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Supply Chain Logistics

Supply Chain Management: Analyzing Air Force and Industry Metrics

Global Logistics Support—The GLSC: Operational Supply Chain Management

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Special Feature

Supply chain management (SCM) transformation is among the top initiatives for government and the private sector alike. The ultimate objective is an integrated supply chain which perfectly synchronizes supply and demand, so that the rate of supply matches the rate of demand along the entire supply chain.

logistics Supply Chains

Supply Chain Management: Analyzing Industry and Air Force Metrics
Global Logistics Support—The GLSC: Operational Supply Chain Management

The Air Force has embarked on a sustainment vision that transforms the purchasing and supply chain management functions to better support the warfighter. The task at hand is to provide world-class materiel support at the best possible price. To do this, most would agree that an overhaul of the supply chain management process is needed. In "Supply Chain Management: Analyzing Industry and Air Force Metrics" Mr Marshall presents a comparative analysis of industry and Air Force supply chain metrics along with an assessment of the measures to determine the effectiveness of Air Force SCM transformation. The assessment provides several recommendations to improve the current suite of metrics used to manage the Air Force supply chain. Supply chain management is a complex process and no single research effort will yield all of the answers to the suite of metrics that should be used. This article summarizes those best practices that seem to indicate successful SCM implementation and operation.

A major change in the world of Air Force supply is the Global Logistics Support Center (GLSC). The GLSC has three primary functions:

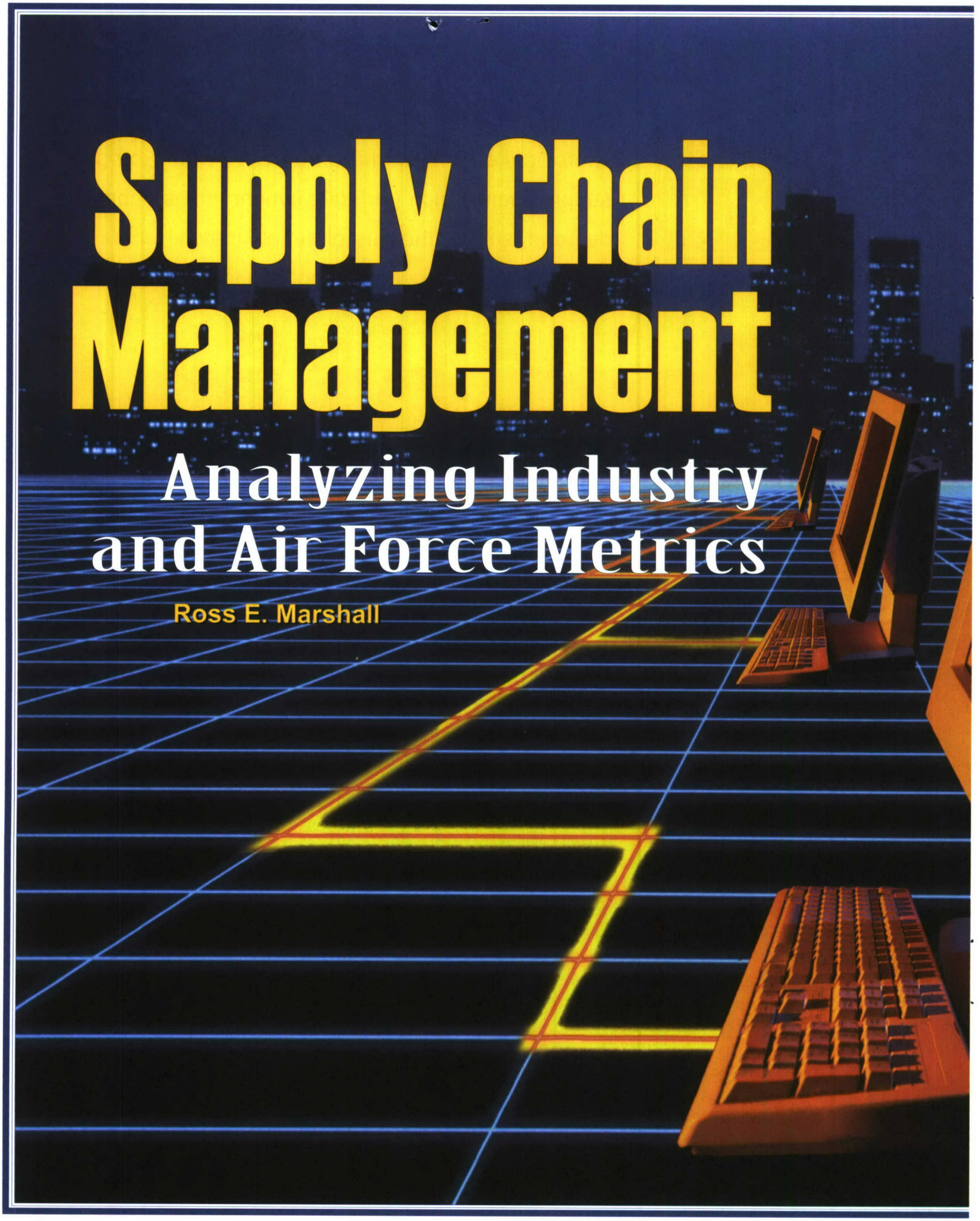
- Enterprise-wide planning of the Air Force supply chain, including planning for material, maintenance, and distribution.
- Providing a single point of contact for customers to resolve immediate logistics issues at the point of execution.
- Providing the single point of entry and authority for enterprise supply chain information management. This will include the management of business rules, processes and procedures, providing functional requirements for supply chain systems and measuring, assessing, and taking action to improve supply chain performance through enterprise metrics and analysis capabilities.

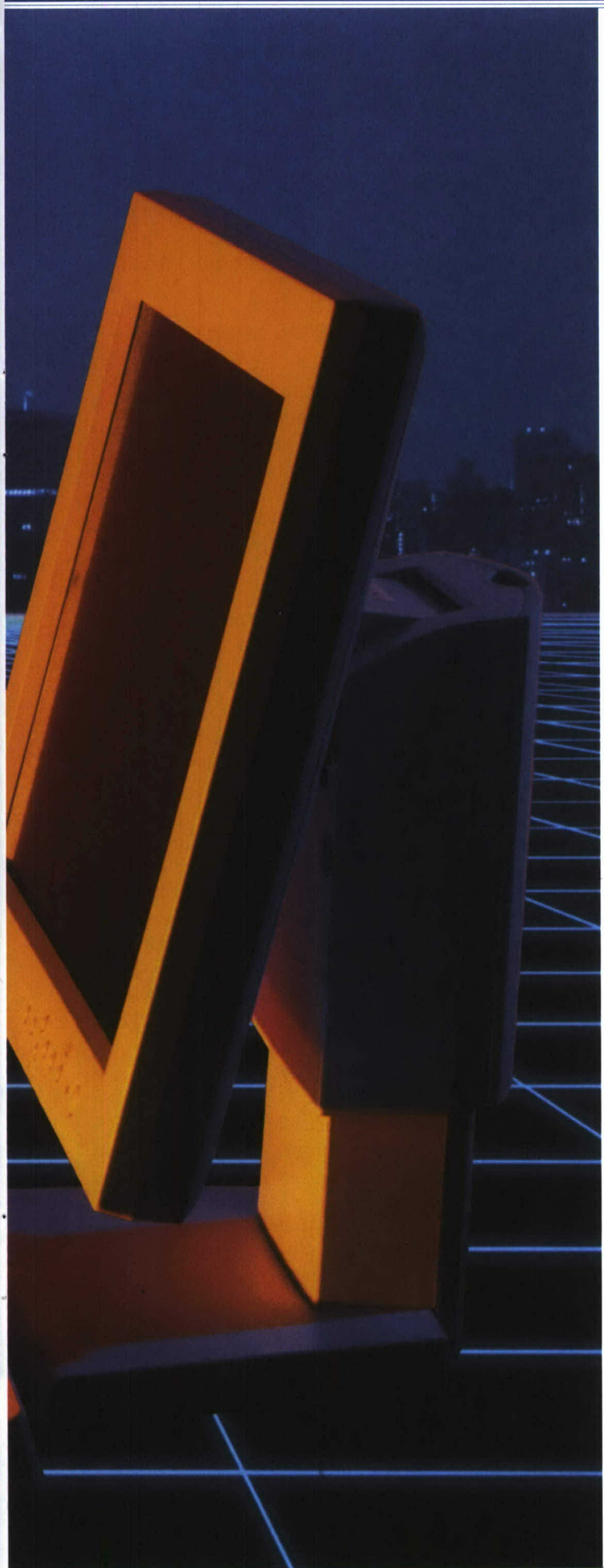
In "Global Logistics Support—The GLSC: Operational Supply Chain Management" Mr Reusser discusses the organizational structure and organizational locations of the GLSC.

Supply Chain Management

Analyzing Industry and Air Force Metrics

Ross E. Marshall





Introduction

Change, then, is part and parcel of today's logistics environment. But those who passively accept change instead of managing it often become its victim, losing control and influence over their environment or even losing their jobs, say the experts. Instead, logistics managers should become change leaders who motivate their organizations to seize the opportunities for improvements that change offers.[1]

—Toby B. Gooley

Special Feature

While current Air Force logistics processes have served us well, and provided unparalleled support since the end of the Cold War, the need to significantly reduce costs while improving weapons system availability is essential. Senior Air Force officials have stated that we've reached a point where our current way of doing the supply chain management (SCM) business, and the systems that support the current process, are limited in their ability to significantly improve readiness beyond the current levels.[2] The logistics doctrines, processes, and systems were developed when there was one large known enemy. Our policies, processes, and training were all optimized to support a major global war, not small-scale contingencies across the globe under widely different constraints.[3] Significant change in sustainment support to the warfighter is a key component in the overall transformation efforts and initiatives being pursued by the Air Force. It is estimated that the overhaul of the SCM system will take 7 years to fully implement.[4] Initially, the overarching goals of the Air Force transformation effort were to improve aircraft systems availability by 20 percent with 0 percent real growth in operating and supporting costs.[5] The goal was later modified, maintaining a 20 percent improvement in weapons system availability with a decrease of 10 percent in operating and supporting costs.[6]

There are several purposes of this article. The first, is to examine SCM processes used within the Air Force and private industry. This is important because a key purpose of the supply chain transformation initiative is for Department of Defense (DoD) logisticians to adopt commercial business practices in an effort to maintain their competitive edge in the rapidly changing global security arena.[7] A brief discussion of Air Force SCM processes will be presented, as well as industry methodologies for managing the supply chain in the private sector. The second purpose is to analyze and assess the usefulness of the metrics and measurements being used, again both within the private sector and the Air Force. These metrics will then be compared to see whether there is a correlation between the two methodologies, and recommendations made as to whether or not the right metrics are being looked at to assess SCM success within the Air Force. It is important for the DoD to have effective SCM because of its impact on military readiness and operations, and the substantial investment in inventory. While the DoD maintains military forces with unparalleled capabilities, timely supply support is critical to sustain them. Since 1990, the DoD's SCM processes have been on the Government Accountability Office's (GAO) list of high-risk areas needing urgent attention and fundamental transformation.[8]

The research methodology will be primarily a review of the existing writings by experts in the field of logistics and SCM, both in government and industry. Also, input from existing Air Force supply

Article Highlights

Despite the proliferation of SCM literature, finding an exact set of measurements which all of industry would agree upon is impossible.

"Supply Chain Management: Analyzing Industry and Air Force Metrics" examines supply chain management (SCM) processes used within the Air Force and private industry. A brief discussion of Air Force SCM processes is presented, as well as industry methodologies for managing the supply chain in the private sector. The article also analyzes and assesses the usefulness of the metrics and measurements being used, again both within the private sector and the Air Force. These metrics are then compared to see whether there is a correlation between the two methodologies, and recommendations made as to whether or not the right metrics are being looked at to assess SCM success within the Air Force.

The research methodology used is a review of the existing writings by experts in the field of logistics and SCM, both in government and industry. Input from existing Air Force supply chain managers was integrated into the analysis.

There have been several long standing discussions within the Air Force regarding how to measure the effectiveness of SCM. This article discusses some of those methods. It concludes with recommendations suggesting the use of specific metrics that will enhance the supply chain manager's ability to meet Air Force goals and more effectively manage the supply chain business.

Major recommendations presented in the article are as follows:

- Continue to use the Sustainment Business Process (SBPM) and Supply Chain Operations Reference Models
- Develop metrics that tie to strategic goals, are actionable, and are leading
- Continue to implement Lean and Six Sigma practices to improve the supply chain.
- Tie appraisal performance awards to successful management of SCM metrics

chain managers will be used. While it is recognized that each of the Services has slightly different approaches to SCM, the scope of this project (principally the government methodologies and recommendations) will be limited primarily to the Air Force.

Regarding performance measures, there have been several long standing discussions within the Air Force regarding how to measure the effectiveness of SCM. This article will discuss some of those methods. Recommendations will be made suggesting the use of specific metrics which will enhance the supply chain manager's ability to meet Air Force goals and more effectively manage the supply chain business.

Supply Chain Management

> *Whether push or pull, our current logistics are reactive. At best, unless we embrace a new paradigm, we will still be depending on the warfighters to tell the logisticians what they need, then trying to supply it as fast as they can. This amounts to an industrial age vendor struggling to satisfy an information age customer. Reactive logistics—the old logistics—will never be able to keep up with warfare as we know it.*[9]
>
> **—The Honorable Michael Wynne, Secretary of the Air Force**

SCM transformation is among the top initiatives for government and the private sector alike. The ultimate objective is an integrated supply chain which perfectly synchronizes supply and demand, so that the rate of supply matches the rate of demand along the entire supply chain.[10] While the principle sounds simple, actual implementation is very difficult. In fact, few businesses feel they really have control over their supply chains and the challenges to optimize such are substantial.[11]

In order to assess government and industry approaches to SCM, and the respective metrics used to measure the supply chain, one must first understand what SCM is, the policies that govern it, and the current processes and initiatives being implemented to improve it. There are numerous definitions of SCM, ranging from simple to complex, which can be found in books, journals, papers, and articles. The following are some common definitions taken from academia, industry, and government.

First, an SCM definition from academia: Dr John Mentzer, a noted expert, author, and professor of SCM at the University of Tennessee, has published numerous articles and written textbooks on supply chain fundamentals and is a leading consultant for many businesses. He defines the supply chain as: "a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from a source to a customer.[12]

Mentzer continues to explain that SCM is then:

> ...the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.[13]

Within the private sector, the foremost industry authority on SCM is the Supply Chain Council (SCC). The SCC is comprised of nearly a thousand companies specializing in SCM and logistics functions. They perform SCM studies and research, present conferences and workshops, provide training, accomplish case studies, and publish articles on SCM issues and best practices. The SCC is the author and developer of the Supply Chain Operations Reference (SCOR) Model, a proven methodology and the only cross-industry supply chain standard being accepted, which facilitates the blending of business objectives, strategy, process, and technology. The SCOR Model will be discussed in more detail later in this article. The SCC defines the supply chain as "the management of internal logistics functions and the relationships between the enterprise and its customers and suppliers."[14]

The DoD definition focuses on the primary mission of logistics—that of providing materiel and related services to the operational customer. The definition, as proposed in the *DoD Supply Chain Management Implementation Guide*, is as follows:

> DoD supply chain management is an integrated process that begins with planning the acquisition of customer-driven requirements for material and services and ends with the delivery of material to the operational customer, including the material returns segment of the process and the flow of required information in both directions among suppliers, logistics managers, and customers.[15]

Simply put, SCM is the management of all processes and functions that are necessary to satisfy a customer's order.

Within the DoD, numerous policies and procedures govern the SCM process. Joint Vision 2020 directs our forces to be faster, more lethal, and more precise through ongoing transformation in dominant maneuver, precision engagement, focused logistics, and full dimensional protection.[16] *The National Security Strategy of the United States of America* describes the pursuit of three priorities, one of which is to improve the capacity of the agencies to "execute responses."[17] This implies that we need to be more expeditionary and develop characteristics of stealth, speed, range, accuracy, lethality, agility, sustainability, reliability and superior intelligence. *The National Military Strategy of the United States of America* describes strategic principles which are imperative to contend with the characteristics of the security environment.[18] One such principle, that of agility, is described as the ability to rapidly deploy, employ, sustain, and redeploy capabilities. Additionally, the importance of mobility will necessitate more expeditionary logistics capabilities. Focused logistics provides the right personnel, equipment, and supplies in the right quantities and at the right place and time. Such focused logistics capabilities will place a premium on networking to create a seamless end-to-end logistics system that synchronizes all aspects of the deployment and distribution process.[19] *The 2006 Quadrennial Defense Review* (QDR) emphasizes the fact that the Department needs to focus on improving visibility into supply chain logistics and assess supply chain metrics.[20] Air Force SCM policies also tie to and conform to DoD's logistics strategies as outlined in the *Defense Logistics Strategic Plan*.[21] This plan sets the overall direction for the military logistics process for the 21st century. The DoD also provides SCM guidance through the *DoD Supply Chain Materiel Management Regulation*, published in May 2003.[22] This document provides guidance on the use of metrics to manage the supply process, as does Air Force Policy Directive 20-1, which states that "crucial logistics goals" must be developed.[23]

The *DoD Supply Chain Management Implementation Guide* is the bible for SCM implementation and improvement within DoD.

Article Highlights

- Focus on real-time training for Supply Chain Managers

While there appears to be no one, agreed-upon solution to the most successful SCM processes and measurements, there are some basic best practices. Mr Reusser concludes that Air Force SCM processes and metrics are not perfect, but, for the most part, they are on track. The use of the Supply Chain Operations Reference Model is having a significant impact in both the public and private sectors, which is evidenced by the numbers and types of organizations that are members of the Supply Chain Council. The Air Force Materiel Command has chosen a very complex process, the Sustainment Business Process Model (SBPM), to achieve SCM transformation. The SBPM should be worked in concert with the Air Force Global Logistic Support Center. Staying focused on the strategic goals of the Air Force, and developing actionable and leading metrics will be critical to the success of SCM improvement.

Article Acronyms

AFMC – Air Force Materiel Command
AFLMA – Air Force Logistics Management Agency
ALC – Air Logistics Center
BSC – Balanced Scorecard
CCOR – Customer Chain Operations Reference
CRM – Customer Relationship Management
DCOR – Design Chain Operations Reference
DoD – Department of Defense
ECSS – Expeditionary Combat Support System
GAO – Government Accountability Office
GLSC – Global Logistics Support Center
IT – Information Technology
MC – Mission Capable
MICAP – Mission Capability
O&S – Operation and Support
SBPM – Sustainment Business Process Model
SCM – Supply Chain Management
SCC – Supply Chain Council
SCOR – Supply Chain Operations Reference
SKU – Stock Keeping Unit
TNMCS – Total Not Mission Capable Supply
TNMCM – Total Not Mission Capable Maintenance
UTC – Unit Type Code
WIP – Work in Process

It provides a roadmap for implementation and presents key principles and strategies for achieving progress toward fully incorporating SCM into the DoD logistics process. It was developed as a tool to assist DoD logisticians at all organizational levels who want to improve materiel support and service to customers.[24]

Within the Air Force Materiel Command (AFMC), the primary resource for SCM implementation is the Sustainment Business Process Model (SBPM). The SBPM describes nearly every element needed to implement a successful SCM process within the Air Force. It includes strategic, operational, and tactical level guidelines. The SBPM is an integrated end-to-end approach to SCM. It covers the range of supplier relationship management (SRM), SCM, and customer relationship management (CRM). SRM refers to collaboration with suppliers in design, sourcing, and buying. It involves contract performance, supplier risk analysis, and strategic process standardization. CRM involves satisfying customers by filling and managing orders more expeditiously and with better quality. SCM is the supply and demand planning bridge between SRM and CRM, and includes such elements as developing the demand forecast, conducting tactical planning and scheduling, managing assets, and performing inventory optimization analysis. The SBPM specifically describes nine critical elements that are needed for SCM implementation. They are:

- Strategic planning
- Managing customers
- Planning the supply chain
- Sourcing
- Make or repair
- Deliver
- Return
- Product sustainment
- Enabling

The SBPM is an expansion of the SCOR Model, which focuses primarily on the plan, source, make, deliver, and return portions of the process.

While the military logistics environment may differ somewhat from the private sector, much of what is currently being done to implement SCM transformation in the Air Force has been learned and patterned after industry practices. Within the private sector, each market or group of customers has a set of needs and the supply chain must be responsive to those needs. Decisions are made regarding how well the supply chain serves its market and how profitable it is for the supply chain participants.[25]

Linking policy and strategy to performance normally requires goals and objectives, as well as a complete measurement system to track progress. Getting the metrics right is critical in determining the success of SCM transformation and implementation. The measurement system cannot simply measure for the sake of measuring.[26] Measurements should drive recommendations and decisions that are actionable. This makes the choice of performance measurements one of the most critical challenges facing organizations. This is true because what gets measured, gets managed, gets fixed. In essence, what you measure is what you get.[27]

The following sections of this article will describe both industry and government SCM measurements, and the methodologies used to develop those measurements. A comparison of private sector and government metrics will then be done and recommendations made, based on best practices for measuring the supply chain.

Private Sector Supply Chain Management Metrics

> *Implementing a set of world-class logistics performance indicators is a prerequisite to any organization being able to achieve world-class logistics. The reason is simple: people behave based on the way they are measured. World-class measures lead to world-class behaviors.*[28]
>
> **—Edward Frazelle**

Despite the proliferation of SCM literature, finding an exact set of measurements which all of industry would agree upon is impossible. This is, in part, because of the past focus on areas such as customer service, cost reduction, and new technologies.[29] Also, little research has been conducted on performance measures that span the entire supply chain spectrum.[30] A major driver as well is the fact that performance measures should be driven by company goals and objectives, which differ significantly by company. While various supply chain experts recommend the use of different approaches and SCM metrics, there are some similarities. The following is a representative selection of SCM approaches to metrics development used in industry. These were selected because they are utilized by some of the most noted authors, experts, and organizations in the SCM arena.

Metrics	Reliability	Responsiveness	Flexibility	Cost	Assets
Perfect Order Fulfillment	X				
Order Fulfillment Cycle Time		X			
Upside Supply Chain Flexibility			X		
Upside Supply Chain Adaptability			X		
Downside Supply Chain Adaptability			X		
SCM Cost				X	
Cost of Goods Sold				X	
Cash-to-Cash Cycle Time					X
Return on Supply Chain Fixed Assets					X
Return on Working Capital					X

Table 1. SCOR Level 1 Metrics

As previously mentioned, the SCC is recognized as an authority on SCM. It consists of nearly a thousand companies worldwide, many of which use the Council's services of training, research, and SCM implementation processes. The SCC is the author of the SCOR Model. The SCC created the SCOR Model as a way for companies to communicate their supply chain process. It establishes a framework for examining the supply chain, categorizing processes, and assigning metrics. Numerous commercial entities, including the aerospace and defense industry, as well as large consumer product manufacturers, helped to develop and implement the SCOR Model.[31] As previously mentioned, the SCOR Model combines and integrates the process elements of a business. The process is defined by the elements of plan, source, make, deliver, and return, and views the process across a full spectrum from the suppliers' supplier to the customers' customer. SCOR Model comprises measures in three levels. Each is a subprocess of the previous plan, source, make, deliver, and return process. SCOR performance measures include more than 100 different metrics which can be used. Changes are constantly being made to the model and metrics, as companies develop new best practices. Metrics have been streamlined and, in fact, metrics in the latest version of the SCOR Model, (SCOR Version 8.0), show level 2 processes with the addition of a cost metric.[32] Version 8.0 of the SCOR Model also describes the Design Chain Operations Reference (DCOR) Model and Customer Chain Operations Reference (CCOR) Model, which were recently announced. CCOR is a reference Model that integrates customer and supplier processes, such as reengineering, process measurement, and benchmarking activities for business transformation. DCOR identifies principal process elements found throughout the design chain and links them to performance attributes and metrics. DCOR and CCOR are product and industry neutral and are cross industry and cross functional.[33] Table 1 is an illustration of the level 1, or strategic level metrics, recommended in the SCOR Model.

Performance Categories	Customer Service (Measured by Fill Rate, On Time Delivery, and Product Returns)	Internal Efficiency (Measured by Inventory Turns, Return on Sales, and Cash-to-Cash)	Demand Flexibility (Measured by Cycle Times, Upside Flex, and Outside Flex)	Product Development (Measured by New Product Sales, Percent Revenue, and Cycle Time)
Business Operations				
Demand Forecast	X	X	X	
Product Pricing	X	X		
Inventory Management	X	X		
Procurement		X	X	
Credit and Collections	X	X		
Product Design	X			X
Production Scheduling		X	X	
Facility Management	X	X		
Order Management	X	X		X
Delivery Schedule	X	X		

Table 2. Strategic Business Performance Metrics

Michael Hugos, a noted author and practitioner of SCM concepts, suggests that there is a basic pattern to the practice of SCM and the development of its measures.[34] He suggests that the supply chain consists of five major business drivers. These drivers are production, inventory, location, transportation, and information. Businesses must align their business strategies around these five drivers. Next, in gaining a high level understanding of these drivers, and how they relate to each other, Hugos recommends that the SCOR Model, developed by the SCC be used.[35] The plan, source, make, deliver, and return categories are the day-to-day operations that determine how well the supply chain works.

Hugos then argues that metrics must be developed in four performance categories. These are customer service, internal efficiency, demand flexibility, and product development.[36] It is at this point that he contends that companies can no longer survive by using lagging metrics (those metrics that are based purely on history), and that leading metrics must be used because the business environment is now characteristic of shorter product life cycles, smaller niche markets, new technologies, and new opportunities.[37] The SCOR Model presents data at three different levels of detail; strategic, tactical, and operational. Table 2 shows strategic level metrics, as recommended by Hugos, which would be used for the company as a whole. Table 3 shows tactical and operational level metrics displayed at the supply chain manager level where the work is actually performed.

These measures are used in some form by a variety of companies such as Dell, 7-Eleven, Wal-Mart, Perkins, Eastern Bag, and Proctor and Gamble.[38]

Another practitioner in supply chain strategy is Edward Frazelle. Frazelle suggests that all world-class logistics organizations are characterized by a number of things, one of which is the extensive use of logistics key performance and financial indicators.[39] He recommends that a company's metrics be designed around four businesslike performance areas and five interdependent processes. The performance areas are financial, productivity, quality, and cycle time. The five processes are customer response, inventory planning and management, supply, transportation, and warehousing.[40] Table 4 illustrates the specific measures recommended by Frazelle and used by the companies for which he consults.

Peter Bolstorff and Robert Rosenbaum are two additional experts in the field of SCM. They suggest that most companies do not have a good handle on their supply chains. They believe, however, that if one can define the organization's supply chain (which should not be hard to do), then it can certainly measure it. Once "...you begin to measure it, you'll find great opportunities to drive continuous process improvement to it."[41] Bolstorff and Rosenbaum are avid believers in the balanced scorecard (BSC), developed by Robert Kaplan and David Norton, and SCOR Model processes. Most private sector businesses today have been influenced by the BSC approach to developing business metrics. Kaplan and Norton's book, *The Balanced Scorecard: Translating Strategy into Action*, published in 1996, is

	Performance Metrics	Complexity Measures	Configuration Measures	Practice Measures
Plan	- Planning costs - Financing costs - Inventory days of supply	- % of order changes - # of SKU's carried - Production volume - Inventory carrying cost	- Product volume by channel - # Channels - # of supply chain locations	- Planning cycle time - Forecast accuracy - Obsolete inventory on hand
Source	- Material acquisition costs - Source cycle time - Raw material days of supply	- # of suppliers - % of purchasing spending by distance	- Purchased material by geography	- Supplier delivery performance - Payment period - % items purchased by lead times
Make	- # of defects - Make cycle time - Build order attainment - Product quality	- # of SKU's - Upside production flexibility	- Manufacturing process steps by geography - Capacity utilization	- Value add % - Build to order % - Build to stock % - % manufacturing order changes - WIP inventory
Deliver	- Fill rate - Order mgt costs - Order fulfillment lead times - Line item return rates	- # orders by channel - # line items - % of line items returned	- Delivery locations by geography - # of channels	- Published delivery lead times - % invoices with billing errors - Order entry methods

Table 3. Tactical and Operational Performance Measures

	Financial Indicators	Productivity Indicators	Quality Indicators	Response Time Indicators
Customer Response	- Total response time - Cost per customer	- Customer orders per person hour	- Order entry accuracy - Communication accuracy - Invoice accuracy	- Order entry time - Order process time
Inventory Planning and Management	- Total inventory cost - Inventory cost per SKU	- Inventory turns - SKU's per planner	- Fill rate - Forecast accuracy	
Supply	- Total supply cost - Supply cost per purchase order	- Purchase orders per person - SKU's per buyer	- Perfect purchase order %	- Purchase order cycle time
Transportation	- Total Transportation cost - Transportation cost per mile	- Stops per route - Fleet yield - Container capacity utilization	- On-time arrival % - Damage % - Miles between accidents	- In-transit time
Warehousing	- Total warehousing cost - Warehousing cost per piece - Warehousing cost per square foot	- Units per person - Storage density	- Inventory accuracy - Picking accuracy - Shipping accuracy - Damage % - Hours between accidents	- Warehouse order cycle time
Total Logistics	- Logistics expenses - Logistics profit - Logistics asset value - Logistics asset turnover - Logistics capital charges - Total logistics cost - Logistics cost-sales ratio - Return on logistics asset - Logistics value added	- Perfect orders per logistics full-time equivalent	- Perfect order %	-Total logistics cycle time

Table 4. Performance Measures

still one of the most popular texts used for developing measures for both private sector businesses and government entities. The BSC provides executives with a comprehensive framework that translates a company's vision and strategy into a coherent set of performance measures.[42] These measures are typically organized into four different perspectives: financial, customer, internal business processes, and learning and growth.[43] By using these four categories of measures, a company *balances* its approach to things most important across the spectrum of the business. The BSC is also a way to minimize information overload by limiting the number of measures used.[44] As will be seen in the next chapter, the BSC approach is specifically used by the Air Force. Bolstorff and Rosenbaum's consulting techniques include a session on developing a balanced set of supply chain metrics with an associated *SCORcard*.[45] The SCORcard is simply a format of SCOR metrics in which a company inserts its business measures. In a perfect world, the Bolstorff and Rosenbaum metrics would be simple—slice financial and customer data by product to come up with an infinite number of perfectly matched measures. Unfortunately, the large number of measures generated makes this nearly impossible. Hence, they suggest a *SCORcard* be developed and defined around customer, internal, and shareholder data and interests.[46] The SCORcard must be flexible in order to allow companies to make decisions on where to track certain measures. For example, a company may report the profitability measures at multiple layers of the organization and the balance sheet only at the corporate level; or it may track revenue by customer, but costs at the product group level. However, in the end, Bolstorff and Rosenbaum believe the SCOR Model is a proven methodology and provides the best practices in SCM, including metrics development, and therefore, should be used when developing a company's strategic, tactical, and operational measures. Table 5 depicts the set of metrics recommended by Bolstorff and Rosenbaum and is in harmony with the SCC's SCOR Model.

Dr Tom Mentzer, who chairs the Supply Chain Management Department at the University of Tennessee, is one of the most sought after authorities in the supply chain business. He is a noted author and consultant for numerous private companies.[47] His guidance has been used by many corporations in establishing supply chain processes and metrics.

Dr Mentzer suggests that to be successful in the SCM business, companies have implemented what he terms the *twelve drivers of SCM competitive advantage*.[48] The twelve drivers are described as follows:

- Coordinating the traditional business functions
- Collaborating with supply chain partners on noncore competency functions
- Looking for supply chain synergies
- Noting that all customers are not created equal
- Identifying and managing the supply chain flow cycles

Performance Category	Level 1 Metrics	Level 2 Metrics	Level 3 Metrics
Supply Chain Delivery	- Delivery performance - Fill rates - Perfect order fulfillment	- On-time delivery - Manufacturing schedule attainment - Warehouse on-time shipment - Transportation on-time delivery - Forecast accuracy - Supplier match % - Customer match %	- Customer orders delivered on time per total number orders - Customer lines delivered on time - Order shipping accuracy - Other metrics as determined by department
Supply Chain Responsiveness	- Order fulfillment lead time	- Order receipt to order entry - Order entry to order shipment - Order shipment to order receipt	- Delivery date of each order - Other metrics as determined by department
Supply Chain Flexibility	- Supply chain response time - Production flexibility	- Source lead time - Order fulfillment - Lead time for order items - Days required to change labor, material, or capacity	- Lead time for constraint items - Manufacturing cycle times - Order fulfillment times - Other metrics as determined by department
Supply Chain Cost	- Cost of goods - Total SCM costs - Selling, general, and administrative costs - Warranty and return costs	- Direct, indirect, material cost - Order manufacturing cost - Material acquisition costs - Information technology cost - Inventory carry cost - Returns cost	- Cost centers - Customer service cost - Warehouse cost - Transportation cost - Cost to support supply chain - Other metrics as determined by department
Supply Chain Asset Management	- Cash to cash cycle time - Inventory days of supply - Asset turns	- Days payable - Days WIP - Days inventory - Working capital fixed assets	- Accounts payable - Material costs - Accounts receivable - Other metrics as determined by department
Profitability	- Gross margin - Operating income - Net income	- Revenue - Cost of goods - Taxes	- Use level 2 metrics - Other metrics as determined by department
Effectiveness of Return	- Return on assets	- Revenue - Cost of goods - Taxes	- Net operating income - Other metrics as determined by department
Share	- Earnings per share	- Company specific	- Use company formula

Table 5. SCM Performance Measures

- Managing demand in the supply chain
- Substituting information for assets
- Recognizing that systems are templates to be laid over processes
- Realizing that not all products are created equal
- Making yourself easy to do business with
- Not letting tactics overshadow strategies
- Making sure your supply chain strategies and your reward structures are aligned

The last element is where Mentzer focuses attention on measurements. He writes," What gets measured gets rewarded, and what gets rewarded gets done."[49]

His methodology for developing the key logistics measurements starts with strategy formulation. Once the corporate strategy has been determined and is understood, planning should take place. Planning is defined as the deliberate process to produce a specific outcome. It includes the design of the logistics system, taking into account all of the elements needed to be both effective and efficient. Next the business must organize for success. There is not much literature found that identifies an ideal organization or structure for SCM. However, Mentzer suggests that understanding specifically what customers want and their resulting input expectations is fundamental to achieving customer satisfaction and therefore should drive the organizational structure.[50] Once the structure is in place, performance measurements can be developed. The key to the specific measures is to reward the company employees and supply chain partners who act in ways consistent with the business strategies. The performance dimensions should include measures of efficiency, effectiveness, quality, productivity, quality of life, innovation, profitability, and budgeting. Key measures include outbound freight cost, order fill rate, on-time delivery, customer complaints, inbound freight cost, order cycle time, forecast accuracy, invoice accuracy, and equipment downtime.[51] Dr Mentzer believes that there has been no firm evidence of the value of the SCOR approach.[52] He further believes that there is no one set of governing standards that define a business model.[53]

The approaches to SCM practices and measures of these notable authors and experts provide a good understanding of the supply chain techniques and metrics being used in the Air Force.

Air Force Supply Chain Management Metrics

From the MAJCOM perspective, there is an expectation that all kits remain full and back orders be driven to zero. From the Air Staff perspective, it would seemingly be that the Net Operating Result is realized and that metrics do not get any worse. From the AFMC perspective, the expectation should be that the logistics system achieves the level of performance that is consistent with its funding level.[54]

—AFMC Supply Chain Metrics Guide

The challenge facing the Air Force logistics community is to provide the best possible material and services support to the operational warfighter at the lowest possible price.[55] However, the Air Force logistics pipeline is a very complex system of interrelated functions, organizations, and processes, responsible for processing millions of dollars of consumable and reparable assets per day.[56] Effective SCM ultimately relies upon the ability to transform a seemingly limitless amount of information into meaningful and useful measurements to guide the sustainment operations. Properly doing so will optimize Air Force supply chain performance.[57]

Over the years, there have been several recommended approaches to Air Force supply chain metrics. Within the Air Force Materiel Command (AFMC), the Directorate of Logistics (HQ AFMC/A4) is responsible for Air Force-managed depot-level reparable spare parts and Air Force-managed consumable spares. In an effort to determine the right metrics to track, research initiatives were implemented and many different approaches emerged. In 1999, the Logistics Management Institute (LMI) was contracted to study SCM metrics and make recommendations. It recommended applying a balanced scorecard approach to basic industry-oriented performance and cost measures as documented in the SCOR Model.[58] The study specifically recommended a set of performance measures tailored for DoD use.[59] This plan identified a total of 110 metrics at the enterprise, functional, and process level.[60] SCM implementers were encouraged to use these measures when selecting the suite of logistics metrics for the future supply chain environment.[61] In 2001, at the request of the Air Force Deputy Chief of Staff for Installations and Logistics, the Air Force Logistics Management Agency (AFLMA) developed a set of measures. The AFLMA set of metrics consisted of 23 measures in 6 segments of the supply process.[62] In 2003, DoD published DoD Regulation 4140.1-R outlining the requirements and procedures for DoD managers working with the supply system. The regulation directs DoD components to use metrics to evaluate the performance and cost of the supply chain operations.[63] The regulation also directs DoD entities to use the SCOR Model.[64] In November 2003, the AFMC Supply Chain Management Division published the *AFMC Supply Chain Metric Guide*, recommending the most recent supply metrics to be used to manage the supply chain.[65] The *AFMC Supply Chain Metric Guide* highlights 10 metrics, 4 of which are performance measures and 6 of which are process oriented.[66]

Through these several initiatives, significant strides have been made to develop supply chain metrics for DoD activities. Based on what has been considered industry best practices, and highly influenced by the SCC, DoD recommended the BSC and the SCOR Model as the approach to SCM metrics.[67] DoD has actually been investigating the SCOR Model since 1997, and since that time, every branch of service has applied the SCOR Model in some way.[68] The Marine Corps is using it to help consolidate their information systems, the Navy has used it to help benchmark their process performance, the Army has studied its best commercial practices, and according to Air Force supply chain managers, the Air Force has incorporated it in its overall SBPM. The SBPM is the current Air Force initiative to transform the entire SCM process and develop its metrics. So, while the current metrics may not overlay completely with the SCOR metrics, that is certainly the intent for the future.

In the meantime, the Air Force Materiel Command (AFMC) has embraced the BSC as its approach to metrics development. Each air logistics center (ALC) and product center has been directed to develop a BSC which feeds into the Command Scorecard. See Figure 1 for an example of AFMC's balanced scorecard, and Figure 2 for an example of Ogden ALC's balanced scorecard.

Operational level and tactical level metrics are reported at the various levels of management within the organization. These measures reflect a level of indenture below the strategic metrics. Operational measures include weapon system mission capable (MC) rates, total not mission capable for supply (TNMCS), total not mission capable for maintenance (TNMCM), weapon system availability, and operation and sustainment costs. The MC rate is a reflection of the percent of the time the weapon is capable and ready to perform its mission. TNMCS and TNMCM are indicators of the percent of time a weapon system is unavailable because of waiting for parts or a maintenance action. Weapon system availability is a measurement of the number of items (aircraft) that are available and mission capable. Lower level metrics are managed by the respective supply chain managers and tend to blend with operational metrics.

As can be seen, a significant challenge is keeping the metrics simple and to a minimum number, yet making them meaningful such that they provide a picture of the health of the supply chain. Table 6 summarizes the metrics currently used by ALCs.

Comparative Analysis

The Air Force is different from other enterprises in many ways, but not in the most essential ones: You coordinate the work of many people to create products and services that you deliver to customers whose expectations are rising faster than your resources.[69]

—M. Michael Hammer

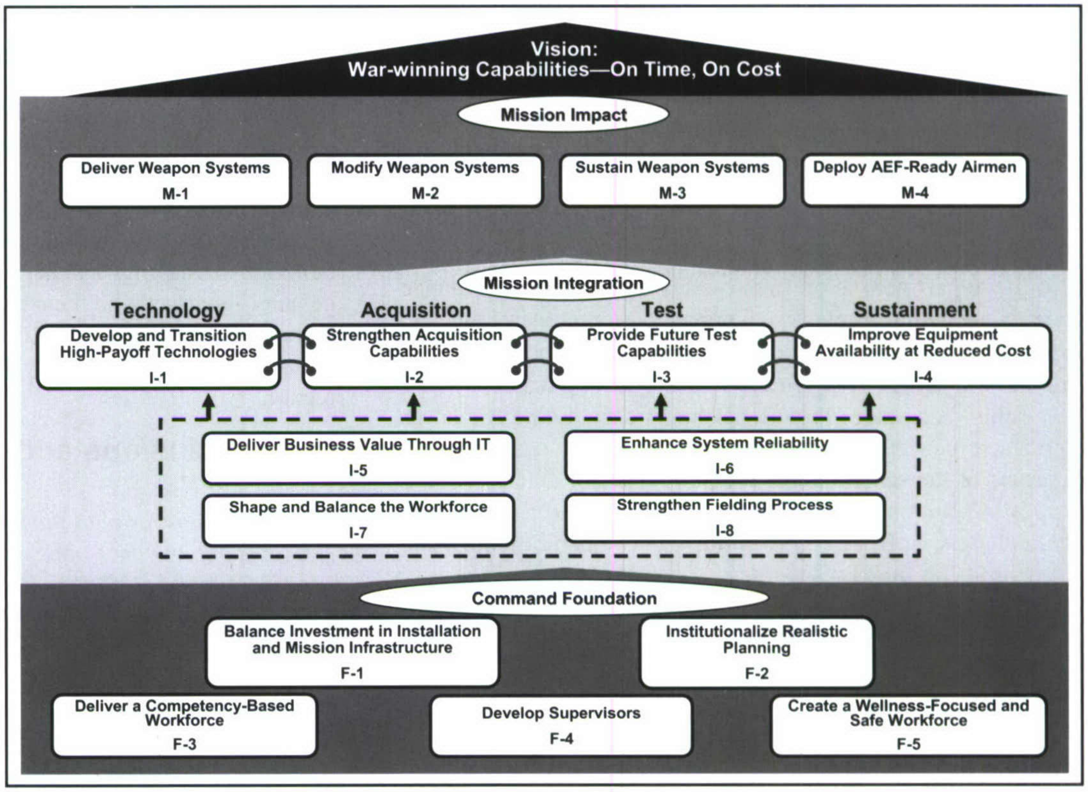


Figure 1. AFMC Balanced Scorecard

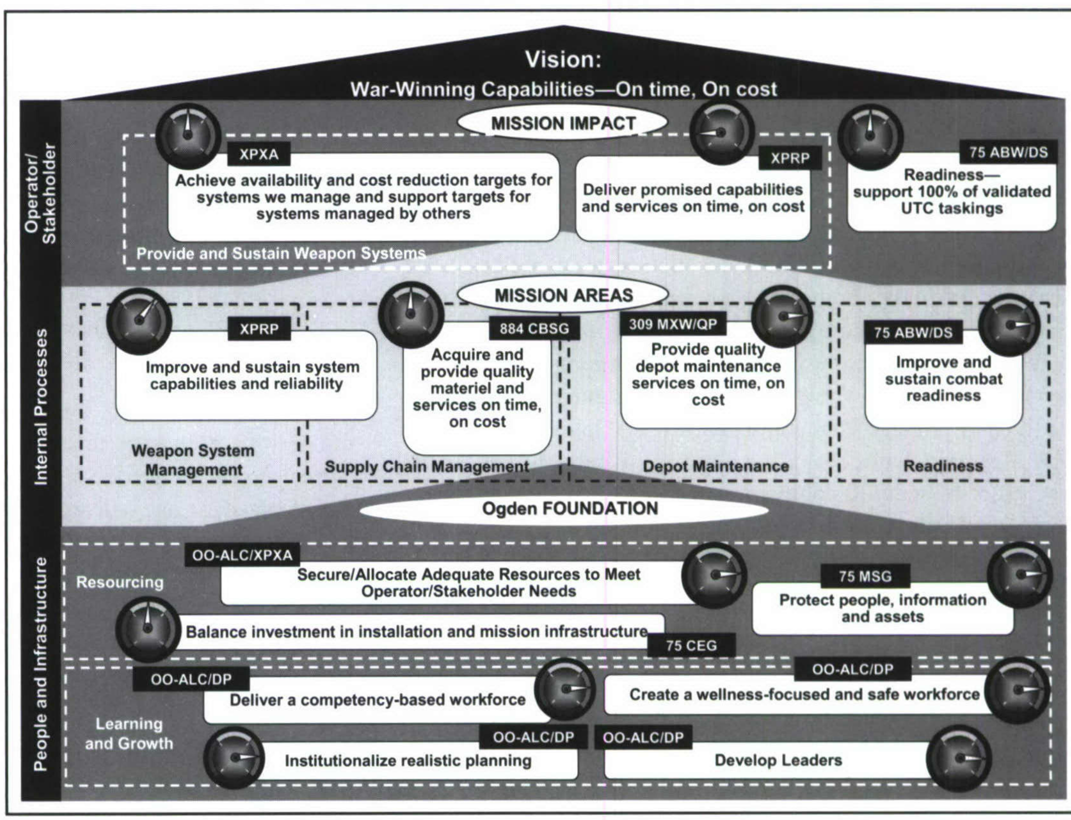


Figure 2. Ogden Air Logistic Center Balanced Scorecard

In order to provide Air Force supply chain managers with valid suggestions on how to manage supply chain performance, a comparison of metrics used by private industry and the Air Force is necessary. While significant differences exist between industry and DoD approaches, there are many similarities as well.[70] The GAO has been assessing and reporting on logistics and supply chain efficiency for several years. In a March 2001 report, it stated that the DoD needs to make more use of supply chain best management practices similar to those used in the private sector to help cut costs and improve customer support, and employ various methods to speed up the flow of parts through the logistics pipeline.[71] Again in 2005, the GAO reported that SCM transformation was an essential element of DoD's business and critical to the success of the department.[72] The report validates that the department is on track with some of its performance metrics, including level of back orders, customer wait time, and orders on time. However, more attention needs to be paid to cost and the implementation of other industry best practices.[73]

Table 7 compares the metrics being used by the Air Force and those being used by several private sector companies. Because of the sensitivity of the private sector data, company names have not been used. Rather, they have been designated by the letters A, B, C, and so forth. The companies represent a wide range of the industry sector, from major aircraft manufacturing companies to household consumer product suppliers and transportation companies. The measures compared are primarily strategic and operational level metrics, and are those most commonly used by several companies. Some companies use slightly different names for the same basic metric. In that case, the most commonly used measure name was used. Since several of the companies are members of the SCC, and their metrics are influenced by the SCOR Model, the SCOR metrics were listed even if not used by a particular company. The data was obtained from a variety of sources. In some cases, data was received informally from company contacts. In other cases, data was obtained from research done by others; however the disclosure of specific company names was not allowed. Some companies' data was received through a third party and therefore inappropriate to release. Again, for these reasons, specific company names are not used.

The data in Table 7 indicates that several organizations, including the Air Force, use similar measures to manage their supply chains. While companies associated with the SCC tend to use the SCOR Model metrics, even they are not consistent in using all of the SCOR recommended metrics. Most companies are very focused on cost and supplier quality. They also are quite focused on tracking downside adaptability, which is an indication of cost when requirements are reduced. Upside flexibility and adaptability are not being used by many supply chain managers, which is surprising since this is a reflection of their suppliers' abilities to meet changing demands, and would seem to be another critical element needing to be managed within the supply chain. Also, few companies seem to be overly interested in the success of their customers, as indicated in both the customer success metric and the availability metric. In an optimal SCM operation, concern would be given for the success of both one's suppliers and one's customers. This trend may change with the growing interest in partnering. Partnerships seem to drive a closer relationship in business aspects of the partners. The data also indicates that little attention is being paid to demand forecasting, another critical element in managing the supply chain. This may not be true. It could simply be that demand forecasting has been difficult to accomplish. Good demand forecasts would enable less supplier adaptability since there would be less variability in the customer orders. Much is being done in the way of systems development to aid in this regard.

Upside flexibility and adaptability are not being used by many supply chain managers, which is surprising since this is a reflection of their suppliers' abilities to meet changing demands, and would seem to be another critical element needing to be managed within the supply chain.

Conclusions and Recommendations

Defense logistics is at the heart of all military operations, from supplying the troops with everything from weapons to food items, logistics is an essential tool for the survivability of the forces. In a changing military landscape where military are transforming the way they fight and what their operational needs will be, the need to become more efficient and effective in the way that operations are supported has led nations to transform the way that material readiness and logistics support is delivered.[74]

—Dr James Finley, Deputy Undersecretary of Defense Acquisition and Technology

Simply put, SCM is the management of all processes and functions necessary to satisfy a customer's order. While the precise metrics needed to measure the supply chain continue to be debated, no one will argue that good measurements are critical in order to successfully implement SCM in the Air Force. In fact, the *DoD Supply Chain Management Implementation Guidebook* specifically calls for "enterprise-wide performance measures" to successfully implement SCM in DoD organizations.[75] The following recommendations are made to further enhance Air Force SCM measurement development:

Recommendation Number 1: Continue to use the SBPM and SCOR

The Air Force has obviously benefited from the work done in the private sector. The current effort underway to shape the SCM process using the SBPM is a result of the SCC's influence. The Air Force fully intends to proceed with the SCOR Model as it maps out the supply chain processes and further defines its metrics. The Air Force should proceed with the use of SCOR through the SBPM process, but should try to accelerate process completion, since history has shown that long, drawn out systems and process solutions rarely succeed. Continued participation in the SCC is also recommended. The SCC offers numerous benefits to the Air Force by providing information on industry best practices, access to leading experts in SCM, and consulting authorities. A study of the companies on the Forbes Magazine's Fortune 1000 list reflected a significant difference in the profitability of companies that are members of the SCC versus those that are not. The bottom line results were nearly two and a half times higher for SCC members than nonmembers.[76]

Recommendation Number 2: Develop metrics that tie to strategic goals, are actionable, and are leading

Metrics should always be tied to strategic goals. The Air Force has done a good job advertising that its strategic goals are to increase weapon system availability and reduce cost. The Air Force needs to stay focused on these goals. Operational goals need to tie to the strategic goals. For example, mission capability hours and customer wait time directly relate to weapon system availability. These measures are actionable but somewhat lagging. Once they go *red*, it is difficult to reverse the trend.

Additional metrics, such as perfect order fulfillment, demand forecast, inventory, and upside and downside flexibility should be incorporated in the Air Force suite of metrics. These metrics would be actionable and provide supply chain managers better information to manage the logistics business. A common complaint from supply chain managers is that it is difficult to predict or forecast material usage and therefore a faulty plan becomes the major impediment for successful supply chain implementation. The implementation of the Expeditionary Combat Support System (ECSS) will incorporate the necessary software to better forecast requirements. However, supply chain managers cannot afford to wait until the implementation of ECSS. Industry uses buffers as well as upside and downside supply chain flexibility and adaptability metrics to compensate for fluctuations in requirements. The Air Force should incorporate these metrics and continue with corporate contracts and commodity councils to measure and track changes in demand.

Recommendation Number 3: Continue to implement Lean and Six Sigma practices to improve the supply chain.

Implementation of Lean and Six Sigma practices are a proven technique to improving processes. Many seem to believe that Lean practices only work in an industrial area, however, there are numerous examples of Lean successes in administrative and other areas. In fact, at the Ogden Air Logistics Center, a Lean team was established to attack the highest driver impacting the F-16 MICAP, the radar antenna. The team consisted of maintenance personnel, facilities and process engineers, production planning and scheduling technicians, supply technicians, and the supply chain manager. Prior to the establishment of the team, there were 105 radar antenna MICAPs, 180 back orders, production flow times were at 28 days, and work in process (WIP) was 67. In less than a year, the team had reduced MICAPs and back orders to zero, flow times had been reduced by 90 percent, and work in process was down to just 6 items. The supply chain manager was instrumental in implementing initiatives to provide the production line with needed parts, as well as making other changes which improved the mean time between failure by 36 percent, causing the antenna to remain in use longer before needing overhaul. The SCC recognizes the value of Lean and now hosts a SCOR/Six Sigma/Lean Convergence Forum which is designed to help attendees

Performance Metrics	Level 1 (Strategic)	Level 2 (Operational)	Level 3 (Tactical)
Net Operating Results	X		
Deficiency Report	X		
MICAP Hours	X		
Customer Wait Time	X		X
MC Rates		X	X
TNMCS		X	X
TNMCM		X	X
System Availability	X	X	X
O&S Costs	X	X	X
Issue Effectiveness			X
Demand Forecast			X
Back Order Age			X
Cost of Goods Sold		X	X

Table 6. Air Force SCM Performance Measures

Organization	AF	A	B	C	D	E	F	G	H	I	J	K	L
Measurement													
Perfect Order Fulfillment		X	X								X		X
Order Cycle Time	X	X	X	X	X	X	X	X	X	X			X
SCM Cost	X	X	X	X	X	X	X	X	X	X	X	X	X
Cost of Goods Sold	X	X	X	X	X	X	X	X	X	X	X	X	X
Demand Forecast		X									X		X
Issue Effectiveness	X	X	X	X	X	X	X	X	X	X			X
Fill Rates	X	X	X	X	X	X	X	X	X	X	X		X
Back Order Average Age	X	X	X	X	X	X	X	X	X	X	X		
Inventory Turns		X	X									X	X
Supplier Quality	X	X	X	X	X	X	X	X	X	X		X	X
Supplier On Time Delivery		X	X									X	X
Customer Success and MC	X		X									X	
Upside Supply Chain Flexibility													X
Upside Supply Chain Adaptability													
Downside Supply Chain Adaptability		X	X	X	X	X	X	X	X	X		X	X
Inventory Days of Supply		X											X
Cash-to-Cash Cycle Time											X	X	X
Availability	X		X										
Member of Supply Chain Council	X	X	X				X	X	X			X	X

Table 7. Comparisons of Metric Usage

understand how SCOR, used in conjunction with Lean and Six Sigma techniques, can assist managers in getting better results across the entire supply chain. The Air Force should implement Lean techniques within the supply chain to get quick successes. While the SBPM, PSCM, and ECSS offer the opportunity for long term transformational gains, Lean offers a methodology for significant improvements in both the short run and long run, and supports the Air Force Smart Operations for the 21st Century initiative.

Recommendation Number 4: Tie appraisal performance awards to successful management of SCM metrics

While it may be difficult to do, appraisal awards should be tied specifically to supply chain performance. Because of the many variables which affect supply chain performance, leaders are hesitant to specifically tie awards to performance of the supply chain. Typically, individuals are rewarded for working hard and doing an apparently good job, regardless of how the supply chain reacts. A more focused effort should be made to tie the two together. The National Security Personnel System should also have a positive impact linking pay to performance.

Recommendation Number 5: Focus on real-time training for Supply Chain Managers

Supply chain managers have complained that training is not real time. The Air Force invested a significant amount of money in training those involved in the supply chain business, but the value of the training was minimized because the systems, processes, and methodologies were not in place to implement the training received. The Air Force should develop training modules that coincide with supply chain transformation implementation efforts. This would enable supply chain managers to immediately implement the efforts being fielded.

Conclusion

In summary, there are numerous definitions of SCM, but simply put, it is the management of all processes and functions necessary to satisfy a customer's order. While there appears to be no one, agreed-upon solution to the most successful SCM processes and measurements, there are some basic best practices. Air Force SCM processes and metrics are not perfect, but, for the most part, they are on track. The use of SCOR is having a significant impact in both the public and private sectors, which is evidenced by the numbers and types or organizations that are members of the SCC. The Air Force Materiel Command has chosen a very complex process, the SBPM, to achieve SCM transformation. The SBPM should be worked in concert with the Air Force Global Logistics Support Center (GLSC). Staying focused on the strategic goals of the Air Force, and developing actionable and leading metrics will be critical to the success of SCM improvement.

Future Research

During this study, a number of potential research opportunities came to light. The following are a few that may be considered:

- The impact of supply chain software in producing positive results for companies with successful supply chains. There is a need to investigate whether the improvement in supply chain performance is worth the investment cost of the system software.
- Expanded studies on the specific metrics used by successful companies in the supply chain business. This should include the factors influencing the success or failure of attempts to implement measurement systems for supply chains.
- An assessment of the characteristics of companies with successful supply chains, including their best practices. From this, draw out the qualities needed for companies to be successful in the future.
- Assess the effectiveness of current Air Force initiatives, such as the GLSC and the SBPM. Since both are new, their success is unknown at the present time.

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Supply chains cannot tolerate even 24 hours of disruption. So if you lose your place in the supply chain because of wild behavior you could lose a lot. It would be like pouring cement down one of your oil wells.

—Thomas L. Friedman

Cannibalization is a quality-of-life issue.

—Lt Gen Michael E. Zettler

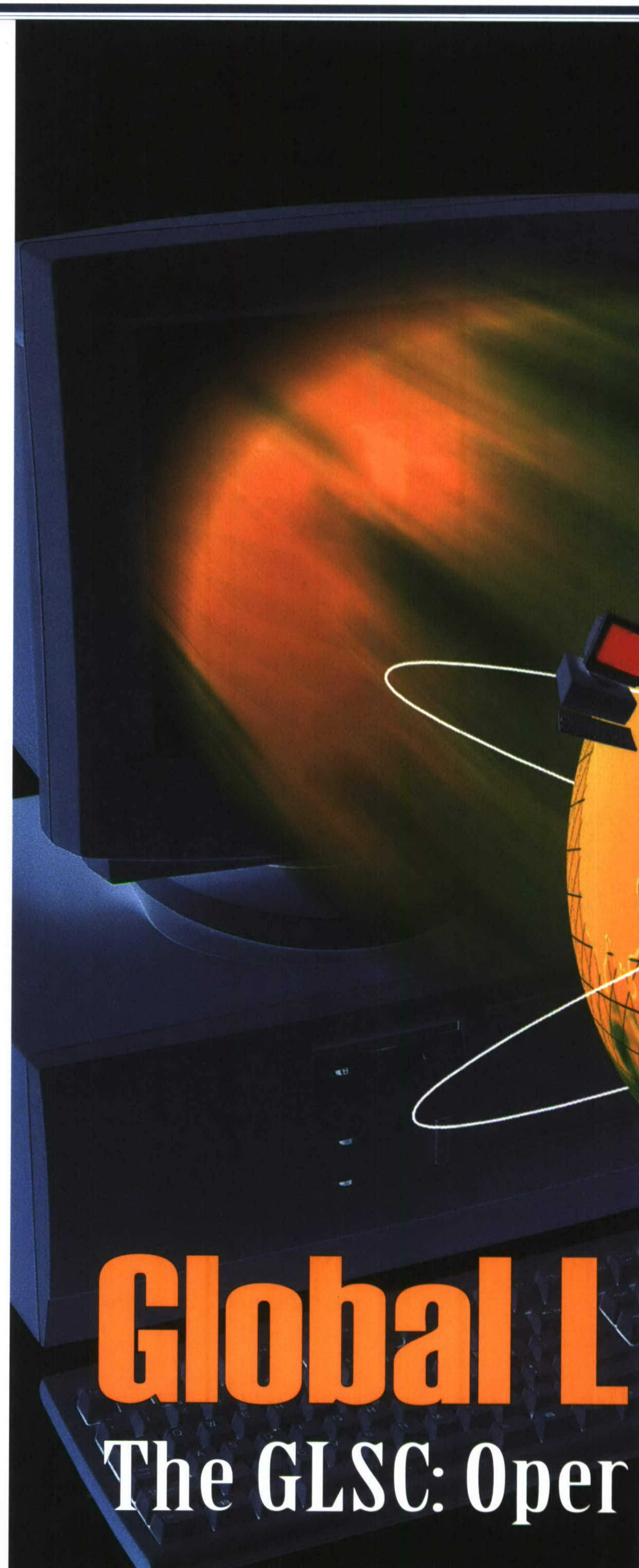
Bringing supply chain integration to reality will transform Air Force supply management.

—Brig Gen Robert Mansfield,

Special Feature

Global L

The GLSC: Oper



The Global Logistic Support Center (GLSC), a new center that will stand up in fiscal year 2008, will be the supply chain manager for the Air Force. The GLSC will support a concept of operations which integrates supply chain (SC) processes into a single end-to-end enterprise which, combined with other key logistics initiatives, will help the Air Force meet its Expeditionary Logistics for the 21st Century (eLog21) goals of reducing SC operating costs by 10 percent and improving aircraft availability by 20 percent.

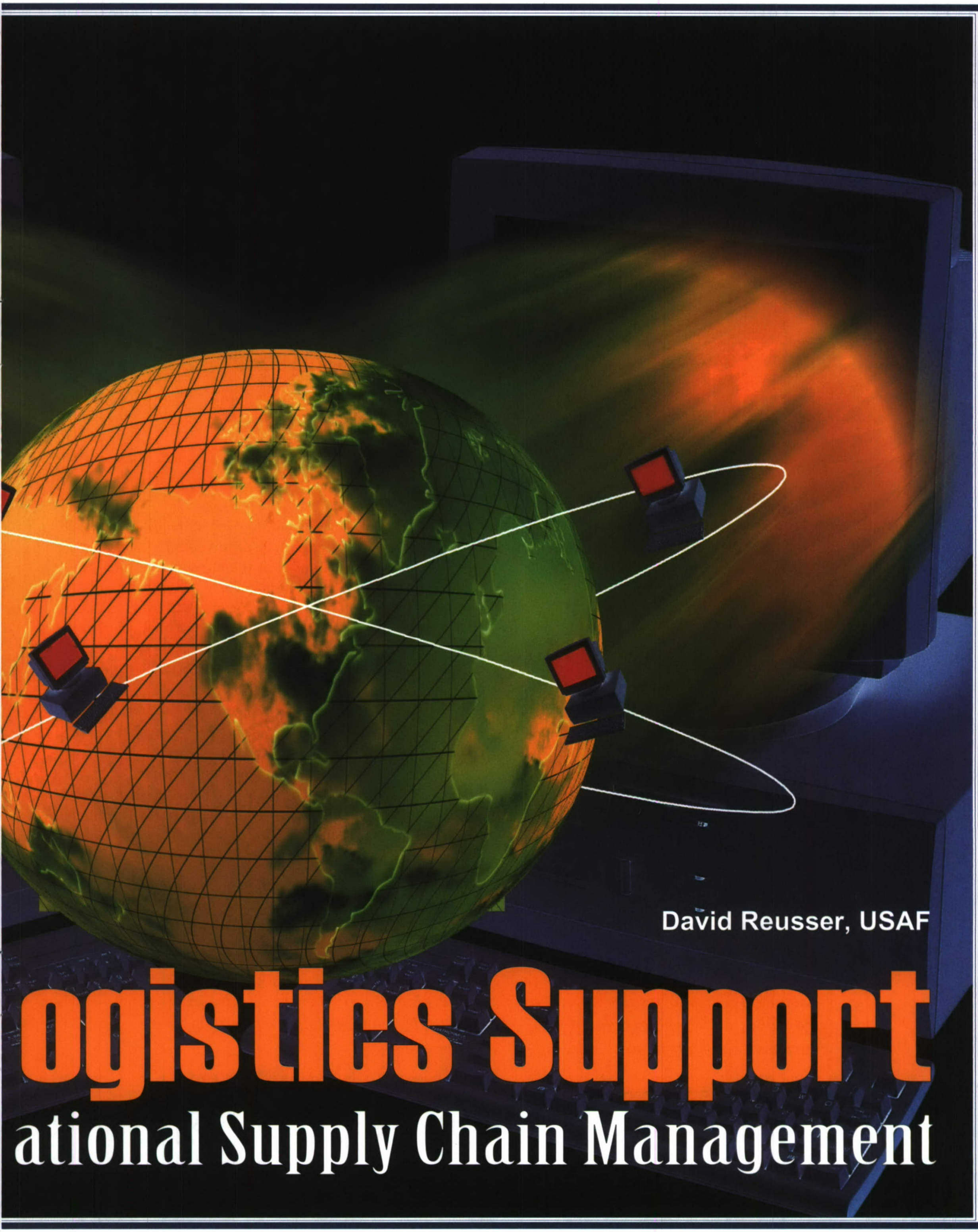
The GLSC Provisional (GLSCP) Office has been working for the past several months to develop a roadmap for standing up the GLSC organization, and to determine its initial operational capability processes. The GLSC will be organized around three main supply chain functions: supply chain planning and execution (SCPE), supply chain operations (SCO), and supply chain strategy & integration (SCS&I). Each of these functions has been translating the strategic direction contained in Headquarters United States Air Force Program Action Directive 07-01 into specific actions which will need to occur to successfully stand up the GLSC capability.

The two most important points are that the GLSC will be an *operational center,* and the vast majority of the people in the GLSC will remain at their current operational locations. The GLSC will be a highly virtual organization with six operating locations across the United States (Langley AFB, Hill AFB, Tinker AFB, Scott AFB, Robins AFB and Wright Patterson AFB). There will also be a small GLSC headquarters collocated with the SCO Wing at Scott AFB. The GLSC Headquarters *proper* will be a lean, small staff of about 16 people who will perform the following functions:

- Ensure the GLSC is focused on warfighter operations
- Provide functional managers for the GLSC
- Support functional personnel
- Work memos of agreement for all necessary support relationships
- Provide a point of entry for GLSC updated procedures and guidance
- Coordinate all taskings in and out of the GLSC

Article Acronyms

CAF – Combat Air Forces
eLog21 – Expeditionary Logistics for the 21st Century
GLSC – Global Logistics Support Center
GLSCP – GLSC Provisional Office
MAF – Mobility Air Forces
P&E – Planning and Execution
SC – Supply Chain
SCM – Supply Chain Management
SCO – Supply Chain Operations
SCPE – Supply Chain Planning and Execution
SCS&I – Supply Chain Strategy and Integration
WPAFB – Wright-Patterson Air Force Base



David Reusser, USAF

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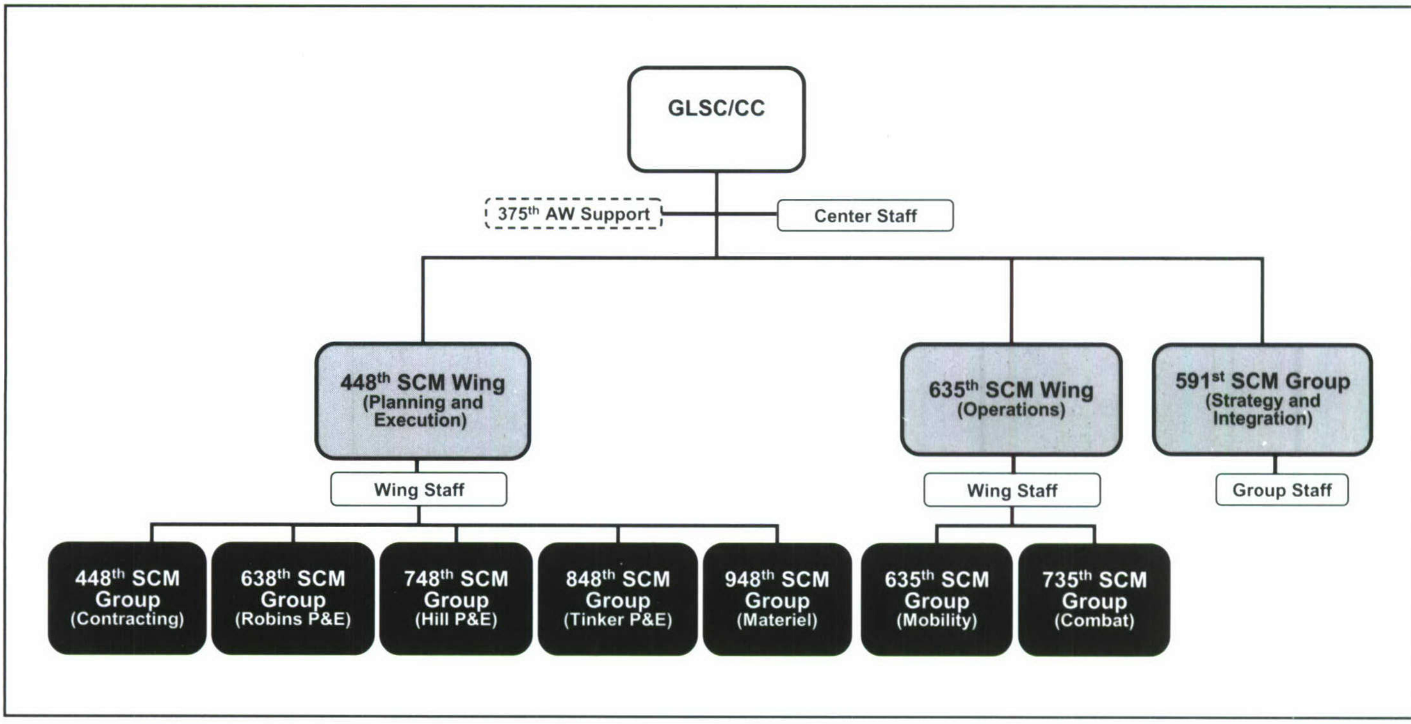


Figure 1. GLSC Organization Structure

Much of the support for this small headquarters proper will come from the 375th Air Base Wing at Scott AFB.

People in the SCS&I (group) will be located at Wright-Patterson AFB (WPAFB)—that includes both the leadership and actual workers (approximately 200 people). Most of the people are currently located at WPAFB where they perform the majority of the current SCS&I functions. A small headquarters staff of approximately five people will also reside at WPAFB. This arrangement provides a direct connection with the Headquarters Air Force Materiel Command (HQ AFMC) functional staff and ensures integration with other eLog21 initiatives [Repair Enterprise 21, Centralized Asset Management, Expeditionary Combat Support System (ECSS), and others]. See Figure 1.

People in the SCO (wing) will be located at Scott, Langley, Robins, Tinker, and Hill AFBs. Overall staffing will be approximately 1,000 people, with the vast majority remaining at their respective Combat Air Forces and Mobility Air Forces Logistic Support Centers and the three AFMC Air Logistic Centers. A small headquarters staff of approximately five people will also reside at Scott AFB. This organization will ensure fast, effective customer support across the Air Force Enterprise.

People in SCPE (wing) will be located at Robins, Tinker, and Hill AFBs. Overall staffing will be approximately 3,300 people, with the majority remaining at their respective operating locations. A small headquarters staff of approximately five people will reside at Tinker AFB. This structure will provide direct interaction with the system program directors and system program managers at each center for requirements identification in order to ensure realistic and flexible enterprise planning. See Figure 1.

Colonel H. Brent Baker, Sr, GLSC(P) commander, related, "Knowing that the GLSC will be a virtual organization and the commander can't be at all locations, he or she really needs to be close to the warfighter and located where time sensitive decisions are most critical." He went on to say, "We must also remember the key attribute for the GLSC, as the Air Force's enterprise supply chain manager, is to function as an *operational* unit."

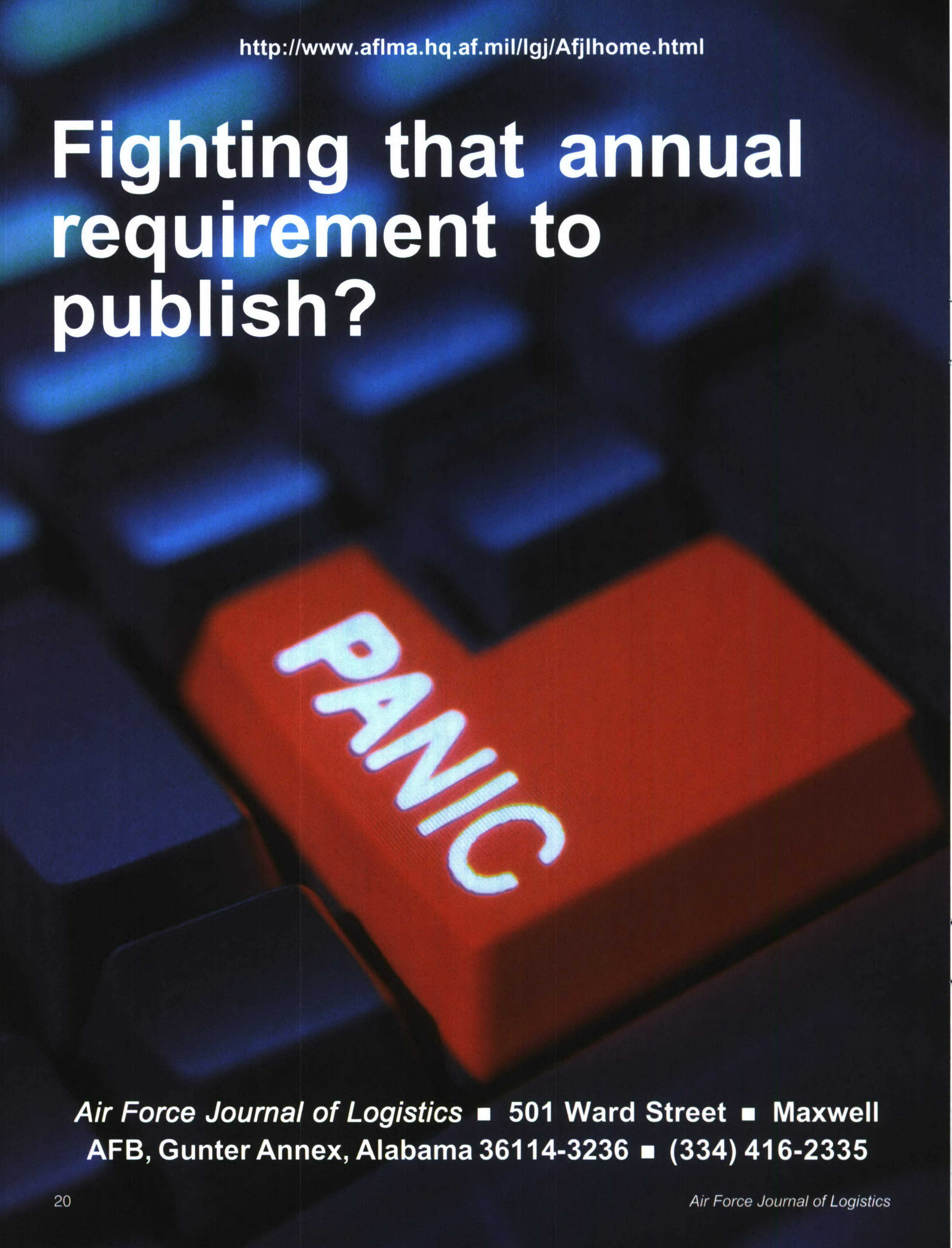
David Reusser is Lead for Change Management at the GLSC Provisional Office, Wright-Patterson AFB, OH. He has worked as an analyst and consultant for the Air Force, Navy, Army, and Department of Transportation.

Sound logistics forms the foundation for the development of strategic flexibility and mobility. If such flexibility is to be exercised and exploited, military command must have adequate control of its logistic support.

—Adm Henry E. Eccles, USN

He who will not apply new remedies must expect new evils; for time is the greatest innovator.

—Viscount Francis Bacon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An enterprise-wide continuous process improvement framework makes it possible for various cross-functional efforts linked together through a governance structure to create synergy.

contemporary issues

ACS: A Royal Australian Air Force Perspective
AFSO21: A Case Study in Process Improvement
DLA Forward Stocking: An Economic Analysis

Contemporary Issues in this edition presents three articles: "ACS: A Royal Australian Air Force Perspective," "AFSO21: A Case Study in Process Improvement," and "DLA Forward Stocking: An Economic Analysis."

In "ACS: A Royal Australian Air Force Perspective" Wing Commander Scott Winchester, RAAF, makes the case that continuing to further improve ACS interoperability between the USAF and RAAF is in the interest of both air forces, with ACS being a fundamental enabler of air operations. The more interoperable ACS capabilities are regardless of whether the USAF or RAAF is the lead or contributing air force in a coalition, the more responsive and agile the combat support arrangements available to support the warfighter. The USAF and RAAF share a high level of commonality regarding ACS principles, with flexibility, adaptability, and scalability being critical factors of how we provide combat support.

Master Sergeant Kimberly A Fiato, USAF, in "AFSO21: A Case Study in Process Improvement" provides a comparative analysis of AFS021 with private sector continuous process improvement (CPI) concepts. The article begins with an external environment analysis which provides a foundation from which to identify external forces driving Air Force transformation and continuous improvement efforts. Next, a content review of Air Force doctrine and CPI case studies provides a frame of reference for a comparative analysis. Finally, the article concludes by summarizing the CPI similarities and differences among various private sector industries.

Previous research has investigated the feasibility of forward stocking relatively expensive, Air Force-managed parts and concluded that forward stocking was not economical. Currently, DLA only forward stocks an item if it has four-or-more demands in a year. The criteria's intent is to ensure only high-use items are stored in-theater. In "DLA Forward Stocking: An Economic Analysis" the authors expand on previous efforts by considering the feasibility of forward stocking inexpensive, DLA-managed parts according to current DLA criteria, and additional criteria developed through the research. A general methodology is presented to model and evaluate the performance of forward stocking. Although the methodology is applicable to any potential theater, only United States Air Force Central Command with storage at Defense Distribution Depot Kuwait, is considered in detail.

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ACS: A Royal Australian Air Force Perspective

Wing Commander Scott Winchester, RAAF

Introduction

The United States Air Force (USAF) and the Royal Australian Air Force (RAAF) share a long and proud history of cooperation and professional interaction since the Second World War. Our respective Services have been fighting side by side for many decades, from the Pacific theatre when our respective aircrews flew combat missions together over New Guinea in the dark days of 1942, to the Korean conflict, Vietnam, and the current Middle-East area of operations. Our nations are extremely close allies and friends, sharing a bond forged closer as a result of the Global War on Terror.

The fluid strategic environment since the Cold War has resulted in USAF and RAAF becoming agile and expeditionary-focused air forces capable of providing a wide range of rapid response options. The effective provision of Agile Combat Support (ACS)[1] to protect and sustain Air Force elements is fundamental to generating airpower and is a significant enabler for a balanced, expeditionary Air Force. The USAF ACS Concept of Operations (CONOPS) is one of seven Air Force CONOPS and is the foundational combat support CONOPS of that Air Force.[2] The level of combat support must be consistent with the operational requirement, and needs to be flexible and responsive. Furthermore, the likelihood of coalition operations is very high, with close cooperation and interoperability between coalition forces vital to generate and sustain airpower. ACS capabilities must be able to incorporate Joint and coalition elements into a USAF, RAAF, or other coalition member-led force.

The USAF and RAAF could expect to join a coalition as either the lead air force or as a contributor. Coalition partnerships prosper when there is a sound understanding of each others capabilities, with different air forces bringing important specialist capabilities to the fight. Hearing another perspective on ACS also expands our own understanding of this important force enabler; what aspects are shared, and what aspects are done differently.

The aim of this article is two-fold: first, outlining how ACS is provided at the tactical level by RAAF, providing a smaller Air Force perspective on ACS and second, outlining ACS interoperability issues between the RAAF and USAF.[3] The article initially outlines the broad principles regarding Australian Defence Force (ADF) airbase doctrine, providing a brief outline of how RAAF is structured to deliver airpower, describing the role and structure of the Combat Support Group (CSG), and outlining the expeditionary combat support capabilities RAAF can bring to the fight. The article then outlines the key points of RAAF tactical level ACS, before detailing recent RAAF operational experience, and the exercise and training hierarchy. The RAAF ACS capability management structure is then briefly explained. Finally, this article details ACS interoperability issues between RAAF and USAF, and outlines the writer's own reflections from working with USAF.


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Discussion

Airbase Doctrine

Australian Defence Force Publication 3.15 (ADDP 3.15), *Airbase Operations* (provisional release) provides the doctrinal framework regarding airbase operations for the ADF, detailing the roles and functions of an airbase, its infrastructure, and force protection requirements to generate airpower and sustain operations.[4] ADDP 3.15 emphasizes airbases are:

- Weapons systems to generate, operate, and sustain airpower missions,
- Pivotal Joint capability that can support a range of operations from special operations; surveillance and reconnaissance; entry, exit, and sustainment points for land operations; and evacuation points. An airbase may need to support one or any combination of operations concurrently.

An airbase needs to be a safe, secure, and effective platform to conduct air operations. With airbase support being operational in nature, it should not be confused with *support* as defined under logistics or other military doctrine.

Delivery of RAAF Airpower

First, let me provide some perspective. The RAAF's permanent force (active duty equivalent) is 13,500 personnel, with approximately 2,500 reservists.[5] Air Command is the RAAF warfighter major command equivalent, responsible for raising, training, and sustaining Air Force capabilities provided to a Joint Force Commander. Air Command is organized into six force element groups (FEGs).[6]

- Air Combat Group operates F/A-18 fighter, F-111 strike, and Hawk jet training aircraft. F/A-18F Block II Super Hornet aircraft will replace the F-111 fleet after 2010. Australia is a Joint Strike Fighter (JSF) project partner.
- Air Lift Group operates the C-17, C-130, B-707, Caribou, and the VIP aircraft fleet, and is receiving KC-30B refueller/strategic airlifters in the future to replace the B-707.
- Surveillance and Response Group (SRG) operates maritime P3C aircraft, and commands the air defence and air traffic control elements, and will receive airborne early warning and control aircraft in the next few years.
- Air Force Training Group is responsible for air and ground training.
- Aerospace Operations Support Group is the research and development FEG.
- CSG is the designated FEG providing ACS for RAAF, commanding the airbases, providing airbase combat support services, and Air Force expeditionary combat support capability in either a Joint or coalition environment.[7]

Combat Support Group

CSG's mission is to provide the ADF with a secure, fully functioning expeditionary airbase capability in either a Joint or coalition environment. CSG provides a range of flexible combat support (FCS)[8] capabilities to meet these requirements, including the provision of services on fixed airbases within Australia. FCS is a fundamental enabler for ADF and RAAF air operations, similar in nature to the way ACS provides the foundation for USAF operations. CSG has 3,300 personnel (25 percent of RAAF uniformed manpower), operates 13 airbases, 3 bare bases, 15 air weapons ranges, and is organized into 3 wings and has 22 squadrons. Refer to Figure 1.

CSG is commanded by a one star officer, with headquarters staff being responsible for the raise, train, and sustain functions of the group. The Combat Support Coordination Centre is the single point of contact for higher headquarters regarding the group's combat support planning and coordinates taskings and activities for the commander. CSG units are organized into 3 wings; 395 and 396 Expeditionary Combat Support wings (ECSW) and Health Support Wing (HSW), each commanded by an O-6. HSW provides the RAAFs medical, dental, environmental health and aeromedical evacuation (AME) capabilities. 395ECSW controls the southern Australian airbases and specialized airfield defence squadrons. The northern airbases, the combat support element located at Butterworth airbase in Malaysia, and the specialist combat support units (combat communication squadron and airfield operational support squadron) are controlled by 396ECSW.

Expeditionary combat support squadrons (ECSS) form the cornerstone of RAAF expeditionary airbase activation and sustainment capability. ECSSs have a dual role, providing ACS at home base and providing an expeditionary combat support capability. Personnel from the specialist combat support units are usually attached to a deploying ECSS or a combat support element to provide an expeditionary airbase ACS capability. The skill sets and professional competencies of ECSS and specialist unit personnel are developed and maintained at home base and

Article Acronyms

ACS – Agile Combat Support
ADDP – Australian Defence Doctrine Publication
ADF – Australian Defence Force
AEG – Air Expeditionary Group
AME – Aero Medical Evaluation
AOR – Area of Responsibility
ASNR – Air Senior National Representatives
BIAP – Baghdad International Airport
CONOPS – Concept of Operations
CSG – Combat Support Group
CRG – Contingency Response Group
C2 – Command and Control
CSSG – Combat Support Sub-Group
ECSS – Expeditionary Combat Support Squadrons
ECSW – Expeditionary Combat Support Wing
FCS – Flexible Combat Support
FEG – Force Element Groups
HSW – Health Support Wing
HQ CSG – Headquarters Combat Support Group
ITV – In-Transit Visibility
PACAF – Pacific Air Forces
RAAF – Royal Australian Air Force
RFID – Radio Frequency Identification
SRG – Surveillance and Response Group
TAV – Total Asset Visibility
TU – Task Unit
TTP – Tactics, Techniques, and Procedures
USAF – United States Air Force
WSP – Weapon System Plan

then used in the expeditionary environment. By way of comparison, generically and on a smaller scale, an ECSS combines the role and function of a USAF contingency response group (CRG) and air expeditionary group (AEG).

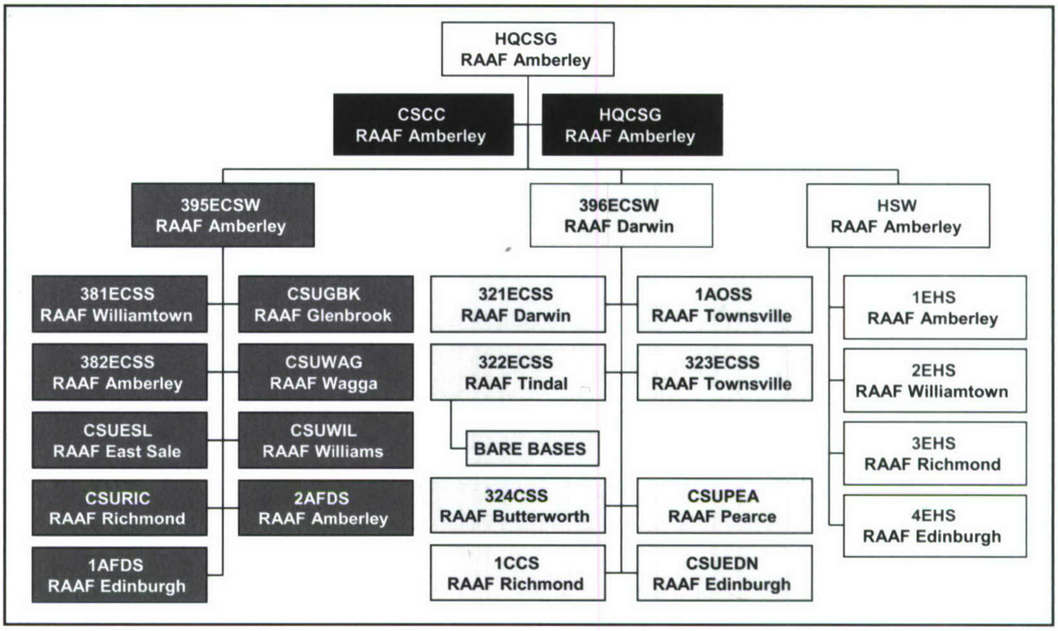

Figure 1. RAAF CSG Organization

RAAF ACS Capabilities

The CSG CONOPS emphasizes flexibility, adaptability and scalability, with CSG ACS functional capabilities structured into nine *capability bricks* which can be combined and tailored, depending on the circumstances, to provide a flexible and scalable combat support package to meet a wide variety of tasks. The ACS capability bricks are: [9]

- Command and control (C2) including command of the airbase and emergency response capabilities, providing support to wing operation centre and joint force air component commander elements, coordinating allocation of airbase facilities and estate, liaising with local and civil authorities, and coordinating air and ground safety.
- Airbase operations support consisting of air traffic control (personnel provided by SRG), airfield navigation and landing aids, foreign object damage control, communications and information systems, ground support equipment, and evacuee handling.
- Airbase force protection involving airbase security, access control, and patrolling agreed tactical area of responsibility.
- Airbase logistics support covering air terminal services, storage and distribution of all classes of supply, vehicles, inventory management, catering, and messing.
- Airfield engineering including maintaining airfield movement surfaces and lighting, base utilities, facility maintenance, airfield surveys, and passive defence works.
- Health and safety, providing health care, casualty evacuation, AME, environmental health, aviation medicine, dental, and psychology services.
- Emergency response and recovery including airfield emergency, rescue and fire fighting, explosive ordnance disposal and improvised explosive device response, and post-attack recovery.
- Administration and coordination covering personnel and welfare services, chaplaincy, physical training, legal, disciplinary, postal, and conditions of service.
- Force Preparation involving preparing air component elements for deployment.

CSG ACS capabilities are wide ranging from activating, protecting and sustaining an expeditionary airbase to providing specialist ACS capabilities that can *plug and play* with other ADF elements or coalition forces. Each expeditionary task is usually different, and CSG tailors a combat support package to support each specific mission. Important determinates for the capability and size of the combat support element include the operational task that can vary from activating an airbase to providing a specialist capability, location of the mission, available infrastructure, coalition and host nation support, unique mission requirements, threat level and environmental factors, expected mission duration and sustainment considerations, and higher level constraints (for example, resource cap).

Key Points of RAAF ACS

CSG is a significant enabler to RAAF as a balanced expeditionary air force capable of achieving the Australian government's objectives. ACS principles form the cornerstone of how CSG conducts business, with the group having to be flexible and adaptable to quickly respond to a wide range of Joint and coalition operational tasks. The following key points detail how RAAF provides combat support:

- A specific organization, Combat Support Group, providing airbase combat support at RAAF fixed airbases, and primary responsibility for providing expeditionary airbase ACS capability in either a Joint or coalition environment.
- Appointing a base commander with responsibility for *fighting the airbase*, ensuring effective delivery of combat support to all airbase activities. The base commander is charged with providing a safe, secure, and effective airbase by commanding the airbase including the provision of infrastructure and support services, controlling airbase services, and commanding airbase force protection and emergency response. In an expeditionary environment, the deployed ECSS commanding officer or senior ECSS officer would be appointed the base commander, and may not be (and usually is not) the senior officer on the airbase.
- One airbase may support many users ranging from air combat, mobility, surveillance, evacuee handling, special operations, to land and maritime forces. Therefore, an airbase may need to support a full range of capabilities.
- ACS functions divided into a *capability brick* construct providing tailorable response options to meet specific mission needs.

- Possessing ACS capabilities able of performing a wide range of airfield services to providing specialist capabilities that can plug and play into other ADF and coalition forces.
- Expeditionary ACS units employing a rotational online concept to respond to *short notice to move* taskings.

CSG Operational Taskings

CSG has maintained a very steady operational tempo since formation in 1998. For example, CSG elements have:

- Deployed to East Timor and the Solomon Islands to activate airfields in support of peacekeeping operations
- Activated a bare base to support P3C Orion aircraft surveillance operations to counter illegal immigration into Australia
- Supported fighter, airlift, surveillance, air traffic control, medical, and training missions in the Middle-East area of responsibility (AOR)
- Provided humanitarian assistance after the Asian tsunami and Pakistan earthquake.

These operations have indeed ranged from activating airfields, supporting ADF task groups forming part of a larger coalition force, to providing specialist ACS capabilities in support of humanitarian assistance.

CSG ACS Training

In addition to operational commitments, CSG has frequent exercise and scheduled training requirements. Intra-unit-level training focuses on individual and career field specific professional competencies, and collective unit exercises concentrate on ensuring personnel and equipment are ready to meet online preparedness requirements and improving expeditionary related competencies. Wing level exercises validate tactics, techniques, and procedures (TTP), measure compliance to wing standard operating procedures, and consolidate individual and collective expeditionary related skills. The emphasis of ADF level and multinational exercises such as Exercises Pitch Black and Talisman Sabre is joint and combined cooperation and interoperability.

ACS Capability Management

RAAF has a formal mechanism to manage and enhance its ACS capability. The FCS Capability Plan is one of four Air Force capability plans, and is the strategic level ACS related capability master plan outlining RAAF current combat support capabilities and what future capabilities are required. Headquarters CSG manages the *CSG Weapon System Plan* (WSP) providing the group's road map for new and enhanced combat support and airbase capability at the operational level. The WSP outlines existing and future capability requirements and reflects the commander's capability priorities. Each functional lead staff officer within HQ CSG (force protection, engineering, logistics, and so forth) are capability functional managers, each maintaining their own WSP subplans, providing a more detailed list of ACS related capability requirements. Subplan requirements are fed into the CSG WSP. The wings and squadrons within CSG are the ACS capability providers, and can raise submissions to identify and assist in overcoming ACS capability deficiencies. Accordingly, ACS capability enhancement can be driven both ways, from the top down by RAAF Headquarters or HQ CSG, or bottom up by the ACS capability providers.

Coalition ACS Interoperability

Modern military operations usually involve air forces working as part of a Joint or coalition force. The ADF may lead coalition operations in Australia's region, or may be a junior coalition partner in operations further afield. Therefore, interoperability is a key component of ensuring coalition forces gain maximum benefit from each contributor and ensuring the collective combat power of coalition forces is effectively utilized. Interoperability needs to occur across a range of areas including people; equipment; terminology; and TTPs. Interoperability needs to work both ways, between senior and junior coalition partners, and is always a challenge being easier said than done. Additionally, the writer appreciates USAF, as the world's most powerful air force and usually the lead contributor to a large coalition force, has to look at interoperability across the full spectrum of allies and coalition partners.

So in what aspects of ACS is interoperability important? The following subparagraphs outline ACS related interoperability issues the writer believes are critical in a coalition environment:

- **C2.** All coalition partners need to plug into the airbase or headquarter C2 network to ensure situational awareness and maintaining a common operating picture, to coordinate and control mission assets, force protection and emergency response components of an airbase. C2 links may be formal or informal depending on the situation. USAF commanders also need to be aware that, in addition to any coalition joint task force C2 linkages, RAAF commanders will also have an Australian national command line.
- **Communications.** To work together effectively coalition partners need access to the appropriate communications networks, whether it be information technology systems (unclassified and classified), radio net, landline, and so forth. Communication systems should be placed in respective work areas to ensure instant connectivity, or if not practical to do so, in a location readily accessible to users. Therefore, coalition requirements need to be factored into airbase and headquarters communication system plans.
- **Information Sharing.** Access to classified information and systems may cause problems, particularly if a coalition consists of numerous partners. Although RAAF is usually given privileged access to classified *need to know* information, the lowest common denominator is sometimes applied to coalition partners, restricting the smooth flow of information. Coalition partners also need to uphold their own responsibilities by ensuring their personnel possess the appropriate security clearances and necessary documentary proof to allow the cross-flow of classified information. Sharing of information works both ways.
- **ACS Equipment.** A good proportion of RAAF inventory is US-sourced, making equipment interoperability more straightforward; however, as ACS covers such a wide range of items, there is no guarantee of similar type equipment seamlessly interfacing. For example, a relatively simple matter (such as differing power voltages) may cause initial connectivity problems. ACS equipment interoperability issues, such as single fuel initiatives are important developments in the Joint and coalition environment.

Additionally, coalition partners need to have established procedures to facilitate the loan of equipment to other nations if advantageous to do so.

- **In-Transit Visibility.** In-transit visibility (ITV) and the larger concept of total asset visibility has been, and continues to be, a problem faced by all military services, let alone an issue that has been resolved at the Joint and coalition level. ITV is a key component of the logistics interface, as it is usually a combined coalition effort to transport and distribute supplies to, and within, an AOR. Traceability and accountability of items is important to air forces, with RAAF and USAF each being in the process of introducing radio frequency identification (RFID) systems to improve ITV. Therefore, it is not by accident the ADF RFID system being introduced has copied the architecture of United States and United Kingdom military systems. How different RFID systems can interface will be an ongoing issue for both air forces, with RAAF and USAF currently undertaking a trial to assess traceability of items through each other's distribution system using RFID technology.
- **Integrated ACS capability.** RAAF and USAF senior leadership are eager to continue to strengthen coalition interoperability with close allies. While the primary focus for Air Force interoperability is related to flying operations, opportunities to improve ACS capability interoperability are being pursued. The RAAF and USAF ACS communities need to practice similarly to how the flying community has been interacting and practicing together for many decades. Both RAAF and USAF need to have ACS capabilities capable of *pluging and playing* into a combat support element led and largely provided by the other air force. The litmus test of whether RAAF and USAF has achieved true ACS interoperability is the ability to quickly form combined combat support elements as required, consisting of RAAF and USAF ACS specialists, and successfully completing designated missions.

Modern military operations usually involve air forces working as part of a Joint or coalition force. The ADF may lead coalition operations in Australia's region, or may be a junior coalition partner in operations further afield. Therefore, interoperability is a key component of ensuring coalition forces gain maximum benefit from each contributor and ensuring the collective combat power of coalition forces is effectively utilized.

Interoperability Mechanisms

The good news is that mechanisms are currently in place to assist with further improving ACS interoperability between RAAF and USAF. ACS interoperability is being achieved by

- **ACS Doctrine.** Although there are some nuances between RAAF FCS and USAF ACS doctrine, essentially both air forces speak and use similar ACS language and terminology. Both RAAF and USAF are expeditionary focused air forces, emphasizing agility and responsiveness.
- **Equipment Compatibility.** Possessing similar type or compatible equipment capable of interfacing easily and effectively greatly assists coalition partners to function together from the very beginning. Having North Atlantic Treaty Organization standards and forums such as Air and Space Interoperability Council assists with the equipment interface issue.
- **Forums.** The Air Senior National Representatives (ASNR) forum has a combat support subgroup (CSSG) charged with providing an implementation plan and roadmap to improve combat support related interoperability between RAAF and USAF. The Pacific Air Forces (PACAF) Logistics, Installations and Mission Support community provides USAF representation on the CSSG. The ASNR long-term objective is an air force element from one nation (either US or Australia) being able to fully integrate into a deployed force from the other nation.
- **Exchange and Liaison Officers.** Both air forces have had for many years a network of exchange and liaison officers providing an excellent opportunity to learn from each other, providing another perspective, and maintaining close working relationships between our air forces. Exchange and liaison officer positions need to remain relevant, ensuring both air forces gain mutual benefit from the positions, and focused on improving interoperability. Establishing short-term (3 to 4 months) work experience positions in ACS related units could also be beneficial to both RAAF and USAF. RAAF has such arrangements with the Royal Air Force and Royal New Zealand Air Force. For example, a RAAF junior officer or senior enlisted airman could gain work experience in a USAF unit to gain valuable hands-on professional knowledge. USAF personnel could do likewise in an RAAF ACS related unit.
- **Exercises and Training.** RAAF and USAF have exercised together for many decades. While the primary focus is understandably on flying operations, opportunities need to be taken within the current exercise program to improve ACS interoperability. To operate rapidly and effectively in an AOR requires a strong commitment to train and exercise together, otherwise the ASNR objective stated above remains a pipe

dream. Accordingly, Pacific Air Forces logistics staff has observed recent RAAF bare base activations supporting flying exercises in northern Australia, commenting favorably on the potential to exercise combat support related capabilities. Senior RAAF ACS leadership have also observed USAF Silver Flag and Eagle Flag exercises, noting the potential benefit to RAAF of participating on future exercises. Both air forces now need to go beyond observer status, committing resources on a frequent basis to participate on each others exercise and training activities, forging a path to closer ACS interoperability. Currently, RAAF leadership is actively pursuing USAF ACS related exercise and training opportunities.

- **Operational Experience.** RAAF and USAF continue to operate side by side in the Middle-East AOR, gaining valuable experience from working closely together. There are clear benefits from working together to support coalition military operations, gaining exposure to each others way of doing business and providing an opportunity to cement professional relationships and understanding.

Personal Observations

The writer now offers some personal observations regarding how USAF and RAAF provide combat support and operate together, and some of the issues faced by both air forces, having had the privilege of working with USAF in the AOR and currently being an exchange officer in the Directorate of Logistics Readiness, (AF/A4R) Headquarters USAF.

The first experience relates to the writer's experience as commander of the RAAF Task Unit (TU) at Baghdad International Airport (BIAP) providing air traffic control services and associated combat support services to support the mission. A close working relationship was developed between the deployed RAAF TU and USAF 447th Air Expeditionary Group (AEG) at Camp Sather, BIAP. This relationship permeated all rank levels and across the spectrum of combat support functions. For example, the 447th AEG provided some necessary communication networks to RAAF allowing direct connectivity to US military elements, which contributed to providing safe airspace and improving RAAF TU situation awareness of the airfield. Working relationships were developed at all levels, covering C2, airfield operations and emergency response, intelligence reporting, force protection, civil engineering, vehicles and fuel. These strong working relationships were developed and maintained through close and frequent liaison, building a level of trust and professional respect. However, these relationships were not based on all work and no play. Relationship building was cemented over a *near-beer* while eating a burger at frequent social functions. This close interaction was mutually beneficial to RAAF and USAF, with relationship building being a crucial part of maintaining a close coalition.

The second experience relates to the writer's current position as an exchange officer working in AF/A4R at the Pentagon. My highest professional respect for the men and women of the USAF has been reinforced by my Air Staff experience, with many USAF initiatives focused on ways to be more agile, scalable, and expeditionary focused. Program Budget Decision 720 cuts resulting in USAF personnel reductions are a key driving force behind doing the same (or more) with less. For example, the USAF logistics readiness career fields are being reduced during the next few years, while still expected to support a similar number of combat coded units. Although RAAF is much smaller compared to USAF, ADF initiatives and personnel reductions during the 1990s made RAAF a more expeditionary, combat focused force. Amalgamation of career fields, multi-skilling personnel, and outsourcing noncombat related functions assisted RAAF to meet its personnel target, while not reducing combat capability. In fact, the writer may be so bold as to suggest these reductions, combined with an increase of operational tempo, sharpened RAAF combat focus. This is not to say there was, and continues to be, many challenges regarding the provision of ACS across RAAF. Accordingly, the writer sees many similarities with the issues currently being faced by USAF and the steps RAAF had (or was forced) to take to trim manpower while supporting the same, or in some cases a growing aircraft fleet, and increasing operational commitment. RAAF is now undergoing a reshaping initiative (with a minor increase in overall personnel numbers); ensuring the right workforce mix is struck to operate and sustain our new and future capabilities, while still maintaining a steady operational tempo.

Conclusion

Continuing to further improve ACS interoperability between USAF and RAAF is in both our respective air force interests, with ACS being a fundamental enabler of air operations. The more interoperable our ACS capabilities are regardless of whether USAF or RAAF is the lead or contributing air force in a coalition, the more responsive and agile the combat support arrangements available to support the warfighter. USAF and RAAF share a high level of commonality regarding ACS principles, with flexibility, adaptability, and scalability being critical factors of how we provide combat support.

Largely because of smaller size and organizational construct, the majority of RAAF tactical level ACS is provided under the single umbrella of CSG, operating and commanding the permanent airbases and providing the air force expeditionary combat support capability in either a Joint or coalition environment. RAAF ACS functional capabilities are structured into *building blocks*, providing tailorable response options from activating an expeditionary airbase to providing specialist ACS capabilities that can plug and play into a Joint or coalition force. CSG ECSS form the cornerstone of RAAF expeditionary airbase activation and sustainment capability. Conceptually and on a smaller scale, an ECSS combines the role and function of a USAF CRG and AEG.

RAAF possesses recent operational experience, ranging from being a junior coalition partner to being lead contributor in a coalition force. CSG elements have, as part of a Joint task force, activated airfields in support of peacekeeping operations, and supported a range of combat operations and humanitarian relief missions in the Middle-East and Asia-Pacific regions. In addition to these operations, CSG units undertake scheduled training and exercises, ranging from unit and wing level activities to Joint and coalition level exercises.

RAAF ACS capability is developed and managed via the Flexible Combat Support Capability Plan and Combat Support Group Weapon System Plan. These plans provide the roadmap for new and enhanced combat support and airbase capability. ACS related capability submissions can either be raised from the top level by either HQ USAF or HQ CSG, or from the bottom up by the units, the ACS capability providers.

USAF and RAAF are both working hard on continuing to improve interoperability in the air and on the ground, taking a multifaceted approach to further improving ways we operate together. ACS interoperability mechanisms are established and becoming more robust, with further ACS related training and exercise opportunities being actively pursued, and allowing the transfer of information and ideas. Interoperability between coalition partners is a two-way street, involving an open exchange of information and concepts, implementing best practice, having a sound understanding of each coalition partner's capabilities and using them to best effect, and training and refining the practical application of interoperability.

Based on my personal observations of working with USAF, I have the highest respect for the professionalism and dedication of the members of the most powerful air force in the world. Both USAF and RAAF are expeditionary focused air forces, striving for ways of improving the flexibility and responsiveness of ACS to support the warfighter.

End Notes

1. The RAAF uses the term Flexible Combat Support (FCS) in lieu of ACS. For consistency, ACS is used throughout this article. RAAF FCS is the mix of functions required to support the desired level of airpower capability including airbase command and control, airbase force protection and emergency response, local air space management, communications and navigation aids, aeromedical staging and evacuation, and various airbase supply and flight line services.
2. Air Force Deputy Chief of Staff for Installations and Logistics, *USAF Agile Combat Support Concept of Operations*, 15 July 2003, 3.
3. The ACS interoperability issues raised in the article are based on my own experiences working with the USAF in the Middle-East area of operations and on exchange posting on the Air Staff, and from information I have solicited from other RAAF officers.
4. Australian Defence Force, Australian Defence Doctrine Publication 3.15, *Airbase Operations (provisional)*, 1 September 2006. ADDP 3.15 provides the application level doctrine for development, maintenance, and command of ADF airbases. Airbases can range from main operating bases, forward operating bases, bare bases, captured enemy airfields, austere airfields, and civilian airports.
5. Australia has no National Guard equivalent.
6. RAAF is structured into groups, wings, and squadrons or units.
7. Combat support is a recognised output or capability as with air combat or airlift.
8. Refer to Note 1 defining RAAF FCS.
9. RAAF Combat Support Group, *Combat Support Group Concept of Operations (CSG CONOPS)*, unclassifed version, 2003.

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AFSO21: A Case Study in Process Improvement

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Introduction

As a result of the National Security Strategy[1] and the Quadrennial Defense Review,[2] the Air Force[3] posture statement outlines forces and major challenges that are driving current Air Force military strategy. The Air Force, and the military as a whole, operates in an ever-changing environment because of:

- Budget constraints
- Adversaries' ability to acquire technology
- Resources needed to build comparable weapon systems and communicate worldwide
- Rates of global economic growth and decline
- Changes in international law and policy
- Electromagnetic technology advances driving the exploitation of cyberspace for warfare[4]

Meeting demands and challenges of such an environment requires strategy making and strategy execution to be an ongoing, continuous process.[5]

External environmental factors, coupled with the impact of September 11, 2001 have "imposed a powerful sense of urgency to transforming the Department of Defense" into a more agile, responsive organization.[6] The strategic move to transform the military into a lighter, leaner force requires aligned efforts within each Service. The Air Force recognized continuous process improvement (CPI) to be a key component of transformation efforts that were directed by the Department of Defense, and therefore, launched a comprehensive program to integrate CPI concepts into everyday operations. This Air Force program is Air Force Smart Operations for the 21st Century (AFSO21).[7]

Since the Air Force and the private sector face similar environmental challenges and share comparable strategic objectives, a comparative analysis of AFSO21 with private sector CPI concepts may expand the usefulness and application of current approaches. With that in mind, the purpose of this article is to explore such similarities. The article begins with an *external environment analysis* which provides a foundation from which to identify external forces driving Air Force transformation and continuous improvement (CI) efforts.[8] Next, a content review of Air Force doctrine and CPI case studies provides a frame of reference for a comparative analysis. Finally, the article concludes by summarizing the CPI similarities and differences among various private sector industries.

Background

Using a PEST (political, economic, social, technological) analysis helps to outline strategically relevant components of an organization's external environment.[9]

Accordingly, a PEST analysis is utilized for this case study to highlight influential factors in military and Air Force strategy; those factors are identified in succeeding paragraphs.

Political and Regulatory Influences

Political and regulatory influences impact Air Force operations in various ways.[10] Current fiscal year budget constraints and reduction in force initiatives imposed by Congress have mandated manpower reductions. As a result, the Air Force must find ways to improve process efficiency. Political influences impact operations as well. Domestic politics and international relations influence which countries military forces can enter to conduct operations and which countries the US provides allied support.

Economic Factors and Influences

There are several economic factors and influences driving Air Force strategy. The two largest are loss of buying power and international economic conditions.[11] The Air Force is experiencing loss of buying power because of the high costs of supporting and sustaining Global War on Terrorism operations, the rising cost of fuel, utilities, personnel and medical care, and the upgrade and replacement of aging weapon systems. Unexpected expenses associated with the implementation of base realignment and closure program initiatives have also contributed to a loss of buying power. Both rising costs and unexpected expenses have lessened capital funds, making conservation a priority. Other economic factors drive strategy as well. For example, international economic conditions often dictate whether the military may be used to preserve or advance global economic growth.[12]

War on Terrorism Influences

The impact of the September 11 attacks moved the global war on terrorism to the forefront and, consequently, drove a variety of changes in Air Force policy, procedures, and doctrine.[13] Terrorists engage in *irregular warfare*, which makes the enemy harder to identify; therefore, the Air Force has shifted to a capability-based approach for counter-threat measures. A capability-based approach is concerned with *how* an enemy might attack rather than *who* might attack. Such a tactic has led to the need for an increased ability to simultaneously conduct both short- and long-term operations of various types, such as security, stability, counterinsurgency, and reconstruction worldwide. Also, a capability-based approach has led to the need for increased participation in Joint and coalition operations with other Services and nations. Personnel are now required to adapt and perform nontraditional functions, such as convoy escorts and protection duties. This ultimately changes the training requirements for ground force teams and host nation escorts.

Technological Innovation

Several advances in modern warfare pose new threats.[14] Newer integrated air defense systems can handle and exchange more information quicker than current aircraft. Man-portable air defense systems—surface to air missiles capable of being fired from the shoulder—are in abundant supply at low cost, making them readily available to potential adversaries. Additionally, the number of advanced aircraft is on the rise, posing a greater threat. Weapons of mass destruction (WMD) are another major concern for several reasons:

- The proliferation of chemical and biological weapon agents is increasing.
- The production of WMD is inexpensive.
- WMDs are easily concealed, making them difficult to detect.
- Terrorists are determined to acquire WMD because they can purchase highly lethal weapons for a relatively low price.

Such concerns place greater emphasis and importance on homeland defense. Finally, advances in electromagnetic and global positioning system technology raise concerns about the future potential of cyberspace warfare.

Clearly, external environmental factors are a major impetus for transformation and continuous process improvement.[15] Although most Air Force (military) operations are different from commercial operations, environmental challenges and strategic objectives are similar in nature. Thus, a literature review and a comparative analysis of AFS021 with private sector programs can serve as a vehicle to examine the following research questions:

- How do Air Force CPI programs differ from those seen in the private sector?
- How are Air Force CPI programs similar to the private sector?
- Do they compliment each other?

Article Acronyms

AFSO21 – Air Force Smart Operations for the 21st Century
CI – Continuous Improvement
CPI – Continuous Process Improvement
PEST – Political, Economic, Social, Technological
WMD – Weapons of Mass Destruction

Doctrine and Literature Review

AFSO21 Playbook and Concept of Operations

The *AFSO21 Playbook* and *AFSO21 Concept of Operations*[16] are Air Force publications that outline and explain the intricate details of major AFSO21 components. A content analysis revealed the interrelatedness between major components and parts. Furthermore, key relationships between AFSO21 philosophy, AFSO21 implementation, and AFS021 core components were established, thus conceptually presenting them as a unified approach. An overview of each component is outlined below.

Perhaps the main thrust behind AFSO21 is its underlying philosophy. The philosophy of AFSO21 is to employ Lean-oriented CPI concepts tailored to unique needs and integrated into Air Force culture through a systematic process which consists of five implementation steps—*the Five-Step Implementation Cycle*.

The Five-Step Implementation Cycle is a cyclic process whose overall objective is to systematically integrate and embed CPI methods into Air Force culture and day-to-day operations. The greatest advantage of this process is flexibility and scalability. It can be applied to various improvement efforts ranging from near-term to long-term. This is accomplished through the following:

- **Leading Change.** Senior leaders establish vision and direction, demonstrate commitment, and set strategy via gap analysis.
- **Organize and Prioritize.** Identify improvement opportunities that are in line with higher level strategy and formalize, prepare, and train teams.
- **Process Redesign.** Define *as-is* (current) and *to-be* states, then devise an action plan to close the gap between current and desired state.
- **Improve.** Implement the action plan.
- **Measure, Assess, and Sustain.** Measure progress and readjust plans and measures if necessary; recognize and reward efforts; realign freed resources; and plan actions for future improvements—starting over at step one.

The objective of the five-step implementation cycle is to provide a systematic, ongoing method to implement CPI initiatives. The efforts and actions of each step are glued together by a sound governance structure.

The governance structure of AFSO21 functions to direct and focus improvement efforts Air Force-wide to achieve overall strategic near-term and long-term objectives. It begins at the most senior level, where overarching strategic plans and priorities are set. With those priorities in mind, mid-level leaders decide which processes need to be standardized enterprise-wide and which processes need to remain flexible to meet the unique needs of lower level operations. Process owners receive designated authority and responsibility for the improvement of core processes to include forming teams, monitoring progress, and publishing results. Steering groups are formed and senior functional subject matter experts are appointed to advise cross-functional improvement initiatives and efforts. Finally, program initiatives are championed and coordinated at intermediate levels and implemented at lower levels through teams. This forms key collaboration points which act as a binding thread that links each step within the Five-Step Implementation Cycle. Successful execution of those steps is enabled by four core components.

- **Knowledge Management.** Leverages technical know-how and tacit knowledge
- **Strategic Communication.** Establishes effective communication of priorities and initiatives in terms that resonate with members of the organization
- **Standardized Training.** Plants and sustains AFSO21 efforts
- **Information Technology Support.** Captures, stores, processes, disseminates, and reports improvement efforts

The many parts of AFSO21 make a unified approach key to operational efficiency. It starts with a philosophy rooted in Lean-oriented concepts that are systematically indoctrinated into Air Force culture and operations through a five-step implementation cycle. The five-step implementation cycle is a cyclic process that can be applied to various improvement efforts ranging from near- to long-term. Efforts are perpetuated through a binding governance structure and enabling set of core components. Similar approaches exist in the private sector.

CPI Practices in the Private Sector – Key Strategic Perspectives

The topic of CPI pertains to many elements within the private sector; therefore, a PEST analysis of each is beyond the scope of this paper. However, before analyzing private sector CPI practices, a review of key strategic perspectives may help to explain the importance of CI concepts.

Most strategic actions are proactive in nature—meaning they are deliberate and purposeful, aimed at ensuring performance objectives are met. However, strategic actions are often taken in an effort to seize opportunities and adapt or respond to threats and environmental changes; therefore, strategy can also be reactionary at times.[17] Both deliberate and reactionary strategic actions are crucial, because together they ultimately lead to a sustainable competitive advantage. Porter's definition of strategy contains similar attributes, but magnifies the importance of strategic positioning bringing greater fidelity to competitive advantage.[18]

Porter contends that strategy encompasses more than operational effectiveness. Further, he notes that differentiation is also an integral part of strategy.[19] Operational effectiveness and differentiation are not mutually exclusive and therefore should not be separated. Together they constitute actions that enable companies to strategically position themselves, equipped and primed to dominate a particular industry or market segment by outperforming rivals.

Combining aspects of both concepts may offer a more expanded definition of strategy as it pertains to CI. Sustainable actions that a company executes will, over time, allow it to strategically position itself to effectively adapt to an ever-changing environment to sustain competitive advantage. Adapting to ever-changing environments presents many challenges.[20]

According to Beinhocker, the *new economy* is a complex adaptive system capable of self-evolving when elements of or within an industry market change.[21] Now the "central challenge (for organizations) … is to be both a competitor and an evolver."[22] Although still in its infancy, this concept suggests the need for companies to employ conservative yet adaptive strategies—coined strategies on the edge of chaos—making them agile and responsive to changes in the private sector environment.[23] Thus, maintaining a delicate balance between standardization, diversity, and innovation is paramount. Key to achieving this balance are practices that are "hardwired into the organization through mental models, culture, policies, and training."[24]

Since business strategies are largely dependent upon resource capacity, a resource-based perspective may help determine viable strategic options. Frawley introduces the concept of resource-based perspective as an important aspect of maintaining a competitive lead.[25] The resource-based perspective is useful in determining what it may take for a company to benefit from its chosen strategy (competitive advantage).[26] First, several studies have revealed that competitors must possess the resource capacity (financial resources and research and development capabilities) in order to successfully enter and compete in a new market.[27] Moreover, competitive advantage results from control and acquisition of industry resources creating resource barriers that make it difficult and more costly for followers and late-movers.[28] Thus, a company must continually assess its current capacity as well as its ability to acquire adequate resources. Combining other perspectives, such as Beinhocker and Porter, with a resource-based perspective may help to further explain and justify why organizations often look to CI techniques for expanding their resource capacities and consequently competitive advantage, making resource-based perspectives a relevant approach for analyzing CPI practices.

Private Sector CPI Practices – From Manufacturing and Production to Engineering

The use of CPI concepts began in manufacturing and production environments, but, as a proven concept, they soon infiltrated other industries. One case study conducted within the engineering community illustrated the relevant worth and use of CPI practices beyond manufacturing and production environments.[29] Like other industries, the engineering community began to search for ways to *do more with less* and to challenge *rote* practices. Additionally, practitioners recognized the need to motivate employees to exceed performance standards and strongly felt that CPI was a vehicle. However, this change in operational mindset was met with resistance.

Change, in the realm of public works engineering, is often considered risky, because it challenges proven, reliable engineering work practices and this can jeopardize project success.[30] Harrison et al., likened this to mass production and the auto industry, emphasizing it as an obsolete paradigm that should be replaced by a Lean production mindset.[31] To support this contention, they sought to demonstrate how public works engineering could benefit significantly from embracing a CI ethic, as it was considered the missing piece.[32]

A CI ethic would provide elements such as teamwork, communication, efficient use of resources, and ongoing CI vital to Lean production.[33] Harrison et al., composed a CPI process model for planning and offered it as the solution.[34] The objective of the CPI planning process is to improve processes, enhance communication, and facilitate *operational consistency*.[35]

The CPI planning process is an ongoing process, almost synonymous with process reengineering, utilized to improve the effectiveness and efficiency of work tasks and activities.[36] Leadership instills a CI mindset. Then, a team approach is utilized to carry out sets of the CI planning process. It appears that this process provides an effective means of embedding CI in the culture and processes of a company. However, success hinges on the following factors:

- The entire organization must recognize the need for change to create buy-in.
- Immediate implementation of recommended improvements illustrates management's commitment.
- A structured approach to brainstorming helps maintain order, ensuring purposeful productive team sessions.
- Using success stories celebrates and reinforces CPI.
- CPI must be institutionalized through peer collaboration groups and benchmarking.

Similar forms or variations of CPI methods emerged, offering enterprise-wide approaches to operational efficiency.

Studies revealed the synergistic value of combining various CPI methods.[37] One such study conducted by Ehie and Sheu illustrated how the integration of Six Sigma and Theory of Constraints techniques could be used to create synergistic results.[38] Combining both techniques forms a framework that focuses CI in two ways. First, the framework emphasizes consideration of system and resource constraints to drive CI efforts in order to make global improvement a general goal. Six Sigma techniques are consistently applied to identify customer requirements, to define which processes are to be improved, to analyze root causes for inefficiencies, and to develop improvement actions. Ehie and Sheu successfully applied this framework to a manufacturing company, improving the efficiency of its gear-cutting operations by $200K per year, while enhancing customer satisfaction.[39] Given the synergistic value and illustrated results, the consolidation of various CI techniques is a notion worth exploring further.

The framework presented by Ehie et al., consists of six phases which are indispensable to the achievement of enterprise-wide improvements.[40]

- **Phase 1.** Identify the constraint and determine the processes to be improved.
  - Find and identify bottlenecks (constraints) that prevent the company from meeting customer needs and productivity goals including quality of output.
- **Phase 2.** Measure current performance and identify root causes.
  - First, determine performance measures or standards.
  - Measure process against standards and analyze process to discover root causes of poor performance.
- **Phase 3.** Exploit the constraint by improving the processes.
  - Figure out how to eliminate root causes of poor performance to improve processes.
- **Phase 4.** Subordinate the systems to sustain improvements.
  - Modify goals to support change or improvement.
  - Monitor change or improvement using statistical process control methods such as value analysis, Pareto and control charts.
  - Train employees how to work with improved process.
  - Reward improvement efforts.
  - Communicate improvements to increase buy-in.
- **Phase 5.** Elevate the constraints.
  - If improvement efforts fall short of meeting goals, investigate root causes.
- **Phase 6.** Check for next constraints.
  - Continue to analyze and monitor processes to detect new constraints.

Another recent study demonstrated application of integrated methods in local governments, broadening its scope beyond business and manufacturing industries.[41]

Private Sector CPI Practices – Service Industries

The theory of production-line approach to services was initially adopted in 1976, marking the beginning of the industrialization of service.[42] As the notion of *service* in the 1990s grew increasingly important, Total Quality Management permeated production environments, placing production-line approaches in the background. However, several studies introduced the concept of Lean service, purporting the *reindustrialization of service* in which principles of manufacturing operations and service operations are converged to create mass customization—Lean service.[43,44]

The "Toyota Way in Services"[45] offers a comprehensive, unified approach to Lean service. This article also suggests that

Lean efforts are starting to take hold in various types of service-like industries ranging from government to medical and construction (technical and service operations), but merely amount to fast solutions that quickly dissipate rather than systematic practices that change the organization culture and operations in a way that produces long lasting solutions. Consequently, enterprise-wide benefits (mutually beneficial outcomes) are less likely to be realized.

Limiting Lean practices to the *shop floor* makes them insular to lower levels rather than accessible and commonly applied throughout the entire organization. Liker et al., proposed a "true systems approach that effectively integrates people, processes and technology—one that must be adopted as a continual, comprehensive, and coordinated effort for change and learning across the organization."[46] Simply put, they defined an evolutionary system focused on continuous learning and improvement.

The axioms that underpin a true systems approach are guiding principles to fine-tune processes, implant appropriate tools and technologies to enable people, piece everything together to create a coherent system, and vector check to ensure feasible, overall efforts.[47] Each axiom is covered in greater detail below.

- **Processes.** Align efforts through guiding philosophies.
  - Establish customer-defined value. Everything about the process should revolve around customer-defined value.
  - Front-load the product development process. Utilize cross-functional teams and collaboration early in the development process to preclude costly variations and changes in later stages.
  - Create a leveled product development process flow. Balance workload assignments, coordinate cross-functional activities, and allocate resources according to demand or work flow requirements.
  - Utilize rigorous standardization to reduce variation and to create flexibility and predictable outcomes. Minimize variation without stifling innovation, creativity, and flexibility.
- **People.** Place the right people armed with in-depth knowledge, indispensable skills and a CI mindset, in the right place, at the right time by orchestrating people systems.
  - People systems include values, culture, training, leadership, organizational structure, professional development, team approaches, and recognition.
- **Tools and Technology.** Implant tools and technologies that support processes and enable people through the following guiding principles:
  - Design and integrate information systems after processes, organizational structures, and work positions are defined.
  - Align your organization through simple, visual communication via: (1) *Hoshin kanri*—policy deployment, the breaking down of goals at the strategic or corporate level into understandable business objectives for tactical levels and (2) Media that effectively communicates the same message to all, enhancing enterprise-wide collaboration and problem solving.
  - Use powerful tools for standardization and organizational learning as standardization is the nexus of CI.
- **Piecing Everything Together to Create a Coherent System.** This purports that the central theme behind Lean is interdependence, in which every aspect of the organization (people, processes, and technology):
  - Must function and interact as a unified system
  - Is connected—meaning change to one part affects all other parts
  - As a system, is only as strong as its weakest link
  - Is a complex system that must be "purposefully designed, aligned and mutually supported[48]
- **Vector Checks.** Vector checks expand efforts by asking questions at a systems or enterprise level:[49]
  - Are the changes leading to new standardized processes that are the basis for further waste reduction? (process)
  - Are people throughout the organization engaged in CI and aligned around a common set of objectives? (people)
  - Are all the soft tools and harder technologies being used to support people improving the delivery of products and services to customers? (technology)

The Toyota Product Development System is regarded as the benchmark for a systems approach to Lean—reducing waste across all processes creates a Lean value chain.

As noted earlier, the idea of applying an industrial or production-line approach to service-oriented processes was first introduced by Levitt in 1976. Bowen et al.,[50] attempted to further illustrate how CPI practices used primarily in manufacturing or production environments may be used in service environments to yield comparable results. Bowen et al., analyzed the convergence of service and manufacturing principles in various service industries—fast-food and airlines—and synthesized results to compose a Lean service model.[51]

Lean service is a model which consists of four primary elements:

- **Learn.** Integrate Lean into service processes
- **Expect.** Setting Lean standards through expectation management
- **Analyze.** Compare, contrast, expand, and benchmark other service models
- **Navigate.** Leverage consultants and practitioners to navigate efforts

Based on the works of Levitt[52] and Bowen et al.,[53] Abdi, Shavarini, and Hoseini[54] propose a revised Lean model that could be used to integrate Lean efforts within service industries at the enterprise level. Although it lacks empirical backing, it emphasizes the increased need and pressure for service-oriented companies to integrate their value chains and lean their processes.[55]

Discussion

Similarities Between the Air Force and the Private Sector

The Air Force and private sector share key strategic perspectives that stress the importance of CPI. "Strategy on the Edge of Chaos"[56] requires standard yet flexible strategies, bringing the relationship between CPI and strategic positioning to the forefront. A resource-based perspective also emphasizes the importance of resource capacity and capabilities, which further explains why companies often look to Lean methods to expand resource capacity.[57] Finally, a revised version of strategy hints that operational efficiency and strategic position together lead to competitive advantage.[58]

As for improvement practices, the comparative analysis revealed a convergence toward a global approach to CPI which possesses many of the same key attributes resident within learning organizations.[59]

- An iterative process embedded in culture and inherent in day-to-day operations
- An enterprise or cross-functional view and management of processes based on the notion that the changes in one part or subsystem invariably affects the whole (systems thinking)
- Reliance on high-functioning, empowered teams
- Full-circle feedback and information exchanges among all levels of the organization to expose tacit knowledge
- Interdependence and cross-functional collaboration
- Change management (to reinforce commitment and behaviors through use of success stories, recognition and rewards)
- Technology that supports processes and enables people

Key Note

Componation and Farrington's study complements the topic of this article in that it helps to highlight the use of teams to better support CI initiatives.[60] Results indicated that "the duration of team activities and the size and scope of the tasks undertaken" make problem solving ideally suited for CI teams.[61] Additionally, training coupled with time was found to be a major influencing factor in successful and effective use of problem-solving tools. Therefore, it was found to augment the research content compiled for the comparative analysis of Air Force CPI with private sector CPI. Further, the majority of case studies researched highlighted teamwork as a key element of Lean efforts, alluding to the criticality of team building in implementing CI initiatives.

Differences Between the Air Force and the Private Sector

The results of the comparative analysis conducted for this article demonstrate that an elaborate governance structure is the most significant and apparent difference between Air Force CPI practices and those seen in the private sector. While the cross-functional collaboration and strong leadership involvement found within the private sector might constitute a governance structure, extant literature has not explicitly characterized it as such.

Conclusion

The Air Force and private sector share key strategic perspectives that call for increased use of enhanced variations of CPI methods, which can be likened to the systems approach inherent in learning organizations. Perhaps elements of both can be coalesced to build an enterprise-wide CPI framework.

An enterprise-wide CPI framework makes it possible for various cross-functional efforts linked together through a governance structure to create synergy. Synergistic results are exploited to facilitate continuous learning and improvement across the enterprise, which enables organizations to maximize resource capacity, optimize value chain activities, and enhance operational efficiency, posturing themselves to employ sustainable actions. Executed over time, this allows organizations to strategically position themselves to effectively counteract rival actions, adapt to ever-changing business environments, enhance financial and operational performance, and capitalize on strengths and competencies to seize opportunities resulting in unmatched competitive advantages.

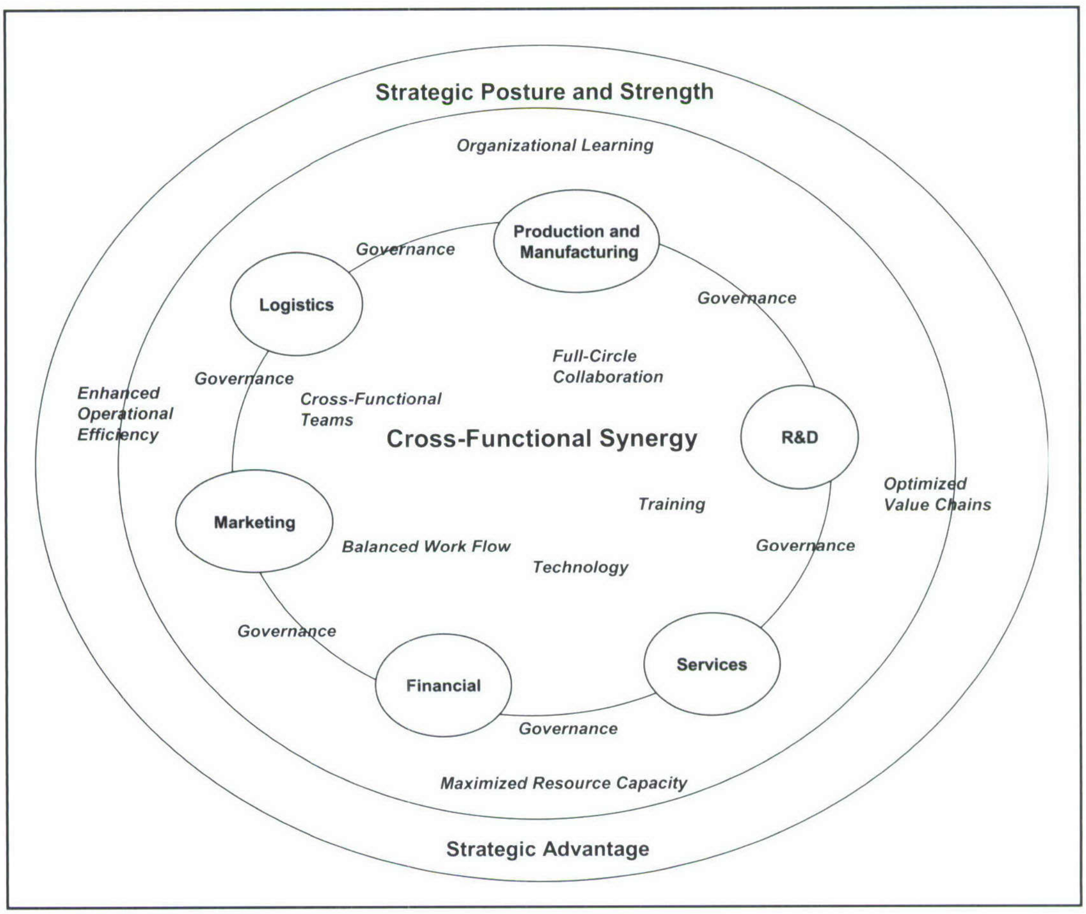

Figure 1. Enterprise-Wide CPI Framework

Future Research

Figure 1 illustrates a proposed Enterprise-wide CPI Framework. However, at this state of development, it is purely theoretical and further research is necessary to test its validity and usefulness.

Since existing AFSO21 literature is somewhat scant, additional research and case studies are also suggested to illustrate various uses of AFSO21 across Air Force operations.

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DLA Forward Stocking: An Economic Analysis

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Introduction

The Defense Logistics Agency (DLA) supplies Air Force units in the area of responsibility (AOR) with relatively inexpensive, consumable items. The DLA-managed items originate in the continental United States (CONUS), where they are stored and shipped directly to the forward bases in the AOR. DLA recently proposed forward stocking, in which items are stored centrally in-theater and then shipped to the AOR bases. Theoretically, forward stocking items should reduce transportation times from the DLA (forward) depot to the forward units. Additionally, forward stocking utilizes less expensive modes of transportation from CONUS to the forward DLA depot.

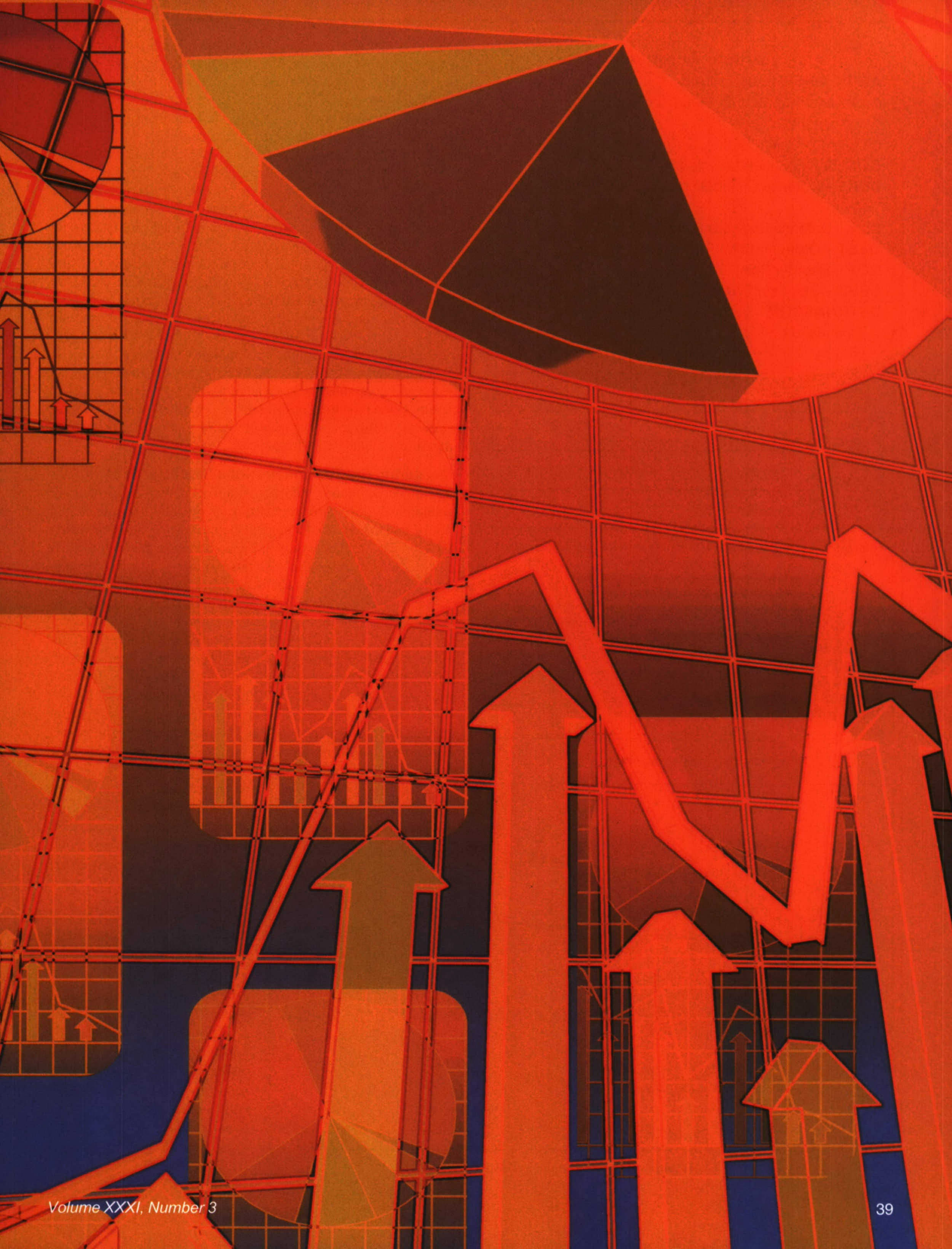
Previous research has investigated the feasibility of forward stocking relatively expensive, Air Force-managed parts and concluded that forward stocking was not economical.[1] Currently, DLA only forward stocks an item if it has four-or-more demands in a year.[2] The criteria's intent is to ensure only high-use items are stored in-theater. This research extends previous efforts by considering the feasibility to forward stock inexpensive, DLA-managed parts according to current DLA criteria, and additional criteria developed through the research. A general methodology is presented to model and evaluate the performance of forward stocking. Although the methodology is applicable to any potential theater, only United States Air Force Central Command (USCENTAF) with storage at Defense Distribution Depot Kuwait (DDKS), is considered in detail.

Research Methodology

A mathematical model was constructed for direct shipping from CONUS to the base, and for shipping to a forward stocking location, and then to the base. Figure 1 depicts the structure of this model.

The model, implemented in Visual Basic, computes the inventory pipeline and transportation costs for each item from CONUS either direct to the air base, or to forward storage and then to the forward base. Inputs to the model are the transportation costs and times of each route, along with the item's cost and daily demand rate. It is important to note the characteristics of direct shipping versus forward stocking. Items traveling directly use faster modes of transportation, such as airlift or commercial carriers; therefore, the pipeline time is shorter, and there is less inventory in the pipeline. On the other hand, items forward stored will travel to the forward storage location via less expensive transportation modes (such as cargo ships), and from forward storage to the base via ground convoys or intratheater airlift. These slower but less expensive modes of transportation increase ship time and therefore may require more pipeline inventory. (See Table 1)

Given ample lead time, any item can be economical to forward stock, since the accumulated savings from lower annual costs



will eventually break even with and then exceed the one-time investment costs. Forward stocking is considered cost beneficial if the breakeven occurs in less than 5 years (in accordance with Air Force Manual 23-110). Therefore, the model evaluates economic feasibility by computing the breakeven time and the resulting savings or cost over a 5-year period.

Definite data was not available for the shipping costs and times; therefore, they were estimated for each leg of the direct and forward route. The pipeline times from CONUS to the base (days) were extracted from the AOR bases' SBSS routing identifier record. The CONUS to forward storage times estimated were derived from analysis of United States Transportation Command (USTRANSCOM) data. The forward storage to base times were derived from USTRANSCOM-provided pipeline performance based on shipment time from the US Army Material Command. Sensitivity analysis was also conducted with varied pipeline times. Transportation costs were based on AFMAN 23-110, chapter 19. Transportation costs and times are shown in Table 2.

The model optimally decides if an item is feasible to forward stock and computes the associated 5-year cost or savings. The optimal model, in turn, enables the development of easier-to-use rules of thumb to select what items to forward stock given a measure to evaluate performance.

Measuring the Performance of a Stockage Criteria

The objective is to develop criteria that identify items that are economical to forward stock. More specifically, the rule should not be one that stocks the highest percentage of items correctly, but one that selects items resulting in the greatest cost benefit. A set of criteria could potentially classify more items correctly than another, but ultimately result in more expense because the mistakes it makes are more expensive. Savings result when an economic item is forward stocked. Savings are the amount of money saved beyond the break-even point over a 5-year period. Likewise, extra expense is incurred when an uneconomical item is forward stocked. The expense is the amount of money by which the savings fall short of the break-even point over a 5-year period.

For a particular item and criteria, there are four possible outcomes (refer to Figure 2). The first outcome is that the item is *economical* and forward stocked. This is a correct decision resulting in savings.

The second outcome is that the item is economical but not forward stocked. This is called alpha-error and the potential savings from forward stocking the item is lost.

Next, an uneconomical item can be forward stocked, resulting in beta-error and extra expense.

Finally, an uneconomical item that is *correctly* not forward stocked has no effect on savings or expense. We seek a rule that minimizes incorrect decisions (alpha and beta error). However, beta error actually incurs costs (as opposed to a lost opportunity for savings), so it is considered the more egregious error.

Article Acronyms

AOR – Area of Responsibility
CAF LSC – Combat Air Forces Logistics Support Center
CENTAF – United States Air Force Central Command
CONUS – Continental United States
DDKS – Defense Distribution Depot Kuwait, Southwest Asia
DLA – Defense Logistics Agency
O&ST – Order and Ship Time
ROP – Reorder Point
SBSS – Standard Base Supply System
USTRANSCOM – United States Transportation Command

	Direct Route	Forward Storage Route
Modes of Transport	More expensive but faster	Less expensive but slower
Pipeline Inventory	Less	More
Safety Level Inventory	Less	More

Table 1. Direct Versus Forward Storage: Inventory Levels and Transportation Modes

Route	Cost ($/Shipment)	Time (Days)
CONUS Base (Direct)	37	11
CONUS Forward Storage	5	30
Forward Storage Base	20	15

Table 2. Pipeline Costs and Time

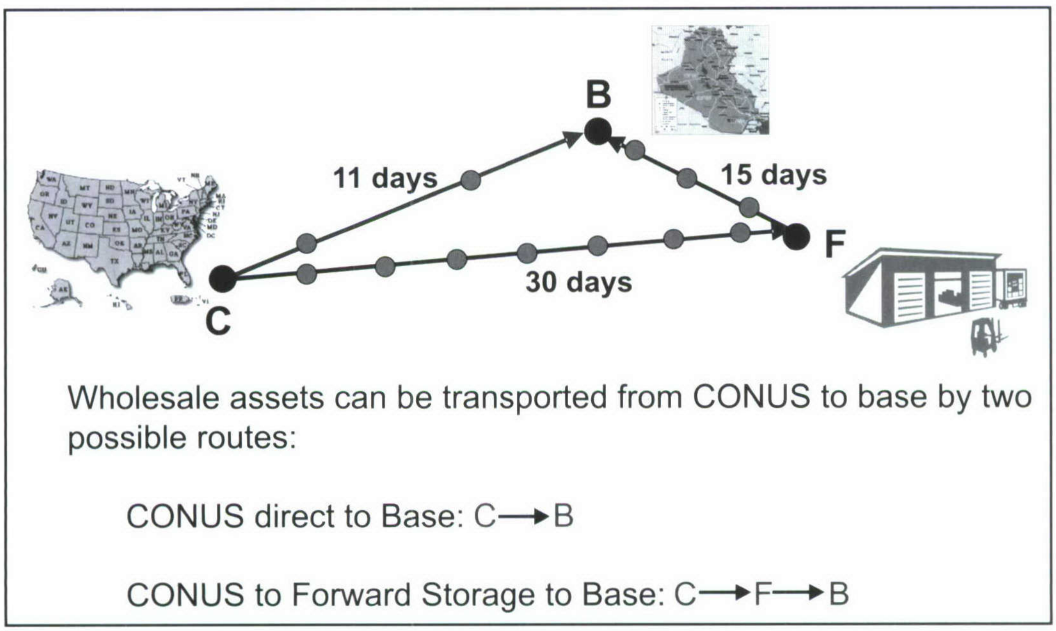


Figure 1. Forward Stocking Model

Proposed Criteria

Recall that DLA currently uses a demand-only criterion of four-or-more demands in a year. The following modified criteria were developed:

Forward Stock If: Unit Price < Some Threshold -and- Demand ⩾ Some Threshold

The modified criteria ensure that items forward stocked are not only high demand but inexpensive, thereby eliminating excessive pipeline inventory costs. Possession of a model, performance measures, and prospective criteria is not sufficient to conduct an analysis. A list of the items demanded in-theater is also required. DLA views theater-wide demand levels; that is, aggregate demand from a number of bases in the theater. Although actual DLA data indicating demand levels were not available, three representative aggregate pipeline inventory levels were constructed for USCENTAF. The first combined demands from five USCENTAF bases: Al Dhafra, Ali Al Salem, Al Udeid, Baghram, and Balad, and represented combined Middle Eastern theater demands. The second consisted of items not currently forward stocked because of insufficient storage space. The third dataset consisted of items currently forward stocked. In summary, the process is as follows for a particular dataset:

- Select cost and demand thresholds
- Compute whether each item is economically feasible to forward stock with cost and demand threshold
- Compare simple rule performance to optimal performance
- Evaluate performance

Results

Analysis was conducted on the combined USCENTAF demands, items currently not forward stocked because of insufficient storage space, and items that are currently forward stocked. Several different sets of criteria are applied to the demand data, and their performance is discussed.

Combined USCENTAF Theater Demands

The combined USCENTAF demands consisted of 24,589 items at Al Dharfa, Ali Al Salem, Al Udeid, Baghram, and Balad as of 30 June 2006. The performance of the current DLA criterion (four-or-more demands in a year) is shown in Table 3.

The current DLA criteria would forward stock 2,483 (1,682+801) items (10 percent of the 24,589). Using this criteria results in a net loss of approximately $675K ($723K - $1.388M) over a 5-year period because of excessive pipeline inventory costs. (Note that the $688K is an opportunity cost and does not actually incur a monetary expenditure. Thus, it does not factor into the net savings or loss.) This is evident by the 801 items forward stocked that are not economical to stock (beta-error) and the associated cost of -$1.40M that overwhelms the transportation savings of $723K. The total net loss of $675K is over a 5-year period.

Now consider the addition of a cost criterion to DLA's demand criterion (Table 4). The best cost criterion was a cost of less than $50.

Adding a cost criterion prevents an excessive pipeline inventory of expensive items, eliminating virtually all the beta-error. This resulted in a net savings of $679K over a 5-year period. Additional savings is generated by lowering the demand criterion to two-or-more demands in a year (see Table 5).

Lowering the demand significantly lowered the alpha-error, capturing additional savings. The beta-error only slightly increased, and the total net savings was $955K over a 5-year period. This rule would stock 20 percent of the items demanded in the AOR, as compared to the 10 percent of items stocked under current DLA criteria.

Items Not Stocked Because of Insufficient Storage Space

Next, the modified cost and demand criterions are applied to the set of items not forward stocked because of insufficient storage space. A total of 15,819 items met the criteria for a demand level at the using air base, but were unable to be forward stocked at

	Forward Stocked	Not Forward Stocked
Economical	1,682 ($723K)	9,920 (-$688K)
Not Economical	801 (-$1.388M)	12,186
Total 5-Year Net Loss: -$675K		

Table 3. DLA Criterion Performance: Demands ⩾ 4/year

	Forward Stocked	Not Forward Stocked
Economical	1,646 ($709K)	9,956 (-$701K)
Not Economical	161 (-$30K)	12,826
Total 5-Year Net Savings: $679k		

Table 4. Performance: Cost < $50; Demands ⩾ 4/year

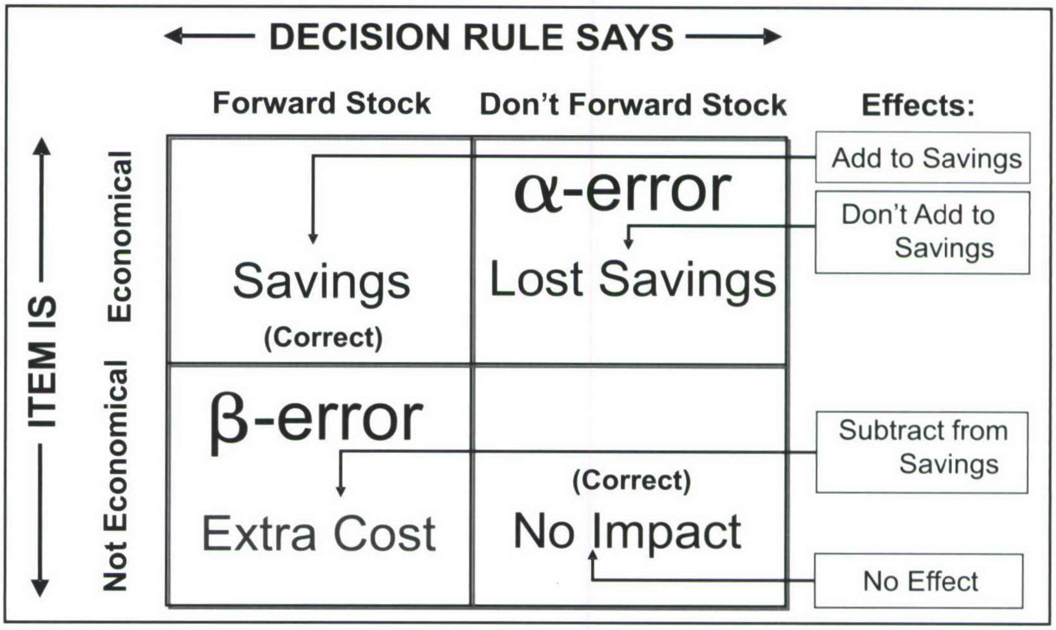


Figure 2. Performance Outcomes

the base because of insufficient storage space. Items that are economical to forward stock should be stored at the Defense Distribution Depot Kuwait (DDKS), Southwest Asia until storage space is available at the forward bases. Items that are not economical should not be stored at DDKS but should remain in CONUS.

Applying the modified cost and demand criterions to the items yields a potential savings of $747K (see Table 6).

A total of 3,026 items (19 percent) met the criteria to forward stock, of which 2,780 are economical. A total net savings of $747K results over a 5-year period. Savings can be increased if pipeline times are reduced. Table 7 shows the performance if the time from DDKS to the forward base is lowered to 5 days.

Although the same amount of items is forward stocked, more items are economical with a shorter pipeline from DDKS. Savings are increased by approximately $85K ($832K - $747K) over a 5-year period. Furthermore, stocking at DDKS is beneficial for all items not stocked at the using base, if the total pipeline time is less than the pipeline time direct from CONUS to the base. Since these items are not stocked at the using base, any pipeline time less than CONUS will reduce back order time. As space becomes available, economical items can be selected for storage at the using base.

Standard Base Supply System (SBSS) demand levels must be adjusted if forward stocked items have different order and ship times (O&ST) than items from CONUS. In the event of reduced forward pipeline times, the reorder point (ROP) can be lowered for forward stocked items yielding a one-time savings. The resulting savings or costs associated with different forward pipeline times were computed assuming all 15,819 items were forward stocked. The results are listed in Table 8.

Therefore, if the forward pipeline is reduced to 5 days, there will be a one-time savings of $1.5M in reduced supply levels at using bases, in addition to the $832K saved over a 5-year period under the proposed cost and demand criteria.

	Forward Stocked	Not Forward Stocked
Economical	4,510 ($1.026M)	7,092 (-$384K)
Not Economical	507 (-$71K)	12,480
Total 5-Year Net Savings: $955K		

Table 5. Performance: Cost < $50; Demands ≥ 2/year

	Forward Stocked	Not Forward Stocked
Economical	2,780 ($774K)	5,341 (-$286K)
Not Economical	246 (-$27K)	7,452
Total 5-Year Net Savings: $747k		

Table 6. Performance: Cost < $50; Demands ≥ 2/year

	Forward Stocked	Not Forward Stocked
Economical	2,861 ($843K)	6,448 (-$337K)
Not Economical	145 (-$11K)	6,345
Total 5-Year Net Savings: $832K		

Table 7. Performance: Cost < $50; Demands ≥ 2/year
(DDKS to Forward Base = 5 Days)

Forward Leg (Days)	Direct Leg (Days)	Cost Difference
1	11	**-$2.6M**
3	11	**-$2.1M**
5	11	**-$1.5M**
7	11	**-$1.1M**
9	11	**-$481K**
11	11	**$0.0K**
13	11	**$357K**
15	11	**$747K**

Table 8. O&ST Cost Differences (Items Not Forward Stocked)

Forward Leg (Days)	Direct Leg (Days)	Cost Difference
1	11	-$21K
3	11	-$16K
5	11	-$12K
7	11	-$8K
9	11	-$4K
11	11	$0K
13	11	$4K
15	11	$7K

Table 9. O&ST Cost Differences
(Items Currently Stocked at Forward Bases)

Items Currently Stocked at Forward Bases

The final set of items consisted of those currently stocked at forward bases. Currently there are 566 items stocked at the using bases, of which 529 are economical to forward stock. If the ship time from DDKS is reduced to 5 days, 537 items would be economical. SBSS demand levels would also require adjustments to their ROP levels yielding one-time savings. The cost differences for various forward O&STs are listed in Table 9.

If ship time from DDKS is reduced to 5 days, a one-time savings of $12K would be realized.

The Combat Air Force Logistical Support Center identified both the need to reduce the DLA-depot-to-using-base times, and the need to track assets shipped from the forward depot, especially shipments for mission capable requirements. Without adequate tracking, delayed and lost shipments occur which create workload delay, replenishment times, and potentially generate excesses, as other orders are placed to compensate for delayed shipments.

There is a *regional stock* alternative. For example, items can be stocked at DDKS without stocking at using bases. Although this would reduce inventory levels at the using bases, it would increase back orders because of the added ship time from the DDKS to the using base. Therefore, this alternative is not recommended.

Throughout the analysis, it was assumed additional inventory storage costs are not incurred. Applying the recommended forward stocking criteria still results in savings, albeit at a lower amount. Savings under DLA covered-storage costs is maximized by lowering the cost criterion to $20. Increasing CONUS-to-DDKS ship time to 60 days also results in a lower savings with an optimal cost criterion of $16.

Conclusion

Prepositioning supplies used by forward airbases at a forward storage location in the AOR is a viable alternative to the current practice of shipping items directly from CONUS. An item is economically feasible to forward stock if the annual savings realized by reduced shipping costs exceeds the increased one-time, inventory investment costs within a 5-year period. Performance of both the current DLA demand criterion and the new criteria using cost were evaluated using three different data sets:

- All items with demands in the Middle Eastern theater
- Items not currently forward stocked because of limited storage space, and
- Items currently stocked at using bases

The current DLA criteria results in excessive costs by forward stocking uneconomical items. By adding a unit-price threshold and lowering the demand threshold, about 20 percent of the items used in the AOR are economical to forward stock and would achieve a $747K, 5-year savings. A sensitivity analysis conducted by varying the CONUS-to-forward-storage and forward-storage-to-base legs indicates that savings are reduced as pipeline times increase. Forward storage can be attractive from a strictly Air Force perspective, by creating a one-time savings through lowered base levels (vice the DoD perspective that incurs increased pipeline inventory). However, the total pipeline time of the forward-storage-to-base legs must be lower than that of the direct leg, to achieve lower base levels. Finally, although the primary focus of this study addresses the economic benefits of forward stocking, the operational ramifications of forward stocking must also be considered prior to implementation.

End Notes

1. Dianna Smith, *Determine Feasibility and Criteria for Forward Stocking Air Force-Managed Items at Defense Logistics Agency Depots*. AFLMA Final Report Number LR200520800, Air Force Logistics Management Agency, Maxwell Air Force Base, Gunter Annex, Alabama, May 2006.
2. Jackie Noble, "Adventures With the DDC-Building a Depot; The Magnificent Seven Make DDC History," *DDC News*, Winter 2004.

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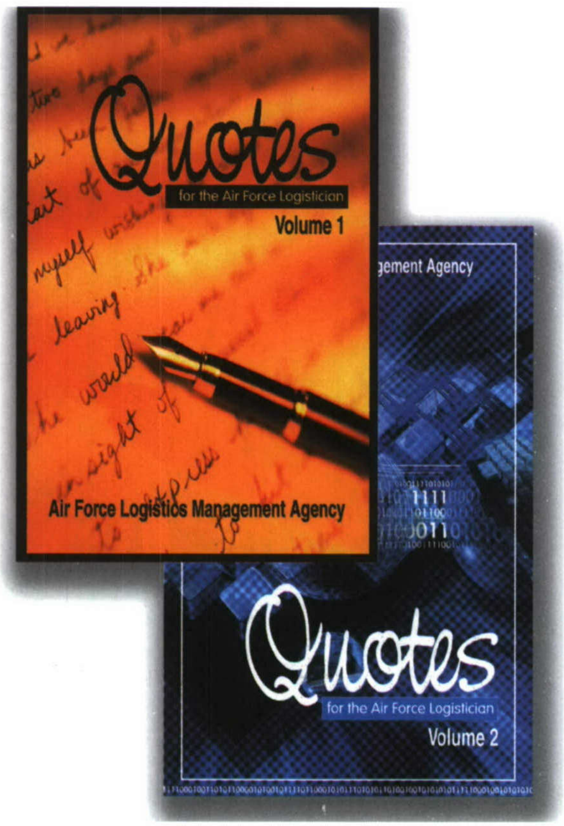

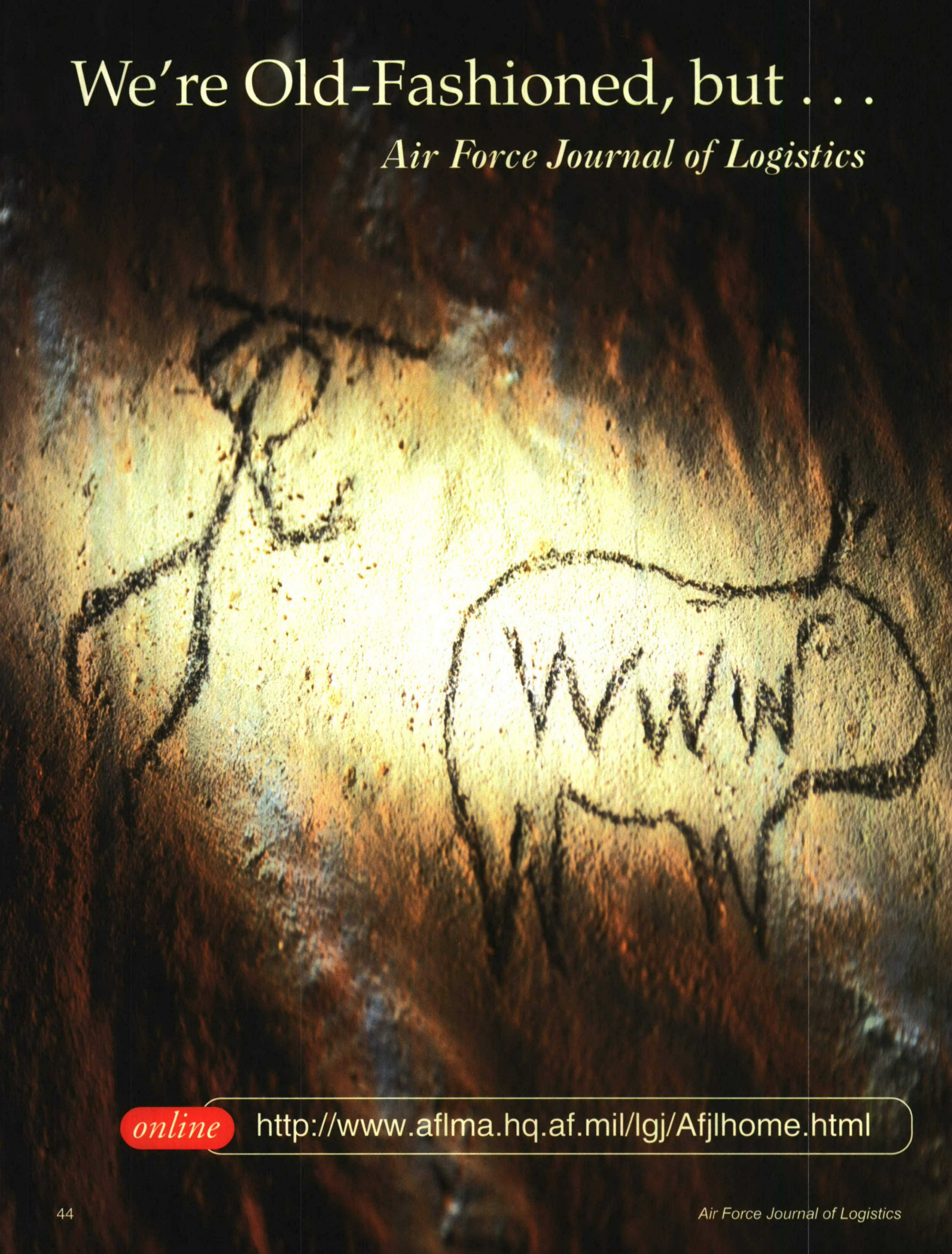
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EXPLORING THE HEART OF LOGISTICS

Operational Readiness as a Function of Maintenance Personnel Skill Level

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Introduction

Oliver, et al., identified the key logistic and operational factors associated with mission capable (MC) rates.[1] Correlation analysis was performed to identify the key factors associated with MC rates and various logistic factors (such as logistic functions and personnel) and operational factors (such as funding and environment) and their associated interactions. Regression analysis was used to explain and predict F-16 MC rates using quarterly data by flying year. Personnel skill levels, cannibalization, and funding levels were found to be significant factors.

These research findings led to the recognition that the Air Force does not currently have a metric to relate maintenance (MX) personnel skill level to operational readiness. Building upon Oliver's work, objectives of this research are to further investigate relationships between personnel skill level and mission capability, and to develop an associated metric and standard. Specifically, a metric which measures MC rate as a function of MX personnel skill level has been developed. A simple example metric is the number of 5-level personnel per aircraft. Once a metric has been determined, a standard for it can be developed which might be thought of as an objective tied to Air Force operational goals. Relationships between maintenance personnel skill level and multiple utilization and reliability and maintainability (RM) performance measures have also been examined. Finally, we have contributed an effective methodology for producing the results described here.

Article Acronyms

FAMMAS – Funding/Availability Multi-Method Allocation for Spares
FY – Fiscal Year
LCOM – Logistics Composite Model
MC – Mission Capable
MX – Maintenance
NMCM – Not Mission Capable Maintenance
NMCS – Not Mission Capable Supply
PMCM – Partially Mission Capable for Maintenance
RM – Reliability and Maintainability
WUC – Work Unit Code

Background

Headquarters Air Force, Air Combat Command and Air Mobility Command have each been developing models to predict readiness rates such as MC rate, aircraft maintenance production capability, and aircraft availability. The common goal of these models is to augment decisionmaking capability among logistics managers at various levels in anticipation of improved readiness. Oliver expressed concern about total readiness Air Force-wide as characterized by a general decrease in MC rate and increases in total not mission capable for maintenance (NMCM) and total not mission capable for supply (NMCS) rates.[2]

While there are many readiness forecasting models in use, several have gained prominence. The Funding/Availability Multi-Method Allocator for Spares (FAMMAS) is one such forecasting model which makes use of an exponential smoothing algorithm to predict MC rates based on past values.[3] Oliver also notes that while FAMMAS does well predicting MC rate based on inflation, carryover and lead time factors, there are other logistics factors such as maintenance manning and maintenance skill levels, retention, break rates, fix rates, operations tempo, spare parts issues, and RM of aircraft that are not taken into account by FAMMAS.

A second readiness forecasting model which has seen much use is the Logistics Composite Model (LCOM). LCOM uses historical data or engineered estimates to populate a Monte Carlo simulation in order to conduct weapon system capability analyses and determine required support resources for a given weapon system capability.[4] LCOM does not examine issues such as the effect of maintenance personnel skill levels on these forecasts.

The Mission Capable Rate and Aircraft Availability Modeling and Simulation Summit in Washington, DC addressed observations of the General Accountability Office and recognized that a suitable model to predict MC rates and establish suitable goals should contain the following dependent variables:

- MC rate
- NMCM rate
- NMCS rate.

Suitable independent variables should deal with resources, funding, manpower, and programming data.[5] As discussed in the remainder of this section, manpower has been specifically studied many times in order to both understand it better and quantify its effects more accurately.[6,7,8,9]

Howell studied the effects of personnel skill level on sortie, mission generation, and manpower requirements.[10] Through the use of operational audits, standard times for the completion of tasks related to the maintenance of F-4E aircraft were obtained. These data, along with failure rates obtained through Air Force maintenance databases, were used to populate a maintenance unit simulation through LCOM. Two separate, unconstrained simulation models were run. The first was run using only 3-level maintainers, and the other was run using only 5-level maintainers. Howell's study found that 3-levels produced only 76 percent of sorties produced by 5-levels, and 3-levels took 1.34 times as many man-hours as the corresponding 5-levels. Additional experimentation with a constrained model found 3-levels actually take an average of 1.463 times as long to complete a given task. These results led to suggestions of grouping teams of 3- and 5-level maintainers in more effective ways.

Garcia and Racher examined the effects of skill level differences within LCOM.[11] They noted that 3-level maintainers must frequently accomplish tasks beyond their skill level. As a result, these tasks take significantly longer and contain more mistakes than if they were performed by 5-level maintainers. Since LCOM fails to model this, manning requirements may be understated. The current work provides a methodology to modify LCOM to reflect differing skill levels in the completion of maintenance tasks.

Dahlman and Thaler sought to identify and quantify the value of 5- and 7-level maintainers.[12] Using a ratio of skilled to unskilled maintainers, a correlation analysis was performed to examine the relationship between the ratio and NMCM rates to emphasize the balance between skill and training.

Independent Variables
Number of 3-Level Maintainers Available
Number of 5-Level Maintainers Available
Number of 7-Level Maintainers Available
Number of 9-Level Maintainers Available
Percent of 3-Level Maintainers Available
Percent of 5-Level Maintainers Available
Percent of 7-Level Maintainers Available
Percent of 9-Level Maintainers Available
Number of Crew Chiefs
Number of Total Maintainers Available

Figure 1. Independent Variables

Dependent Variables
MC Rate
Utilization Variables 8-Hour Fix Rate Average Aircraft Inventory Flying Hours Sorties
Reliability and Maintainability Variables CANN Hours Maintenance Reliability TNMCM Hours

Figure 2. Dependent Variables

Methodology

Our methodology consists of performing four analysis tasks for each dependent variable MC rate, four utilization variables and three RM variables.

- Define how variables would be used in the analysis
- Perform correlation analysis between dependent and independent variables
- Construct regression models for each dependent variable
- Select models for each dependent variable

We use quarterly data collected from fiscal year (FY) 1993 through FY00.[13] These data were obtained through the Reliability and Maintainability Information System from the Equipment Inventory, Multiple Status and Utilization Reporting System and Product Performance Subsystem databases. Personnel variable data were acquired from the Personnel Data System. This section gives a detailed description of how each analysis task is performed and the results of each task.

Variable Definition

As our objective is to examine relationships between personnel skill level and readiness, our first task is to select relevant independent (related to personnel skill level) and dependent (related to readiness) variables from Oliver et al.[14] As shown in Figure 1, we identify ten independent variables including the numbers and percentages of 3-, 5-, 7- and 9-level maintainers. Figure 2 contains the dependent variables including MC rate, utilization variables and RM variables. To clarify, the 3-, 5-, 7- and 9-level maintainers represent the availability of each level maintainer to the F-16C/D airframe.

MC rate refers to the percentage of time that aircraft are fully or partially mission capable. Eight-hour fix rate represents the cumulative percentage of Code 3 aircraft breaks recovered within 8 hours of landing. Average aircraft inventory represents the average number of assigned aircraft. Flying hours represent the number of hours flown by all F-16C/D aircraft in each quarter. Sorties are the number of flights recorded for all F-16C/D in each quarter. Cannibalization hours represent the number of hours expended on cannibalization per work unit code (WUC). Maintenance reliability is the number of times a WUC is coded NMCM or partially mission capable for maintenance (PMCM). Total not mission capable maintenance hours are the number of hours recorded for aircraft not being mission capable for maintenance reasons (does not include PMCM hours).

Correlation Analysis

To identify existing linear relationships between independent and dependent variables, Pearson product moment correlation is computed for each independent and dependent variable combination. Variables with correlation coefficients greater than 0.80 are identified as good regression model candidates. Figure 3 contains the results of the correlation analysis. We have also systematically investigated meaningful interaction among the independent variables identified for inclusion in our models.

Dependent Variables	Independent Variables				
	# of Level 3 Maintainers	# of Level 5 Maintainers	# of Level 7 Maintainers	# of Level 9 Maintainers	# of Crew Chiefs
MC Rate	-0.620	0.738	0.835	0.859	0.051
8-hr Fix Rate	-0.530	0.895	0.930	0.873	0.090
Average Aircraft Inv	0.845	-0.540	-0.739	-0.659	0.101
Flying Hours	0.385	-0.323	-0.462	-0.307	0.052
Sorties Flown	0.330	-0.272	-0.368	-0.197	0.114
CANN Hours	0.457	-0.742	-0.813	-0.746	-0.008
MX Reliability	0.626	-0.708	-0.865	-0.793	-0.101
TNMCM Hours	0.618	-0.605	-0.759	-0.770	-0.071
Dependent Variables	% of Level 3 Maintainers	% of Level 5 Maintainers	% of Level 7 Maintainers	% of Level 9 Maintainers	# of Total Maintainers
MC Rate	-0.838	0.466	0.858	0.847	0.758
8-hr Fix Rate	-0.896	0.623	0.862	0.767	0.905
Average Aircraft Inv	0.778	-0.301	-0.902	-0.639	-0.560
Flying Hours	0.419	-0.068	-0.552	-0.216	-0.359
Sorties Flown	0.350	-0.106	-0.426	-0.086	-0.292
CANN Hours	0.768	-0.441	-0.791	-0.659	-0.769
MX Reliability	0.816	-0.329	-0.931	-0.733	0.750
TNMCM Hours	0.739	-0.278	-0.849	-0.779	-0.640

Figure 3. Correlation Results

Regression Modeling

Regression Model Construction

The first step of our regression modeling is to develop candidate regression models for each dependent variable. In order to find good candidate models, seven distinct regression techniques are identified and conducted as described in Figure 4. Each of these regression techniques is employed separately on two subsets of the independent variables. One subset contains percentages of each level of maintainers, number of crew chiefs, and number of total maintainers. The other subset contains the numbers of each level maintainer, number of crew chiefs, and number of total maintainers. This ensures that the percentages and numbers of each level maintainer are never included in the same model, thereby maintaining independence. Figure 5 contains resulting models from each regression technique for the MC rate dependent variable.

Regression Model Selection

The regression model construction step results in multiple candidate models for each dependent variable. The need arose to select the best model for each dependent variable by examining the linear fit of the models, the efficiency of models, and adherence to model assumptions.

The first step is to examine the linear fit of each candidate model. Any candidate model which does not result in a fit parameter (adjusted R-squared value) of 0.64 or greater was eliminated from further consideration, reducing the number of candidate models from 82 to 60. This criterion determines that no candidate model provides a good fit for flying hours and sorties. This result suggests that factors other than personnel skill level are influencing these two performance measures, and therefore flying hours and sorties are eliminated from further analysis.

The next criterion used to select the final models is model efficiency. Here, efficiency is defined as how well the model fits the data (adjusted R-squared) given the number of variable inputs needed to obtain this fit (independent variable terms).

Technique	Description
Regression 1	Multivariate regression analysis containing all independent variables (no interactions)
Regression 2	Variation of Regression 1 containing only significant independent variables based on p-value of 0.05 or less
Regression 3	Multivariate regression analysis containing only independent variables with a correlation coefficient of 0.8 or higher; Interaction effects with high correlations were included
Regression 4	Variation of Regression 2 containing only significant independent variables and interactions based on p-value of 0.05 or less
Regression 5	Stepwise regression analysis starting with all independent variables (no interactions)
Regression 6	Stepwise regression analysis starting with only two and three way interactions
Regression 7	Combination of Regression 5 and Regression 6; Stepwise regression analysis starting with all independent variables and two and three way interactions

Figure 4. Regression Techniques

Efficient frontiers for each of the six remaining dependent variables are developed by graphing the adjusted R-squared value versus the number of variable terms for each remaining candidate model. Dominant models, or those models that lie on the efficient frontier, are identified as models that achieve better or equal adjusted R-squared values with fewer variable terms. A summary of all candidate models with fit criteria greater than 0.64 is shown in Figure 6. We have identified the most efficient models for each dependent variable, and we have reduced the number of candidate models from 60 to 18.

A summary of the efficiency analysis is given in Figure 7. An abbreviated naming scheme for the candidate models is given by regression analysis technique number and type of skill level

Mission Capable Rate	
Percentage of Maintainers	**Number of Maintainers**
Regression 1: MC rate = $5.24 - 4.54x_{\%3} - 5.30x_{\%5} - 4.01x_{\%7} + 2.75x_{\%9} - 0.000002x_{chiefs} + 0.000001x_{total\ maintainers}$ R-Sq = 84.3%, R-Sq (adj) = 80.5%	**Regression 1:** MC rate = $0.729 - 0.000114x_{\#3} - 0.000134x_{\#5} - 0.000106x_{\#7} + 0.000077x_{\#9} - 0.000002x_{chiefs} + 0.000116x_{total\ maintainers}$ R-Sq = 84.1%, R-Sq (adj) = 80.3%
Regression 2: No variables were significant from Regression 1.	**Regression 2:** No variables have a p-value that are significant.
Regression 3: MC rate = $0.622 - 0.046x_{\%3} + 26.7x_{\%7}x_{\%9}$ R-Sq = 80.9%, R-Sq (adj) = 79.6%	**Regression 3:** MC rate = $0.699 + 8.63E\text{-}8x_{\#7}x_{\#9}$ R-Sq = 74.7%, R-Sq (adj) = 73.9%
Regression 4: MC rate = $0.607 + 27.6x_{\%7}x_{\%9}$ R-Sq = 80.9%, R-Sq (adj) = 80.2%	**Regression 4:** This regression is redundant to Regression 3.
Regression 5: MC rate = $0.347 + 1.27x_{\%7} + 4.89x_{\%9}$ R-Sq = 82.0%, R-Sq (adj) = 80.7%	**Regression 5:** MC rate = $0.792 - 0.000017x_{\#3} + 0.000123x_{\#9}$ R-Sq = 77.3%, R-Sq (adj) = 75.7%
Regression 6: MC rate = $0.639 - 9.43x_{\%5}x_{\%9} + 42.1x_{\%7}x_{\%9}$ R-Sq = 82.5%, R-Sq (adj) = 81.3%	**Regression 6:** MC rate = $0.650 - 6.59E\text{-}9x_{\#3}x_{\#9} + 4.47E\text{-}8x_{\#7}x_{\#9} - 1.29E\text{-}12x_{\#5}x_{\#7}x_{\#9}$ R-Sq = 83.7%, R-Sq (adj) = 82.0%
Regression 7: This regression is redundant to Regression 6	**Regression 7:** MC rate = $1.59 - 4.68E\text{-}5x_{\#5} - 0.00236x_{\#9} + 1.14E\text{-}7x_{\#5}x_{\#9} + 1.85E\text{-}7x_{\#7}x_{\#9} - 8.2E\text{-}12x_{\#5}x_{\#7}x_{\#9}$ R-Sq = 86.6%, R-Sq (adj) 84.0%

Figure 5. Regression Analyses for Mission Capable Rate

Dependent Variables	# of Independent Variable Terms					
	1	2	3	4	5	6
MC Rate		0.802	0.84	0.82		0.805
		0.807	0.813			0.803
		0.739	0.796			
		0.757				
8 Hour Fix Rate	0.813	0.861	0.859	0.847		0.842
	0.861	0.857	0.863			0.84
			0.859			
Average Aircraft Inventory	0.808		0.92	0.932	0.973	0.917
	0.704		0.943		0.982	0.941
					0.973	
CANN Hours	0.649	0.65	0.651		0.746	0.665
		0.649	0.647			0.669
			0.694			
MX Reliability	0.861	0.886	0.891	0.901		0.894
		0.859	0.74			0.898
		0.87				
		0.88				
		0.883				
		0.872				
TNMCM Hours	0.711		0.792	0.776	0.794	0.779
			0.792			0.774
			0.794			0.854

Figure 6. Adjusted R-Squared Values for Efficiency Analysis

data (P for percentage and N for number). For example, a candidate model developed for percentage of skill level data using regression 5 is Regression 5P. Figure 8 presents the efficiency analysis graph for MC rate. Here we can see that candidate models Regression 5P and Regression 7N lie on the efficient frontier as they dominate the other models.

The third criterion used to identify the final models is whether or not the efficient models for each dependent variable meet four common linear regression assumptions.

- The error term, ϵ, has mean zero
- The error term, ϵ, has constant variance
- Errors are not correlated
- Errors are normally distributed

A description of how each of these assumptions is tested is provided in Figure 9.

Figure 10 contains the results of each assumption test for the efficient models. Models that do not meet all four of the criteria were removed from consideration as final recommended models. This decreased the number of candidate models from 18 to 15.

Final Model Identification

A final model is chosen based on the results presented in the previous section. The last criterion enforced in identifying final models is avoiding the use of interaction terms when other model criteria are similar. The final models for the six remaining dependent variables are presented in Figure 11.

Further Investigation

Because none of the constructed models for predicting MC rate capture budget constraints, additional steps are taken to model budgetary effects. The dependent variable flying hours is used as an indicator of budget amounts since the number of flying hours recorded depends partially on budget constraints. The variable of flying hours is defined as the number of aircraft flying hours recorded.[15] Other than the addition of flying hours as an independent variable, the same methodology is followed to estimate new regression models.

The regression procedure outlined in Figure 4 is followed to examine whether the addition of flying hours would result in more descriptive models of MC rate. Upon inspection, all but two of the resulting models do not differ from those previously constructed. The two models that do include flying hours are Regressions 1N and 1P for the percentage data set. The reason flying hours is included in these models is that Regression 1 requires that all independent variables are used.

The models estimated using Regression 1, including flying hours, are not more efficient compared to those excluding flying

Dependent Variable	Efficient Frontier Models
MC Rate	Regression 5, P
	Regression 7, N
8 Hour Fix Rate	Regression 5, N
	Regression 6, P
Average Aircraft Inventory	Regression 3, P
	Regression 5, N
	Regression 6, N
Cannibalization Hours	Regression 3, N
	Regression 5, P
	Regression 7, N
	Regression 6, N
Maintenance Reliability	Regression 2, P
	Regression 2, N
	Regression 4, P
	Regression 7, P
TNMCM Hours	Regression 3, P
	Regression 6, P
	Regression 7, N

Figure 7. Efficient Frontier Models for Each Dependent Variable

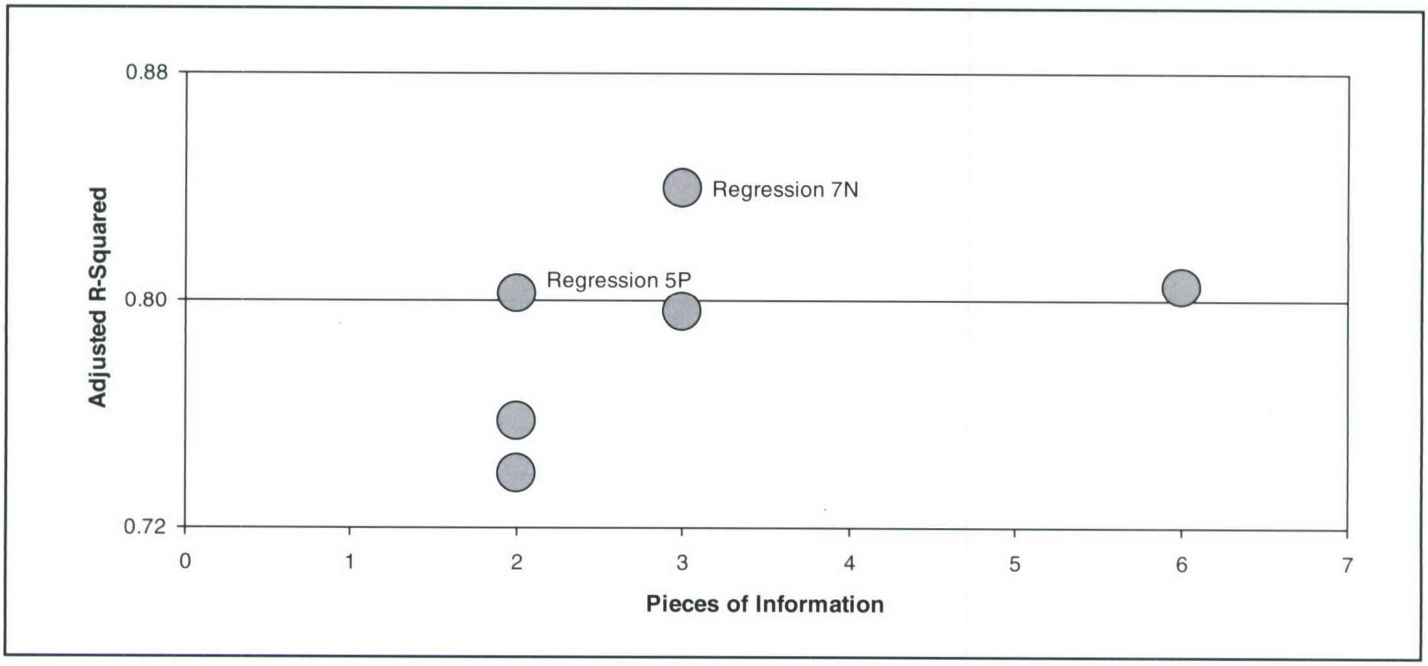

Figure 8. Efficiency Analysis Graph

hours. A conclusion which can be drawn from this analysis is that (assuming flying hours effectively represent budget constraints) models using only personnel skill level are more efficient than models including budget constraints in addition to personnel skill level.

Results

The statistical variability inherent in the regression model and the varying nature of the skill levels require that a range, or interval, be given instead of point estimates to illustrate what is useful about models such as these. Prediction intervals are calculated for each given combination of 7- and 9-level maintainers. A summary of the prediction intervals can be seen in Figure 12. The confidence used to calculate the prediction intervals is 95 percent. When the prediction intervals are compared to point estimates, it can be seen that the intervals provide more combinations of independent variables resulting in the standard MC rate. This result gives decisionmakers more flexibility with personnel levels that might reasonably facilitate the standard for MC rate. The result also gives decisionmakers a considerably more realistic range of values instead of simple point estimates of MC rate.

Figure 12 provides an examination into standards, according to the results reported here, that Air Force should maintain for percentages of 7- and 9-level maintainers to ensure that the expected value for MC rate might not fall below the desired threshold of 84 percent.

Assumption	Test Description
Has zero mean	One-sample t-test where H_0: The sum of the residuals = 0; models failed this assumption if their p-value was less than 0.95.
Has constant variance	The residuals were ordered according to the value of the predicted values of the variable being modeled. The residuals were then halved and a 2-sample t-test was performed where H_0: variances are equal. If the resultant p-value was less than 0.05, it failed this assumption.
Errors are uncorrelated	Each residual (r_j) was compared to the next r_{j+1} residual by computing a correlation value. Correlation coefficients of 0.80 or higher failed this assumption.
Errors are normally distributed	Ryan-Joiner test for normality where p-values less than 0.05 failed this assumption.

Figure 9. Assumption Test Description

Conclusions

There have been shown here systems to formally explore and find relatively good models based on valid assumptions of dependent variables such as MC rate, utilization variables, and RM variables. Independent variables in the study include numbers and percentages of 3-, 5-, 7- and 9-level maintainers, and numbers of crew chiefs and total maintainers available. Our focus has been on the estimation of MC rate as a function of percentages of 7- and 9-level maintainers. With this we have explained 82 percent of the variation observed in MC rate.

Based more specifically on prediction intervals, the user of our model can contemplate combinations of 7- and 9-level

Dependent Variable	Model	1-Sample t test (p-value)	Ryan-Joiner Test (p-value) *(Residual Normality)*	Correlation Coefficient for error terms	2-Sample t test (p-value)
MC Rate	Regression 5, P	1.000	> 0.100	0.48	0.697
	Regression 7, N	1.000	> 0.100	0.198	0.412
8 Hour Fix Rate	Regression 5, N	1.000	> 0.100	-0.241	0.680
	Regression 6, P	1.000	> 0.100	-0.256	0.733
Average Aircraft Inventory	Regression 3, P	1.000	0.070	0.889	0.048
	Regression 5, N	1.000	> 0.100	0.504	0.430
	Regression 6, N	1.000	> 0.100	0.199	0.477
CANN Hours	Regression 3, N	1.000	> 0.100	0.373	0.168
	Regression 5, P	1.000	> 0.100	0.370	0.167
	Regression 6, N	1.000	> 0.100	0.337	0.313
	Regression 7, N	1.000	> 0.100	0.188	0.452
Maintenance Reliability	Regression 2, P	1.000	> 0.100	0.216	0.873
	Regression 2, N	1.000	> 0.100	0.204	0.044
	Regression 4, P	1.000	> 0.100	0.239	0.675
	Regression 7, P	1.000	> 0.100	-0.102	0.429
TNMCM Hours	Regression 3, P	1.000	0.021	0.493	0.816
	Regression 6, P	1.000	0.087	0.151	0.732
	Regression 7, N	1.000	0.050	0.332	0.470

Figure 10. Assumption Test Results

MC Rate (%)	% Level 9				
% Level 7	2.25	2.50	2.75	3.00	3.25
23	72.80 – 77.03	74.02 – 78.25	75.25 – 79.47	76.47 – 80.69	77.69 – 81.91
24	74.11 – 78.25	75.34 – 79.47	76.56 – 80.69	77.78 – 81.92	79.01 – 83.14
25	75.38 – 79.52	76.60 – 80.75	77.83 – 81.97	79.05 – 83.19	80.27 – 84.41
26	76.61 – 80.84	77.83 – 82.06	79.05 – 83.28	80.27 – 84.50	81.50 – 85.73
27	77.79 – 82.20	79.01 – 83.42	80.23 – 84.64	81.46 – 85.86	82.68 – 87.08

Figure 11. Final Models

maintainer percentages and their probable effects on MC rate. For example, we have illustrated six different realistic personnel combinations that should produce MC rates consistent with 84 percent standard for MC rate.

End Notes

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Dependent Variable	Final Model
MC Rate	$0.347 + 1.27x_{\%7} + 4.89x_{\%9}$ r-sq = 82.0%, r-sq (adjusted) = 80.7%
8-Hour Fix Rate	$0.441 + 0.000040x_{\#7}$ r-sq = 86.5%, r-sq (adjusted) = 86.1%
Average Aircraft Inventory	$760 + 0.0624x_{\#3} + 0.0363x_{\#5} - 0.0736x_{\#7}$ r-sq = 94.9%, r-sq (adjusted) = 94.3%
CANN Hours	$33,857 - 2.49x_{\#7}$ r-sq = 66.0%, r-sq (adjusted) = 64.9%
Maintenance Reliability	$24,947 - 72,293x_{\%7}$ r-sq = 86.6%, r-sq (adjusted) = 86.1%
TNMCM Hours	$-178,625 + 41.7x_{\#5} - 0.0366x_{\#7}x_{\#9}$ r-sq = 80.7%, r-sq (adjusted) = 79.4%

Figure 12. Prediction Intervals for MC Rate Within Observed Values

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Be nice to your mother but love your logisticians and communicators.

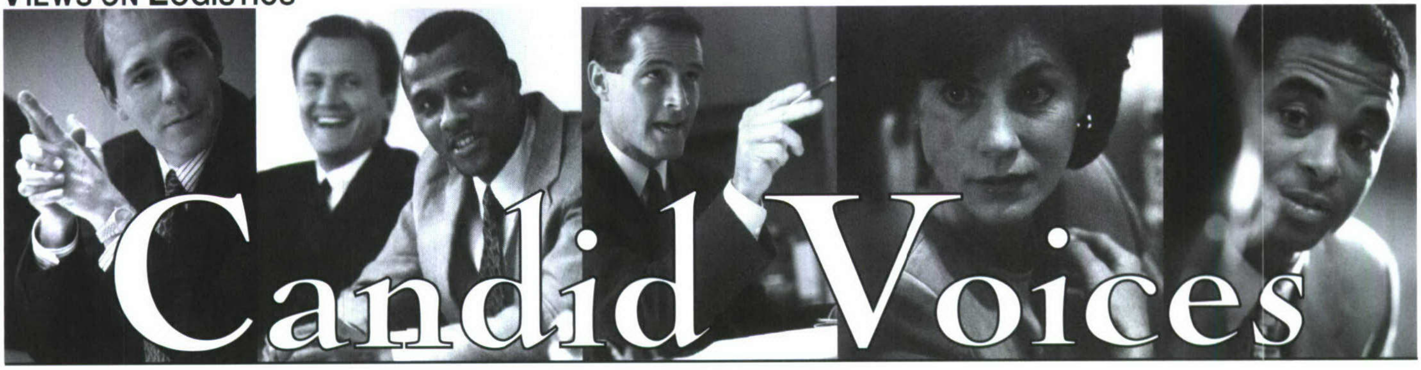
—Gen Charles A. Horner, USAF

You think out every possible development and decide on the way to deal with the situation created. One of these developments occurs; you put your plan in operation, and everyone says, "What genius…" whereas the credit is really due to the labor of preparation.

—Marshal of France Ferdinand Foch

…instant history [was] invariably shallow history.

—Anthony Cordesman



Foreign Comparative Testing Program

John C. Andreadakis II, Centurum Technical Solutions

Picture this: you're deployed overseas in Operation Iraqi Freedom or Operation Enduring Freedom on a mission with other coalition forces. As you engage the enemy through coalition operations, you notice that your coalition partners have a piece of equipment that really makes a difference. You wish your Service had that piece of gear and wonder: "how soon could I get my hands on that equipment…and what would it really take to get the item into service?"

What if I told you that US warfighters can rapidly get their hands on superior foreign equipment and technology they see while serving in friendly foreign counties around the world? What if I were to tell you that this includes the time to test and field the equipment? The answer—we can do just that via the Foreign Comparative Testing (FCT) Program managed from Comparative Testing Office in the Office of the Under Secretary of Defense (Acquisition, Technology and Logistics). From bullets to aircraft loading equipment to nanotechnology, the FCT program provides funding for test articles and the testing and evaluation of foreign equipment. Additionally, since the Office of the Secretary of Defense (OSD) and Congress approve the projects, procurement funding is virtually *locked-in* for the specific projects. FCT gives the US warfighter a way to acquire needed assets within 6 to 24 months of submitting a proposal. Candidate projects are submitted annually to the OSD by June, and funding is normally released by mid-October. With a 2-year test-to-procure goal, the FCT program saves time, money, and effort versus the lengthy traditional acquisition cycle.

Since its inception in 1980, the FCT Program has funded over 528 projects with $932M, resulting in procurements in excess of $6.7B in fiscal year 2005 constant year dollars. Fifty-five million dollars has been awarded to the Air Force over the past 20 years, resulting in procurements in excess of $1B.

Article Acronyms

DACP – Defense Acquisition Challenge Program
FCT – Foreign Comparative Testing
MEMS IMU – Micro-Electro Mechanical System Inertial Measurement Unit
OSD – Office of the Secretary of Defense

Through the FCT Program, all of the Services are afforded the opportunity to leverage our allies' technologies, and provide the warfighter with much needed equipment, in a rapid manner. Each Service has a program office dedicated to supporting the FCT Program. The efforts of each program office allow the program to grow stronger and gain support and interest from warfighters and foreign vendors alike. The representatives from each of the Services attend all major international air shows, as well as conduct industry tour of various nations, looking for equipment that could satisfy the needs of the airmen, soldiers, sailors, and marines.

Successful FCT projects result from world-class foreign defense items produced by allied and other friendly countries, strong US user advocacy and support, a valid operational requirement, and solid procurement potential. Many FCT projects have reduced the total ownership cost of military systems, cutting overall acquisition and support expenditures while enhancing standardization and interoperability, improving allied cross-service support, and promoting international cooperation and interoperability.

The US Air Force has always played a major role in the FCT Program by identifying allied and friendly-nation resources as a solution to Air Force shortfalls. Examples of Air Force FCT programs are:

- **Next Generation Small Loader.** The Air Force had a requirement to acquire a 25 ton loader, which could be used with cargo aircraft. Two foreign sources were identified with potential equipment to fulfill the requirement. After rigorous testing of the equipment, in accordance with Air Force standards, a single candidate was qualified as best value for the Air Force, and procured.
- **Micro-Electro Mechanical System Inertial Measurement Unit (MEMS IMU).** The MEMS IMU was the solution to creating a better guidance system, which was smaller, lighter, and more efficient, allowing missile systems to carry a larger, heavier payload.
- **20 MM Replacement Rounds.** The Air Force 20MM rounds had been condemned to *emergency use only*, because of misfiring in the chambers, putting Air Force pilots and aircraft at risk. Two foreign sources were identified to fulfill this shortfall. Rounds from each source were tested in accordance

with DoD standards and requirements in order to identify the best item to fill the Air Force stockpile.

There is a complementary domestic program to FCT called the Defense Acquisition Challenge Program (DACP). The purpose of DACP is very similar to FCT, but DACP focuses solely on getting *domestic* solutions rapidly to the warfighter. For more information on these two special programs, go to http://www.safia.hq.af.mil/fct for the Air Force Foreign Comparative Testing Program and http://www.acq.osd.mil/cto/ for the Defense Acquisition Challenge Program.

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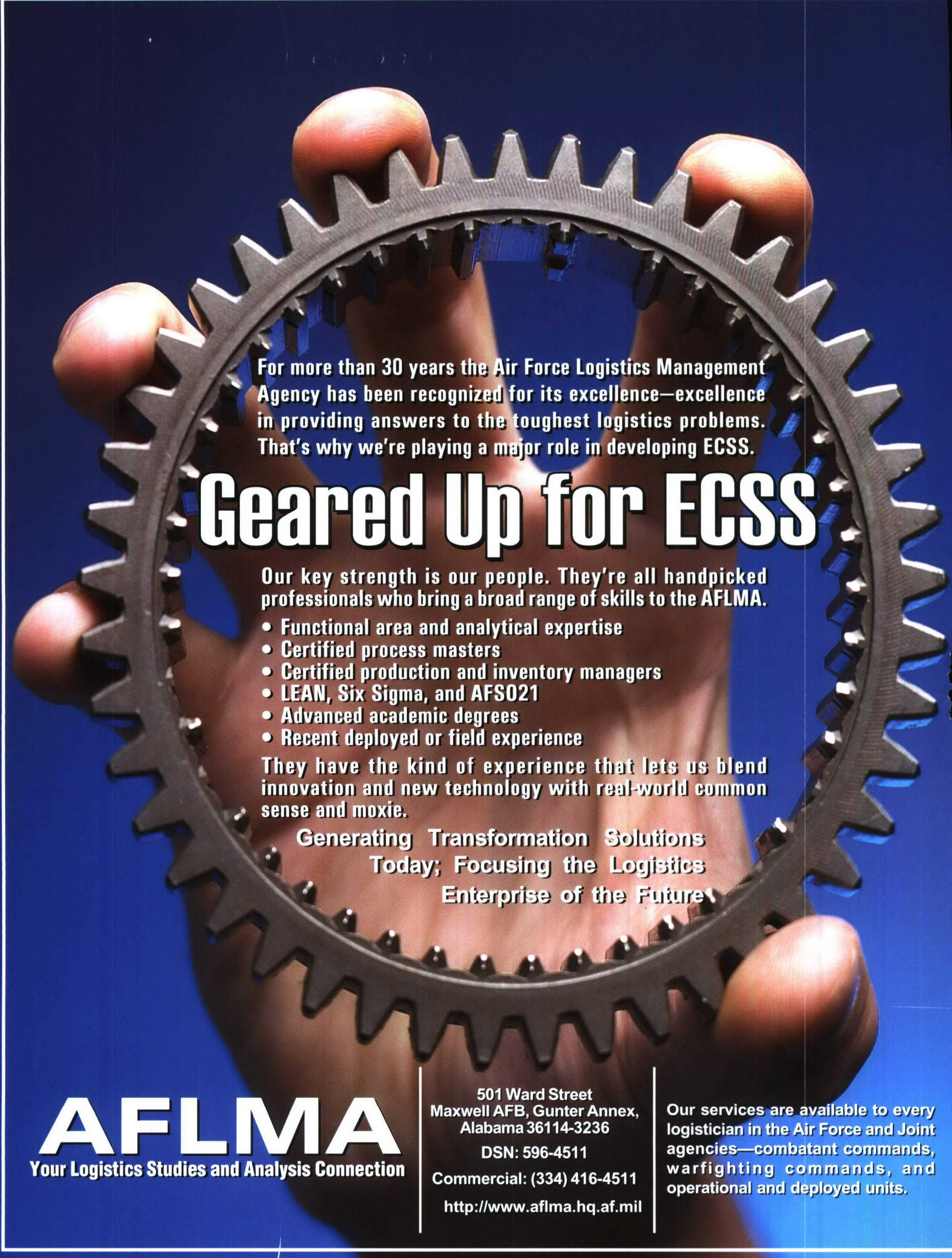
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