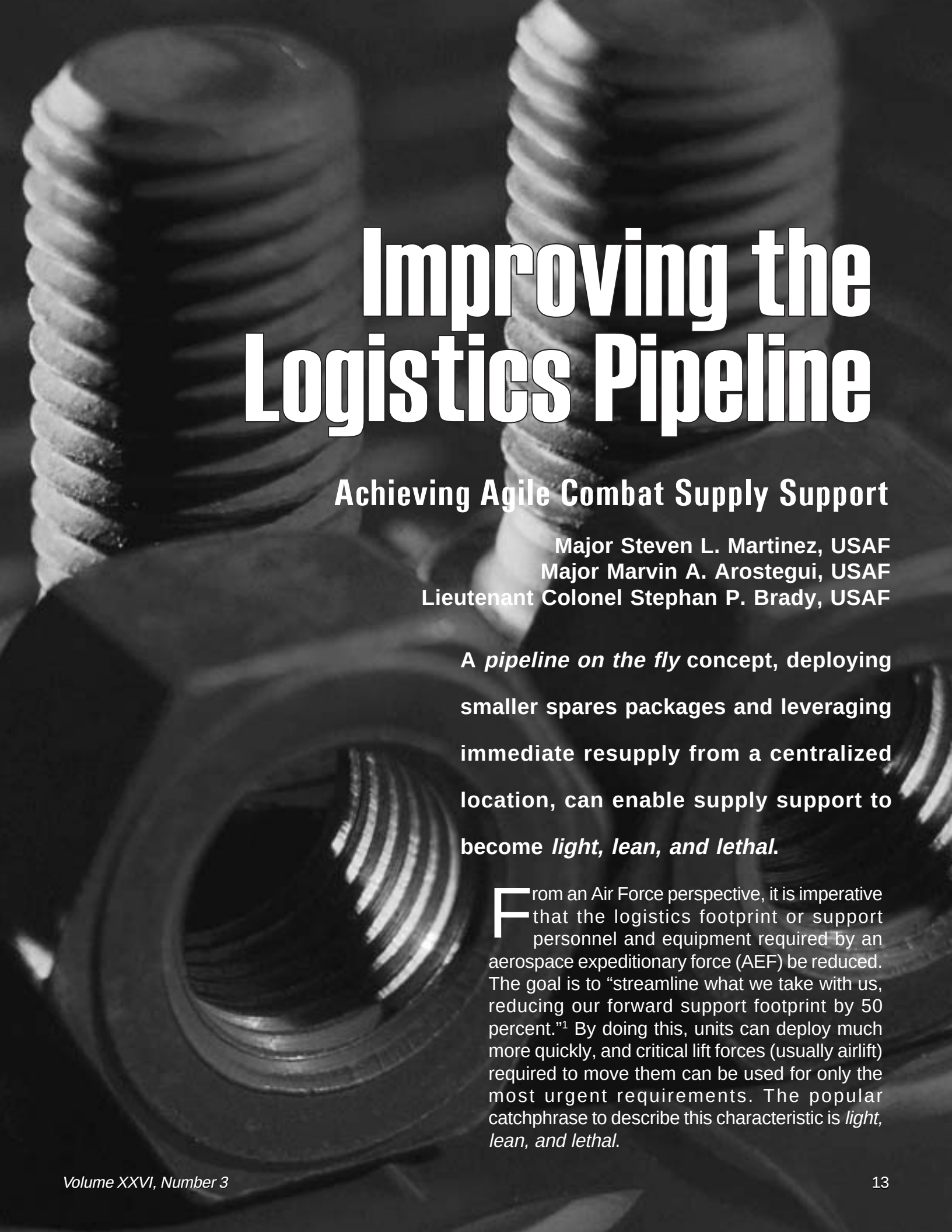
RFM can be a useful tool for forecasting consumable requirements at the depots, but users must be fully aware of the logic of the system to use it properly and avoid its misuse.

Notes

1. Maj Kevin Gaudette, Dr Douglas Blazer, and H. Kenneth Alcorn, "Managing Air Force Depot Consumables, *Logistics Dimensions 2003*, Air Force Logistics Management Agency, Maxwell AFB, Gunter Annex, Alabama, Dec 02, 22.
2. "Reparability Forecast Model Background Paper," CACI, Aug 96.
3. One of the authors has been directly involved with Air Staff discussions on transferring the forecasting function to DLA. If DLA takes on the function, an option that has been discussed is that of using either RFM or a system like it to perform this function.
4. This is somewhat simplified for the sake of this article. Forecasts play a role in determining stock levels, whether the forecast is based on past demand or on some anticipated demand. Orders are then placed periodically to keep physical stock close to the stock levels, with order size being largely a matter of policy. Other factors involved in the forecasting, leveling, and ordering functions include leveling technique, cost structure, service-level targets, and policy.
5. The EOQ leveling function in the D035A will be replaced gradually by COLT, and its ordering function has been replaced by daily orders in lieu of ordering the EOQ when stock reaches the reorder point.

(Continued on page 44)

Logistics Support



Improving the Logistics Pipeline

Achieving Agile Combat Supply Support

Major Steven L. Martinez, USAF
Major Marvin A. Arostegui, USAF
Lieutenant Colonel Stephan P. Brady, USAF

A *pipeline on the fly* concept, deploying smaller spares packages and leveraging immediate resupply from a centralized location, can enable supply support to become *light, lean, and lethal*.

From an Air Force perspective, it is imperative that the logistics footprint or support personnel and equipment required by an aerospace expeditionary force (AEF) be reduced. The goal is to "streamline what we take with us, reducing our forward support footprint by 50 percent."[1] By doing this, units can deploy much more quickly, and critical lift forces (usually airlift) required to move them can be used for only the most urgent requirements. The popular catchphrase to describe this characteristic is *light, lean, and lethal*.

In fact, the goal of the Air Force is to be able to deploy an AEF within 48 hours and up to five AEFs in 15 days. This will be done through improvements generated by leveraging "information technology, rapid transportation, and the strengths of both the organic and industrial logistics base to ensure responsive, dependable, precise support."[2]

Within the realm of supply support, the movement of spare parts and key consumable items, normally contained in a readiness spares package, is a major consideration for planning the deployment of a unit. As such, methods to reduce the size of mobility readiness spares packages (MRSP) must be investigated. Currently, MRSP requirements are computed based on 30 days of support for a contingency, with the assumption there will be no resupply. The amount of spares authorizations allotted to each base for every weapon system comprises the assets needed to support the most taxing scenario involving the greatest number of aircraft that would deploy from that location. In practice, supply and sortie generation personnel coordinate with each other to tailor each kit, based on the expected number of sorties and duration of each sortie for the contingency. However, it seems as though there is no situation, except for a deployment that you cannot resupply within 30 days, for which it is necessary to keep 30 days of spares on hand. Therefore, it seems logical, for cost and airlift-requirement reduction purposes, to stock at the home station only the minimum number of spares required to support a deployment, up to the point at which the resupply pipeline can deliver an asset to the forward operating location.

Also, it is probable that the Defense Transportation System, through which aircraft parts are moved, can be improved so that the assets needed for an entire military operation do not have to be deployed at the outset of a contingency. In contrast, by reducing the total shipment time and the variability in these times, holding at the home station those spares projected to be needed later in the deployment may be a viable way to reduce the initial lift requirement (Figure 1).

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

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

Risk Pooling

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

> Risk pooling suggests that demand variability is reduced if one aggregates demand across locations because, as we aggregate demand across different locations, it becomes more likely that high demand from one customer will be offset by low demand from another. This reduction in variability allows us to reduce safety stock and, therefore, reduce average inventory.[3]

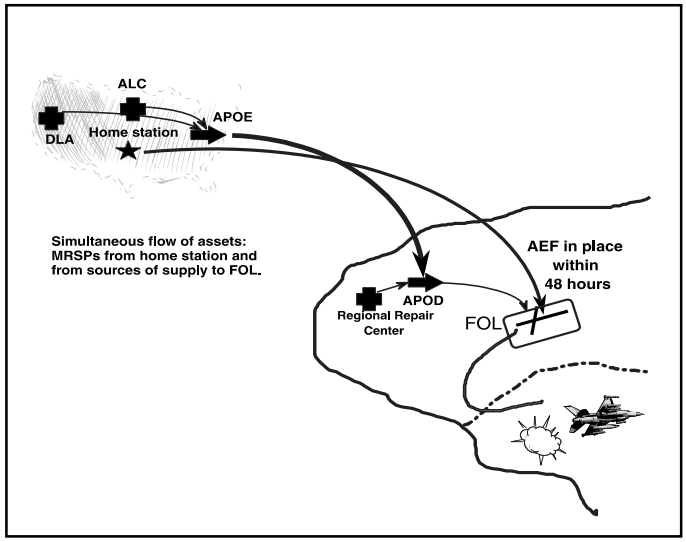


Figure 1. Simultaneous Movement of Parts from Sources of Supply to Point of Use

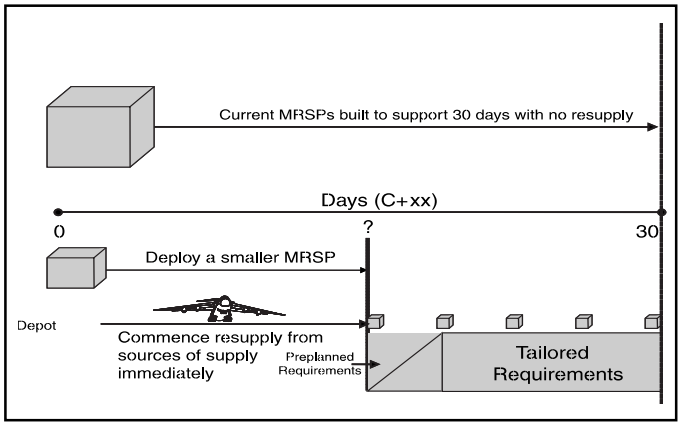


Figure 2. Pipeline on the Fly

Tradeoff Framework

While there are numerous considerations involved when incurring costs in a business enterprise, there must exist a method by which these costs are categorized and compared. A classic methodology used in the study of logistics to decide on the implementation of just in time (JIT) is to compare costs using the inventory-transportation tradeoff (Figure 3). In this type analysis, it is given that a firm desires to decrease total operating costs and is weighing decreases in on-hand inventory costs (for example, purchasing, warehousing, and personnel) from carrying less material against increases from using premium transportation to move items quickly and consistently through the logistics network. It must be stressed that it is much more important to reduce the variability of the transportation than it is to speed it up. A process that is reliable and consistent allows for more effective planning and forecasting of demands.

Logistics Response Time

To analyze the logistics pipeline, there must be a useful way to measure it. The process of transforming a need into an asset in hand recently has been evaluated in several ways. The following is a discussion of the two most recent measurements that have been used by the Air Force: order and ship time (O&ST) and logistics response time (LRT).

It is important to understand how the Air Force Materiel Command (AFMC) LRT metric ties into the logistics pipeline model. Each segment can be aligned with a step in the pipeline, as shown in Figure 4. The base requisition time reflects step 1, the time required to transmit an order from the requester to the source of supply. In step 2, both the ICP (order receipt) and Defense Logistics Agency (DLA) (acquisition or order picking) processes occur at the depot. The transit time reflects the rest of the logistics pipeline, from the time the depot inputs an item into the transportation system until the item is received by the user and status is updated to reflect the asset arrived.

The time it takes to place an order for an item from the forward operating location and receive it had to be calculated. This provided the frame of reference for determining what range of resupply times is probable in future contingencies. Sample data taken from Operation Noble Anvil, the US air campaign in support of Operation Allied Force, and the US and North Atlantic Treaty Organization's action to bring an end to Serbian atrocities in Kosovo were analyzed statistically to construct the feasible region of times.

The data tended to follow a lognormal distribution, as ascertained through the use of a distribution analysis software program. Because the values follow such a distribution (Figure 5), it is more valid to view the median or mode as a measure of central tendency than the mean or average logistics response time.

The median is "the middle number when the measurements are arranged in ascending (descending) order."[5] Another way to describe the significance of this statistic is to note that 50 percent of the area under a graph of the distribution of values lies to the left of the median, and 50 percent of the area lies to the right. This statistic is a more valid measure of central tendency than the mean since it is less susceptible to the effects of very large or very small data values. In addition, the mode was considered in the research since it "is the measurement that occurs most frequently in the data set."[6] This statistic is especially useful in cases when it is important to ascertain the section of the quantitative data set in which most of the observations occur.[7] As shown previously in Figure 5, the skewing of the data results in a mean value that is much higher than the median. So consideration of the median and mode was appropriate (Table 1).

The results shown in Table 1 indicate that the current logistics pipeline—tested in one of the most recent combat situations—performs rather well, since a part almost always arrived where needed in 6 days. However, it seemed that the process included a lot of variance and, hence, made it less than reliable. Compared to the descriptive statistics for the O&ST values used in calculating the kit spare parts requirements, the current pipeline seemed to perform better.

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

The three outputs in Table 2 represent the elimination of the highest 5 percent (95), 10 percent (90), and 25 percent (75) of the LRT values, respectively.

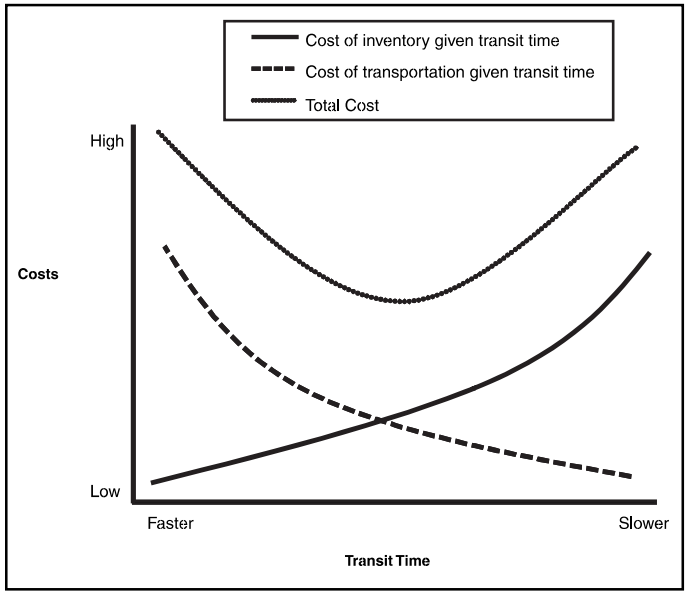


Figure 3. Inventory-Transportation Tradeoff

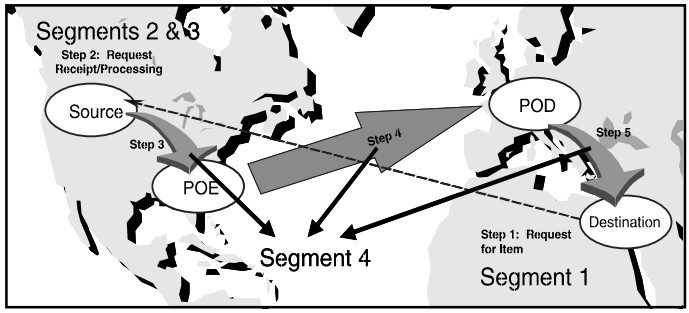


Figure 4. Relationship of AFMC LRT Segments to the Logistics Pipeline

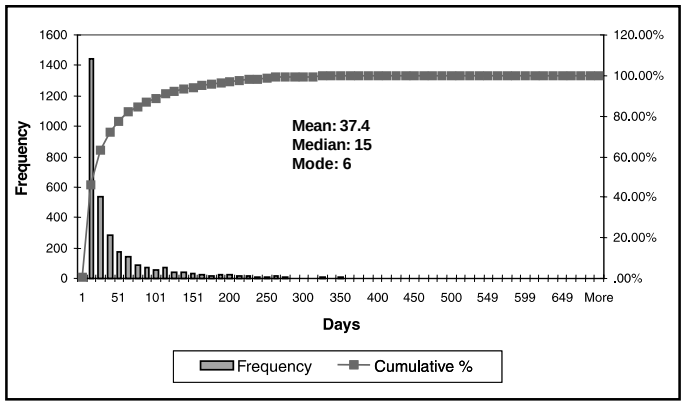


Figure 5. Histogram of Logistics Response Times from Operation Allied Force and Noble Anvil[4]

Operations Allied Force and Noble Anvil LRTs	
Mean	**39.41511224**
Standard Error	1.050801383
Median	**15**
Mode	**6**
Standard Deviation	59.09765275
Sample Variance	3492.532561
Kurtosis	22.57363628
Skewing	3.674828978
Range	698
Minimum	1
Maximum	699
Sum	124670
Count	3163
Confidence Level (95.0%)	2.060323046

Table 1. Excel Descriptive Statistics Output for Allied Force and Noble Anvil Logistics Response Times

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

Table 2. Descriptive Statistics without Outliers

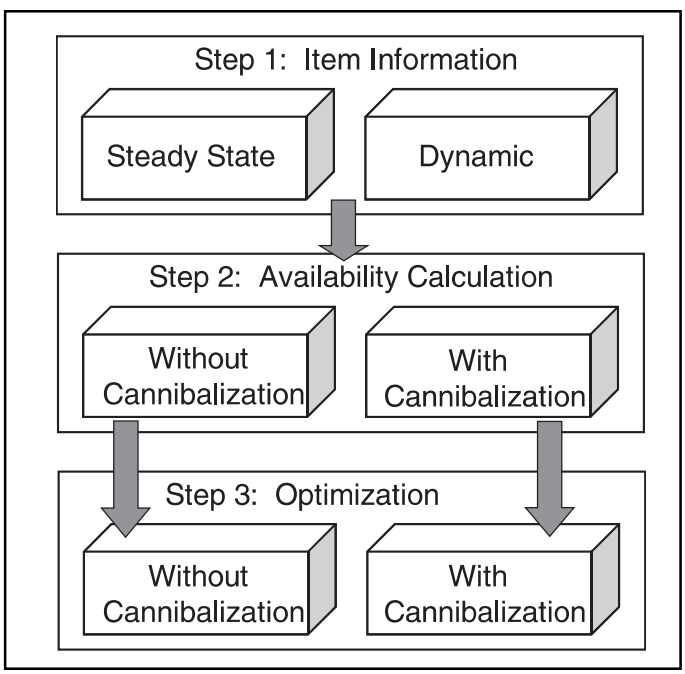


Figure t. Basic Model Methodology[10]

As the data indicate, perhaps a better approximation of the actual average logistics response time is around 16-18 days.

Impact of Kit Reductions

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

Aircraft Sustainability Model

The Aircraft Sustainability Model (ASM) is used by the Air Force to calculate the number of spares required to be maintained in an MRSP. The logic of the program ensures that the spares mix producing the highest aircraft availability, given a level of funds, is created. The model requires data elements provided by either the Dyna-Metric Microcomputer Analysis System or the D087 report from AFMC, known also as the Requirements Execution Availability Logistics Module (REALM). REALM contains information pertaining to items such as demands (failures) per flying hour, base and depot repair times, probability of repair at a given location, condemnation rates, shipping times, unit cost, quantity per application, and procurement lead time.[8]

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

- The first step involves characterizing the probability distribution of the number of items in various stages of the resupply process (or pipeline)—unserviceables in repair at bases or depot and serviceables and unserviceables in transit. The relationship between these quantities and the number and location of spares in the system determines the probability of a back order.
- The second step is to relate that item information to weapon-system performance; specifically, to determine the expected number of item back orders, the expected number of aircraft not mission capable supply, and several other weapon-system-oriented measures of supply performance.
- The third step is to produce the availability-versus-cost curve and the associated optimal spares mix for a specified availability or budget target. The model uses a marginal analysis technique that determines the best mixes of spares for a wide range of targets.[9]

This technique is illustrated in Figure 6. In the first step, the user inputs information, based on either a steady-state (peacetime) or dynamic (wartime) flying-hour scenario, into the model. Since the research analyzed support of combat operations, dynamic flying-hour data were used. The second step actually calculates the expected aircraft availability based on the cannibalization option chosen in step 1. Then the third step allots an optimal spares mix through marginal analysis, recommending the purchase of items that have the highest benefit-to-cost ratio first.

It creates a *shopping list* of spares and *purchases*, each one in order, until either all spares are allocated or the specified funding level for spares is exhausted.[11] Because of the importance of generating every sortie in wartime operations, cannibalization or the removal of a working item from a nonfunctional aircraft to another aircraft is a normal practice. Therefore, the full cannibalization option was used throughout the research.

NSN	78.4	56.8	35.2	13.6	0.0	0.0	% Reduction
1560007242853FL	13	19	26	30	30	30	
1560008601911FL	13	19	26	30	30	30	
1560008601912FL	13	19	26	30	30	30	
1560011273340FL	6	8	11	13	13	13	
1620010639477	13	19	26	30	30	30	
1630004927144	13	19	26	30	30	30	
///	///	///	///	///	///	///	
6620005573023	13	19	26	30	30	30	
6620005619380	7	11	15	17	17	17	
6620011404405	7	11	15	17	17	17	
6620011450265	13	19	26	30	17	17	
6620011519590	13	19	26	30	14	14	
6620012471816	13	19	26	30	30	30	
Average	4.806	9.982	14.783	20.083	23.138	23.138	
Goal	5	10	15	20	25	30	

Table 3. Sample Solver Calculations

To evaluate the effect of changes to the logistics response time on spares requirements, it was necessary to adjust the data within the kit files from D087 to reflect various average order and ship times. Although logistics response time includes more than just order and ship time, the only other repair time values in the kit file were *base repair* and *depot repair*. There was no point in considering base repair time since it was assumed that none would be available. This assumption is discussed later when the values for base repair time of components is explained. Also, depot repair time values include more data than does the logistics response time. Therefore, including this number in the analysis could have injected more error. So the simplest and most accurate substitute for logistics response time was order and ship time.

The adjustment of O&ST values was accomplished by exporting the kit data into an Excel spreadsheet and modifying the values representing expected wartime order and ship times for each item in the kit (Table 3).

Using the solver add-in, these values were adjusted to provide overall average order and ship times of 5, 10, 15, and 20 days for the entire kit of each aircraft type. In Table 3, the % Reduction column represents the percentage decrease applied to the original values that result in an average (*Average*) that is equal to or less than the target (*Goal*) value. The spares packages for all four aircraft had average order and ship times less than 25 days, so there was no need to create higher adjusted average values. These new item order and ship times had to be rounded to the nearest integer, put back into the Excel spreadsheet, and input into the Aircraft Sustainability Model.

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

Experimental data run in the Aircraft Sustainability Model were accomplished for each aircraft—B-52H, F-15E, F-16C, and KC-135—with various combinations of order and ship time and the day order and ship begins (DO&SB) (Table 4). For each weapon system, the number of aircraft the kit was designed to support (primary aircraft authorized) was matched with various values of order and ship time and DO&SB.

Similar combinations of values were used for each of the weapon systems in this analysis, with the value for primary aircraft authorized based on the size of actual spares kits used in the Air Force. Once the total cost of the kit was calculated, it was compared with the cost of the current 30-day kit. A percentage difference was computed to show the degree of decrease that results from the changes in order and ship time and DO&SB. An example of the results attained in this analysis is shown in Table 5.

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

Table 4. Sample of Experimental Runs in the Aircraft Sustainability Model

These analyses indicate there may be significant cost savings that can be achieved by either reducing the order and ship time or DO&SB, or both. Further, these reductions can be attained while still maintaining the minimum level of support (target aircraft availability rate) used to compute spares requirements.

Just as compelling were the reductions in the kit size realized through the changes in order and ship time and DO&SB. Again, a sample of the reductions in kit size is shown in Table 6. As was seen in the values for kit cost, there were significant reductions in kit size when the order and ship time and DO&SB were decreased.

The Effect of *Pipeline on the Fly*

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

The response surface graph in Figure 6 is an example of the illustrations created to give an indication of the relative strengths of both independent variables in producing the value for kit cost and kit size. For the B-52H, there was a distinct linear decrease that corresponded with the decrease in order and ship time. Also, there was almost no variation in the axis that represents the values for DO&SB.

In fact, the response surfaces for the F-15E, F-16C, and KC-135 indicated the same relationships. All showed a decline in the kit cost and size values that match the trend in order and ship time, and very little changed in relation to the decrease in the variable DO&SB. Visually, it was apparent that order and ship time had a significant impact on the kit cost, while it seemed that DO&SB had very little influence on the reductions that occurred. The response surfaces for kit size also illustrated this relationship, an example of which can be seen in Figure 7.

A/C	PAA	O&ST	DO&SB	Kit Cost ($M)	% Diff *
B-52H	6	5	0	15.56	61.55
B-52H	6	5	7	16.65	58.86
B-52H	6	5	15	16.65	58.86
B-52H	6	10	0	23.57	41.76
B-52H	6	10	7	24.19	40.23
B-52H	6	10	15	24.71	38.95
B-52H	6	15	0	30.58	24.44
B-52H	6	15	7	30.92	23.60
B-52H	6	15	15	32.10	20.69
B-52H	6	20	0	37.35	7.71
B-52H	6	20	7	37.68	6.90
B-52H	6	20	15	38.80	4.13
*vs 30-day kit cost of $40.47M					

Table 5. Sample of Results from ASM

A/C	PAA	O&ST	DO&SB	Kit Size (Pallets)	%Diff*
B-52H	6	5	0	7.84	67.05
B-52H	6	5	7	9.95	58.20
B-52H	6	5	15	9.95	58.20
B-52H	6	10	0	12.33	48.19
B-52H	6	10	7	13.10	44.98
B-52H	6	10	15	13.57	42.98
B-52H	6	15	0	14.74	38.07
B-52H	6	15	7	14.81	37.76
B-52H	6	15	15	16.26	31.69
B-52H	6	20	0	17.75	25.42
B-52H	6	20	7	17.88	24.86
B-52H	6	20	15	20.59	13.48
*vs 30-day kit size of 23.8 pallets					

Table 6. Sample of Results from ASM Experimental Runs, B-52H Kit Size

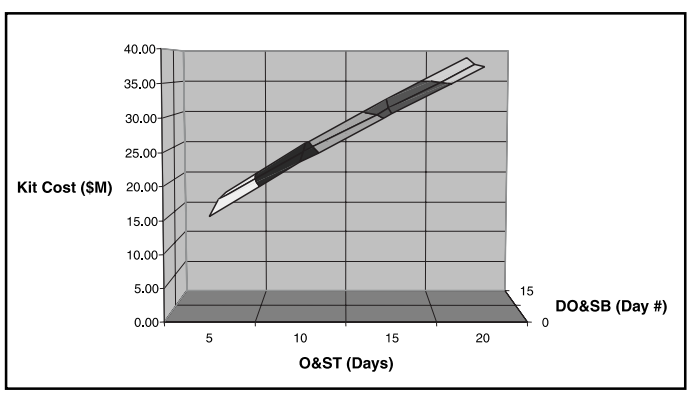


Figure 6. Sample Response Surface for Kit Cost, B-52H

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

For the equation

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

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

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

The results (Table 7) indicated that the variable order and ship time was the only significant contributor to the value of kit cost for F-15Es.

The change in DO&SB did not have a significant impact on the dependent variable kit cost. The same was true for all kit sizes and costs, except for the B-52H (both kit size and cost) and the KC-135 (kit size). It can be concluded, then, when only these two variables were considered in a model, order and ship time was a significant predictor of the output results while the effect of DO&SB was not clear.

FSL Option of the Aircraft Sustainability Model

To better evaluate the *pipeline on the fly* concept, the forward support location (FSL) option of the Aircraft Sustainability Model was employed. In its basic form, the FSL option allows the user to analyze the spares level required when using a central inventory point that is in the same geographic area as the spare parts kits at the forward operating locations. The forward support location, then, is an intermediate storage location between the end user and the depot. In the research, the objective was to understand the feasibility of the *pipeline on the fly* concept. Therefore, the FSL option was used in a modified manner so that it would model only the stockage of aircraft spares at depots and forward operating locations (Figure 8).

By setting the *resupply time from the depot* parameter at a value of 99, the model effectively stocked at only two echelons: the forward support location and forward operating location. Assuming there was a requirement to stock an asset at either the forward support location, with a reasonable order and ship time, or the depot, with an order and ship time of 99 days, the model always chose to place it at the forward support location. Henceforth, the forward support location can be thought of as the depot, and the depot can be thought of as the manufacturer. When this was done, the model was, in effect, forced to stock an asset either at the depot or at one of the forward operating locations.

When the FSL option was used, it seemed the *pipeline on the fly* concept was modeled more aptly. In contrast to the use of DO&SB in the Aircraft Sustainability Model, the FSL option provided results that could be used to illustrate the impact on the logistics pipeline from implementing a change in the process. An example of the results obtained from the FSL option is shown in Table 8.

In Table 8, *Percent Reduction* was the difference between the 30-day value (either cost or size) and the value obtained at the various order and ship times. Then, *Kit Sum Cost/Size* were the individual kit sizes or costs multiplied by the number of spare parts kits in the Air Force. The *Depot Cost/Size* represented the amount of spares that the FSL option recommended for stockage at the depot and, when added to the *Kit Sum Cost/Size*, became the *Overall Cost/Size*. Finally, the *30-Day Kit Cost/Size* reflected the cost and size of a standard spares kit analyzed in the Aircraft Sustainability Model with the same sortie data (number of sorties per aircraft, hours per sortie, and total hours per day), and that standard kit multiplied by the number of kits is the overall *30-Day Kit Cost/Size.*

At this point, using a graphical depiction of the results helps one appreciate the magnitude of savings possible by using this type analysis. The Air Force's newest airlifter, the C-17 Globemaster III, is capable of carrying a maximum payload equal to 18 pallets.[12] Assuming a typical AEF deployment consists of at least one MRSP from each of the four weapon systems analyzed in the research, such a movement would require 66 pallets of parts and cost $85,510,862.33.[13] To move this load, the Air Force would need to use 3.67 C-17 aircraft (Figure 9).

In contrast, simply using the FSL option with no reduction in order and ship time (O&ST = Baselines) lowered the single-deployment airlift requirement by nearly 24 percent. The airlift requirement gradually slimmed to .59 C-17s when the order and ship time was cut to 5 days. When the size of each spares package was multiplied by the number of kits the Air Force maintains and added to the size of spares stocked at the depot, an overall kit size was the result (Figure 10).

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

While these results are significant with respect to the Air Force's objective of reducing its deployment footprint, the cost savings attained through the use of FSL option analyses are perhaps more amazing. When compared with the cost of a single deployment of current 30-day kits, using the FSL option, without adjusting the order and ship time, lowered the cost by more than 28 percent to $61,279,584.88, for a savings of $24,231,584.45 (Figure 11).

The savings achieved by using the FSL option and reducing the order and ship time to 5 days nearly equaled the cost of a single deployment of current 30-day MRSPs.

In a fashion similar to overall kit size, the cost of each kit was multiplied by the number of kits the Air Force had and added to the spares stocked at the depot to calculate an overall kit cost. Again, merely using the FSL option with the baseline kit data resulted in almost a 27-percent reduction in the cost of aircraft spares, from $714,862,875.61 to $512,163,811.78. This savings was the same amount needed to purchase almost one C-17 aircraft (Figure 12).

Lowering the order and ship time to 5 days further increased the savings to $628,719,490.99 or the cost of 2.66 C-17 aircraft.

Summary

The research effort was conducted to gain an understanding of the effect improving the logistics pipeline had on the way the Air Force supplies aircraft spares in combat operations. Through various improvement efforts, the Air Force is attempting to streamline its logistics functions. This will enable a future AEF to be employed as a *light, lean, and lethal* combat power. Two main areas in this endeavor are reducing the cost of support and trimming down the size of the materiel needed for this support.

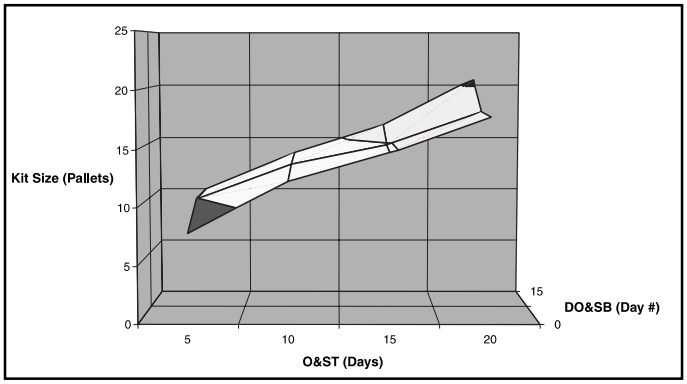


Figure 7. Sample Response Surface for Kit Size, B-52H

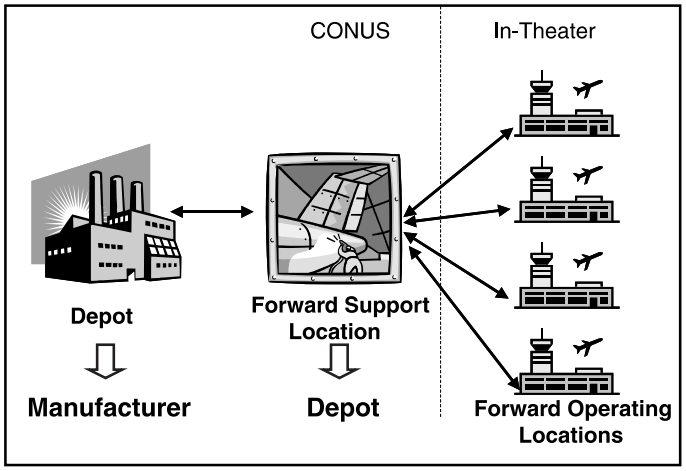


Figure 8. Modified FSL Option

Response: F-15E Kit Cost Summary of Fit

R Square	0.958523
R Square Adj	0.949306
Root Mean Square Error	0.204555
Mean of Response	0.204555
Observations (or Sum Wgts)	0.967512

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
O&ST	1	1	8.70220417	207.9702	<.001
DO&SB	1	1	0.0007988	0.0191	0.8931

Table 7. Sample Regression Analysis Results from JMP, F-15E Kit Cost

F-15E	No of Kits	3			
O&ST	Kit Cost	% Reduction	Kit Sum Cost	Depot Cost	Overall Cost
5	$349,725.54	97.49	$1,049,176.62	$3,286,395.21	$4,335,571.83
10	$2,744,519.97	80.28	$8,233,559.91	$3,286,395.21	$11,519,955.12
15	$5,011,562.15	63.99	$15,034,686.45	$3,286,395.21	$18,321,081.66
20	$7,430,842.24	46.61	$22,292,526.72	$3,286,395.21	$25,578,921.93
21	$7,787,953.55	44.04	$23,363,860.65	$3,606,465.48	$26,970,326.13
	30-Day Kit Cost	**$13,917,843.06**		**Overall 30-day Kit Cost**	**$41,753,529.18**
O&ST	Kit Size	% Reduction	Kit Sum Size	Depot Size	Overall Size
5	0.23	94.18	0.68	1.70	2.37
10	1.20	68.96	3.60	1.70	5.30
15	1.71	55.74	5.14	1.70	6.84
20	3.33	14.00	9.99	1.70	11.68
21	3.43	11.39	10.29	1.74	12.03
	30-Day Kit Size	**3.87**		**Overall 30-day Kit Size**	**11.62**
Note: Kit sizes are in pallets					

Table 8. Sample FSL Option Results, F-15E

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

Figure 9. Airlift Requirement in a Single Deployment

Overall Kit Sizes for MRSPs with:	
30-Day Kits (573.00 pallets or 31.83 C-17s)	
O&ST = Baselines (418.68 pallets or 23.26 C-17s)	
O&ST = 20 Days (362.83 pallets or 20.16 C-17s)	
O&ST = 15 Days (267.83 pallets or 14.88 C-17s)	
O&ST = 10 Days (194.65 pallets or 10.81 C-17s)	
O&ST = 5 Days (84.70 pallets or4.71 C-17s)	
Note: 1 C-17 = 18 pallet positions (HQ USAF 2001)	

Figure 10. Overall Kit Sizes

Assessed in the research were the effects of reducing the logistics response time and implementing a *pipeline on the fly* technique. To fully comprehend the impact of both these efforts, the research was structured to answer five main investigative questions:

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

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

What is the *logistics pipeline*?

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

A measurement that is currently used by the Department of Defense and the Air Force is the logistics response time. To date, it is the metric most representative of the various segments comprising the logistics pipeline. As such, the logistics response time is the key concept around which the research was conducted, and its reduction and its effect on MRSPs was one of the main objectives.

Kit Cost and Savings for a Single Deployment with:	
Cost with 30-Day Kits ($85.51M or 0.36 C-17s)	
Savings with O&ST = Baselines ($24.23M or 0.10 C-17s)	
Savings with O&ST = 20 Days ($31.20M or 0.13 C-17s)	
Savings with O&ST = 15 Days ($45.29M or 0.19 C-17s)	
Savings with O&ST = 10 Days ($59.24M or 0.25 C-17s)	
Savings with O&ST = 5 Days ($74.60M or 0.32 C-17s)	
Note: 1 C-17 = $236.7M (FY98 constant $) (HQ USAF 2001)	

Figure 11. Kit Cost and Savings for a Single Deployment

Overall Kit Cost and Savings for MRSPs with:	
Cost with 30-Day Kits ($714.86M or 3.02 C-17s)	
Savings with O&ST = Baselines ($202.70M or.0.86 C-17s)	
Savings with O&ST = 20 Days ($286.26M or 1.13 C-17s)	
Savings with O&ST = 15 Days ($391.19M or 1.65 C-17s)	
Savings with O&ST = 10 Days ($506.95M or 2.14 C-17s)	
Savings with O&ST = 5 Days ($628.72M or 2.66 C-17s)	
Note: 1 C-17 = $236.7M (FY98 constant $) (HQ USAF 2001)	

Figure 12. Overall Kit Cost and Savings

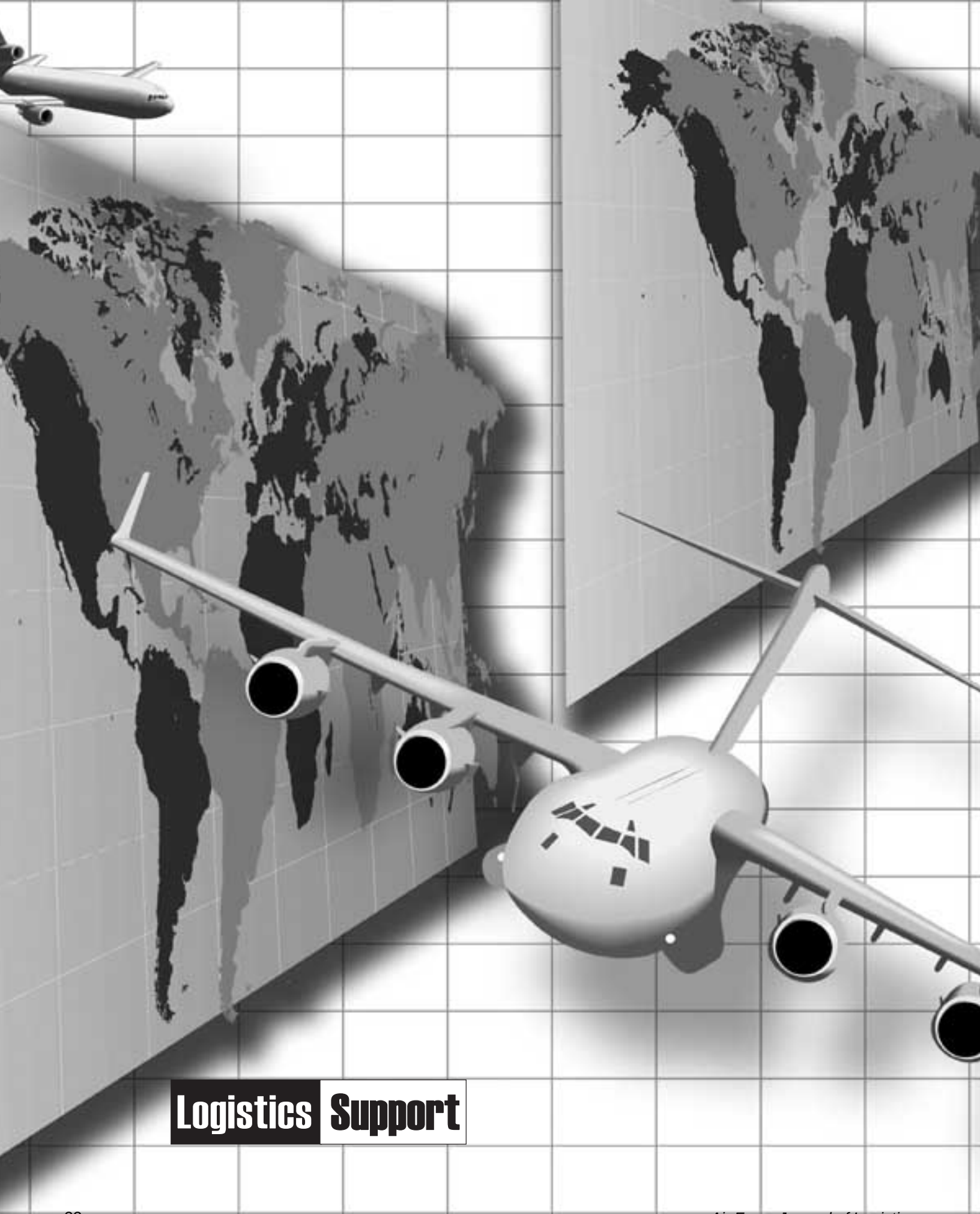
How quickly can the logistics pipeline be established?

While the assumption was made that base support for an AEF would be in place within 48 hours after the deployment order is given, the literature pointed to several issues that have kept the goal from becoming a reality. However, the example cited was only a sample of one event that occurred in 1997.[14] Therefore, it is likely that, through various subsequent exercises and simulations, functions required to enable supply processes at a bare base could now be in place earlier than 1 week after the deployment commences. Just what that number of days is cannot be ascertained at this point. However, it seems safe to conclude that it would occur much earlier than the minimum reasonable order and ship time, now or in the near future. Even if a part was shipped on day 0 of a contingency, the order and ship time required to move that asset to the forward operating location would exceed the number of days needed to set up supply operations. Therefore, it does not seem that the time needed to make a deployed location fully operational would be of great concern in relation to the time required to establish a viable logistics pipeline.

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

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

(Continued on page 45)



Logistics Support

Lionel Galway, PhD
Mahyar A. Amouzegar, PhD
Don Snyder, PhD
Richard Hillestad, PhD

A New Concept to Speed Expeditionary Aerospace Force Deployment

Footprint Configuration

The EAF is replacing the forward presence of airpower with a force that can deploy quickly from the CONUS in response to a crisis anywhere in the world.

From the Cold War to the EAF

Since the end of the Cold War, the Air Force has been required to perform numerous overseas deployments, many on short notice, in support of crises, ranging in size from humanitarian relief to Operation Desert Storm, and maintain a permanent presence in several areas to act as a deterrent to potential adversaries.[1] To meet these challenges, it has reorganized itself into an expeditionary aerospace force (EAF). That reorganization is replacing the forward presence of airpower with a force that can deploy quickly (within 48 hours[2]) from the continental United States (CONUS) in response to a crisis anywhere in the world, commence operations immediately upon arrival, and sustain those operations as needed.

The EAF concept requires the Air Force to be able to deploy combat aircraft to bases with a range of infrastructures, from Cold War warm bases

(fully equipped with prepositioned materiel and often in active use) through international airports with little military infrastructure, down to bases that have no more than water and fuel, a bare base. Further, due to uncertainties in the location and scale of future conflicts, a major part of deployment planning must be *generic*, unlike Cold War planning that developed detailed plans for specific bases.

However, quickly deploying the support structure for operations is not as easy as moving the aircraft themselves. Under current concepts of operation, all the materiel and personnel to initiate and sustain operations, the deployment *footprint*, must be present for operations to commence. The support processes constitute the major portion of any deployment, and the speed and agility of deployment hinge on the size of this logistical requirement.[3]

Given that most of the current combat platforms and their support systems were developed during the Cold War, it is not surprising that little of the support equipment was explicitly designed for rapid deployment to austere operating locations. In a series of reports, RAND and Air Force researchers examined the deployability of various specific support capabilities, including flight-line maintenance, avionics repair, low-altitude navigation and targeting infrared for night (LANTIRN) pod maintenance, and jet engine intermediate repair, as well as munitions, fuel support, and billeting.[4] The consensus of the research was that moving all the support for an aerospace expeditionary task force (ASETF)[5] package to a forward operating location (FOL) within the notional timeframe of 48 hours was almost certainly infeasible given the current support process, organization, and equipment.

One result of this work—and of experience in Kosovo—was a call for *footprint reduction*, reducing the amount of materiel and personnel actually deployed to FOLs. According to *Air Force Vision 2020*, "We will streamline what we take with us, reducing our forward support footprint by 50%." In line with this statement of the problem, much effort and attention has been directed at the reduction of support equipment. For example, new and smaller F-15 avionics testers were developed, and new, lighter shelters and billeting equipment are being proposed. However, for many areas such as munitions, significant mass reduction will require substantial investment in new technology and development, and for some areas such as civil engineering, large reductions in the size of earth-moving equipment seem infeasible.

The primary goal in developing expeditionary support concepts is to speed the deployment of aerospace capability so it can be employed quickly and sustained. While it is certainly plausible that there is scope for physical footprint reduction as defined above and that reduction is one important tool in achieving the deployment goal, the research previously cited and the current activities of several Air Force functional communities have recognized that the key to fast deployment is not only the physical reduction of weight but also the restructuring of the footprint and time and space phasing appropriate parts of it.[6]

To include these other strategies, we need a broader concept for the size of support that can be used to analyze the time and resources needed to deploy support processes.

Beyond Footprint: Footprint Configuration

Footprint Hierarchy

The first step in examining a footprint from a broader perspective is to recognize that logistics planners work with a footprint at three different levels, illustrated schematically in Figure 1:

- Unit-type code (UTC) level: a specific support or operational capability, including both materiel and personnel
- Force or base level: all capabilities needed to initiate and sustain operations for a given force at an individual base (a set of UTCs)
- Theater level: all capabilities needed over an entire theater given a specific mix of forces and bases to perform a campaign (set of force or base packages, plus other theater support facilities)

UTC Level. The UTC is the basic deployment unit of materiel and personnel in all branches of the military. For example, the UTC 3FQK3 represents an 18-primary aircraft authorized (PAA) F-15E squadron, consisting of 449 people and 417.3 short tons of materiel. It does not include a jet engine intermediate maintenance shop, so if this is required, an HFQK3 UTC must be deployed with 40 people and 55.3 short tons of additional equipment. In some cases, the entire capability of a standard UTC may not be needed, in which case the UTC is *tailored* by functional area personnel.[7]

The Desert Storm experience,[8] the development of the EAF concept, and further experience in Kosovo spurred a large-scale effort to rework all Air Force UTCs.[9] These efforts include *right sizing* UTCs (redefining standard UTCs to support smaller expeditionary forces in a range of conflicts). A parallel and complementary focus has been to break individual UTCs into modular building blocks so capabilities can be fit more precisely to specific circumstances. In addition, there are also simultaneous efforts by pilot units and functional area managers to physically reduce UTCs.

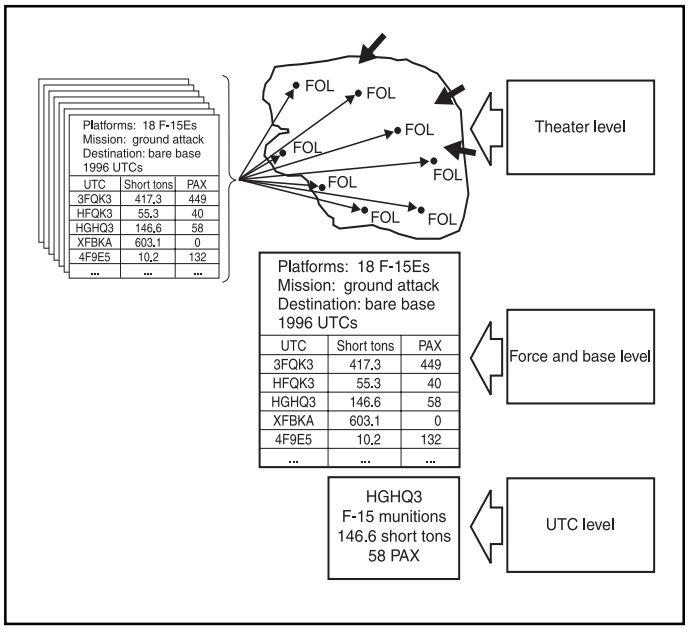


Figure 1. Footprint Hierarchy Schematic

Force or Base Level. The second level of the footprint hierarchy, the force or base level, is the list of required UTCs that depend on the combat force and mission (for example, an 18-PAA squadron of F-15Es flying air-to-ground bombing missions), the state of the base, and the threat level.

Theater Level. The third and highest level of footprint hierarchy is the sum of all deployed materiel and personnel needed in an entire theater of operations. In the simplest case, where each base is completely self-contained, this would be the sum of individual force or base footprints. But some support capabilities and supplies can be placed in forward support locations (FSL).[10] Therefore, analysis on the theater level must take into account economies of scale that alleviate redundancies of capability among bases, create efficiencies in distribution of materiel, and reduce airlift requirements in the crucial initial phase of a deployment.

Focus on Force or Base Level

Working at either the UTC or theater level can reduce the footprint, facilitating improvements in rapid and flexible deployment. But the keystone to reducing time to deployment lies in examining the second hierarchical level: the requirements for transforming a base that does not have a full military infrastructure to one that is completely equipped to launch the required combat missions.

Evaluating the progress of footprint reduction at the base level provides a unique vantage point of the levels above (theater) and below (UTC). For example, base-level analysis will accurately assess the reduction of one UTC by jettisoning materiel available in another UTC.[11] Base-level analysis also reveals which UTCs provide the best payoff in reduction for a given expenditure of resources, rather than requiring each individual *functional* to achieve equivalent degrees of reduction. Finally, understanding the requirements at a base level provides the basic data needed to plan for the capabilities and materiel that might best be positioned in FSLs to exploit economies of scale in a theater composed of many FOLs.

Comprehensive UTC Lists for Force or Base Packages

Expeditionary force or base packages are *generic* UTC lists not tied to specific bases. Unfortunately, such UTC lists for bare bases do not seem to exist for any current or proposed force packages outside the popup aerospace expeditionary wings (AEW).[12] Although clearly *virtual*, generic lists exist in the skill base of the functional experts at major command (MAJCOM) headquarters, the lack of a canonical list of support for a given force package leaves logistics planners with few means of coordinating footprint changes on a level higher than the UTC.

It has been suggested that the various deliberate planning and historical time-phased force deployment data (TPFDD), such as those from Noble Anvil, could be used in lieu of such generic lists. While such efforts provide valuable insight for the construction of generic lists, in general, these data are not adequate for strategic logistics planning. First, very few of these deployments are to true bare bases, so they do not directly answer the question of defining the total package required to support any given force. Further, for each historical or planned base and force package, there are specific circumstances and assumptions unique to each situation that must be taken into account.[13] In most cases, drawn from planning data, each base has prepositioned materiel and assumptions about resources available on the local economy in that specific location. Finally, many of the UTCs in either deliberate planning or in historical data are heavily tailored.

Figure 2. Division of Footprint into FOL and Remote (Not at FOL) Pieces

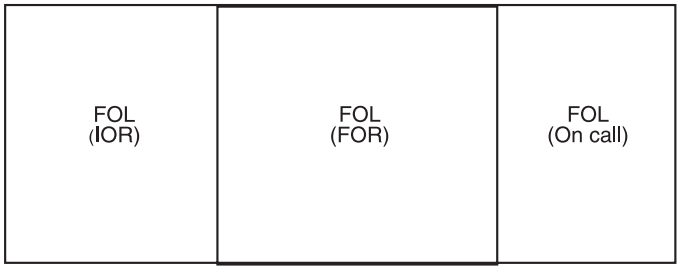


Figure 3. Subdivision of FOL Footprint Portion into Initial and Full Operating Requirements and On Call

The EAF will have to develop the capability to assemble lists of UTCs for different force packages to deploy to any operating location. The determining parameters would also include components of destination infrastructure and threat level, among others. Such capability-based lists could be used for strategic planning of transportation resources, a starting point for footprint changes (identifying large UTCs that are natural candidates for reduction or restructuring, accounting for materiel shifted out of one UTC to another without acknowledging that no total reduction has been achieved), and a template against which deliberate and crisis planning for specific locations could be compared.

Footprint Configuration

Footprint configuration provides a framework for visualizing and assessing the broader array of strategies for decreasing the deployment time line.

FOL Versus Remote Support Processes. Researchers have observed that support processes[14] can be divided into those that must be done at an FOL from where aircraft fly and those that can be done remotely, either at FSLs or even at CONUS support locations.[15] The footprint in terms of equipment (or personnel) can, therefore, be initially divided into two pieces as illustrated in Figure 2.

The FOL Segment. The FOL segment can, in turn, be subdivided into the following three pieces, as shown in Figure 3:

- The initial operating requirement (IOR) is required at the FOL to initiate combat operations.
- The follow-on operating requirement is needed at the FOL to sustain combat operations at the desired tempo.
- The on-call segment is required at an FOL only in specific circumstances and is deployed only when needed.

For example, the IOR for munitions would consist of an initial stockpile of munitions, fins, and fuses, plus the munitions

assembly and movement equipment. The follow-on requirement, in this case, would be the resupply of munitions necessary to continue carrying out operations. The on-call category can be specialized fuses that can be used only for a very specific mission.

The Remote Segment. The remote segment can be subdivided further into two pieces as in Figure 4.

- FSLs are facilities that can support FOLs with selected maintenance or supply processes linked to the FOLs by intratheater transport.
- CONUS support locations are support facilities in the CONUS linked to FOLs by using intertheater transportation.

FSLs were established during the Kosovo conflict as centralized intermediate repair facilities at locations such as Royal Air Force Lakenheath and Spangdahlem Air Base, Germany, to support FOLs in Italy and Turkey with avionics and engine repair and phase maintenance. Currently, many F-16 avionics line-replaceable units are repaired by CONUS facilities no matter where the aircraft are located around the world.

Putting It All Together: Footprint Configuration. Putting these subdivisions together gives a time and space phasing of the different segments of this process in this potential configuration. Figure 5 is a comprehensive picture of what is prepositioned (shaded region), what needs to be moved and when, and what need not be moved at all for this process.

We have presented the discussion this far in terms of a single support process. However, the real interest is in combining all support processes into a force or base package as shown in Figure 6.

Some processes may be required to be entirely at the FOL, with no part that can even be on call (for example, notional support process B). Others may not have any part at a CONUS support location (process E), while for others, the proportion in each segment may vary, along with what can be prepositioned. But the real value is that it provides a framework for explicit decisions about what parts of individual support processes need to be moved and, if they do, when they are needed. The concept of footprint configuration also allows for the traditional reduction in weight and personnel while encompassing other strategies.

Footprint configuration also recognizes that different process configurations can interact, either at the force, base, or theater level. If an FSL can be established with robust transportation for jet engine intermediate repair, then an FSL for avionics at the same location can use the transportation links already established. So in making decisions about how to reconfigure a process, all levels of the footprint hierarchy need to be considered.

Evaluating Footprint Configurations: Metrics

Because the basis of footprint configuration is to structure support process arrival across space and time, the characteristics of footprint configuration are multidimensional.

There are four primary metrics:

- Time to IOC
- Time to FOC for the desired capability
- Transportation resources required to move the IOR
- Transportation resources required to move the follow-on operating requirement[16]

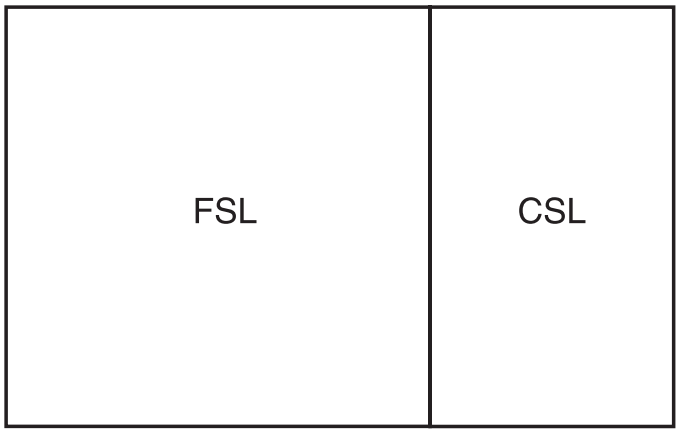


Figure 4. Subdivision of Remote Footprint Portion into Subdivisions at Forward and CONUS Support Locations

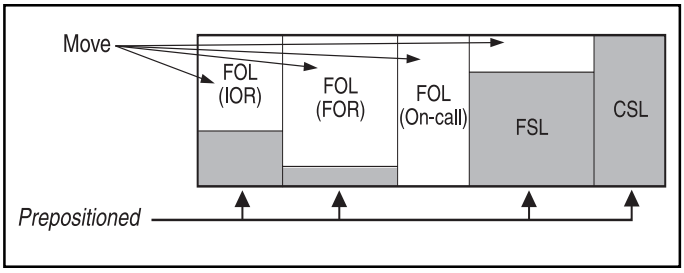


Figure 5. Footprint Configuration for a Notional Individual Support Process

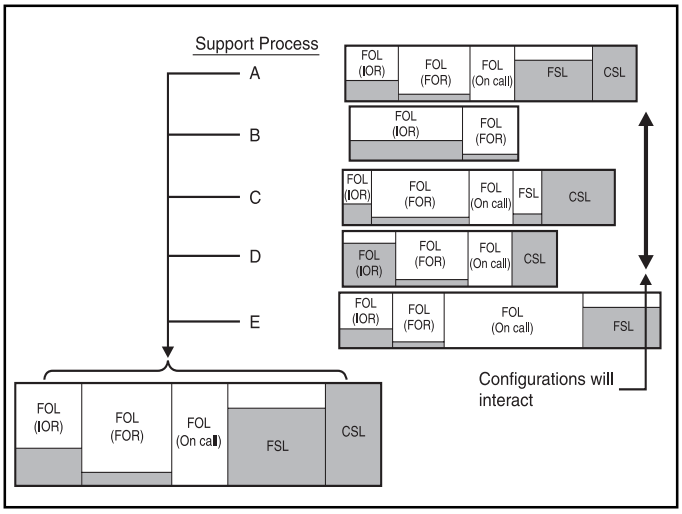


Figure 6. Combining Footprint Configurations for Multiple Support Processes

Achieving desired values on these four metrics requires trading off or controlling several other key metrics:

- Materiel mass and personnel moved.
- Cost—investment and operating costs are both important.
- Flexibility—is the configuration chosen capable of supporting different kinds of operations under varying circumstances? Too much prepositioning could reduce the flexibility to use other FOLs.
- Risk—there are a series of risk analyses that need to be done for any configuration, including risks of depending on

transportation; the vulnerability of FOLs with prepositioned materiel and centralized facilities; and political, cost, and technical risks.

For many of these metrics, input from the operations side of the Air Force will be required. How much flexibility is needed and how much can be traded for speed and robustness? Which risks are acceptable and which are unacceptable? What is IOC and, hence, IOR? What are the missions and operational rates needed? The close linkage between operations and logistics required by expeditionary operations presents a new challenge for the Air Force.[17]

Developing and Evaluating Alternative Footprint Configurations

When there are a number of different metrics and goals to be simultaneously satisfied, inevitably, there will have to be tradeoffs and compromises.[18] First, we need to be sure all aspects of support are accounted for. This is the role of parameterized UTC lists discussed previously. Second, for any proposed configuration, we need the capability to evaluate defined metrics (and any additional ones deemed necessary). Third, we need to be able to rank and weight the metrics so we can make tradeoffs for decisionmakers for alternatives based on the metric values (for example, some high costs may be paid to get a substantial decrease in deployment time). The primary focus should be on evaluating key force or base combinations since these are the fundamental building blocks of expeditionary deployments.

Evaluating Force or Base Packages

Building on the list of UTCs for a given force or base package, an evaluation tool can allow decisionmakers to modify the deployment list by selecting new or alternative UTCs or by allowing pieces of UTCs to be time phased, prepositioned, or deployed to an FSL instead of an FOL. Such decisions would change the ultimate package deployed and would be reflected in the key metrics of time to IOC and deployment resources computed by the tool. Figure 7 shows the notional structure of the broader tool. A set of requirements models for different support processes sits at the center (and interacts) so that changes in personnel in one support area, for example, are reflected in billeting. Requirements parameters (force and mission characteristics, technological changes, and so forth) are inputs to the model, and the outputs are the size and movement requirements.[19]

After evaluating different configurations, a selection must be made about which configuration (choice of FSL functions, prepositioning, technological development) will be implemented. To identify a configuration that performs well across the multiple metrics proposed, the RAND-developed DynaRank Decision Support System[20] could be used. This tool, an EXCEL add on, is a scorecard-development tool, which allows the user to specify a hierarchy of metrics and options to be compared. Scorecard manipulation functions allow multiple options to be sorted, ranked, and displayed by individual metric performance or aggregate weighted performance as selected by the decisionmaker (who, thus, has control over which metrics are most important).

For the near future, the two most important types of base infrastructures are the warm base and the *international airport* type base. Current planning suggests the following force packages are the most important for fighter operations:

- Full squadrons of F-15Es (ground attack), F-16CJs (Suppression of Enemy Air Defenses), and either or both F-15s and F-16s for air-to-air
- The *canonical* ASETF: 12 each of F-15Es, F-15Cs, and F-16CJs, for a small, balanced package of capability
- A six-ship, single-mission design series package of F-15s and/or F-16s for air-to-air[21]

The combination of the two base infrastructures with the force and mission packages above should provide a comprehensive view of how well the Air Force could carry out expeditionary operations over a wide spectrum of situations. One final point of emphasis: this evaluation should be done in terms of *generic* deployments, not specific ones. In this way, attention is focused on the strategic problems of expeditionary support, not on details of specific bases and units.

Evaluating Individual UTCs and Theater Configurations

Most of the work in reengineering and reconfiguring specific UTCs will reside with the functional area experts at the MAJCOMs and pilot units. In most cases, evaluating UTCs will be diagnostic to help identify promising areas of research for improving the performance at the force or base level. For example, initially, interest might focus on the heaviest UTCs: munitions, civil engineering, Harvest Falcon, and vehicles. High-technology areas such as medical and communications are also important to track because of the ongoing opportunities for technology insertion.

Some critical support processes are *not* organic to the Air Force, such as ground-based air defense and theater missile defense. However, these systems can be heavy and, by our definition, are part of the support of an airbase in that they are required, in some circumstances, to commence and sustain operations. It may, therefore, be in the interest of the Air Force to track their deployability as well.

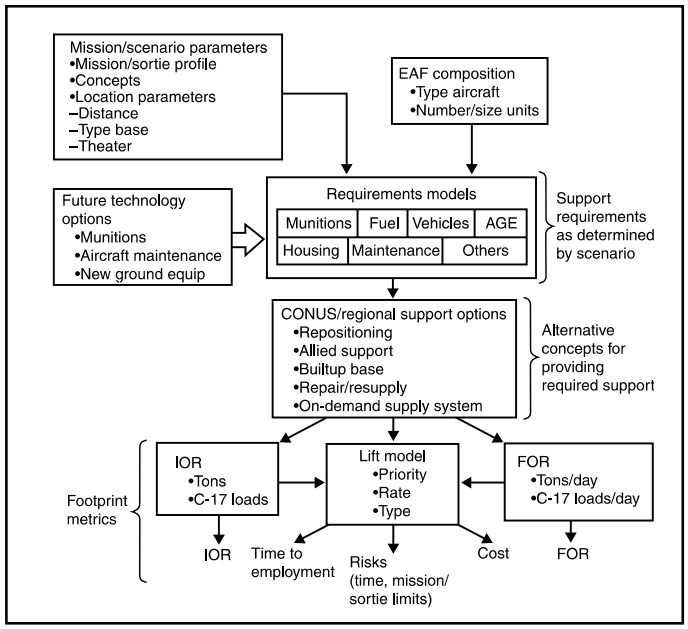


Figure 7. Evaluation Tool for Force or Base Package

Operational commanders and support planners at the theater level are interested in the deployment and beddown of a large force at multiple sites throughout a theater and being prepared for several different scenarios. However, with the force or base level understood (including the presence of theater-level facilities such as FSLs), evaluating and tracking the theater-level performance of footprint configurations is then a matter of aggregating the performance at the relevant individual bases.

Recommendations

- **Adopt the concept of footprint configuration as an organizing principle for restructuring support processes.** By being able to organize all the strategies in a common framework with a clear set of metrics, the selection of appropriate strategies for individual support processes will be clearcut and rigorous.
- **Develop parameterized UTC lists to generate a comprehensive list of UTCs needed to deploy given force capabilities to different base infrastructures.** This capability is central to expeditionary planning in that it allows evaluation of speed of deployment for a range of forces and destinations.
- **Exercise more centralized control of UTC development.** Because there is a primary global metric and deployment time and different support processes have different sizes and reconfiguration options, we believe more centralization to direct and evaluate efforts is important. Currently, most of the responsibility for making process changes resides at the pilot unit for each UTC. While involvement of process experts is critical, there needs to be central oversight of the allocation of the reengineering effort because the goal is the deployment of a complete force package.[22]
- **Evaluate changes in deployment speed and other major metrics for selected force packages and base infrastructure combinations to track progress.**
- **Set up a system to aggregate the force or base evaluations to theater level for current warplans and for strategic support planning for proposed plans.** As with the force or base evaluations, this would evaluate changes in deployment speed, time to IOC, and deployment resources but theater-wide plan for basing and employing expeditionary forces. In the current defense structure, these evaluations are clearly of interest to the MAJCOMs supporting the several geographic combatant commanders, who would probably wish to set up their own tracking systems based on actual theater plans. But recent events, such as the operations in Kosovo and Afghanistan, have indicated many major operations will draw operational forces and support from several combatant commanders, so corporate tracking to evaluate all warplans for review, as a whole, by senior Air Force leadership may be an emerging necessity. As with coordinating UTC development centrally, this will be a move toward a more centralized overview of a support system that is increasingly seen in global terms.[23]
- **Develop tools to help decisionmakers evaluate and select among alternative footprint configurations.** Such tools, together with the parameterized UTC lists advocated above, would allow analysts to evaluate many different footprint configurations quickly and rigorously. Because we do not expect there to be a configuration that dominates in all metrics simultaneously, decisionmakers also will need to organize the results of evaluating different configurations to allow them to weight the results of individual metrics to come to a final decision. This is in line with the view that logistics must become a *strategic* planning function in an expeditionary world.[24]

Notes

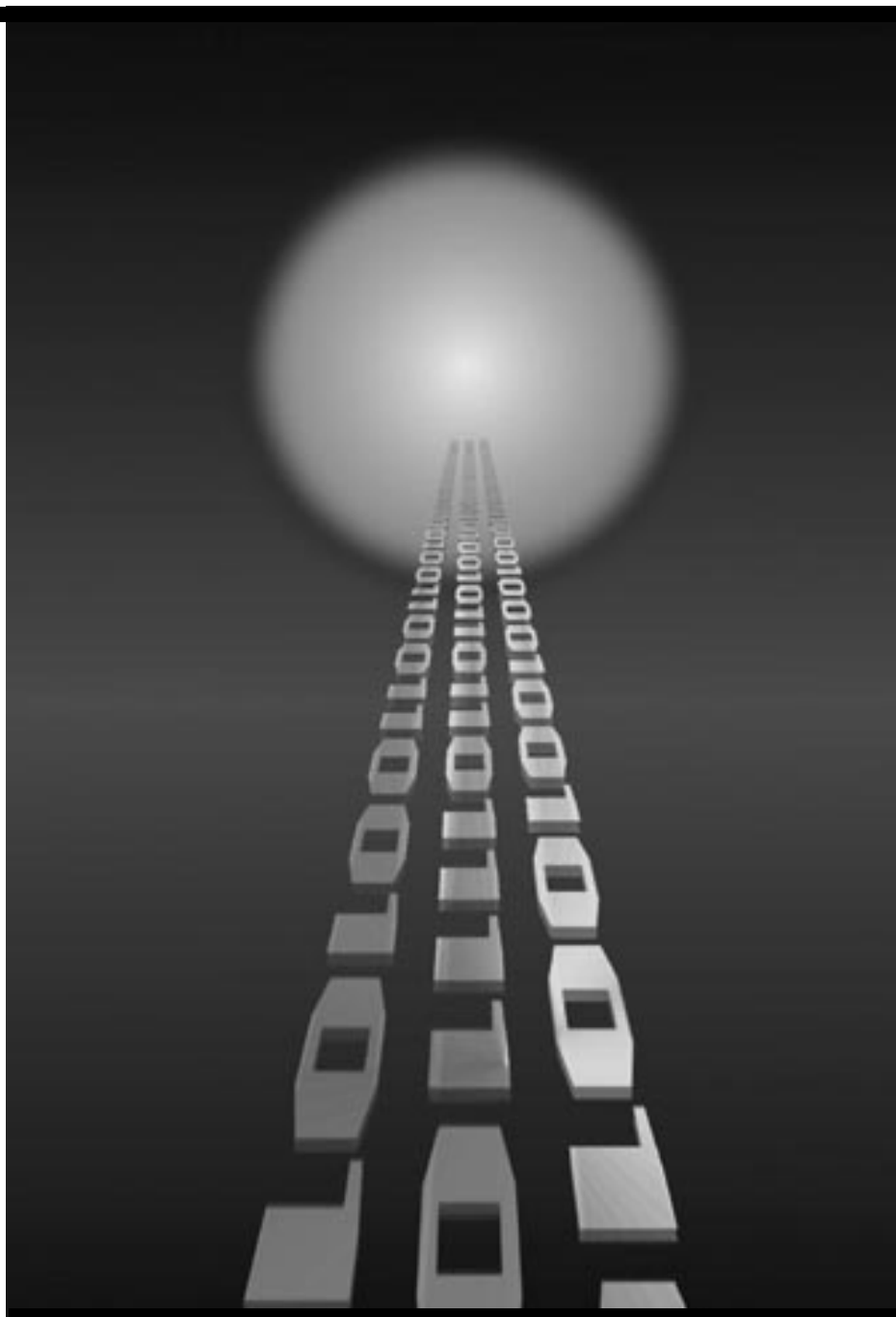
1. Bill Sweetman, "Expeditionary USAF Sets Course," *Jane's International Defense Review*, Vol 33, May 00.
2. US Air Force, *Vision 2020: Global Vigilance, Reach, and Power*, Washington DC, 2001.
3. Lionel A. Galway, Robert S. Tripp, Timothy L. Ramey, CMSgt John G. Drew, *Supporting Expeditionary Aerospace Forces: New Agile Combat Support Postures for the EAF*, RAND, Santa Monica, California, MR-1075-AF, 2000.
4. See, for example, Tam T. Vo, *Exploratory Analysis of the Deployment Feasibility of United States Air Force Air Expeditionary Forces*, Air Force Institute of Technology, Wright Patterson AFB, Ohio, Sep 97; Frank C. O'Fearna, *Reduction of the Aircraft Ground Equipment: Footprint of an Air Expeditionary Force*, master's thesis, AFIT/GOR/ENS/99M-14, Air Force Institute of Technology, Wright-Patterson AFB, Ohio, Mar 99; Galway, et al, 2000; Robert S. Tripp, Lionel A. Galway, Timothy L. Ramey, Mahyar Amouzegar, and Eric L. Peltz, *Supporting Expeditionary Aerospace Forces: A Concept for Evolving to the Agile Combat Support/Mobility System of the Future*, RAND, MR-1179-AF, 2000; Eric Peltz, Hyman L. Shulman, Robert S. Tripp, Timothy Ramey, Randy King, and John G. Drew, *Supporting Expeditionary Aerospace Forces: An Analysis of F-15 Avionics Options*, RAND, Santa Monica, California, MR-1174-AF, 2000; Paul Killingsworth, Lionel A. Galway, Eiichi Kamiya, Brian Nichiporuk, Timothy L. Ramey, Robert S. Tripp, and James C. Wendt, *Flexbasing: Achieving Global Presence for Expeditionary Aerospace*, RAND, Santa Monica, California, MR-1113-AF, 2000; Amatzia Feinberg, Hyman L. Shulman, Louis W. Miller, and Robert S. Tripp, *Supporting Expeditionary Aerospace Forces: Expanded Analysis of LANTIRN Options*, RAND, Santa Monica, California, MR-1225-AF, 2001; and Mahyar A. Amouzegar, Lionel Galway, and Amanda Geller, *Supporting Expeditionary Aerospace Forces: An Analysis of Jet Engine Intermediate Maintenance Options*, MR-1431-AF, 2001.
5. Terminology surrounding the expeditionary aerospace force (EAF) has changed over the 5 or so years of its existence. As it stood during research reported here, EAF denoted the overall operational concept, AEFs were the ten subdivisions of Air Force forces (two of which are on call at a time), and ASETF was used for whatever force was actually being deployed. Subsequently, two units were designated to initially handle very fast deployments, and these were designated AEWs. However, the acronym AEF was originally used for the deploying force, and it is possible that an entire on-call AEF would be deployed for a major conflict. In this document, we will use ASETF for the deploying force.
6. For examples of Air Force functional thinking, see "Civil Engineer Expeditionary Combat Support," AF/ILE, briefing dated 24 Jul 00, and "Medical Aspects of Dispersed Expeditionary Operations," ACC/SG, briefing dated 1 Apr 01. For a review of similar Army thinking, see Eric Peltz, John Halliday, and Steven Hartman, "Combat Service Support Transformation: Emerging Strategies for Making the Power Projection Army a Reality" (forthcoming), RAND, Santa Monica, California.
7. Jeffrey M. Hess and Merry D. Wermund, *Analysis of Standard Type Unit Development*, Thesis, AFIT/GLM/LSM/92S-23, Air Force Institute of Technology, Wright-Patterson AFB, Ohio, 1992.
8. In Operation Desert Storm, it was noted that many Air Force UTCs arrived with as much as a 40-percent increase in personnel and a 300-percent increase in equipment over their nominal values and, further, some UTCs did not have their stated capability. See Stephen J. Hagel, "Capturing Logistics Data, Part II," *Air Force Journal of Logistics*, Air Force Logistics Management Agency, Maxwell AFB, Gunter Annex, Alabama, Vol 16, Winter 1992.
9. Briefing, "United States Air Force UTC Refinement Effort," AF/XOXW, undated.

(Continued on page 45)

Focused Logistics is the capability to provide the joint force with the right personnel, equipment, and supplies at the right time, in the right place, and in the right quantity .

Focused Logistics and Combat Capability

Support Plans for the Future



Lieutenant Colonel Jon V. Ramer, USAF

Of all the tenets detailed in *Joint Vision 2010* (JV2010), Focused Logistics is perhaps the most difficult to link to military combat capability. Specifically, how do the duties of a maintenance troop, supply clerk, or transporter affect Focused Logistics? What tells the troops and their leaders they are achieving the desired results? As defined by JV2010, Focused Logistics is the capability to provide the joint force with the right personnel, equipment, and supplies at the right time, in the right place, and in the right quantity across the full spectrum of a military engagement. But defining *how* to do this and, more important, how to measure doing this *correctly* is the real challenge.

Fortunately, there are data sets that could let leaders in the logistics chain know how the concepts of Focused Logistics are being achieved. Analysis of current data trends suggests there is a direct correlation between customer wait time (CWT) and mission-capability (MC) rates: as CWT goes down, the MC rate goes up. The fusion of these data sets, though not presently analyzed by Air Force logistics leaders, lends credence to present long-term logistics plans for rapid resupply and suggests that further fusion of logistics data sets could provide unprecedented visibility, control, and enhancement of combat support.

Focused Concept

The basic concept of Focused Logistics is not difficult to relate. Per JV2010, it will be "the fusion of information, logistics, and transportation technologies to provide rapid crisis response, the ability to track and shift assets even while en route, and to deliver tailored logistics packages at the strategic, operational, and tactical level of operations." Focused Logistics will be fully adaptive to the needs of an increasingly dispersed force and will provide support in hours or days, instead of weeks or months. As admirable as these goals are, achieving them is not that easy.

Requirements and Constraints

The ambitious logistics support plans of the future are based on achieving specific technological goals that could be considered highly optimistic. Intelligent and intuitive decision support-planning tools will need to be developed for logistics to be proactive to warfighters' needs. The efficiencies and benefits of Focused Logistics will require a fusion of logistical information from supply, transportation, local maintenance, depot maintenance, contractor maintenance, and acquisition data systems and the development of rapid transportation technologies.

The many capabilities inherent in the concept of Focused Logistics come with just as many constraints though. Interconnectivity of data systems and equipment compatibility, two critical components, are yet-to-be-developed computer technologies. The operational commander will depend on the smooth flow of information from the engaged forces. Without the free flow of data and sophisticated technologically advanced computers and software to determine the availability and location of supplies, a commander cannot maximize combat capability. Development of such systems will be time consuming and difficult, if not impossible. Many initiatives to accomplish this have been in work for years without even being able to develop standard architectures.

Emerging Strategy

Despite developmental constraints, military logistics is undergoing an incredible transformation. Efforts to transform Department of Defense (DoD) logistics are driven by new operational requirements that demand greater speed and precision delivery. Until a few years ago, there simply was no defined doctrine or long-term plan for improving logistical support. The strategy of yesteryear was to move and stock huge quantities of supplies into a theater of operations *just in case*. In contrast, today's support strategy is based on the rapid movement of mission-specific assets *just in time* so they arrive where they are needed, when they are needed, while long-term consumable resupply is delivered by sealift.

An Unclear Path

The transformation is not yet complete and not without considerable contention. There have been many proposals and counterproposals as to the right path to follow. Despite extensive discussion and much published literature, the path is still unclear.

An article published by the Joint Staff in 1997 states that Focused Logistics should be implemented in a two-phase approach. Phase one calls for creating a success-oriented roadmap rooted in current realities yet tied to enhanced future capabilities with a focus on warfighting deficiencies. Phase two should expand that scope and address longer range issues with an emphasis on creative thinking and capabilities in 2007 and beyond. While this article does name specific joint assessment and review programs that should be given attention during phase one, it gives no specifics on how to link these programs to the front-line troop and gets even more vague for the execution of phase two. It does, however, call for accurate and timely metrics for monitoring progress of the plan.

Published in June 1996, *Joint Vision 2020* (JV2020) described a different path. It outlined four major steps for logistics transformation, with deadlines for each step to be completed. The first step was to implement systems to assess customer confidence across the entire logistics chain using the metric of customer wait time, to be completed in fiscal year (FY) 2001. Second was to implement time-definite delivery using a simplified priority system driven by the customer's required delivery date by the end of FY02. Third was to implement automated identification technologies and data systems that provide accurate, actionable total asset visibility by FY04. The fourth and final step was to implement a Web-based, shared data environment for all military forces to ensure the warfighter's ability to make timely and confident logistics decisions by FY06.

As of late FY02, only the Air Force had achieved an operable Web-capable system that could report customer wait time. This system only became fully functional and was used to report metrics to the Chief of Staff of the Air Force for the first time in November 2001. Plans to implement time-definite delivery and a new simplified priority system across the DoD are stuck in discussion. Furthermore, the total asset visibility required by FY04 does not seem achievable by that date as data systems for each of the major logistics functions, supply, maintenance, transportation, and acquisition are not linked. Indeed, a data architecture has not even been designed to link the information from those diverse systems, despite the establishment of the Logistics Architecture Office in October 1999 to do just that.

This one task is even more daunting considering the data systems for Air Force maintenance functions have not been linked. Base-level maintenance shops use the G081/CAMS systems, each of the three Air Force depots has its own system for tracking repairs, and contractor depots report repair actions via the G009 system. None of these systems shares data. FY04 is not that far away, and the hurdles for total asset visibility are enormous.

The problems with achieving Focused Logistics have been noticed by many. The Government Accounting Office published a report in October 2001 severely criticizing DoD plans for logistics transformation:

> The *DoD Logistics Strategic Plan* is not sufficiently comprehensive and does not provide adequate overarching logistics strategy to effectively guide the Defense components logistics plans . . . . Furthermore, the Department's long-range initiative to design a logistics architecture for the years 2010 and beyond is progressing slowly.

The growing disconnects between the planned steps in logistics transformation and achievable results only highlight a similar disconnect between the desired end result of JV2020 and vagaries of how logistics troops are supposed to effect that result. How does anyone know Focused Logistics has been achieved?

Definitions

To analyze data in support of achieving Focused Logistics, some specific data definitions and interrelationships must first be discussed. These are customer wait time, mission capability, and the logistics pipeline.

Customer Wait Time

Customer wait time is defined as the amount of time from when a customer makes a requisition, the start time, to the moment that requisition is satisfied, the stop time. It is measured and reported in days per requisition. Start and stop times are recorded via transactions from the Standard Base Supply System. Lower wait times are better.

Mission Capability

The MC rate is a calculated percentage rate derived from the number of hours a unit has an aircraft and the number of hours it is capable of flying its assigned mission, totaled for all aircraft assigned. Hours are recorded and reported by base maintenance computer systems. Higher rates are better.

Logistics Pipeline

The logistics pipeline is defined as the entire process for requisitioning an asset, from initial requisition to shipping, to stocking, to customer issue and use. It can be defined by five segments:

- The time from initial request to depot receipt of request
- The time from depot receipt to depot release of asset
- The time from depot release to shipping pickup
- The time from shipping pickup to receipt by base supply
- The time from receipt by base supply to delivery to the customer

The period from the start of segment one to the end of segment five is the customer wait time. Data on these five segments are reported by several different computer systems: base supply for segments one and five, depot and contractor maintenance for segments two and three, and transportation for segment four.

Focused for Effect

Clearly, many different logistics data systems must be linked to provide metrics and visibility over the logistics pipeline. Though not specifically stated in any official guidance, achieving the goals of Focused Logistics will require reducing the time requisitions spend in each segment of the pipeline. Information fusion and total asset visibility will reduce segments one, two, and three by requisitioning the closest available asset and getting it into the transportation channel to the customer. Rapid transit technologies target segment four by expediting movement of an asset to the customer. The effects of Focused Logistics will reduce customer wait time.

This is how the logistics troops can see the effects of their efforts on achieving Focused Logistics. By doing their job quicker and finding faster, more efficient ways to process materials and information, they can reduce the time requisitions stay in the logistics pipeline. As the next section shows, this has a direct correlation on combat capability.

Data Analysis

In 1991, the average logistics response time for all Air Force requisitions was 42 to 45 days. By 1999, a typical supply requisition took 36 days from customer order to customer receipt. In 2001, improvement initiatives reduced that time to an average of just 20 days. The stated goal in the Air Force strategic logistics transformation plan is to reduce the average customer wait time to 10 days by 2006 and 5 days by 2010. Knowing past performance and future goals is not sufficient though, the goal must be linked to something the warfighter considers important: mission capability. It is possible to graph these two critical metrics and analyze performance over time.

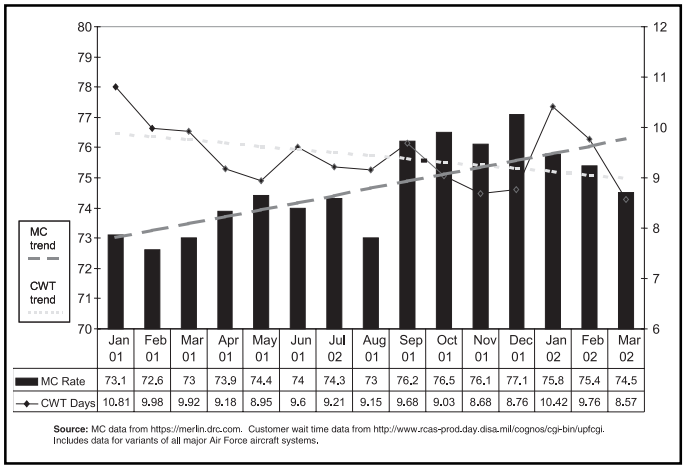
Data on monthly mission capability and customer wait time have been collected and graphed by primary weapon-system groupings—fighters, bombers, airlift and tankers, trainers—command and control, and reconnaissance and rolled into an all-systems chart. Analysis of 15 months of customer wait time data and 15 months of matching data for mission capability indicates a correlation between the two metrics. For all major weapon systems in the Air Force inventory, as customer wait time *decreases*, mission capability *increases*.

Though there are several factors like funding, spares availability, repair capability, flow time, computer connectivity, and more that can affect either MC rate or customer wait time, it is unlikely that *every* weapon system in the Air Force inventory would be affected in the same way. Some systems have depot repair problems (KC-135); others do not (KC-10). Some have parts difficulties (F-15 engines); others do not (F-117). Some are new systems (B-2); others are old (B-52). Logistical problems that affect one weapon platform do not affect a totally different one. Yet, universally, the mission capability and customer wait time data in every grouping give the same trend: as customer wait time goes down, mission capability goes up. It is reasonable to conclude these two trends are connected.

This combination of data trends can fulfill two important needs for Focused Logistics: how to know it is being successfully achieved and how logistics troops can know their activities are helping achieve it. It also suggests that the guidance in JV2010 and JV2020 is on track and will further reduce customer wait time, thereby increasing combat capability.

Recommendation

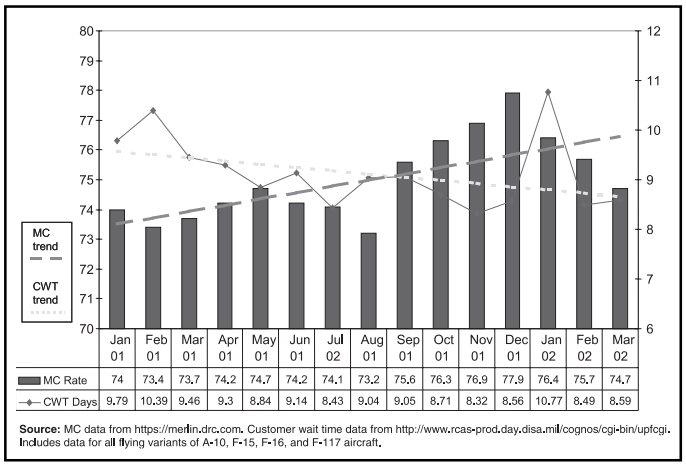
Mission capability is the Air Force's most critical metric and is used to measure everything from flying hours, to spare parts funding, to combat capability. As established by the logistics strategic transformation plan and JV2020, customer wait time is the first critical metric for logistics transformation. The source for the mission-capability data is the Multi-Echelon Resource Logistics Information Network (https://merlin.drc.com). The source for customer wait time data is the Weapon Systems Management Information System (http://www.rcas-prod.day.disa.mil). These two critical data sources are *not* linked. They do not share data despite the fact both have the ability to report data over discrete time periods, filtered by many similar data elements. The fusion of data from these systems would give leaders the ability to drill down into specific logistics problems and see what effect these problems are having on mission capability and combat effectiveness.



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	73.1	72.6	73	73.9	74.4	74	74.3	73	76.2	76.5	76.1	77.1	75.8	75.4	74.5
CWT Days	10.81	9.98	9.92	9.18	8.95	9.6	9.21	9.15	9.68	9.03	8.68	8.76	10.42	9.76	8.57

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for variants of all major Air Force aircraft systems.

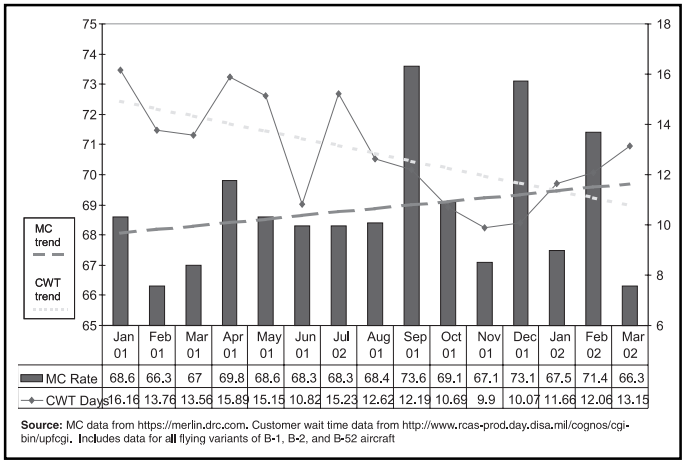
Figure 1. Trend Graph of All Weapon-System MC Rates and CWTs



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	74	73.4	73.7	74.2	74.7	74.2	74.1	73.2	75.6	76.3	76.9	77.9	76.4	75.7	74.7
CWT Days	9.79	10.39	9.46	9.3	8.84	9.14	8.43	9.04	9.05	8.71	8.32	8.56	10.77	8.49	8.59

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for all flying variants of A-10, F-15, F-16, and F-117 aircraft.

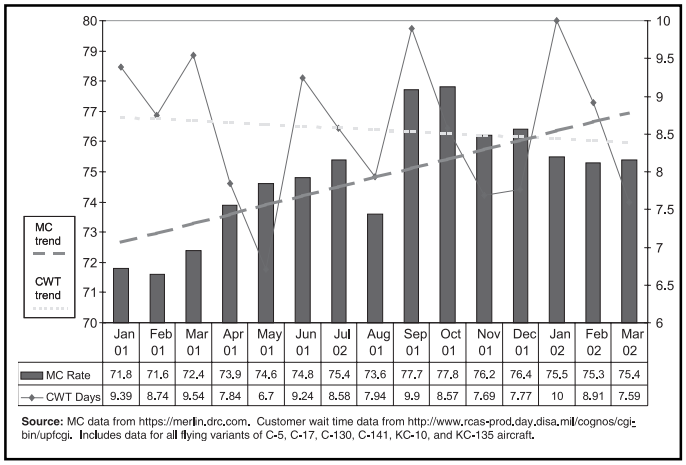
Figure 2. Trend Graph of All Fighter MC Rates and CWTs



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	68.6	66.3	67	69.8	68.6	68.3	68.3	68.4	73.6	69.1	67.1	73.1	67.5	71.4	66.3
CWT Days	16.16	13.76	13.56	15.89	15.15	10.82	15.23	12.62	12.19	10.69	9.9	10.07	11.66	12.06	13.15

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for all flying variants of B-1, B-2, and B-52 aircraft

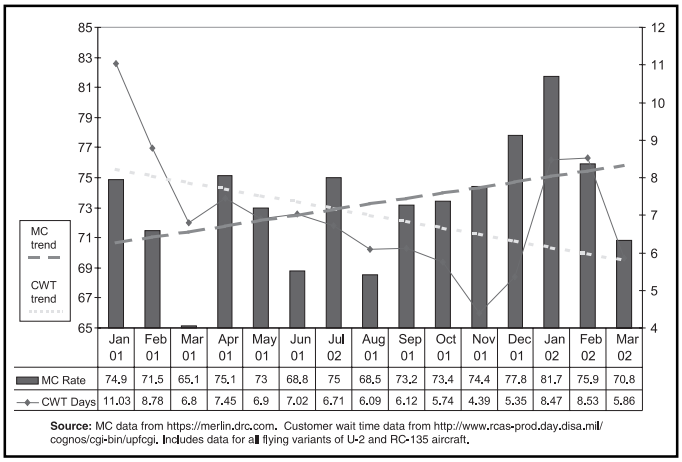
Figure 3. Trend Graph of All Bomber MC Rates and CWTs



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	71.8	71.6	72.4	73.9	74.6	74.8	75.4	73.6	77.7	77.8	76.2	76.4	75.5	75.3	75.4
CWT Days	9.39	8.74	9.54	7.84	6.7	9.24	8.58	7.94	9.9	8.57	7.69	7.77	10	8.91	7.59

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for all flying variants of C-5, C-17, C-130, C-141, KC-10, and KC-135 aircraft.

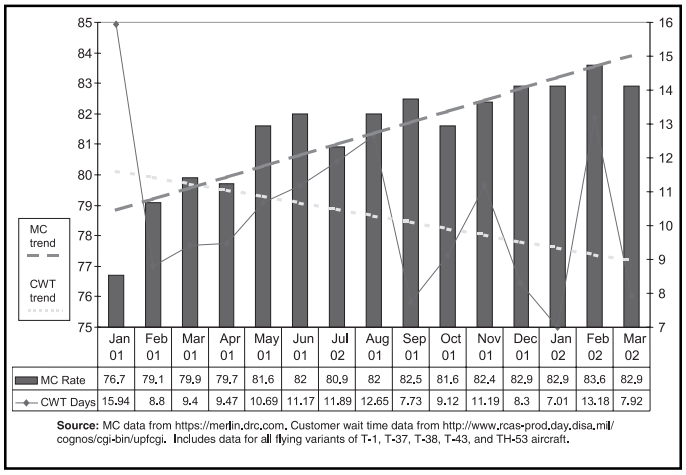
Figure 4. Trend Graph of All Airlift and Cargo MC Rates and CWTs



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	74.9	71.5	65.1	75.1	73	68.8	75	68.5	73.2	73.4	74.4	77.8	81.7	75.9	70.8
CWT Days	11.03	8.78	6.8	7.45	6.9	7.02	6.71	6.09	6.12	5.74	4.39	5.35	8.47	8.53	5.86

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for all flying variants of U-2 and RC-135 aircraft.

Figure 5. Trend Graph of All Recce MC Rates and CWTs



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	76.7	79.1	79.9	79.7	81.6	82	80.9	82	82.5	81.6	82.4	82.9	82.9	83.6	82.9
CWT Days	15.94	8.8	9.4	9.47	10.69	11.17	11.89	12.65	7.73	9.12	11.19	8.3	7.01	13.18	7.92

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for all flying variants of T-1, T-37, T-38, T-43, and TH-53 aircraft.

Figure 6. Trend Graph of All Trainer MC Rates and CWTs

Information Fusion

Though there are many proposed concepts for achieving Focused Logistics, the most effective alternatives are initiatives to continue reducing customer wait time, thereby increasing combat capability. Further fusion of logistics information systems and creation of total asset visibility will allow logistics leaders to make better decisions and improve combat support.

Desired End Result

The revolution in military affairs needed to create tomorrow's more capable force will not be possible without an accompanying logistics transformation. This transformation is being driven by the emerging concepts in JV2010. To meet those needs, the

(Continued on page 46)

EXPLORING THE HEART OF LOGISTICS

Why So Many AWP LRUs?

Maurice W. Carter
Rick London

Introduction

The Air Force Materiel Command (AFMC) continues to struggle with stockage policy for repair parts to support the component repair program where line-replaceable units (LRU) and shop-replaceable units (SRU) are shipped from major command (MAJCOM) bases to the depot for repair and distribution back to the bases. Most component repair parts are managed and supplied by the Defense Logistics Agency (DLA) to each AFMC depot according to levels and demands established by the depot. Over the years, a variety of methods have been used to establish the level of these repair parts to be maintained at the depot. As these levels are inadequate to support the component repair program, either the LRU or SRU needing repair is not inducted for repair because the repair parts are not in the D035 inventory or the LRU or SRU is inducted without those repair parts. In the latter case, the LRU or SRU is put in awaiting parts (AWP) status, and needed repair parts are back ordered. AFMC continues to have what seems to be an excessive number of AWP LRUs or lost inductions, often called skip-overs.

Background

The Execution and Prioritization of Repair Support System (EXPRESS) was implemented throughout AFMC depots starting in 1995. Its logic prioritizes warfighter needs for LRUs to be supplied from the depot component repair program. By netting out all LRU repair pipelines, the system determines each day what each repair shop should induct. After it determines the prioritized induction list of LRUs for each shop, it proceeds down the prioritized list of LRUs to see if the needed resources are in place to execute the repair of each item on the list. If one of the resources is unavailable, the system skips over that LRU and checks the next item on the list. This process continues down the prioritized list to find any LRU that has all the depot resources to do the repair. That *successful* list is sent to the D035 Express Table for immediate induction into the repair shop.

EXPRESS looks at four basic depot resources to determine their availability before an LRU is placed on the shop induction list: carcass availability, shop capacity, component repair parts shown on the bill of materiel from G005M, and Materiel Support Division funds that pay for the repair. As the system progresses down the prioritized LRU list, resources are decremented from the available list. Repair parts are handled differently and are described below.

Because of the many uncertainties in this process, a variety of parameters and switch settings are available to the user to cause the system to send the best mix of LRUs to the shop each day to make the best use of the shop capacity and support warfighter needs. This approach is used so the process can be automated but allows for manual override where the user has conflicting information.

One of the major problems the command has in supplying the right mix of LRUs to the MAJCOMs is not having the right depot resources in place on the day of execution (the day EXPRESS shows the need on the prioritized list). This causes the system to skip over higher priority work and go down the list to lower priority work. This emphasizes the need for a planning process consistent with the EXPRESS objective function to maximize warfighter support and puts needed depot resources in place for the day of execution. The planning process must allow the required lead time for all needed resources.

This article addresses one of those needed depot resources. Each LRU repaired in the depot requires specific repair parts. Not having the right mix of parts has continued to cause many skip-overs and costly AWPs.

Buying the Right Mix of Repair Parts

Consistent Logic is Missing

A variety of systems have been used to procure repair parts and put them in the AFMC D035 account for use in the depot repair program. A number of these programs rely on historical usage data to indicate future usage. In a steady-state system where needs are being routinely met, this is a good approach. However in the Air Force, operational programs do change. Further, priority repair needs are often being met through extraordinary means outside the routine. Consequently, AWPs abound. For the Air Force, historical usage is not a good indicator of the real requirement.

Particularly with EXPRESS operations, a needed LRU is not inducted into repair if the expected required repair parts are unavailable. Consequently, no historical demand data for those parts are generated to show need.

The need for parts must be established by requirement of the end-item LRU and its priority. EXPRESS does generate a list of

parts that would be used, but no historical usage data are generated.

While it is true we do finally accomplish repair on those most needed LRUs, regardless of parts availability, it is often done by costly, extraordinary means such as local manufacture, local buy, or cannibalizations of parts from other LRUs. Historical usage data become unreliable in these situations. In general, use of historical data causes the system to repeat the same problems.

EXPRESS Parts Logic

EXPRESS uses probability logic to determine if the needed parts are in place before a LRU is put on the shop induction list. It uses the quantity per assembly and replacement percent recorded in the bill of materiel (BOM) in the G005M system. The user can select the desired probability of having needed repair parts in place before induction for each LRU. This process is easily understood with a 100-percent replacement factor and few parts on the BOM. For example, if LRU 1 needs one repair component (C1) and it is replaced 100 percent of the time, EXPRESS will

SLIMM PAP*	DLA BC 9 QTY	DLA BC 9 $s	AF BC 8 QTY	AF BC 8 $s
0.1	36,105	9,823,862.00	2,090	443,887.00
0.2	37,533	10,366,850.00	2,110	453,527.00
0.3	38,662	10,836,400.00	2,127	470,081.00
0.4	39,660	11,239,960.00	2,144	474,989.00
0.5	40,625	11,643,280.00	2,157	484,398.00
0.6	41,658	12,065,620.00	2,173	488,812.00
0.7	42,793	12,536,620.00	2,192	523,351.00
0.8	44,244	13,131,700.00	2,215	540,891.00
0.9	46,297	13,953,960.00	2,244	556,114.00
1.0**	53,602	16,780,330.00	2,353	605,302.00

*SLIMM PAP is a predetermined probability repair goal for the reparable end item (LRU).
**Actual number is .999999999999999 before the machine rounds to 1.

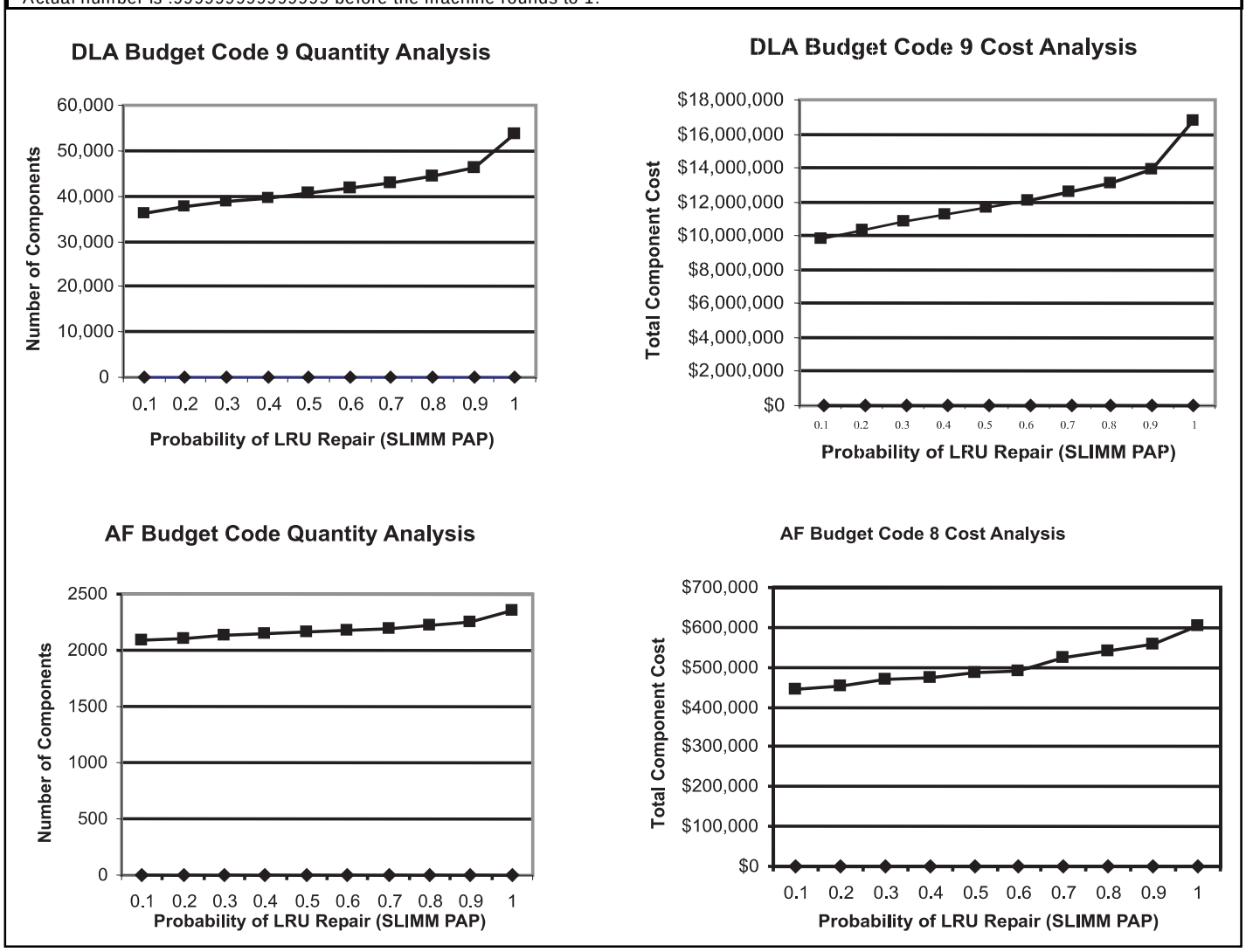


Figure 1. LRU Component Cost Analysis Using EXPRESS Planning Module (90-Day Forecast Period with a 25-Percent Back Order Catchup Goal)

induct only as many of LRU 1 as there are C1s in supply. However, the process gets more complicated as the replacement percent is less than 100, and there are many components in the BOM.

Another example:

LRU 1 has C1 with a 50-percent replacement (%RPL=50), and there are no C1 parts in supply. The probability (P) of successful repair is 50 percent.

LRU 2 has C1 and C2 both with %RPL=50 and no C1 or C2 parts in supply. P=25%.

LRU 3 has C1, C2, and C3, %RPL=50 and no parts in supply. P=12.5%.

This example demonstrates important logic used in EXPRESS. If we were to want to repair 11 LRU 1s, LRU 2s, or LRU 3s and there were 5 (the expected value within rounding) each C1s, C2s, and C3s in supply, the probability of repairing the eleventh LRU on the EXPRESS priority list would vary widely as above for the three LRUs. That is, as EXPRESS works down the prioritized list, the eleventh LRU 3 on the list would have a probability of successful repair of 12.5 percent where LRU 1 would be 50 percent and LRU 2 would be 25 percent.

EXPRESS uses the binomial probability distribution to calculate the probability of successful repair using all parts and %RPL from the G005M BOM for each successive LRU on the prioritized list.

This same logic exists in the EXPRESS Planning Module (EPM). It also makes appropriate adjustments in its calculation when a common repair component is used on a different LRU with a different %RPL.

Setting Stock Levels in Coordination with BOMs

As shown in the above example, the probability of repair is very dependent on the number of components on the BOM needed to do the repair and their availability. The example shows, if we just stock each component at its expected usage rate and with no consideration of the number of other components used for an LRU, the probability of repairing the LRUs will vary widely. As the number of components increases, the probability that one of those components will need more than the expected quantity increases dramatically, resulting in the LRU not being inducted (or going AWP) and other components, even below the expected usage level, being left on the shelf.

EXPRESS Planning Module logic accounts for this reality by setting a desired probability level of repair of the LRU and then calculates the required stockage of each repair part to achieve thae desired probability of repair of the LRU. In that calculation, the numbers of components on the BOM are accounted for.

Is This Approach Costly?

The actual usage of component repair parts will not change. Repair will use what parts are needed and will equate to the calculated expected value if accurate replacement percents are used. What will change is the stockage level of parts that could cause a one-time capitalization for some levels while other levels could be lowered. The EPM model can be used to determine the cost of parts required to achieve varying probabilities of repairing LRUs. Figure 1 shows the cost of completely buying component parts needed for various probability levels of LRU repair referred to in the model as the SLIMM PAP. Repair parts used in the depot are either procured from the DLA (Budget Code 9) or are managed and procured by the Air Force (Budget Code 8). As calculated from the charts, increasing the probability of LRU repair from 50 to 80 percent would increase the stockage cost 13 percent for the DLA-managed parts and 12 percent for Air Force-managed parts. This difference would be a one-time cost only. We believe this cost is modest when weighed against the cost of AWPs and mission capabilities (MICAPs). It is noteworthy to point out that achieving a 100-percent probability of LRU repair over the 50-percent probability is only a 44-percent increase and could possibly be outweighed by the cost of LRU inventory tied up in depot pipelines where only a 50-percent probability of repair is achieved. Further studies using the model could show these tradeoffs.

Is This the Right Approach?

AFMC has tried and tested a variety of methods to set parts levels, but it continues to struggle with AWPs and MICAPs. Most are caused by not having the right repair parts. Any repair shop will attest its biggest problem is not having the right repair parts available when needed to repair an LRU.

We should not let the tail wag the dog. The desired LRU probability is the dog. It should be set, and it should drive the needed levels for repair parts. Conversely, setting levels on repair parts independent of the LRU BOM determines the LRU repair probability, which will vary widely with how we set those levels. It is time to turn this around. The LRU requirement should drive the levels.

We often believe using the probability calculation on an LRU with many components will break the bank. Our trial runs show it will not. We need to use it wisely and determine initial parts costs weighed against MICAPs and AWPs. Moreover, probability theory is real. Anyone can flip a handful of pennies ten times and count the number of heads and tails and demonstrate probability theory. It is time to apply it to our stockage policy now that the tools are available.

Mr Carter is an operations research manager in the Maintenance Directorate, Ogden Air Logistics Center, Hill AFB, Utah. Mr London is a logistics management specialist and the EXPRESS Planning Module OPR in the Maintenance Directorate, Ogden Air Logistics Center.

notable quotes

Freedom is the oxygen of the soul.

—Moshe Dayan

Directorate of Communications Operations Sets Strategic Course

Lieutenant Colonel Kimberly Crider, USAF

On 30 April 2002, the Directorate of Communications Operations (AF/ILC) was established under the Deputy Chief of Staff (DCS), Installations and Logistics (AF/IL). This directorate was formed in conjunction with the standup of the new DCS for Warfighting Integration (AF/XI). As a result, the DCS, Communications and Information (AF/SC) was disestablished.

These changes have twofold importance. The alignment of command and control, communications and computers, and intelligence, surveillance, and reconnaissance under the DCS for Warfighting Integration allows the Air Force to concentrate on integrated planning, programming, and modernization of manned and unmanned space systems and infrastructure to close the seams in the find, fix, track, target, engage, and assess (F2T2EA) kill chain. At the same time, the formation of the Directorate of Communications Operations under the DCS, Installations and Logistics ensures a keen focus on the Air Force communications and information (C&I) network and systems operations, maintenance, and readiness, to include resource advocacy, enterprise information management, force structure, and career management for C&I professionals worldwide.

To ensure this focus is sharply tuned to current Air Force needs and challenges, the Directorate of Communications Operations recently put forth its mission statement and a clear vision of the role it will fulfill for C&I professionals throughout the Air Force. The AF/ILC mission—*To develop communications and information policies and procedures for Air Force enterprise operations and maintenance and ensure communications and information professionals Air Force-wide are organized, trained, and equipped for full-spectrum operations*— establishes ILC's major functions, which include C&I career-field management and force development, resource advocacy, force structure, aerospace expeditionary force sustainment, C&I readiness, information assurance standards, and policy and guidance for Air Force enterprise operations and maintenance, records management, information management, visual information, publishing and postal operations, C&I systems, telecommunications, wireless, navigational aids, and long-haul network.

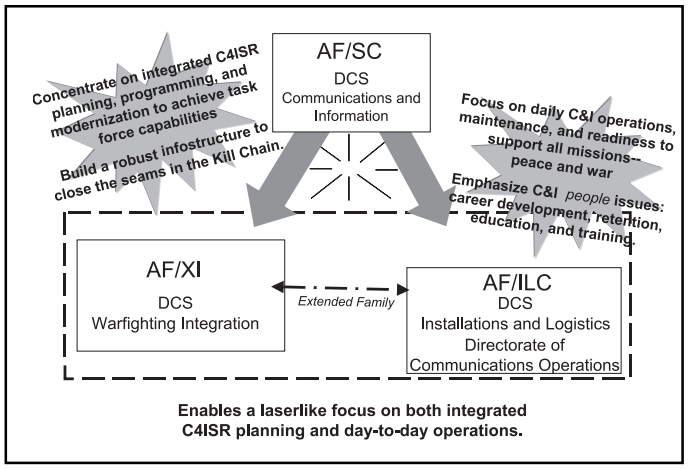


Figure 1. DCS Communications and Information

ILC's vision is to be recognized by its constituents: joint, major command (MAJCOM), and wing commanders; Air Staff and Department of Defense agency partner; and most important, C&I professionals throughout the Air Force as *the Air Force advocate for communications and information operations, maintenance, and readiness.*

The ILC strategic goals and supporting objectives, defined by ILC leaders, address many challenges and opportunities affecting C&I operations, maintenance, and readiness—including, but not limited to, organizational realignments, evolving Air Force missions, stressed career fields, high ops tempo, resource constraints, and rapid technological change. The goals are designed to extend over several years, providing strategic focus for the organization.

USAF/ILC Strategic Goals

1. Ensure efficiently sized, secure, reliable, and robust global communications and information capabilities to support expeditionary air force requirements.
2. Ensure communication and information assets are seamlessly integrated into operational missions to satisfy Air Force requirements.
3. Partner with AF/XI and AF/IL to advocate for resources to completely fund operations, maintenance, and sustainment of existing communication and information systems and manpower.
4. Implement a career-management master plan that outlines specific retention, education and training, and career development initiatives for all military and civilian communication and information career fields
5. Actively and responsively communicate with MAJCOMs on all communication and information issues and provide effective, timely policy and guidance, resources, and other support to meet operational, maintenance, and readiness needs.
6. Provide frequent opportunities for mentoring, professional development, and communication and information crosstalk with the Air Force Senior Communicator, Air Force Chief Information Officer, and other key partners.
7. Actively articulate AF/ILC roles and responsibilities across the Air Force and seek the necessary span of control, associated resources, and manpower to ensure AF/ILC's ability to provide policy and guidance, resources, and support for effective and efficient operation and maintenance of the Air Force enterprise.

These goals and their supporting objectives are published in the 2002-2003 HQ USAF/ILC Strategic Plan. Department of Defense agencies may request a copy from Lieutenant Colonel Kim Crider, kimberly.crider@pentagon.af.mil, DSN 478-1737.

Lieutenant Colonel Crider is the Individual Mobilization Augmentee to the Director, Directorate of Communications Operations, Deputy Chief of Staff for Installations and Logistics, Washington DC.

Current
Logistics Research

Logistics Analysis

Richard A. Moore

Science is the great antidote to the poison of enthusiasm and superstition.

—Adam Smith

Have you ever been faced with the following situations? Your senior leaders just received an impressive presentation from the ACME Logistics Corporation showing an entirely new way to improve logistics support, and you have been asked whether it is something the Air Force can use. Or maybe you believe a current logistics process is broken, but you have not been able to develop a solution that clearly can be shown to be an improvement. The application of professional scientific analysis provides the quantitative evidence needed by management to make these types of decisions. This is the business of the Management Sciences Division of the Air Force Materiel Command (AFMC/XPS).

Although a part of the AFMC Directorate of Plans and Programs (AFMC/XP), we routinely perform studies and analyses for clients outside the directorate, particularly in the AFMC Logistics Directorate (AFMC/LG). The majority of our analysts have advanced degrees in technical areas, such as operations research, mathematics, engineering, and management sciences.

This article highlights work in 2002 to help the Air Force logistician make informed decisions. Following is a summary of three of our significant spares management studies and a list of other logistics management contributions. Details and points of contact for topics mentioned in this article are available in our 2002 annual report, which can be found at https://www.afmc-mil.wpafb.af.mil/HQ-AFMC/XP/xps/xps_annrep.htm. Requests for a printed or an electronic copy should be sent to Samantha Hetrick (937-257-3887 or samantha.hetrick@wpafb.af.mil).

COLT—Improving Spares Support to Depot Maintenance and to the Flight Line

Customer Oriented Leveling Technique (COLT) is a marginal analysis math model developed by XPS to set stock levels on Defense Logistics Agency (DLA)-managed parts at the AFMC repair depots (air logistics centers [ALC]). We worked with the AFMC Supply Division (AFMC/LGS) to implement COLT at the beginning of fiscal year (FY) 2002. It is directly responsible for executing AFMC's roughly $700M annual General Support Division (GSD) spares budget. It optimizes execution of funding to minimize the expected customer wait time to depot maintenance operations.

During calendar year 2002, we worked with the ALCs to fine tune COLT. We also tracked and reported the performance results throughout the year. Incredibly, with roughly the same amount of spares funding in previous years, COLT has achieved a 57-percent reduction in customer wait time from the start of its implementation until December 2002.

Besides using COLT to set stock levels, we have used COLT to help AFMC/LGS allocate FY02 and FY03 funding to the ALCs and justify additional funding from the Air Staff during FY02. The justification resulted in roughly $50M in additional spares funding to provide depot maintenance with the parts to support surge operations.

Given the tremendous success from implementing COLT at the ALCs, we turned our attention to implementing it at the base level, where the environment is very similar. The rules used in the Standard Base Supply System (SBSS) to set stock levels for DLA-managed items are very similar to those that existed at the ALCs prior to COLT. So we believe the same magnitude of improvements seen at the ALCs is possible at Air Force bases. We partnered with the Directorate of Logistics, Supply Division at the Air Combat Command (ACC) and Air Education and Training Command (AETC) to test COLT at one of their respective bases. ACC chose Seymour Johnson AFB, South Carolina, and AETC selected Laughlin AFB, Texas.

COLT was implemented for Seymour Johnson in July 2002 at the ACC Regional Supply Squadron (RSS) at Langley AFB, Virginia. Unfortunately, the GSD budget was so restrictive late in FY02 that no performance improvements were possible from improved stock levels. By November 2002, the budget picture was stabilized, and the base was beginning to benefit from COLT stock levels.

COLT was installed at Laughlin in October 2002, but data issues hampered implementation up through the end of 2002. We will continue to work with both ACC and AETC in 2003 to achieve the full benefits of COLT.

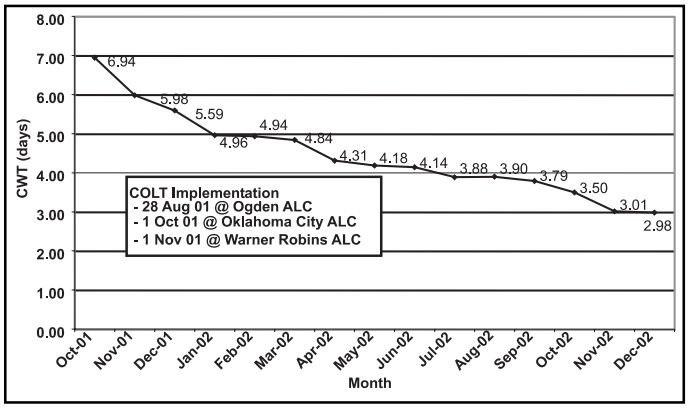


Figure 1. AFMC Command-Wide CWT

GSD Financial Management—How Financial Processes Impact the Warfighter

The General Support Division is the *pot* of money used to purchase the majority of parts used at the ALCs. The GSD account is managed using unit cost ratio (UCR) and unit cost targets, where the amount of money the supply function at an ALC can use to stock parts is a function of the amount of parts supply sells to depot maintenance. Specifically, the unit cost ratio is computed as year-to-date obligations, plus credit returns divided by sales. A *sale* occurs when depot maintenance *buys* a part from supply—supply is *selling* the part to maintenance. An obligation, on the other hand, is the money supply has available to restock its shelves—to buy parts from wholesale sources of supply (for example, DLA). A *credit* is granted from supply to maintenance under certain circumstances when a serviceable part is returned from maintenance to supply.

Since the GSD account is managed to achieve a unit cost target as sales (the UCR denominator) increase, the amount of obligation authority (the UCR numerator) should increase as well, at least in theory. But we discovered during implementation of COLT at the ALCs that, in practice, the obligation authority has to first be requested and then approved. In some cases, including during FY02, the approval process—which goes from AFMC/LGS to AFMC/FMR to AF/ILPY to Secretary of the Air Force/FMBM and sometimes to the Comptroller, Office of the Secretary of Defense—can take several months to complete.

This slow responsiveness was highlighted during 2002 when surge operations at the depots led to faster than expected consumption of parts and faster than expected depletion of the available obligation authority to replenish that consumption, causing concern among GSD fund managers. These managers were not inclined to give additional obligation authority when the General Support Division was already obligating funding faster than expected. Additionally, COLT was being used to set stock levels on these parts, and it was targeting the year-end unit cost target, so it *front loaded* the expenditure of obligation authority with the anticipation sales would materialize by the end of the year to pay for those expenditures. The perceived overobligation of funds decreased confidence in depot supply, and the GSD fund managers were not inclined to release additional obligation authority until sales started to catch up with the obligations expensed.

Throughout the year, the actual unit cost ratio came back in line with the year-end target, as COLT was designed to do. It actually was too low (greatly more sales than obligations) at one point before the end of the year. The General Support Division was eventually given additional obligation authority to bring the unit cost ratio up to the originally specified target. The problem, however, is that warfighter support suffered during the funds request and approval and spares replenishment lead time.

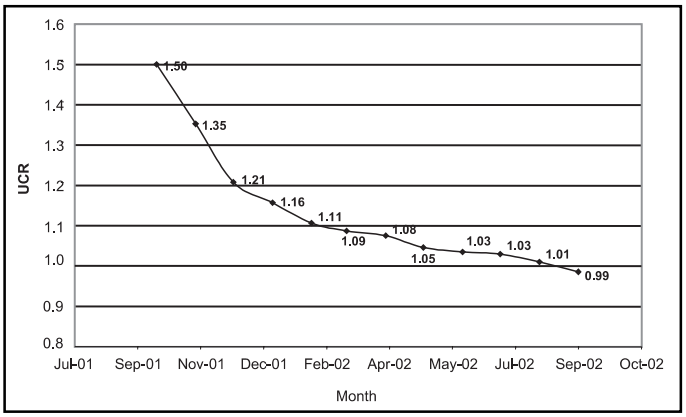


Figure 2. Unit Cost Ratio (UCR) FY02 AFMC Depots (Combined)

Our concern is that current GSD business rules and practices are not adequately flexible, in a rapidly changing world, to enable proactive spare parts support. When the depots have to *eat* out of inventory until additional obligation authority can be released, it is the warfighter who pays the price. We will continue to work with our customers in AFMC/LG to find ways to improve warfighter support and remove financial inefficiencies.

An Expert Selection Forecasting Algorithm for D200A—Improving Accuracy and Usability

The Secondary Items Requirements System (SIRS or D200A) is used to compute future spares requirements. To compute these requirements, D200A forecasts expected future quarterly demands for each part it manages. D200A has four different techniques available to forecast these demands, including an 8-quarter moving average, a 4-quarter moving average, simple exponential smoothing, and a regression technique known as predictive logistics. These techniques use past demand data and program data (for example, flying hours) to forecast quarterly demands during each item's procurement lead time. The forecast is then used to make decisions regarding how many items to repair, purchase, or declare in excess.

The 8-quarter moving average is used as the default forecasting technique for more than 65,000 items currently managed in D200A. To use a technique other than an 8-quarter moving average, an item manager must manually indicate which technique to use by updating a series of indicator codes. Because of the large number of items, a majority of the items use the default 8-quarter moving average technique because there are insufficient time and resources to investigate alternatives. Unfortunately, this results in missed opportunities to improve forecasting accuracy that might be possible if other techniques are used.

To improve this process, we developed an expert selection forecasting algorithm that automatically selects which forecasting technique to use for each item. The algorithm selects among the 8-quarter moving average, the 4-quarter moving average, and a range of simple exponential smoothing models. Selection is based on which technique best fits each item's available historical data. We developed a prototype of the algorithm in Microsoft Visual Basic for Applications and tested it using several data sets. The results indicate that, on average, the expert selection algorithm generally produces more accurate forecasts than the 8-quarter moving average technique currently used for the vast majority of SIRS items. In fact, we demonstrated an 11- to 13-percent reduction in the dollar value of the forecasting error with our expert selection technique over the current 8-quarter moving average technique. Based on these results, AFMC/LGIR will implement our algorithm within D200A for the December 2002 computation cycle.

Other Contributions

We also helped Air Force logisticians with professional scientific analyses in many other ways. Following is a brief summary of those efforts, roughly grouped into four functional areas:

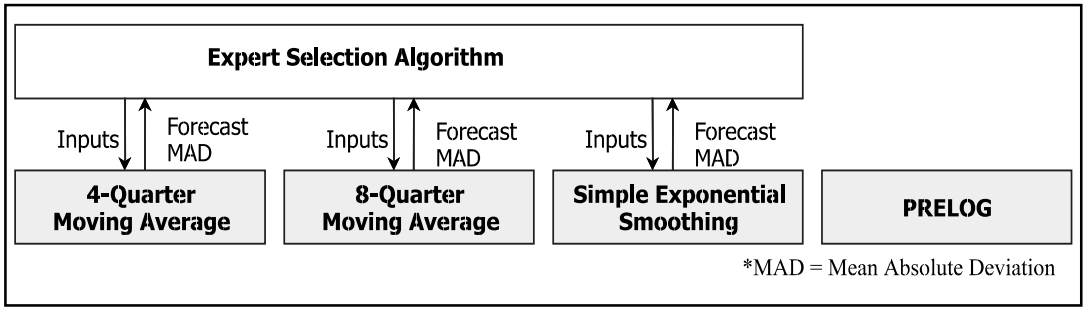


Figure 3. Expert Selection Algorithm

- Performance Measurement
  - Provided a tool (supply chain managers' metric tool) to the ALCs to objectively set performance metric targets. Used the tool to provide back order, issue and stockage effectiveness, logistics response time, customer wait time, and mission capability-hour targets in response to various AFMC and ALC requests.
  - Provided a user-friendly, customizable database interface tool to the Air Force Security Assistance Center and AFMC/LGI to enable increased visibility into warfighter support as measured by the logistics response time of requisitions for recoverable items. Used the tool to show that units engaged in Operation Enduring Freedom received parts ordered from Air Force depots about 3 days sooner (on average) than the uninvolved units.
  - Developed initial estimates of the impact of depot repair constraints on wartime capability assessments and designed an improved capability assessment methodology that integrates models and data systems to facilitate analysis of wartime materiel support of tasked units.
  - Demonstrated benefits of strategic sourcing by showing that parts managed under strategically sourced contracts have generally experienced significant decreases in acquisition lead time, increases in on-time deliveries, and price stabilization since implementation of the process in 1999.
  - Enhanced our simulation model developed for the 2001 Focused Logistics Wargame to make it more flexible and efficient and to provide capability for *what if* analyses.
  - Determined that shortcomings in data do not make it feasible to correlate funding for sustaining engineering activities with warfighter support.
  - Served as technical leads for development of an AFMC predictive support awareness *knowledge wall* to identify and quantify issues inhibiting AFMC from being more proactive in providing sustainment support to the warfighter.
  - Prototyped a new process for valuing spares inventory at a moving average cost instead of the latest acquisition cost and demonstrated an overall 1.8-reduction in inventory value.
- Computing Spares Requirements
  - Led analysis efforts for seven Spares Campaign initiatives and assisted with an eighth.
  - Determined that a commercial forecasting package was not able to generate more accurate forecasts for engine and electronic warfare items compared to the 8-quarter moving average technique currently in D200A.
  - Guided implementation of software changes to D200A that can lead to significant reduction in spares requirements for roughly the same level of performance. Also validated and tested a new research version of the Aircraft Availability Model used in D200A.
  - Initiated a long-term, archival database of inputs and processing results of both the Air Force Weapon System Support Program and DLA Weapon System Support Program. Further, we developed software tools to organize information contained in the systems.
  - Validated the optimization logic in Air Force contingency spares computations by showing spares costs are sensitive to changes in the planned contingency flying-hour program.
- Setting Stock Levels
  - Worked with the Logistics Management Institute (LMI) to design and build a prototype math model that calculates optimal stock levels for whole engines, modules, and engine components for depots, queen bees, and distinct bases to cover demands on supply from peacetime through 180 days of a contingency.
  - Worked with LMI to update the readiness-based leveling (RBL) math model to be more consistent with the D200A spares requirements process. Demonstrated this could lead to a 35-percent reduction in the wait time for spares and a 50-percent reduction in the number of problem parts.
  - Conducted financial analysis of all quarterly RBL computations for AFMC/LG management. Provided critical information that convinced AFMC to field the computed levels.
  - Demonstrated that the warfighter-focused approach used to compute stock levels for recoverable parts (RBL) can be applied to consumable parts.
- Executing Spares Requirements
  - Updated the Execution and Prioritization of Repair Support System (EXPRESS) math model to improve parts support to engine and aircraft overhaul repair lines at the depots. Also showed that EXPRESS-managed items are one-third as likely to have had unnecessary depot repairs as non-EXPRESS-managed items.
  - Conducted extensive testing of the AESOP™ engine simulation model and decision-support system tool to show it was not functioning in accordance with contractual requirements.
  - Validated an offline process that motivates bases to evacuate unneeded broken parts and initiated an analysis to validate the standard system (RAMP/SBSS) process.
  - Provided critical information to AFMC/LGI and the MAJCOMs to use in evaluating the accuracy of MAJCOM flying-hour input to EXPRESS.

Mr Moore is chief, Analytic Applications, Management Sciences Division, AFMC Directorate of Plans and Programs, Wright-Patterson AFB, Ohio.

A Physically Fit Airman: An Essential Element for Agile Combat Support in the AEF

Lieutenant Colonel Michael W. Alexander, USA

The Air Force has embraced a doctrinal concept, the air and space expeditionary force (AEF), that calls for units to deploy within a very short timeframe to support joint or combined operations. Underpinning this concept is Agile Combat Support (ACS). Deploying units will depend on ACS to move the aircraft, logistical equipment, supplies, and personnel to meet taskings and conduct operations. For the Air Force to be effective in the fluid AEF environment, service members need to be well trained in their particular specialty, and they also must be physically fit.

The author's personal experience with physical fitness requirements and needs in an expeditionary environment is based on experiences when the 2d Battalion, 37th Armor (2-37 AR) received a short-notice deployment order to execute a peacekeeping mission in the Federal Yugoslavian Republic of Macedonia (FYROM). The program discussed in this article proved to be effective in preparing the soldiers for a very demanding and physically taxing mission.

Task Force Able Sentry

In December 1996, 2-37 AR from Friedberg, Germany, was selected to conduct a United Nations (UN) peacekeeping mission in FYROM. The operational name for the mission was Task Force Able Sentry. The mission was to provide a presence along the Albanian, Serbian, and Bulgarian borders. The unit provided this presence by patrolling (walking) along the mountainous borders of these countries, holding the UN flag high. What made this mission particularly unusual for the soldiers was that infantry soldiers usually performed this mission, not tankers. Grunts (infantry) usually do all the walking; tread heads (tankers) drive. But the tables had turned, and the armor unit was given a foot-patrol mission. To succeed, it had to prepare to execute the mission, which would be physically demanding. A 6-week physical training program had to be designed to prepare the unit for the rigors of patrolling the FYROM border.

Basically, the mission called for a squad of 12 soldiers to patrol 10-15 miles a day across extremely mountainous terrain, with a 60-pound rucksack and a rifle. An additional benefit (if you wanted to call it that) was the soldiers had to walk along the mountain ridgeline as high as possible to be seen by the Albanians, Serbians, and Bulgarians. This ensured these countries of UN presence. These mountain ridges were about 3,000 feet above sea level, so the training had to be tough. The commander was very aware that the tankers were in good physical condition for fighting with M1A1 tanks, but they were not prepared for the kind of mission assigned. The bottom line was the unit had about 6 weeks to prepare for the mission. So we had to come up with a training plan to get the soldiers physically ready to patrol.

The physical training had to be focused on cardiorespiratory and muscular endurance. Each of the four company commanders was given a 6-week physical training program that consisted of road marches with fully packed rucksacks. The patrolling sessions were conducted at least 4 days a week. The company commander could pick training days based on a training schedule. Each company commander was also responsible for tracking the progress of each soldier to ensure progress was being made in reaching the fitness goal.

Each soldier carried a rifle, along with a ruck, during the training, so the training basically replicated the mission the soldiers would be conducting. Each week, the company commander was required to increase the mileage by 2 miles. This incremental progress helped build the soldiers' cardiorespiratory fitness and muscular endurance so, by the time of deployment, the companies were completing up to 12 miles a session across some hilly terrain in the local area. When the commander provided the mission brief to the brigade commander prior to deployment, he felt confident the soldiers were physically and mentally ready to execute Able Sentry.

The Advantages of Good Physical Fitness

Since 1991, I have been deployed to three operational missions: Desert Storm, Bosnia, and FYROM. In each mission, I was a part of the advanced element that deployed into the theater to establish the logistical and operational footprint. It has been my experience that one of the key prerequisites for any service member is to be in good physical condition. Why? Because upon arrival, most of our work was moving equipment, setting up base camps, and clearing space so we could operate the equipment essential to the mission. As a member of an advanced party in an uncertain environment, you are required to do a lot of physical work, and you do not need people getting sick or fatigued. Individual fitness is an essential element for deploying units.

Both the Army and Air Force are embracing doctrines that call for units to be prepared to deploy anywhere in the world within a very short time. To be successful prior to and during deployments, these units need to be mission focused, have their deployable equipment combat ready, and have sound logistical systems, and the service members need to be physically fit. The Army experiences discussed in this article are very similar to the challenges faced by Air Force units that deploy to remote areas. One could also argue that physical fitness is a foundational element for Agile Combat Support.

Experience in Enduring Freedom showed Air Force members had the enormous task of carving out a workable airfield and base camp in undeveloped areas in and around Afghanistan. Lieutenant Colonel Phillip Bossert—an Air Force logistics officer, who was a tanker airlift control element commander in Afghanistan during Operation Enduring Freedom—said his airmen conducted physical training at least two times a week to prepare themselves for the rigors of the deployment. They had to be in good physical condition to be able not only to conduct strenuous tasks for long hours but also deal with the stress of being in Afghanistan during a combat operation.[1]

Deployments often produce stress and anxiety because of the many unknowns—destination, departure date, and length of the deployment. It has been my experience that units whose members are in good physical condition are more productive and perform their missions with less stress. Physical fitness is an important element for readiness for any deployable unit. So what does it mean to be physically fit?

Physical Fitness Defined

Simply put, physical fitness includes four components—cardiorespiratory fitness, flexibility, muscular strength, and muscular endurance. Each of these is important for total fitness, and a good fitness program for a deployable unit should include them as a base.[2]

Components of Physical Fitness

Cardiorespiratory fitness involves the heart and lungs: the lungs put oxygen in the blood, and the heart pumps the blood throughout the body. When the cardiorespiratory system is fit, people can be active without experiencing shortness of breath or becoming fatigued easily. Exercises that can improve cardiorespiratory fitness include running, swimming, walking, road-marching, and biking.[3] Cardiorespiratory fitness is the one most often included in military training. Although cardiorespiratory fitness is very important, all four components must be included in a fitness program to attain good overall fitness.

Most experts stress the importance of developing and maintaining good flexibility. Flexibility is attained when muscles and joints are loose and can move through a full or near-full range of motion without feeling tight or stiff. Flexibility is important because it can help prevent injuries when engaged in physical activities.[4] Activities that will improve flexibility include stretching, tumbling, and yoga.

Muscular strength is the ability to exert a force against some form of resistance. Lifting weights, picking up books from a desk, and standing up from a chair are examples of muscular strength. Strengthening muscles allows people to lift a heavier weight, pick up more books, or stand up from a chair with greater ease. Experts agree that the best way to improve muscular strength is by conducting weight-training exercises. But a deployed unit needs people with strong and toned muscles who can operate over time—muscular endurance.[5]

Muscular endurance refers to the ability to repeat muscle exertions. Situps, pushups, moving many boxes of books, and squatting repeatedly are examples of muscular endurance activities. As muscular endurance increases, the ability to repeat muscle exertions also increases.[6] In general, deployed service members use this component of physical fitness most often when moving equipment and supplies.

Recommended Fitness Program

The ideal fitness program for a deploying unit is one that includes activities involving all four components of fitness, done three times a week for at least 1 hour, with all the unit's members participating, especially the leadership. The program should be simple enough so when the unit deploys it can continue. Additionally, if the unit's mission calls for physical labor, an effective physical training session should replicate some of the movements involved. For example, 2-37AR training sessions included walking patrols just as they would be done during the mission. Further, the commander should look at changing the type of exercise programs periodically. This will keep the training fresh and help continue the troops' progress.[7]

Most units need good fitness training, perhaps not as aggressive as the 2-37AR physical training model when preparing for the FYROM mission, but one that is challenging. The Army fitness manual, Field Manual 21-20, recommends that a unit conduct physical training for at least 1 hour three times a week. During this period, a well-planned program could incorporate each component of physical fitness with the eventual benefit of a physically fit service member prepared for in-garrison requirements or deployment.[8]

My experience with deployable units has shown that this 1-hour session, at least three times a week, focusing on all components of fitness, will prepare a unit physically for the rigors of deployment. A typical hour-long program could be as follows:

0630-	Form up
0630-0640	Stretching head to foot
0640-0700	Muscular endurance training, timed pushups, pull-ups, and situps.
0700-0725	Two-mile run or walks
0725-0730	Cool-down stretch[9]

As simple as this program is, it can be very effective if executed properly. However, two major keys to success are unit leaders' understanding that each person will progress differently and leadership participation in the program.

In the 2-37AR, the battalion commander required the company commanders, first sergeants, platoon leaders, platoon sergeants, and all other leaders in the company chain of command to participate in physical training along with the soldiers. Additionally, all the staff guys (including me) had to find time to get out there and sweat and grunt with the soldiers. Initially, there was some resistance, but the commander was firm. This training was difficult initially for some of the older leaders, but as all advanced to get in patrol condition, the training became much more enjoyable.

One of the added benefits to a good unit physical training program is esprit de corps. This is of great benefit especially before a deployment. Soldiers really get motivated when they see their leadership working alongside them preparing for the mission. Many of the soldiers enjoyed the training because it was tough; leaders were involved; and most of all, it was different from regular physical training.

As mentioned earlier, some variety is good in exercise programs. While a good physical training program should exercise the four components of fitness, it does not always have to be just running, pushups, or situps. Another program that works well for units is hand-to-hand combat training, which I instituted in the cavalry squadron I commanded. We found qualified martial arts instructors and had them set up a program based on the Army combative program.[10] The soldiers learned some hand-to-hand and disarming techniques and worked with pugil sticks. This program was leadership-intensive to ensure it did not get out of hand, but the soldiers really liked it. If we had deployed, the leadership felt the program could be continued because it would give the soldiers the confidence needed to protect them in a close combat encounter and keep them in fighting shape. This program worked remarkably well getting soldiers in shape and building esprit de corps and was fun.

Other fitness programs include competitions between units such as fun runs, speed marches, and boxing smokers. The list is limitless, but the key element is the level of fitness that leaders want their troops at prior to deployment and the level they want them to maintain while deployed. Once this goal is established, incorporating the four components of fitness into a simple but effective training plan that is executed at least three times a week for at least an hour will physically prepare a unit for deployment.[11]

Army Experience

When 2-37 AR arrived in FYROM and each company moved to its respective base camp along the border in March 1997, we started our mission. When the soldiers faced heavy snow in the mountains, they put on their snow equipment and walked patrols. In June, when the thaw came, the soldiers faced unseasonable heat through August. The leadership modified the uniforms for the weather, and away marched the soldiers, executing their mission with vigor. During the 6 months of patrolling, our soldiers were very successful. This success can be measured by the fact there were no incidents on the border because of our constant presence.

The UN commander commented that he was very surprised that a US Army armor unit could perform so well. There were many reasons for the unit's success, but key to the success was the soldiers' physical fitness. We could not have achieved success without good physical fitness training that included the four components of fitness.

Conclusions

The Air Force should incorporate mandatory physical fitness programs into its unit training to ensure members are prepared for the rigors of deployment. This training should focus on the four components of physical fitness: cardiorespiratory, flexibility, muscular strength, and muscular endurance. It should be simple but focused on the particular fitness goals outlined by the unit leadership, based on mission requirements. Additionally, the program should be designed to continue to maintain the fitness level in the deployed area of operations. As with in-garrison training, the frequency should be three times a week for a least 1 hour. Finally, unit leadership should be visible during all unit fitness training; this reinforces the importance of training and helps build esprit de corps. Good fitness training is an essential element of Agile Combat Support and will help AEF units to be successful in any environment.

Notes

1. Author's interview with Lt Col Phillip Bossert, USAF, Air War College student, Maxwell AFB, Alabama, 12 Sep 02.
2. "Flexibility and Cardiorespiratory Fitness," *Health Teacher*, 1999 [Online] Available: 9/13/2002,www.healthteacher.com/lessonguides/physical/4-5/pa2el45/teaching.asp.
3. *Ibid*.
4. *Ibid*.
5. *Ibid*.
6. *Ibid*.
7. Army Field Manual 21-20, Physical Fitness, Jun 99, 1-5.
8. *Ibid*.
9. *Ibid*.
10. *Ibid*.
11. *Ibid*.

Lieutenant Colonel Alexander is a student at the Air War College, Maxwell AFB, Alabama.

notable quotes

We are face to face with our destiny and we must meet it with a high and resolute courage.

—Theodore Roosevelt

Take calculated risks. That is quite different from being rash.

—General George S. Patton

("Managing Air Force Depot Consumables" continued from page 5)

RFM actually addresses two problems: demand variability and demand dependence. With regard to the first, it provides depot materiel managers a tool to help cope with *anticipated* variations in demand. Although safety stock provides protection from these variations, it is still *blind* in the sense that it does not specifically account for individual, known fluctuations. Where the EOQ model assumes demand will be constant for the foreseeable future, in reality, demand fluctuates through time, often in ways that can be anticipated. A recent example was the dramatic increase in flying hours required for operations in Afghanistan. Since such a known increase in flying will certainly result in a greater number of repair actions, it is appropriate to have a system in place that can estimate the effect on consumable part requirements. To accomplish this estimate, RFM borrows the system logic of materiel requirements planning (MRP)[14] systems. In so doing, it addresses the second issue of dependent demand, since MRP systems calculate parts requirements dependent on requirements at the end-item level. RFM was, therefore, developed partly as a forecasting decision-support system to help identify times when the EOQ level will be inadequate.

RFM performs two primary functions:[15]

- It can provide an assessment of inventory availability, given the current projection of repairs in the Secondary Item Requirements System (D200A).
- It can provide the user with an estimate of shortfalls if the current projection changes (a *what if* analysis).
- In either case, materiel managers can generate special requisitions and expedite shipments to meet consumable demands for repairs. These special requisitions are generated automatically by RFM but are subject to review by depot materiel managers.

Assumption 4: Single Echelon System (Solution: Daily Ordering and COLT). A fourth critical assumption made by the EOQ model, which is violated in the Air Force depot environment, is that it operates in a single echelon system. This assumption basically implies that the SBSS (at bases) and D035K (at depots) order in batches of quantity Q* directly from suppliers. In reality, for consumable items, the depots order in batches of Q* from the Defense Logistics Agency (DLA), which, in turn, orders (also in batches of Q*) from suppliers. This additional echelon exacerbates the problem of demand variability, often severely, resulting in a problem known as the *bullwhip effect*,[16] meaning that demand variability gets worse as you move up the supply chain.

The Air Force developed two solutions to account for the multiechelon nature of its depot demand. The first was the result of an AFLMA study published in 1998, which found that more frequent ordering of some higher cost, low-demand consumables from DLA would help s*mooth* the demand that DLA sees.[17] AFMC responded with a policy of daily ordering of all consumables at the depots, which, although a more drastic step than AFLMA recommended, has allowed DLA to see actual Air Force demands more directly so less safety stock is required to account for variability. The second solution, only recently developed, is the COLT developed by AFMC.[18]

COLT was developed using the same mathematical logic as the AAM and Aircraft Sustainability Model (ASM) used in reparable inventory management.[19] The main difference lies in its objective. Where AAM and ASM seek to maximize the number of aircraft fully operational for a given inventory investment,[20] COLT seeks to minimize the customer wait time.[21] All three take a systems view of inventory management, accounting for multiple echelons of supply (in this case, bases, ALCs, and DLA). All three use a marginal analysis approach to determine which items and how many of each to stock, incrementally adding individual items to the inventory that provides the maximum *bang for the buck*. The biggest difference is in how *bang* is defined.

Assumption 5: Known Ordering and Holding Costs (Solution: Flat Rates). The final assumption discussed is known as ordering and holding costs. In practice, these costs are extremely difficult to estimate and usually vary significantly from item to item. Ordering costs generally vary depending on the lot quantity and physical size of the shipment, and the lot quantity Q* calculated by the economic order quantity actually requires it as an input.[22] This circular logic reduces the model's effectiveness in minimizing costs. Holding cost is comprised of a number of components, the largest of which is known as the *opportunity cost*.[23] Essentially, the opportunity cost represents the benefit that could be gained by investing the money in something other than inventory. In commercial businesses, this opportunity cost is generally the interest that could be earned on a capital investment, usually referred to as the *hurdle rate*.[24] Since government organizations do not have tangible investments, holding cost becomes a nebulous concept. Quantifying the benefit of investing in an additional F-15 instead of inventory, for example, is nearly impossible. The Air Force, recognizing this difficulty, has historically used flat holding and ordering costs that apply to all items indiscriminately and has been reluctant to change them because of their substantial impact on inventory levels.[25] Without accurate costs, the EOQ model's attempt to minimize total cost is adversely affected. This is perhaps the least problematic assumption violation, since the total cost is actually relatively flat around the economic order quantity (Figure 2). This means errors have a minimal effect on the total cost, relatively speaking.[26]

Conclusion

The EOQ model has been in use for decades, mainly because of its simplicity and ease of implementation. With the advent of affordable desktop computing power greater than that of older mainframes, more sophisticated models are now available that address many of EOQ's faulty assumptions. This article has discussed five of those assumptions, their effects, and steps the Air Force has taken to deal with those effects.

To protect against stockouts caused by variability in demand and lead times, the Air Force has traditionally used safety stock levels but more recently has implemented RFM to help reduce its dependence on high safety stocks. RFM, regardless of the core system used to determine levels, plays a watchdog role that gives materiel managers visibility of impending stockouts and the ability to conduct *what if* analyses to cope with known demand changes. Daily ordering of consumables at the air logistics

centers was implemented after a 1998 AFLMA study found that more frequent ordering of some consumables would reduce the *bullwhip effect* and allow DLA to provide higher service rates with less safety stock. The benefits, in most cases, outweighed the additional ordering cost associated with a greater number of orders. AFMC's development of the COLT model is its latest effort to transform Air Force-consumable inventory management and has proven to be a major step forward. The systems approach of COLT at last acknowledges the multiechelon, dependent nature of demands inherent in most Air Force items and makes inventory decisions based on a tangible and measurable impact to the customer.

Air Force depot-consumable management has progressed gradually from exclusive use of historical data (for forecasting) and the EOQ model (for leveling and ordering). The forecasting function, although still dependent on historical demand data, has been augmented with a more accurate RFM forecast. The leveling function has graduated from the economic order quantity to the recently developed COLT, taking customer wait time into consideration in the establishment of levels. Finally, the ordering function has changed from the batch ordering of economic order quantity to daily orders, providing DLA with a more accurate picture of Air Force demand. The future may well see more improvements and changes, but the last 7 years have brought more change to consumable inventory management than the Air Force has seen in many decades.

Notes

1. Capt Buddy Berry, Capt Brad Anderson, Dr Douglas Blazer, John Dietz, and 1st Lt Severine Colborg, "Harmonization of Air Force and Defense Logistics Agency Economic Order Quantity Policies," Air Force Logistics Management Agency, Maxwell AFB, Gunter Annex, Alabama, Oct 98.
2. "Reparability Forecast Model," CACI briefing to OC-ALC/LPP, Oklahoma City ALC, Tinker AFB, Oklahoma, 21 May 97.
3. Don Kringen and Jason Vinson, "Customer-Oriented Leveling Technique," AFMC Briefing, Wright-Patterson AFB, Ohio, 9 Oct 01.
4. Roger G. Schroeder, *Operations Management: Decision Making in the Operations Function*, New York: McGraw-Hill, 1993, 588.
5. Richard J. Tersine, *Principles of Inventory and Materials Management*, New Jersey: PTR Prentice Hall, 1994, 92.
6. *Ibid*.
7. Tersine, 94.
8. Tersine, 207.
9. Tersine, 205.
10. Tersine, 207.
11. "Reparability Forecast Model Background Paper," CACI, Aug 96.
12. James F. Cox III and John H. Blackstone, *APICS Dictionary*, Alexandria, Virginia, 2002.
13. "Reparability Forecast Model Background Paper."
14. "RFM Users Manual," CACI, Jul 97.
15. "Reparability Forecast Model Background Paper."
16. Hau L. Lee, V. Padmanabhau, and Seungjin Whang, "Information Distortion in a Supply Chain: The Bullwhip Effect," *Management Science*, Vol 43, No 4, Apr 97.
17. "Harmonization of Air Force and Defense Logistics Agency Economic Order Quantity Policies."
18. "Customer-Oriented Leveling Technique."
19. *Ibid*.
20. *Ibid*.
21. *Ibid*.
22. Tersine, 14.
23. *Ibid*.
24. *Ibid*.
25. AFMC Instruction 23-105, "Consumable Item Requirements Determination," Wright-Patterson AFB, Ohio: HQ AFMC, 28 Apr 97.
26. Tersine, 98.

Major Gaudette is a third year doctoral student at the Kelley School of Business, Indiana University, Bloomington, Indiana. Mr Alcorn is the RFM functional manager, Agile Logistics Policy Branch, Depot Maintenance Division, Logistics Directorate, AFMC, Wright-Patterson AFB, Ohio. Dr Blazer is a senior research fellow, Logistics Management Institute.

("Reparability Forecast Model" continued from page 11)

6. Richard B. Chase and Nicholas J. Aquilano, *Production and Operations Management*, 6th ed, Burr Ridge, Illinois: Irwin, 1992, 704.
7. *Ibid*.
8. The materials plan presented here omits some elements for clarity. A real materials plan would include starting balances and scheduled receipts, which would be taken into account in determining the net requirements.
9. Adapted for RFM, original MRP version from Chase and Aquilano, 704.
10. *RFM Users Manual*. CACI, Jul 97.
11. *Ibid*.
12. *RFM Users Manual*. RFM uses three different types of calculations for the replacement factor. The first is 8 quarters of consumable demands divided by 8 quarters of end-item production. The second, similar to the first, uses only 4 quarters of data. The final method uses the replacement percentage in the G005M and multiplies it by the units per assembly.
13. [100 seats]/[1,000 chairs repaired X 1 per assembly] = 0.1 [300 backs]/[1,000 chairs repaired X 1 per assembly] = 0.3 [1,000 legs]/[1,000 chairs repaired X 4 per assembly] = 0.25
14. The mathematical expression here is actually the *strong* Law of Large Numbers, which says that the sample mean approaches the population mean with a probability of one. There is also a *weak* Law of Large Numbers, which says the same thing but with a less rigorous mathematical foundation. More detail can be found in almost all statistics books.
15. The underlying data are omitted for brevity but are available from the corresponding author on request.
16. Kevin Gaudette, "Materiel Requirements Planning in Air Force Depot-Level Maintenance," master's thesis, Air Force Institute of Technology, Wright-Patterson AFB, Ohio, Sep 98.
17. This recommendation requires more detailed data collection than is generally available. Consumable usage data need to be generated at the shop level to calculate the actual variability in demand.
18. *RFM Users Manual*
19. "Reparability Forecast Model Background Paper."
20. See Don Kringen and Jason Vinson, "Customer-Oriented Leveling Technique," AFMC Briefing, Wright-Patterson AFB, Ohio, 9 Oct 01, for estimates of supportability improvements using COLT.
21. See Capt Buddy Berry, Capt Brad Anderson, Dr Douglas Blazer, John Dietz, and 1st Lt Severine Colborg, "Harmonization of Air Force and Defense Logistics Agency Economic Order Quantity Policies," Air Force Logistics Management Agency, Maxwell AFB, Gunter Annex, Alabama, Oct 98, for estimates of results using daily ordering.

Major Gaudette is a third year doctoral student at the Kelley School of Business, Indiana University, Bloomington Indiana. Mr Alcorn is the RFM functional manager, Agile Logistics Policy Branch, Depot Maintenance Division, Logistics Directorate, AFMC, Wright-Patterson AFB, Ohio. Major Mangan is the maintenance supervisor, 8th Aircraft Maintenance Squadron, Kunsan Air Base, Korea.

("Improving the Logistics Pipeline" continued from page 21)

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

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

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

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

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

Based on the regression analysis conducted to determine the significance of order and ship time and DO&SB on the value of the independent variables kit cost and kit size, it was evident that DO&SB was almost insignificant. The resultant values of kit cost and size were affected almost completely by order and ship time. By this result alone, it seems that efforts to reduce the cost and the size of Air Force MRSP should focus on ways to reduce order and ship time rather than DO&SB. However, the results obtained through the use of the FSL option of the Aircraft Sustainability Model indicated there might be significant benefits—namely, savings in cost and airlift requirement—that could be achieved through the implementation of the *pipeline on the fly* technique. In fact, the unique adaptation of the FSL option created during the research pointed to the possibility that the Air Force could save more than 80 percent in both spares cost and cargo movement needs when the *pipeline on the fly* approach is combined with a reduction of the order and ship time to 5 days.

Notes

1. Michael E. Ryan and F. Whitten Peters, *America's Air Force: Vision 2020*, HQ Air Force, Washington DC, Jun 00, http://www.af.mil/vision/, 20 Aug 00.
2. *Ibid.*
3. David Simchi-Levi, Phillip Kaminsky, and Edith Simchi-Levi, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*, Boston, Massachusetts: The McGraw-Hill Companies, 2000, 59.
4. AFMC Logistics Support Office Logistics Response Time, Wright-Patterson AFB, Ohio [Online] Available: https://137.245.226.104/LRT/database2.htm, 13 Sep 00.
5. James T. McClave, P. George Benson, and Terry Sincich, *Statistics for Business and Economics*, Upper Saddle River, New Jersey: Prentice Hall, Inc, 1998, 55.
6. McClave, et al, 58.
7. *Ibid.*
8. Michael F. Slay, et al, *Optimizing Spares Support: The Aircraft Sustainability Model*, AF501MR1, The Logistics Management Institute, McLean, Virginia, Oct 96, 1-1-1—2.
9. Slay, et al, 1-3.
10. Slay, et al, 1-4.
11. *Ibid.*
12. Headquarters, Air Force, "USAF Fact Sheet: C-17 Globemaster III" [Online] Available: http://www.af.mil/new/factsheets/C_17_Globemaster_III.html, 25 Jan 01.
13. Correspondence with Capt Eve Burke, Air Combat Command, Weapon System Assessments and Analysis Section, Langley AFB, Virginia, 12-20 Dec 00, and with Capt Daniel Lockhart, Air Mobility Command, Combat Aircraft Support Section, Scott AFB, Illinois, 11-20 Dec 00.
14. Jamie D. Allen and Brian Bedesem, "Deploying and Sustaining an F-117A Expeditionary Fighter Squadron: Why Agile Combat Support Is Needed Now," *Air Force Journal of Logistics*, Vol XXII, No 4, Oct 99.

Major Martinez is chief, Wartime Supply and Fuels Analysis Branch, Supply Division, Air Force Logistics Management Agency, Maxwell AFB, Gunter Annex, Alabama. This article is an excerpt from his thesis while a student in the Graduate Logistics Management Program at the Air Force Institute of Technology, Wright-Patterson AFB, Ohio. Lieutenant Colonel Brady is assistant professor of Logistics Management, Air Force Institute of Technology. Major Arostegui is commander, 374th Logistics Readiness Squadron, Yokota Air Base, Japan.

("Footprint Configuration" continued from page 28)

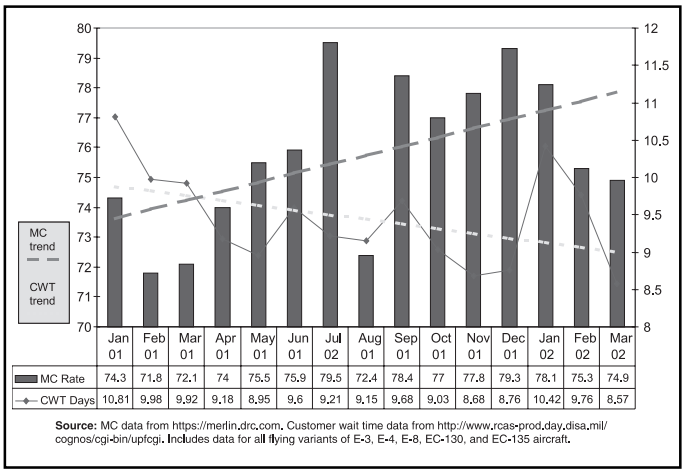
10. See Robert S. Tripp, Lionel A. Galway, Paul S. Killingsworth, Eric L. Peltz, Timothy L. Ramey, John G. Drew, *Supporting Expeditionary Aerospace Forces: An Integrated Strategic Agile Combat Support Planning Framework*, RAND, Santa Monica, California, MR-1056-AF, 1999, and Killingsworth, et al 2000.
11. For example, the medical community initially elected to drop power generation capability from its expeditionary facilities in the expectation of hooking into the bare base power grid. However, the latter was being reduced because it was assumed several functional areas had their own power sources. See *Bare Base Annual Report 2000*, ACC/LGXW, 1 Dec 00, Rev A 26 Dec 00.
12. The 366th Wing, Mountain Home AFB, Idaho, is one of the popup AEWs charged with being ready to deploy instantly to a warm base worldwide. As part of its planning process, the 366th has developed a

list of 120 plus UTCs to augment the support resources at a generic warm base and expects to use the list as a template TPFDD to be completed when it actually deploys.

13. For example, total deployment figures for bases used in Operation Noble Anvil do not shed much information on resources needed to commence operations, and they may be contaminated by the *Poppa Bear* buildup (in which resources but not aircraft were deployed). Also, the TPFDD for Operation Noble Anvil also may not include some intratheater movements in Europe carried out by civilian transport.
14. In this project, we focused on support processes, but much of the subsequent discussion holds true for the operational part of the footprint as well.
15. Peltz, et al, 2000, and Galway, et al, 2000.
16. Unless these are feasible (in the sense of being acceptable to the theater combatant commander or CINC) under a variety of circumstances, expeditionary aerospace forces will not be used.
17. Tripp, et al, 2000.
18 Galway, et al, 2000, and Tripp, et al, 2000.
19. Tripp, et al, 1999.
20. Richard J. Hillestad and Paul K. Davis, *Resource Allocation for the New Defense Strategy: The DynaRank Decision-Support System*, MR-996-OSD, Santa Monica, California, 1998.
21. This stems from the parallel interest of the Air Force for dispersed operations. See the output of the Dispersal Conference, 20-21 Feb 01, in Washington DC, sponsored by AF/XOX.
22. Hess and Wermund.
23. Tripp, et al, 1999.
24. Tripp, et al, 2000.

Dr Galway, Dr Amouzegar, Dr Snyder, and Dr Hillestad are members of the research staff of the RAND Corporation, Santa Monica, California. The work reported in this article is described in more detail in Galway, Amouzegar, Hillestad, and Snyder, Reconfiguring Footprint to Speed EAF Deployment, RAND, MR-1625-AF, 2002.

("Focused Logistics and Combat Capability" continued from page 32)



	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 02	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02	Mar 02
MC Rate	74.3	71.8	72.1	74	75.5	75.9	79.5	72.4	78.4	77	77.8	79.3	78.1	75.3	74.9
CWT Days	10.81	9.98	9.92	9.18	8.95	9.6	9.21	9.15	9.68	9.03	8.68	8.76	10.42	9.76	8.57

Source: MC data from https://merlin.drc.com. Customer wait time data from http://www.rcas-prod.day.disa.mil/cognos/cgi-bin/upfcgi. Includes data for all flying variants of E-3, E-4, E-8, EC-130, and EC-135 aircraft.

Figure 7. Trend Graph of All Command and Control MC Rates and CWTs

military logistics system must become responsive, dependable, efficient, and effective. Initiatives to combine logistics data in new ways and reduce customer wait time are the only way to improve combat capability and satisfy those emerging concepts.

Lieutenant Colonel Ramer is chief of the Weapons Systems and Standardization Section at RHQ Allied Air Forces Southern Europe, Naples, Italy.

notable quotes

Smart is when you believe only half of what you hear. Brilliant is when you know which half to believe.

—Robert Orben

The object of war is victory.

—General Douglas MacArthur

Editorial Advisory Board

Colonel Richard M. Bereit, USAF, Retired
Flagstaff, Arizona 86001

Brigadier General Michael A. Collings
Director of Maintenance and Logistics,
Air Combat Command
Langley AFB, Virginia 23665-2791

Lieutenant General Charles H. Coolidge, Jr
Vice Commander, Air Force Materiel Command
Wright-Patterson AFB, Ohio 45433-5001

Lieutenant General Stewart E. Cranston, USAF, Retired
Burke, Virginia 22015-4154

Major General Terry L. Gabreski
Director of Logistics, Air Force Materiel Command
Wright-Patterson AFB, Ohio 45433-5001

Brigadier General Elizabeth Ann Harrell
Director of Maintenance, Air Force Deputy Chief of Staff for Installations and Logistics
Washington DC 20330-1030

Brig Gen Peter J. Hennessey
Director of Resources, Air Force Deputy Chief of Staff for Installations and Logistics
Washington DC 20330-1030

Professor I. B. Holley, USAFR, Retired
Durham, North Carolina 27705-5651

Colonel Kenneth P. Knapp
Air Force Materiel Command Chair to Air University
Maxwell AFB AL 36112-6427

Colonel Clarence T. Lowry, USAF, Retired
Montgomery, Alabama 36106

Brigadier General Robert E. Mansfield
Special Assistant for Supply Chain Integration and Logistics Transformation, Deputy Chief of Staff for Installations and Logistics
Washington DC 20330-1030

Colonel Ronne G. Mercer
Commander, Air Force Logistics Management Agency
Maxwell AFB, Gunter Annex, Alabama 36114-3236

Lieutenant General John M. Nowak, USAF, Retired
Fairborn, Ohio 45324-6292

Ms Susan A. O'Neal
Air Force Assistant Deputy Chief of Staff for Installations and Logistics
Washington DC 20330-1030

Brigadier General Loren M. Reno
Director of Logistics, Air Mobility Command
Scott AFB, Illinois 62225-5308

Lieutenant General George Rhodes, USAF, Retired
Fairborn, Ohio 45324-5818

Major General Earnest O. Robbins II
Air Force Civil Engineer
Washington DC 20330-1260

Colonel Albert H. Smith, Jr, USAF, Retired
Austin, Texas 78704-7916

Brigadier General David L. Stringer
Director of Logistics, Air Education and Training Command
Randolph AFB, Texas 78150-4440

Brigadier General Kevin J. Sullivan
Director of Logistics Readiness, Air Force Deputy Chief of Staff for Installations and Logistics
Washington DC 20330-1030

Major General Donald J. Wetekam
Commander, Warner Robins Air Logistics Center
Robins AFB, Georgia 31098-1662

Lieutenant General Michael E. Zettler
Air Force Deputy Chief of Staff for Installations and Logistics
Washington DC 20330-1030

The EAB is made up of well-known and respected senior military officers—all logisticians—prominent leaders from industry, and leading academicians.

AIR FORCE JOURNAL of LOGISTICS

Volume XXVI,
Number 4
Winter 2002

Coming in Future Issues

- Expeditionary Logistics
- Maintenance Support
- AFMC Career Broadening Program

Available Soon!

NEW!

The *Vehicle Maintenance Safety Handbook* was produced in partnership with Headquarters Air Force and MAJCOM vehicle maintenance subject-matter experts for use in the Air Force 2T3 vehicle maintenance community. It is designed to improve safety awareness in the Air Force vehicle maintenance community and provides practical information and draws on lessons learned from actual safety incidents.

Logistics Dimensions 2003 is a collection of ten essays, articles, and studies that lets the reader look broadly at many of the issues associated with the expeditionary air force of the 21st century. While small, *Logistics Dimensions 2003* addresses several of the major issues or challenges facing Air Force logistics. The content was selected to both represent the diversity of the challenges faced and stimulate discussion about these challenges.

The Editorial Advisory Board selected "Supply Chain Command and Control"—written by Debbie Alexander, John Gunselman, Jody Cox, Jonathan Mathews, Gregory Grehawick, Christopher Brockway, Jondavid DuVall, Joseph Codispoti, Charles Masters—as the most significant article to appear in the *Air Force Journal of Logistics*, Vol XXVI, No 3.