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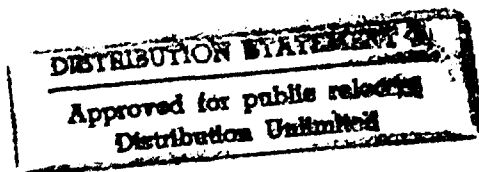
DOCUMENTED BRIEFING

RAND

Weapon System Sustainment Management

*A Concept for Revolutionizing
the Army Logistics System*

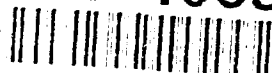
John Dumond, Rick Eden, John Folkeson



Arroyo Center



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Weapon System Sustainment Management

*A Concept for Revolutionizing
the Army Logistics System*

John Dumond, Rick Eden, John Folkeson

*Prepared for the
United States Army*

Arroyo Center

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PREFACE

This publication documents an executive-level briefing prepared for the RAND Board of Trustees meeting in April 1993. It was presented initially to a joint session of the Board and the Air Force Advisory Group (AFAG, the oversight committee for Project AIR FORCE, the federally funded research and development center for policy studies operated by RAND for the Air Force) on April 8, 1993. Since then it has been briefed widely to senior members of the Army, Air Force, and DoD acquisition and logistics communities.

The briefing has two purposes. The first is to advocate three strategies for revolutionizing the Army's logistics system—indeed, the DoD logistics system generally—to make it much leaner, more flexible, and more responsive. These are the characteristics needed to meet the demands of the post-Cold War era, in which defense budgets have become austere while the logistics system has been called upon to support power projection from the continental United States to widely differing contingencies (Panama, Saudi Arabia, Somalia, perhaps Bosnia, and humanitarian assistance). The three strategies are the following:

- Focus the entire system on the support needs of the operational commander (the "customer").
- Design and redesign weapon systems to be more supportable.
- Design and manage processes to be more responsive and efficient.

The second purpose of the briefing is to illustrate these three strategies by drawing on RAND studies in each area. RAND has a long and continuing history of conducting logistics research for the Services and the Office of the Secretary of Defense. It is well positioned (in terms of its research agenda, its intellectual capital, and its client relationships) to help the Army move toward a radically leaner and more agile logistics system.

This briefing was prepared as part of a synthesizing project called "Weapon System Sustainment Management." The project is co-sponsored by Robert Keltz of the Army Materiel Command, LTG Samuel N. Wakefield of the Combined Arms Support Command, and William Neal of the Strategic Logistics Agency. The research was conducted in the Military Logistics Program of the Arroyo Center. John Halliday is the program director.

THE ARROYO CENTER

The Arroyo Center is the U.S. Army's federally funded research and development center (FFRDC) for studies and analysis operated by RAND. The Arroyo Center provides the Army with objective, independent analytic research on major policy and organizational concerns, emphasizing mid- and long-term problems. Its research is carried out in four programs: Strategy and Doctrine; Force Development and Technology; Military Logistics; and Manpower and Training.

Army Regulation 5-21 contains basic policy for the conduct of the Arroyo Center. The Army provides continuing guidance and oversight through the Arroyo Center Policy Committee (ACPC), which is co-chaired by the Vice Chief of Staff and by the Assistant Secretary for Research, Development, and Acquisition. Arroyo Center work is performed under contract MDA903-91-C-0006.

The Arroyo Center is housed in RAND's Army Research Division. RAND is a private, nonprofit institution that conducts analytic research on a wide range of public policy matters affecting the nation's security and welfare.

James T. Quinlivan is Vice President for the Army Research Division and the Director of the Arroyo Center. Those interested in further information about the Arroyo Center should contact his office directly:

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SUMMARY

This publication documents an executive-level briefing that summarizes a concept for revolutionizing the Army logistics system. The concept, called Weapon System Sustainment Management (WSSM), has been developed at RAND with the help of senior Army logistics leaders. The WSSM concept synthesizes the results of a very large body of logistics research conducted by RAND over several decades for the Services and the Office of the Secretary of Defense.

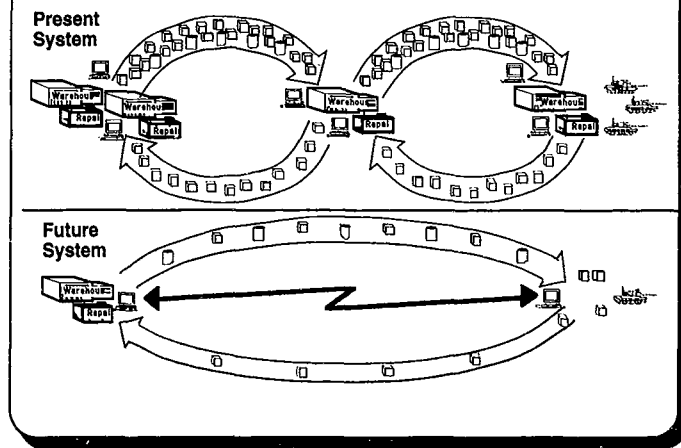
THE NEED TO REVOLUTIONIZE THE ARMY LOGISTICS SYSTEM

The current logistics system was designed to support a massive European war. With the end of the Cold War, the U.S. military is being downsized and reshaped to meet the requirements of a new era in which military power will need to be projected from the continental United States to any number of contingencies around the world. To meet the support needs of the Army in this new era, the Army logistics system must become leaner, more flexible, and more responsive: leaner because defense budgets will no longer enable the Army to maintain a massive logistics system; more flexible because the Army must prepare for a wide range of potential contingencies rather than focus on a major European case; and more responsive because of increased uncertainty regarding the nature of the threat and because neither forward positioning nor host nation support can be assumed. The following figure suggests schematically how the future Army logistics system will differ radically from the current massive system.

The envisioned changes are so great that one might question whether they are even feasible. However, there are grounds for optimism.

Radical new management techniques have enabled the best commercial firms to become leaner and more flexible. On many measures—such as inventory, defects per unit, on-time delivery, production lead time—these firms have achieved order-of-magnitude improvements of the sort that the Army logistics system must strive for. Many have argued that a new management paradigm is emerging. This paradigm is marked by an increased focus on the customer, the establishment of measurable, customer-related goals, the “re-engineering” of processes to achieve the goals, and continuous product and process improvement. Weapon

The Army Logistics System Must Become Leaner, More Flexible, and More Responsive



System Sustainment Management applies similar management concepts to improve the Army logistics system, as shown in the next figure:

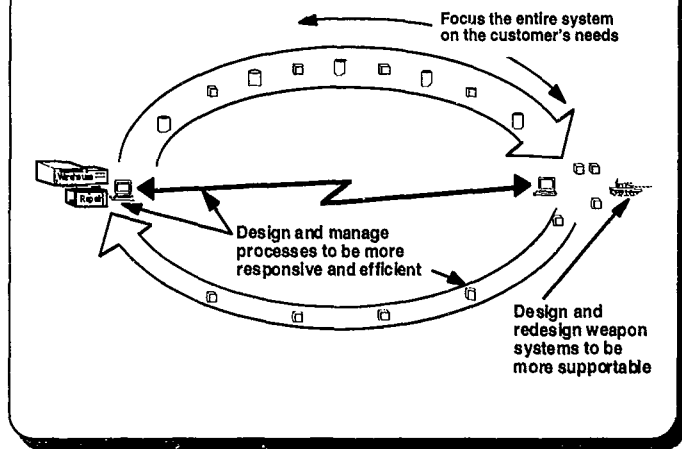
- Focus the entire system on the customer's needs.
- Design and redesign weapon systems to be more supportable.
- Design and manage processes to be more responsive and efficient.

The briefing addresses each of these concepts in turn.

FOCUS THE ENTIRE SYSTEM ON THE CUSTOMER'S NEEDS

Currently, managers throughout the Army logistics system rely on local measures that are not linked to a common system goal. For instance, transportation managers may use a measure such as a full truck load to assess the performance of their assets; likewise, repair shop managers may use a measure such as the rate of labor or equipment utilization. These measures encourage efficient use of resources locally, but they do not indicate whether a specific management action improves the efficiency and effectiveness of the logistics system as a whole. Successful

Management Concepts Similar to Those Used by the Best Commercial Firms Can Improve Army Logistics Systems



commercial firms teach the importance of focusing on the customer. The customer for the logistics system is the operational commander who needs logistics support. More specifically, the operational commander requires sufficient weapon systems to perform the planned mission. The responsibility of the logistician is to manage the inputs (personnel, capital, materiel, information, etc.) and the processes (distribution, repair, etc.) of the logistics system to provide the sustained weapon system availability that the operational commander needs.

The logistician faces an additional challenge in attempting to provide this output at a time when logistics resources are being reduced. RAND is analyzing two fundamental ways to compensate for reduced resources: (1) re-engineering logistics processes to make them more efficient and more effective and (2) making better use of information to support those re-engineered processes. Logistics managers must be able to control resources effectively and to assess the performance of the system so that the use of resources can be adjusted accordingly. The assessment capability permits logistics managers to understand how their decisions affect the goal. A decision support tool for assessment is useful to managers in two ways. First, it lets them anticipate problems in meeting the goals of the operational commander. For example, it might indicate

that at a certain point in the planned mission the commander would not have available the needed number of weapon systems. Second, when problems have been identified, the same tool can be used to assess how alternative policies affect the performance of the system.

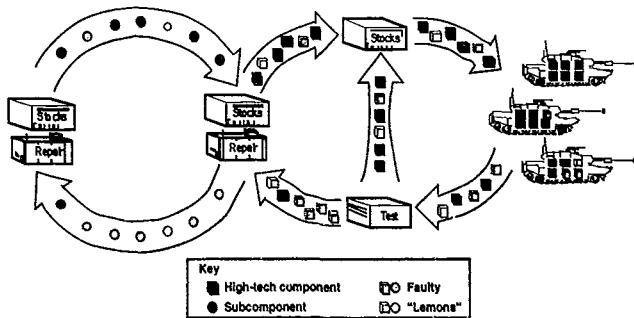
RAND has developed assessment tools for the Army and the Air Force. It developed an assessment tool called Dyna-METRIC for the Air Force, which has implemented it as part of its Weapon System Management Information System. RAND recently adapted the tool to the needs of the Army. The Army has field-tested a prototype of this version at the U.S. Tank-Automotive Command to assess support of the M1A1 Abrams Tank and the Bradley Fighting Vehicle. The Army and RAND have further experimented with using the tool to assess the support of systems in Somalia.

DESIGN AND REDESIGN WEAPON SYSTEMS TO BE MORE SUPPORTABLE

Weapon systems create a burden on the logistics system. U.S. weapon systems are increasingly complex as more high-tech (largely digital) components are added to increase capability. Unfortunately, this added complexity also results in reduced availability and increased costs. As the figure below illustrates, the added burden comes about in two ways. First, high-tech components and subcomponents do not usually fail outright but rather exhibit spotty and degraded performance. Such failure modes are hard to diagnose and isolate, with the result that maintainers often will remove, test, and repair several components—most of them good—in search of the faulty component. Second, a few individual components are “lemons”—that is, they are chronically defective and cycle through the repair system repeatedly. These lemons account for about half of the workload on subcomponents at their respective depot-level repair shops. Compared to a non-lemon component of the same design, a lemon consumes twenty times as many subcomponents. Both the fault isolation problems and the presence of lemons in weapon systems cause commanders to overestimate the number of available systems that are truly fully mission capable.

In the Cold War, the United States had a strong rationale for fielding new weapon systems that were not fully matured in terms of their reliability and maintainability. Their operational capability was needed to maintain a margin of technological superiority over the Soviets. This rationale has diminished in the post-Cold War era, and the United States can now adopt a less-compressed acquisition strategy that will permit complex

More Complexity in Weapon Systems Results in Reduced Availability and Increased Costs



weapon systems to be more fully matured before fielding, thus reducing their burden on the logistics system.

RAND has developed a concept for improving the sustainability of weapon systems to achieve increased weapon system availability at lower costs. This concept calls for maturing the design of newly developed weapon systems, particularly during the low rate production phase, and identifying the lemons during the fielded phase. The key element of the approach is intensive data collection and analysis before full rate production. The approach requires that the design of the weapon system be frozen during low rate production so that a known design configuration can be operated intensely while data are collected and analyzed. Using the results of this analysis, the Army would modify the design of the weapon system to make it more mature and supportable. These improvements would lead to improved availability at lower costs throughout the fielded life of the system. To support the intensive analysis, a database would be established during the earliest phases of acquisition. This database would be integrated across time, echelons, and functions and would be sustained through the life of the system to identify additional design problems that may emerge as a result of aging effects or mission changes.

The database would also be used to identify and remove "lemons." These are high-tech components that exhibit chronic performance problems. Although such components constitute about 9 percent of the total set, they are responsible for a very large proportion of the logistics burden and contribute very little to operational capability. These lemons can be identified through the use of a database that tracks components' operational and maintenance history by serial number.

RAND has recommended that the Army apply this concept to the Comanche and to the upgrade of the Apache. The recommendation for the Comanche emerged during a 1987 study of the Army's proposed new attack helicopter (then called the Light Helicopter Experimental). That study projected that just eight high-tech components in the avionics suite would account for 80 percent of the spares and repair costs and 70 percent of the system downtime. Maturation of these components was recommended to enable the program to achieve its performance and cost goals. Serial number tracking would also permit the culling of lemons.

Although the Comanche acquisition is delayed, the Army can gain experience with these concepts by applying them to the planned upgrade of the Apache. The concept is also applicable to fielded systems; however, because the application of maturation development affects component design, some of its potential benefits will be offset by the cost of retrofitting an existing fleet.

DESIGN AND MANAGE PROCESSES TO BE MORE RESPONSIVE AND EFFICIENT

As depicted in the top panel of the first figure, the current logistics system is too costly, slow, and inaccurate. As of the end of 1992, the DoD had over \$80 billion in spare parts. Yet with all this mass, the system still is not responsive. In a study of support in Operation Desert Storm, RAND researchers interviewed unit-level commanders and logisticians who for months received no spare parts to bring out-of-commission weapon systems to mission-ready status—even though the supply system shipped massive stocks to the theater, including 25,000 forty-foot containers whose contents were unknown. The system certainly did what it was designed to do—project a massive amount of materiel forward—but having mass does not necessarily provide the weapon system availability needed by commanders.

RAND is advocating a management concept called "velocity management" that aims to replace much of the current reliance on logistics mass to a reliance on the improved velocity, accuracy, and

reliability of logistics processes. The commercial sector has demonstrated that the speed, accuracy, and reliability of processes can be dramatically improved. RAND is analyzing ways in which Army logistics processes, and those of DoD generally, can be re-engineered to achieve the same type and magnitude of improvements. The key is to remove non-value-adding activities and to improve the performance of value-adding activities.

With RAND's assistance, the Air Force recently conducted a field test that demonstrated how re-engineered processes can lead to radical improvements. The Air Force re-engineered the depot repair process for 32 high-value and very high-value components in 400 aircraft. The result was a 75 percent improvement in turnaround time for the high-value components (from 32 to 8 days) and an 81 percent improvement for very high-value components (from 32 to 6 days). The re-engineered system saved millions of dollars per year and delivered the same performance as the old system.

Improved velocity of logistics processes reduces the need for expensive inventory. RAND analysis of Martin Marietta data associated with just one high-tech component of the Apache helicopter provides an example. The analysis showed that if the Army could increase the velocity of this component through the depot repair pipeline from about 90 to about 15 days, then it could reduce the value of stock in the pipeline from about \$60 million to about \$10 million (an 83 percent reduction).

These two examples from the Air Force and the Army illustrate process improvements on the same scale as those found in the best commercial firms. Logistics managers will need to use greatly reduced resources more efficiently and effectively. No longer will it be possible to rely on massive resources to cover uncertainty and risk. Logistics managers will need decision support tools to help them control reduced resources. Such tools will help a manager decide how to use available repair and supply resources to meet the needs of the operational commander in the most efficient manner. RAND has developed control tools for the Army and the Air Force. The RAND-developed control methodology, called DRIVE for the Air Force, is undergoing field testing at Ogden and San Antonio Air Logistics Centers. RAND also adapted the methodology to the Army's needs. The Army, which calls the system RBM or Readiness Based Maintenance, has field tested the tool at the U.S. Army Missile Command to control repair of the Multiple Launcher Rocket System. RAND has also developed another version of the tool that reflects the new DoD policy to increase the operational unit's incentives to reduce repair costs.

CONCLUSION

The management concept described here, Weapon System Sustainment Management, integrates much RAND logistics research. As we have indicated, RAND's experience with assessment tools (the Dyna-METRIC family) began with the Air Force and grew to include the Army as well.

Similarly, the maturation development concept has been developed through a series of studies addressing the needs of different Air Force and Army systems. RAND's experience with the DRIVE family of control tools also includes both Air Force and Army applications. Some of the examples of improved processes and streamlined logistics structures that appear in this briefing were developed in other RAND projects on modular logistics, alternative support structures, and alternative maintenance concepts. A current study on the Army distribution system is also contributing to the Weapon System Sustainment Concept. RAND's Weapon System Sustainment Concept is influencing DoD as well as the Army. The Department of Defense is undertaking a thorough review of the existing logistics business practices in the Services with the goal of identifying improved processes that, to the extent possible, are standardized across Services. Then the DoD will mandate the development and implementation of standardized logistics information systems to support those improved processes. RAND has several projects ongoing for clients who are engaged in this activity (including the Army, Air Force, Navy, Defense Logistics Agency, Assistant Secretary of Defense for Production and Logistics, and the Director of Defense Information) and so is well positioned to contribute to its outcome. We believe that the Weapon System Sustainment Management concept can be applied to achieve the goal of a leaner, more agile logistics system and that RAND-developed tools such as Dyna-METRIC and DRIVE may provide the basis for part of a standardized logistics management system.

ACKNOWLEDGMENTS

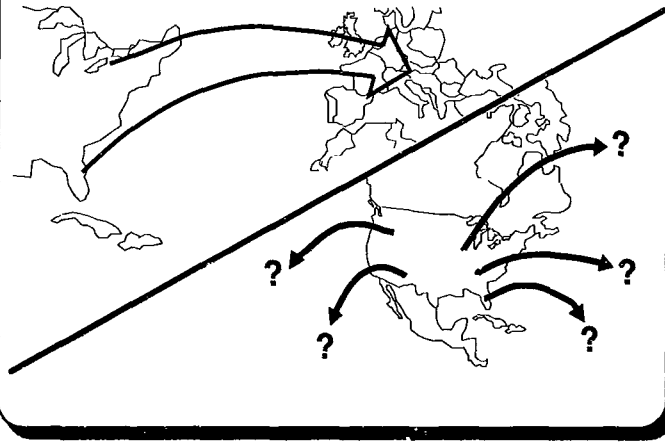
This briefing reports on a project that synthesizes and integrates the results of considerable research done within the military logistics programs at RAND over several decades. The new defense logistics environment has reaffirmed the relevance of many of the policy insights and recommendations developed over the years. The new environment calls for policy innovations with the potential for significant improvements in both effectiveness and efficiency. It is not practical to list all those researchers who contributed to this body of logistics research, but several contributed directly to the synthesis of the integrated view presented in the briefing. Michael Rich, Mort Berman, James Quinlivan, and John Halliday provided a perspective with respect to both scope and theme that was crucial. Marc Robbins provided a key creative spark for "visualizing" the logistics system for greater clarity of communication, the key to a successful briefing. Hy Shulman, Jean Gebman, Karl Hoffmayer, Mary Chenoweth, and Pat Boren all contributed significant work and effort to the examples presented. Louis Miller provided a technical review that guided us to increased clarity and rigor in our exposition. The structure of the presentation was enhanced by the rhetorical contributions of Paul Steinberg. The integration of our briefing's narrative and graphics into a document form was managed through the secretarial efforts of Betsy Sullivan and Olivia Contreras.

**Weapon System Sustainment
Management:**

**A Concept for Revolutionizing the
Army Logistics System**

This briefing reports on a project called Weapon System Sustainment Management. The purpose of the project is to develop a concept to guide the Army as it revolutionizes the way it performs its logistics function. The project synthesizes and integrates the results of considerable research done within the military logistics programs at RAND for the last several decades with the help of senior leaders in the Army and in other Services and DoD agencies. (The briefing does not in any sense provide a survey of that research, but does cite a wide range of selected specific studies at pertinent points.)

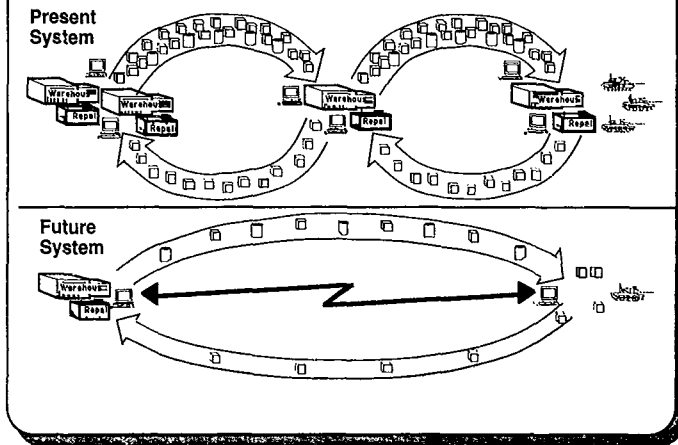
The Current Logistics System Was Designed to Support a Massive European War



With the end of the Cold War, a new approach to providing and managing logistics support is clearly needed. The current Army logistics system was designed to support an enormous European war. It presumed a tremendous amount of mass sent forward, both in terms of mass of forces and mass of logistics support.

The new environment calls for a much leaner force being projected from the continental United States to conduct any variety of lesser operations throughout the world. The logistics structure must be redesigned to support the new environment.

The Army Logistics System Must Become Leaner, More Flexible, and More Responsive



This figure presents schematic views of the current logistics system and the logistics system that we envision to be appropriate to the new environment. In the current system, a tremendous amount of mass forward is ready to support any size force. The operational units have their own set of repair capability and stocks that are supported by a large distribution system. Another set of stocks and repair capability exists within the theater, and a third set remains in the continental United States.

A few numbers will help establish the massive scale of this system. As of the end of 1992, the DoD has over \$150 billion in inventory, of which the Army logistics system has \$40 billion, and one-third of that (\$14 billion) is in spare parts.¹ If it were a private firm, it would have been number seven in *Fortune* 500. (The Air Force would have ranked in the top five of

¹Washington Headquarters Services (1992). The value of current inventories within each Service is now significantly less than it was just a few years ago, for two reasons. First, the Services have devalued their inventories several times. Second, some inventory has been shifted out of the Services as a result of the consolidation of supply depots within the DoD; however, within the Defense Logistics Agency (DLA), inventory levels have grown correspondingly.

Fortune 500.²) Annually, the Army performs almost one half million repairs and overhauls at the depots. Such volume is not handled expeditiously. Frequently, these repairs take from three weeks to nine months to complete. Requests from Army units generally take days to weeks to reach a source of wholesale supply.

As the bottom schematic suggests, we believe the Army must seek radical, even order-of-magnitude improvements in the performance of its logistics system. The challenges of power projection include supporting deployed forces from afar, because the existence of a fully developed theater is unlikely. It is possible that echelons of support that have been doctrinal for major operations, such as the scenario of a major European land war, will be eliminated. In their place will be a much leaner structure designed to provide support more rapidly and accurately. The intermediate echelons of support will likely be more tailored to specific mission needs with an eye to minimizing the deployment burden. To meet the new power projection needs of the Army, the Army logistics structure must become much leaner, more flexible and responsive. It is possible that such revolutionary changes appear daunting and some might question whether they are even feasible. But there are reasons to be hopeful.

²"The New Eagles: . . ." (1992).

New Management Techniques Have Enabled the Best Firms to Become Leaner, More Flexible

Measure	Before	After	Firm
Inventory	\$173,000,000	\$22,000,000	Cummins Diesel Parts
Safety Stock	30 days	5 days	Detroit Diesel Remanufacturing
On-Time Delivery	15%	80%	Titeflex
Production Lead Time	Several weeks	3 days	Titeflex
Defects per Car	7	1.5	Big Three

When we use the terms "leaner," "flexible," and "responsive," immediately comparisons to commercial industry come to mind. American industry has been successfully pursuing order-of-magnitude improvements to meet the challenges of their increasingly competitive environment. For example, we see order-of-magnitude improvements with regard to reductions of inventory. The service parts division of Cummins reduced its average inventory on the floor from \$173 million to \$22 million.³ Detroit Diesel Remanufacturing has been able to reduce its safety stock from 30 days to five days by re-engineering its operations.⁴ On-time delivery performance can be greatly improved also. Titeflex, a small firm that manufactures high pressure hoses and connectors, had secured a niche with the U.S. government.⁵ In the late 1980s, competition for that market developed and Titeflex needed to make changes. Within two years they moved from 15 percent on-time delivery performance to over 80 percent, and they reduced their production lead time from weeks to days. Even U.S. automakers have risen to the challenge of significantly

³Discussion with managers at Cummins, March 1993.

⁴American Production and Inventory Control Society meeting (1992).

⁵Blaxill and Hout (1991).

improving the quality of their product. These examples demonstrate that order-of-magnitude improvements in business performance are feasible today.

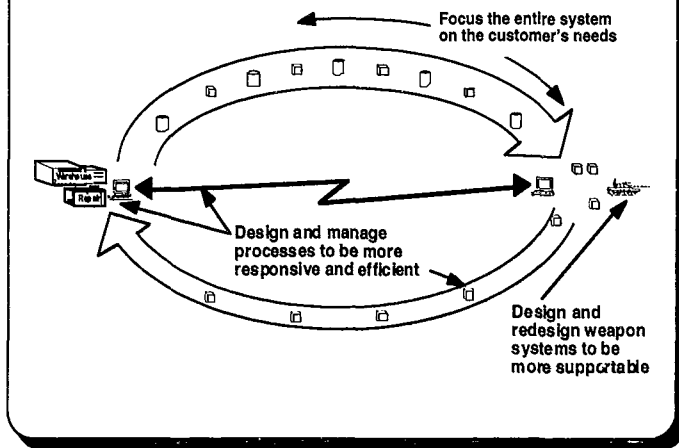
A New Management Paradigm Is Emerging

- **Focus on the customer**
- **Evolve products and services to add value for the customer**
- **Establish a measurable goal**
- **"Re-engineer" processes to achieve goal**
- **Continually improve process efficiency**

It is widely recognized that a new management paradigm is developing in the business world. This paradigm has several elements. It is based upon satisfying the customer, where the customer is the focus of all the efforts of the serving organization. Products and services are evolved to meet the customer's needs to add value for that customer. A measurable performance goal is established in support of that customer. Old processes are re-engineered. By "re-engineered" we are referring to major changes to the way business is being done, not marginal changes or short-term emphasis.⁶ Major changes are sought that eliminate non-value-adding activities and improve those that are value-adding.

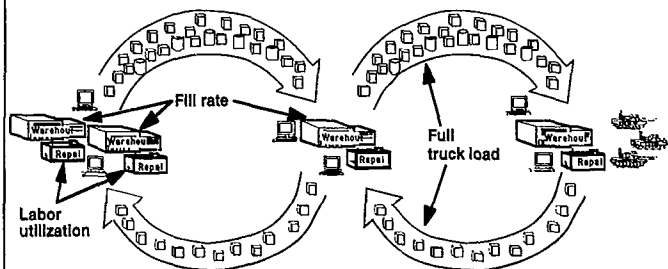
⁶See Hammer and Champy (1993).

Similar Management Concepts Can Improve the Army Logistics System



We believe that the Army can revolutionize its logistics system by applying similar concepts. First, logistics managers should focus the entire system on customer's needs. Second, managers should design and redesign weapon systems to be more supportable—i.e., to evolve the product to meet the customer's needs and to reduce the logistics burden. Third, managers should design and manage all logistics processes—i.e., re-engineer them—to make them more responsive and efficient. This briefing will cover each of these three management concepts, starting with focusing the logistics systems on the customer's needs.

Logistics Managers Rely on Local Measures That Are Not Linked to a Common Goal



Currently the performance of many logistics managers is not linked to the needs of the logistics system's final customer, the operational commander. Rather, the logistics system relies upon a set of local measures. A few logistics managers, at the unit level, where the operational forces reside, may be close enough to observe the logistics needs of those forces and take actions to support the commander. But at echelons more distant from the unit in the theater, and within the continental United States, the ability to see the support requirements of operational forces declines. While these more distant organizations want to "do the right thing," their aim has been to improve the efficiency of each of their organizations, and local performance measures are developed and used for this purpose.

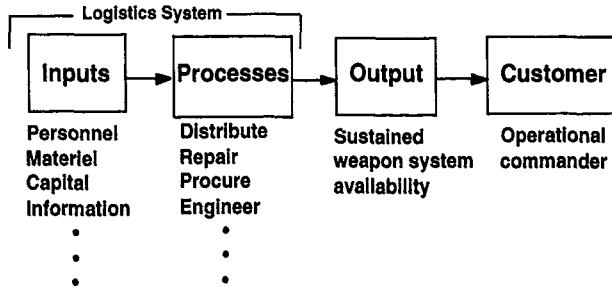
One example of a local measure is "fill rate," which is used within the supply community. On the surface, this measure may appear to be a logical choice; however, its use leads to problems. For example, DLA rates its centers on how well they provide support in terms of the number of requisitions they fill upon receipt. Over time the supply managers have learned that if they keep high-volume items in stock (which also tend to be low-cost items), their fill rate will look better. Unfortunately, many items that hold down the availability of a weapon system are high-cost, low-

demand items. So, although the supply manager has an excellent fill rate, weapon system availability may suffer.

Another local measure is full truck-load shipments. Transporters will reduce the frequency of pickups and dropoffs because they get rated on how full the trucks are loaded, not the effectiveness of the system as a whole. Similarly, repair organizations tend to be rated on the utilization of their repair capacity, not necessarily on which items they repair or on how well they fix items that will, in fact, contribute to a weapon system's availability.

In short, local measures lead only to local efficiencies without regard to how they affect overall system effectiveness and the needs of the ultimate customer.

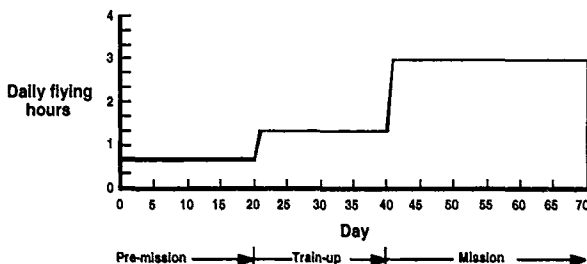
Successful Commercial Firms Teach the Importance of Focusing on the Customer



In contrast to relying on local measures, the most successful commercial firms teach the importance of focusing on the customer and meeting the customer's needs. We believe that the logistics system should learn from the commercial sector. The customer of the logistics system is the operational commander. The operational commander needs his weapon systems to be available throughout the mission scenario. As this schematic diagram suggests, the logistics system is a collection of inputs and processes that must be combined to provide that output.

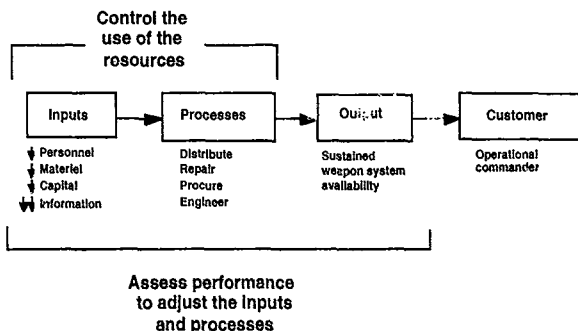
The Operational Commander Requires Sufficient Weapon Systems to Perform the Planned Mission

- Hypothetical operational plan requires a minimum of 35 (out of 46 assigned) Comanches



Let us examine more fully what the customer of the logistics system requires. Consider a hypothetical situation in which an operational commander has 46 Comanches assigned to him and requires a minimum of 35 Comanches to be available to execute a planned scenario. The scenario to be supported is going to be at least seventy days in length. On about day 40 of this scenario, operations are planned that will require each of 35 helicopters to fly about three hours a day. He plans that for the 20 days preceding that period of operation, his force will conduct some preparatory training. During the train-up period, he plans an hour and a half of flying per day per Comanche. Before the train-up, normal peacetime operation will continue during which the Comanches fly about three-quarters of an hour per day. The logistics managers need to be able to sustain the output and weapon system availability at those planned levels through the scenario.

Managers in the System Need to Understand How Their Decisions Affect the Goal



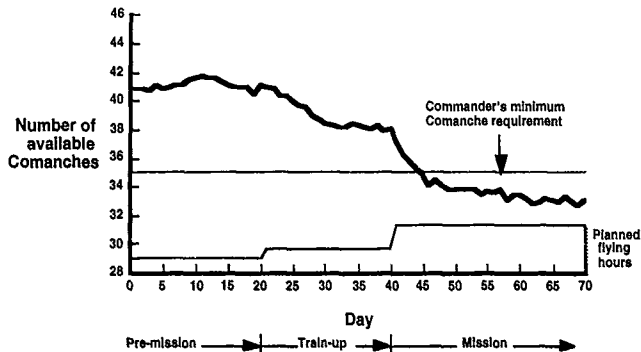
The logistics manager is concerned with controlling the use of his inputs and processes in such a way as to meet the customer's needs. To do that he must continually assess the performance of his inputs and processes and then make adjustments as necessary to get to the required level of weapon system availability.

As an additional challenge, the new environment calls for more effective use of the reduced resources. In this new environment, the set of resources (personnel, materiel, and capital) are being drawn down (indicated by downward arrows on the graphic). Logistics mass is going to be considered a liability and not an asset because it costs too much and is troublesome to deploy.

RAND is looking at two fundamental ways to compensate for reduced resources: (1) re-engineering logistics processes to make them more efficient and more effective and (2) making better use of information in support of those re-engineered processes. We are not advocating new information systems only, but new information systems in support of radically improved processes. Experience has shown that attempts to

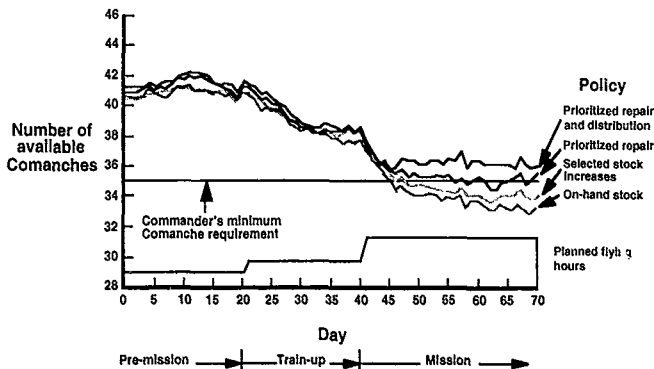
achieve a "technological fix" by automating existing ways of doing business does not lead to radical improvements in performance or cost reduction.

The Logistics Managers Should Try to Anticipate Problems in Meeting the Customer's Needs



Logistics managers need decision support tools that will help them assess how well they will be able to meet the logistics needs of operational commanders. Recall the hypothetical scenario from two charts back. The logistics manager in our example is concerned with sustaining the required level of Comanches throughout the scenario. (The planned flying hours of a scenario are shown again at the bottom of this slide, beginning with the operation at peacetime levels, and then a period of train-up, and then through the more significant and demanding portion of the mission.) Using an assessment tool, the manager finds that, with a given set of logistics policies, he is projected to be able to meet the combat commanders' needs until four days into the most demanding portion of the scenario.

Assessment Tools Enable Logistics Managers to Assess How Alternative Policies Affect the Goal



An assessment tool also enables logistics managers to assess how alternative policies will affect the goal.

In this case, the logistics manager is projecting the ability of four alternative policies to meet the needs of the operational commander. Clearly, the revised policy alternative that uses prioritized repair and prioritized distribution of spares is projected to do better than the other three. Implementation of such a policy in the short term might consist of directing "top priority" to be given to this particular commander's needs. (More formal policy implementation for long-term changes over the set of all possible forces and scenarios would likely require the installation of comprehensive decision aids and major changes to current policies. One such decision aid, called Readiness Based Maintenance (RBM), is discussed later in this briefing.)

Assessment tools can also be used to support the planning, programming, and budget execution system. For example, assessments of the capability (and, therefore, the shortfalls) of the current logistics system to meet the operational requirements of the Army can guide the execution of the current budget, as well as the planning and programming for future resources.

RAND Has Developed Assessment Tools for the Army and Air Force

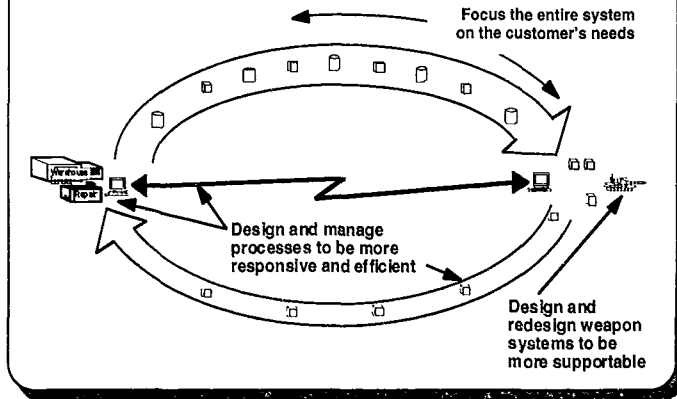
- **RAND developed an assessment methodology (Dyna-METRIC) for Air Force**
 - **Implemented as Weapon System Management Information System**
- **RAND adapted the methodology to Army's needs**
 - **Field tested at U.S. Tank-Automotive Command to assess support of M1-A1 Abrams Tank and the Bradley Fighting Vehicle**
- **Army and RAND are experimenting with methodology to assess capability to meet commanders' system availability requirements in Somalia**

RAND has been developing, prototyping, and testing assessment tools to help logistics managers understand their sustainment capability. Early in the 1980s, we started work with the Air Force on an assessment tool called Dyna-METRIC.⁷ It is now being used by the Air Force Materiel Command. RAND is currently working with the Army to develop a version that is adapted to meet the distinctive needs of the Army.⁸ The Army version has recently been tested at the U.S. Army Tank-Automotive Command, which continues to use it to assess the logistics support of a number of systems that are now operated in Somalia.

⁷Hillestad (1982).

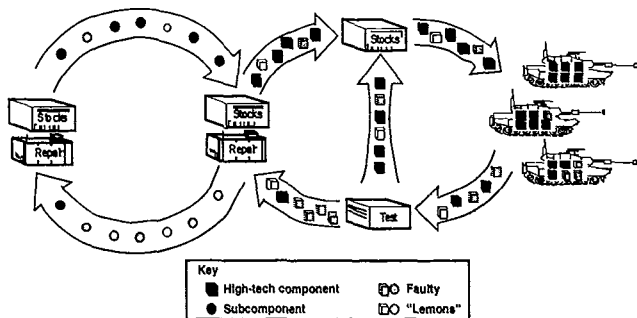
⁸Tsai (1992).

The Second Strategy Is to Design and Redesign Weapon Systems to Be More Supportable



To this point, the briefing has explained the first of the three management concepts that we advocate for the Army under Weapon System Sustainment Management, namely, focusing the entire system to meet the customer's needs, which is sustained availability of weapon systems to support an operational commander. Now let us turn to the second concept, designing and redesigning weapon systems to be more supportable.

More Complexity in Weapon Systems Results in Reduced Availability and Increased Costs



Weapon systems create a burden on the logistics system. If they were made more fuel-efficient or more accurate, for example, the demands for fuel and munitions would be less.

Complex weapon systems that provide a margin of superiority create an extra burden on the logistics structure because of their complexity. When components fail, we expect faulty components to be identified, removed for repair, and then made available as a replacement stock for another faulty component. Unfortunately, that is not always the case with high-tech components. As the schematic suggests, two types of problems cause the burden. One type is a design problem that shows up in all the weapon systems; the other type shows up in just a few high-tech "lemons," i.e., components that exhibit chronic performance degradations.⁹

As the schematic suggests, these design problems and these lemons flood the current system with both false negatives—components that are thought to be broken but are not—and false positives—components that

⁹The problem of lemons among weapon systems and weapon system components was first investigated by RAND in the early 1960s. See McGlothlin and Donaldson (1964), and Donaldson and Sweetland (1966).

are thought to be fixed or "good" but are not. The current acquisition and maintenance processes lack a strong capability to isolate and remove these design problems and lemons.

Good examples of these two problems are provided by RAND's analysis of the reliability and maintainability of high-tech components of the F-16.¹⁰ (Similar problems exist with the F-15, M1A1 tank, and the Apache.¹¹) Frequently, the high-tech components of the F-16 radar will encounter a fault. As a result of that fault, some troubleshooting will occur. About one time in two the maintenance technicians find nothing wrong. When they do find something wrong, they may isolate the wrong item to replace. They often replace two or three parts to fix the same problem. Some of these removed components are, in fact, good, but they are placed into the repair system as bad. When these good components get tested, they should test good and be returned to stock. However, these good components sometimes test bad and a "repair" is made. Unfortunately, some faulty components pass the diagnostic test as being good when they are not, and are also sent back to stock. These faulty components then get put back into weapon systems where they are again found faulty as they move into the operational scenario. These fault isolation and removal problems were found at each echelon of the maintenance system (see Table 1).

Table 1

Fault Isolation and Removal Problems Appeared at Each Echelon of F-16 Support

Maintenance Actions	Depot	Intermediate	Unit
With repair, (%)	80	67	50
Without repair, (%)	20	33	50

At the unit level, where the weapon system is maintained, half the maintenance actions to correct a malfunction result in no repair. Of those repairs that were made by removing a faulty component and replacing it, the maintainer at the intermediate echelon was unable to identify the fault one-third of the time. Similarly, 20 percent of the subcomponents returned from the depot without repair.

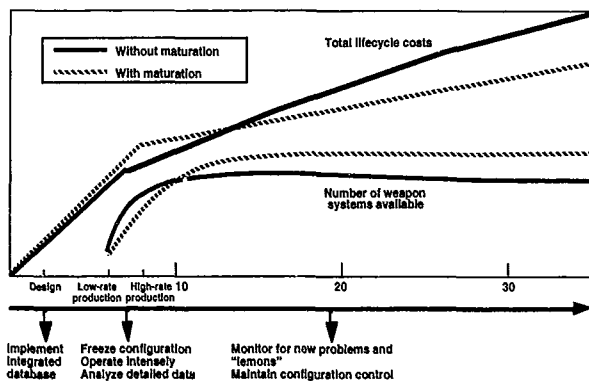
¹⁰Gebman et al. (1989).

¹¹For the F-15, see Gebman et al. (1989); for the M1A1, see Berman et al. (1988); for the Apache, see Robbins et al. (1991).

There are two important implications to these data. The first is that many maintenance hours are expended without benefit. The second is that many weapon systems, components, and subcomponents are considered fully operational when they are not. In other words, these design problems generate excessive support costs and result in overestimating the capability of a fielded weapon system.

Lemons represent a different problem. They are very difficult to identify and even more difficult (sometimes even impossible) to fix. They frequently circulate through the logistics system, moving from one weapon and unit to others. Lemons cause about 20 times the number of replacements of subcomponents at the intermediate echelons, even though these subcomponents are not faulty—remarkably, lemons create about half the workload on the depot repair shops. And, of course, the presence of these lemons in weapon systems causes commanders to overestimate the number of available systems that are truly fully mission capable.

Maturation Development Offers Improved Availability at Lower Costs



RAND has developed an approach, called maturation development, to improve the current process for developing and maintaining weapon systems. The approach addresses both of the maintainability problems identified on the previous chart—design problems and lemons. As this chart suggests, maturation development is anticipated to result in increased weapon system availability rates at lower lifecycle costs.

The current acquisition process (solid lines) was designed to serve the needs of the Cold War. When the United States faced a very strong Soviet threat, weapon systems were designed, developed, and fielded very quickly because their superior capability was needed. There were good reasons for fielding weapon systems that were not fully mature in terms of their reliability or maintainability. The acquisition process did not have the time or the opportunity to mature these weapon systems to achieve the full level of availability that they might have enjoyed had the development cycle been longer. But now that we are in an environment in which we need not rush to a high rate of production, the Army can change the acquisition process to permit the maturation of high-tech systems before fielding.

RAND has developed an approach to mature high-tech components so that they are more reliable and maintainable. The elements of this approach are listed under the notional graph above. The key element of this maturation approach is an intensive data collection and analysis period before full-rate production. The approach calls for the manager to freeze the weapon system design during the low-rate production phase of the acquisition process, operate a small number of the systems intensely, and collect and analyze a great deal of detailed data. Using the analysis, the Army would modify the design of the weapon system to improve its R&M performance—one with a lower lifecycle cost. This data collection period might take months, perhaps a couple of years.

To support this intensive data analysis phase, an integrated database would be established during the earliest phases of acquisition. After the logistics design problems were identified and the weapon system was modified, the effects of the changes would be monitored. This verification of the fixes occurs during the late stages of low-rate production and after the modified weapon system is fielded.

Through the fielded phase, the analysis system would be used to detect and isolate the lemons as well as any new design problems that emerged as a result of changing missions or aging effects.

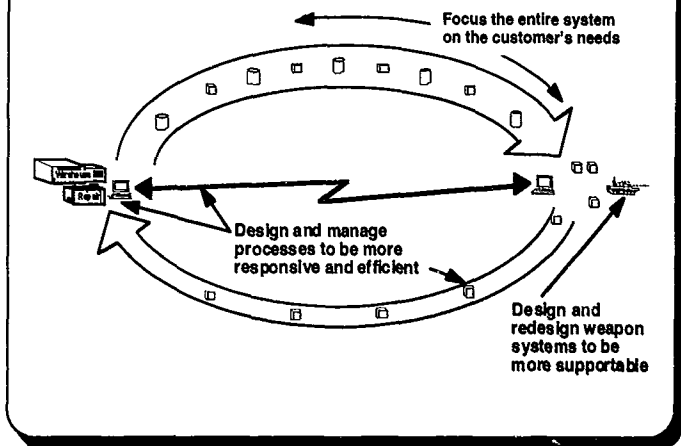
The Army Can Apply Maturation Development to Apache Upgrade and Comanche

- **RAND analysis of Army's proposed new attack helicopter projected that eight high-tech components would account for**
 - 80 percent of costs of spares
 - 80 percent of repair costs
 - 70 percent of downtime
- **RAND proposed maturation development to address these problems**
- **Comanche is delayed but Army has opportunity to test maturation approach on Apache fleet**

This maturation approach was initially developed in RAND research on the F-15/F-16 in the mid-1980s. That experience informed a large RAND study in support of the Light Helicopter Experimental (LHX), now called the Comanche helicopter.¹² In the late 1980s, RAND estimated that the high-tech components of the LHX would likely cause 80 percent of the cost of the spares, 80 percent of the repair cost, and result in 70 percent of the downtime. Now that acquisition of the Comanche is delayed, RAND is working with the Army to test this maturation approach during the upgrade of the Apache fleet. The approach is applicable not only to the development of new weapon systems but also to system upgrades and mission modifications.

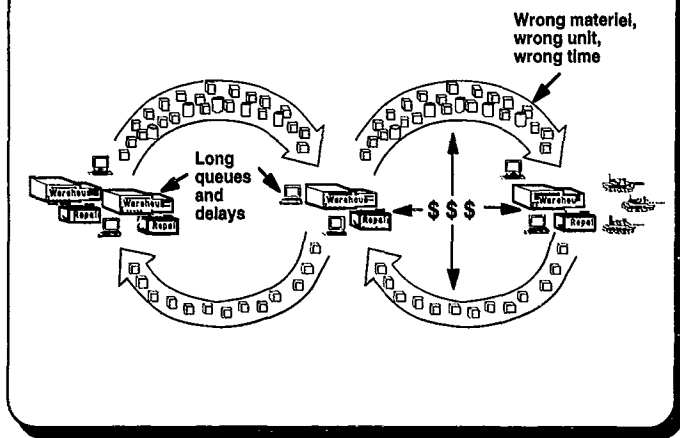
¹²Berman et al. (1989).

The Third Strategy Calls for Changes in Logistics Structure



That concludes the portion of the briefing devoted to the second management concept—redesigning weapon systems to make them more supportable. Now the briefing turns to the third concept. RAND is also looking at ways to design and manage the logistics processes as a whole to make them more responsive and more efficient for all weapon systems.

The Current System Is Too Costly, Slow, and Inaccurate



The current logistics system is much too costly, slow, and inaccurate. Over \$14 billion is tied up in Army inventory of spare parts to support Army needs. These stocks accumulate in warehouses and repair facilities. The Army has relied on such logistics mass to buffer against uncertainty. But ineffective processes have crept in. Long queues and delays have developed. Moreover, having stock everywhere does not necessarily mean that the right stock will be at the right place at the right time, as the Army found out during Operation Desert Storm. The Army had units that for months did not receive the correct repair parts to return out-of-commission tanks to mission-ready status. Although many logistics managers thought that the logistics system performed very well in Operation Desert Storm—and by some measures it did—many operational commanders would criticize the performance of logistics support and many Congressional members would criticize its cost. The system certainly did what it was fundamentally designed to do, namely, push a massive amount of materiel forward. The Defense Logistics Agency reported a fill rate of 96 percent, indicating to them (using a local measure) that they did an excellent job. But parts did not get to the commanders who needed them. For example, the military had 25,000 forty-foot containers of materiel delivered to the theater that had to be opened to determine their contents. Many were not opened until months

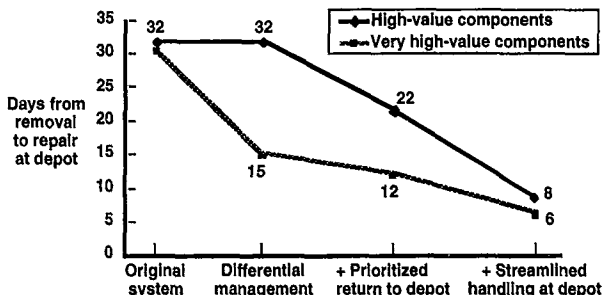
after the war was over. So having massive amounts of stock—even in theater—does not necessarily provide the availability required by operational commanders.

“Velocity Management” Aims to Substitute Velocity for Mass

- **Definition:**
 - **Velocity management is a concept that advocates improved flow of materials through the logistics processes**
- **The speed and accuracy of logistics processes can be improved**
- **The processes need to be re-engineered to increase the ratio of value-added to non-value-added activities**

RAND is advocating a management concept called Velocity Management, which aims to substitute velocity and accuracy for mass in the logistics system. We have seen in the commercial sector that the speed and accuracy of processes can be dramatically improved. RAND is looking at ways that DoD processes can be re-engineered to provide that same velocity by eliminating non-value-added activities and focusing on improving the value-added activities.

Re-engineered Processes Can Lead to Radical Improvements



SOURCE: Analysis of data from Coronet Deuce exercise involving 32 components in 400 Air Force F-16 aircraft.

RAND's Project AIR FORCE has been working with the Air Force as it makes some radical improvements to one process associated with repair of high-tech components. This chart displays the magnitude of those improvements.

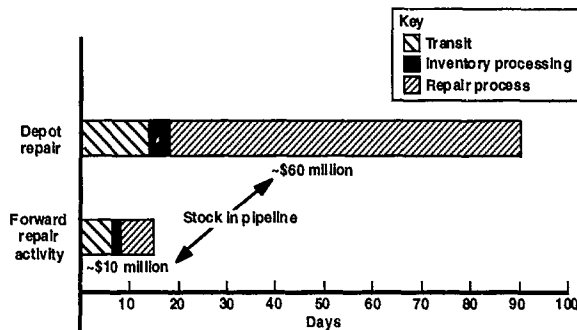
During two recent exercises, the Air Force focused on reducing the repair cycle of 32 high-cost components of the F-16. The original repair system being re-engineered had two categories of high-cost components: components that were of very high value, which were supposed to undergo a very expedited repair cycle, and components that were of high though substantially less value.¹³ Under the original system, both types of components took about 32 days from the time they were removed from the aircraft to the time they were repaired at the depot and made ready for reissuance. RAND and the Air Force tested a way to move the components through the system more rapidly—to improve the velocity that would enable the Air Force to reduce inventory further. By re-

¹³The "value" of components was established by multiplying unit cost times demand rate times flying hours per day. Seven of the 32 components valued in this way exceeded \$300,000 per day. These are the "very high-value" components. The other, "high-value" components were valued at up to \$75,000 per day.

engineering the processes, they deleted a lot of non-value-added activities that occur from the point that the component fails to the point when it is received at the depot. By applying differential management and special handling throughout the process to the seven very high-cost components, they reduced their repair cycle times by more than half—to 15 days. They then took additional actions to remove ten days from the repair cycle of the high-value components and an additional three days from the very high-value components through further improvements in retrograde handling. Through these improvements, the Air Force saved approximately \$10 million a year in operating and support costs and still sustained the same levels of availability it had using the old processes.

Then the Air Force streamlined further the handling of the components at the depot and was able to remove another 14 days of non-value-adding activities from the high-cost cycle and six days from the very high-cost cycle. That amounts to a total improvement of 75 percent in the repair of high-value components and an 81 percent improvement in the repair of very high-value components. This reduction in cycle time caused by re-engineering its processes provided the Air Force greater flexibility and responsiveness and was of the order of magnitude needed in these changing times.

Improved Velocity of Logistics Processes Reduces Need for Expensive Inventory

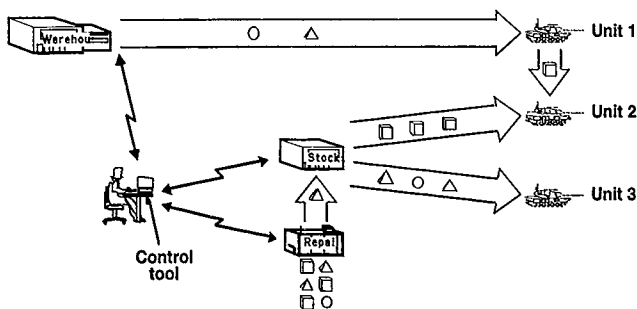


SOURCE: Martin-Marietta repair history file for Apache TADS/PINVS (1985-90).

Reducing cycle times—the amount of time it takes to get things through the system—provides other benefits as well. One, clearly, is the reduction in inventory needed to support the shorter pipelines. RAND analysis of some Martin-Marietta data associated with one high-tech element of the Apache helicopter provides an example.¹⁴ It takes about \$60 million in stock of Target Acquisition Designation Sight/Pilot Night Vision Sensor (TADS/PINVS) components to keep a 90-day repair pipeline filled. If the Army could increase the velocity of these components through the repair process and achieve 15-day repair cycles, it could reduce the necessary stock to about \$10 million. In this case, transit times as well as inventory processing and repair processing times are reduced. Transit time can be reduced by using a priority distribution system. Non-value-adding administrative delays can be deleted to improve the velocity through the repair process.

¹⁴Related analyses appear in Robbins et al. (1991).

Logistics Managers Will Need to Use Greatly Reduced Resources More Efficiently



The application of velocity management will improve the speed, accuracy, and reliability of logistics processes and permit less reliance on logistics mass, particularly stocks. The result is a much leaner system. We recognize the need to use resources much more effectively with this much leaner system. No longer will it be possible to rely on massive resources to cover uncertainty and risk. Decision support tools are needed to help control these lean resources. As an example, consider the situation of a logistics manager concerned with supporting several operational units simultaneously. Each operational unit is about to engage in an activity that will consume logistics resources. This logistics manager is concerned with providing the right stocks to the units, in a prioritized fashion, so that each unit will meet its requirements. He is concerned not only with distributing stocks but also with repairing those assets that are now broken, so that they will be available to distribute in the near future. And he is also concerned with determining what he needs to acquire from the echelon above. His focus is on using the whole set of logistics resources to sustain the operations. RAND has been working on tools to help the manager focus on the customer's needs—sustained weapon system availability.

RAND Has Developed Control Tools for the Army and the Air Force

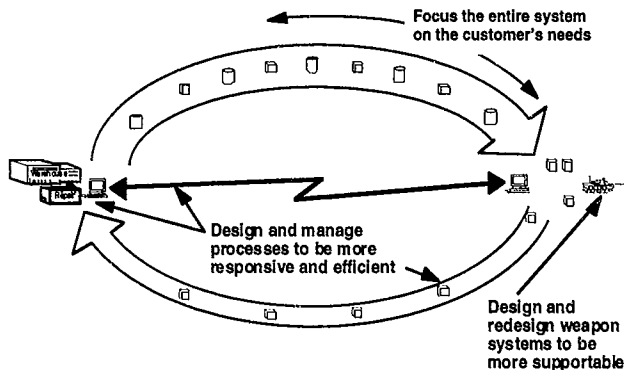
- **RAND developed a control methodology (DRIVE) for Air Force**
 - Field test of prototype at Ogden Air Logistics Center
- **RAND adapted the methodology to meet Army's needs**
 - Field tested at U.S. Army Missile Command to control repair of Multiple Launcher Rocket System
- **RAND extended the methodology to reflect the new DoD policy to increase unit incentives to reduce repair costs**
 - New methodology enables explicit tradeoffs between repair capacity and stock budget

RAND's work with the Air Force in the early 1980s on a model called DRIVE serves as the basis for tools that have been implemented within the Air Force.¹⁵ The DRIVE-derived RBM model has been revised to support the Army's needs and has completed testing at the U.S. Army Missile Command.¹⁶ Another version of that model that addresses more of the issues associated with the unit level has also been developed and is currently being tested at the 4th Infantry Division at Ft. Carson.

¹⁵Abell et al. (1992).

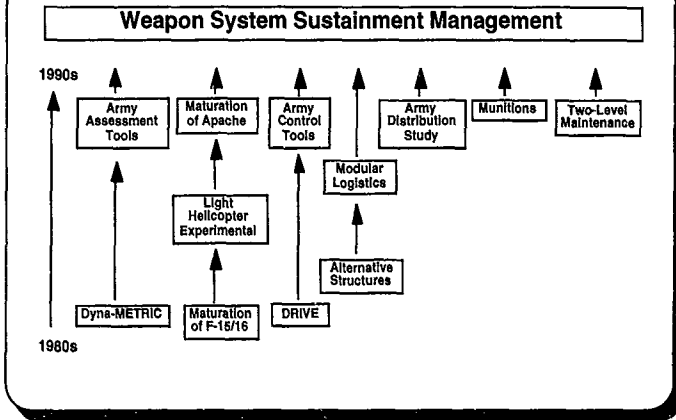
¹⁶*Readiness-Based Maintenance Economic Analysis Final Report* (1992). See also Tripp et al. (1990) and Boren et al. (1991).

Similar Management Concepts Can Improve the Army Logistics System



To review, Weapon System Sustainment Management calls for three concepts for revolutionizing the Army logistics system: (1) focusing all the logistics actions on the customer's needs, (2) designing and redesigning the weapon systems to meet the customer's needs and to reduce the burden on the logistics structure, and (3) redesigning the processes themselves to be more efficient. The aim is to provide a much leaner, more flexible logistics system that will meet the Army's needs in the current environment.

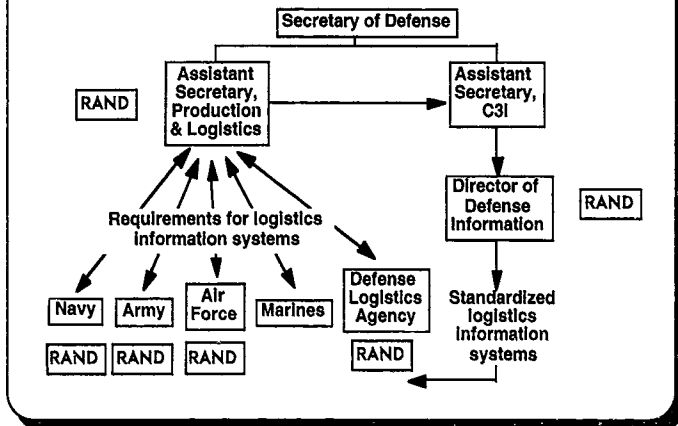
Weapon System Sustainment Management Integrates Much RAND Logistics Research



As we have indicated throughout the briefing, this management concept draws from many RAND logistics studies over the past few decades. This figure traces some of that history.

The maturation concept identified in RAND's F-15/F-16 research led to the work with the LHX and now with the Apache. The DRIVE and Dyna-METRIC models have been extended to provide control tools and assessment tools to the Army. Other research to improve velocity and reduce mass continues. The modular logistics project draws from previous work done on alternative logistics structures: Both focus on developing leaner, more agile, and more responsive support structures. The two-level maintenance research now being done within the Air Force is designed to increase the velocity of material through the system. RAND's current research on the DoD distribution system is exploring how to re-engineer the distribution process to increase velocity through the system. All of these projects contribute to improved weapon system sustainment management.

RAND's Weapon System Sustainment Concept Is Influencing DoD



RAND is now well positioned to help the DoD community as it moves forward to meet the challenges of the new environment. The Department of Defense is being asked to develop standardized logistics information systems that will be provided to each Service to support its logistics processes. These logistics processes will be re-engineered to meet the new environment and the new information systems will support the re-engineered processes. The Services are working with the Assistant Secretary of Defense for Production and Logistics to define that set of information system requirements. The set of requirements will then be provided to the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence, and passed to the Director of Defense Information for implementation. The new information systems will be developed to support these requirements and re-engineered processes. RAND is helping in all of those areas through projects with several major players.

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