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An Architecture for a Lean Transformation

DENNIS F.X. MATHAISEL

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Preface

An increased military operational tempo, aging weapon systems, an aging workforce, limited financial resources, and new technologies are some of the reasons why the military needs an aggressive sustainment transformation plan. *Sustainment* is defined as the maintenance, repair, and overhaul (MRO) practices that keep the systems (the products of the military enterprise) operating and up to date (via new technology upgrades) throughout their entire life cycle. The goal is to achieve a quantum leap in sustainment throughput and efficiency by transforming military depot workload and processes into those of a best-in-class commercial-type facility. In order to produce a successful transformation, military depots require an integrated set of activities and support methods that execute their strategic vision, program concepts, acquisition strategy, schedule, communications plan, and implementation strategy. To accomplish this objective, this book describes a lean enterprise architecture (LEA) strategy to transform the MRO industrial enterprise. LEA is a structure to organize the activities for the transformation of the enterprise. It is the application of systems architecting methods to design, construct, integrate, and implement a lean enterprise using maintenance engineering methods and practices. The design process incorporates lean attributes and values as design requirements in creating the enterprise. The application of the LEA is designed to be less resource intensive and disruptive to the organization over the traditional lean enterprise transformation methods and practices.

The Office of the Secretary of Defense of the U.S. government has recognized the need for process improvement and directed all Department of Defense (DoD) logisticwide initiatives to undergo a transformation by adopting commercially proven practices and strategies. This directive is a radical departure from the traditional military paradigm, and it is aimed at all enterprises that perform DoD work. These enterprises include contractors such as Boeing, Honeywell, IBM, Lockheed Martin, and Raytheon. These logistic transformation objectives include the implementation of many commercial best practices, such as lean and cellular manufacturing, systems engineering, and supply-chain management. Transformation offices have been established in the military to implement these new strategies. The problem is that these offices have no condensed, user-oriented context to refer to in the search for the necessary tools with which to implement the strategies. The rush to field new products and systems without using sustainability requirements continues to plague projects in the government, as well as the commercial sectors of our economy.

The intent of this book is to help develop the management and technical skills necessary to design and implement cost-effective, integrated, sustainment networks and agile organizational structures. At the same time, new tools are needed to help address the unique problems facing the military sustainment community. These problems include aging systems and commercial off-the-shelf life-cycle support challenges. For example, the Lockheed C-5 military transport was designed in the 1960s with a life expectancy to the year 2000. Because of cutbacks in new DoD systems procurement, its life was extended well into the 21st century. How does such old technology sustain itself well beyond its expected life? Another example is the V-22 Osprey tilt-rotor aircraft program, which initially had significant operational test and evaluation problems. Most of these problems have been overcome, but what performance-based logistics maintenance support program design is best for this new system?

Commercially proven supply-chain management and lean enterprise practices have significantly benefited the manufacturing and retail industries, but they have been difficult to apply in the defense industry because of the high degree of variability in both source material and low-volume production requirements. Under ideal conditions, a sustainment supply chain network would be responsive and flexible enough to meet varying demand conditions. The right types of material and parts would be available in the right quantities, at the right place, at the right time, and at an affordable cost. Parts and material shortages, coupled with increased maintenance requirements, are just some of the issues facing the sustainment community today. The logistic transformation from a (Cold War) mass-production model into a "lean and agile" model requires significant management and technological change. In much the same way, commercial enterprises supporting the military need to ascertain how to sustain themselves during transformations in the DoD enterprise.

The author has investigated many of these problems and the application of new technologies, tools, and strategies that could be leveraged in providing leaner and agile sustainment networks. This book focuses on the various process-improvement initiatives that are available to help sustain the military enterprise, and it presents a lean enterprise architecture to accomplish that objective. It is the first volume in the *Sustaining the Military Enterprise* series. Future volumes by the author will provide the sustainment community with the required maintainability, reliability, supportability, and logistics practices and technologies, and it will also present the necessary principles of maintenance and systems engineering that are required for military sustainability.

Acknowledgments

First and foremost, special gratitude must be extended to my wife, Clare Comm, for her love, patience, and encouragement throughout the long and arduous production of this manuscript.

My sincere appreciation must also be extended to two individuals without whom this book would not be possible: Mario F. Agripino, president of EC Systems Engineering (http://www.ec-systemsengineering.com); and Timothy P. Cathcart at the Naval Undersea Warfare Center in Newport, Rhode Island. Each of these individuals possesses over 20 years of hands-on experience in the sustainment field. This collective experience proved invaluable to the production of this book. They contributed generously to the ideas contained within, and they provided support and feedback during its production. Furthermore, it was Tim Cathcart who first encouraged me to write this book. My thanks to you both!

Finally, I would like to thank the Massachusetts Institute of Technology, the U.S. Air Force, and Babson College. It was my involvement in the Lean Sustainment Initiative at MIT in collaboration with the U.S. Air Force that provided the incentive and knowledge that led to the production of this manuscript, and the Babson College Board of Research provided the funding that enabled me to benchmark the institutions used as case studies in this manuscript.

About the Author

Dennis F. X. Mathaisel is professor of management science in the Department of Mathematics and Science at Babson College, and holds a doctor of philosophy degree from the Massachusetts Institute of Technology. For 20 years he was a research engineer at MIT. He was also cofounder and president of Scheduling Systems Incorporated, a computer software firm, and in the early 1970s he was a branch manager at the McDonnell Douglas Corporation.

Dr. Mathaisel's interests focus on the sustainability of complex and aging systems. He is an expert in lean sustainment, and was an MIT colead for the Lean Sustainment Initiative for the U.S. Air Force. Dr. Mathaisel has written several papers on lean sustainment and enterprise transformation. Through his experience working with several government and commercial organizations he has learned how an effectively designed and executed enterprise transformation plan can promote the vision, commitment, sense of urgency, senior leadership buy-in, and shared goals and objectives that are necessary for a successful adaptation of enterprisewide lean sustainment.

Dr. Mathaisel has consulted for the Federal Aviation Administration, the National Aeronautics and Space Administration, the U.S. Air Force, and the U.S. Department of Transportation (Office of the Secretary); Pratt & Whitney; FedEx, the Flying Tiger Lines, Continental Airlines, Garuda Indonesia Airline, Hughes Airwest, Iberia Airlines, Northwest Airlines, Olympic Airlines, Pan American World Airways, Trans World Airlines, and USAirways, among many other institutions. These assignments have focused on enterprise sustainment, the application of lean manufacturing to sustainability, decision support systems, maintenance and logistics, scheduling, fleet and route planning, and transport systems analysis and engineering.

Dr. Mathaisel is a private pilot and an owner of a Cessna 182 aircraft based at Hanscom Air Force Base, near Concord, Massachusetts.

Chapter 1

The Current Military Sustainment System

> Some believe that with the United States in the midst of a dangerous war on terrorism, now is not the time to transform our armed forces. I believe that the opposite is true. Now is precisely the time to make changes. The war on terrorism is a transformational event that cries out for us to rethink our activities, and to put that new thinking into action. . . .
>
> As we prepare for the future, we must think differently and develop the kinds of forces and capabilities that can adapt quickly to new challenges and to unexpected circumstances. We must transform not only the capabilities at our disposal, but also the way we think, the way we train, the way we exercise and the way we fight. We must transform not only our armed forces, but also the Department that serves them by encouraging a culture of creativity and prudent risk-taking. We must promote an entrepreneurial approach to developing military capabilities, one that encourages people to be proactive, not reactive, and anticipates threats before they emerge.
>
> **—Donald H. Rumsfeld, "Secretary's Foreword," in U.S. Department of Defense,** *Transformation Planning Guidance*

Transformation has become the new buzzword within the U.S. Department of Defense (DoD). In fact, the National Defense Authorization Act for fiscal year

2005, Title VIII, Subtitle F, requires the secretary of defense to provide the department's plans to increase the emphasis placed on lean manufacturing technologies and processes in acquisition programs, and the potential for broader application of such technologies and processes throughout the department—in particular, sustainment. *Sustainment*, or *depot maintenance activity*, is defined here as the means by which the military enterprise is enduring. It also is defined as the maintenance, repair, and overhaul (MRO) practices that keep systems (the products of the enterprise) operating and up to date (new technology upgrades) throughout their entire life cycle. Depot maintenance activity involves repairing, overhauling, and modifying and upgrading defense systems and equipment. It also includes the limited manufacture of parts, technical support, modifications, testing, and reclamation as well as software maintenance.

In addition to the "war on terrorism," an increased military operational tempo, aging weapons systems, an aging workforce, limited financial resources, inadequate resource management, and the availability of new sustainment technologies are only some of the reasons why nearly every MRO depot has conducted a study of its sustainment enterprise to become more efficient. Most of these studies focus on individual elements of this system, such as transforming a turbine engine blade shop using lean principles and cellular nanufacturing concepts, or instituting a purchasing and supply-chain management (PSCM) initiative. However, to more effectively solve the sustainment problem, research should be conducted on the whole enterprise, from raw-material suppliers to delivery of the repaired/overhauled system.

This volume focuses on the tools and processes that management, product development, systems engineering, and operational support teams should consider in the design, development, operation, and improvement of their depot maintenance systems that are cost effective in all phases of the product's life cycle, "from cradle to grave." The goal is to minimize non-value-added activities throughout the entire sustainment enterprise.

To counter the challenges currently facing the sustainment system, military maintenance, repair, and overhaul depots must implement an aggressive transformation plan for the future. The DoD 2001 Quadrennial Defense Review has described the need to reduce the logistics footprint, improve DoD global mobility, and increase the reliability of DoD weapons systems. In addition, the new DoD Defense Acquisition Management series directive 5000.1 (Defense Acquisition System) and instruction 5000.2 (Operation of the Defense Acquisition System) are oriented toward achieving these objectives while also reducing the time required for development and deployment of needed war-fighter capability through implementation of evolutionary acquisition strategies and spiral development processes. The goal of all these directives is to achieve a quantum leap in sustainability throughput and efficiency by transforming depot workload and processes into those of a "best in class" facility using best practices, process improvement initiatives, and advanced manufacturing/sustainment processes and layouts.

A question arises as to whether to transform the entire enterprise (either the entire depot or each strategic business unit) all at once or to incrementally repair one cell at a time. This volume contributes to the question by defining and describing a lean enterprise architecture for the transformation of the entire MRO enterprise. Three disciplines guide the design: the application of current process improvement initiatives in the transformation, enterprise architecture, and systems engineering concepts.

Professionals involved in sustainment need a parallel set of skills and tools. One set should focus on the management aspects of the integration of the support elements and the sustainment issues with other program management functions. The other set should focus on the engineering aspects of sustainment. To date, no condensed, practical, and user-oriented text has been available to meet these two needs. To address this void, the author has researched new approaches specifically designed for the problems currently facing the sustainment community. These papers provide the essential technical skills, methods, and tools needed to implement many new strategies and principles that are required in order to effectively sustain the military enterprise and the products created by that enterprise. The present volume is the result of these efforts.

1.1 Introduction

Since 1990, the DoD has reduced its budget by 29 percent. This reduction has greatly impacted weapons system acquisition and in-service support (Cordesman 2000). Reduced budgets have forced the branches of the military to extend the life of current legacy systems with significant reductions in acquisition of replacement systems. In addition, current weapons systems are faced with escalating operations and maintenance costs. These sustainment costs are due to

- Increased operational tempo
- Increased mean time between maintenance cycles due to increased operational requirements
- Increased life extension of existing weapons systems due to delays in new-system acquisition
- Unforeseen support problems associated with aging weapons systems
- Material shortages because of diminishing manufacturing resources and technological obsolescence
- An aging MRO workforce, one-third of which is eligible for retirement in the next five years
- The development and introduction of new sustainment technologies, such as advanced systems electronics and failure detection
- Reduction of the organic infrastructure due to base realignment and closure
- Insufficient investment in the current plant and equipment

As sustainment costs increase, there is less funding available to procure replacement systems. An analysis conducted by the DoD (Gansler 1999) has concluded that unless mission requirements and the operational tempo are reduced or there are significant increases in the budget, the operational maintenance cost portions of the budget will equal the total current (net present value) budgets by the year 2024 (see fig. 1.1). This chain of events has been illustrated and characterized in figure 1.2 as the “DoD death spiral.” To waive off this death spiral, the DoD must find innovative solutions to support legacy systems that are cost effective and flexible. The DoD must economically manage these system life cycles in order to address obsolescence and modernization issues without degrading readiness, cost, and performance objectives.

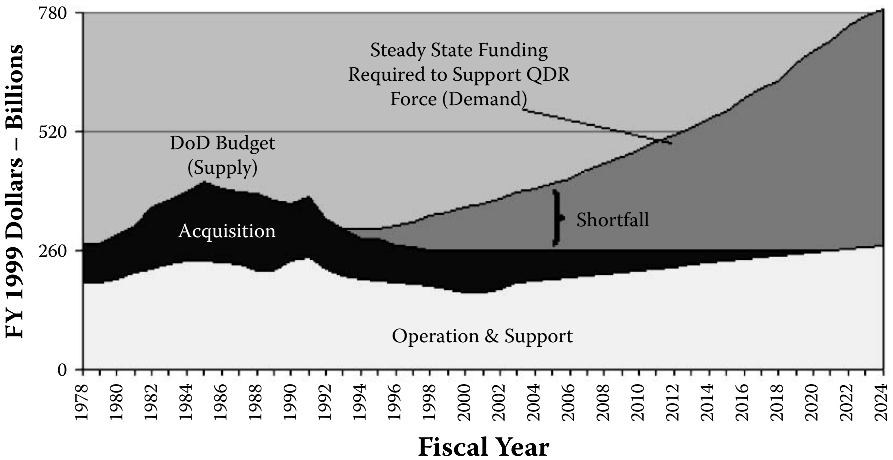

Figure 1.1. The DoD Budget Profile (from Gansler 1999).

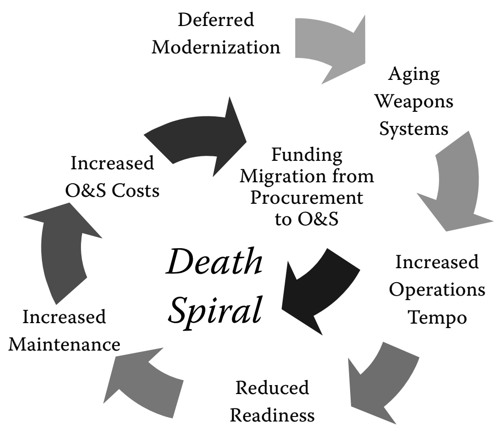

Figure 1.2 The DoD “Death Spiral” (from Gansler 1999).

Along with DoD budgets, the defense industry sector has shrunk dramatically. In order to effectively compete in a significantly smaller market, the industry has seen a large number of corporate mergers. With the restructuring of the new industry base, many of the supply chain networks no longer exist. Second- and third-tier supply-chain businesses have gone out of production. The defense industry sector is changing, and their associated supply-chain network is eroding rapidly.

With over 60 percent of the total aircraft system life cycle cost associated with operations and aircraft maintenance, and as aircraft systems age, there is great opportunity to optimize sustainment costs (Blanchard and Fabrycky 1998). With some degree of success, industry and government partnerships have been formed to attempt to address these issues. Examples include agile combat support (Eady and Williams 1997), flexible sustainment (Performance-Based Business Environment 1997), the U.S. Army's Modernization through Spares program (Kros 1999), the Lean Aerospace Initiative,[1] and the Lean Sustainment Initiative.[2] These initiatives focus on three primary areas:

1. Modernization through commercial off-the-shelf technology solutions ("technology refreshment" and "technology insertion")
2. Manufacturing, production, and logistics methods (the "just in time," lean, and agile initiatives).
3. Modernization of the industrial base (the flexible manufacturing system, material resource planning systems, and advanced manufacturing technologies).

However, these initiatives focus on individual elements of the sustainment system, not the whole enterprise; thus, the question arises, are these efforts coordinated? Organizations have the mind-set that if it was not invented here it has no value. Therefore, the results of independent efforts often are not used by organizations other than those that are the target of the investigation. These projects overlap, and in many cases multiple initiatives are conducted on the same research areas (Warren 1998).

The forces depend upon a highly responsive sustainment system to ensure that well-maintained equipment is ready and available to the warfighter. The variance in the demand for these resources places an increased responsibility on the depots. Existing depot maintenance production methodologies need to be made more flexible to meet these varying demand requirements. However, the supporting facility infrastructure, equipment, processes, and personnel are operating with less-than-optimal flow processes, facility constraints, and outdated equipment. Current batch-and-queue methods of production are task oriented and functionally isolated (Sharma and Moody 2001). Current systems are designed and arranged as separate elements, which results in excessive travel time and distance for parts. Past performance-improvement efforts were concerned with the process, not the product. There is a big distinction between process flow and product flow. Process flow was instituted to ensure that each process was operated efficiently without regard to end item support to the customer. The process flow approach was deemed a mistake and, ultimately, expensive. In addition, some portion of the industrial processing equipment is aging and is at the point of needing refurbishment or replacement. The equipment is prone to excessive downtime due to long lead-supply items, out-of-business contractors, and obsolete parts.

To effectively respond to this increased, yet unpredictable, demand for mission-ready resources, the depots must confront the challenges with an aggressive transformation plan for the complete industrial complex and processes. The focus should be on increasing throughput and customer support, with the additional benefits of reducing flow time, and increasing available capacity and labor productivity, so that the depot can achieve more productive work. The transformation entails changes in repair processes, material support, financial accounting systems, and management mind-set. The industrial space needs to be transformed to function with commercial efficiencies through the use of process improvement initiatives like lean manufacturing (Lamming 1993; Liker 1997; Womack and Jones 1996; Maskell 2003). Recent U.S. Air Force initiatives, such as the Air Force Materiel Command's depot maintenance transformation and PSCM, have already adopted commercially proven lean MRO transformation methodologies and practices. These methods and practices facilitate increased capacity, higher quality, and higher productivity while simultaneously reducing inventory and costs (Liker 1997). Also applicable to the transformation effort are the principles of cellular manufacturing (Levasseur, Helms, and Zink 1995; Mungwattana 2000; Sekine 1992; Singh and Rajamaani 1996). The integration of people, machines, and the control and manufacturing processes that bind them together within "cells" reduces cost, material scrap, workforce requirements, lead times, reworking, and flow times, and it optimizes the use of floor space. Such changes must be foundational and fundamental to the way depots conduct business. Limited resources and significant cultural changes compound the transformation process. Further, the necessity to provide continuing support to operations throughout the transition process increases the challenge.

Lean enterprise engineering and cellular manufacturing, particularly in a large depot organization, is a complex task that requires a critical balance be maintained within four major areas during all stages of transformation:

1. The lean and cellular MRO strategy
2. An infrastructure that supports a lean/cellular operation
3. Change management: a symbiotic relationship between the decision-making personnel and the operating personnel to establish ownership of lean goals and the responsibility of the government to provide additional education and training required to effect change.
4. Continued support of the MRO requirements during the transformation

These interrelated functional areas are key to a transformation, from conceptualization through acquisition planning and integration, and on into the support phase of the implementation.

The transformation also requires an architecture that portrays the overall "flow" of the action phases necessary to initiate, sustain, and continuously refine the enterprise transformation that would result in the implementation of the lean/cellular principles and practices (Brown 2000). Should this architecture be enterprisewide? Or, should the architecture support an incremental, cell-by-cell, transformation?

1.2 Characterization of the Current Military Sustainment System

The DoD depot maintenance program was at its peak in 1987 in terms of workload, people, and facilities. It has changed significantly since then. The primary event that framed these changes and put certain key actions into motion was the end of the Cold War and the associated force-structure downsizing. A number of other diverse but interrelated factors—such as threat changes, new war fighting plans, and changes in maintenance concepts—influenced defense downsizing. With these change agents in the works, the DoD began restructuring its depot maintenance program. This restructuring primarily has been achieved through three series of actions: (1) the base realignment and closure (BRAC) process, which was designed to reduce the DoD's infrastructure; (2) increased reliance on the private sector for depot maintenance support; and (3) a major downsizing of depot maintenance personnel. Today, the DoD has a smaller depot structure (see fig. 1.3) with three Air Force air logistics centers, five Army depots, two Marine Corps multicommodity maintenance centers, three Navy aviation depots, four naval shipyards, one naval surface warfare center in Indiana,[3] and the aerospace maintenance and regeneration center in Arizona.[4]

Thus, as a result of the BRAC process, in 2001, 19 of the 38 public-sector maintenance depots that existed in 1987 remain in operation as government-owned and -operated activities, primarily supporting DoD maintenance but with several diversifying to also support commercial customers. Additionally, most of the remaining military depots are smaller in size since 1987 as equipment has been consolidated and facility footprints downsized. Some of the prior military facilities were privatized, such as the San Antonio, Texas, air logistics center, and continue to function with important maintenance activities. During the period 1987–2001, depot maintenance personnel have been reduced by 59 percent, the third highest percent of any category of DoD civilian personnel (U.S. General Accounting Office 2001a). Also, while the number of systems being maintained has declined since 1987, system complexity and age have increased, thus increasing the amount of depot maintenance work required for many systems. For example, in 2001 the average amount of time for a C-141 overhaul was about 9,200 hours, or one-third more than the average amount of time in 1987.

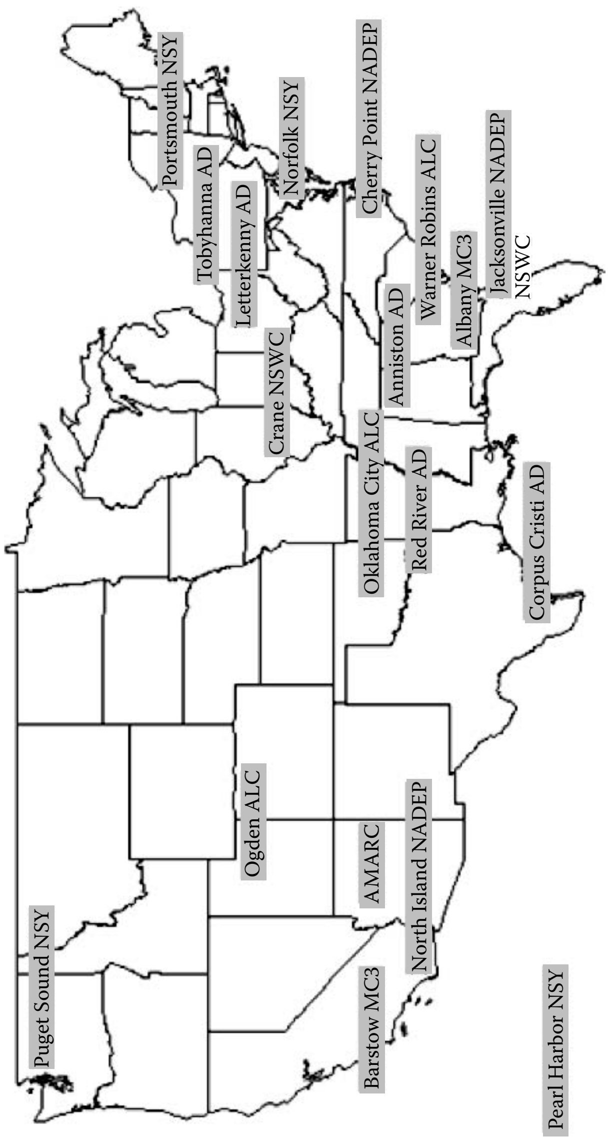

Figure 1.3 The DoD Depot Maintenance System.

In terms of defense contractors, information is not available regarding the number of contractor facilities in which the tens of thousands of depot-level maintenance contracts are being performed or the value of the equipment that is involved. Increasingly, the DoD is contracting for a variety of logistics activities that may include supply and weapons system support, engineering, configuration management, maintenance, and a variety of other functions. As recommended in various studies, the DoD has implemented a policy change placing increased reliance on defense contractors for depot maintenance and related logistics activities. While no central database provides reliable information about depot maintenance contracting, contractors' share of depot maintenance funding has increased by 90 percent while the military depots' share of funding has declined by 6 percent in the period 1987–2001 (U.S. General Accounting Office 2001a). Although workload production data is not available for contract work, the military depots' production hours were down 64 percent during this period. This policy shift to the private sector has most directly affected workloads for new and upgraded systems, because work on these is largely going to the private sector.

In terms of the amount of money being spent on sustainment, depot maintenance activities are funded through the Defense Working Capital Fund (DWCF) budget. The fiscal year 2006 DWCF budget was $112.1 billion, of which $58.8 billion was for supply management and $14.6 billion for depot maintenance activities (shipyards; Navy aviation; and Air Force, Army, and Marine depots; Donnelley and Proctor 2005). The depot maintenance program funds the overhaul, repair, and maintenance of aircraft, missiles, ships, submarines, combat vehicles, and other equipment.

The current military sustainment system is complex, but it can be characterized in a simple way as comprising four major elements: supply support, intermediate/depot maintenance and operational support, integrated logistic support, and the in-service engineering process. This characterization, illustrated in figure 1.4, demonstrates the necessary coordination among the various sustainment organizations.

Starting on the right side of figure 1.4, the supply support function consists of the supply chain, the supply system, and the Government Industry Data Exchange Program. The supply chain is comprised of the vendors (V) and suppliers (S) that provide consumable materials and refurbishment services to the supply system and depot. The item manager has overall responsibility for inventory management, handled through inventory control points. Inventory locations are referenced as designated stock points, which maintain spares and consumable inventories.

The intermediate and depot maintenance functions consist of those maintenance organizations responsible for keeping weapons systems in a serviceable condition. The designated overhaul point, also known as the organic military depot, performs maintenance that includes servicing, inspection, test, adjustment and alignment, removal, replacement, reinstallation, troubleshooting, calibration, repair, modification, and overhaul of weapons systems and components (Blanchard, Verma, and Peterson 1995; Jones 1995). Maintenance data and failure analysis are provided

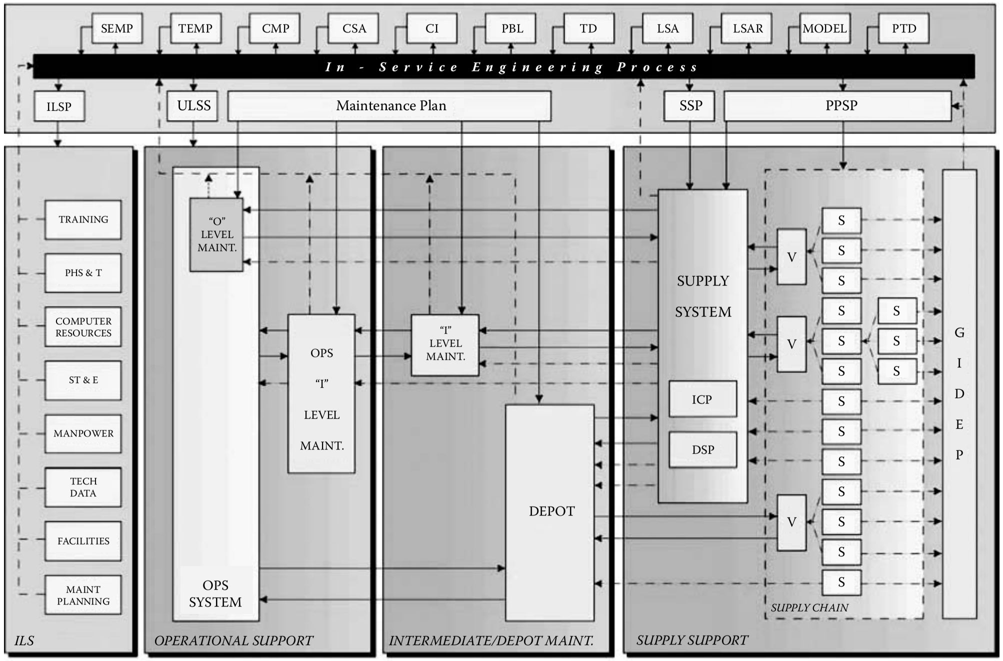

Figure 1.4 The Current Military Sustainment System.

Key: CI = configuration item; CMP = configuration management plan; CSA = configuration status accounting; DSP = designated stock point; GIDEP = Government Industry Data Exchange program; ICP = inventory control point; I-Level = intermediate level maintenance; ILS = integrated logistic support; ILSP = integrated logistic support plan; LSA = logistics support analysis; LSAR = logistics support analysis record; O-Level = operational level maintenance; PBL = product baseline; PPSP = postproduction support plan; PTD = provisioning technical documentation; S = supplier; SEMP = system engineering master plan; SSP = supply support plan; ST&E = special tools and equipment; TD = technical data; TEMP = test and evaluation master plan; ULSS = users' logistics support summary; V = vendor.

to the in-service engineering process. Intermediate maintenance organizations provide operational support services at the customer's base of operations. Depot maintenance organizations perform MRO services to the weapons system and its associated components. The depot procures consumable materials from the supply system and commercial sources.

The integrated logistics support function on the far right of figure 1.4 is a composite of all support considerations, including system design for sustainability and the logistics infrastructure that is necessary to assure effective and economical support of a system throughout its existing life (Blanchard 1998). The primary objective is to achieve and maintain readiness objectives. Logistics include all of the support elements necessary to sustain the weapons system, including such elements as training and support; packaging, handling, storage, and transportation; and computer resources and support.

The in-service engineering process, at the top of figure 1.4, is responsible for maintaining the system configuration of the product and identifying postproduction support problems and product improvements associated with the operation, maintenance, and integrated logistic support of all weapons system support elements. Other responsibilities include the evaluation, definition, and testing of solutions to possible postproduction support problems using systems engineering processes in an effective and expeditious manner to support required readiness objectives for the remainder of a weapons system's life cycle (INCOSE 1998).

To illustrate the inefficiency and complexity of the current military sustainment system, figure 1.5 shows the system from the perspective of the distribution channel and the supply chain. In that figure, the distribution channel on the left includes the processes necessary to provide a ready-for-issue (RFI) spare part to the war fighter, including the technical maintenance services provided by the maintenance sustainment organizations. The supply channel on the right includes the processes necessary to replenish the RFI stock inventory required to support the distribution channel. This process includes replenishing the consumables, the MRO of RFI spares, and the associated lower-level supply-chain activities. Note that there are seven levels for the distribution and supply chain. Another perspective of this complexity is also illustrated in figure 1.6, which places the item manager in the center of the complicated supply-channel and distribution-channel activity. Such a model is good for the support of large, slowly changing platforms and systems, but it possesses negative characteristics, such as:

- It is a seven-tier sustainment system: there are too many links in the supply chain
- It contains uncoupled processes
- It has fragmented organizational structures
- It possesses uncoordinated supplier and distribution channels
- It is a push-oriented, not pull-oriented system, which violates one of the fundamental principles of lean sustainment
- It is not responsive in today's MRO environment

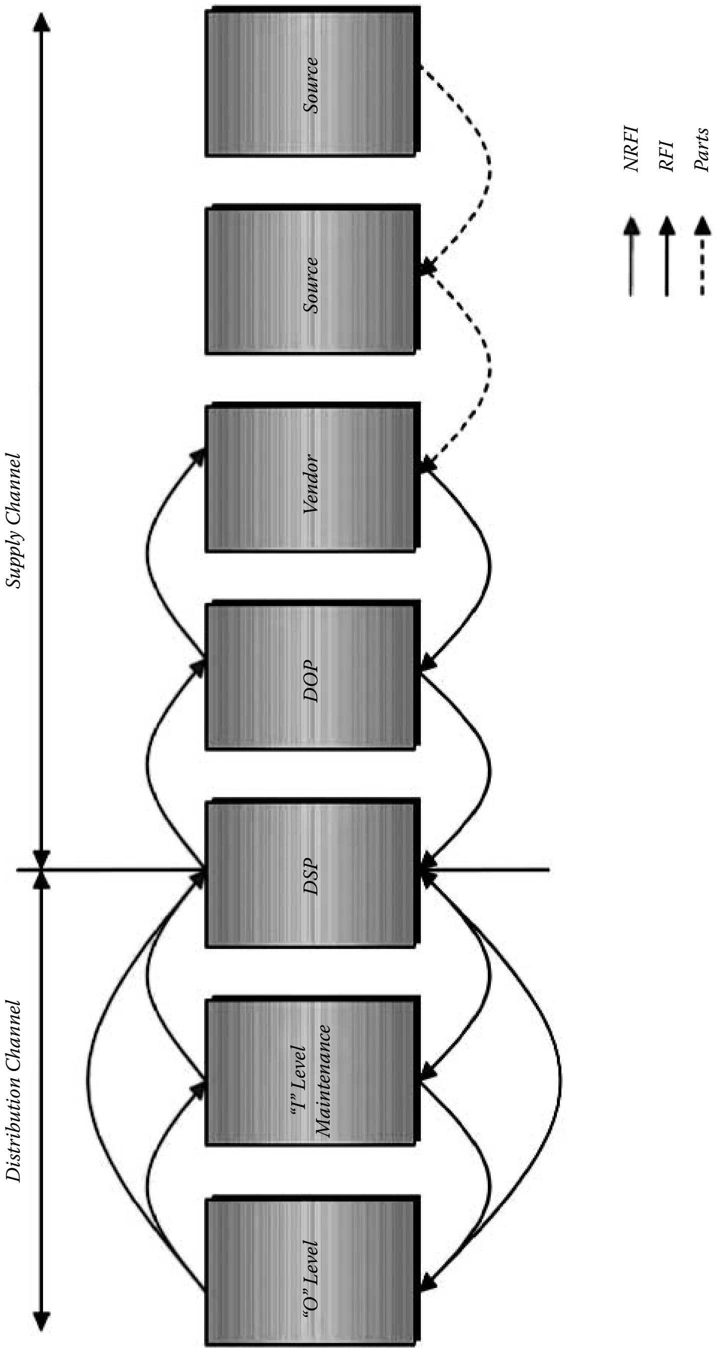

Figure 1.5 The Current Military Sustainment Supply Chain.

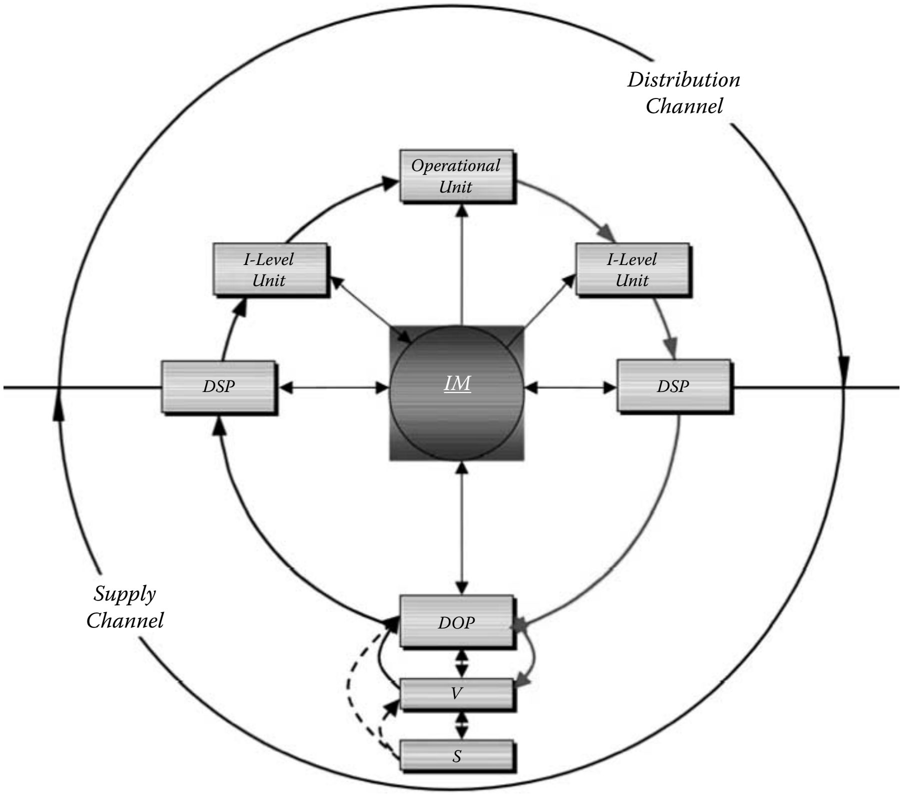

Figure 1.6 Current Military Sustainment Distribution and Supply Channels.

The complexity of the channels in figures 1.5 and 1.6 indicate that there is an opportunity to integrate many of the system functional elements to effectively meet supply system and fleet requirements concurrently.

1.3 Analysis of the Current Military Sustainment System

One key measure of military sustainment performance is the availability of weapons systems to carry out their missions. The high-level metric that is most often tracked is the mission capable (MC) rate and its associated full mission capable (FMC) rate. These rates are the percentage of time a weapons system can perform at least one (MC) or all (FMC) of its assigned missions. The U.S. General Accounting Office (GAO) has examined key DoD aircraft MC and FMC rates, and whether the respective services have been able to meet their MC and FMC goals. What the GAO found was that the average annual MC and FMC rates for fiscal years 1998–2002 was about 77–83 percent for the Army and the Air Force,

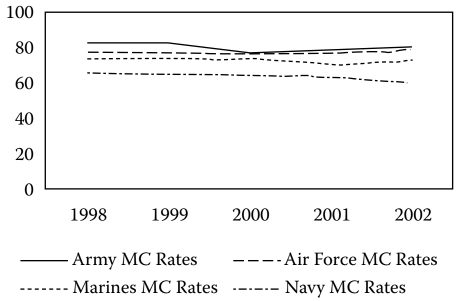

Figure 1.7 Mission Capable (MC) Rates (from U.S. General Accounting Office 2003).

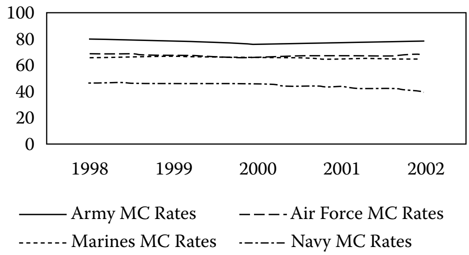

Figure 1.8 Full Mission Capable (FMC) Rates (from U.S. General Accounting Office 2003).

about 71–75 percent for the Marines; and 61–67 percent for the Navy (see fig. 1.7). A similar pattern follows for the average FMC rates for the services (see fig. 1.8). Average MC and FMC rates varied by service and type of aircraft. Among aircraft types, the average MC rates varied from 60 to 80 percent. Average MC rates were the highest for helicopters, followed by cargo aircraft and tankers, fighter/attack aircraft, bombers, and electronic command/control aircraft (U.S. General Accounting Office 2003).

The GAO also found that less than one-half of 49 key active-duty aircraft models that it had reviewed met their MC or FMC goals during fiscal years 1998–2002. In most cases the actual rates reported above were at least 5 percentage points below the goals. The difficulties in meeting the goals are caused by a complex combination of logistical and operational factors. One big factor is the age of the weapons systems. For example, the average military aircraft age is 21 years, which, of course, varies considerably by platform (see table 1.1; Michaels 2004).

As these systems age, spare-parts shortages adversely affect the performance of assigned missions (MC and FMC rates) and the economy and efficiency of maintenance activities. For instance, table 1.2 shows the reported rates for U.S. Air Force aircraft that were mission capable and those that were not mission capable due to the shortage of spare parts to repair them.

Table 1.1 Aircraft Age

Aircraft	*Age (in Years)*
B-52 Bomber	41
KC-135 Refueling Tanker	40
C-5 Transport	35
UH-1 Helicopter	31
C-130 Transport	25
F-16 Fighter	13
NH-90 Helicopter	5

Table 1.2 Reported Rates for Aircraft that Were Mission Capable and Not Mission Capable

Fiscal Year	*Aircraft Reported as Mission Capable (Percent)*	*Aircraft Reported as Not Mission Capable Due to Supply Problems (Percent)*
1996	78.5	11.0
1997	76.6	12.6
1998	74.3	13.9
1999	73.5	14.0
2000	72.9	14.3
2001 (1st Quarter)	72.9	14.0

Source: U.S. General Accounting Office 2001a.

Spare-parts shortages are pervasive throughout the military sustainment system. The majority of reasons cited by item managers at the maintenance facilities for spare-parts shortages were most often related to more spares being required than were anticipated by the inventory management system and delays in the Air Force's repair process as a result of the consolidation of repair facilities. Other reasons included (1) difficulties with producing or repairing parts, (2) reliability of spare parts, and (3) contracting issues. For example, the anticipated quarterly demand for a machine bolt for the F-100-220 engine was 828, but actual demand turned out to be over 12,000. As a result, some F-100-220 engines were not mission capable because they were waiting for more bolts to be obtained. In another case, a contractor produced sufficient quantities of a visor seal assembly for the C-5, but the parts failed to meet design tolerances. As a result of this production problem, demands for this part could not be met for the Air Force (U.S. General Accounting Office June 2001b). Similar results are reported for the Navy (GAO July 2001c). The Army reports that the fact that actual demands for parts were often greater than anticipated, delays in