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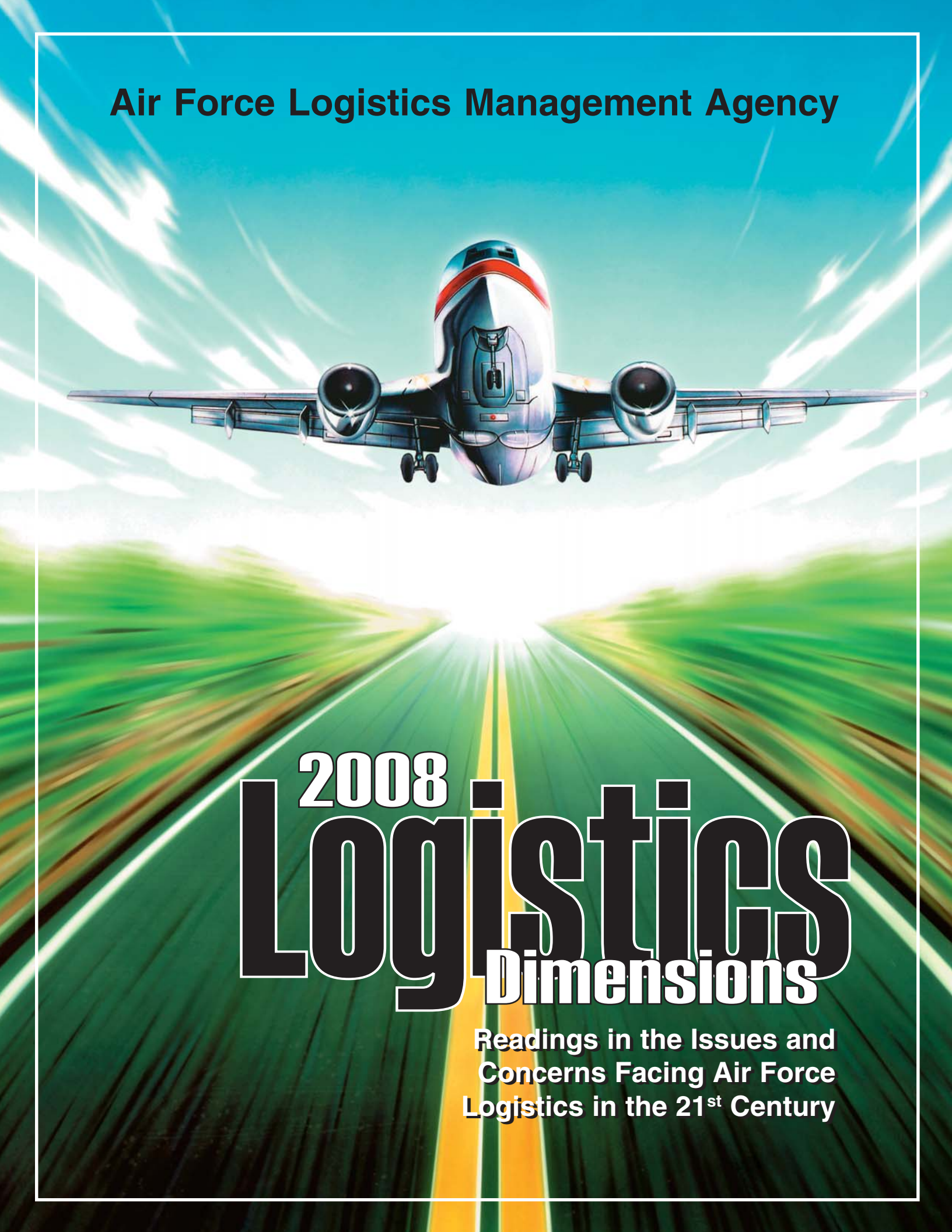

# 2008 Logistics Dimensions

Readings in the Issues and Concerns Facing Air Force Logistics in the 21st Century

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## Readings in the Issues and Concerns Facing Air Force Logistics in the 21st Century

**The Editors, Air Force Journal of Logistics**

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**501 Ward Street**
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**August 2008**

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# Foreword

## Logistics Dimensions 2008

*Logistics Dimensions 2008* is a collection of 19 essays, articles, and vignettes that lets the reader look broadly at a variety of logistics concepts, ideas, and subjects. Included in the volume is the work of many authors with diverse interests and approaches. The content was selected for two basic reasons—to represent the diversity of the ideas and to stimulate thinking. That's what we hope you do as you read the material—think about the dimensions of logistics. Think about the lessons history offers. Think about why some things work and others do not. Think about problems. Think about organizations. Think about the nature of logistics. Think about fundamental or necessary logistics relationships.

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# Contents

## Featured Readings

Foreword ..... 5

C-5 TNMCM Study II: Realistic Metrics to Drive Operational Decisions ..... 9

Beyond Authorized Versus Assigned: Aircraft Personnel Capacity ..... 16

Aligning Maintenance Metrics: Improving C-5 TNMCM ..... 28

Establishing C-5 TNMCM Standards ..... 40

Supply Chain Management: More Than Integrated Logistics ..... 50

Logistics Support: Relating Readiness to Dollars ..... 58

Supply Chain Management: Analyzing Industry and Air Force Metrics ..... 66

Sense and Respond Combat Support: Command and Control-Based Approach ..... 80

Contingency Contracting: Analyzing Support to Air Force Missions in Iraqi Freedom ..... 92

Sustaining Airpower: Influence of Logistics on RAF Doctrine ..... 102

## General Readings

DLA Forward Stocking: An Economic Analysis ..... 112

Logistics for the 21st Century: Deployment Distribution Operations Center, Quick Fix or Long-Term Solution? ..... 118

Operational-Level Analysis: DoD's Strategic Mobility and Logistics Support to the Homeland Security Architecture ..... 130

## Vignettes

Historical Perspective ..... 38

Lessons from the First Deployment of Expeditionary Airpower ..... 49

Concentration and Logistics ..... 79

Napoleon and Logistics Capacity ..... 101

The Themes of US Military Logistics ..... 111

Military Logistics and the Warfighter ..... 117

# C-5 TNMCM Study II

## Realistic Metrics to Drive Operational Decisions

**Major Scotty A. Pendley, AFLMA**

**In order to blueprint an exportable methodology, the study team developed and utilized the Hierarchical Holographic Model and a ranking and filtering process. This overall process is suitable for complex problem modeling and is exportable to other weapon systems.**

### Introduction

Aircraft maintenance has been and continues to be a challenging, complex task involving a delicate balance of resources to include personnel, equipment, and facilities. Adding to this challenge is the fact that the balancing act occurs in a very hectic environment where the United States Air Force flies 430 sorties per day in support of Operations Iraqi Freedom and Enduring Freedom. And somewhere in the world, a mobility aircraft takes off approximately every 90 seconds.[1] At the same time, the number of airmen supporting our aircraft is declining. "Since 2001 the active duty Air Force has reduced its end-strength by almost 6 percent but our deployments have increased by at least 30 percent, primarily in support of the Global War on Terror."[2] This reduction in personnel is part of the Air Force process of drawing down the total force by approximately 40,000 people, with many of these cuts in aircraft maintenance career fields. Also adding to the growing maintenance workload is an aircraft fleet which now averages almost 24 years old, with the average still increasing.[3]

### Background

When it comes to aircraft maintenance, the Air Force depends on metrics to gauge whether or not we are measuring up to the standard and succeeding in our maintenance efforts. One of the most recognized metrics is the total not mission capable maintenance (TNMCM) rate. Air Force Instruction (AFI) 21-101 describes TNMCM as "perhaps the most common and useful metric for determining if maintenance is being performed quickly and accurately."[4] Although a lagging type indicator, it is one of several key metrics followed closely at multiple levels of the Air Force. Over the last few years, the Air Force TNMCM rate increased across many platforms. TNMCM discussions by Air Force leadership ultimately resulted in the Air Force Materiel Command Director of Logistics (AFMC/A4) requesting the C-5 TNMCM Study II (AFLMA) to conduct an analysis of TNMCM performance with the C-5 Galaxy aircraft as the focus. AFLMA was commissioned to conduct an analysis of C-5 TNMCM performance to identify root causes, indicators, and potential corrective actions to bring TNMCM within standard, the intent being to export the methodology and any lessons learned to other weapon systems.

Considering the numerous potential factors which impact TNMCM rates, as well as the C-5's historical challenges in the areas of availability and achieving established performance standards, it was obvious that this project's scope was broad, and a smart way to eat such a *big elephant* was needed. Our team just had to figure out a way to consume the beast one piece at a time and not become overwhelmed during the process. AFLMA eventually conducted two studies in support of the original study request. This article and succeeding articles focuses on the second of those studies, the C-5 TNMCM Study II, and the methodology used to accomplish this daunting task.

## Problem Statement

The Air Force C-5 fleet TNMCM rate steadily increased from 25 percent to 38 percent from 2004 to 2006. In addition, the current methodology for establishing aircraft metric standards is insufficient at communicating the overall health of the fleet. Finally, a better understanding of the return on investment (ROI) of previous improvement initiatives will enable leadership to more efficiently direct resources.

The study included five overall objectives:

- Identify root causes and indicators of increasing C-5 TNMCM rates
- Identify potential corrective actions necessary to bring the C-5 TNMCM rate within standards
- Develop a standardized analytical approach which is exportable to other Air Force aircraft
- Analyze the process for calculating and establishing aircraft TNMCM standards
- Review historical C-5 modifications and reliability initiatives for ROI

The scope of this research was limited to the various models within the C-5 fleet and no other mission design series (MDS). The scope included previous work related to Air Force aircraft maintenance, historical aircraft modifications, metrics and factors which potentially impact those metrics, and previous and ongoing C-5 issues and challenges. The study team also examined commercial aviation maintenance practices and metrics for applicability. The bulk of the research focused on disaggregated data and analysis, that is, comparisons between C-5 aircraft models and between the total force component (active duty, Guard, or Reserve) in order to examine potential root causes in greater detail.

## Research and Analysis

This project involved two main phases: data collection and data analysis. The data collection phase involved a thorough review of existing literature and resources related to aircraft maintenance, particularly C-5 aircraft, and also literature which could assist with scoping and organizing a project of this magnitude. In addition, current commercial aircraft maintenance philosophy and practices were examined as well as applicable Department of Defense (DoD) and Air Force regulations and instructions.

The data collection phase included numerous discussions with C-5 aircraft program managers and aircraft maintenance subject matter experts (SME). Points of contact were established from various phases of the C-5 support, sustainment, and policy arenas including representatives from Air Mobility Command (AMC), Air Force Materiel Command (AFMC), the C-5 Depot at Warner Robins Air Logistics Center (WR-ALC), and Headquarters (HQ) Air Force Air Staff. In addition, personnel from the RAND Corporation and the Logistics Management Institute (LMI) were consulted.

The project's first phase also included preliminary analysis of data from the system of record, the Reliability and Maintainability Information System (REMIS), as well as some basic trending and historical data from the Multi-Echelon Resource and Logistics Information Network (MERLIN) database. In conjunction with this preliminary analysis, our team conducted site visits at the C-5 Aircraft Sustainment Group at Wright-Patterson Air Force Base (AFB), C-5 Sustainment Wing and Depot facilities at Robins AFB, Westover Air Reserve Base (ARB), Dover AFB, and Stewart Air National Guard Base (ANGB). These site visits were invaluable in understanding C-5 maintenance and data collection processes across the total force, the complexity of the airframe itself, facilities and equipment, ongoing modernization efforts, and the day-to-day processes required to maintain the C-5.

Question sets were developed for each of the different areas of a maintenance complex to include the squadrons and flights within a typical maintenance group (MXG). These question sets were utilized to gather data during the site visits and were refined as the project continued in an effort to develop a standardized questioning protocol which was repeatable and could be exportable for use with similar research in the future.

## TNMCM Root Causes and Indicators

To visualize the complexity and interaction of all potential factors affecting C-5 TNMCM time, the study team employed a tool from the field of risk analysis, a Hierarchical Holographic Model (HHM).[5] HHM is an established risk analysis methodology developed by Dr Yacov Y. Haimes at the University of Virginia. Dr Haimes has completed several studies for the DoD, such as risk analysis of military operations other than war[6] and the probability of land mine contamination.[7] Haimes also used HHM in work for National Aeronautics and Space Administration (NASA) to determine the various risk scenarios affecting space shuttle missions.[8]

The HHM provided a framework for considering multiple decompositions (perspectives or views) of the system. Overall, each major view in an HHM represents a high-level factor, in this case factors contributing to not mission capable maintenance (NMCM) hours, and these high-level factors are decomposed into submodels. The HHM also enables both a systematic and systemic framework for the problem and each submodel can be analyzed independently as well as in relationship to other submodels, with analysis of an entire HHM providing a coordinated solution to the problem. With the tools just mentioned and initial data from numerous sources, the study moved into the data analysis phase.

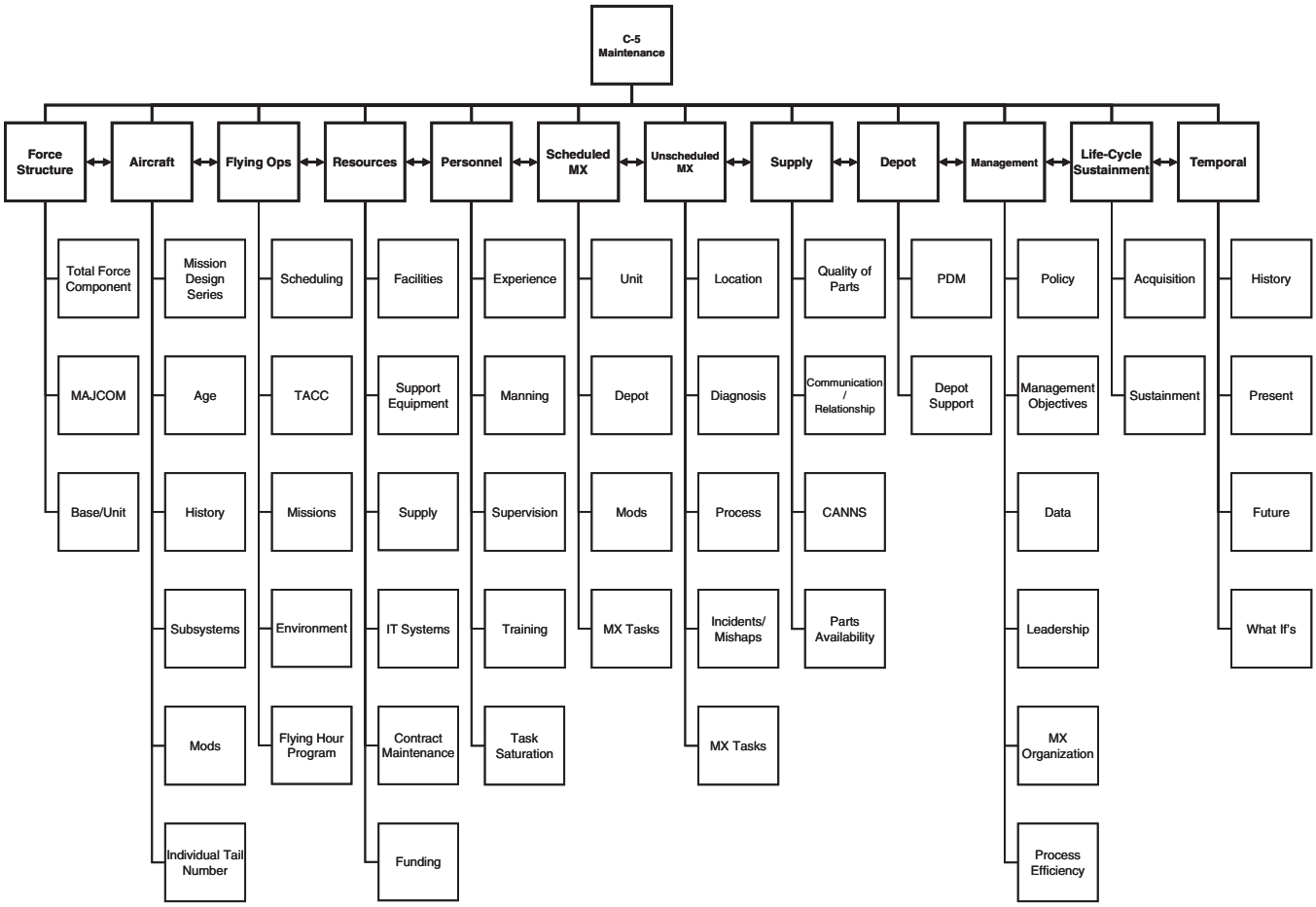
Preliminary analysis resulted in an initial HHM with 184 factors that potentially contribute to the C-5 TNMCM rate. The HHM went through several iterations before it was considered complete. The final iteration of the HHM is shown in Figure 1. The 12 high-level factors are listed horizontally across the top with submodels for each high-level factor located vertically underneath. In order to scope the project to a manageable number of factors to analyze further, and focus the remaining research on factors with the most potential to result in decision-quality results, our team developed a ranking and filtering process. This process considered each factor according to three criteria (factor weights in parenthesis):

- Impact on maintenance time (0.53)
- Data availability (0.30)
- Previously published research on the factor (0.17)

The three criteria were also scored using an ordinal scale with high = 1.0, medium = 0.5, and low = 0.0.

Table 1 describes the rule set observed when scoring the factors. The calculated total score for each factor was the result of the linear decision model; that is, the total score was equal to the sum product of the criteria weights and the criteria scores. The result was a normalized score on the interval [0, 1] for each factor. This score could then be used to perform an ordinal ranking of all 184 factors according to the criteria. The factors were sorted by total score, then alphabetically by category and subcategory. It is important to note that factors with little previous research actually received higher scores. This was part of an effort by the study team to go beyond the existing body of work and factors previously or currently considered on a regular basis.

Using this iterative process, the original 184 initial factors were scaled down to 25 high-level factors. In most cases, continuing analysis of the 25 high-level factors revealed limitations to either data availability, quantifiable impact, or both. Two factors ultimately stood out as the most fruitful to produce actionable, decision-quality results. These factors were




**The HHM is a diagram that allows us to visualize the complex relationship of the factors related to C-5 maintenance.**

**Figure 1. Hierarchical Holographic Model for the C-5 Maintenance System**

| | | Scores | | |
|---|---|---|---|---|
| | | 1.0 | 0.5 | 0.0 |
| Criteria | Impact to NMCM Time and TNMCM Rate | Direct impact; clear relationship witnessed from preliminary studies; or something so obvious that it should not be ignored. | Indirect impact; or intuitive relationship, but not sure exactly how. | Minimal impact; only related in an "Everything is connected in the universe" way. |
| | Data Availability | Data exists in a single source; source recognized as the original source; minimal effort to draw fact-based conclusions. | Data exists in multiple unrelated sources; extensive mining and data reduction required; or data exists for recent FYs only. | No data known to exist; would have to conduct an acute data collection effort to draw any fact-based conclusions. |
| | Previous Work or Studies | Fairly new idea; cutting edge of C-5 and/or general aircraft maintenance body of knowledge. | 1-2 major studies; no actions taken or decisions have been made to address the factor. | 2 or more major studies; actions have been taken or decisions have been made to address the factor. |

**Table 1. Factor Subjective Scoring Rationale**

$$NEP = T_{75}(A_{75NT} + (P_t A_{75T})) + T_3(P_e A_3)$$

**Equation 1. Net Effective Personnel**

| Factor | Description | Value |
|---|---|---|
| $T_{75}$ | Ancillary/CBT Factor for 7- and 5-levels | 0.948 |
| $A_{75NT}$ | The number of available nonmanager 7-levels and 5-levels who are not trainers | Varies day-to-day |
| $P_t$ | Trainer Productivity | 0.85 |
| $A_{75T}$ | The number of available nonmanager 7-levels and 5-levels who are trainers | Varies day-to-day |
| $T_3$ | Ancillary/CBT Factor for 3-levels | 0.925 |
| $P_e$ | Trainee Productivity | 0.4 |
| $A_3$ | The number of available 3-levels | Varies day-to-day |

**Table 2. Net Effective Personnel Factors**

aligning personnel capacity with demand and the logistics departure reliability (LDR) versus TNMCM metrics paradigm.

## Aligning Personnel Capacity with Demand

One measure historically used to quantify personnel availability is the ratio between authorized and assigned personnel. While this ratio is an indicator of maintenance capacity, it provides only a limited amount of information. Authorized versus assigned ratios do not take into account the abilities and skill levels of the maintenance personnel, nor does it factor in the availability of the personnel on a day-to-day basis. These issues were addressed in the C-5 TNMCM Study II by quantifying "we need more people," beyond the traditional metric of authorized versus assigned personnel.

To further analyze this factor, our team developed a new personnel capacity equation which encompassed three factors which impact variability in the maintenance technician pool.

- Personnel availability
- Skill-level productivity
- Ancillary and computer-based training (CBT) requirements

The influence of these three factors and their impact on the viable resource pool for the 436 MXG at Dover AFB was examined over a 9-week period during March-April 2007. This collective impact yielded a new resource pool representing a depiction of *effective* capacity rather than just the authorized versus assigned ratio. This new resource pool was denoted as Net Effective Personnel, or NEP, and is detailed in Equation 1. The newly designated factors, factor descriptions, and the associated values used in the NEP equation are listed in Table 2.

The *T* factors relate to training, the *A* factors relate to available personnel, and the *P* factors relate to productivity. These factors were applied to the number of available technicians as recorded in the Dover Aircraft Maintenance Squadron availability snapshots using the newly proposed NEP calculation.

The resulting Dover AFB NEP results and the calculated demand at Dover, defined as aircraft launches and recoveries, were compared using averages for both values over each weekday. This resulted in a comparison of the ratio of NEP per demand event. From this, we demonstrated a current suboptimization of personnel distribution over an average week. Therefore, the study team proposed a realignment of maintenance personnel capacity to better utilize available personnel. This resulted in an estimated improvement (reduction) in the TNMCM rate of 0.040, or approximately 4 percentage points. This assumed the data set utilized represented typical demand.

## LDR versus TNMCM Metrics Paradigm

The second factor for detailed focus was the LDR versus TNMCM metric comparison. Based on site visits and feedback from MXG senior leaders and all but one C-5 MXG commander (MXG/CC), the study team determined that the primary metric of the MXG/CC was LDR and that aircraft availability, which is directly related to the TNMCM rate, was the primary metric of higher level leadership. While not totally unexpected, the focus of different levels of an organization on different metrics can be problematic for the enterprise when the pursuit of goals at the local level may not be complimentary to goals at the strategic level. If the metrics are not aligned, pursuit of better performance in a lower level metric could result in worse performance for higher level metrics.

To analyze the potential effects of misaligned metrics, the study team utilized a definition of aligned metrics, which stated that a set of metrics is aligned if improvement in the lower level metric implies improvement of the higher level metric. In order to test the theoretical effect of improving home station LDR (HSLDR) on TNMCM rates, the study team constructed a discrete event simulation using Arena software. The simulation allowed the team to study how different maintenance operations could affect the HSLDR and TNMCM rates in a controlled environment, something impossible to do in the real world. The simulation used Dover AFB aircraft arrival and maintenance-related data from January 2006 through March 2007 to examine the impact of four different priority policies for a hypothetical aircraft maintenance queue. These policies were

- Least maintenance – priority given to an aircraft that requires the least man-hours to make it mission capable (MC)
- Most maintenance – priority to aircraft with the most man-hours of repair remaining
- First-in-first-out (FIFO)
- Last-in-first-out (LIFO)

The simulation confirmed that LDR and TNMCM react differently depending on the prioritization policy. The simulation also demonstrated that changing prioritization policies can improve TNMCM but at a cost to predictability and

LDR, depending on the scenario. Overall, the simulation results supported the idea that the priorities of the maintainers impact the metrics and suggest that current maintenance policies do not ensure TNMCM improvement, but do improve LDR.

## TNMCM Standard

Another study objective was to analyze the process for calculating and establishing aircraft TNMCM standards. The 2003 CORONA directed that Air Force-wide standards for MC, TNMCM, and total not mission capable supply (TNMCS) be established. While directed toward TNMCM, this research revealed that the MC standard is the foundation for calculating the other two metrics' standards. As the process currently exists, the Air Force MC standards are based on requirements and those requirements are determined in one of three ways:

- The flying hour or flying schedule requirement,
- A contract logistics support (CLS) contract, or
- Another requirement based on major command (MAJCOM) input with those inputs determined by the designed operational capability (DOC) statement, readiness study, or any operational requirement the MAJCOM may use

This is not the case for the separate Air Force Reserve Command (AFRC) and Air National Guard (ANG) fleet C-5 MC standards. Those two values are calculated at the Air Staff level. The AFRC MC standard is calculated from utilization rate, attrition, turn pattern, annual fly days, spares, aircraft held down for scheduled maintenance, and primary aerospace vehicle (aircraft) authorized (PAA). The ANG MC standard equation uses variables portraying daily operations and maintenance (O&M) flying hours, aircraft taskings per flying day over and above O&M flying, average number of aircraft required for standard flying operations each day, required daily spares, and the forecast number of unit possessed aircraft over the year.

In the case of the C-5, AMC provides the active duty fleet MC standard to the Air Staff and this standard is based on the Mobility Requirements Study (MRS). However, it is not actually calculated in the MRS, it is an assumption used in the MRS. The director of the AMC Office of Analysis, Assessments, and Lessons Learned (AMC/A9) concurred that the C-5 MC standard is not based on any formal calculation or analysis, and stated that the original estimate (circa 1990) of a 75 percent MC rate was deemed a *prudent objective* for planning purposes.[9]

During Operations Desert Shield and Desert Storm in fiscal year 1991, the C-5 fleet MC rate achieved was less than 71 percent. During Operation Iraqi Freedom in FY 03, the C-5 fleet MC rate was less than 64 percent. This is particularly intriguing because numerous personnel interviewed suggested that MC rates are usually better during conflicts. Indeed, the highest quarterly MC rate the C-5 fleet has ever achieved, 81.8 percent, was observed during FY 91, Quarter 1 (Operation Desert Shield). These observations bring into question the feasibility of a 75 percent figure for use as a realistic peacetime standard. Still, consistent failures to meet a standard are more than likely perceived as a shortfall in the performance of the units supporting the C-5, rather than an unrealistic expectation not being met. A tremendous amount of time and effort is put forth explaining why standards are not met. Historical performance would suggest that the standard is not driving improvement in performance, which is the fundamental purpose of a performance measure. It should drive performance, not simply document it, and the measure should be useful for decisionmaking.

The examination of the standards calculation methodology suggests that the C-5 MC, TNMCM, and TNMCS standards fall short in the areas of accuracy, objectivity, and ease. AFI 21-101 states that "metrics shall be used at all levels of command to drive improved performance."[10]

At least in the case of the C-5, the existing maintenance standards referenced here and their associated metrics appear to fall short of this goal.

## Historical Modifications and Improvement Initiatives Return on Investment

At the beginning of this article a reference was made to how our study team needed to eat the entire elephant smartly, the elephant being the C-5 TNMCM Study II. Our team realized very early that a research partner would be needed in order to accomplish all the study's objectives in the given time frame. AFLMA formed a strategic partnership with the Office of Aerospace Studies (OAS) at Kirtland AFB in order to accomplish the return on investment objective of the study. The OAS research team consisting of Captain Greg Steeger and First Lieutenant Matt Compton pursued three questions asked by the project sponsor:

- What was the C-5 advertised reliability *out of the box*
- What modifications were completed on the aircraft
- What was the ROI from these modifications

OAS developed the ROI methodology, data requirements, and the overall research process for this particular study objective. OAS used the Air Force Smart Operations for the 21st Century (AFSO21) definition for ROI in conjunction with a formula which utilized the maintenance man-hours (MMH) saved from completing a modification in the year after the modification was completed. The MMH savings were then multiplied by the cost per MMH and that resulting number was then divided by the total modification cost to ultimately calculate the ROI for a particular C-5 modification.

OAS also conducted an exhaustive literature review of their own and analyzed the C-5 time compliance technical order (TCTO) database scouring literally thousands of TCTOs, in addition to a site visit to Warner Robins Air Logistics Center in pursuit of all potential data sources and subject matter expertise which might assist in that phase of the research. Still, OAS research was limited by a lack of data. Detailed historical data on many past C-5 modifications either did not exist or could not be located. Much of the data required for their objective of the study was apparently lost when the C-5 depot responsibilities transferred from Kelly AFB to Robins AFB. Regardless, OAS developed a sound methodology for analyzing potential ROI for aircraft modifications. OAS wrote their portion of the study's report as a stand alone document and it was included in the overall final study report as Appendix F.

## Conclusions

In order to blueprint an exportable methodology, the study team developed and utilized the HHM and a ranking and filtering

process. This overall process is suitable for complex problem modeling and is exportable to other weapon systems.

The exhaustive analysis resulted in the study team scaling down from 184 potential C-5 TNMCM root causes to two factors yielding actionable, decision-quality results. These factors were aligning personnel capacity with demand and the LDR versus TNMCM metrics paradigm.

The process for calculating and establishing Air Force level TNMCM standards is not well known across the Air Force and not equally applied across the total force. Also, the process currently in use does not produce realistic, capability-based metrics to drive supportable operational decisions.

Finally, OAS conducted a thorough review of historical documents, aircraft modifications, and existing data sources in an effort to answer the sponsor's original questions. OAS also developed a sound methodology to analyze potential ROI but with limited availability of reliable data—the results proved inconclusive.

## Recommendations

### Methodology

Similar research efforts for any MDS will require reaccomplishment of the full HHM and ranking and filtering processes.

### Root Causes and Indicators

- Apply the NEP methodology utilizing data from other units to verify potential gains.
- In order to most directly improve TNMCM, all levels of leadership would need to make TNMCM their primary metric.

### TNMCM Standard

Develop a repeatable methodology to compute the standard that:

- Reflects day-to-day minimum operational requirements
- Adjusts to fully mobilized force capabilities and surge mobility requirements
- Accounts for historic capabilities and fleet resources

### ROI

- To succinctly calculate an aircraft modification ROI, the Air Force needs to develop and implement better tracking methods to capture the required data needed for ROI calculations.
- Ensure data integrity is improved and maintained in the current maintenance data collection systems as well as in the future Expeditionary Combat Support System (ECSS).

## Additional Recommendation

Incorporate the inputs from field personnel and this research into the ongoing ECSS blueprinting effort.

### Notes

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*I knew full well that the maintenance I was going to get would determine the success or failure of the operation. I must get the maximum performance out of the planes assigned to my command, or I would fail to do the job.*

**—Lt Gen William H.Tunner, USAF**

*The very serious responsibility for maintaining what we are given is based on the hard reality that we will never have all the equipment, supplies, facilities, and funds we require. On the battlefield, we will be short because of combat losses, accidents, interruptions in the supply system, or just insufficient resources to fill all needs. Thus, a well-trained soldier must be taught to maintain and conserve what he has—in peace and in war.*

**—Gen John A. Wickham, USA**

*… no success is possible—or even conceivable—which is not grounded in an ability to tolerate uncertainty, cope with it, and make use of it.*

**—Martin van Creveld**

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## Introduction

Most would agree that aircraft maintenance has been and continues to be a challenging, complex task involving a delicate balance of resources to include personnel, equipment, and facilities. This balancing act occurs in a very hectic environment. The Air Force flies 430 sorties per day in support of Operation Iraqi Freedom and Enduring Freedom. A mobility aircraft takes off somewhere in world approximately every 90 seconds.[1] As the demand for aircraft continues to grow, the number of airmen who support these aircraft is declining. "Since 2001 the active duty Air Force has reduced its end-strength by almost 6 percent but our deployments have increased by at least 30 percent, primarily in support of the Global War on Terror."[2] This reduction in personnel is part of the Air Force's process of drawing down the total force by approximately 40,000 people, with many of these cuts in aircraft maintenance career fields. Also adding to the growing maintenance workload is an aircraft fleet which now averages almost 24 years old, with the average age still increasing.[3]

When it comes to aircraft maintenance, the Air Force depends on metrics to know whether or not we are measuring up to standards. Several metrics exist which attempt to measure the success or failure of our maintainers' efforts. One of the most recognized metrics is the total not mission capable maintenance (TNMCM) rate. Air Force Instruction 21-101 describes TNMCM as "perhaps the most common and useful metric for determining if maintenance is being performed quickly and accurately."[4] Although a lagging type indicator, it is one of several key metrics followed closely at multiple levels of the Air Force. Over the last several years, the TNMCM rate for many aircraft gradually increased. This fact was highlighted during a 2006 quarterly Chief of Staff of the Air Force Health of the Fleet review. Follow-on discussions ultimately resulted in the Air Force Materiel Command Director of Logistics (AFMC/A4) requesting the Air Force Logistics Management Agency (AFLMA) to conduct an analysis of TNMCM performance with the C-5 Galaxy aircraft as the focus. AFLMA conducted two studies in support of this request.

## Background

The *C-5 TNMCM Study II* (AFLMA project number LM200625500) included five objectives. One of those objectives was to determine root causes of increasing TNMCM rates for the C-5 fleet. An extensive, repeatable methodology was developed and utilized to scope an original list of 184 factors down to two potential root causes to analyze in-depth for that particular study. These two factors were aligning maintenance capacity with demand, and the logistics departure reliability versus TNMCM paradigm. To address the root cause factor of aligning maintenance capacity with demand, a method of determining available maintenance capacity was needed. To meet this objective, a new factor designated as net effective personnel (NEP) was developed. NEP articulates available maintenance capacity in a more detailed manner that goes

# Beyond Aut
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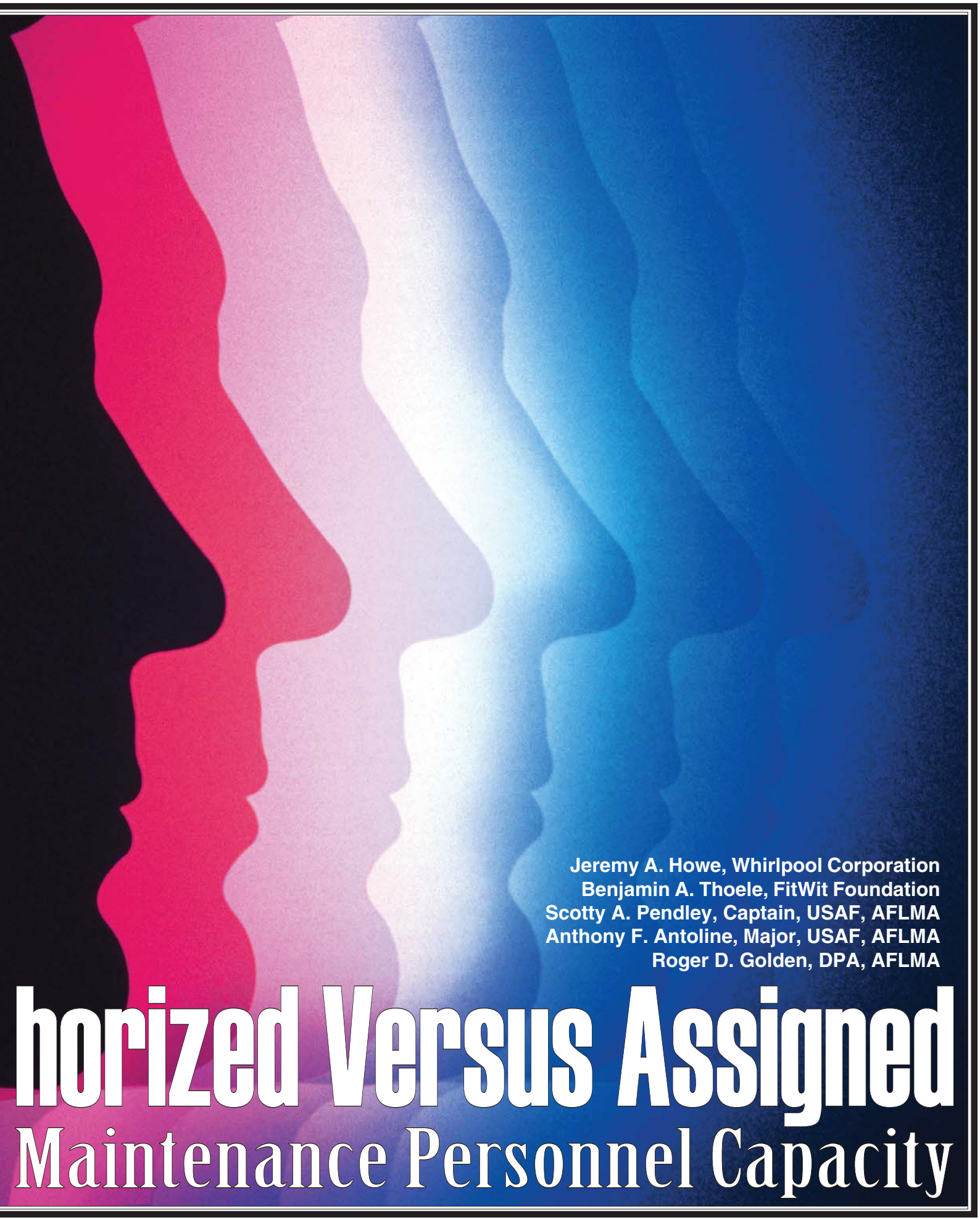

Jeremy A. Howe, Whirlpool Corporation
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# horized Versus Assigned Maintenance Personnel Capacity

# Article Highlights

**Ultimately, the NEP methodology has the potential to be used alone or in conjunction with the Logistics Composite Model to better portray maintenance personnel requirements and capabilities based on experience and skill levels.**

"Beyond Authorized Versus Assigned: Aircraft Maintenance Personnel Capacity" quantifies the phrase "we need more people" beyond the traditional metric of authorized versus assigned personnel. The article is based on work done for a recent Air Force Logistics Management Agency project—*C-5 TNMCM Study II*. During this project, an extensive, repeatable methodology was developed and utilized to scope an original list of 184 factors down to two potential root causes. These two factors were aligning maintenance capacity with demand, and the logistics departure reliability versus TNMCM paradigm. To address the root cause factor of aligning maintenance capacity with demand, a method of determining available maintenance capacity was needed. To meet this need, a new factor designated as net effective personnel (NEP) was developed. NEP articulates available maintenance capacity in a more detailed manner that goes beyond the traditional authorized versus assigned viewpoint. The article describes how the NEP calculations were developed during the C-5 TNMCM Study II. The NEP calculations were ultimately used in conjunction with historical demand to propose base-level maintenance capacity realignments resulting in projected improvements in the C-5 TNMCM rate.

The ratio between authorized and assigned personnel is typically used to quantify personnel availability. While this ratio is an indicator of maintenance capacity, it provides only a limited amount of information. Authorized versus assigned ratios do not take into account the abilities and skill levels of the maintenance personnel, nor does it factor in the availability of the personnel on a day-to-day basis. These issues were addressed in the *C-5 TNMCM Study II* by quantifying "we need more people" beyond the traditional metric of authorized versus assigned personnel. This capacity quantification was done as part of the larger effort of aligning beyond the traditional authorized versus assigned personnel viewpoint. The remainder of this article describes the need for NEP and how the NEP calculations were developed during the *C-5 TNMCM S*tudy II. The NEP calculations were ultimately used in conjunction with historical demand to propose base-level maintenance capacity realignments resulting in projected improvements in the C-5 TNMCM rate.

## Personnel as a Constraint

The analytical methodology applied to the C-5 maintenance system determined that personnel availability was an important factor to consider. This idea is not new; indeed, the force-shaping measures underway in the Air Force have brought the reality of constrained personnel resources to the forefront of every airman's mind. Without exception, maintenance group leadership (MXG) at each base visited during the C-5 TNMCM Study II considered personnel to be one of the leading constraints in reducing not mission capable maintenance hours. The study team heard the phrase "we need more people" from nearly every shop visited:

> *"The biggest problem for the maintainers here is a shortage of people."*[5]

> *"With more people we could get a higher MC [mission capable]. We're currently just scrambling to meet the flying schedule."*[6]

> *"Hard-broke tails and tails in ISO [isochronal inspection] get less priority than the flyers. We run out of people—we physically run out."*[7]

The Air Force defines total maintenance requirements (authorizations) on the basis of the Logistics Composite Model (LCOM) and current manpower standards. LCOM is a stochastic, discrete-event simulation which relies on probabilities and random number generators to model scenarios in a maintenance unit and estimate optimal manpower levels through an iterative process. The LCOM was created in the late 1960s through a joint effort of RAND and the Air Force Logistics Command. Though intended to examine the interaction of multiple logistics resource factors, LCOM's most important use became establishing maintenance manpower requirements. LCOM's utility lies in defining appropriate production levels, but it does not differentiate experience.[8] Once these requirements are defined, the manpower community divides these requirements among the various skill levels as part of the programming process. Overall, the manpower office is charged with determining the number of slots, or spaces, for each skill level needed to meet the units' tasks. The personnel side then finds the right *faces*, or people, to fill the spaces.

One measure historically used to quantify personnel availability is the ratio between authorized and assigned personnel. While this ratio is an indicator of maintenance capacity, it provides only a limited amount of information. Authorized versus assigned ratios do not take into account the abilities and skill levels of the maintenance personnel, nor does it factor in the availability of the personnel on a day-to-day basis. These issues were addressed in the *C-5 TNMCM Study II* by quantifying "we need more people" beyond the traditional metric of authorized versus assigned personnel. This capacity quantification was done as part of the larger effort of aligning

capacity with demand. The process of capacity planning generally follows three steps:

- Determine available capacity over a given time period
- Determine the required capacity to support the workload (demand) over the same time period
- Align the capacity with the demand[9]

The following describes how the study team pursued step 1, determining available capacity over a given time period, using data from the 436 MXG at Dover Air Force Base (AFB) and characterizing the results in terms of what the study team denoted as NEP.

## Determining Available Capacity

When personnel availability and capacity are discussed at the organizational level, typically the phrase *authorized versus assigned* personnel is used. However, are all people assigned to maintenance organizations—namely, an aircraft maintenance squadron (AMXS) or a maintenance squadron (MXS)—viable resources in the repair process? Most maintainers will answer no. While it is true that all assigned personnel serve a defined and important purpose, not everyone in these organizations is a totally viable resource to be applied against maintenance demand. This impacts maintenance repair time and aircraft availability.

TNMCM time begins and ends when a production superintendent advises the maintenance operations center to change the status of an aircraft. The length of that time interval is determined by several things. One factor is the speed of technicians executing the repair, which includes diagnosis, corrective action, and testing (illustrated in Figure 1) the repair node of Hecht's *restore-to-service* process model.

As illustrated by the Hecht process model, there are other important components required to return an aircraft to service, but the pool of manpower resources required to support the repair node is critically linked to TNMCM time. Within a mobility aircraft maintenance organization, this pool represents hands-on 2AXXX technicians whose primary duty is performing aircraft maintenance. Specifically, the study team defined the technician resource pool as follows:

> **Technicians**: the collective pool of airmen having a 2AXXX AFSC, that are 3-level or 5-level maintainers, or nonmanager 7-level maintainers whose primary duty is the hands-on maintenance of aircraft and aircraft components.

The distinction of nonmanager 7-levels generally reflects 7-levels in the grades of E-5 and E-6. In active duty units, 7-levels in the grade of E-7 do not typically perform hands-on aircraft maintenance, but are instead directors of resources and processes—they are managers.[11] This is in stark contrast to Air National Guard units, where 2AXXX personnel in the senior noncommissioned officer ranks routinely perform *wrench-turning*, hands-on maintenance.[12] For the research detailed in the *C-5 TNMCM Study II*, personnel analysis centered on data from the 436 MXG at Dover AFB and utilized the study team's definition of technicians.

## Net Effective Personnel

Authorized versus assigned personnel figures usually quantify the entire unit. With the definition of technicians in mind, it is

# Article Highlights

amount of information. These ratios do not take into account the abilities and skill levels of the maintenance personnel, nor does it factor in the availability of the personnel on a day-to-day basis. The NEP methodology described in the article is a repeatable process which produces data that provides leadership with a better representation of the personnel resources and actual capacity available to an Air Force aircraft maintenance organization on a day-to-day basis. The NEP methodology will be tested further and validated using personnel data from other units to verify similar results and potential gains. Ultimately, the NEP methodology has the potential to be used alone or in conjunction with the Logistics Composite Model to better portray maintenance personnel requirements and capabilities based on experience and skill levels.

### Article Acronyms

AFB – Air Force Base
AFLMA – Air Force Logistics Management Agency
AFSC – Air Force Specialty Code
AMXS – Aircraft Maintenance Squadron
ANGB – Air National Guard Base
APG – Aerospace and Powerplant General
CBT – Computer-Based Training
CMS – Component Maintenance Squadron
EMS – Equipment Maintenance Squadron
ETCA – Education and Training Course Announcement
LCOM – Logistics Composite Model
MXG – Maintenance Group
MXS – Maintenance Squadron
NEP – Net Effective Personnel
TDY – Temporary Duty
TNMCM – Total Not Mission Capable Maintenance

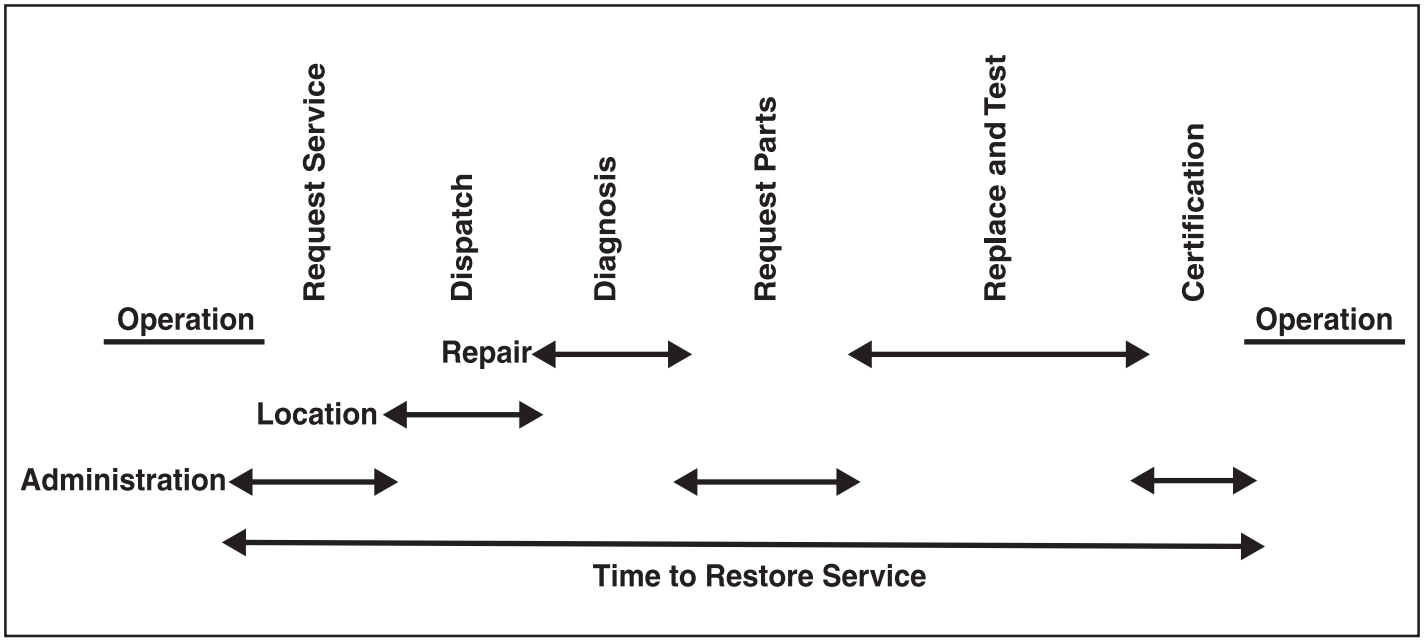


**Figure 1. Time to Restore Service Process Model[10]**

| Technician Category | Productivity Factor |
|---|---|
| Non-manager 7-levels | 100% |
| Non-manager 7-level trainers | 85% |
| 5-levels | 100% |
| 5-level trainers | 85% |
| 3-levels | 40% |

**Table 1. Productivity Factors[15]**

important to consider three additional factors that introduce variability into the personnel resource pool. These factors are:

- Skill-level productivity
- Ancillary and computer-based training (CBT)
- Availability

The study team examined the influence of these three factors, as well as their impact on the viable resource pool for the 436 MXG. This collective impact yielded a new resource pool representing a depiction of *effective* capacity rather than just the authorized versus assigned ratio. Again, this new resource pool is denoted as Net Effective Personnel, or NEP.

### Factor 1: Skill – Level Productivity

In order to accurately examine the quantitative adequacy of a resource, as well as how a resource has historically been used to meet demand, there must be parity among individual resource units. Consider the previous definition of technicians. If one were to select two people at random, would they be equally capable resources? Not necessarily, if one was a 3-level trainee and the other was a 5 or 7-level resource. In order to collectively examine people in terms of comparable resources, and to account for the skill-level variability in typical aircraft maintenance organizations, productivity factors were applied to the resource pool.

As part of this research effort, the study team utilized its strategic partnership with RAND Project Air Force. Through personal interviews with RAND personnel and review of recently published RAND research, the study team learned that RAND had explored the productivity of trainees and trainers in aircraft maintenance units. Trainees were defined as 3-levels, who are not as productive as 5- and 7-levels. Additionally, some 5- and 7-levels were not as productive as others because they spend time training and instructing 3-level personnel.[13] In terms of specific productivity based on RAND research, 3-levels were estimated to be 40 percent productive, 5-level trainers and nonmanager 7-level trainers were estimated to be 85 percent productive, and 5-levels and nonmanager 7-levels were 100 percent productive if they were unencumbered with training responsibilities.[14] For the purpose of this analysis, the number of trainers was considered to be equal to the number of 3-levels assigned—a one-to-one ratio. The productivity factors for the viable resource pool are summarized in Table 1.

These productivity factors also are similar to results from additional RAND research at Travis AFB published in 2002.[16] Considering the productivity factors from Table 1, the net effect of these productivity factors alone was a reduction of the 436 AMXS viable resource pool by an average of 5.68 percent.[17]

### Factor 2: Ancillary Training and Computer-Based Training

In recent times the impact of ancillary training and CBT has been such an important issue for Air Force senior leaders, that it was the sole topic of the airman's Roll Call of 9 February 2007.[18] This document indicated that some active duty airmen spend disproportionate amounts of time on ancillary training, which detracts from their ability to perform official duties. Moreover, the document suggested that some ancillary training may no longer be relevant.[19] In the context of the viable pool of aircraft maintenance technicians, this would mean that, some of the time, personnel resources may be on duty but unavailable to perform hands-on maintenance due to an ancillary training requirement.

A consensus majority of personnel interviewed during the study team's site visits echoed these concerns, describing an *insidious growth* of new training requirements in recent years.[20] An additional concern voiced by interviewees pertained to

computer resources. Interviewees described a situation where office workers have ready access to a personal computer (PC), but dozens of maintenance technicians often share only a handful of communal PCs. Consequently, their ability to complete computer-based ancillary training is constrained. One unit training manager explained that in the past, a group training briefing would be conducted for an entire work center, fulfilling each individual's training requirement simultaneously.[21] Today, an online course issues the required certificate of completion for only one individual, thereby necessitating that each airman conduct the training individually. The net result is more time away from primary duties (for example, repairing aircraft). In order to assess the influence of ancillary training and CBT on the technician resource pool, the study team quantified the average daily impact.

A list of various ancillary and computer-based training items that are applicable to the relevant pool of aircraft maintenance personnel was collected from three data sources:

- The USAF Education and Training Course Announcement (ETCA) Website[22]
- The unit training monitor at the AFLMA
- The unit training monitor for the 105 MXG at Stewart Air National Guard Base (ANGB)

The training was categorized by data source, course number (if applicable), and course name. Training was also categorized as follows.

- Mandatory for all personnel, such as law of armed conflict training
- Voluntary or job-specific, such as hazardous material management training

Also, requirements were identified by the recurrence frequency (one-time, annual, or semiannual). Some requirements are aligned with the 15-month aerospace expeditionary force cycle; this would equate to a yearly recurrence frequency of 0.8 (12/15). Finally, training was categorized by the duration in hours for each requirement as identified by the data sources.

Most training courses only take up a portion of the duty day. The average duration for courses considered was 2.8 hours, with many listed at one hour or less. In situations like these, a manager would still view the individual as *available* for the duty day.[23] Therefore, the study team examined the impact of CBT and ancillary training as a separate factor and not as a part of the availability factor (factor 3). Final calculations resulted in the following totals:

- Hours of mandatory one-time training (denoted $M_o$), 101.5 hours
- Hours of mandatory annually-recurring training ($M_a$), 67.2 hours
- Voluntary or job-specific one-time training ($VJS_o$), 85.8 hours
- Voluntary or job-specific annually-recurring training ($VJS_a$), 10.3 hours

In order to quantify the daily impact of these training items, the study team made the following assumptions:

- An 8-hour workday
- 220 workdays in a calendar year. (5 days per week x 52 weeks per year) = 260; 260 – (30 days annual leave) – (10 federal holidays[24]) = 220 workdays
- 3-levels required all of the mandatory, one-time training
- 5-levels and 7-levels required only the annually-recurring portion of the mandatory training
- As an average, all 3-levels required 10 percent of the voluntary or job-specific, one-time training
- As an average, all 5-levels and 7-levels required 10 percent of the voluntary or job-specific, one-time, annually-recurring training
- As an average, all training durations would be increased 20 percent to account for travel, setup, and preparation[25]

When employing the above assumptions, the figures in Table 2 were calculated to be best estimates of the time impact of ancillary training and CBT.

The best estimates for CBT and ancillary training requirements account for 7.51 percent and 5.24 percent of the workday for 3-, 5-, and 7-levels, respectively. The complementary effectiveness rates for this factor are expressed as 0.9249 (1 – 0.0751) for 3-levels and 0.9476 (1 – 0.0524) for 5 and 7-levels. These rates are listed as the ancillary and CBT factors for 3-, 7-, and 5-levels respectively in Table 6.

Table 3 illustrates how these rates change when the percentages of voluntary and job-specific training (V/JST) or the percentage of travel and setup buffer are varied. The matrices in Table 3 illustrate the results of sensitivity analysis of various CBT and ancillary training factors that would result for combinations of voluntary or job-specific training, or travel and setup buffer ranging from zero to 25 percent. The range of all calculated factors is approximately 3 percent for both technician categories. Note that the CBT and ancillary training factors chosen utilizing the study team's assumptions are boxed and shaded. For both 3-, 5-, and 7-levels, the calculated training factors fall very near the mean developed in the sensitivity analysis. Some values shown in Table 3 are the result of rounding. For the 436 MXG at Dover AFB, the net effect of these CBT and ancillary training factors alone was a reduction of the viable resource pool by an average of 1.58 percent.[26]

| Technician | Hours per Year | Hours per Workday | Percentage of 8-Hour Workday | Minutes per Workday |
|---|---|---|---|---|
| 3-level | 132.10 | 0.60 | 7.51% | 36.03 |
| Formula | $1.2(M_o+(0.1VJS_o))$ | (Hrs/yr)/220 | (Hrs/workday/8)*100 | (Hrs/workday)*60 |
| 5- / 7-level | 92.17 | 0.42 | 5.24% | 25.1 |
| Formula | $1.2(M_a+(0.1(VJS_o+VJS_a))$ | (Hrs/yr)/220 | (Hrs/workday/8)*100 | (Hrs/workday)*60 |

**Table 2. Best Estimate of CBT and Ancillary Training Time Requirements**

| 3-Levels | | | | | | |
|---|---|---|---|---|---|---|
| | % Travel/Setup Multiplier | | | | | |
| % V/JST | 1 | 1.05 | 1.1 | 1.15 | 1.2 | 1.25 |
| 0.00 | 0.942 | 0.939 | 0.937 | 0.934 | 0.931 | 0.928 |
| 0.05 | 0.940 | 0.937 | 0.934 | 0.931 | 0.928 | 0.925 |
| 0.10 | 0.937 | 0.934 | 0.931 | 0.928 | **0.925** | 0.922 |
| 0.15 | 0.935 | 0.932 | 0.929 | 0.925 | 0.922 | 0.919 |
| 0.20 | 0.933 | 0.929 | 0.926 | 0.922 | 0.919 | 0.916 |
| 0.25 | 0.930 | 0.927 | 0.923 | 0.920 | 0.916 | 0.913 |
| **5- and 7-Levels** | | | | | | |
| | % Travel/Setup Multiplier | | | | | |
| % V/JST | 1 | 1.05 | 1.1 | 1.15 | 1.2 | 1.25 |
| 0.00 | 0.962 | 0.960 | 0.958 | 0.956 | 0.954 | 0.952 |
| 0.05 | 0.959 | 0.957 | 0.955 | 0.953 | 0.951 | 0.949 |
| 0.10 | 0.956 | 0.954 | 0.952 | 0.950 | **0.948** | 0.945 |
| 0.15 | 0.954 | 0.951 | 0.949 | 0.947 | 0.944 | 0.942 |
| 0.20 | 0.951 | 0.948 | 0.946 | 0.944 | 0.941 | 0.939 |
| 0.25 | 0.948 | 0.946 | 0.943 | 0.940 | 0.938 | 0.935 |
| **Descriptive Statistics** | | | | | | |
| | **Mean** | **Min** | **Max** | **Range** | | |
| 3-Level | 0.928 | 0.913 | 0.942 | 0.030 | | |
| 5- and 7-Level | 0.949 | 0.935 | 0.962 | 0.027 | | |

**Table 3. CBT and Ancillary Training Factor Sensitivity Analysis**

| | | 3-Level | 5-Level | 7-Level | Total | % of Total |
|---|---|---|---|---|---|---|
| Reason Unavailable | **Assigned** | 32 | 28 | 22 | 82 | 100% |
| | Temporary Duty | | 6 | 4 | 10 | 12% |
| | Qualification and Training Program | 9 | | | 9 | 11% |
| | Detail | 2 | 3 | 2 | 7 | 9% |
| | Leave | 2 | 3 | 2 | 7 | 9% |
| | Scheduled Off Day | 2 | 1 | 2 | 5 | 6% |
| | Medical Profile | | 2 | 1 | 3 | 4% |
| | Part-day Appointment | 1 | 1 | 1 | 3 | 4% |
| | Full-day Appointment | | | 2 | 2 | 2% |
| | Compensatory Off Day | | | 1 | 1 | 1% |
| | Flying Crew Chief Mission | | 1 | | 1 | 1% |
| | Out Processing | | 1 | | 1 | 1% |
| | Permanent Change of Assignment | | 1 | | 1 | 1% |
| | Field Training Detachment Course | | 1 | | 1 | 1% |
| | First Term Airmen's Center | 1 | | | 1 | 1% |
| | Bay Orderly | 1 | | | 1 | 1% |
| | **Available** | 14 | 8 | 7 | 29 | 35% |

**Figure 2. 436 AMXS APG Day Shift Personnel Availability Snapshot[27]**

### Factor 3: Availability

Manpower resources must be present to be viable, and on any given day, aircraft maintenance organizations lose manpower resources due to nonavailability. Examples include temporary duty (TDY) assignments, sick days, and other details. To illustrate, Figure 2 depicts the actual availability of 436 AMXS airframe and powerplant general (APG) technicians on day shift for Thursday, April 12, 2007. For this work center, on this particular day and shift, roughly 65 percent of assigned technicians were not available for the various reasons listed.

Much like aircraft maintenance, some events that take people away from the available pool are scheduled and known well in advance, while others are unexpected, such as illnesses and family emergencies.

Although scheduled and unscheduled events both have an impact, scheduled events are anticipated and can be planned for. Adjustments can be made and resources can be shifted. Consequently, resource managers want to monitor and manage scheduled personnel nonavailability to the greatest extent possible. In order to assess the impact of this factor on the resource pool, the study team monitored the personnel availability of the 436 AMXS at Dover AFB from 1 March through 30 April 2007 via 9 weekly snapshots. 436 AMXS supervision tracks manpower via a spreadsheet tool that identifies the availability status of each assigned 3-level, 5-level, and nonmanager 7-level in their hands-on maintenance resource pool. For AMXS, this represents technicians from six different shops, identified with the corresponding Air Force specialty codes (AFSC) as follows:

- Airframe and Powerplant General (APG) – 2A5X1C, 2A5X1J
- Communication and Navigation (C/N) – 2A5X3A
- Electro/Environmental Systems (ELEN) – 2A6X6
- Guidance and Control (G/C)[28] – 2A5X3B
- Hydraulics (HYD) – 2A6X5
- Engines (JETS) – 2A6X1C, 2A6X1A

The AMXS snapshot spreadsheet is updated (but overwritten) continually as status changes occur.[29] By monitoring changes in these snapshots, the study team was able to examine not only the impact of personnel nonavailability in aggregate, but also the degree to which the discovery and documentation of events altered the size of the capacity pool. Using the Dover AMXS snapshots, the study team calculated the number of available technicians in the aircraft maintenance resource pool.

The study team monitored the actual availability figures for the 436 AMXS over the 9-week period of March and April 2007, for a total of $n = 61$ daily observations. Across all shifts, the total number of personnel assigned to the AMXS personnel resource pool was 411 for the month of March, and 412 for the month of April. Actual availability figures, however, were much lower. Table 4 summarizes the descriptive statistics of this analysis.

The upper row of Table 4 statistics reflects the actual number of technicians available, while the bottom row reflects that number as a percentage relative to the total number of technicians assigned. For example, in the month of March, the maximum number of available technicians observed was 202, or 49 percent (202 of 411) of the total assigned. The mean availability for March was 36 percent. These figures take into consideration that some of the nonavailable personnel may be performing duties elsewhere for the Air Force such as flying crew chief missions or other TDY assignments. Therefore, they would not be viable assets for the aircraft maintenance resource pool at Dover AFB. The net effect of this nonavailability factor was a reduction of the AMXS home station viable resource pool by an average of 65.39 percent. This is reflected as the 35 percent mean highlighted for March-April 2007.

As discussed previously with Factors 1 and 2, the productivity of available technicians is reduced due to skill-level training needs, as well as ancillary and CBT training requirements. The study team applied productivity factors from Table 1 and CBT and ancillary training factors from Table 2 to the observed number of available technicians in AMXS. These calculations quantified the final pool of viable personnel resources, which is denoted as NEP. Because of daily variations in the number of 3-, 5-, and 7-skill level technicians available, the factors were applied to each daily observation. In performing these calculations, the study team developed a representation of the effective personnel resource pool. Specifically, the NEP figures account for the realities of availability and productivity, and allow the resource pool to be viewed objectively, unconstrained by concerns such as skill-level differences. The value of such a resource picture is that it provides a suitable mechanism for comparing maintenance capacity (NEP resource pool) with maintenance demand. The summary descriptive statistics for the 436 AMXS NEP are indicated in Table 5. Averaging across the observed timeframe, the 436 AMXS had approximately 113 net effective technicians in its viable resource pool on any given day. This figure is approximately 27 percent of the total assigned quantity of technicians, again using the previously discussed definition for technicians.

Therefore, to arrive at the results shown in Table 5, the study team considered the factors from Table 1 and 2, as well as the ancillary and CBT factors complimentary effectiveness rates calculated.

Each factor and rate detailed to this point was assigned a new designation for ease of use in the proposed NEP equation. The newly designated factors, factor descriptions, and the associated values are listed in Table 6.

The *T* factors relate to training, the *A* factors relate to available personnel, and the *P* factors relate to productivity. These factors

| 411 Assigned | March 07 | | | | April 07 | | | | March-April 07 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | Range | Min | Max | Mean | Range | Min | Max | Mean | Range |
| Available | 100 | 202 | **147** | 102 | 104 | 163 | **137** | 59 | 100 | 202 | **142** | 102 |
| % of Assigned | 24% | 49% | **36%** | 25% | 25% | 40% | **33%** | 14% | 24% | 49% | **35%** | 25% |

**Table 4. 436 AMXS Availability Descriptive Statistics**

| 411 Assigned | March 07 | | | | April 07 | | | | March-April 07 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | Range | Min | Max | Mean | Range | Min | Max | Mean | Range |
| Available | 79 | 167 | **120** | 88 | 77 | 124 | **105** | 47 | 77 | 167 | **113** | 90 |
| % of Assigned | 19% | 41% | **29%** | 21% | 19% | 30% | **26%** | 11% | 19% | 41% | **27%** | 22% |

**Table 5. 436 AMXS Net Effective Personnel Descriptive Statistics**

| Factor | Description | Value |
|---|---|---|
| $T_{75}$ | Ancillary/CBT Factor for 7- and 5-levels | 0.948 |
| $A_{75NT}$ | The number of available nonmanager 7-levels and 5-levels who are not trainers | Varies day-to-day |
| $P_t$ | Trainer Productivity | 0.85 |
| $A_{75T}$ | The number of available nonmanager 7-levels and 5-levels who are trainers | Varies day-to-day |
| $T_3$ | Ancillary/CBT Factor for 3-levels | 0.925 |
| $P_e$ | Trainee Productivity | 0.4 |
| $A_3$ | The number of available 3-levels | Varies day-to-day |

**Table 6. Net Effective Personnel Factors**

were applied to the number of available technicians as recorded in the AMXS availability snapshots using the newly proposed NEP calculation, shown as Equation 1. Equation 1 is the cumulative NEP equation which accounts for all three factors which create variability in the resource pool and yields a numerical quantity of net effective personnel. To determine the NEP percentage, one need simply divide the right side of the equation by the number of assigned technicians (7-level nonmanagers, 5-levels, and 3-levels).

Figure 3 provides an Excel spreadsheet snapshot of an example NEP calculation for a generic maintenance unit. The maintenance unit's NEP is calculated using Equation 1 by entering the personnel totals in each of the five categories in the left column. These values are then multiplied by the factors in the right column to determine NEP. In this example, the unit has 104 technicians available but the NEP is only 77. In other words, the practical available maintenance capacity is only 77 technicians, not 104 as it initially appears.

To summarize, the study team's arrival at NEP followed an iterative sequence of three factor reductions:

- Skill-level productivity differences, to include those for trainees and trainers
- Ancillary training and CBT
- The nonavailability of personnel

Figure 4 graphically illustrates these iterations based on the relative size of the impact of the three factors on reductions to the overall resource pool. As shown in Figure 4, nonavailability had the biggest impact, productivity factors were next, and finally the effect of CBT and ancillary training had the smallest impact.

In addition to AMXS, an Air Force Maintenance Group usually includes a separate equipment maintenance squadron (EMS) and component maintenance squadron (CMS). However, if total authorizations are under 700, EMS and CMS will be combined into a maintenance squadron such as the MXS at Dover AFB. Various flights within a typical MXS maintain aerospace ground equipment, munitions, off-equipment aircraft and support equipment components; perform on-equipment maintenance of aircraft and fabrication of parts; and provide repair and calibration of test, measurement, and diagnostic equipment.[30] Technicians assigned to MXS usually perform maintenance not explicitly linked to the launch and recovery of aircraft (as is the focus of AMXS). However, some MXS personnel directly support flight line activities.

A more complete representation of the net effective personnel pool for aircraft maintenance resources in an MXG would include not only personnel in AMXS, but also those in MXS. The number of nonmanager 7-levels, 5-levels, and 3-levels assigned to the 436 MXS was determined from Air Force Personnel Center data to be 318.[31] Using the study team's definition of technician, this results in 729 technicians in the 436 MXG (411 in AMXS plus 318 in MXS). However, because the study team could not obtain exact daily availability figures for MXS similar to those of AMXS, the study team applied each of the calculated daily NEP percentages for AMXS against the number of assigned technicians to MXS. This calculation yielded daily estimates of the number of NEP for MXS. Since AMXS and MXS are both aircraft maintenance units with many of the same AFSCs and similar demands on their personnel, any differences from actual numbers as a result of this method were considered negligible for this analysis.

The study team then added the AMXS NEP figures to the MXS NEP figures, resulting in a collective NEP figure for the flight line maintainers at Dover AFB. These collective NEP

$$NEP = T_{75}\left(A_{75NT} + \left(P_t A_{75T}\right)\right) + T_3\left(P_e A_3\right)$$

**Equation 1. Net Effective Personnel**

| | | | |
|---|---|---|---|
| # of available 3-levels | 30 | CBT Factor (3-levels) | 0.925 |
| # of available 5-levels who are trainers | 30 | CBT Factor (5/7-levels) | 0.948 |
| # of available 5-levels who are **not** trainers | 32 | Productivity Factor (trainees) | 0.400 |
| # of available non-manager 7-levels who are trainers | 0 | Productivity Factor (trainers) | 0.850 |
| # of available non-manager 7-levels who are **not** trainers | 12 | | |
| **NEP** | | **77.0** | |

**Figure 3. Example Net Effective Personnel Calculation**

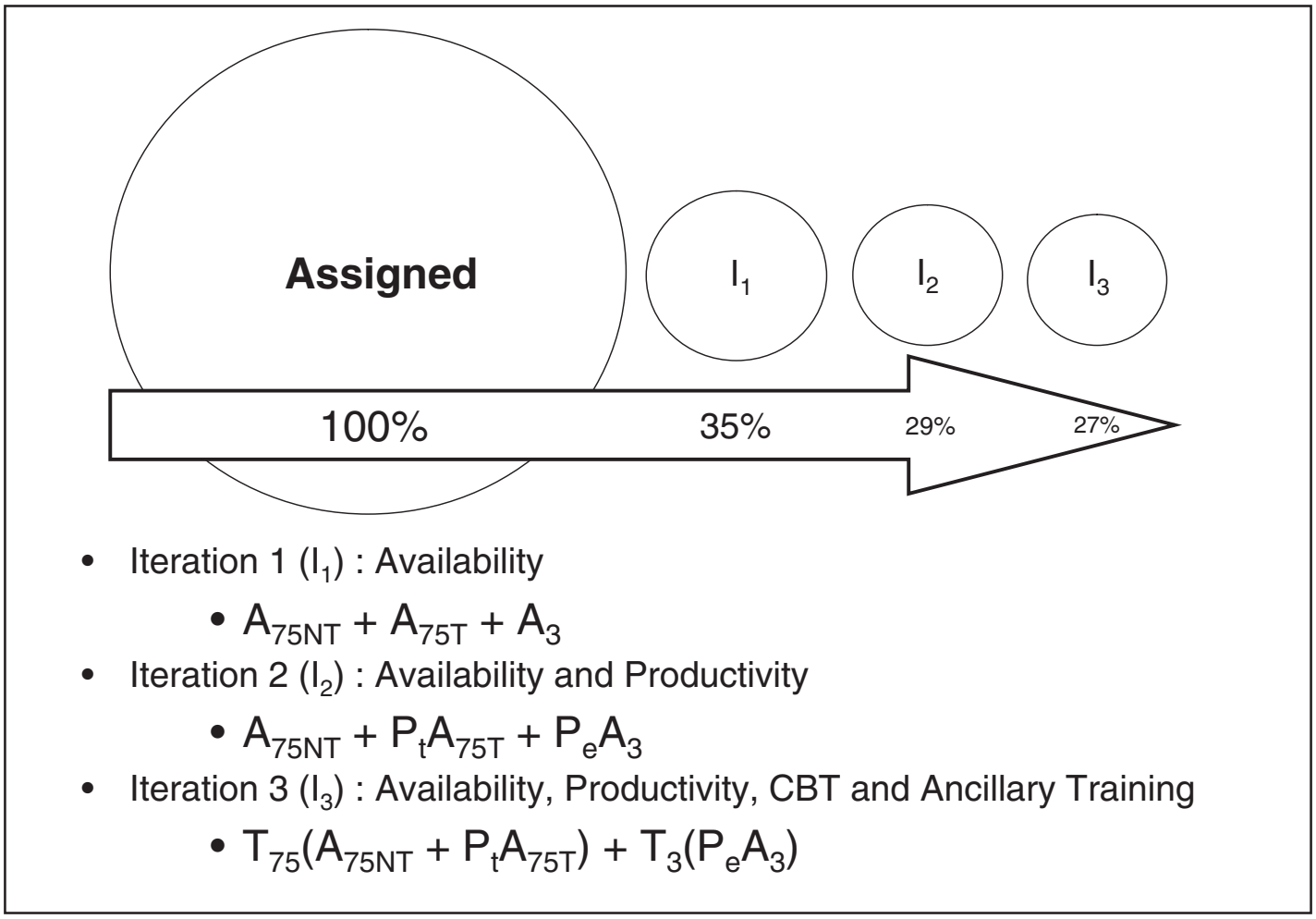


**Figure 4. The Iterations of Net Effective Personnel**

figures are shown in Table 7. The upper portion of the table shows the NEP figures grouped by columns (day of the week) with each row representing 1 of the 9 weeks over the entire period that data was tracked. The bottom section of Table 7 also displays the descriptive statistics for NEP across both AMXS and MXS combined. The highest average NEP value was 222 on Thursdays, representing approximately 30 percent of the baseline total of 729 people.

## Conclusion

The ratio between authorized and assigned personnel is typically used to quantify personnel availability. While this ratio is an indicator of maintenance capacity, it provides only a limited amount of information. These ratios do not take into account the abilities and skill levels of the maintenance personnel, nor does it factor in the availability of the personnel on a day-to-day basis. The Net Effective Personnel methodology described in this article is a repeatable process which produces NEP figures that provide leadership with a better representation of the personnel resources and actual capacity available to an Air Force aircraft maintenance organization on a day-to-day basis. The NEP methodology will be tested further and validated using personnel data from other units to verify similar results and potential gains. Ultimately, the NEP methodology has the potential to be used alone or in conjunction with LCOM to better portray maintenance personnel requirements and capabilities based on experience and skill levels.

As previously mentioned, the NEP methodology described in this article was developed as part of the larger *C-5 TNMCM Study II*. The entire study can be found at the Defense Technical Information Center Private Scientific and Technical Information Network Website at https://dtic-stinet.dtic.mil/.

### Notes

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2. Honorable Michael W. Wynne and General T. Michael Moseley, "Strategic Initiatives," presentation to the House Armed Services Committee, 24 October 2007.
3. Michael W. Wynne, "Savings Less Than Expected in Drawdown," briefing to the Center for Strategic and Budgetary Assessments, *Air Force Times*, [Online] Available: www.airforcetimes.com/news/2007/09/airforce wynnedrawdown 070924, accessed 9 September 2007.
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5. Study team notes from 439 MXG daily production meeting, Westover ARB, 12 December 2006.
6. Study team notes from meeting with 436 MXG/CD, Dover AFB, 8 January 2007.
7. Study team notes from meeting with 105 MXG/CC, Stewart ANGB, 18 January 2007.
8. Carl J. Dahlman, Robert Kernchner, and Davis E. Thaler, *Setting Requirements for Maintenance Manpower in the US Air Force*, Santa Monica, California: RAND Corporation, 2002, 136.

| | Day of the Week NEP Distributions | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
| NEP | 186 | 219 | 228 | 211 | 259 | 219 | 187 |
| | 148 | 209 | 226 | 219 | 213 | 182 | 140 |
| | 153 | 212 | 211 | 242 | 219 | 195 | 155 |
| | 188 | 242 | 289 | 297 | 245 | 205 | 169 |
| | 165 | 210 | 220 | 216 | 294 | 235 | 198 |
| | 137 | 186 | 187 | 195 | 205 | 175 | 148 |
| | 173 | 206 | 192 | 188 | 194 | 176 | 168 |
| | 167 | 213 | 201 | 195 | 183 | 186 | 174 |
| | 176 | 203 | | | 185 | 194 | 180 |
| **n** | 9 | 9 | 8 | 8 | 9 | 9 | 9 |
| **Min** | 137 | 186 | 187 | 188 | 183 | 175 | 140 |
| **Max** | 188 | 242 | 289 | 297 | 294 | 235 | 198 |
| **Mean** | 166 | 211 | 219 | 221 | 222 | 196 | 169 |
| **% of Assigned** | 23% | 29% | 30% | 30% | 30% | 27% | 23% |
| **Range** | 51 | 56 | 102 | 109 | 110 | 59 | 58 |
| **Variance** | 300 | 221 | 1031 | 1241 | 1385 | 404 | 349 |
| **Standard Dev** | 17 | 15 | 32 | 35 | 37 | 20 | 19 |

**Table 7. Day of the Week NEP Distributions for 436 MXG (AMXS and MXS)[32]**

9. J.R.T. Arnold and S. Chapman, *Introduction to Materials Management*, 5th ed., Pearson Education, 2003, 244.
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11. John G. Drew, Kristin F. Lynch, Jim Masters, Robert S. Tripp, and Charles Robert Roll, Jr., *Maintenance Options for Meeting Alternative Active Associate Unit Flying Requirements*, Santa Monica, California: RAND Corporation, MG-611-AF, 2008.
12. *Ibid*.
13. *Ibid*.
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15. *Ibid*.
16. Dahlman, et. al., 132.
17. This figure represents data from the 436 AMXS for March-April 2007.
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20. Study team notes from meeting with 436 MOS Supervision, 9 January 2007.
21. 436 AMXS/MXAA, Dover AFB, March – April 2007.
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23. *Ibid*.
24. US Office of Personnel Management, "Federal Holidays," [Online] Available: http://www.opm.gov/fedhol/, 11 April 2007.
25. It should be noted that the study team performed sensitivity analysis on the last three assumptions. See Table 3.
26. 436 AMXS/MXAA.
27. Data for 12 April 2007, 436 AMXS/MXAA, Dover AFB.
28. G/C is alternatively known as Automatic Flight Controls & Instruments.
29. 436 AMXS/MXAA.
30. *Ibid*.
31. Air Force Personnel Center, data pull, 27 March 2007.
32. Values in Table 7 are rounded to nearest whole number.

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*If I had to sum up in a word what makes a good manager, I'd say decisiveness. You can use the fanciest computers to gather the numbers, but in the end you have to set a timetable and act.*

**—Lido Anthony (Lee) Iacocca**

*If opportunity doesn't knock, build a door.*

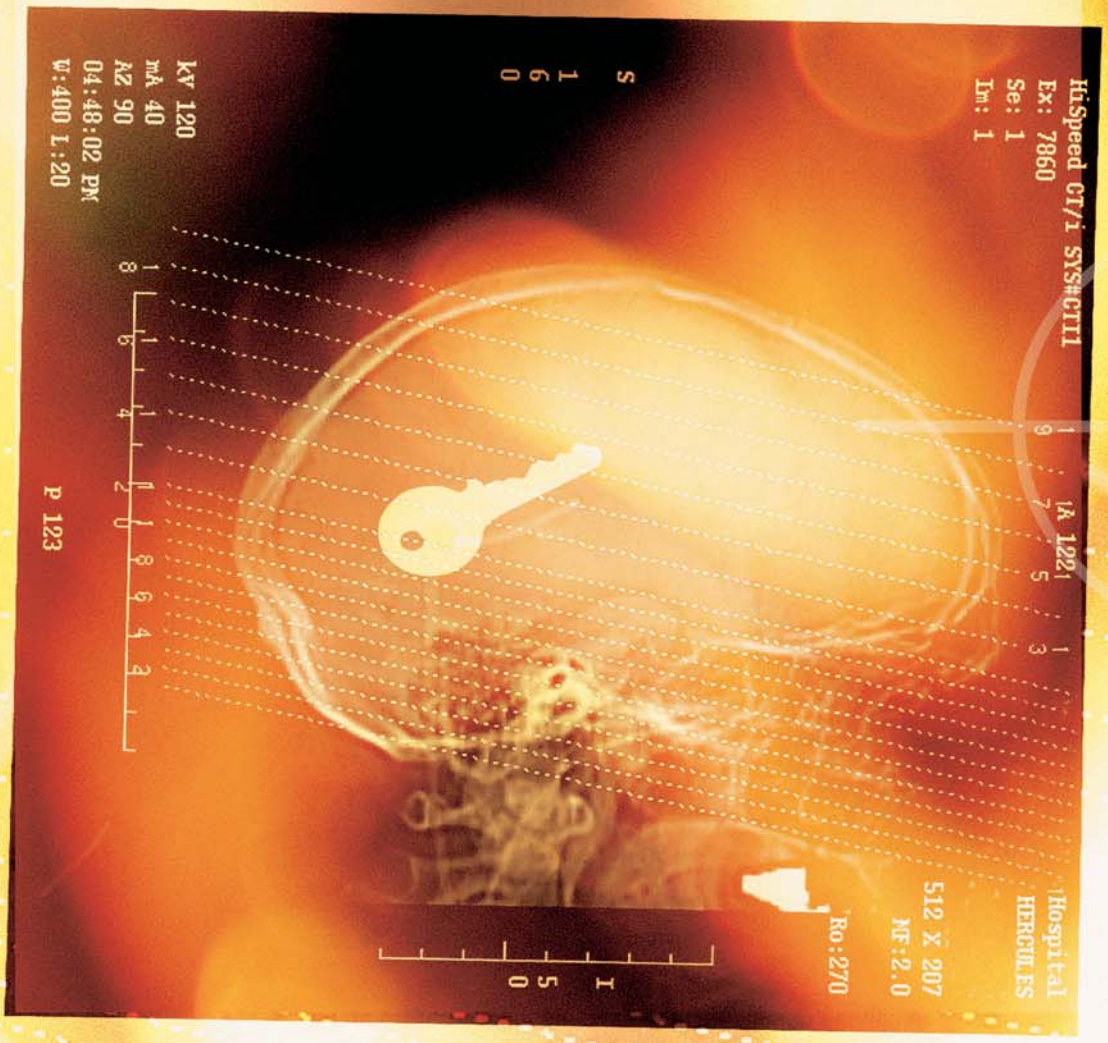
**—Milton Berle**

*Ability is of little account without opportunity.*

**—Napoleon Bonaparte**

*Who bravely dares must sometimes risk a fall.*

**—Tobias George Smollett**

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# Aligning

## Introduction

Metrics are often used as roadmaps to help us know where we have been, where we are going, and how or if we are going to get there.[1] Metrics should generally be used to gauge organizational effectiveness and efficiency and to identify trends, not as a pass or fail indicator. Individually, they are snapshots in time.[2] Metrics are a statement of what is important to your organization and embody a way of thinking about your business; when metrics change, so does people's point of view. But what exactly is a metric and what constitutes a good versus bad metric?

Air Force Instruction (AFI) 21-101, *Aircraft Equipment and Maintenance Management,* describes metrics, specifically maintenance management metrics, as a crucial form of information used by maintenance leaders to improve the performance of maintenance organizations, equipment, and people when compared with established goals and standards.[3] AFI 21-101 also lists four attributes for metrics including:

- Accurate and useful for decisionmaking
- Consistent and clearly linked to goals and standards
- Clearly understood and communicated
- Based on a measurable, well-defined process[4]

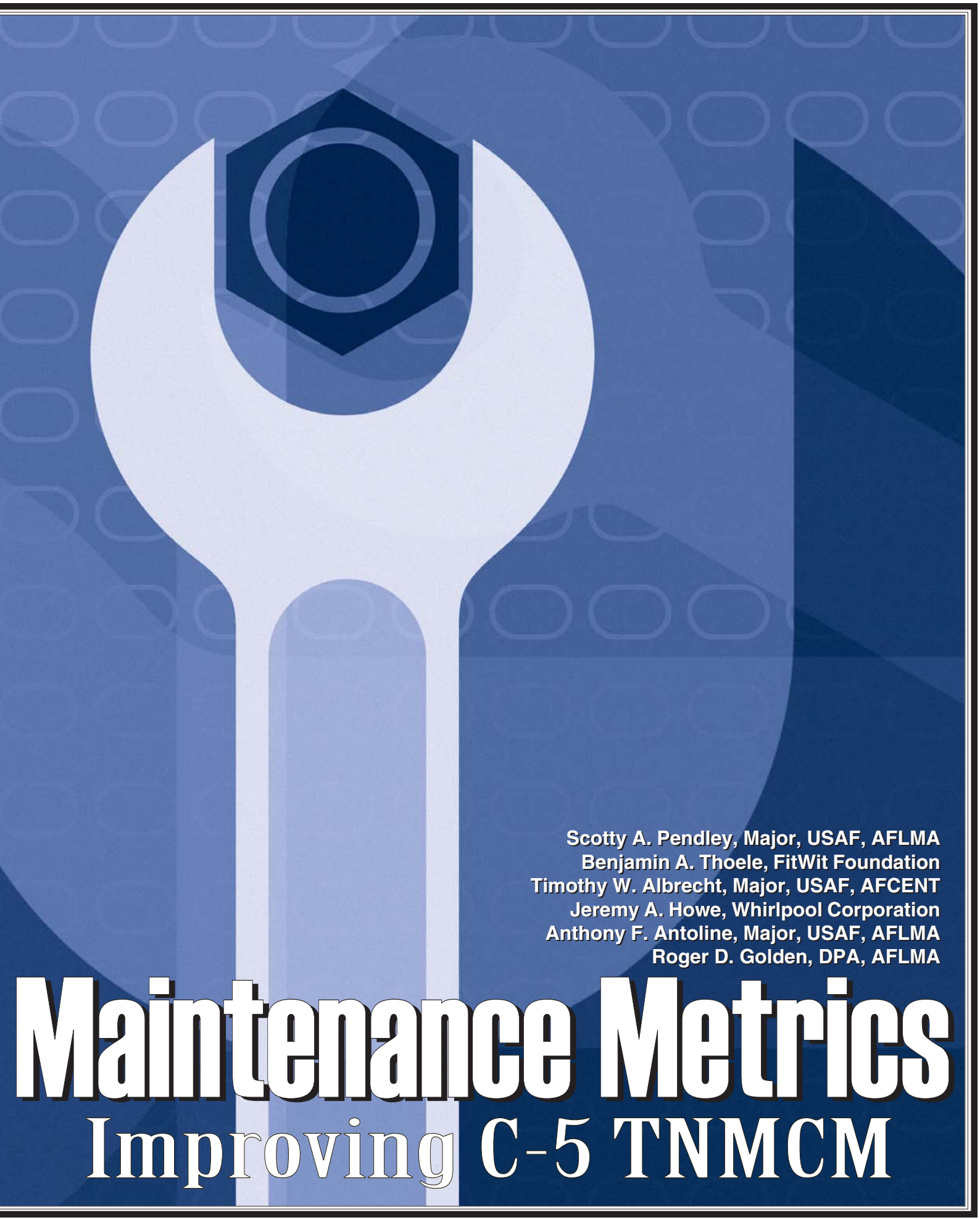
Dr Michael Hammer, a recognized leader in the field of process reengineering, also notes four principles of measurement.

- Measure what matters, rather than what is convenient or traditional
- Measure what matters most, rather than everything
- Measure what can be controlled, rather than what cannot be controlled
- Measure what has impact on desired business goals, rather than ends in themselves[5]

Hammer also points out several flaws with traditional metrics such as too many, fragmented, disorganized, internally focused, irrelevant to the customer, not used systematically, and not aligned with goals.[6] It is this last flaw (metrics not aligned with goals) which became a focus of examination during an Air Force Logistics Management Agency (AFLMA) study of rising Air Force total not mission capable maintenance (TNMCM) rates and potential root cause factors affecting these rates.

## Background

At the request of the Air Force Materiel Command Director of Logistics (AFMC/A4), AFLMA conducted an analysis in 2006-2007 of TNMCM performance with the C-5 Galaxy aircraft as the focus. The *C-5 TNMCM Study II* included five objectives. One of those objectives was to determine root causes of increasing TNMCM rates for the C-5 fleet. To achieve that particular objective, an extensive, repeatable methodology was



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# Maintenance Metrics

## Improving C-5 TNMCM

# Article Highlights

**Realignment of metrics must start at the highest levels of the Mobility Air Force (MAF). The MAF should choose its value measure and create a set of metrics aligned with that measure.**

At the request of the Air Force Materiel Command Director of Logistics, AFLMA conducted an analysis in 2006-2007 of total not mission capable maintenance (TNMCM) performance with the C-5 Galaxy aircraft as the focus. The *C-5 TNMCM Study II* included five objectives. One of those objectives was to determine root causes of increasing TNMCM rates for the C-5 fleet. To achieve that particular objective, an extensive, repeatable methodology was developed and utilized to scope an original list of 184 TNMCM factors down to two root causes for in-depth analysis. Those two factors were aligning maintenance capacity with demand and the logistics departure reliability versus the TNMCM paradigm. This article details the analysis of the second of these two factors.

This second factor was also described as a disconnect or misalignment between the C-5 maintenance group leadership's primary metric, home station logistics departure reliability (HSLDR), and one of the major command and Air Force senior leadership's primary metrics, aircraft availability. The remainder of this article describes how real-world and simulated data supported the early hypothesis that HSLDR and TNMCM were not aligned metrics. Finally, a brief discussion explains why the study team believed a disconnect existed between the base-level and command-level metrics.

The research demonstrated that HSLDR is aligned with neither aircraft availability nor TNMCM, as there is only a weak correlation between them. Maintainers at the wing level work to support operational effectiveness; however, higher levels of Air Force supervision appear more focused on improving strategic readiness. This disconnect in priorities was determined to be a root cause of the C-5 TNMCM rate being below Air Force standards.

If the Air Force's primary goal is to improve the C-5 fleet TNMCM rate, then priorities of the maintainers in the field must change. As the maintenance group (MXG) leadership focuses on HSLDR performance, not TNMCM, the MXP developed and utilized to scope an original list of 184 TNMCM factors down to two root causes for in-depth analysis. Those two factors were aligning maintenance capacity with demand and the logistics departure reliability (LDR) versus TNMCM paradigm. This article details the analysis of the second of these two factors.

This second factor was also described as a disconnect or misalignment between the C-5 maintenance group (MXG) leadership's primary metric, home station logistics departure reliability (HSLDR), and one of the major command (MAJCOM) and Air Force senior leadership's primary metrics, aircraft availability (AA). The remainder of this article describes how real-world and simulated data supported the early hypothesis that HSLDR and TNMCM were not aligned metrics. Finally, a brief discussion explains why the study team believed a disconnect existed between the base-level and command-level metrics.

## Primary Metrics of C-5 Maintenance Leadership

The *C-5 TNMCM Study II* originated because the project sponsor placed significant importance on TNMCM rates. Based on site visits and feedback from all but one C-5 MXG commander (MXG/CC) or other MXG senior leaders, the study team determined that the primary metric of the MXG/CC was HSLDR. AA, which is directly related to the TNMCM rate, was a primary metric of higher level leadership. Major General McMahon, then AMC director of logistics (AMC/A4), spoke to the study team in December 2006 concerning aircraft availability as the future cornerstone maintenance metric (as opposed to mission capable [MC) rates].[7] Similarly, personnel from the AMC/A4M office stated that aircraft availability is the number one concern for AMC Headquarters as opposed to MC rates.[8]

During site visits to Dover Air Force Base (AFB), Stewart Air National Guard Base, and Westover Air Reserve Base, the study team received feedback from base-level maintenance leadership concerning maintenance metrics. Some of the comments included:

> "We don't manage by MC-Rate … we don't chase the numbers. We care about departure reliability, and [the Air Force] should be looking at en route reliability."[9]

> "We don't look at the TNMCM rate … numbers aren't the issue. We focus on the mission and the flying schedule."[10]

> "What's important? Anything that makes us fly. The metric for the base is departure reliability … Ops isn't happy with a 73 percent LDR."[11]

> "MC rate is way down on the list of things we pay attention to…We're currently scrambling to meet the flying schedule. Our priorities go to the scheduled aircraft."[12]

> "Our primary metric is LDR."[13]

Based on feedback from AFMC/A4 and AMC/A4 leadership, MXG/CCs at three C-5 bases, and telephone discussions with MXG leadership at other C-5 bases, the study team concluded that the primary metric of the MAJCOM A4 leadership was AA, which includes TNMCM, and that the primary metric of the MXG/CCs was HSLDR.

## HSLDR, TNMCM, and AA Defined

AFI 21-101 defines the HSLDR, TNMCM, and AA metrics and their uses. Additional insight on the use of these metrics can be found in the *Metrics Handbook for Maintenance Leaders*.

**Home-Station Logistics Departure Reliability (HSLDR) Rate.** This is a leading metric used primarily by the Mobility Air Forces (MAF) for airlift aircraft. This delineates down to only first-leg departures of unit-owned aircraft departing home station.[14]

***HSLDR Rate (%) = ((# of HS Departures – # of HS Logistics Delays)/# of HS Departures) x 100***

**Total Not Mission Capable Maintenance (TNMCM) Rate.** TNMCM rate is the average percentage of possessed aircraft (calculated monthly or annually) that are unable to meet primary assigned missions for maintenance reasons…. Any aircraft that is unable to meet any of its wartime missions is considered not mission capable (NMC). The TNMCM is the amount of time aircraft are in NMCM [not mission capable maintenance] plus not mission capable both (NMCB) status.[15]

NMCB is mentioned in AFI 21-101 as the percentage of unit-possessed hours that aircraft are not mission capable due to both maintenance and supply.[16]

***TNMCM (%) = ((NMCM Hrs + NMCB Hrs)/ Unit Possessed Hrs) x 100***

**Aircraft Availability (AA) Rate**. Aircraft availability is the percentage of a fleet that is in neither depot possessed status nor unit possessed NMC status.[17]

***AA (%) = (MC Hours/Total Possessed Hrs) x 100***

Note that TNMCM rate and AA rate are both part of the family of metrics that relate to aircraft status hours. Also important to remember is that unit possessed aircraft must be in one of four statuses:

- MC (to include partially mission capable for maintenance or supply)
- NMCM
- Not mission capable supply (NMCS)
- NCMB

Therefore, the percentage of MC hours must decrease as the percentage of NMCM, NMCS, and NMCB hours increase.

## Metrics at Different Levels of the Organization

One might expect two different levels of an organization to have two different primary metrics. For the Air Force, the focus at the base maintenance level is expected to be on the tasks at hand to execute the mission on a daily basis. However, a strategic focus at the command A4 level is to be expected, looking across the availability of the entire fleet. Consider Dr Michael Hammer's presentation of this phenomenon in Table 1.

# Article Highlights

simulation indicated that improving the TNMCM rate would require an increase in resources. Therefore, in order to improve the TNMCM rate without increased resources, the maintainers in the field must make TNMCM a priority. While it is impossible to model the current system perfectly, the results suggest that current maintenance policies do not ensure TNMCM improvement, but do improve HSLDR, which is the stated priority of the MXG leadership. Therefore, the study team recommended that MAJCOM leadership and MXG leadership decide on a set of metrics that are better aligned toward the same goal.

## Article Acronyms

AA – Aircraft Availability
AFB – Air Force Base
AFI – Air Force Instruction
AFLMA – Air Force Logistics Management Agency
AFMC – Air Force Materiel Command
AMC – Air Mobility Command
D&C – Delays and Cancellations
Est TNMCM – Estimated TNMCM
FIFO – First In First Out
FY – Fiscal Year
HS – Home Station
HSLDR – Home Station Logistics Departure Reliability
LDR – Logistics Departure Reliability
LIFO – Last In First Out
MAF – Mobility Air Force
MAJCOM – Major Command
MC – Mission Capable
MCO – Maintenance Carryovers
MCR – Mission Capable Rate
MDR – Maintenance Dispatch Reliability
MOS – Maintenance Operations Squadron
MX – Maintenance
MXG – Maintenance Group
MXP – Maintenance Priority
NMC – Not Mission Capable
NMCB – Not Mission Capable Both
NMCM – Not Mission Capable Maintenance
NMCS – Not Mission Capable Supply
REMIS – Reliability and Maintainability Information System
TDR – Technical Dispatch Reliability
TNMCM – Total Not Mission Capable Maintenance
UAOOS – Unscheduled Aircraft Out of Service

The first column in Table 1 lists the various categories across the spectrum of oversight for an organization, ranging from enterprise goals to local activities. The headings in the top row list the range of positions in the hierarchy of jobs within the organization. In general, senior leaders are primarily accountable for setting the vision and strategy across the entire business enterprise. Process owners are responsible for developing and executing operations and processes to support higher strategy, while professionals actually perform specific work tasks through various activities. Consider this same chart in terms of C-5 aircraft maintenance, shown in Table 2. The base-level focus on on-time departure reliability falls within the *operating objective* level, providing ready airplanes for the flying schedule. On the surface, this supports the strategic performance objectives of cargo and passenger delivery. These processes are, after all, at the core of the airlift mission. On-time departure reliability, as a measurement, only considers those airplanes scheduled to fly (departing).[19] TNMCM, on the other hand, is concerned with the categorization of aircraft status, and pertains to all possessed airplanes, regardless of whether or not there is an operational demand.[20] The takeaway here is that the study team's observations of the C-5 aircraft maintenance enterprise supported Dr Hammer's view presented in Table 1. The study team found that different levels of the C-5 maintenance hierarchy do in fact focus on different primary metrics.

## Aligning Metrics

Although it may be common for different organizational levels to focus on different metrics, this split focus can be problematic for the enterprise when the pursuit of goals at the local level is not aligned to goals at the strategic level. That is, pursuit of better performance in one metric could result in suboptimal performance of higher level metrics. When this occurs, the metrics are not aligned. The study team utilized the following definition for aligned metrics:

> **Definition 1 - Aligned Metrics.** A set of metrics is said to be aligned if, with all other variables held constant, improvement in the lower level metric implies improvement of the higher level metrics.

For example, consider the priorities of a trucking company. The company is concerned with a higher level metric, known as a value measure, of increasing profit. The value measurement is in dollars. Shop managers at a truck maintenance facility use a lower level metric, known as a process measure, of reducing repair cycle time. By reducing the repair cycle time, the labor cost per truck is reduced, and each truck is returned to revenue-generating status sooner. All other variables held constant, reduced labor costs and greater numbers of operational trucks increase profit for the company. In this way, improving cycle time implies improvement in profit.[21] By Definition 1, these metrics are aligned.

Now consider the Air Force maintenance metrics of HSLDR rate and TNMCM rate. The base focus on departure reliability may have a direct effect on prioritizing unscheduled maintenance actions to best meet the flying schedule. This optimization can cause an airplane that is *hard broke* to be prioritized below another airplane in order to get the *less broke* airplane repaired more quickly and readied for the next flight. This decision, while supporting the objective of on-time departure reliability, may actually have a negative effect on the TNMCM rate. If, however, HSLDR and TNMCM were aligned, an improvement to HSLDR would imply an improvement to TNMCM. To investigate the alignment of the HSLDR, TNMCM, and AA metrics, the study team analyzed data from August 2004 through December 2006 for the 436 MXG at Dover Air Force Base (AFB). The 436 Maintenance Operations Squadron (MOS) analysis section provided the data for the HSLDR and TNMCM rates; the source for the AA rates was the Multi-Echelon Resource and Logistics Information Network.

Mathematically, metric alignment implies that two metrics are fairly strongly related. To test the correlation mathematically, the study team employed the correlation coefficient denoted by the symbol $\rho$ (rho). The correlation coefficient is a number between -1 and 1 which measures the degree to which two variables are linearly related and is scaled such that $\rho > 0$ indicates a positive correlation between the variables. A value of $\rho = +1$ implies a perfect correlation with all ordered pairs (points) falling on a straight line with a positive slope. A value of $\rho = -1$ implies a perfect negative correlation with all points on a straight line with a negative slope.[22] For the purposes of this study, the study team partitioned the correlation coefficient values in the following manner:

- $|\rho| \leqslant 0.20$ implies a very weak correlation
- $0.20 < |\rho| \leqslant 0.50$ implies a weak correlation
- $0.50 < |\rho| \leqslant 0.80$ implies a moderate correlation
- $0.80 < |\rho| \leqslant 1.0$ implies a strong correlation

Figure 1 illustrates the relationship between the TNMCM rate and HSLDR rate.

| | Leadership | Process Owner | Professionals |
|---|---|---|---|
| Enterprise Goals | High* | Low | Medium |
| Strategic Performance | High* | High | Medium |
| Operating Objectives | Medium | High* | Medium |
| Process Performance | Medium | High* | High |
| Activity Performance | Low | | High* |
| * = primary accountability | | | |

**Table 1. Accountability and Attention[18]**

| | AMC/A4 | MXG/CC | Technicians |
|---|---|---|---|
| **Enterprise Goals** – increase aircraft availability, reduce costs | High* | Medium | Low |
| **Strategic Performance** – deliver cargo and passengers accurately and on-time | High* | High | Medium |
| **Operating Objectives** – provide ready airplanes for the flying schedule | Medium | High* | Medium |
| **Process Performance** – isochronal inspections, unscheduled repair process | Medium | High* | High |
| **Activity Performance** – inspect and repair airplanes | Low | High | High* |
| * = primary accountability | | | |

**Table 2. Accountability and Attention for C-5 Aircraft Maintenance**

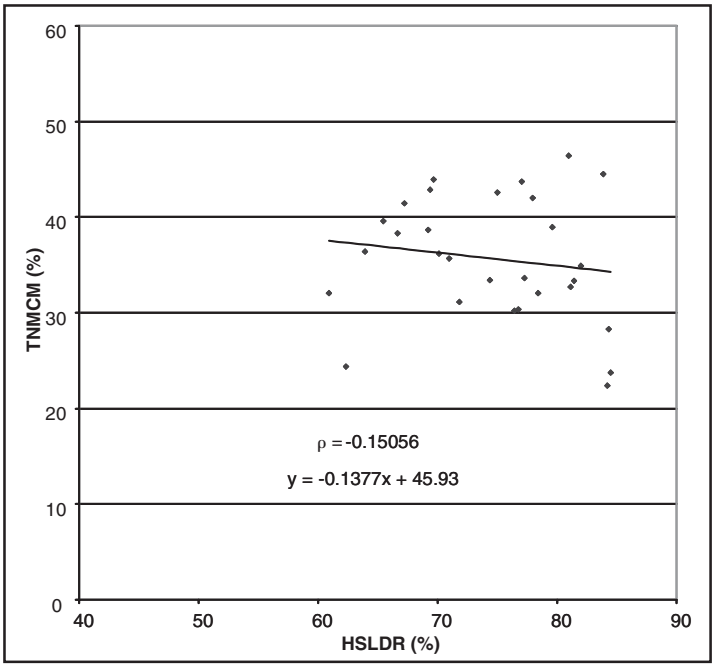


**Figure 1. HSLDR and TNMCM Rates Scatter Plot for 436 MXG August 2004 to December 2006**

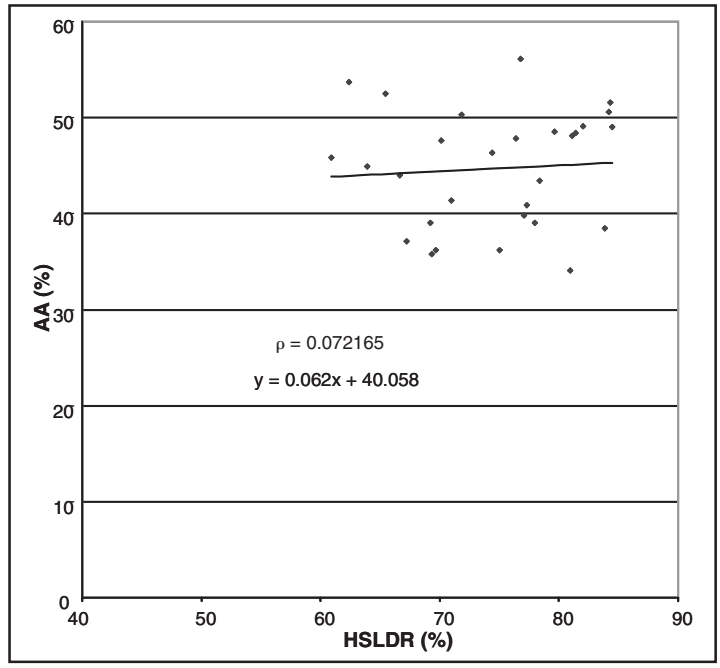


**Figure 2. HSLDR and AA Rates Scatter Plot for 436 MXG August 2004 to December 2006**

If the metrics were aligned, the graph should show evidence of a strong negative correlation. That is, as HSLDR increased, TNMCM would decrease and vice versa. In this case, the scatter plot reveals no definite relationship, appearing more like a *shotgun* spread. For comparison purposes, the least squares regression line for the data is drawn and the line equation is presented. A regression equation allows for the expression of a relationship between two or more variables algebraically. From Figure 1, the correlation coefficient between HSLDR and TNMCM is very weak, with $\rho$ = -0.15056. Therefore, improvement of the HSLDR rate does not imply improvement of the TNMCM rate. By the study's definition, HSLDR and TNMCM were not aligned metrics.

Figure 2 illustrates the relationship between the HSLDR rate and AA rate, the primary metric at the MAJCOM A4 level. Again, the plot resembles a shotgun spread, and there is a very weak correlation coefficient with $\rho$ = 0.072165. HSLDR and AA do not appear aligned according to the study's definition.

Figure 3 illustrates the relationship between the TNMCM and AA rates. Here, the scatter plot reveals a negative correlation. Likewise, the correlation coefficient indicates a moderate negative correlation with $\rho$ = -0.77927. This evidence supports the idea that TNMCM and AA are aligned according to the study definition. As the TNMCM rate improves (decrease), the AA rate also tends to improve (increase). This result is not surprising since TNMCM and AA are a part of the same family of status-hour metrics.

In summary, Figures 1, 2, and 3 suggest that TNMCM and AA are aligned, and HSLDR is not aligned with either TNMCM or AA. As stated earlier, the MXG/CC's focus on HSLDR as their primary metric, not TNMCM and AA. Therefore, the MXG/CCs and their personnel make decisions about resources and day-to-day operations which impact HSLDR first. Since HSLDR is not aligned with TNMCM and AA, there is no guarantee that TNMCM or AA will improve as a result of the current operations.

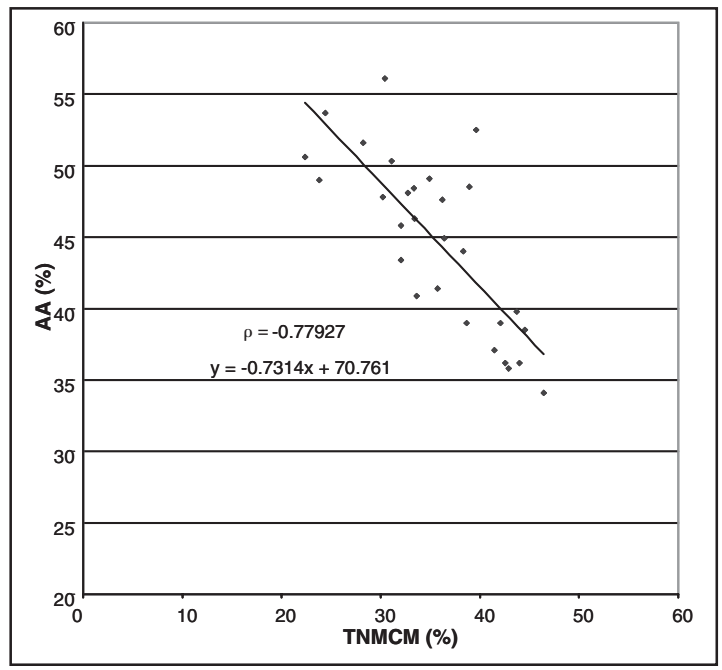


**Figure 3. TNMCM and AA Rates Scatter Plot for 436th MXG August 2004 to December 2006**

The MXG efforts, therefore, are not directly aimed at improving TNMCM rates when they are focusing on improving HSLDR rates.

## Experimentation Using C-5 Maintenance Priority (MXP) Simulation

In order to test the impact to TNMCM rates of base-level HSLDR-centric maintenance decisionmaking, the AFLMA study team created a discrete event simulation using *Arena* simulation software. The simulation facilitated an analysis of how different maintenance operations could affect the HSLDR and TNMCM

rates in a controlled environment. This analysis would be impractical to do in the real world. The following sections summarize the development and results of the C-5 maintenance priority (MXP) simulation.

## MXP Problem Formulation and Objectives

The MXP model was designed to study the employment of different queuing prioritization policies and their effect on key maintenance performance metrics in the support of C-5 aircraft. These policies determine the order in which aircraft awaiting maintenance are processed. Field interviews conducted by the study team revealed that in order to improve HSLDR, the maintenance commanders gave priority to those aircraft that "have the best chance of being returned to a [fully mission capable] status in minimum time."[23] These *recovery maintenance* practices were utilized at both Travis AFB and Dover AFB for C-5 maintenance.[24] The MXP model labels this as the least maintenance (MX) policy and determines the priority of queued aircraft based on the remaining man-hours of repair. Thus, the aircraft with the fewest man-hours of repair remaining relative to other queued aircraft receives top priority when maintenance resources become available. Alternatively, the most MX policy gives priority to the aircraft with the most man-hours of repair remaining. The two remaining policies are first-in-first-out (FIFO) and last-in-first-out (LIFO). These queuing policies order aircraft according to their arrival. With FIFO, a newly arrived aircraft goes to the back of the queue. In a LIFO policy environment, a newly arrived aircraft goes to the front of the queue.

## MXP Data Collection

Data for the MXP came from multiple sources. Aircraft arrival data was provided by the 436 MOS at Dover AFB for the period from January 2006 through March 2007. Manpower data was provided by the 436th Aircraft Maintenance Squadron for March and April 2007. Data for the possessed aircraft inventory, HSLDR rates, and TNMCM rates were provided by the 436 MOS for the fourth quarter fiscal year (FY) 2006. Data for the maintenance processes were taken from the Reliability and Maintainability Information System (REMIS) for fourth quarter FY 2006. The study team determined that these data sets were the most suitable given the availability of data.

## MXP Assumptions

Two important assumptions were made in the formulation of the MXP simulation:

- TNMCS time was assumed to have no impact on the maintenance operations or the TNMCM rate. The impact of supply operations was assumed to be accounted for in the repair time data. The MXP does not model any TNMCS time.
- Unit possessed time for all aircraft was assumed to be constant and equal for the four maintenance policies modeled in the MXP simulation.

## MXP Model Conceptualization

The MXP simulation modeled C-5 maintenance operations at Dover AFB. The simulation modeled 18 aircraft (the average number of possessed aircraft for Dover AFB in the fourth quarter FY 2006) that arrive at the base according to a daily arrival schedule with a fixed number of breaks. To achieve the desired arrival stream attributes within the *Arena* simulation framework, the MXP model employed three separate processes.

The first process created 18 C-5 aircraft entities at time zero. The entities then entered an arrival queue at a gate which opens according to the aircraft arrival schedule. Once opened, the gate allowed a single aircraft to proceed to the maintenance process before closing until the next arrival signal was received. The same 18 aircraft entities flowed from arrival process to the maintenance process before being recycled back to the arrival process. In this way, the model never had more than 18 aircraft in the system at one time.

The second process tracked the day of the week. A clock entity was created at time zero and thereafter stepped through the days of the week at 24-hour intervals. The simulation employed two schedules that depend on the day of the week cycle. The first was related to the maintenance process and defined how many manpower resources were available to perform maintenance on a given day. The second schedule governed the aircraft arrival pattern.

The final process related to aircraft arrivals determined when the gate should be opened allowing an aircraft *to arrive* and proceed to the maintenance process. These triggers were created according to a schedule derived from 15 months of aircraft arrival data at Dover AFB. The data defined day-specific discrete probability distributions of the number of aircraft arrivals. These distributions are given in Table 3.

The manpower resources and repair times required to complete the repairs were drawn from distributions based on the real-world data. The aircraft wait in the maintenance queue until resources are available for repair. Repairs are then completed in three phases.

The values in each row of Table 3 represent the probability of the particular number of arrivals (represented as 0 through 8 in the column headings) on that day of the week. Each row sums to one. These daily arrival distributions are the building blocks for a random aircraft arrival stream based on historic observations at Dover AFB. When all repairs are complete, the manpower resources are released to perform other repairs and the aircraft departs the base.

REMIS data was used to derive a discrete distribution of the number of personnel on a work crew associated with a repair action. Each repair action is assigned a randomly sized crew. Table 4 shows the crew size probability distribution used in the simulation. For example, there is a 0.519 probability that a repair action requires two maintenance personnel. When all repairs are complete, the manpower resources are released to perform other repairs and the aircraft departs the base. The data did not indicate any instances of crew sizes of seven or eight people during the timeframe of the data.

Figure 4 illustrates the overall view of the basic maintenance processes modeled in the MXP.

C-5 arrivals are triggered according to an arrival schedule. After arrival, aircraft require (seize) maintenance resources, maintenance actions are performed, and then manpower resources are released. This cycle is accomplished three times before returning the aircraft to the arrival queue.

In order to model the parallel and serial nature of aircraft maintenance actions, the study team adopted the repair bin methodology used by Balaban et al., in their mission capable

rate (MCR) simulation model, which they demonstrated using the C-5 fleet.[25] In reality, certain repair actions are accomplished simultaneously with other repair actions. However, by regulation, some actions cannot be performed simultaneously with certain other maintenance actions. Balaban et al., modeled this parallel and serial operation by grouping repair actions for a given aircraft into three bins or buckets. Repairs within a given bin are performed simultaneously, but the bins are repaired serially. Thus, all repairs in bin one are completed before beginning bin two repairs. The repair time for each bin is the longest of the repair times contained in the bin.[26] The MXP model also used three bins. The first bin contained 65 percent of the total number of repair actions, the second bin contained 25 percent, and the third bin contained 10 percent. This is very similar to the probabilities used in the MCR model—60, 30, and 10 percent, respectively.[27]

## MXP Model Validation

As previously stated, the least MX priority system most closely matched the recovery maintenance practices in place at both Dover AFB and Travis AFB. Therefore, the study team deemed the least MX model the best representation of the current, real-world process and considered this model the as-is model. The study team used the HSLDR rate in order to validate the MXP simulation with the real-world maintenance processes. After calibrating the MXP, the least MX model achieved an HSLDR rate of 0.821 with a 95 percent confidence interval that included the real-world HSLDR rate of 0.833 for the timeframe of the data. It is important to note that the model's intended use was not as a predictive model (given C-5 break rates, how many maintenance resources are required to satisfy a given AA rate?), but only to make a relative comparison between the four given prioritization policies. The model was not designed to determine HSLDR/TNMCM/MX backlog or to determine maintenance manning levels.

## MXP Results and Conclusions

Table 5 summarizes the MXP simulation results for the four policies examined with respect to three metrics: HSLDR, estimated TNMCM (Est TNMCM), and Sum of MX in the queue (MX backlog). MX backlog covers the middle ground between the other two metrics—the prioritization policy determines which aircraft the maintenance group returns to mission capable status soonest while the remaining aircraft accrue TNMCM time. MX backlog is a measure of the ability of the maintenance system to generate all possessed aircraft if called upon to do so. An ideal policy is one that would produce a high LDR rate, a low TNMCM rate, and a low MX backlog. Table 5 summarizes the results for each policy with regard to these three metrics.

- Least MX. The least MX model was the baseline for comparison to the other MX prioritization policies. It most closely resembled the *as-is* process of recovery maintenance. The HSLDR achieved in the model was representative of the real-world HSLDR rate and was used to validate the model. Likewise, the Est TNMCM rate achieved matched the real-world value for the timeframe of the data. MX backlog for the least MX model was the largest for the four policies considered. The MX backlog measured the ability to improve the steady-state TNMCM rate. The higher the backlog, the harder it was for the MX system to improve from their steady state TNMCM. Higher backlog means longer aircraft generation time.
- Most MX. The most MX prioritization policy had the same LDR (statistically speaking, within a 95 percent confidence

| Arrivals (AC) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Sunday | 0.231 | 0.461 | 0.2 | 0.093 | 0.015 | - | - | - | - |
| Monday | 0.092 | 0.139 | 0.292 | 0.215 | 0.108 | 0.092 | 0.047 | - | 0.015 |
| Tuesday | 0.015 | 0.047 | 0.2 | 0.261 | 0.185 | 0.154 | 0.107 | 0.031 | - |
| Wednesday | 0.015 | 0.077 | 0.093 | 0.307 | 0.308 | 0.138 | 0.062 | - | - |
| Thursday | - | 0.062 | 0.107 | 0.216 | 0.338 | 0.185 | 0.092 | - | - |
| Friday | 0.077 | 0.077 | 0.138 | 0.293 | 0.184 | 0.185 | 0.031 | 0.015 | - |
| Saturday | 0.169 | 0.416 | 0.246 | 0.061 | 0.062 | 0.046 | - | - | - |

**Table 3. Probability of Number of Aircraft Arrivals by Day of the Week**

| Crew Size (CS) | 1 | 2 | 3 | 4 | 5 | 6 | 9 |
|---|---|---|---|---|---|---|---|
| P(CS) | 0.323 | 0.519 | 0.123 | 0.022 | 0.003 | 0.001 | 0.009 |

**Table 4. Crew Size Probability**

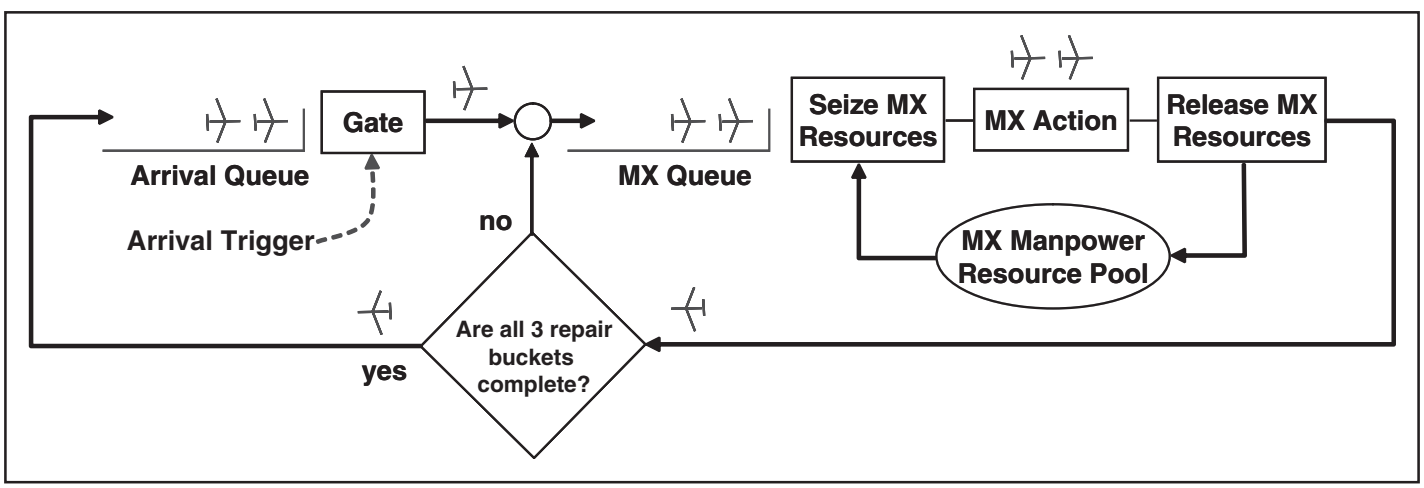


**Figure 4. Maintenance Process as Modeled in the C-5 MXP Simulation**

| Policy | HSLDR | Est TNMCM | Mx Backlog |
|---|---|---|---|
| Least Mx | 0.821 | 0.322 | 45K |
| Most Mx | 0.816 | 0.305 | 23K |
| FIFO | 0.764 | 0.307 | 20K |
| LIFO | 0.735 | 0.393 | 30K |

**Table 5. Summary of MXP Results for Study Metrics**

interval) as the least MX policy. Both the Est TNMCM and MX backlog improved over the least MX policy. This is intuitive because the most MX policy actively applies resources to the biggest maintenance jobs first. However, the variability from day to day increased significantly with this policy. This means that the predictability and stability for scheduling purposes suffered greatly.

- FIFO. The FIFO policy had a reduced LDR when compared to the least MX policy. However, the Est TNMCM improved, and was statistically the same as the Est TNMCM for the most MX policy (within 95 percent confidence intervals). The MX backlog was lower than the least MX policy as well.
- LIFO. The LIFO policy appeared to be the least attractive with regard to the key metrics. As compared to the least MX policy, it had a reduced LDR and increased Est TNMCM. It also had a reduced MX backlog when compared to the least MX policy but was the second worst of all the policies examined.

These results reveal several things about the prioritization policies and their impact to the LDR and TNMCM rates. First, LDR and TNMCM react differently depending on maintenance policy. The current policy in place (least MX) achieves a high LDR but has a mediocre estimated TNMCM when compared to the other policies, and the worst MX backlog, which indicates that it is very difficult to improve the TNMCM rate. It is possible to improve the TNMCM rate by changing the prioritization policy. However, the improved TNMCM would come at the cost of predictability and stability in day-to-day operations (as with most MX policy) and LDR, as is the case with the FIFO policy. The results of the simulation added support to the original hypothesis that HSLDR and TNMCM are not aligned metrics, but did not completely confirm it. While the current system can not be modeled perfectly, the simulation results did suggest that current maintenance policies do not ensure TNMCM improvement, but do improve LDR. It is safe to conclude that TNMCM and LDR are not necessarily aligned, complementary metrics.

Several personnel interviewed during the study team's site visits suggested that awareness exists of the just-described disconnect between enterprise goals (aircraft availability) and operating objectives. "There is a huge disconnect between AMC's focus on the availability of tails (airplanes) and our focus on on-time departure reliability."[28]

Consequently, while process owners are diligently focused on supporting the strategic performance objectives of delivering cargo and passengers, they are unable to simultaneously align their performance with the enterprise goal of increased aircraft availability.[29]

## Maintenance Metrics at Delta Airlines

As a means of comparing business practices, the study team elected to compare Air Force maintenance metrics with those of a leading commercial organization, Delta Airlines. The team interviewed representatives from Delta Airlines' reliability program office. The study team was told the focus of Delta's reliability program is driven by what is termed as Delays and Cancellations (D&C).[30] These are unscheduled events that have an operational impact and require a mechanical dispatch. For each delay or cancellation, there is a direct, net consequence to Delta's revenue, so there is a high priority placed on diagnosing the cause.

Delta personnel identified nine main aircraft maintenance metrics used by Delta. These metrics are summarized in Table 6.[31] Note that technical dispatch reliability (TDR) includes all maintenance related to primary delays and cancellations, whereas mechanical dispatch reliability (MDR) includes only those primary events for which the reliability program is responsible. Repairs due to damage, *cannot duplicate* actions, maintenance carryovers, and maintenance errors (such as over-servicing) are not included in MDR. Dispatches are the term used for all of Delta's revenue flights.[32] Although there is not an explicit hierarchy, the first two metrics, TDR and MDR, are directly linked to the daily revenue-producing flights on Delta's schedule. These metrics track the volume of, and reasons behind, delays and cancellations for a revenue flight.

Maintenance carryovers are Delta Airlines' equivalent to delayed discrepancies in the Air Force. Maintenance carryovers are repairs that may be delayed (or carried over) to a more opportune time. Unscheduled aircraft out of service (UAOOS) measures the number of aircraft out of service due to an unscheduled event (such as a broken component). Delta measures UAOOS by counting the number of aircraft in this category three times per day (0900 hours, 1200 hours, and 1800 hours), and averaging that count over specified intervals.[33] Prioritization of repair is often given to aircraft that can be returned to service quickly, but the level of impact to fleet operations may be the driving factor.[34] As an example, a broken B-777 has a much bigger impact than a broken MD-88; the MD-88 fleet has many spares, while the B-777 does not.[35] The UAOOS metric is analogous to the Air Force TNMCM rate, though it is only focused on the unscheduled aircraft and is counted in whole aircraft rather than hours. Delta's primary metrics (those driven by delays and cancellations) are not measured to an objective standard (*met* or *not met*), instead, they *alert* when they exceed a control limit for 2 consecutive months.[36] Additionally, Delta personnel interviewed suggested that the metrics are driving desired behavior; this is supported by measured performance, as TDR averaged 97 percent fleet-wide at the time of the original study's publication.[37]

Delta has a very clear enterprise-level value measure—profit. This clear value measure lends itself well to metric definition at the operational level, which is why Delta focuses on the D&Cs. The D&Cs have a direct net effect on the revenue producing flights, which in turn has a direct impact on profit.

## Value Metrics in the Mobility Air Forces

The MAF on the other hand, seems to have two competing enterprise-level value metrics.

- Strategic Readiness. AA and TNMCM rates measure the ability of the fleet to be fully mobilized at any given time

- Operational Effectiveness. HSLDR rates measure the ability of the fleet to meet the daily mission requirements.

Conventional wisdom argues that increased strategic readiness facilitates operational effectiveness—increased AA and decreased TNMCM should lead to increased HSLDR. However, as previously shown, there is a weak correlation between HSLDR and both AA and TNMCM. Again, these metrics are not aligned.

## Conclusions

This article discussed the focus on different metrics to include HSLDR, TNMCM, and AA at varying levels of the Air Force maintenance enterprise. It also demonstrated that HSLDR is aligned with neither AA nor TNMCM, as there is only a weak correlation between them. Maintainers at the wing level work to support operational effectiveness; however, higher levels of Air Force supervision appear more focused on improving strategic readiness. This disconnect in priorities was determined to be a root cause of the C-5 TNMCM rate being below Air Force standards. This article does not advocate one metric over another. That choice is left for Air Force leadership to make. This article illustrates that, in this case, the primary metrics at varying levels of aircraft maintenance are not aligned and not complementary to one another.

If the Air Force's primary goal is to improve the C-5 fleet TNMCM rate, then priorities of the maintainers in the field must change. As the MXG leadership focuses on HSLDR performance, not TNMCM, the MXP simulation indicated that improving the TNMCM rate would require an increase in resources. Therefore, in order to improve the TNMCM rate without increased resources, the maintainers in the field must make TNMCM a priority. While it is impossible to model the current system perfectly, the results suggest that current maintenance policies do not ensure TNMCM improvement, but do improve HSLDR, which is the stated priority of the MXG leadership. Therefore, the study team recommended that MAJCOM A4 leadership and MXG leadership decide on a set of metrics that are better aligned toward the same goal.

This realignment of metrics must start at the highest levels of the MAF. The MAF should choose its value measure and create a set of metrics aligned with that measure. For example, if the MAF directs that operational effectiveness is its primary value, then metrics such as Tons of Cargo Moved or Million Ton Miles Moved over a given time period could be used as the value metric. Then it must be determined whether or not metrics at lower levels are aligned with the value metric. Once that is determined, all levels of maintenance leadership will have the same overarching priorities. Dr Hammer describes the entire view as *pulling it together* and lists three things to consider:

- Deciding what to measure is a science
- Deciding how to measure is an art
- Using measures is a process

## Recommendations

- If improving C-5 TNMCM rates is the goal, all levels of maintenance leadership must make improving TNMCM rates a priority.
- AMC should determine its priorities between operational effectiveness and strategic readiness, and determine metrics aligned with these priorities.
- Conduct a study to determine whether or not increased AA is correlated with increased operational effectiveness in million ton miles or another pertinent metric. The answer to this

| Metric | Formula |
|---|---|
| Mechanical Dispatch Reliability (MDR) | $100 - \left(\left(\frac{\text{Delays + Cancellations}}{\text{Revenue Departures}}\right) \times 100\right)$ |
| Technical Dispatch Reliability (TDR) | $100 - \left(\left(\frac{\text{Technical Issues}}{\text{Revenue Departures}}\right) \times 100\right)$ Where technical issues include dispatches for mechanical, process, policy, and paperwork issues associated with delays and cancellations. |
| Unscheduled Aircraft Out of Service (UAOOS) Count | Number of Unscheduled Aircraft Out of Service |
| In-Flight Shutdown Rate (IFSDR) | $\frac{(\text{Total Inflight Shutdowns x 1,000})}{\text{Total Engine Hours}}$ |
| Maintenance Carryovers (MCO) Count | Number of Maintenance Carryovers |
| MEL Count | Number of Restricted Items |
| Unscheduled Removal Rate (Used for the Engines and APUs) | $\frac{(\text{Total Unscheduled Removals x 1,000})}{\text{Total Hours}}$ |
| Pilot Reports (PIREPS) | $\left(\frac{\text{Pilot Reports x 1,000}}{\text{Total Flying Hours}}\right)$ |
| Flight Exception Rate | Number of Diversions, Air Turn Backs and Rejected Takeoffs for Mechanical Reasons |

**Table 6. Delta Airlines Maintenance Metrics**

question will help determine the applicability of AA towards measuring operational effectiveness.

- AMC/A4 develop simpler, more concrete maintenance metrics that are easily countable and give an indication that operational effectiveness and or strategic readiness is going to be affected.

As previously mentioned, the metrics analysis, modeling, and simulation described in this article was developed as part of the larger *C-5 TNMCM Study II*. This is the second in a series of articles related to that study. The entire study can be found at the Defense Technical Information Center (DTIC) Private Scientific and Technical Information Network (STINET) Website at https://dtic-stinet.dtic.mil/.

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## Historical Perspective

*The battle is fought and decided by the quartermasters before the shooting begins.*

**—Field Marshal Erwin Rommel**

No matter their nationality or specific service, military logisticians throughout history have understood the absolute truth represented in the above quote. Whether they were charged with supplying food for soldiers, fodder for horses or the sinews of modern war—petroleum, oil, and lubricants (POL), they have understood that victory is impossible without them—even if, sometimes, it seemed their vital contributions were forgotten or ignored. None of the great military captains of history were ignorant of logistics. From Frederick the Great to Napoleon to Patton, they all understood the link between their operations and logistics. The great captains also have all understood that history had much to teach them about the nature of the military profession. Yet, military logisticians do not often spend time studying the history of military logistics.

There are at least three general lessons from history that might prove of some use in understanding how best to prepare for the future. The first of these is the best case operationally is often the worst case logistically. The second is promises to eliminate friction and uncertainty have never come to fruition. And the third is technological change must be accompanied by organizational and intellectual change to take full advantage of new capabilities. While these lessons are not exclusive to logistics, when applied to the understanding and practice of military logistics, they provide a framework for understanding the past and planning for the future.

Colonel Karen S. Wilhelm, USAF

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# Establishing C-5 TNMCM Standards

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The process for calculating and establishing Air Force-level TNMCM standards is not well known across the Air Force and not equally applied across the total force. Also, the process currently in use does not produce realistic, capability-based metrics to drive supportable operational decisions.

## Introduction

This article details the process for calculating and establishing Air Force aircraft total not mission capable maintenance (TNMCM) standards. It is impossible to discuss the TNMCM rates and standards without including discussions of the mission capable (MC) and the total not mission capable supply (TNMCS) rates and standards. These three rates are dependent upon one another. Because the rates are percentages of total unit-possessed time, one rate cannot increase or decrease without impacting the other two. The Air Force standards applied to these metrics are interrelated as well. As discussed in this article, the TNMCM and TNMCS standards depend on the MC standard. Thus, the formulation of the MC standard is the foundation for the TNMCS and TNMCM standards.

The 2003 CORONA directed that Air Force-wide standards for MC, TNMCM, and TNMCS be established. While directed toward TNMCM, the research detailed in this article also revealed that the MC standard is the foundation for calculating the other two metric standards. As the process exists currently, the Air Force MC standards are based on requirements which are determined in one of three ways:

- The flying hour or flying schedule requirement
- Contract logistics support (CLS) contract
- Another requirement based on major command (MAJCOM) input determined by the designed operational capability (DOC) statement, readiness study, or any operational requirement the MAJCOM may use

In the case of the Air Force's C-5 Galaxy, Air Mobility Command (AMC) provides the active duty fleet MC standard to the Air Staff based on the *Mobility Requirements Study* (MRS). However, the standard is not actually calculated in the MRS, it is an assumption used in the MRS.

This is not the case for the separate Air Force Reserve Command (AFRC) and Air National Guard (ANG) fleet C-5 MC standards. Those two values are calculated at the Air Staff level. The AFRC MC standard is calculated from utilization rate, attrition, turn pattern, annual fly days, spares, aircraft held down for scheduled maintenance, and primary aerospace vehicles authorized. The ANG MC standard equation uses variables portraying daily operations and maintenance (O&M) flying hours, aircraft taskings per flying day over and

# Article Highlights

**There are numerous implications for the complex, seemingly disjointed standards methodology that are problematic for the Air Force at the strategic, operational, and tactical levels.**

At the request of the Air Force Materiel Command Director of Logistics, AFLMA conducted an analysis in 2006-2007 of total not mission capable maintenance (TNMCM) performance with the C-5 Galaxy aircraft as the focus. The *C-5 TNMCM Study II* included five objectives. One of those objectives was to analyze the process for calculating and establishing TNMCM standards. This article details the analysis conducted in support of that particular study objective.

It is important to recognize that any discussion of TNMCM rates and standards must also include discussions of the mission capable (MC) and the total not mission capable supply (TNMCS) rates and standards. These three rates are dependent upon one another. Because the rates are percentages of total unit-possessed time, one rate cannot increase or decrease without impacting the other two. The Air Force standards applied to these metrics are interrelated as well. As the authors point out, the TNMCM and TNMCS standards depend on the MC standard. Thus, the formulation of the MC standard is the foundation for the TNMCS and TNMCM standards.

The research demonstrates that the process for calculating and establishing Air Force-level TNMCM standards is not well known across the Air Force and not equally applied across the total force. Also, the process currently in use does not produce realistic, capability-based metrics to drive supportable operational decisions.

The authors conclude by recommending that a repeatable methodology be developed to compute the TNMCM standard so that it:

- Reflects day-to-day minimum operational requirements
- Adjusts to fully mobilized force capabilities and surge mobility requirements
- Accounts for historic capabilities and fleet resources

above O&M flying, average number of aircraft required for standard flying operations each day, required daily spares, and the forecasted number of unit possessed aircraft over the year.

## Background

At the request of the Air Force Materiel Command Director of Logistics (AFMC/A4), an AFLMA study team conducted an analysis in 2006-2007 of TNMCM performance with the C-5 aircraft as the focus. The *C-5 TNMCM Study II* included five objectives. One of those objectives was to analyze the process for calculating and establishing aircraft TNMCM standards. This article details the analysis conducted in support of that particular study objective.

## Maintenance Metric Definitions

Air Force Instruction (AFI) 21-101, *Aircraft Equipment and Maintenance Management,* defines the MC, TNMCS, and TNMCM metrics and their uses. For additional insight on the use of these metrics see *Metrics Handbook for Maintenance Leaders*.

### Mission Capable (MC) Rate

Though a lagging indicator, the MC rate is perhaps the best known yardstick for measuring a unit's performance. It is the percentage of possessed hours for aircraft that are fully mission capable (FMC) or partially mission capable (PMC) for specific measurement periods (such as monthly or annually).[1]

$$\text{MC (\%)} = \frac{\text{FMC Hours + PMC Hours}}{\text{Possessed Hours}} \times 100\%$$

### Total Not Mission Capable Maintenance (TNMCM) Rate

Though a lagging indicator, the TNMCM rate is perhaps the most common and useful metric for determining if maintenance is being performed quickly and accurately. It is the average percentage of possessed aircraft (calculated monthly or annually) that are unable to meet primary assigned missions for maintenance reasons (excluding aircraft in *B-Type* possession identifier code status). Any aircraft that is unable to meet any of its wartime missions is considered not mission capable. The TNMCM is the amount of time aircraft are in NMCM plus not mission capable both (NMCB) status.[2]

$$\text{TNMCM (\%)} = \frac{\text{NMCM Hrs + NMCB Hrs}}{\text{Possessed Hours}} \times 100\%$$

### Total Not Mission Capable Supply (TNMCS) Rate

Though this lagging metric may seem a logistics readiness squadron responsibility because it is principally driven by availability of spare parts, it is often directly indicative of maintenance practices. For instance, maintenance can keep the rate lower by consolidating feasible cannibalization actions to as few aircraft as practical. This monthly (annual) metric is the average percentage of possessed aircraft that are unable to meet primary missions for supply reasons. The TNMCS rate is the time aircraft are in not mission capable supply (NMCS) plus not mission capable both maintenance and supply (NMCB) status. TNMCS is based on the number of airframes out for mission capable (MICAP) parts that prevent the airframes from performing their mission (NMCS is not the number of parts that are MICAP).[3]

$$\text{TNMCS (\%)} = \frac{\text{NMCS Hrs + NMCB Hrs}}{\text{Possessed Hours}} \times 100\%$$

## Fiscal Year (FY) 2007 C-5 Fleet Standards and Standards Calculations

As previously mentioned, during a 2003 CORONA, the Air Force Chief of Staff (CSAF) directed the establishment of Air Force-wide standards for the MC, TNMCS, and TNMCM metrics. Headquarters (HQ) Air Force Instalations and Logistics (now AF/A4) was named the office of primary responsibility (OPR). Their charter was to develop Air Force standards rooted in operational requirements and resources dedicated to each weapon system or mission design series (MDS). They subsequently developed calculation methodologies for calculating MC, TNMCS, and TNMCM standards. However, as of the time of the original study research, the study team found no official publication documenting the methodology for calculating these maintenance metric standards. Consequently, OPRs at the HQ Air Force and MAJCOM levels provided the study team with the definitions for the calculation methodologies that produced the C-5 fleet maintenance standards used in FY 2007. Table 1 summarizes the 2007 C-5 standard percentage rates for the MC, TNMCS and TNMCM metrics. An explanation of each method for deriving the standards follows.

## MC Standard

The MC standard provides the foundation for calculating the other maintenance metric standards. According to HQ Air Force, Directorate of Maintenance, Weapons Systems Division, Sustainment Branch (AF/A4MY) personnel, the MC standards are based on requirements. The MC standard represents the percentage of MC aircraft required at the beginning of each flying day. That requirement is determined by one of the following three ways:[5]

- The flying hour or flying schedule requirement, calculated using Equation 1, 2, or 3.
- Contract logistics support (CLS) contract.
- Some other requirement based on MAJCOM input. That input can be a DOC statement, readiness study, or any operational requirement the MAJCOM may use.

The Air Reserve Component (ARC), a composite of both ANG and AFRC, MC standard is based on the number of aircraft committed to the flying schedule. However, the ANG flying commitment is based on O&M flying hours, transportation working capital fund (TWCF) hours, and the number of operations alert committed aircraft per flying day. Also included is the daily spares requirement. This commitment in aircraft is divided by the forecasted possessed aircraft to determine the MC requirement.[6]

Each year, AF/A4MY personnel request input from AMC for the MC standard. AMC determines the MC rate necessary to meet their airlift requirement and then gives their desired MC rate to Air Staff. Air Staff then uses this rate as the MC standard. This process is currently used to determine the active duty MC standards for the C-17, C-5, C130, KC-10, and KC-135 airframes.[7] These MC standards are based solely on AMC's input. AF/A4MY personnel do not calculate the MC standard for any of the above listed active duty fleets.

# Article Highlights

### Article Acronyms

AA – Aircraft Availability
AAT – Aircraft Availability Target
AC – Aircraft
ACC – Air Combat Command
AE – Aeromedical Evacuation
AFB – Air Force Base
AFI – Air Force Instruction
AFLMA – Air Force Logistics Management Agency
AFMC – Air Force Materiel Command
AFRC – Air Force Reserve Command
AFSO21 – Air Force Smart Operations for the 21st Century
AMC – Air Mobility Command
ANG – Air National Guard
BE – Business Effort
CLS – Contract Logistics Support
CONOPS – Concept of Operations
CSAF – Chief of Staff, United States Air Force
DOC – Designed Operational Capability
DoD – Department of Defense
FMC – Fully Mission Capable
FY – Fiscal Year
GAO – Government Accountability Office
HQ – Headquarters
LMI – Logistics Management Institute
LRS – Logistics Readiness Squadron
MAJCOM – Major Command
MC – Mission Capable
MCS – Mobility Capabilities Study
MDS – Mission Design Series
MERLIN – Multi-Echelon Resource and Logistics Information Network
MICAP – Mission Capable
MRS – Mobility Requirements Study
NMCB – Not Mission Capable Both
NMCM – Not Mission Capable Maintenance
NMCS – Not Mission Capable Supply
O&M – Operations and Maintenance
OPR – Office of Primary Responsibility
PAA – Possessed Aircraft Authorized
PMC – Partially Mission Capable
REMIS – Reliability and Maintainability Information System
RERP – Reliability Enhancement and Re-Engining Program
TNMCM – Total Not Mission Capable Maintenance
TNMCS – Total Not Mission Capable Supply
TWCF – Transportation Working Capital Fund
UTE - Utilization

| | | Active Duty | ARC | *AFRC* | *ANG* |
|---|---|---|---|---|---|
| **MC** | **Standard** | 75 | 50 | *50* | *47* |
| | **Method** | *MAJCOM Input* | *Equation 3* | *Equation 1* | *Equation 2* |
| **TNMCS** | **Standard** | 8 | 8 | | |
| | **Method** | *Equation 4* | *Equation 4* | | |
| **TNMCM** | **Standard** | 24 | 50 | | |
| | **Method** | *Equation 6* | *Equation 6* | | |

**Table 1. FY 2007 C-5 Maintenance Standards and Calculation Methodologies[4]**

The three MC standard requirement algorithms are detailed in Equations 1, 2, and 3. Equation 1 is typically used with active duty aircraft fleets.

$$MC_{Std} = \left[\frac{12 \times UTE}{(1 - Attrition) \times (Turn\ Pattern) \times (Fly\ Days)}\right] + \left[\frac{Spares + MC_{SchdMX}}{PAA}\right]$$

**Equation 1. MC Standard[8]**

Where:

$MC_{std}$ is MC Standard.

*UTE* is the sortie utilization rate, which is the number of sorties required to fly each month by authorized aircraft. 12 x *UTE* yields the annual sorties required to meet the flying hour program (FHP).

*Attrition* is the annual attrition rate of sorties lost due to operations, maintenance, and other considerations such as weather. Dividing by (1-*Attrition*) yields the sorties required to be scheduled to account for attrition.

*Turn pattern*, or turn rate, is the total number of sorties scheduled divided by the number of *first go* sorties. For example: a unit schedules 100 sorties during the week and 60 of them occur on the *first go* of the day. The turn rate would be 100/60 = 1.67. Dividing by *turn pattern* yields the number of front-line flyers. Dividing by the number of *fly days* yields the number of front-line flyers per day.

*Fly Days* = 232. This figure assumes 244 *working days* minus 12 *goal days*.

*Spares*, or front line spares, is the number of scheduled spare aircraft for the *first go*.

$MC_{SchdMX}$ is the average number of aircraft per squadron held down on each flying day for scheduled maintenance including delayed discrepancies, health of the fleet management, washes, and so forth.

*Spares* + $MC_{SchdMX}$ is expressed as a percentage of squadron possessed aircraft authorized (PAA).

*PAA* is the number of aircraft authorized for a unit to perform its operational missions.[9]

Equation 2 is the algorithm used by the ANG.

$$MC_{ANG} = \left[\frac{\left[AC_{O\&M} + AC_{TWCF/BE/AE} + AC_{Ops} + Spares\right]}{AC_{Forecast}}\right]$$

**Equation 2. MC Standard for ANG[10]**

Where:

$AC_{O\&M}$ is the average number of committed aircraft based on the O&M requirements per flying day.

$AC_{TWCF/BE/AE}$ is the number of aircraft required for taskings per flying day that the ANG supports above its O&M flying (such as TWCF, aeromedical evacuation (AE), business effort [BE]).

$AC_{Ops}$ is the average number of aircraft required for standard flying operations per flying day.

*Spares* is the same as in Equation 1, but is reported as the number of aircraft per flying day.

$AC_{Forecast}$ is the number of aircraft that are expected to be unit possessed over the year based on depot maintenance schedules and other considerations.

$\lceil x \rceil$ shown in the numerator of Equation 2 denotes the smallest integer greater than or equal to *x*. This function rounds any decimal value up to the next whole number. The ceiling function is used in order to speak in terms of whole aircraft.

Equation 3 is utilized to calculate the MC standard for the composite ARC portion of an aircraft fleet.

$$MC_{ARC} = \frac{(MC_{AFRC} \times PAA_{AFRC}) + (MC_{ANG} \times PAA_{ANG})}{PAA_{AFRC} + PAA_{ANG}}$$

**Equation 3. MC Standard for ARC Fleet[11]**

The MC standard for the AFRC ($MC_{AFRC}$) fleet is calculated using the standard MC equation given in Equation 1. For simplicity, the result of this formula is rounded to the nearest tenth.

## TNMCS Standard

Active duty and ARC fleets use the same methodology for TNMCS once the MC standard is established. This calculation is shown in Equation 4. Note that separate TNMCS standards for AFRC and ANG are not calculated.

$$TNMCS_{Std} = 1 - AAT$$

**Equation 4. TNMCS Standard[12]**

The aircraft availability target (AAT), ties the TNMCS standard to the funding and requirements for spare parts that are calculated in the Requirements Management System.[13] It assumes the supply pipeline and spare safety levels are fully funded. The *AAT* for the C-5 has been at 92 since the beginning of the maintenance standard development. This yields a TNMCS standard of 8 which is applied to both ARC components.

Equation 5 defines the aircraft availability target calculation.

$$AAT = Required\ MC + NMCM_{3\ year\ historical}$$

**Equation 5. AAT Calculation[14]**

*Required MC* is determined the same way that the Air Force active duty MC standard is determined.[15]

$NMCM_{3\ year\ historical}$ is the 3-year historical average of the NMCM rate for the particular MDS under consideration.

It is important to note that the maintenance metrics standards established for FY07 (Table 1) used the FY05 calculated AATs.

This is because the C-5 parts on the shelf in FY07 were based on the FY05 AATs.[16] As just mentioned, the FY05 AAT for the C-5 fleet was 0.92. The Logistics Management Institute (LMI) updated the AAT-setting methodology in 2006 to include computations for *Required MC* and NMCM rates for both day-to-day operations and predeployment.[17]

## TNMCM Standard

Active duty and ARC fleets use the same methodology for TNMCM once the respective MC standard is established. This calculation is shown in Equation 6. Note that separate TNMCM standards for AFRC and ANG are not calculated.

$$TNMCM_{Std} = 1 - (MC_{Std} + TNMCS_{Std}) + NMCB_{3\ yr\ historical}$$

**Equation 6. TNMCM Standard[18]**

$NMCB_{3\ yr\ historical}$ is the average NMCB rate over the previous 3 years. The data used for the FY07 calculation came from the Reliability and Maintainability Information System (REMIS); the average NMCB for FY04, FY05, and FY06 equaled 0.07.[19]

## Standards Calculation Examples

This section applies the above formulas to the real-world data that produced the metric standards in Table 1.

### FY07 Active Duty C-5 Fleet

MC Standard (MAJCOM Input):

AMC stated that the MC standard is 0.75 (75 percent) based on an operational requirement used in the Mobility Requirements Study (MRS) 2005 (MRS-05).

TNMCS Standard (Equation 4):

$$TNMCS_{Std} = 1 - AAT = 1 - 0.92 = 0.08$$

TNMCM Standard (Equation 6):

$$\begin{aligned} TNMCM_{Std} &= 1 - (MC_{Std} + TNMCS_{Std}) + NMCB_{3\ yr\ historical} \\ &= 1 - (0.75 + 0.08) + 0.07 \\ &= 0.24 \end{aligned}$$

### FY07 ARC C-5 Fleet

The data required to calculate the ARC standards for FY07 is given in Table 2. AFRC and ANG provided the data in response to the FY07 Air Force Standards Data Call.

The PAA numbers the commands provided were 32 for the AFRC and 16 for the ANG. These values reflected the PAA before the PAA was adjusted to accommodate units recently gaining C-5s. To compute the AFRC MC standard, AF/A4MY used the PAA based on AFRC input, which was 32. However, for the weights in determining the composite ARC MC standard, AF/A4MY used the PAAs for FY07, which included the additions for the gaining units. These values are 40 for AFRC and 29 for ANG.

AFRC MC Standard (Equation 1):

$$MC_{AFRC} = \left[\frac{12 \times UTE}{(1 - Attrition) \times (Turn\ Pattern) \times (Fly\ Days)}\right] + \left[\frac{Spares + MC_{SchdMX}}{PAA}\right]$$

$$MC_{AFRC} = \left[\frac{12 \times 8.5}{(1 - 0.23) \times (1.3) \times (232)}\right] + \left[\frac{2 + 0}{32}\right] = \left[\frac{102}{232.232}\right] + \left[\frac{2}{32}\right] = 0.502$$

ANG MC Standard (Equation 2):

$$\begin{aligned} MC_{ANG} &= \left[\frac{[AC_{O\&M} + AC_{TWCF/BE/AE} + AC_{Ops} + Spares]}{AC_{Forecast}}\right] \\ &= \left[\frac{[3.84 + 1.19 + 0.45 + 1.3]}{15}\right] \\ &= \left[\frac{[6.78]}{15}\right] = \left[\frac{7}{15}\right] = 0.47 \end{aligned}$$

ARC MC Standard (Equation 3):

$$\begin{aligned} MC_{ARC} &= \frac{(MC_{AFRC} \times PAA_{AFRC}) + (MC_{ANG} \times PAA_{ANG})}{PAA_{AFRC} + PAA_{ANG}} \\ &= \frac{(0.50 \times 40) + (0.47 \times 27)}{67} = 0.488 \approx 0.50 \end{aligned}$$

TNMCS Standard (Equation 4):

$$TNMCS_{Std} = 1 - AAT = 1 - 0.92 = 0.08$$

TNMCM Standard (Equation 6):

$$\begin{aligned} TNMCM_{Std} &= 1 - (MC_{Std} + TNMCS_{Std}) + NMCB_{3\ yr\ historical} \\ &= 1 - (0.50 + 0.08) + 0.08 \\ &= 0.50 \end{aligned}$$

Of note is the fact that the 3-year average NMCB was actually 0.166 (based on Multi-Echelon Resource and Logistics Information Network [MERLIN] data). AF/A4MY capped the NMCB at 0.08 because the historical NMCB cannot theoretically exceed the TNMCS. Recall that TNMCS is the sum of NMCS and NMCB; therefore, NMCB *should be* less than or equal to TNMCS.[21] The TNMCS standard is established as a resourced goal and the Air Force is trying to achieve a balance in the maintenance standards.[22]

## AMC Determination of the C-5 MC Operational Requirement

According to AF/A4MY and AMC/A4MXA, AMC provides Air Staff with the value for the MC standard for the active duty fleet. This standard has been 75 percent since 2003, the year that Air Force-wide standards were implemented.[23] AMC/A4MXA stated that the value of 75 percent was based on the MRS.[24] According to the AMC/A9 office, every major mobility study including the MRS (1992), the *MRS Bottom-Up Review Update* (1995), MRS-05 (2000), and the *Mobility Capabilities Study* (2005), has used 75 percent as the C-5 MC rate standard to

| | PAA Command Input | PAA (FY07 Actual) | UTE | Attrition | Turn Pattern | Fly Days | Spares | MC for Sched Mx |
|---|---|---|---|---|---|---|---|---|
| AFRC | 32 | 40 | 8.5 | 0.23 | 1.3 | 232 | 2 | 0 |
| | PAA Command Input | PAA (FY07 Actual) | O&M AC/day | TWCF,BE, AE AC/day | Spares/ day | Ops AC/day | Possessed AC Forecast | |
| ANG | 16 | 27 | 3.84 | 1.19 | 1.3 | 0.45 | 15 | |

**Table 2. Data for AFRC and ANG MC Standard Calculations[20]**

determine the capability of the C-5 fleet to support the mobility forces.[25]

Examination of the MRS-05 revealed the MRS-05 did not calculate an MC standard; the MRS-05 assumed an MC rate of 76 percent for a fleet in which all C-5s have had the Reliability Enhancement and Re-Engining Program (RERP) modifications. The MRS-05 explains that the use of 76 percent MC rate is because of expected RERP improvements. The study also assumes a 65 percent MC rate for aircraft that have not received the RERP improvements.[26] The director of the AMC office of Analysis, Assessments, and Lessons Learned (AMC/A9) concurred that the C-5 MC standard is not based on any formal calculation or analysis, and stated that the original estimate (circa 1990) of a 75 percent MC rate was deemed "a prudent objective" for planning purposes.[27] AMC/A9 stated that the 75 percent MC rate assumes a fully mobilized total force to support C-5 maintenance operations.[28]

In summary, the FY07 MC, TNMCS, and TNMCM standards for the C-5 active duty fleet are based on the assumption that the C-5 fleet can achieve a 75 percent MC rate with the entire fleet receiving RERP upgrades or a fully mobilized total force to support maintenance operations.

## Implications of the Methodology

There are numerous implications of this complex, seemingly disjointed standards methodology that are problematic for Air Force members at the strategic, operational, and tactical levels. First, Equation 1, in its present state, is more appropriate for fighter aircraft than mobility aircraft.[29] For example, the *Turn Pattern* and $MC_{SchdMX}$ variables are reflective of fighter aircraft flying schedules. Mobility aircraft are less often *turned* on the same flying day, and mobility aircraft units, having a relatively small number of PAA, often have less opportunity to hold aircraft down for fleet health purposes. Consequently, this is a contributing factor to AF/A4MY's rationale of using AMC's input to determine active duty standards. The study team concluded that if Equation 1 is not appropriate for heavy aircraft, then it should not be used as a foundation for the MC standard. The variables used to measure performance need to accurately reflect the relevant process.

An additional issue is a lack of consistency across the total force components. The active duty component uses AMC input to determine the MC standard, but the ARC uses calculation methodology. Moreover, in addition to the planning objective used to determine the active duty maintenance standards and the calculations used to determine the ARC standards, the total force components, including the ANG, have maintenance metric goals. These goals are separate from the Air Force standards and are calculated differently. Within the ANG, units report their performance with regard to the ANG goals, and not necessarily the ARC metric standards. While the functional mission differences between fighter and mobility aircraft may justify distinct calculation methodologies, inconsistencies within a given airframe (for example, the C-5) are less easily supported. Consistency, in fact, is identified by AFI 21-101 as one of four important characteristics of a metric. These four characteristics are:

- Accurate and useful for decisionmaking
- Consistent and clearly linked to goals or standards
- Clearly understood and communicated
- Based on a measurable, well-defined process[30]

The fourth characteristic mentioned above highlights another concern given the current methodology for calculating the C-5 standards. Fundamentally, the process is not rigidly followed as part of formal policy; rather, the practice of establishing standards involves numerous deviations, discussed at length earlier in this article (active duty MC input, AAT from FY05, ANG goals). Simply stated, there was no complete, published, defined process. In April 2003, the United States Government Accountability Office (GAO) discussed these same issues in a report addressing aircraft availability goals across the Department of Defense (DoD).[31] The GAO found that all branches of military Service fail to clearly define the standards computation process for aircraft maintenance metrics.

The following selected comments were taken from the GAO report's executive summary:

> Despite their importance, DoD does not have a clear and defined process for setting aircraft availability goals. The goal-setting process is largely undefined and undocumented, and there is widespread uncertainty among the military Services over how the goals were established, who is responsible for setting them, and the continuing adequacy of MC and FMC goals as measures of aircraft availability. DoD guidance does not define the availability goals that the Services must establish or require any objective methodology for setting them. Nor does it require the Services to identify one office as the coordinating agent for goal setting or to document the basis for the goals chosen.[32]

Speaking in terms of consequence, the GAO suggested that the "lack of documentation in setting the goals ultimately obscures basic perceptions of readiness and operational effectiveness."[33] Additionally, the report documented several findings specifically relevant to establishing standards for the Air Force. These findings included:

- Air Force officials told [the GAO] that they generally try to keep the goals high because it is difficult to stop the goals from dropping further once they begin to be lowered.[34]
- Air Combat Command could find no historical record of the process used to establish most of the goals.[35]
- AMC compared the goals with the actual rates for the previous 2 years. Depending upon actual performance, the goal could then be changed, sometimes on the basis of subjective judgments.[36]

It is vitally important to examine the effectiveness and validity of metrics and their associated standards. Many hours are spent preparing for and participating in meetings discussing the performance of organizations, all of which is wasted if the metrics or standards are ineffective at measuring organizational performance and driving the desired behavior. Budgets and other requirements are driven in part from metrics. If the metrics being utilized are not valid, the effectiveness of the organization to meet warfighter needs is also difficult to accurately measure.

Air Force maintenance metrics are presented with an associated numerical standard or goal[37] and managers are required to account for failure to meet those standards. These failures are reported at unit, command, and Air Force levels, but what if the established standard is inaccurate, unrealistic, or unattainable? Consider Table 3, which identifies historical MC performances

for the C-5 at various points in time compared with the assumption used in establishing the C-5 MC standard.

During Operations Desert Shield and Desert Storm in FY91, the MC rate was less than 71 percent. During Operation Iraqi Freedom in FY03, the MC rate was less than 64 percent. This is particularly intriguing because numerous personnel interviewed during the original research suggested MC rates have been or should be usually better during conflicts.[39] Indeed, the highest quarterly MC rate the C-5 total fleet achieved, 81.8 percent, was observed during first quarter of FY91 (during Operation Desert Shield). Considering the data points in Table 3 are rates achieved during wartime scenarios, the feasibility of using 75 percent as the day to day, peacetime C-5 MC standard appears questionable at best.

Still, consistent failures to meet a standard can often be perceived as a shortfall in the performance of the units supporting the C-5, rather than an unrealistic expectation not being met. Again, a tremendous amount of time and effort is put forth explaining why standards are not met. Historical C-5 MC rate performance would suggest that the standard and its associated metric are not driving improvement in performance, which is the fundamental purpose of a performance measure. A metric and its associated standard should drive performance, not simply document it, and the measure should be useful for decisionmaking. Additionally, the *Air Force Smart Operations for the 21st Century Concept of Operations (CONOPS)* identifies good process metrics as having the following attributes:[40]

- Accurate – reliably expresses the phenomenon being measured
- Objective – not subject to dispute
- Comprehensible – readily communicated and understood
- Easy – inexpensive and convenient to compute
- Timely – data sources are available
- Robust – resistant to being gamed and hard to manipulate[41]

As previously stated, the current standards methodology involves differences across the total force. Additionally, the study team interviewed many subject matter experts while conducting site visits for this research. Some of them indicated the consistent inability to achieve an MC standard of 75 percent led to an attitude of frustration, indifference and apathy towards the standards.[42] AFI 21-101 states that "metrics shall be used at all levels of command to drive improved performance."[43] In the case of the C-5, the existing maintenance standards methodology associated with the MC and TNMCM metrics appear to cause those metrics to fall short of this goal.

## Alternative Strategies to Performance Measurement

As described in the second article in this series, the AFLMA study team interviewed representatives from the Delta Airlines reliability programs office as a means of comparing business practices. Delta personnel identified nine main aircraft maintenance metrics. Of note was the fact that Delta's primary metrics (those driven by delays and cancellations) were not measured to an objective standard (met or not met); instead, they alert when they exceed a control limit for 2 consecutive months.[44]

Using control limits, found in control charts, is a commonly used technique for determining if a process is in a state of statistical control. First developed by Shewhart, many influential quality leaders have advocated the proper use of control charts, most notably W. Edwards Deming. Generally speaking, recent data is examined to determine the control limits that apply to future data with the intent being to ascertain whether the process is in a state of control.[45] Charts alone cannot induce process control; stabilization or improvement is the challenge of people in the process.[46] Viable control limits can only be developed for processes in a state of statistical control, and they are best applied to process variables rather than product variables.[47] For example, consider the manufacturing process of a metal component. The product variables might be thickness or diameter, whereas process variables could be temperature or pressure at the point of forging. The benefit of monitoring process variables better allows someone to assign cause to variation. Using the previous example, variance in component diameter indicates a problem but requires further investigation to determine the cause. However, excessive pressure measurements identify the cause behind improper component diameter. Essentially, process variable measurements identify causes that could affect product variables.[48]

Today, many maintenance units are using versions of control charts to monitor performance in terms of the various metrics listed in AFI 21-101.[49] For example, Figure 1 illustrates TNMCM performance (large solid black line), with upper and lower control limits (represented by the solid red lines), at Dover Air Force Base (AFB) during calendar year 2006. Although the effort to use control charts is a step in the right direction, there can be two major problems associated with the use of charts akin to those of Figure 1.

First, Air Force metric measurements such as TNMCM are not process variables; consequently, they do not lend themselves to the immediate, precise root-cause analysis that usually follows from control charts. This is evidenced by the copious explanatory notes pages accompanying products like the CSAF quarterly review slideshow.[51] In fact, the *C-5 TNMCM II* study team's analytical effort identified 184 factors that bear influence on the C-5 TNMCM rate. An additional confounding element is that status of aircraft and the categorization of hours (such as *possessed*) bear direct influence on the outcome of rates such as TNMCM, and this process is not consistent. Study team discussions with maintenance personnel revealed that aircraft status is not an exact science, and status documentation can be vulnerable to manipulation for the sake of improving numbers. For example, this can happen by delaying aircraft status changes

| | MC Rate | Time Period |
|---|---|---|
| AMC C-5 MC Standard | 75% | ~1990 – Present[38] |
| Operation Desert Shield/Desert Storm | 70.6% | Fiscal Year 1991 |
| Operation Iraqi Freedom | 63.4% | Fiscal Year 2003 |
| Highest Quarterly MC Rate Achieved | 81.8% | Fiscal Year 1991, Quarter 1 |

**Table 3. C-5 Fleet Historically Achieved MC Rates[38]**

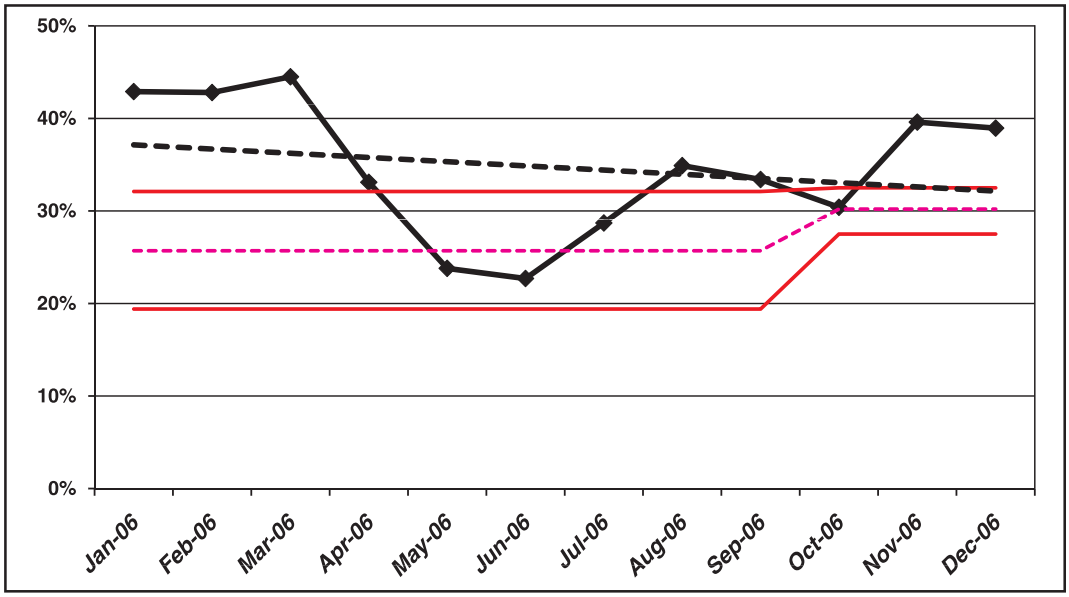


**Figure 1. Example of TNMCM Control Chart, Dover AFB 2006[50]**

by not changing the status to NMCM or NMCS as soon as an aircraft breaks and maintenance is underway or work stoppage occurs due to needed parts.

The categorization of hours is something that is in stark contrast with the host of metrics used by Delta Airlines, which upon examination appeared more tangible, more easily measured, and less easily manipulated. Again, a thorough discussion of Delta's maintenance metrics was included in a previous article in this book.

Next, upon examination of the control chart in Figure 1, one sees that the centerline mean (small dashed line between the solid red lines) is set at 30.2 for the months in FY07, with the upper and lower control limits set at 32.5 and 27.5, respectively.[52] The study team sought to uncover the specific methodology used to arrive at the centerline mean, as well as the upper and lower control limits. Personnel at Dover stated that the control limits are downward directed from headquarters AMC. The managing office at AMC stated that the control limits were derived from 2 years of historical data for all of AMC, with a range of one standard deviation above and below the mean.[53] There are two issues with this approach. First, the figure is not arrived at through subgroup sampling of at least 20 subgroups, as advocated by statistical analysis literature.[54] Secondly, this centerline mean is known as the *AMC goal* for the TNMCM rate. Interestingly, it is higher (that is, less ambitious) than the active duty TNMCM standard, which was 24 for the FY07 timeframe. The fact that AMC units are using a different figure than the established active duty standard for management purposes is further evidence that fleet standards appear to have limited influence on performance at base levels.

However, as noted in the 2005 AMC Metrics Handbook, because AMC command goals are rooted in wartime operational requirements, there are some standards that are difficult or impossible to achieve during peacetime operations.

> Using the *command average* is one way around this shortcoming. Comparing (your base) to command averages helps to gauge true performance and is invaluable for identifying if a problem is local or fleet wide. AMC weapons system managers (WSMs) use command averages for understanding overall performance of their fleets. When discussing performance problems with AMC WSMs, base personnel should have a good understanding of where their base performance numbers are in relation to the command average.[55]

It should be noted that the study team was not advocating the use of the active duty standard as the centerline mean for this control chart. In fact, extreme caution must be taken when using a standard value as opposed to the sampling mean as the centerline for performance. Although the intent might be to control the process mean at a particular value, one runs the risk that the current process is incapable of meeting that standard. For example, if the lower and upper control limits are calculated from the standard, and the current process mean exceeds the standard, subgroup averages might often exceed the upper limit, even though the process is in control. This lessens the ability to determine assignable causes of variation, because the only observation is that the process isn't conforming to the desired value.[56] This may, in fact, be what was actually occurring with the MC metrics for the C-5 fleet.

## What Should the TNMCM Standard Be?

If the existing standard's equations were used with current C-5 aircraft data (rather than using the 75 percent MC input from AMC for the active duty fleet) to calculate the active duty fleet MC, TNMCS, and TNMCM standards, the resulting standards[57] would be:

- MC Standard = 56.8
- TNMCS Standard = 20.6
- TNMCM Standard = 29.3

These figures are presented for informational purposes only in order to illustrate the stark contrast with the active duty standards in place at the time of the original report's publication (MC = 75, TNMCS = 8, and TNMCM = 24). The study team was not advocating the use of the standards presented above. Instead, the examination presented here and in the study report led to the recommendation that AMC and Air Staff develop a repeatable methodology to compute a standard focused on three things. These three things are listed in the recommendations section of this article. Such a methodology would better align to the original charter from the 2003 CORONA, which was to develop Air Force standards rooted in operational requirements and resources dedicated to the weapon system or MDS.

## Conclusions

The process for calculating and establishing Air Force-level TNMCM standards is not well known across the Air Force and

not equally applied across the total force. Also, the process currently in use does not produce realistic, capability-based metrics to drive supportable operational decisions.

## Recommendations

Develop a repeatable methodology to compute the standard that:

- Reflects day-to-day minimum operational requirements
- Adjusts to fully mobilized force capabilities and surge mobility requirements
- Accounts for historic capabilities and fleet resources

As previously mentioned, the analysis of maintenance metric standards described in this article was developed as part of the larger *C-5 TNMCM Study II*. This is the third and final article in a series related to that particular research. The entire study report can be found at the Defense Technical Information Center private Scientific and Technical Information Network Website at https://dtic-stinet.dtic.mil/.

### Notes

1. AFI 21-101, *Aircraft and Equipment Maintenance Management*, HQ USAF/A4MM, 29 June 2006, 27-28.
2. AFI 21-101, 28.
3. *Ibid*.
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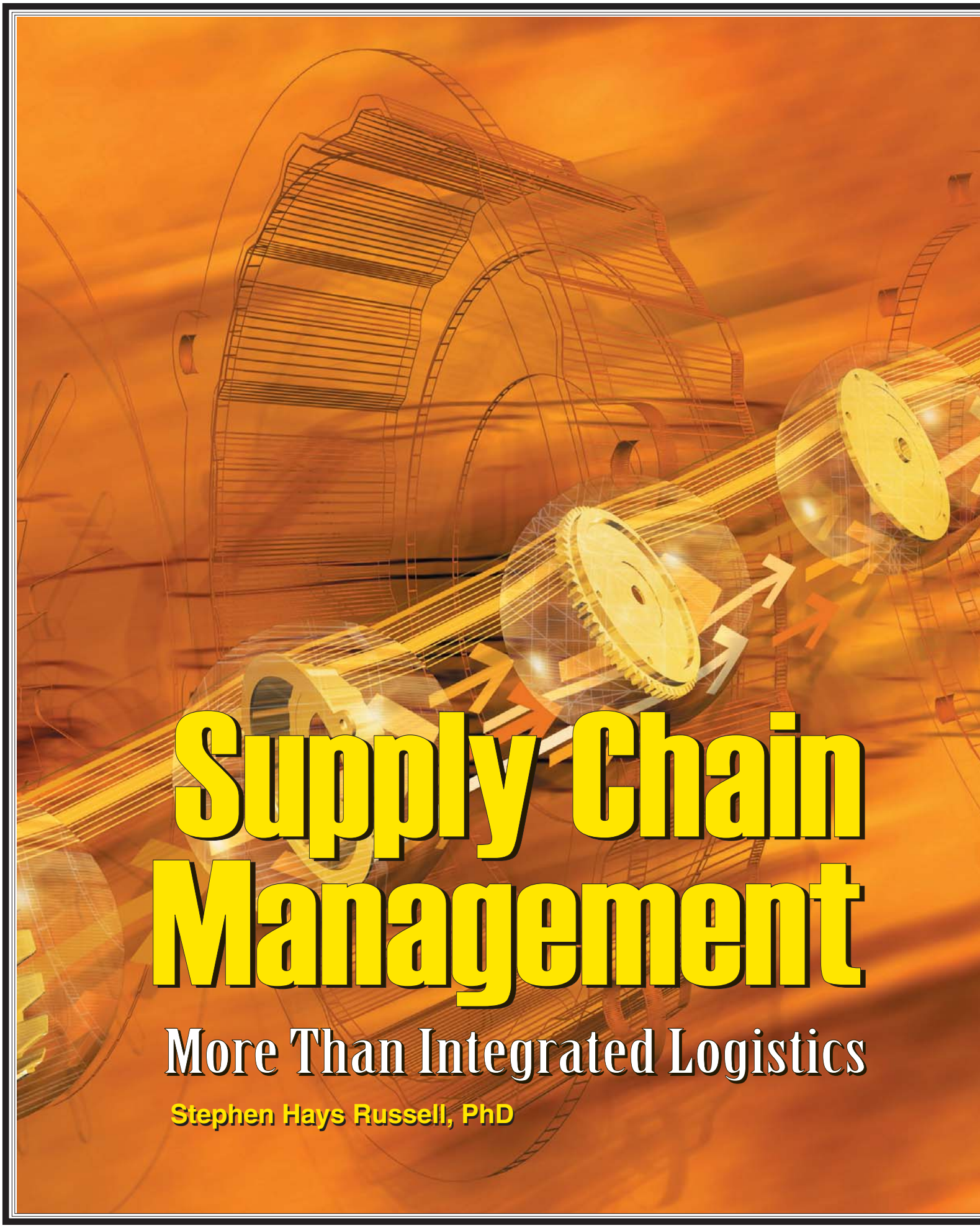
## Lessons from the First Deployment of Expeditionary Airpower

The lens of history speaks to many of the issues that are significant in today's expeditionary airpower environment. Particularly relevant are the lessons learned during first deployment of expeditionary airpower by the Royal Flying Corps during WWI. These include:

- The use of airpower is an expensive proposition.
- Maintaining aircraft away from home station demands considerable resources.
- Attrition from active operations is often very high.
- Effective support demands the ready availability of spares.
- Transport and protecting the transportation system is critical.
- Preserving mobility (the ability to redeploy quickly) is a constant battle.
- The supply system must be adequate in scope with a margin in capacity to meet unplanned events.
- The essential *lubricant* is skilled manpower.

Air Vice-Marshal Peter J. Dye, RAF



# Supply Chain Management

## More Than Integrated Logistics

Stephen Hays Russell, PhD

**Supply chain management is more than a passing stage in the continuing evolution of management practice.**

## Introduction

Logistics as a management discipline originated in the military and later branched into the commercial sector as business logistics. Now, the hottest topic in the commercial sector is supply chain management. With the Department of Defense (DoD) jumping on this latest revolution in management thought, questions arise as to what exactly is supply chain management.

This article examines the historical evolution of management thought to its newest frontier—supply chain management, reviews the emerging practices that define supply chain management in both commercial and military applications, and demonstrates that supply chain management is more than integrated logistics.

## The Development of Formal Management Thought

The evolution of management thought began in a formal way with Frederick Taylor's *Principles of Scientific Management* published in 1911. Taylor focused on issues of worker productivity. In the ensuing decades, research in management practices was directed toward efficiencies in manufacturing and services (collectively referred to as operations). Beginning in the 1950s, work by Harry M. Markowitz and others spawned a thought revolution on capital markets and financial management. During the 1960s, new approaches in marketing emerged as the areas of consumer behavior and the analysis of distribution systems became the focus of much business-related research. During the decade of the 1970s, a trend which began in the 1960s—the migration of military logistics practices to the private sector—accelerated as corporations recognized the need to improve their distribution functions and American universities began to offer degree programs in logistics management.

New attitudes and approaches toward personnel management emerged in the 1980s as organizations recognized the importance of human resource considerations in productivity enhancement and in long-range strategic planning. The term *human resource management* was introduced. The 1980s also saw a major emphasis on quality management as US business faced increased competition from Japan.

The 1990s was a decade in which logistics management truly came of age in management thought and in private sector business practices. As the emphasis on quality matured and high quality became the standard, firms began to differentiate themselves in terms of their logistics performance. Specifically, the focus of research and practice in logistics was in terms of employing the new information technologies of the 1990s to develop capabilities and protocols for efficient and responsive material flows to meet the ever-increasing demands of customers.

The evolution of management as a discipline during the twentieth century generated a body of literature and a set of practices which today define the science of management as effective, efficient planning and control of operations, finance, marketing, quality, human resources, and logistics (see Figure 1).[1]

By the year 2000, this collective maturing of management thought set the stage for a new frontier of emphasis, seeking increased customer service levels, market share, and profits by focusing on organizational interconnectivity in terms of a *supply chain*.

| Years | Events |
|---|---|
| 1911 | **Management** emerges as a formal discipline of study and practice |
| 1920s – 1950s | Writings on **operations**, worker productivity, and output metrics |
| 1950s | Modern era of **finance** is launched |
| 1960s | Modern thought in **marketing** principles and practices formulated |
| 1970s | Accelerating trend by **business** to adopt principles of military **logistics** to distribution systems |
| 1980s | Contemporary approaches to **human resource management** emerge<br>**Quality** revolution |
| 1990s | Explosive growth in logistics research and **logistics emphasis in organizations** |
| 2000s | **Supply chain management revolution** |

**Figure 1. Evolution of Management Thought**

# Article Highlights

**The term supply chain management was coined in 1982 by Keith Oliver, a management consultant at Booz Allen Hamilton. Oliver used the term to develop a vision for tearing down functional silos that separated production, marketing, and distribution. The concept was enlarged by J.B. Houlihan in 1985 when he expounded upon efficiencies and mutual benefits associated with information sharing and decision coordinating up and down a supply chain.**

This article examines the historical evolution of supply chain management, reviews the emerging practices that define supply chain management in both commercial and military applications, and demonstrates that supply chain management is more than integrated logistics.

A supply chain is the sequentially-connected organizations and activities involved in creating and making a product available. A supply chain can also be viewed as a value chain inasmuch as suppliers, manufacturers, transporters, and all other components of a supply chain add value. It may also be viewed as a demand chain.

In the late 1990s, an entire culture focusing on the supply chain emerged.

According to Dr Russell, some view supply chain management as a sophisticated new name for integrated logistics. However, supply chain management is more than integrated logistics because supply chain management involves far more than logistics. Supply chains ride on the back of information systems, they include manufacturing operations, they interface with marketing and finance, and they involve such concepts as strategic sourcing, business process connectivity, risk sharing, and supplier involvement in new product development. Managing a supply chain involves activities that are outside the purview of logistics.

## The Supply Chain Management Revolution

A supply chain is the sequentially-connected organizations and activities (from Mother Earth to the ultimate customer) involved in creating and making a product available. A supply chain can also be viewed as a *value chain* inasmuch as suppliers, manufacturers, transporters, and all other components of a supply chain add value. Conversely, if one looks in the reverse direction at the same activities, a supply chain can be viewed as a *demand chain*.

The term *supply chain management* was coined in 1982 by Keith Oliver, a management consultant at Booz Allen Hamilton.[2] Oliver used the term to develop a vision for tearing down functional silos that separated production, marketing, and distribution. The concept was enlarged by J. B. Houlihan in a 1985 article that expounded upon efficiencies and mutual benefits associated with information sharing and decision coordinating up and down a *supply chain*.[3]

In the late 1990s an entire culture focusing on the supply chain emerged. Universities introduced supply chain management majors or supply chain management concentrations in masters of business administration programs (Arizona State University, Syracuse University, and the University of Wisconsin, for example). Wal-Mart honed supply chain management concepts by building worldwide communication and relationship networks with suppliers to improve reliable material flows with lower inventories. Indeed, Wal-Mart is viewed by many as the premier practitioner of supply chain management with its demonstrated ability to get a network of worldwide suppliers, warehouses, and retail stores to behave almost "as a single firm with near real-time information…."[4,5]

By the year 2000, the trend for major organizations to establish high-level executive positions with supply chain titles was in full swing.[6]

In 2005, the Council of Logistics Management changed its name to the Council of Supply Chain Management Professionals (CSCMP).

The pervasiveness of the supply chain management revolution is skillfully described by Thomas L. Friedman in his 2005 best-selling book *The World is Flat*. He considers supply chain management and its enabling information technology revolution as being behind fundamental changes in the world economy.[7]

## Defining Supply Chain Management

The supply chain management concept seeks utopian performance in commerce: all activities up and down a supply chain orchestrated and coordinated (as though a single entity) to synchronize supply and demand at all levels, the sharing of information and technologies to increase innovation and to shorten product development cycles, reduction in order cycle time, replacing stocks with flows, effectively and efficiently responding to customer demands, reduced costs, and increased customer satisfaction.

Some view supply chain management as a sophisticated new name for integrated logistics. However, supply chain management is more than integrated logistics because supply chain management involves far more than logistics.[8] Supply chains ride on the back of information systems, they include manufacturing operations, they interface with marketing

and finance, and they involve such concepts as strategic sourcing, business process connectivity, risk sharing, and supplier involvement in new product development. Managing a supply chain involves activities that are outside the purview of logistics.

Figure 2 illustrates the conceptual transition from classical logistics to supply chain management, and the component parts of supply chain management. Classical logistics is concerned with the acquisition, storage, and distribution of material to get the right product to the right customer, at the right time, at the right place, in the right condition, in the right quantity, at the right cost (the *Seven R's of Logistics*).

Modern logistics, along with modern manufacturing, has moved beyond classical activities by incorporating Lean practices. Here the focus is on more than just time and place utility. Lean logistics and Lean manufacturing emphasize flows rather than stocks. Stockpiles of material are viewed as generally wasteful and as hiding underlying problems such as excessive production runs, poor demand forecasting, faulty inventory data, and erroneous distribution decisions. A just-in-case attitude is replaced with a just-in-time or other Lean approach as systemic process problems are eliminated. In short, inventory is replaced with information in the form of real-time demand (point of sale data, for example), more accurate forecasts, and visibility on inventory location.

As illustrated in Figure 2, Lean logistics and Lean manufacturing become two of the five components of supply chain management. Contrary to a popular view that supply chain management is just super-charged logistics, the cornerstone of supply chain management is not logistics. Alliances with key partners, and information technology that allows supply chain partners to share accurate information on a timely basis are the building blocks of efficient and responsive supply chain operations.[9] Upon this foundation, the introduction of Lean manufacturing and Lean logistics processes, together with the integration of key business processes up and down the supply chain create supply chain management.

Alliances are collaborative relationships with key partners built upon trust. In alliances, upstream partners are more than sources. They are resources to the focal firm for problem solving, and for innovation (new technologies for example). With alliances, partners are viewed as extensions of the focal firm and decisions are made in the context of mutual gain. Such collaboration is the underpinning of supplier relationship management (upstream) and customer relationship management (downstream).

Information technology is the glue that holds the supply chain together. The functional areas within the firm operate from a common, shared database. Alliance partners share data. The accuracy, the speed, the relevance, the availability, and the accessibility of information are critical for successful supply chain performance.

## Supply Chain Information Systems

Information systems supporting supply chain operations are of four categories:

- **Enterprise resource planning (ERP) software.** ERP software processes all transactions in every functional area and provides real-time access to an enterprise-wide data base. ERP replaces the legacy information systems which through the years have been cobbled together by operations, finance, marketing,

# Article Highlights

Russell concludes with three key points:

- Integrated logistics in a commercial context is coordinating logistics activities with other functional areas of the firm and with customers and suppliers. In a military context, integrated logistics is designing reliability, maintainability, and supportability into weapon systems, focusing on customer requirements, and coordinating supply support, training, technical data, and all other integrated logistics support elements.
- Supply chain management is more than integrated logistics. Supply chain thinking represents a major breakthrough in thought about the interconnectivity of information technology, logistics processes, and customer support. Supply chain management is alliances with supply chain partners, Lean processes, and end-to-end integration of key business processes. The enabling technology is information.
- Supply chain management is more than a passing stage in the continuing evolution of management practice. It is a major revolution which is already delivering end-to-end visibility, cost reductions, and new levels of performance metrics in meeting customer requirements.

### Article Acronyms

**ACS** – Agile Combat Support
**AFLC** – Air Force Logistics Command
**AFSC** – Air Force Systems Command
**DoD** – Department of Defense
**EDI** – Electronic Data Interchange
**eLog21** – Expeditionary Logistics for the 21st Century
**EPC** – Electronic Product Code
**ERP** – Enterprise Resource Planning
**ILS** – Integrated Logistics Support
**IWSM** – Integrated Weapons Systems Management
**LSA** – Logistics Support Analysis
**NCW** – Network-Centric Warfare
**OFT** – Office of Force Transformation
**OSD** – Office of the Secretary of Defense
**RFID** – Radio Frequency Identification
**S&RL** – Sense and Respond Logistics
**SCA** – Supply Chain Analytics

engineering, procurement, and so forth. Legacy systems are capability inhibited, difficult to connect to other functional areas, and cannot support supply chain dynamics.

- **Electronic data interchange (EDI) or Internet connectivity.** EDI and the Internet facilitate an interconnected business environment that allows partners to share decision-relevant information up and down the supply chain.
- **Electronic product code (EPC) technologies.** EPC technologies include bar codes, optical scanners, and radio frequency identification (RFID) technologies. EPC allows for item, case, pallet, and vehicle tagging for a *track and trace* capability in a supply chain.
- **Supply chain analytics (SCA).** SCA is any software designed to assess and improve supply chain performance. SCA can do such things as evaluate capacity, materials, and customer demand imbalances; or identify which carriers and distribution centers are most responsive.

## Integrating Business Processes

The final component of supply chain management is that which makes a supply chain operational—integration of key business processes among the players up and down a supply chain.

### Product Development

The objective of the product development process is to bring state-of-the-art products that meet customer wants and needs to market faster than the competition. This happens with internal integration of functions, and upstream and downstream involvement of supply chain partners.

In a supply chain management environment, engineering, manufacturing, procurement, logistics, marketing, and suppliers (and sometimes customers) work synergistically in cross-functional teams during product development.

Suppliers, viewed as resources, are involved early in the design stage of a new product. Suppliers (including supplier's suppliers) contribute information on new materials, new technologies, design engineering, process engineering, value analysis, supportability issues, and cost management. Early supplier involvement means shortened product development cycles and faster time to market of superior products.

Downstream, customers are often brought into the process through collaboration to understand their performance and design requirements, as well as their demand patterns.

### Demand Management

Modern supply chains are customer-driven pull systems. The focal firm's supply capabilities must be synchronized with known and forecasted demand patterns of downstream customers. The buy-make-move functions at all levels of a supply chain are driven by real-time demand data or by meaningful, current, adaptable forecasts that reduce uncertainty and promote responsive material flows throughout the supply chain. Such a process allows for higher levels of customer service with reduced inventories.

### Manufacturing Scheduling and Management

Coordination of manufacturing scheduling and management throughout a supply chain occurs with sharing of business plans and real-time inventory and demand information, and with an integrated business process of collaborative planning and forecasting. The supply chain concept requires movement away from the old, industrial economy mindset of *make to stock* to the information-age economy which means production at all levels reflects demand and supply synchronization.

### Order Fulfillment

Real-time visibility on inventory quantity and location, collaborative processes, and shared data foster flexible and responsive management of customer orders across global supply chains. Supply chain capabilities allow for seamless, continuous replenishment systems that meet or exceed customer expectations.

### Product Support

The supreme goal of supply chain management—effective, efficient customer service with superior products and service—requires a network of activities for responsive, after-sale product support. This includes high service levels for spare and repair parts, technical data, maintenance and calibration services, warranties, and returns.

In sum, by formula we can define supply chain management as:

**Alliances + Information Technology + Lean Manufacturing + Lean Logistics + Integration of Key Business Processes**

Figure 3 contrasts characteristics of classical logistics with pure supply chain management. To be sure, these are comparisons of extremes. Classical logistics does not represent information-age or modern, Lean practices. Pure supply chain management is an ideal based upon levels of trust, risk, and information purity that are not descriptive of all situations and environments. Nonetheless, this comparison highlights the evolving characteristics of a management revolution called supply chain management.

## Evolution from Logistics to Supply Chain Management

Figure 4 graphically portrays the evolution of logistics thought and practice.

Although logistics activities parallel the conduct of war and have existed for thousands of years, the term appears to have received its first official definition in 1905.[10]

Logistical activities on a massive scale occurred during World War II as huge stockpiles of materiel were pushed into theaters. The industrial-age *iron mountain* approach was the sure way to provide strategic support to military forces.

During the 1950s, two factors forced a consideration of *efficiency* in addition to effectiveness in providing logistical support to armed forces. First, the two Hoover Commissions (Commissions on the Organization of the Executive Branch of the Government) and congressional inquiries into military supply management during the Korean War identified waste and inefficiencies in military procurement and logistics. These findings spawned efficiency initiatives by the Department of Defense (DoD) that included creation of the first, single DoD-wide logistics executive (Assistant Secretary of Defense for Supply and Logistics); separate management approaches for *repairables* (now called *reparables*) and *consumables*; introduction of the item manager concept; and efforts toward standardization for items common to the three Services.[11]

Second, major challenges associated with America's first supersonic bomber, the B-58, manifested the need to consider maintainability in design of weapon systems. Not only did engineering complexities of the B-58 make it difficult to fly, flying-hour costs were huge, and maintenance intricacies required inordinate training and skill levels and highly specialized equipment. In 1965 early retirement was ordered for this aircraft. The B-58 demonstrated the need for configuration management; reliability and maintainability engineering, and life-cycle cost management to be included in the field of logistics.[12]

During the 1960s, an engineering perspective was added to the management aspect of logistics. Logistics became a quantitative science. The principles underlying logistics support analysis and integrated logistics support emerged.

The systems approach to logistics matured in the 1970s and 1980s. The art and science of logistics was treated as a set of interrelated activities. In 1970, logistics engineers and provisioning specialists from Air Force Logistics Command (AFLC) were, for the first time, collocated with a system program office in Air Force Systems Command (AFSC).[13] In 1976 AFLC created the Acquisition Logistics Division to work closely with AFSC to promote maintainability and support of weapons systems and ancillary equipment.[14] This era saw a major push on design for maintainability, supportability, and life-cycle cost management.

In 1992, AFLC and AFSC were merged into Air Force Materiel Command. This merger strengthened the systems view of logistics by marrying the research, science, engineering, and acquisition strategy expertise of AFSC with the logistics engineering and management expertise within

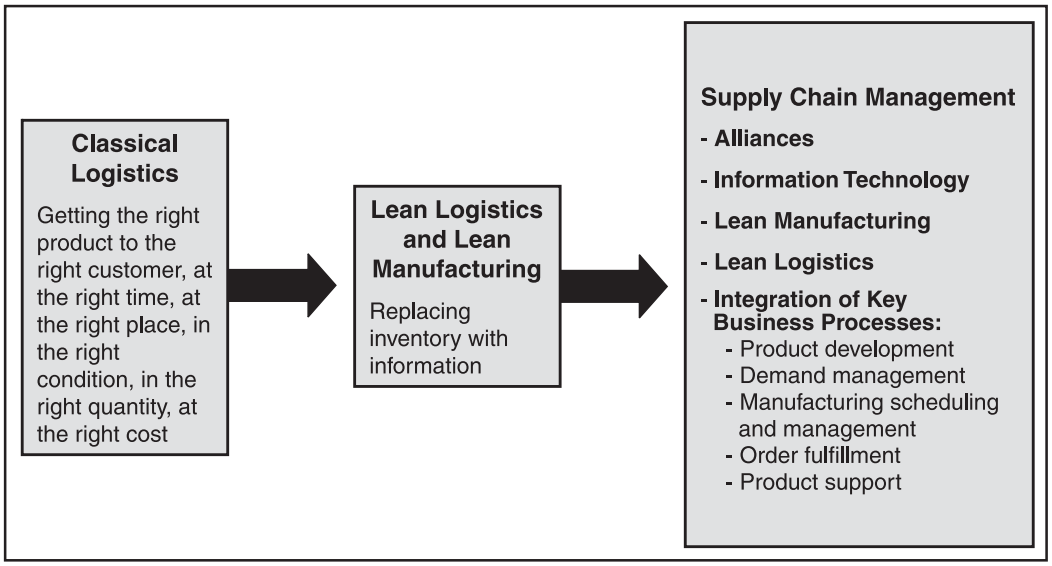



**Figure 2. Conceptual Transition from Classical Logistics to Supply Chain Management**

| | Classical Logistics | Pure Supply Chain Management |
|---|---|---|
| Starting point | Requirements determination | Business process renovation |
| Organization | Functional silos | Integrated supply chain |
| Strategy | Predetermined plans of action | Adaptive capabilities for flexible response |
| Span of vision | First tier sources and customers | End-to-end system |
| Management focus | Logistics optimization | Extended enterprise optimization |
| Performance standards | Provider-developed | Customer-dictated |
| Partner selection | Quote and competition | Proposal and negotiation |
| Partner connectivity | Short-term contracts | Long-term contracts and strategic alliances |
| Contractual environment | Legalistic | Institutional trust |
| Relationships | Transactional; arms length | Long term, collaborative |
| Relationship objective | Opportunistic advantage | Mutually satisfactory outcome with emphasis on continuity of the relationship |
| Procurement objective | Contract compliance at minimum cost | Best value (innovation, quality, service, and price) |
| Supplier base | Huge | Circumscribed to select or world-class suppliers |
| View toward supplier | Source | Resource |
| Material verification | Material Inspections | Certified suppliers |
| Business environment | Adversarial | Mutual gain |
| Transportation approach | Service objective at minimum cost | Consistent, reliable, responsive service |
| Inventory approach | Push system; just-in-case | Pull system; replace inventory with information |
| Material flows | Scheduled | Self-synchronizing |
| Information | Industry standards, performance audits, status and exception reports | Enterprise resource planning system, electronic product codes, Internet connectivity, and supply chain analytics |
| Cost and service | A trade-off | Reengineer processes to increase service levels and reduce costs |
| Cost focus | Acquisition cost | Total cost of ownership |
| Support asset focus | Stocks | Flows |
| Risk | Low | Higher |

**Figure 3. Comparative Characteristics of Classical Logistics and Supply Chain Management**

AFLC. The Agile Combat Support (ACS) doctrine became the targeted core competency for Air Force logistics. Program managers were given a *cradle-to-grave* responsibility for their acquisition programs as part of the integrated weapons systems management (IWSM) philosophy.[15]

On the commercial side of logistics, the marketing profession began to look at principles of military logistics as a way to improve distribution in the private sector in the mid-1960s. By the 1980s and 1990s, business logistics (defined as a customer-driven order fulfillment process with nine dimensions, as portrayed in Figure 4) became an important area for corporate strategy.

The 1990s also saw the blossoming of the information age, which offered the facilitating technologies for the supply chain management revolution of the 21st century.

## Supply Chain Management in the US Military

The private sector borrowed best-practice concepts in military logistics beginning in the 1960s. The defense establishment is now implementing commercial best practices by pursuing the concepts, practices, and technologies of supply chain management.

Although DoD created a supply chain executive position in 1998 (Deputy Under Secretary of Defense for Supply Chain Integration), a supply chain management campaign by the Office of the Secretary of Defense (OSD) was not launched until 2003.[16]

The impetus for this campaign was Secretary of Defense Donald H. Rumsfeld's 2001 initiative to transform US military capabilities and the establishment of the Office of Force Transformation (OFT).[17] Arthur K. Cebrowski, OFT's first director, developed the guiding philosophy of the transformation which he called network-centric warfare (NCW). NCW is best viewed as a theory of war in the information age. Information sharing among networks of intelligence, operations, and logistics communities facilitates speed of command, flexible and situational response, and sustainability.[18]

As part of the NCW model, OFT unveiled the Sense and Respond Logistics (S&RL) initiative in 2003.[19] S&RL is a philosophical umbrella for military supply chain management. It is a strategy for developing supply chains with players, information systems, capabilities, and protocols to respond rapidly to changing combat support requirements in the field. The *sense* aspect of S&RL is a real-time information system for gathering demand signals from the field. *Respond* is capabilities for flexible and speedy action within end-to-end supply chains. In short, S&RL is about the use of networks and sensors to create an agile supply chain with total asset visibility and real-time support capability. In an S&RL world, logistics mass is replaced with logistics speed.[20]

Responsibility for the S&RL project has been given to the Office of the Undersecretary of Defense for Acquisition, Technology and Logistics. Their mandate is to pursue the underlying technologies and to work with the individual military departments to identify and develop their potentials for S&RL.[21]

In the interim, OSD has directed the implementation of modern supply chain practices for all DoD components. The DoD Supply Chain Material Management Regulation (DoD 4140.1-R dated 23 May 2003) mandates a supply chain framework and guiding principles for effective and efficient end-to-end material support, meeting customer expectations while minimizing inventories, promulgating supply chain best practices in material management, and establishing the customer as the foundation driving all material management decisionmaking. This regulation requires all DoD components to measure total supply chain performance.[22]

The supply chain transformation within the US Air Force was formally launched in 2003 with the Expeditionary Logistics for the 21st Century (eLog21) campaign. The goal of eLog21 is, by philosophy, to offer efficient, agile combat support; by vision, an enterprise view of logistics; and in practicality, to use supply chain concepts and technology to improve weapons availability by 20 percent and to reduce support costs at the same time.[23]

The eLog21 program contains all the elements of modern supply chain management. Fulfillment processes are being reengineered to increase customer service and to reduce costs. Revised and integrated business practices for sustainment mirror private sector best practices. RFID is being extensively employed for asset tracking.

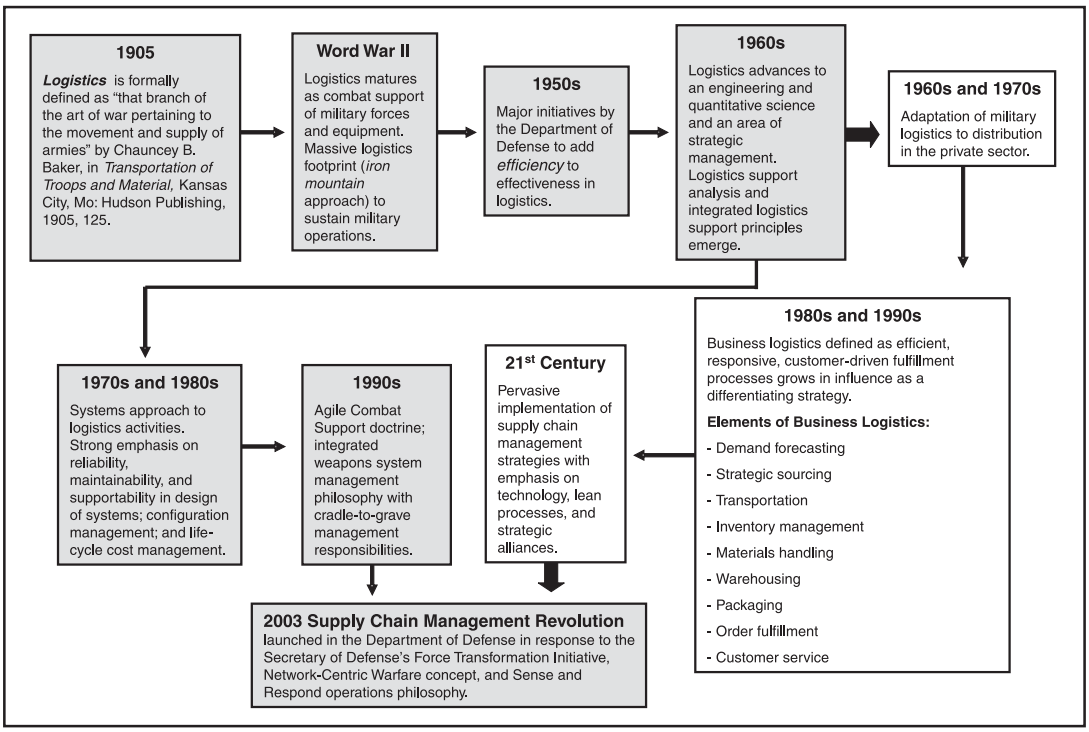



**Figure 4. Evolution of Logistics Thought and Practice**

And major investment in supporting information technology, the Expeditionary Combat Support System (which is the Air Force version of enterprise resource planning technology used in the private sector) is programmed.

## Summary

Integrated logistics in a commercial context is coordinating logistics activities with other functional areas of the firm and with customers and suppliers. In a military context, integrated logistics is designing reliability, maintainability, and supportability into weapon systems, focusing on customer requirements, and coordinating supply support, training, technical data, and all other integrated logistics support elements.

Supply chain management is more than integrated logistics. Supply chain thinking represents a major breakthrough in thought about the interconnectivity of information technology, logistics processes, and customer support. Supply chain management is alliances with supply chain partners, Lean processes, and end-to-end integration of key business processes. The enabling technology is information.

Supply chain management is more than a passing stage in the continuing evolution of management practice. It is a major revolution which is already delivering end-to-end visibility, cost reductions, and new levels of performance metrics in meeting customer requirements.

### Notes

1. "Historical Background of Organizational Behavior," [Online] Available: http://web.cba.neu.edu/~ewertheim/introd/history.htm, accessed 2 Apr 2007). Another element in the evolution of management thought is that of human motivation and the relationship between work environment and productivity. This field of inquiry (called organizational behavior) originated with the famous Hawthorne Studies on worker productivity in the 1920s and advanced with such notable contributions as Maslow's Hierarchy of Needs (1950s) and Douglas McGregor's human relations approach to management called Theory X and Theory Y (1960s).
2. Keith Oliver, "When Will Supply Chain Management Grow Up?" *Strategy + Business*, Fall 2003, Issue 32, [Online] Available: www.strategy-business.com/press/16635507/03304, accessed 23 Apr 2007.
3. J.B. Houlihan, "International Supply Chain Management," *International Journal of Physical Distribution and Materials Management*, Vol 15, No 1, 1985, 51-56.
4. Scott Webster, *Principles and Tools for Supply Chain Management*, Boston: McGraw-Hill-Irwin, 2008, 7.
5. Thomas L Friedman, *The World is Flat: A Brief History of the Twenty-First Century*, New York: Farrar, Straus and Giroux, 2006, 151. Friedman characterizes Wal-Mart's efficient global supply chains as "The Wal-Mart symphony in multiple movements—with no finale."
6. Early examples include Kraft Foods, The Home Depot, Fairchild Semiconductor, Logitech, Delta Airlines, Whirlpool Corporation, Tyco International, and General Motors.
7. Thomas L Friedman.
8. Nonetheless, the intellectual home for the supply chain management revolution has been in logistics. Logisticians lead this movement. The logistics managers at Wal-Mart, for example, spearheaded the move to supply chain management in that organization. The leading-edge thinkers in the supply chain revolution (Douglas M. Lambert of Ohio State University, James R. Stock of the University of South Florida, and John T. Mentzer of the University of Tennessee, for example) are logisticians by background.
9. This thought appears to have been advanced first by Douglas M. Lambert of Ohio State University and director of the Global Supply Chain Forum. See Douglas M. Lambert, *Supply Chain Management: Processes, Partnerships, and Performance,* 2d Edition, Sarasota, Florida: SCM Institute, 2006.
10. Chauncey B. Baker, *Transportation of Troops and Material*, Kansas City: Hudson Publishing, 1905, 125. For an expanded discussion on the origin of the term *logistics* and for various definitions, see Stephen Hays Russell, "The Growing World of Logistics," *Air Force Journal of Logistics*, XXIV, No 4, 15-19.
11. See "History of the Defense Logistics Agency," [Online] Available: www.dla.mil/history, accessed 18 Feb 2007.
12. For an example, see "B-58 Hustler," [Online] Available: www.globalsecurity.org/wmd/systems/b-58-fc.htm, accessed 18 Feb 2007.
13. In 1970, the B-1 System Program Office (SPO), as part of an initiative dubbed *Innovations*, colocated SPO personnel (engineers and program control people) at contractor sites (North American Rockwell in Los Angeles and General Electric Aircraft Engine Group in Evendale, Ohio). The SPO also had AFLC collocate personnel in these satellite SPOs.
14. *The Logistics of War: A Historical Perspective*, Maxwell AFB, Gunter Annex: Air Force Logistics Management Agency, 2000, 360.
15. Although intended for acquisition programs, the IWSM philosophy was expanded to product and materiel managers. The objective was to create a seamless process for spares by integrating the acquisition and sustainment processes.
16. In April 2003, OSD charged the Services with a series of supply chain transformation objectives including reengineering logistics processes, total asset visibility, and time-definite delivery. The individual Services, however, were pursuing supply chain concepts prior to that date. The Air Force Purchasing and Supply Chain Management (PSCM) project was initiated in February 2001 and progressed to its current design in April 2004. The Expeditionary Logistics for the 21st Century (eLog21) program, of which PSCM is a component and the Air Force approach to supply chain transformation, began in February 2003. For a comprehensive overview of the eLog21 program see, *Expeditionary Logistics for the 21st Century Campaign Plan*, [Online] Available: www.af.mil/shared/media/document/AFD-060831-041.pdf, accessed 30 Mar 2007.
17. See "Office of Force Transformation Homepage" [ [Online] Available: www.oft.osd.mil, accessed 18 Feb 2007.
18. D. S. Alberts, J.T. Garstka, and F.P. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority*, 2d ed (Revised), Washington, DC: CCRP Publications, August 1999, [Online] Available: www.dodccrp.org/files/alberts_ncw.pdf, accessed 18 Feb 2007.
19. Sense and respond as a business philosophy was developed by Stephan H. Haeckel of the IBM Advanced Business Institute in 1993. See S.H. Haeckel and A.J. Slywotsky, *The Adaptive Enterprise: Creating and Leading Sense and Respond Organizations*, Harvard Business School Press, 1999; and "Operational Sense and Response Logistics: Co-evolution of an Adaptive Enterprise Capability," Office of Force Transformation, November 2004, [Online] Available: www.oft.osd.mil/Initiative/srl/S&RL_Concept_Short.doc, accessed 12 Mar 2007.
20. For an excellent treatment of the Sense and Respond model see Karen Butner, et. al., *Reshaping Supply Chain Management: Vision and Reality*, Boston: Pearson Custom Publishing for IBM Global Business Services, 2007.
21. An insightful discussion on the progress and the challenge of organizational change in moving DoD components to S&RL is found in Heather B. Hayes', "Sense and Respond in Fits and Starts," *Defense Systems*, Sept/Oct 2006, [Online] Available: www.defensesystems.com/issues/1_5/features/474-1.html, accessed 11 Apr 2007.
22. Office of the Deputy Under Secretary of Defense for Logistics and Materiel Readiness, *DoD 4140.1-R DoD Supply Chain Materiel Management Regulation*, 23 May 2003, [Online] Available: www.ditc.mil/whs/directives/corres/pdf/414001r.pdf, accessed 2 Jan 2007.
23. "eLog21 Fact Sheet," [Online] Available: https://acc.dau.mil/CommunityBrowser.aspx?id=32774, accessed 2 Mar 2007; "eLog21 Purchasing and Supply Chain Management," *Air Force Journal of Logistics*, 23 May 2003, [Online] Available: www.accessmylibrary.com/coms2/summary_0286-1448758_ITM, accessed 2 Mar 2007.

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*relating readiness to dollars*

# Logistics Support

**The Air Force now has tools that relate dollars to base-level supply performance and can be used to trade off readiness against dollars. These tools are currently being used to optimally determine what to buy, repair, and distribute with available dollars. As the Air Force moves to an expeditionary combat support enterprise solution, these tools, and tools like them, will become more important.**

## How to Make Logistics Decisions

Air Force decisionmakers at all levels need tools that relate dollars to operational capability. For example, if the Air Force has $100M, where should it be spent to achieve the most combat capability? A more strategic question is whether to spend the $100M on weapon systems, logistics support, or people.

In the 1980's, the Air Force logistics community realized it needed a way to link dollars to readiness for the resources it managed—spares, equipment, and consumables, as well as munitions and fuel. Since that time, a number of models have been developed to do just that—link dollars to readiness for Air Force-managed peacetime and wartime spares, equipment, and consumables. In this article we briefly discuss the four major models and how they can be used (see Table 1).

In the late 1980s, the Air Force implemented the Aircraft Availability Model (AAM) as part of the Secondary Item Requirements System (D041 then, now D200A) in order to compute the safety-level component for Air Force spares. It has been used since then and continues in use today. The AAM models the complexity of the Air Force spares logistics system. It is a multi-echelon model that maximizes aircraft availability (total nonmission capable supply) given some level of funding. It also models depot- and base-level repair and resupply (retrograde and order and ship times) to a given operations tempo (usually flying hours). Further, AAM includes the spares indenture levels—only shortages of line replaceable units (LRU) will directly ground a weapon system, while shop replaceable units are needed to ensure LRUs are serviceable.

### Article Acronyms

AAM – Aircraft Availability Model
AA – Aircraft Availability
ACC – Air Combat Command
AEF – Aerospace Expeditionary Force
AFMC – Air Force Materiel Command
ASM – Aircraft Sustainability Model
COLT – Customer-Oriented Leveling Technique
CRSP – Consumable Readiness Spares Package
CWT – Customer Wait Time
DLA – Defense Logistics Agency
EBO – Expected Back Orders
ECWT – Expected Customer Wait Time
ERS – Equipment Requirements System
FAD – Force Activity Designator
FRAT – Funds Requirement Analysis Tool
FY – Fiscal Year
GSD – General Support Division
LRU – Line Replaceable Unit
MAJCOM – Major Command
MDS – Mission Design Series
PEC – Program Element Code
RSP – Readiness Spares Package
SA – Supply Availability
SBSS – Standard Base Supply System
WMP – War Mobilization Plan

The AAM uses marginal analysis to build aircraft availability (AA) curves, which can then be used to identify and prioritize what spares to buy with available dollars. Under AAM, the item which creates the largest increase in aircraft availability per dollar (marginal analysis—*bang per buck*) is the next item selected to buy.

Figure 1 illustrates an AA curve and shows that for a given weapon system (or group of weapon systems) the Air Force needs $235M in spares funding to achieve 95 percent aircraft availability. Decreasing the amount of funding by $25M decreases aircraft availability to 94 percent. Figure 2 shows the AA analysis for four weapon systems. This illustrates how Air Force decisionmakers can determine where to take the funding cut and what the impact would be on each weapon system. For example, the Air Force may decide it is better to decrease the B-1 AA by 1.6 percent than to reduce the AA for any of the other weapon systems.

| Model | Commodity | Readiness Measure |
|---|---|---|
| Aircraft Availability Model (AAM) | Peacetime Reparable Spares | Aircraft Availability |
| Aircraft Sustainability Model (ASM) | War Time Reparable Spares and Consumables | Aircraft Availability, Sortie Capability, S-ratings, Issue Effectiveness (for Consumables) |
| Equipment Prioritization | Equipment | Fill Rate, S-Ratings |
| Customer Oriented Leveling Technique (COLT) | Peacetime Expendable Items (DLA Managed) | Customer Wait Time, Expected Back Orders |

**Table 1. Tools to Link Readiness to Dollars**

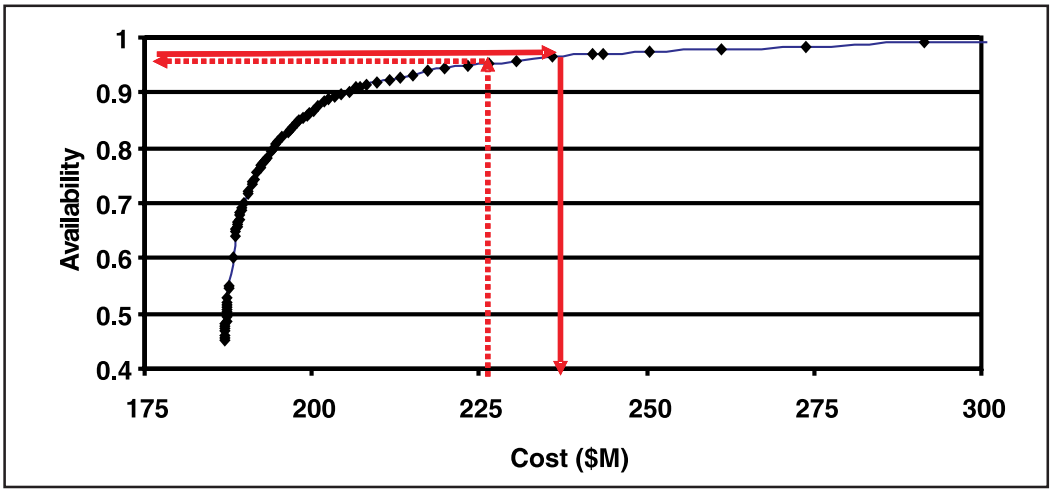


**Figure 1. Aircraft Availability Curve**

| Category | Tier 0 | Tier 1 | Tier 2 | Tier 3 | Tier 4 | Tier 5 | Tier 6 | Tier 7 | Tier 8 |
|---|---|---|---|---|---|---|---|---|---|
| **SPRS** | | | | | | | | | |
| All Use Codes | 100% | | | | | | | | |
| **Use Code A (Mobility)** | | | | | | | | | |
| FAD 1, 2, and 3 | | 90% | 90% | 90% | 92% | 94% | 96% | 98% | 100% |
| FAD 4 and 5 | | 80% | 90% | 90% | 92% | 94% | 96% | 98% | 100% |
| **Use Code C (Joint Use) and Use Code D (WRM)** | | | | | | | | | |
| FAD 1, 2, and 3 | | 90% | 90% | 90% | 92% | 94% | 96% | 98% | 100% |
| FAD 4 and 5 | | 80% | 90% | 90% | 92% | 94% | 96% | 98% | 100% |
| **Use Code B (Support Equipment)** | | | | | | | | | |
| FAD 1, 2, and 3 | | 80% | 90% | 90% | 92% | 94% | 96% | 98% | 100% |
| FAD 4 and 5 | | 65% | 80% | 90% | 92% | 94% | 96% | 98% | 100% |

**Table 2. Prioritization Tiers**

## Aircraft Sustainability Model

The Aircraft Sustainability Model (ASM) uses similar logic to the AAM to compute requirements for wartime spares. It computes the minimum cost mix of spares to support a squadron for a 30- or 60-day wartime (War Mobilization Plan [WMP] 5) requirement to a given direct support objective target (which is the number of available aircraft). For example, ASM can be used to compute and assess the spares needed for an F-16 readiness spares package (RSP) to support a 30-day WMP requirement to achieve a 75 percent AA at the end of day 30. ASM is also used to provide a squadron's Status of Resources and Training System S-ratings given a level of spares for an RSP.

ASM has a capability, albeit more limited than the AAM, to link readiness to dollars. ASM is geared for the squadron level—for example, what spares should be bought to increase F-16 availability for a given squadron. Work is ongoing to expand ASM's capability to conduct fleet-wide assessments. An ASM has been built to compute RSPs for expendable items. It provides the least-cost mix of consumable items to meet a given (85 percent) issue effectiveness target.

## Equipment Prioritization Model

Historically the Air Force has only received 40 to 50 percent of the funding required for support equipment buys. To make matters worse, there was no way to prioritize what portion of the equipment to buy with the available (less than full) funding. To correct this problem, the Air Force recently implemented the Logistics Management Institute and Air Force Logistics Management Agency-developed Equipment Prioritization Model in the Equipment Requirements System (ERS). This model uses marginal analysis to maximize the number of organizations' equipment fill rates, thereby maximizing the number of fully mission ready (S-rating) by force activity designator (FAD) and use code. Figure 3 illustrates how the Equipment Prioritization Model works.

The model prioritizes to increase the fill rate the most per

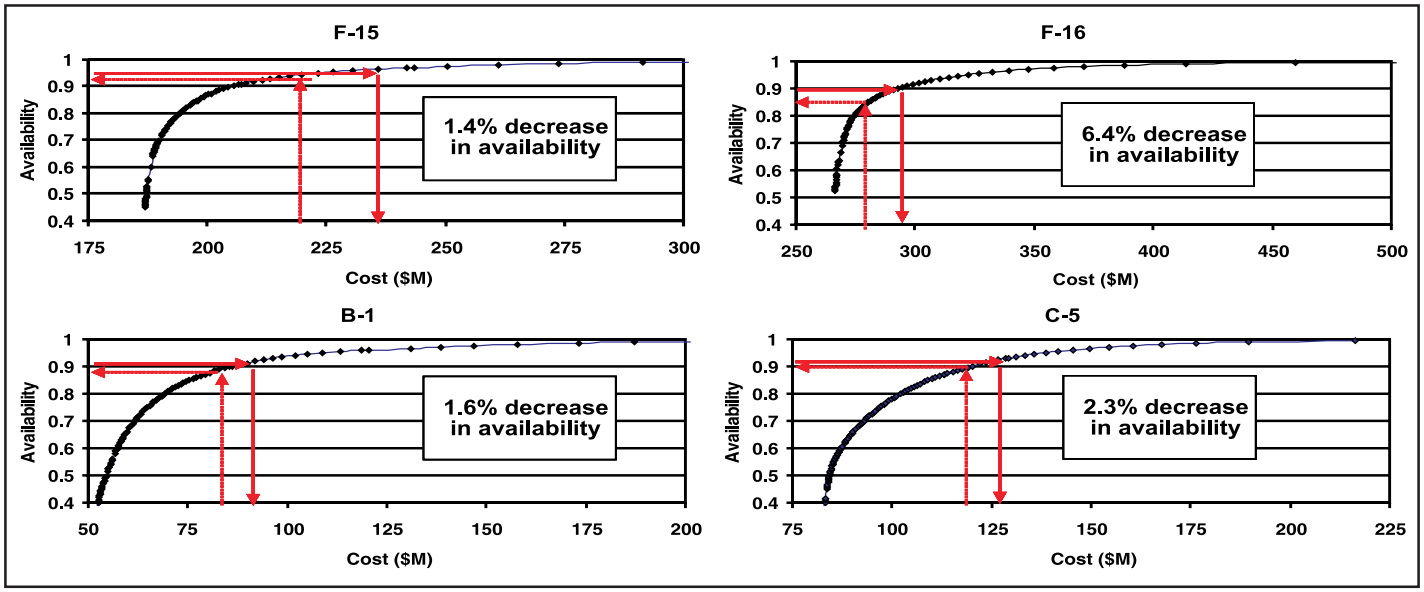


**Figure 2. AA Curves – Four Weapon Systems**

dollar. It prioritizes FAD 1, 2 and 3, use code A (mobility) organizations to a higher fill rate target than FAD 4 and 5 organizations. Use code C and D (war readiness materiel) is prioritized next and then use code B (peacetime). The model buys the items up to the fill rate target by *priority bucket* and then, like a waterfall, starts buying assets in the next bucket. Finally, when all of the buckets in a tier meet their fill rate targets, the model starts again at the top for the next tier. In this way, it still buys items for the lower priority units. The model optimizes the number of mission ready mobility and war reserve materiel organizations without neglecting the peacetime requirements. Table 2 shows the prioritization tiers.

The model can be, and is used to:

- Prioritize the equipment buy requirement
- Distribute and redistribute malpositioned equipment
- Prioritize repair
- Allocate operations and maintenance buy dollars

In the past, the Air Force allocated equipment funds to the major commands (MAJCOM) proportional to their gross requirements. If the Air Force received 50 percent funding, the MAJCOM with the greatest authorization total would get the largest share of the funds. For example, if Air Combat Command (ACC) had 70 percent of the gross authorizations, it would receive 70 percent of the available funds. With this is mind, we compared three alternative ways to allocate the available funds—the gross requirement, existing *holes* (net requirement), and the enterprise method (using the Air Force prioritization model).

Figure 4 provides an example comparing the gross requirement baseline to allocating using the net requirement.

In our simple example, Case 1 has 10 authorized and 9 in-use (on-hand) so it needs 1 item. Case 2 has 8 authorized and 4 in-use, so it has 4 holes. The gross authorization method would fund Case 1, since it has the most authorizations, whereas the net requirement would fund Case 2 since it has the most shortages. The gross requirement does not consider the asset position, so fully mission capable organizations could still be allocated funds over units that are not fully mission capable (rated S-2 or lower).

Next we compared the holes versus the enterprise allocation method (see Figure 5).

Case 1 has 1,014 authorized and 108 holes for a fill rate of 89 percent. The organization is a FAD 4, use code B (peacetime) priority. Case 2 has 400 authorized and 92 holes for a 77 percent fill rate for a higher priority requirement (FAD 2, use code A, mobility). The Holes allocation method would allocate to the

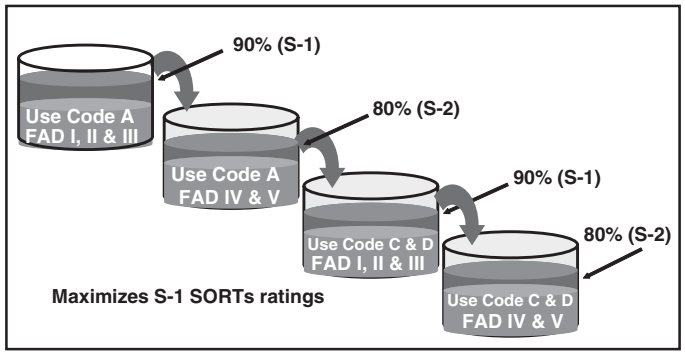


**Figure 3. Equipment Prioritization Waterfall**

| |
|---|
| **Case 1**<br>Authorized 10, In Use 9 (1 Hole) |
| **Case 2**<br>Authorized 8, In Use 4 (4 Holes) |
| Gross would fund Case 1 before Case 2 |
| ***Gross allocation does not consider asset position*** |

**Figure 4. Example: Authorized (Gross Requirement) Versus Holes (Net Requirement)**

| |
|---|
| **Case 1**<br>Authorized: 1,014; Holes: 106; Fill Rate: 89% FAD IV Use Code B |
| **Case 2**<br>Authorized: 400; Holes: 92; Fill Rate: 77% FAD II Use Code A |
| Holes would allocate to lower priority need (Org 1) before FAD II Use Code A |
| ***Holes method does not consider mission importance*** |

**Figure 5. Holes Versus Enterprise**

lower priority need (Case 1). The net requirement does not consider the importance of the shortage to the mission.

Figure 6 shows the differences in the allocation based on actual fiscal year 2006 (FY06) funding and asset position. Note the enterprise method allocates more to Air Mobility Command and Pacific Air Forces since they have relatively more net requirement (holes) and more high-priority shortages.

Figure 7 displays the number of S-1 rated (90 percent fill rate or higher) organizations by MAJCOM that could result from a funding allocation (using the Air Force prioritization model to optimally determine what to buy with the allocated funds). The starting position is the number for S-1 organizations with existing (as of FY06) assets before any buy funds are allocated. With the gross requirement, some MAJCOMs cannot get all of their organizations to S-1 (at least to the 90 percent fill rate). The gross requirement does not consider shortages, so funds are not allocated to some MAJCOMs that have relatively low fill rates. With the net holes allocation method, all MAJCOMs expect that Air Force Materiel Command (AFMC) can have all of their organizations achieve an S-1 rating. With the enterprise method, all MAJCOMs can have all of their organizations achieve the S-1 rating.

The Air Force has approved using the enterprise method to allocate available equipment buy funding and is programming that capability into the ERS. Note some equipment buy funds are allocated by program element code (PEC) or some other program (modernization replacement) constraint. ERS will allocate funds to fit the appropriate (PEC or program) constraint. That is, if a certain amount of funds is allocated to a certain PEC, then ERS will optimally allocate to those MAJCOMs within that PEC.

## Customer-Oriented Leveling Technique

The Customer-Oriented Leveling Technique (COLT) sets consumable (Defense Logistics Agency [DLA]-managed) levels for the Air Force depot and bases to minimize customer wait time (CWT) constrained by available dollars. It relates General Support Division (GSD) stock fund dollars to base-level (time-weighted) expected back orders (EBO) and CWT. In this way managers can relate available dollars to base-level performance. COLT can:

- Link to the DLA wholesale level to reduce the total cost of DLA and base levels to reach a given base CWT target
- Determine how to allocate GSD funds to equalize or target support by MAJCOM, base, or weapon system (for example, provide higher levels of support for contingency bases)
- Identify funding tradeoffs for unexpected needs (in the year of funds execution)
- Determine the next item to buy to decrease CWT from an Air Force perspective

### Linking Base and DLA Levels

Currently DLA sets (wholesale) levels to achieve an 85 percent supply availability (SA) (off-the-DLA-shelf fill rate) target. COLT then uses that expected (depot delay) DLA performance with the 85 percent SA target to set base levels. For example, if the DLA level for an item is relatively high and therefore there is little expected depot delay (most requests are filled immediately), then

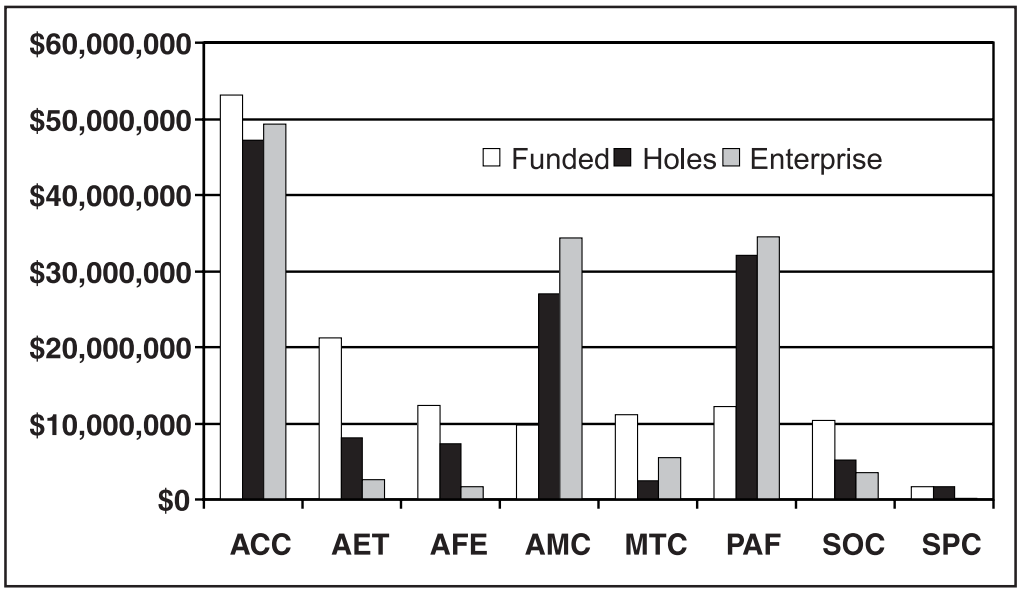


Figure 6. Funding Allocation by MAJCOM

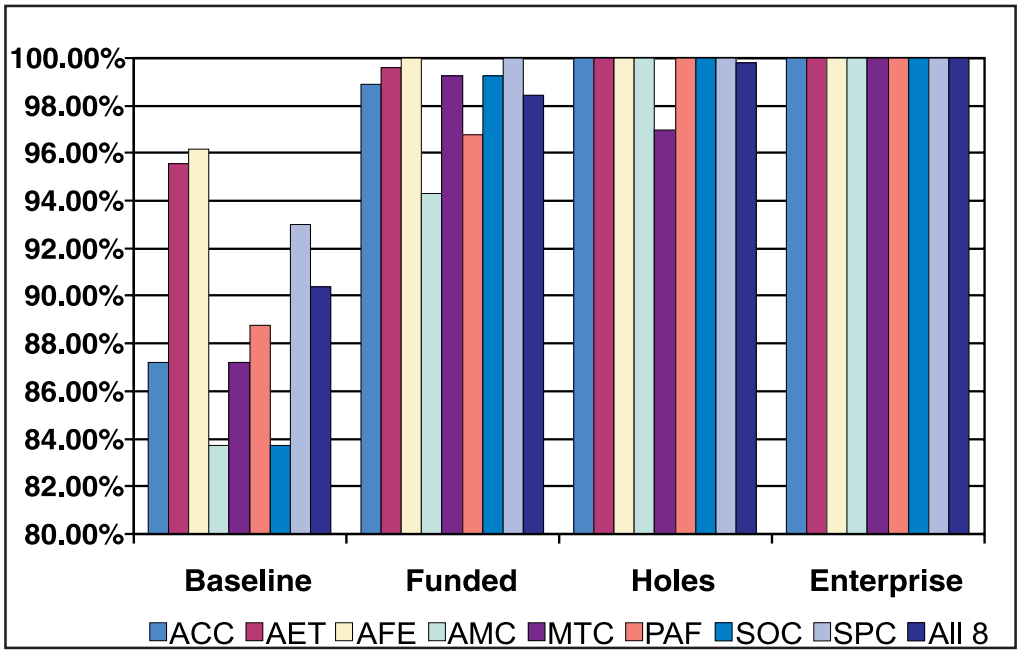


Figure 7. Percentage of SORTS 1 Organizations

COLT would stock less at the base. If DLA increased its SA target, COLT might reduce its base level (see Figure 8).

The question is what level of DLA SA target will result in the least overall (DLA and base) inventory investment—combined level. The Air Force is working with DLA to explore enterprise models (not just COLT) that address this question.[1]

### Equalize or Target Support

COLT provides the opportunity to equalize or target support across the enterprise. The Standard Base Supply System (SBSS) levels (and SBSS levels of funding) do not equalize support. Table 3 provides an example for two C-5 bases, Dover and Travis AFB. COLT is constrained by the amount of funds that SBSS would spend at a base (COLT is run to be cost neutral at a base). Using the SBSS obligations, COLT provides unequal support—an expected CWT (ECWT) of .83 days at Dover and .68 days at Travis.

By changing the funding allocated to each base (without changing the overall obligation funding), COLT can provide equal support—.78 days. However, to do so requires Dover to receive some ($.95M) obligation funds from Travis. The Air Force can use COLT to allocate available funding to provide equal COLT performance (see Figure 9).

Without changing the Air Force obligation total, COLT can better allocate funds to various bases to equalize support.

COLT can also optimize CWT across the enterprise. In fact, the Air Force does so for the air logistics centers (ALC). Figure 10 shows how the Air Force sets COLT levels for the three ALCs. AFMC runs COLT for all three ALCs as if there were a single ALC. COLT then uses overall available ALC funding to set levels to minimize CWT across the ALCs. The result is the lowest overall CWT, but not equal CWT for each ALC.

To illustrate further, refer back to Table 3. The middle row shows the *merged* results for Dover and Travis. Running COLT merging the two bases into *one big base* results in the minimal overall CWT of .75 days. In summary, the Air Force can use COLT as a tool to allocate GSD stock fund dollars to optimize the enterprise CWT, to equalize support across the bases or to target support to various bases. Basically COLT provides the opportunity to take an

| Run | Base | Total Obligations | COLT ECWT | DL ECWT |
|---|---|---|---|---|
| Baseline | Dover | $8.77M | 0.82 | 2.18 |
| Baseline | Travis | $8.66M | 0.68 | 2.33 |
| Merged | Both | $17.43M | 0.75 | 2.25 |
| Match CWT | Dover | $9.73M | 0.78 | 2.18 |
| Match CWT | Travis | $7.70M | 0.78 | 2.33 |

**Table 3. C-5 Example**

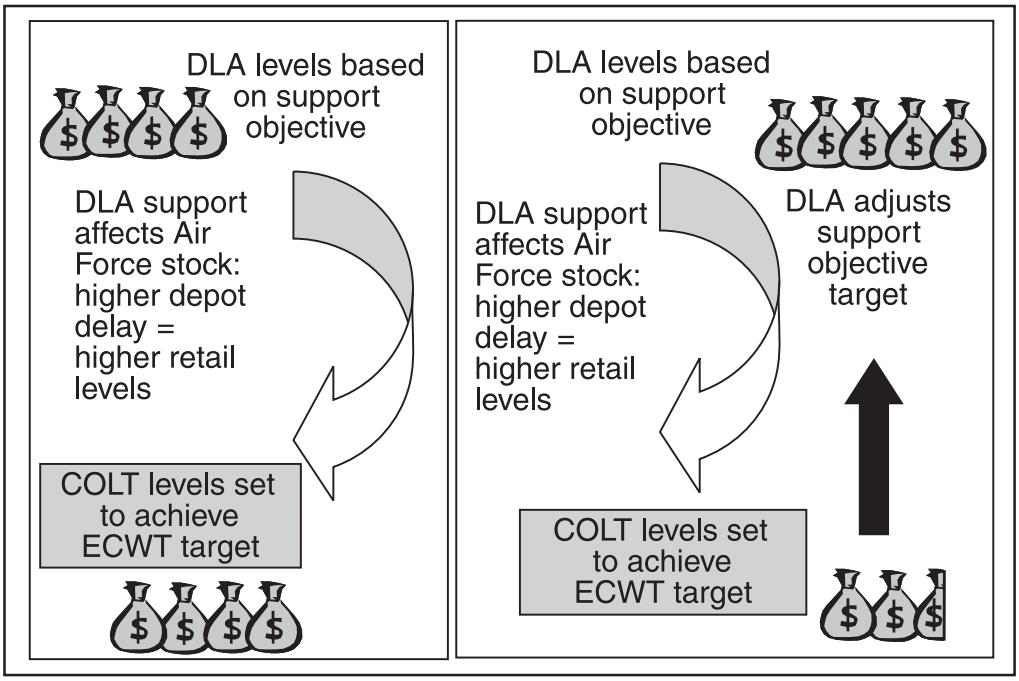


**Figure 8. DLA COLT-Linked Levels**

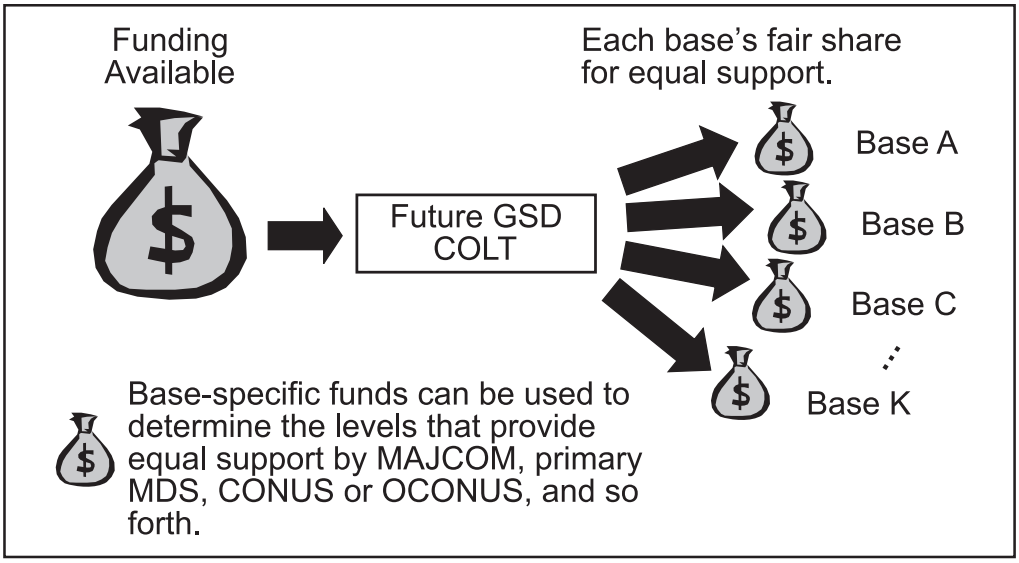


**Figure 9. Optimal Merged Levels**

enterprise view (instead of a base view) for stock fund management and level setting.

### Funding Tradeoffs

COLT can provide stock fund managers with the information they need to make funding tradeoffs.

As Figure 10 shows, COLT can optimally ration the amount of funds left after funds are taken for some other higher priority use. For example, if the Air Force needed some amount of funds for a new stockage policy initiative, COLT can identify the impact on ECWT (and EBOs) of taking money from selected bases, or from each base Air Force-wide.

For example, the Air Force recently set a policy to replace mobile bench stocks with consumable readiness spares packages (CRSP). CRSPs require stock fund dollars to implement and the Air Force wanted to implement CRSPs for the Aerospace Expeditionary Force (AEF) 5/6 rotation. The initial creation of the CRSP required an investment of stock fund dollars. COLT can identify prospective tradeoffs for funding. In Table 4 we show three possible options to obtain this funding:

- Taking it all from the home station
- Taking it from the ACC bases using the same mission design series (MDS)
- Taking it from all active duty bases using the same MDS

As expected, when taking all the funds from a single base, the impact (in ECWT) is relatively large on that base. Spreading out the costs to multiple bases (based on the number of mission squadrons) reduces the impact to any one base and overall. Estimates of the four CRSPs needed for the next AEF rotation are $800K.

### Buy Prioritization

Just as COLT can be used to allocate funds, it can also be used to execute (determine what items to buy with) those funds. In fact, we've developed a tool—the Funds Requirement Analysis Tool (FRAT)—that optimally determines the next item to buy if there are insufficient funds to buy the total requirement. FRAT currently is a base-level tool, it prioritizes all the shortages at a base and, given a level of funding, it will create requisition transactions to buy the items that result in the minimum CWT. (Note, this does not change the COLT levels—the requirement—rather it determines what portion of that requirement to buy.)

COLT also provides the opportunity to determine what DLA-managed items to buy next for a group of bases, a MAJCOM, a weapon system, or Air Force-wide. For example, rather than the next item to buy for the F-15 at Langley AFB, what item should the Air Force buy to reduce F-15 CWT Air Force-wide?

## Summary

The Air Force now has tools that relate dollars to base-level supply performance and can be used to trade off readiness against dollars. These tools are currently being used to optimally

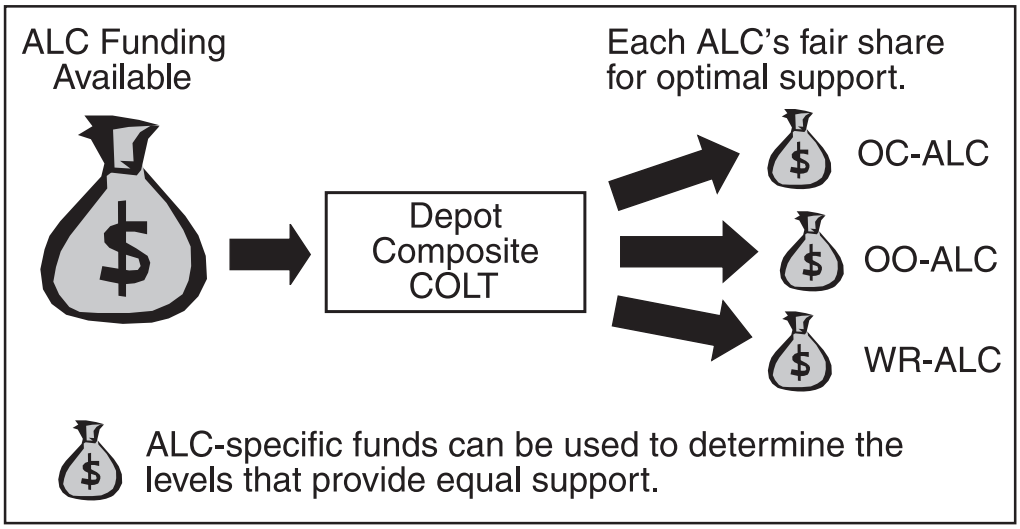


**Figure 10. Optimized Levels Current Depot COLT**

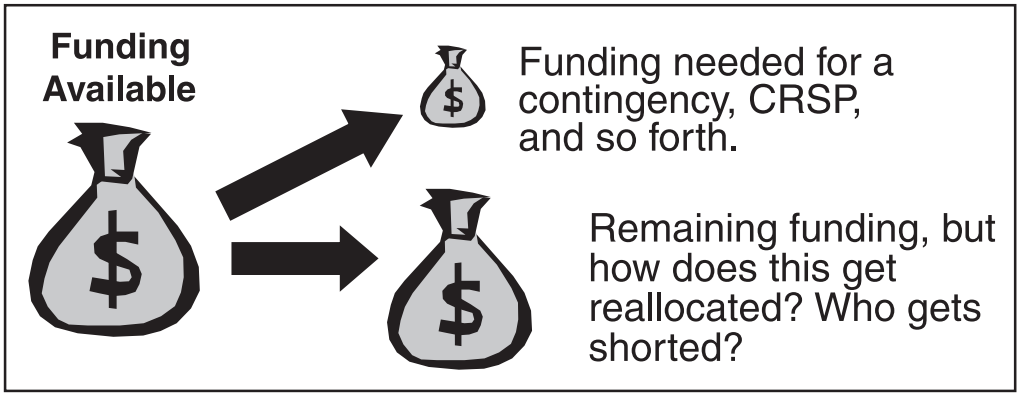


**Figure 11. Sourcing Shortages**

| Option | Bases | Levels Change | ECWT Change |
|---|---|---|---|
| Home Station | Total | 22.3K ( 3.2%) | +0.067 (8.2%) |
| | Mt Home (100%) | 22.3K ( 3.2%) | +0.067 (8.2%) |
| ACC | Total | 21.3K ( 1.4%) | +0.025 (3.0%) |
| | Mt Home (33%) | 6.4K ( 0.9%) | +0.020 (2.4%) |
| | S-J (67%) | 14.9K ( 1.8%) | +0.029 (3.5%) |
| Active | Total | 18.7K ( 0.5%) | +0.012 (0.9%) |
| | Mt Home (17%) | 2.8K ( 0.4%) | +0.009 (1.1%) |
| | S-J (33%) | 7.1K ( 0.8%) | +0.013 (1.6%) |
| | Elmendorf (17%) | 4.1K ( 0.3%) | +0.008 (0.4%) |
| | Lakenheath (33%) | 4.8K ( 0.6%) | +0.019 (1.2%) |

**Table 4. F-15 CRSP Example**

determine what to buy, repair, and distribute with the available dollars. As the Air Force moves to enterprise management organization and systems, these tools, and tools like them, will become more important.

Air Force managers have the information they need to measure the impact of funding cuts on various commodities (spares, equipment, and consumables) to base-level readiness. What is still needed are tools to trade off one commodity for another or one resource (people, fuel, ammunition, spares, and so forth) for another. With the formation of the Global Logistics Support Center, an organization that will need and use the existing models to make enterprise decisions, we anticipate the development of the next generation of models to meet the information needs to manage multiple resources across the enterprise.

### Notes

1. An 85 percent SA does not mean every item will have an 85 percent fill rate. Rather, it means that, overall, DLA will satisfy 85 percent of item requests from off-the-shelf stock. Some (relatively inexpensive) items will have fill rates higher than 85 percent and some lower. COLT minimizes CWT, so COLT will stock relatively less of an item with little depot delay.


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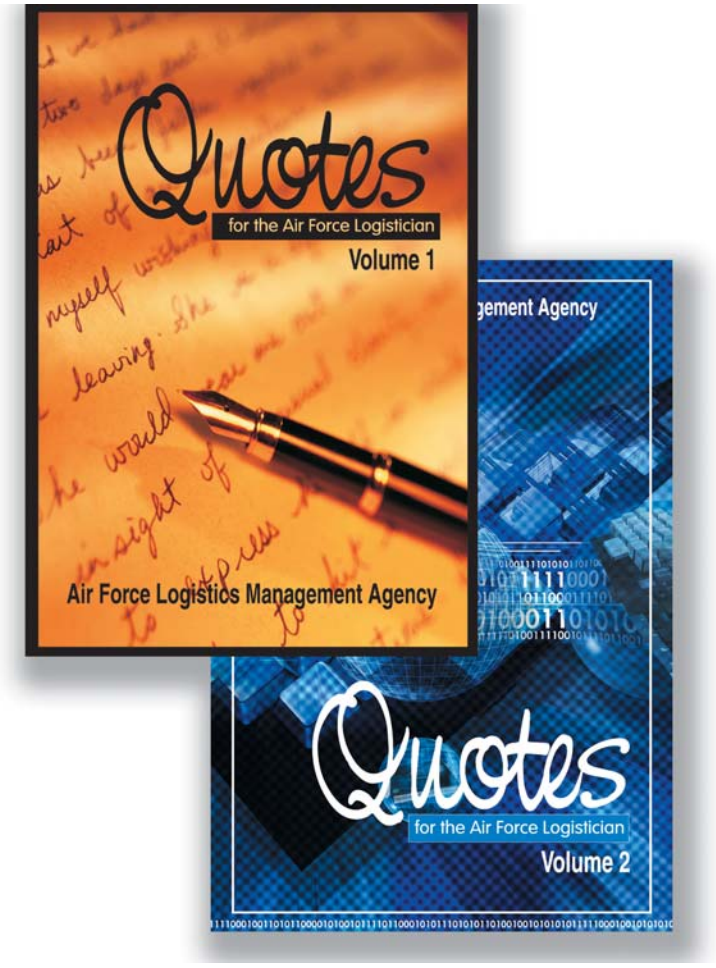



Why a set of quotations for Air Force Logisticians? An obvious answer is there isn't one. But that's not the only reason, and it's certainly not the most important reason. The primary reason for producing this set was to provide a teaching resource that can be used in classrooms, education, training, and mentoring programs for Air Force logisticians. It is a tool that can be used by instructors, teachers, managers, leaders, and students. It is also a tool that can be used in research settings and a resource that should stimulate comment and criticism within educational and mentoring settings. Copies of the set are provided free of charge to any Air Force logistician, educational institution, teacher, instructor, commander, or manager.

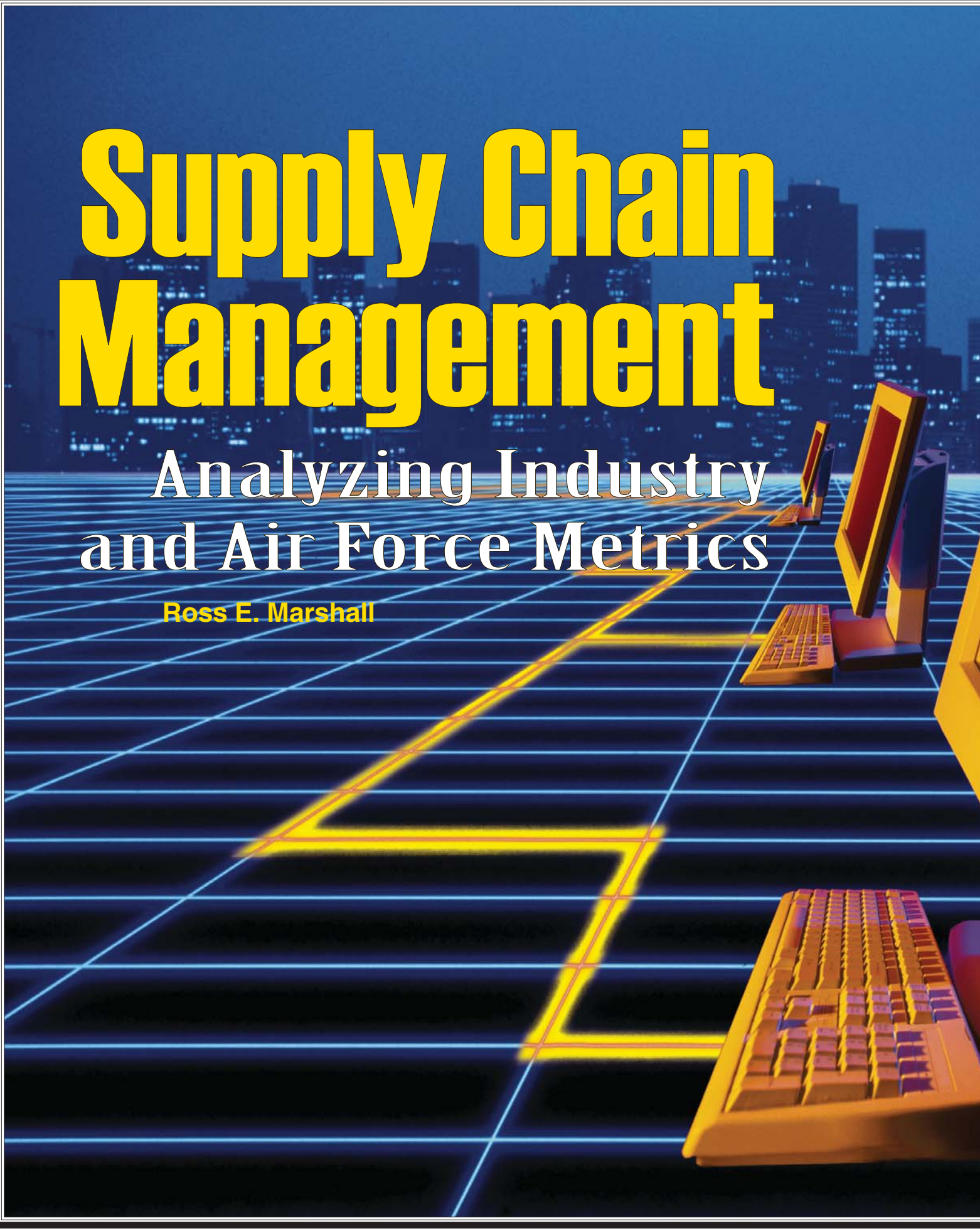
**AFLMA**

**Generating Transformation Solutions Today; Focusing the Logistics Enterprise of the Future**

# 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**

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

**Table 3. Tactical and Operational Performance Measures**

| | Financial Indicators | Productivity Indicators | Quality Indicators | Response Time Indicators |
|---|---|---|---|---|
| **Customer Response** | - Total response time<br>- Cost per customer | - Customer orders per person hour | - Order entry accuracy<br>- Communication accuracy<br>- Invoice accuracy | - Order entry time<br>- Order process time |
| **Inventory Planning and Management** | - Total inventory cost<br>- Inventory cost per SKU | - Inventory turns<br>- SKU's per planner | - Fill rate<br>- Forecast accuracy | |
| **Supply** | - Total supply cost<br>- Supply cost per purchase order | - Purchase orders per person<br>- SKU's per buyer | - Perfect purchase order % | - Purchase order cycle time |
| **Transportation** | - Total Transportation cost<br>- Transportation cost per mile | - Stops per route<br>- Fleet yield<br>- Container capacity utilization | - On-time arrival %<br>- Damage %<br>- Miles between accidents | - In-transit time |
| **Warehousing** | - Total warehousing cost<br>- Warehousing cost per piece<br>- Warehousing cost per square foot | - Units per person<br>- Storage density | - Inventory accuracy<br>- Picking accuracy<br>- Shipping accuracy<br>- Damage %<br>- Hours between accidents | - Warehouse order cycle time |
| **Total Logistics** | - Logistics expenses<br>- Logistics profit<br>- Logistics asset value<br>- Logistics asset turnover<br>- Logistics capital charges<br>- Total logistics cost<br>- Logistics cost-sales ratio<br>- Return on logistics asset<br>- 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<br>- Fill rates<br>- Perfect order fulfillment | - On-time delivery<br>- Manufacturing schedule attainment<br>- Warehouse on-time shipment<br>- Transportation on-time delivery<br>- Forecast accuracy<br>- Supplier match %<br>- Customer match % | - Customer orders delivered on time per total number orders<br>- Customer lines delivered on time<br>- Order shipping accuracy<br>- Other metrics as determined by department |
| **Supply Chain Responsiveness** | - Order fulfillment lead time | - Order receipt to order entry<br>- Order entry to order shipment<br>- Order shipment to order receipt | - Delivery date of each order<br>- Other metrics as determined by department |
| **Supply Chain Flexibility** | - Supply chain response time<br>- Production flexibility | - Source lead time<br>- Order fulfillment<br>- Lead time for order items<br>- Days required to change labor, material, or capacity | - Lead time for constraint items<br>- Manufacturing cycle times<br>- Order fulfillment times<br>- Other metrics as determined by department |
| **Supply Chain Cost** | - Cost of goods<br>- Total SCM costs<br>- Selling, general, and administrative costs<br>- Warranty and return costs | - Direct, indirect, material cost<br>- Order manufacturing cost<br>- Material acquisition costs<br>- Information technology cost<br>- Inventory carry cost<br>- Returns cost | - Cost centers<br>- Customer service cost<br>- Warehouse cost<br>- Transportation cost<br>- Cost to support supply chain<br>- Other metrics as determined by department |
| **Supply Chain Asset Management** | - Cash to cash cycle time<br>- Inventory days of supply<br>- Asset turns | - Days payable<br>- Days WIP<br>- Days inventory<br>- Working capital fixed assets | - Accounts payable<br>- Material costs<br>- Accounts receivable<br>- Other metrics as determined by department |
| **Profitability** | - Gross margin<br>- Operating income<br>- Net income | - Revenue<br>- Cost of goods<br>- Taxes | - Use level 2 metrics<br>- Other metrics as determined by department |
| **Effectiveness of Return** | - Return on assets | - Revenue<br>- Cost of goods<br>- Taxes | - Net operating income<br>- 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**

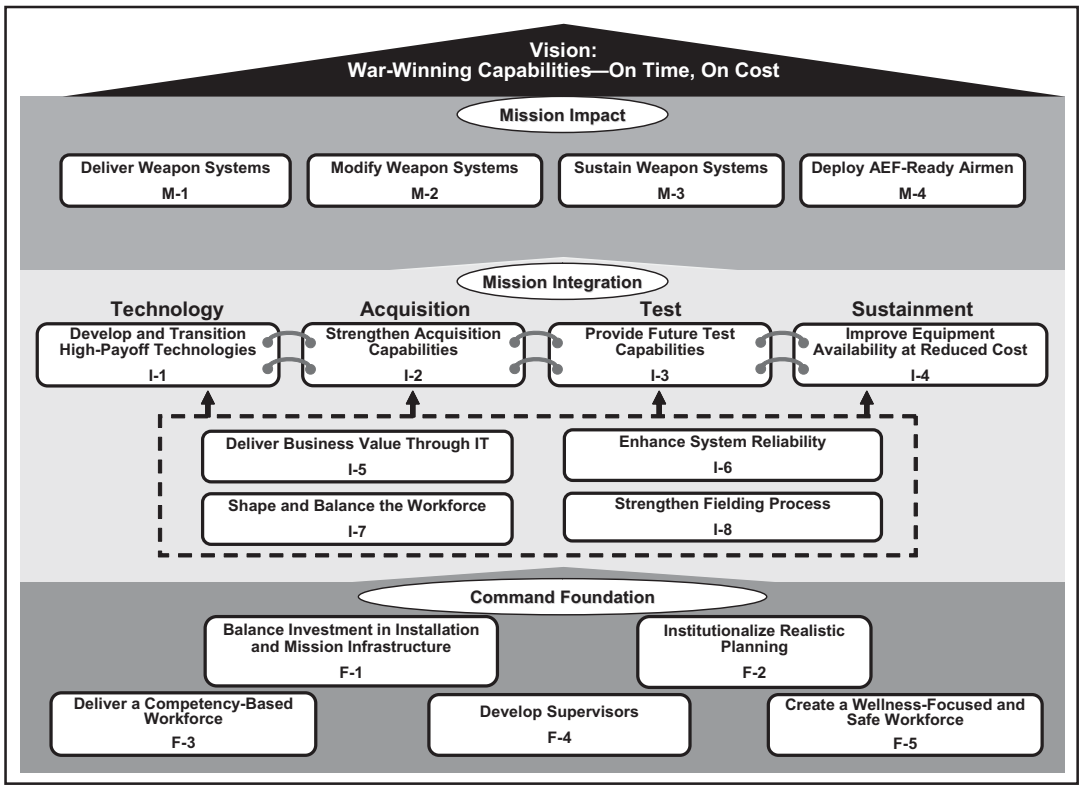



**Figure 1. AFMC Balanced Scorecard**

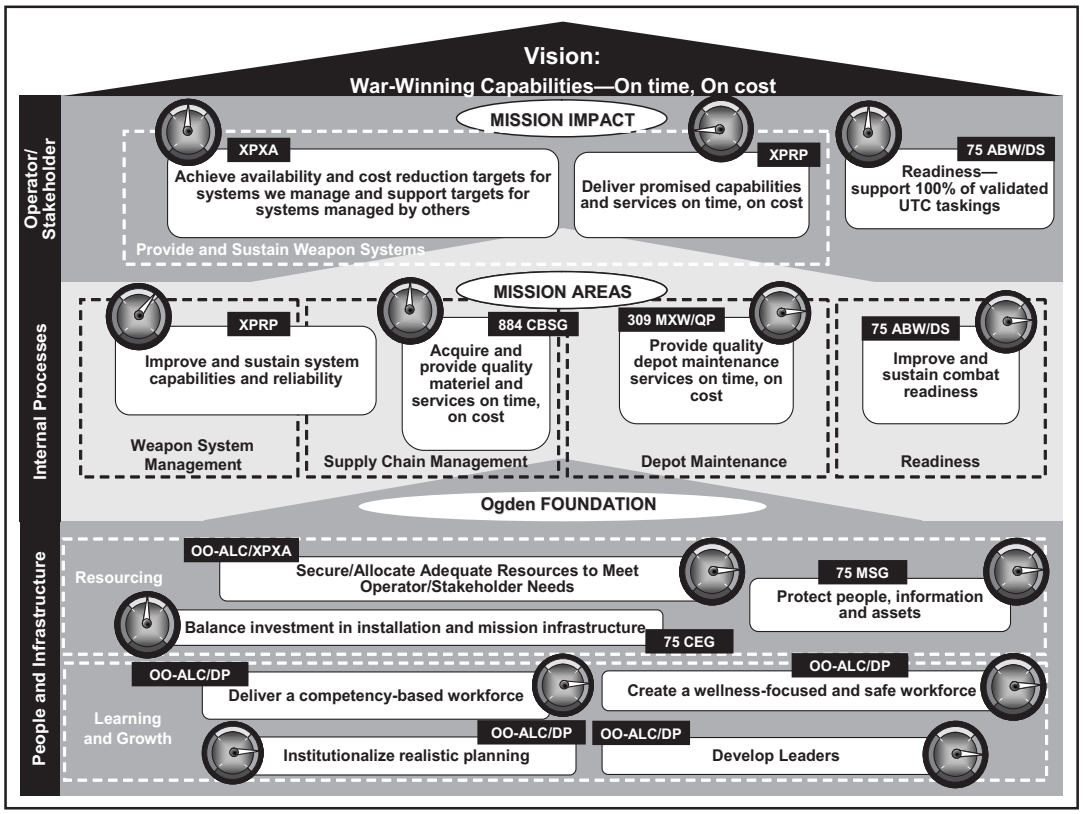



**Figure 2. Ogden Air Logistic Center Balanced Scorecard**

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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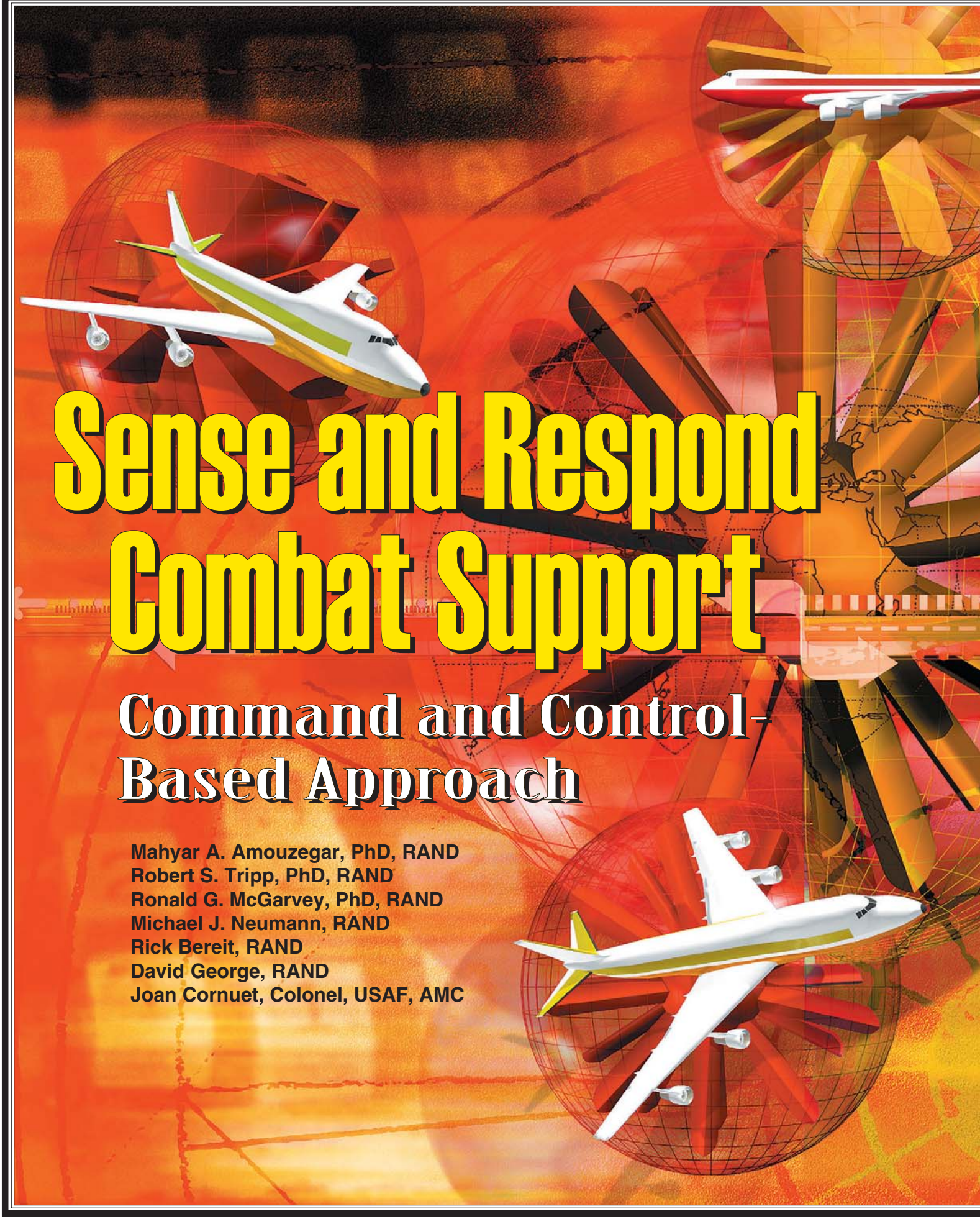
## Concentration and Logistics

To win in battle we must concentrate combat power in time and space. Strategy and tactics are concerned with the questions of what time and what place; these are the ends, not the means. The means of victory is concentration and that process is our focus here. There are only four key factors to think about if we seek success in concentration. This is not a simple task. Although few in number, their impact, dynamics and interdependencies are hard to grasp. This is a problem as much of perspective as of substance. It concerns the way we think, as much as what we are looking at. The factors are not functions, objects or even processes. They are best regarded as conditions representing the nature of what we are dealing with in seeking concentration. They are as follows. Logistics is not independent. It exists only as one half of a partnership needed to achieve concentration. Why is understanding this so important? Logistics governs the tempo and power of operations. For us, and for our enemy. We have to think about the partnership of operations and logistics because it is a target. A target for us, and for our enemy. Like any target, we need to fully understand its importance, vulnerabilities and critical elements to make sure we know what to defend and what to attack. All military commanders, at all levels of command, rely on the success of this partnership. How well they understand it will make a big difference concerning how well it works for them and how well they work for it.

Wing Commander David J. Foster, RAF



# Sense and Respond Combat Support

## Command and Control-Based Approach

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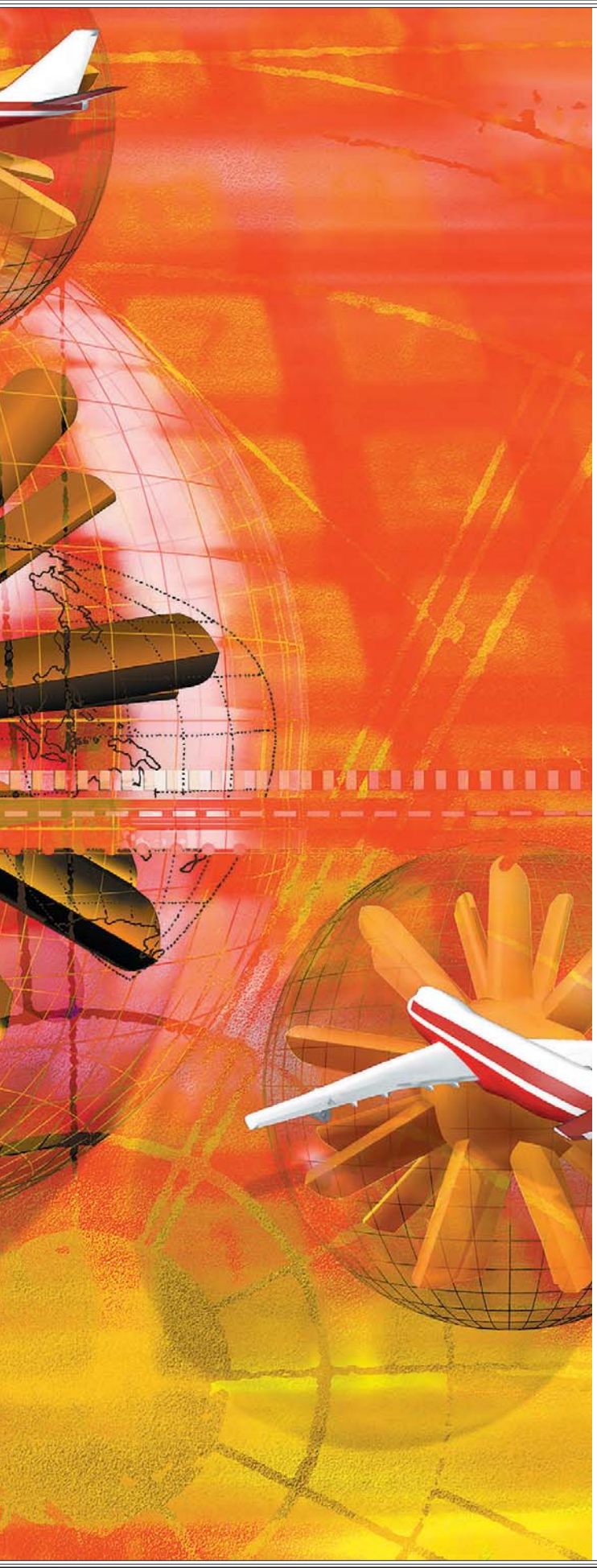

*Nothing is too wonderful to be true.*

**—Kay Redfield Jamison**

## Introduction

Modern warfare has evolved from conflicts dominated by massed manpower, the so-called *first generation* of modern (post-Westphalian) war, to a warfare that has integrated political, social, economical, and technological issues. A recent National Defense University study maps this evolution from first generation warfare, culminating in the Napoleonic Wars, to second-generation wars dominated by firepower. Third generation war was the new maneuver tactics developed by the Germans in World War II. Unconventional enemy, in terms of insurgencies and counter-insurgencies, dominates the fourth generation.[1] In fourth generation warfare, the nation-states no longer hold a monopoly on weapon systems and may be involved in long conflicts with stateless enemies. Although insurgency is not new (dating back over two millennium)[2] the political features of insurgency have become a predominate character of modern insurgents. Advances in information technology also have had a revolutionary impact in these types of warfare.

A constant throughout the history of warfare has been the central role of logistics in the successful prosecution of any conflict. However, the 20th century logistical system lagged behind rapidly changing technology and tremendous efforts were put into the scientific study of logistics. Most of the early supply systems operated on a *push* concept rather than in response to actual needs and changes. It was thought that having an abundance of resources in theater ensured that combat support (CS) elements would be able to provide everything needed to achieve the desired operational effects. In practice, the presence of *mountains of supplies* did not always ensure warfighters' demands were met. In fact, the backlog of war materiel congested the CS system because of inefficiencies in the transportation system and the prioritization processes. It was evident that a more comprehensive capability was needed for matching CS assets to warfighter needs. In the past, prediction and responsiveness have been viewed as competing concepts. However, in this article, we argue that both are necessary and can be integrated within a command and control system to create military sense and respond capabilities.

Military logistics planning grew even more difficult with the collapse of the Soviet Union and the dissolution of the associated threat to United States interests in Europe. The shift in global power exposed the inefficiencies of legacy CS systems that had been hidden under a static and focused, albeit immense, threat. The geopolitical divide that once defined US military policy was replaced by a temporary rise of regional hegemons, which in turn slowly evolved (and continues to evolve) into a geopolitical environment that is defined not only by regional powers, but also by nontraditional security threats. The uncertainty associated with planning for military operations was thus extended to include uncertainty about the *locations* and *purpose* of operations.

# Article Highlights

**Unless significant improvements are made to last-mile transportation in theater, S&RL will have only a limited effect on operations. A robust, assured transportation network is the foundation on which expeditionary operations, as well as S&RL implementation, rests. The complete integration of transportation into the CSC2 architecture is essential.**

Most of the early supply systems operated on a *push* concept rather than in response to actual needs and changes. It was thought that having an abundance of resources in theater ensured that combat support (CS) elements would be able to provide everything needed to achieve the desired operational effects. In practice, the presence of *mountains of supplies* did not always ensure warfighters' demands were met. In fact, the backlog of war materiel congested the CS system because of inefficiencies in the transportation system and the prioritization processes. It was evident that a more comprehensive capability was needed for matching CS assets to warfighter needs. In the past, prediction and responsiveness have been viewed as competing concepts. In "Sense and Respond Combat Support: Command and Control-Based Approach," the authors argue that both are necessary and can be integrated within a command and control system to create military sense and respond capabilities. In the course of the article they outline how this may be accomplished.

The authors conclude by noting that significant challenges remain before the Air Force can realize a sense and respond combat support (S&RCS) capability. To develop effective tools that accurately link logistics levels and rates to

The Air Force, in response to the changing military environment, designed and developed a transformational construct called the Air and Space Expeditionary Force (AEF).[3] The implementation of the AEF changed the Air Force's mindset from a threat-based, forward-deployed force designed to fight the Cold War to a primarily continental United States-positioned, rotational, and effects-based force able to rapidly respond to a variety of threats while accommodating a high operations tempo in the face of the uncertainties inherent in today's contingency environment. The AEF prompted a fundamental rethinking and restructuring of logistics. This modern perspective of CS does not merely consider maintenance, supply, and transportation but is expanded to include civil engineering, services (billeting and messing), force protection, basing, and command, control, communications, and computers.

The shift to a more expeditionary force compelled a movement within the Air Force toward a capability called agile combat support (ACS). One of the Air Force's six distinctive capabilities, ACS includes actions taken to create, effectively deploy, and sustain US military power anywhere—at our initiative, speed, and tempo. ACS capabilities include provision for and protection of air and space personnel, assets, and capabilities throughout the full range of military operations.[4] ACS ensures that responsive expeditionary support for right-sized forces used in Joint operations is achievable within resource constraints. ACS began to emerge as a concept in a series of Air Force and RAND publications,[5] which detailed both micro- and macro-level analyses. One of the key conclusions of these studies has been the need for a robust and responsive combat support command and control (CSC2) architecture.

## Combat Support Command and Control: Key to Agile Combat Support and Essential for Sense and Respond Combat Support

Command and control (C2), although often associated with operations, is also a fundamental requirement for effective CS. As warfighting forces become more flexible in operational tasking, the support system must adapt to become equally flexible. The C2 of modern CS assets must be woven thoroughly with operational events—from planning through deployment, employment, retasking, and reconstitution. Additionally, CS goals and objectives must be increasingly linked directly to operational goals and objectives. The traditional distinction between *operations* and *CS* loses relevance in such an environment. CS activities need to be linked to operational tasking with metrics that have relevance to both warfighter and logistician.

In essence, CSC2 sets a framework for the transformation of traditional logistics support into an ACS capability. CSC2 should provide the capabilities to

- Develop plans that take operational scenarios and requirements, and couple them with the CS process performance and resource levels allocated to plan execution to project operational capabilities. This translation of CS performance into operational capabilities requires modeling technology and predicting CS performance.

- Establish control parameters for the CS process performance and resource levels that are needed to achieve the required operational capabilities.
- Determine a feasible plan that incorporates CS and operational realities.
- Execute the plan and track performance against calculated control parameters.
- Signal all appropriate echelons and process owners when performance parameters are out of control.
- Facilitate the development of operational or CS get-well plans to get the processes back in control or develop new ones, given the realities of current performances.

CSC2 is not simply an information system. Rather, it sits on top of functional logistics systems and uses information from them to translate CS process performance and resource levels into operational performance metrics. It also uses information from logistics information systems to track the parameters necessary to control performance. It includes the battlespace management process of planning, directing, coordinating, and controlling forces and operations. Command and control involves the integration of the systems, procedures, organizational structures, personnel, equipment, facilities, information, and communications that enable a commander to exercise C2 across the range of military operations.[6] Previous studies built on this definition of C2 to define CS execution, planning, and control to include the functions of planning, directing, coordinating, and controlling CS resources to meet operational objectives.[7]

The objective of this transformed CSC2 architecture is to integrate operational and CS planning in a closed-loop environment, providing feedback on performance and resources. The new CSC2 components significantly improve planning and control processes, including

- Planning and forecasting (prediction)
  - Joint analysis and planning of CS and operations
  - Determining feasibility, establishing control parameters
- Controlling
  - Monitoring planned versus actual execution—a feedback loop process allowing for tracking, correction, and replanning when parameters are out of control
- Responsiveness
  - Quick pipelines and the ability to respond quickly to change

One of the key elements of planning and execution is the concept of an effective feedback loop that specifies how well the system is expected to perform during planning, and contrasts these expectations with observations of the system performance realized during execution. If actual performance deviates significantly from planned performance, the CSC2 system warns the appropriate CS processes that their performance may jeopardize operational objectives. The system must be able to differentiate small discrepancies that do not warrant C2 notification from substantial ones that might compromise future operations. This requires the identification of *tolerance limits* for all parameters, which is heavily dependent on improved prediction capabilities. This feedback loop process identifies when the CS plan and infrastructure need to be reconfigured to meet dynamic operational requirements and notifies the logistics and installations support planners to take action, during both planning and execution.

# Article Highlights

operational effects, the modern Expeditionary Combat Support System must be developed and tested in conjunction with operations and intelligence systems.

Technologies associated with S&RL are still in an early stage of development and may not be fielded for a number of years. Ultimately, the Expeditionary Combat Support System should relate how combat support performance and resource levels affect operations, but current theoretical understanding limits these relationships. The Air Force does not appear to be lagging behind industry in the implementation of S&RL capabilities but should continue to make judicious investments in this field.

The Air Force has recently established the Global Logistics Support Center as the single agent responsible for end-to-end supply chain management. The creation of this entity holds promise for the achievement of S&RCS capabilities. The Global Logistics Support Center should be in a position to advocate for future improvements while exploring ways to provide the capability utilizing current systems.

### Article Acronyms

**ABM** – Agent-Based Models
**ACS** – Agile Combat Support
**AEF** – Air and Space Expeditionary Force
**C2** – Command and Control
**CoAX** – Coalition Agent Experiment
**CS** – Combat Support
**CSC2** – Combat Support Command and Control
**DARPA** – Defense Advanced Research Projects Agency
**DoD** – Department of Defense
**ECSS** – Expeditionary Combat Support System
**IT** – Information Technology
**OFT** – Office of Force Transformation
**RFID** – Radio Frequency Identification
**S&R** – Sense and Respond
**S&RCS** – Sense and Respond Combat Support
**S&RL** – Sense and Respond Logistics

A robust CSC2 construct will enable a sense and respond capability that integrates operational and CS planning in a closed-loop environment, providing feedback on performance and resources. Figure 1 illustrates this concept in a process template that can be applied through all phases of an operation from readiness, planning, deployment, employment, and sustainment to redeployment and reconstitution.

This comprehensive transformation of CSC2 doctrine and capabilities blends the benefits of continuously updated analytical prediction with the ongoing monitoring of CS systems, which, given a robust transportation capability, enables the rapid response necessary to produce a sense and respond combat support (S&RCS) model appropriate for military operations in the 21st century.

## Defining Sense and Respond Combat Support

The emphasis on the ability to *respond* quickly and appropriately through the command and control function to the broader areas constituting CS is how this article differentiates S&RCS from the traditional definition of sense and respond logistics (S&RL). Implementing S&RL concepts and technologies through the CSC2 architecture is the way to achieve an S&RCS capability.

In an often volatile commercial market, the manufacturer and distributor constantly monitor changes in buying patterns and adapt quickly to maintain market share. By employing S&RL, commercial enterprise has been able to reduce investments in warehouses and stock. Industry now increasingly produces what is desired and required rather than what a planner thinks should be built based on internal production goals. Commercial S&RL, in theory, reduces stock and overhead costs and responds rapidly to change.[8] The key to these improvements is a robust system of information-gathering and analysis or, in military terms, a highly efficient C2 system.

Commercial practices and commercial definitions of S&RL fall short of what is needed to create S&RCS in the Air Force environment. Although there are similarities between some of the issues and constraints of the military and those of a large corporation, the risk of human casualty, the consequences to the international political order, and vastly different military objectives set the Department of Defense (DoD) apart from any corporation of comparable size. The scope of activities included in military CS is also much broader than that of commercial logistics; any reorganizational concept must consider the nuances of military operations. It is interesting to note that firms have designed Lean supply chains to be resilient to business disruptions,[9] but it has been shown that resiliency for firms may not translate to resiliency for the entire supply chain and the government provision of pliability and redundancy may be necessary in an era of Lean supply chain management.[10] In the military case, the Air Force is the sole user and provider and thus the business notions of resiliency may not be entirely applicable.

Traditionally, ongoing planning and tasking often occur in isolation from those who would subsequently be required to support the levels and rates of tasking. Coordination, if any, occurs after initial planning cycles are completed. Modern, responsive systems demand information-sharing among all partners in the military enterprise. Moreover, tools and technology play a vital role in this enterprise.

## A Brief Survey of Sense and Respond Tools and Technology

The DoD Office of Force Transformation (OFT) developed the military sense and respond logistics concept, borrowing heavily from research in the commercial sector (which was in turn indebted to earlier military efforts, such as the observe, orient, decide, and act loop)[11] to describe an adaptive method for maintaining operational availability of units by managing their end-to-end support network. OFT addresses S&RL from a Joint force perspective and as an important component of DoD's focused logistics strategy.

OFT considered architectural development planning that includes the development of an information technology S&RL prototype. One of these architectural concepts is the Integrated Enterprise Domain Architecture, which has the objectives of integrating, accommodating, and employing concepts and components of logistics, operations, and intelligence architectures and of their command, control, communications, computers, intelligence, surveillance, and reconnaissance concepts.[12] Presently, Integrated Enterprise Domain Architecture is in a predevelopment stage, but plans are to eventually link it to other architectures or programs, including Joint Staff J4, Joint Forces Command, US Marine Corps, United States Transportation Command, and possibly certain organizations in the Navy and the Army. Among the in-work project linkages is

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the RAND-Air Force CSC2 Operational Architecture as the Air Force vehicle for coordinating with concepts in S&RL.

Overall, the OFT program for S&RL is in a very early stage, but it has the potential to influence and effect near- to mid-term changes in some current programs using S&RL technologies. OFT suggests that elements of the concept can be employed in an evolutionary development in the very near term and could result in immediate operational gains.[13] OFT has also identified a number of technologies that are essential in an S&RL system, two of which were highlighted as especially important components: radio frequency identification and intelligent (adaptive) software agents.

However, before we discuss these components it is noteworthy to present some of the technical requirements that are essential in supporting sense and respond CS. Although there is great diversity amongst various approaches to sense and respond logistics implementation and its applications, a general theme is best stated by the IBM Sense and Respond Enterprise Team.[14] These criteria are in line with RAND's CSC2 concepts which the Air Force is in the process of implementing.[15] In general, technologies and innovation to support sense and respond (S&R) must have the following:

- The ability to detect, organize, and analyze pertinent information and sense critical business (force) conditions
- The filters for enterprise data to enable stable responses to disturbances in the business or military environment
- The intelligent response agents that analyze global value chain relationships and information and derive the optimal strategy for the best supply chain performance
- Predictive modeling at multiple levels: strategic, tactical, and operational
- Agent coordination mechanisms at multiple levels: strategic, tactical, and operational
- The ability to learn by comparing previously predicted trends with recorded data and information to improve future responses
- A software infrastructure to integrate heterogeneous and collaborative agents implementing critical business policies and making operational decisions

This concept can be contrasted with the OFT perspective. OFT, within its All Views Architecture, lists specific systems architecture components for S&RL, including the following capabilities:[16]

- Passive and active tagging, instruments, and sensors that provide location status, diagnoses, prognoses, and other information relative to operations space entities, especially for conditions and behavior that affect force capabilities management, logistics, and sustainment.
- Intelligent software agents that represent operations space entities, conditions, and behaviors, provide a focus for control of action or behavior, or act as monitors.
- S&RL knowledge bases oriented toward force capabilities management, logistics, and sustainment.
- S&RL reference data, again focused on force capabilities, assets, and resources related to force capabilities management, logistics, and sustainment.
- S&RL rule sets, which govern the operations and organization of S&RL functions, activities, and transactions.
- S&RL cognitive decision support tools uniquely supporting force capabilities management, logistics, and sustainment.
- Unique S&RL processes, applications, portals, and interfaces not provided either by Distributed Adaptive Operations

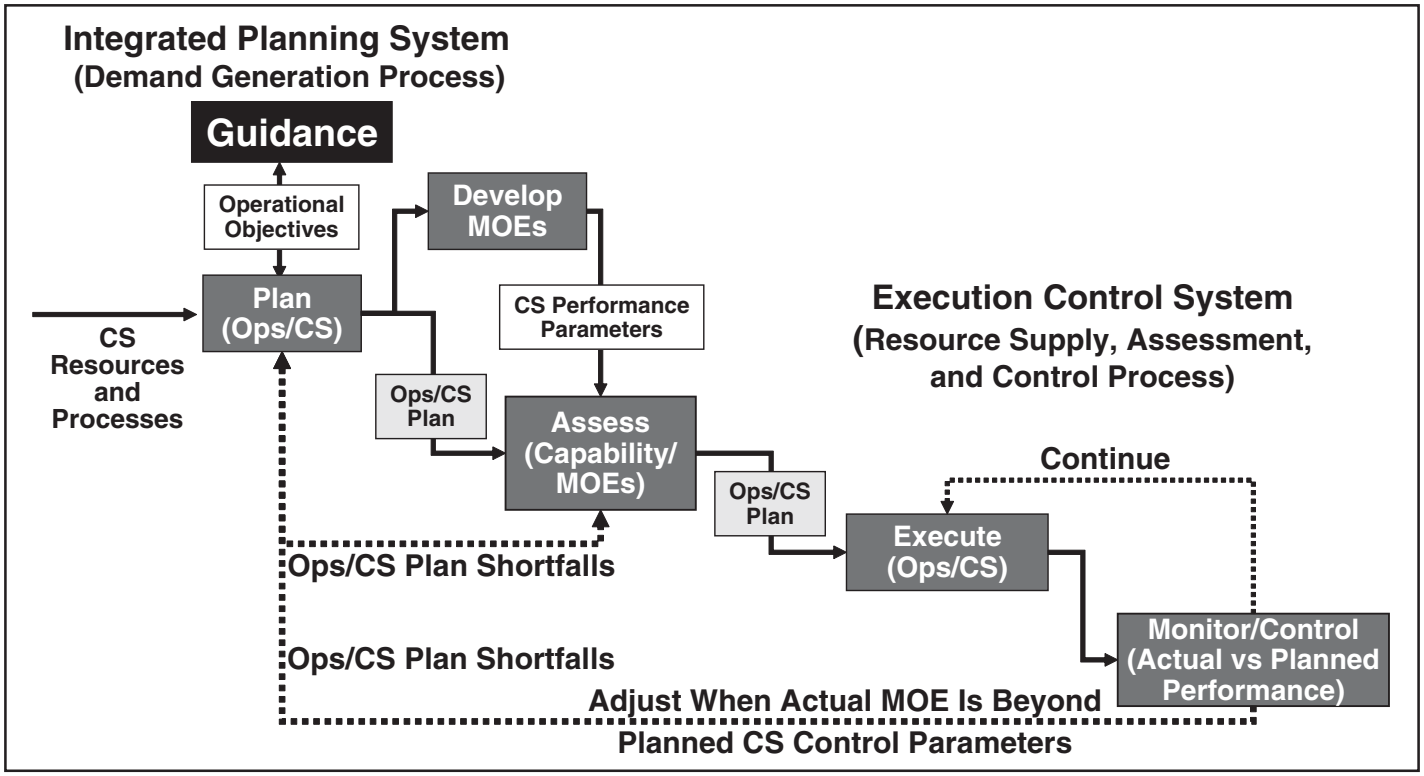


**Figure 1. Feedback Loop Process**

Command and Control or the Network-Centric Operations and Warfare infrastructure.

These are representative of the technologies and innovations that have been identified with military and commercial S&RL initiatives. In the next section, we discuss two important technologies needed to enable an ultimate S&RCS capability: radio frequency identification (RFID) and intelligent (adaptive) software agents.[17]

**Radio Frequency Identification.** RFID is an automatic identification technology that provides location and status information for items in the CS system. RFID technologies are fairly mature and have been fielded in both commercial and military arenas. Technically, RFID offers a way to identify unique items using radio waves. Typically, a reader communicates with a tag, which holds digital information in a microchip. However, some chipless forms of RFID tags use material to reflect back a portion of the radio waves beamed at them. This technology is of equal interest to military and commercial enterprises.

There are several examples of real-time information-gathering and distribution. For example, in Iraq, some Marine units had active tags not just on pallets but also on vehicles. RFID readers were set up at a distribution center in Kuwait, at the Iraq-Kuwait border, and at checkpoints along the main arteries in Iraq. When trucks passed the readers, the location of the goods they were carrying was updated in the DoD's intransit visibility network database. This enabled commanders on the ground to see the precise location of the replenishments needed to sustain operations. RFID implementation is limited, but the DoD goal is to minimize human involvement when collecting data on shipments and their movements.

**The Application of Agent Technology.** The application of agent technology in S&RL research has become pervasive both in military and nonmilitary programs. Agent-based modeling (ABM) allows a more robust simulation of CS operations.[18] Agent-based models are already in wide use within the DoD for force-on-force simulations but have only recently been adapted for military logistics use. The logistics domain is distributed and involves decentralized (autonomous) organizations. These organizations are also

- Intentional entities, with goals, functions, roles, and beliefs, using processes and expertise to achieve their goals
- Reactive, and thus responsive to changes that occur in their environment
- Social, so they interact with other organizations to achieve their goals, where the social interaction is typically complex, such as negotiation, rather than just action requests

The similarity in characteristics between agents and organizations makes agents an appropriate choice for modeling organizations. This also explains agent functionality in carrying out organizational or human processes in S&RL applications. Moreover, robust distributed C2 strategies can also be tested using ABMs.[19] Although some simple supply chain simulations have been done for logistics, almost none have modeled actual organizations with the requisite detail and calibration necessary to compare alternative policies and gain insight.

Although individual automated software agents are already employed commercially for particular tasks, intelligent multi-agent systems are still in early development.[20] Consequently, ABMs have only had a limited effect on practical decisionmaking. Only in recent years have academic researchers explored the use of intelligent agents for supply chain management.[21] Although ABMs are properly understood as multi-agent systems, not all agents or multi-agent systems are employed for modeling and simulation purposes. Several researchers, including some under DoD contracts, have developed applications of ABMs for supply chain management.[22]

Agents have been used in telecommunications, e-commerce, transportation, electric power networks, and manufacturing processes. Within telecommunications, software agents bear the responsibility for error-checking (such as dropped packets), routing and retransmission, and load-balancing over the network. Web-search robots are agents that traverse Websites collecting information and cataloging their results. When a customer searches for an item on a Website, say Amazon.com, at the bottom of the page there is a list of similar products that other customers interested in the item also viewed. Similar agents assemble customized news reports and filter spam from e-mail. Data-mining agents seek trends and patterns in an abundance of information from varying sources and are of particular interest for all-source intelligence analysis.[23]

## A World of Initiatives

The following discussion represents recent and current initiatives, both public and private, to develop sense and respond capabilities.

- The Defense Advanced Research Projects Agency (DARPA) has been working on an end-to-end logistics system under the Advanced Logistics Project.[24] Under this project, DARPA developed an advanced agent architecture with applications to logistics. As follow-on to Advanced Logistics Project, DARPA initiated a program called Ultra-Log that attempted to introduce robust, secure, and scalable logistics agents into the architecture. Ultimately, Ultra-Log is seeking valid applications to DoD problems (such as Defense Logistics Institute applications) while adopting commercial open-source models.
- DARPA led another experiment called Coalition Agent eXperiment (CoAX), which was an example of the utility of agent technology for military logistics planning. A multi-agent logistics tool, implemented within CoAX, was developed using agent technology to have agents represent organizations within the logistics domain and model their logistics functions, processes, expertise, and interactions with other organizations. The project generated important lessons for S&RL, identifying two types of issues that need to be overcome for agents to be effectively used for military logistics planning—technological and social (human acceptability). RAND believes the issues are the same for use in executing logistics functions. Under technology, the identified issues include logistics business process modeling, protocols, ontologies, automated information-gathering, and security. We found some of these being addressed in DARPA's work. Under social acceptability, the following were important: trusting agents to do business for you, accountability and the law, humans and agents working together, efficiency metrics, ease of use, adjustable autonomy, adjustable visibility, and social acceptability versus optimality.

- The Air Force Research Laboratory, Logistics Readiness Branch (AFRL/HEAL) has focused its attention on human factor issues in S&RL, with a concentration on cognitive decision support.[25] AFRL proposes to focus on the human aspects of distributed operations by researching and developing enhanced or novel methodologies and measures to evaluate the effect of collaboration technologies on human performance from an individual, team, and organizational perspective. This group suggests that human performance metrics should be created along with other performance metrics for S&RL functions and activities in the military enterprise, although such considerations are currently not being called for in the requirements.

In addition to the multiple DoD-led initiatives, a number of commercial sector and university initiatives have developed some of the technologies needed to enable an S&RCS capability and presents a number of industrial applications of fielded S&R systems. These included an IBM Sense and Respond Blue program, which was a major influence on the military OFT enterprise definition and emphasized the employment of careful planning as well as intelligence, flexibility, and responsiveness in execution in order to achieve high levels of distributed efficiency.[26] In addition, General Electric Transportation Systems developed and fielded an autonomic logistics capability for its locomotive engine business. This capability is enabled through an onboard computing and communications unit that hosts software applications, continuously monitors locomotive parameters, and provides communications to General Electric's Monitoring and Diagnostics Service Center.[27]

Based on this technology review of both military and commercial activities and initiatives (and a more thorough review detailed in the RAND monograph[28]), we concluded that although current technology has enabled a limited set of sense and respond capabilities, a full implementation of S&RL concepts remains dependent on substantial future technological development. The largest challenge ahead for implementing a broader S&RCS capability is the development of an understanding of the interactions between CS system performance and combat operational metrics. Without the proper metrics for measuring the agent (and other) technologies used in S&RCS implementation, it is difficult to project where or when CSC2 effectiveness best stands to gain from this technology insertion. This is an important subject to address through information technology prototyping for CSC2 because it should drive information technology investments among S&RL technologies.

## Air Force Combat Support Command and Control Implementation Effort

The Air Force has taken initial steps to implement the CS command and control operational architecture. Its efforts are designed to help enable AEF operational goals. Implementation actions to date include changes in C2 doctrine, organizations, processes, and training. Although progress has been steady, the area of information systems and technology requires increasing application of modern capabilities. The emerging modernized logistics information systems emphasize mostly business process improvements, with little focus on CS challenges and requirements. Additionally, CS systems are not being coordinated and tested in an integrated way with operations and intelligence systems. The architecture and requirements for peacetime and wartime logistics and CS information systems will need to be more closely coordinated.

The Air Force has begun evaluating the effectiveness of CSC2 concepts in exercises. Improving CSC2 organizations, processes, and information systems hardware, software, and architecture will require several years of active involvement by US Air Force Headquarters as well as Air Force initiatives to restructure a system that was previously organized around fixed-base, fight-in-place air assets. However, there are active efforts to structure CSC2 activity and policy in a way that should effectively support forces throughout the 21st century. Below is a summary of the status of Air Force implementation actions.

**C2 Doctrine.** The Air Force initiated a review of its doctrine and policy and began revisions to reflect the robust AEF CSC2 operational architecture. Such actual and planned changes to Air Force doctrine and policy are on the right track. As doctrine is changed, procedures, policies, organizations, and systems can then be changed to align with the changing concepts of warfare. Perhaps the most significant opportunity for improvement is the integration of CS and operational planning. Currently, there are no standard processes for operational planners to communicate operational parameters to CS planners. This deficiency greatly hinders timely, accurate CS planning. Creating a framework, reinforced in doctrine, to delineate specifically what information operations planners provide, in what format, and to whom could

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address this shortfall. Solidifying this linkage between operations and logistics in crisis action planning would enable a step forward in the coordination, timeliness, and accuracy of CS planning.

**Organizations and Processes.** The Air Force has made progress in establishing standing CS organizations with clear C2 responsibilities and developing processes and procedures for centralized management of CS support resources and capabilities.

**Training.** The Air Force has made much progress in improving CSC2 training, including the formation of an education working group, to address the development and enhancement of formal education programs. The group will also address the implementation of significant new C2 instruction at the Air Force Advanced Maintenance and Munitions Officers School at Nellis Air Force Base, Nevada,[29] and the development of the Support Group Commanders Course and the new CS Executive Warrior Program, which will provide training for support group commanders, who are potential expeditionary support group commanders and A4s.

**Information Systems.** This area needs the most change. These changes should include the following:

- Relate operational plans to CS requirements
- Convert CS resource levels to operational capabilities
- Conduct capability assessments and aggregate on a theater or global scale
- Conduct tradeoff analyses of operational, support, and strategy options
- Focus integration efforts on global implementation of a few selected tools
- Standardize tools and systems for consistent integration

Most of the logistics information systems' modernization efforts are linked to improving information technology solutions, which support day-to-day business processes. Modernization of the peacetime systems will certainly yield some improved CSC2 information ability. However, the requirements for a more robust S&RCS capability need to be considered within the wartime CSC2 architecture. CS system modernization will need to assess both peacetime and deployment requirements and produce tools and capabilities that will satisfy business processes as well as CSC2 needs.

**Enterprise-Wide Systems and Combat Support Command and Control.** CSC2 analytical and presentation tools will need to augment typical data processing with increasingly modern sense and respond capabilities. Batch processing and analysis, a proven rate and methodology for most of the Air Force's 60 years of experience, will not effectively support agile combat operations and effects-based metrics. To respond to continuously changing desired effects, enemy actions, rates of consumption, and other controlling inputs, the 21st century logistics warfighter will need to accumulate, correlate, and display information rapidly and in graphic formats that will be equally understandable for operators and logisticians. Data will need to be refreshed much more rapidly than the former monthly and quarterly cycles. Daily decisions will require daily (if not hourly or possibly continuous) data refresh cycles.

A closed-loop planning and control system is essential to a robust military S&RCS architecture. Currently, information about Air Force resource and process metrics is organized by commodity or end item and located on disparate information systems. Creating a single system accessible to a wide audience would enhance leadership visibility over these resources. Such a system needs to have enough automation to translate lower-level process and data into aggregated metrics, which can be related in most cases to operational requirements.

**Significant challenges remain before the Air Force can realize an S&RCS capability. To develop effective tools that accurately link logistics levels and rates to operational effects, the modern Expeditionary Combat Support System must be developed and tested in conjunction with operations and intelligence systems. Only through integrated testing can the CSC2 architecture be properly developed and implemented.**

The greatest change required in modernized logistics systems is to reorient existing logistics systems toward combat-oriented ones. The peacetime-only materiel management systems need to be structured to participate in the enterprise-wide sharing of data and culling of information.

Stand-alone, single-function systems need to be replaced with systems that serve several functions for CS leaders at all echelons. Finally, modern CSC2 systems need to provide information useful in both peacetime and wartime decisionmaking.

## Future Work and Challenges

The Air Force has made some progress toward implementing doctrine and policy changes, and plans are in place to continue to close the information technology and analytical tools gaps. An expanded Air Force *to-be* CSC2 execution planning and control architecture system would enable the Air Force to meet its AEF operational goals. New capabilities include the following:

- Enable the CS community to quickly estimate support requirements for force package options and assess the feasibility of operational and support plans
- Facilitate quick determination of beddown needs and capabilities
- Ensure rapid time-phased force and deployment data development
- Support development and configuration of theater distribution networks to meet Air Force employment timelines and resupply needs
- Facilitate the development of resupply plans and monitor performance
- Determine the effects of allocating scarce resources to various combatant commanders
- Indicate when CS performance begins to deviate from desired states and facilitate development and implementation of get-well plans

CS and operations activities must be continuously monitored for changes in performance and regulated to keep within planned objectives. Significant advances must be made in the way planning, directing, coordinating, and controlling functions are performed to move the Air Force toward a robust S&RCS capability. These essential elements of an effective C2 system must be altered to allow them to accomplish the important aspects of sensing and responding to changes in operating parameters when the violation of tolerance becomes evident. These sense and respond activities will need to take place in a nearly real-time environment.

The objective of rapid sensing and response is to alert decisionmakers to initial deviations in the plan, rather than reacting after-the-fact, to situations affecting mission capability. Emphases of metrics in the future need to be on *outcomes*, rather than on *outputs*. The RAND report details necessary adaptations that include (at the minimum) the following improvements in CSC2 architecture and activities.

- **Planning.** With the AEF's short timelines and pipelines, it is critical to be able to add CS information to initial planning, giving planners flexibility and confidence. CS execution planning functions include monitoring theater and global CS resource levels and process performance, estimating resource needs for a dynamic and changing campaign, and assessing plan feasibility. Because capabilities and requirements are constantly changing, these activities must be performed continuously so that accurate data are available for courses of action and ongoing ad hoc operational planning.
- **Directing.** CS-directing activities include configuring and tailoring the CS network, and establishing process performance parameters and resource thresholds.[30] Planning output drives infrastructure configuration direction—there must be an ongoing awareness of CS infrastructure and transportation capabilities to feed into operational planning and execution. Once combat operations commence, the logistics and installations support infrastructure must be regulated to ensure continued support for dynamic operations. The system must monitor actual CS performance against the plan. The performance parameters and resource buffers established during execution planning will provide advance warning of potential system failure.
- **Coordinating.** Coordination ensures a common operating picture for CS personnel. It includes beddown site status, weapon system availability, sortie production capabilities, and other similar functions. Coordination activities should be geared to providing information to higher headquarters to create an advance awareness of issues should one be needed at a later date. Great effort must be made to effectively filter the information flows up the command chain, to avoid overwhelming commanders with information of little utility, but to provide sufficient information to improve battlespace awareness.
- **Controlling.** During the execution of peacetime and contingency operations, CS control tracks CS activities, resource inventories, and process performance worldwide, assessing root causes when performance deteriorates, deviates from what is expected, or otherwise falls out of control. Control modifies the CS infrastructure to return CS performance to the desired state. CS control should evaluate the feasibility of proposed modifications before they are implemented and then direct the appropriate organizations to implement the changes.

## Toward a Responsive System

The Air Force has already begun to take steps to implement some of these concepts and technologies with varying degrees of success. Air Force implementation actions include making doctrine changes to recognize the importance of CSC2, as part of S&RCS capabilities, and identifying training and information system improvements.

However, significant challenges remain before the Air Force can realize an S&RCS capability. To develop effective tools that accurately link logistics levels and rates to operational effects, the modern Expeditionary Combat Support System (ECSS) must be developed and tested in conjunction with operations and intelligence systems. Only through integrated testing can the CSC2 architecture be properly developed and implemented.

Technologies associated with S&RL are still in an early stage of development and may not be fielded for a number of years. Ultimately, ECSS should relate how CS performance and resource levels affect operations, but current theoretical understanding limits these relationships. The Air Force does not appear to be lagging behind industry in the implementation of S&RL capabilities but should continue to make judicious investments in this field.

The Air Force has recently established the Global Logistics Support Center (GLSC) as the single agent responsible for end-to-end supply chain management. The creation of this entity holds promise for the achievement of S&RCS capabilities. The GLSC should be in a position to advocate for future improvements while exploring ways to provide the capability utilizing current systems.

Finally, the observations of the Joint Logistics Transformation Forum are worth repeating: Unless significant improvements are made to *last-mile* transportation in theater, S&RL will have only a limited effect on operations. A robust, assured transportation network is the foundation on which expeditionary operations, as well as S&RL implementation, rests. The complete integration of transportation into the CSC2 architecture is essential.

## Notes

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31. Heuristically determined thresholds can be established while more sophisticated expert rules or algorithms are being developed. For instance, Brigadier General Hennessey AMC/LG) uses zero-balance stock positions coupled with forces supporting an engaged combatant commander as a rule to determine when lateral actions should be taken to resupply a unit *at war*. Using this rule, he authorizes the AMC/Regional Supply Squadron (RSS) to reallocate stocks from units with stock to those with zero balances. The idea is to prevent mission degradation by focusing attention on the items that will cause the next mission degradation.

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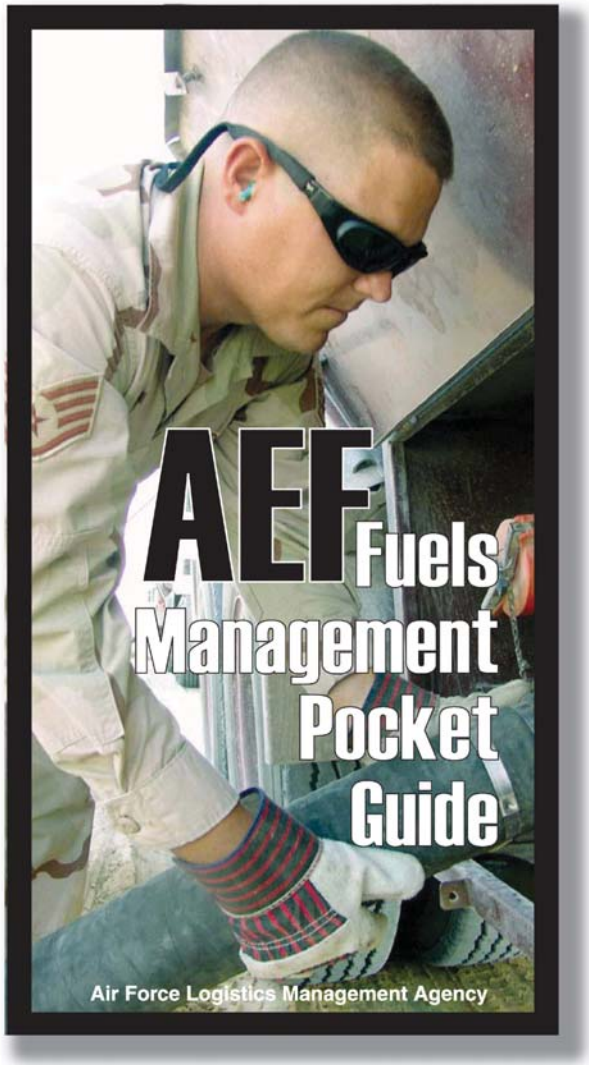


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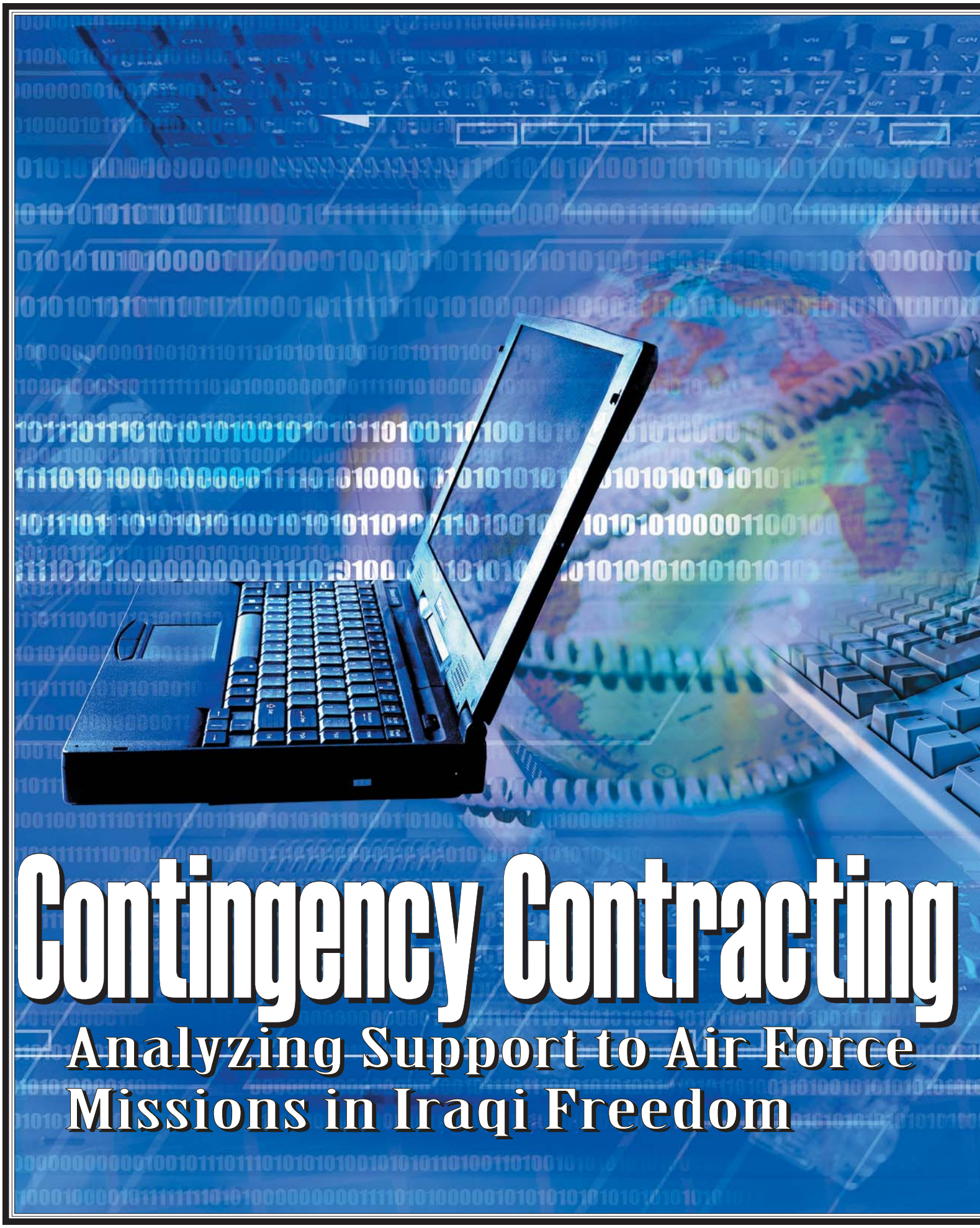


# Contingency Contracting

## Analyzing Support to Air Force Missions in Iraqi Freedom

## Introduction[1]

Contractors have been an important part of US war efforts since they were hired to take care of cavalry horses for the Continental Army during the Revolutionary War. While the history of contracted support to US military operations is a long one, the role of that support has expanded rapidly and extensively, particularly since the end of the Cold War.[2,3,4] Today the US Air Force, as well as the other US military services, buys an enormous amount and variety of goods and services to support its contingency operations. These purchases are necessary for a wide range of activities, including feeding, housing, and protecting military personnel; repairing aircraft weapon systems; and transporting personnel and supplies. The outcomes of these purchases directly affect the Air Force's ability to succeed in a contingency environment.

Purchasing goods and services to support contingency operations can provide several types of benefits to the Air Force. As with most types of outsourcing, contract support frees up airmen to perform core military activities. Providers that specialize in the outsourced goods or services often can offer improved performance and cost outcomes, if managed effectively. Buying in theater reduces requirements for scarce transportation resources, potentially shortening deployment timelines, and also garners host-nation support for US military presence. Additionally, having the capability to purchase as needed, rather than being forced to predict requirements in advance, helps commanders meet emerging demands and the often-changing requirements associated with the realities of war.

Since September 11, 2001, the Air Force has been involved in two significant contingency operations in the United States Central Command (USCENTCOM) area of responsibility (AOR): Operation Enduring Freedom (OEF) in Afghanistan, and Operation Iraqi Freedom (OIF) in Iraq. To take advantage of the depth of contingency contracting experience built during recent operations, the Deputy Assistant Secretary of the Air Force for Contracting asked RAND Project Air Force to gather and analyze data on goods and services purchased to support Air Force missions in OIF to determine the size and extent of contractor support for OIF and how plans for and the organization and execution of contingency contracting activities might be improved to better support the warfighter in future operations.

The motivation for this study was that insights from comprehensive data on recent multiyear contingency contracting experiences would help inform decisions about a number of important policy issues.

First, such data could be used to improve the Air Force's ability to plan for combat operations at contingency operating locations, particularly by linking purchases to supplemental information about the phases of operations (such as deployment, the building of a base, the sustainment of operations at a base, or the closing of a base) and mission activities supported by those purchases.

# Article Highlights

**While price information can be a powerful tool for contingency contracting officers (CCO), additional information about the relative performance of suppliers and other factors related to meeting requirements, such as the urgency, transportation needs, or security threats, would be helpful in interpreting such comparisons.**

In "Contingency Contracting: Analyzing Support to Air Force Missions in Iraqi Freedom" the authors describe the construction of a database of CCO purchases supporting Air Force activities in Operation Iraqi Freedom during fiscal years 2003 and 2004. The results of their analysis demonstrate how this database can be a powerful analytic tool to inform and support policy decisions and initiatives for CCO staffing and training, combat support planning, and sharing lessons within the theater.

They recommend the Air Force (and the Department of Defense more broadly) establish a standardized methodology for collecting contingency contracting data on an ongoing basis to facilitate planning and policy decisions for future contingencies.

To facilitate the types of analyses required, the Air Force needs to systematically gather contingency contracting data on an ongoing basis. To be most useful, the CCO data system must make it possible to quickly access detailed

For example, the Air Force could make more informed tradeoffs between purchasing required assets as needed during operations in theater or purchasing them in advance and then using airlift or other transportation assets to move materials from the United States or regional storage locations to operating locations.

Second, purchasing data could be used to improve training for future contingency contracting officers (CCOs). Insights about how purchasing evolves with operational phases could be used to design more realistic training courses. Further, information about typical goods and services purchased, types of contracts used, and supply bases at specific locations could be used to better prepare CCOs before deployment.

Third, information about contracting workloads at different types of bases and other purchasing organizations during different phases of operations could be used to better align CCO organizations and personnel assignments (both CCO numbers and skill levels) with warfighter requirements.

Finally, descriptive data on individual transactions are important inputs in efforts to improve purchasing practices across the theater. For example, CCOs could achieve more effective price negotiations based on improved visibility of prices of similar goods or services, as well as identification of potential opportunities to improve the Air Force's leverage with key suppliers through contract consolidation across commodity groups or sites.

## Defining Contingency Contracting for Operation Iraqi Freedom

The Air Force Federal Acquisition Regulation Supplement (AFFARS) provides the following relevant definitions:

- A contingency is "an emergency, involving military forces, caused by natural disasters, terrorists, subversives, or required military operations."
- CCOs are people with "delegated contracting authority to enter into, administer, and terminate contracts on behalf of the Government in support of contingency … operations."[5]

In this article, we use a broad definition of contingency contracting for OIF that includes war preparations in early fiscal year (FY) 2003, the major combat operations in mid-FY 2003, and postwar activities beginning in the latter part of FY 2003. Although United States Central Command Air Forces (USCENTAF) was the primary major command involved in Air Force operations, many other commands and organizations made purchases in support of this effort. For example, purchases were made to support US Air Forces at European bases, Air Force Special Operations Command forces, and Air Mobility Command operations.

## Building the Database

To develop a baseline of Air Force contingency contracting for OIF and obtain insights relevant to the policy issues introduced above, we sought to develop a comprehensive database of Air Force OIF contingency purchases, which were made by a large number of organizations around the world. Our analyses are based on CCO purchases at 24 purchasing organizations located within the USCENTCOM AOR that supported OIF during FY 2003 and FY 2004. These data include more than 24,000 transactions obligating more than $300M.

We chose these data for several reasons. The current lack of visibility into the details of the forward transactions and the decentralized nature of the CCO purchases suggest that there could be opportunities to improve planning for and execution of these activities, for example, through preplanning for certain types of goods or services, more effective price negotiation, or contract consolidation with key suppliers to the AOR. In addition, the numbers of dollars and individual transactions for USCENTAF are much greater than equivalent data received from other commands and organizations that supported OIF.

In order to create a comprehensive Air Force contingency contracting database for OIF, the RAND team used transaction logs maintained by the office of the USCENTAF comptroller, headquartered at Shaw Air Force Base, South Carolina. These data on CCO purchases were tracked in Microsoft® Excel® spreadsheets, which included similar, but not identical, data fields and spreadsheet formats for contract and government purchase card (GPC) files across purchasing organizations in fiscal years 2003 and 2004.[6] As a result, it was necessary for RAND to develop a detailed process to merge these files into an aggregated master database that would enable our analyses.[7]

The Air Force spreadsheets contained data fields such as a text description of the goods and services purchased, the date the purchase was requested, the price paid, and the supplier. In addition, the RAND team created three new variables for our analyses. First, we created a variable for the purchasing organization (the base or other organization) with which the comptroller associated the transaction. Second, we used the text description for each transaction to categorize the purchase according to one or more types of goods or services. And third, we used several pieces of data from the spreadsheets to create a variable for the type of transaction to identify whether the purchase was made using a GPC or a contract vehicle. Contracts are further broken down into blanket purchase agreements[8] (BPAs) and *other* contracts.

## Baseline of Contingency Contracting for Operation Iraqi Freedom

This section provides an overview of the results of our baseline analysis of purchases supporting Air Force OIF activities during FY 2003 and FY 2004 at Air Force operating locations in the USCENTCOM AOR. RAND's database allowed the team to analyze the USCENTAF CCO purchases in several important ways. After an overview of expenditures, we describe:

- Who (which organizations) made purchases
- What types of goods and services were purchased
- When the purchases were made (time periods)
- How the purchases were made (contracting tools used)
- From whom (suppliers) the purchases were made

### Who

Figure 1 provides information on the time frames for purchasing activity for each of the OIF purchasing organizations during FY 2003 and FY 2004. (Purchasing activity corresponds to operations for each of these organizations.) Only five organizations had contracting activity throughout both years. Some were active for only a few months.

An analysis of spending by location indicates that the most spending by far occurred at Al Udeid. Two things may explain this:

# Article Highlights

descriptions of individual transactions, as well as aggregate those transactions according to categories of purchases, types of contract vehicles used, locations of purchases, suppliers dealt with, and so forth.

The authors also recommend establishing a standardized automated system for transaction-specific data that could be either virtually connected to a master database or regularly downloaded into such a database as a means of recording and cataloging purchases. Such a system should also include an easy method both for categorizing purchases across a wide range of commodities and services and for identifying suppliers in a standardized way. Contingency contracting representatives and logistics planners should work in concert to develop the database, ensuring that one standardized system will satisfy the requirements of both organizations.

### Article Acronyms

**AFFARS** – Air Force Federal Acquisition Regulation Supplement
**AOR** – Area of Responsibility
**BPA** – Blanket Purchase Agreement
**CAOC** – Combined Air Operations Center
**CCO** – Contingency Contracting Officer
**USCENTAF** – United States Central Command Air Forces
**USCENTCOM** – United States Central Command
**DFAS** – Defense Finance and Accounting Service
**FY** – Fiscal Year
**GPC** – Government Purchase Card
**OEF** – Operation Enduring Freedom
**OIF** – Operation Iraqi Freedom
**PSAB** – Prince Sultan Air Base
**RED HORSE** – Rapid Engineer Deployable Heavy Operational Repair Squadron Engineers

First, expenditures there include not only those for air base operations, but also for the Combined Air Operations Center (CAOC), which relocated from Prince Sultan Air Base (labeled *PSAB)* to Al Udeid during this period. Second, Al Udeid served as the forward headquarters of the Air Force in Southwest Asia during both OIF and OEF. Unfortunately, Al Udeid's and the CAOC's contract expenditures were captured only in a separate financial management system which lacks the necessary resolution to allow detailed analysis.[9]

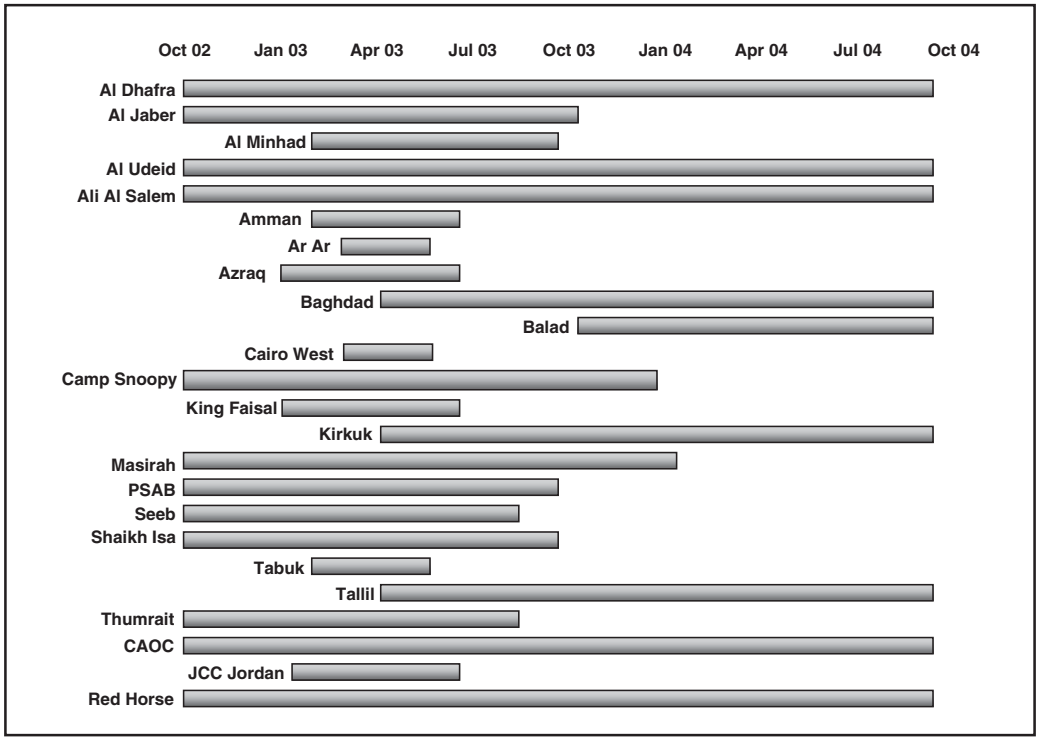



**Figure 1. Timelines for Purchasing Activity, by Purchasing Organization**

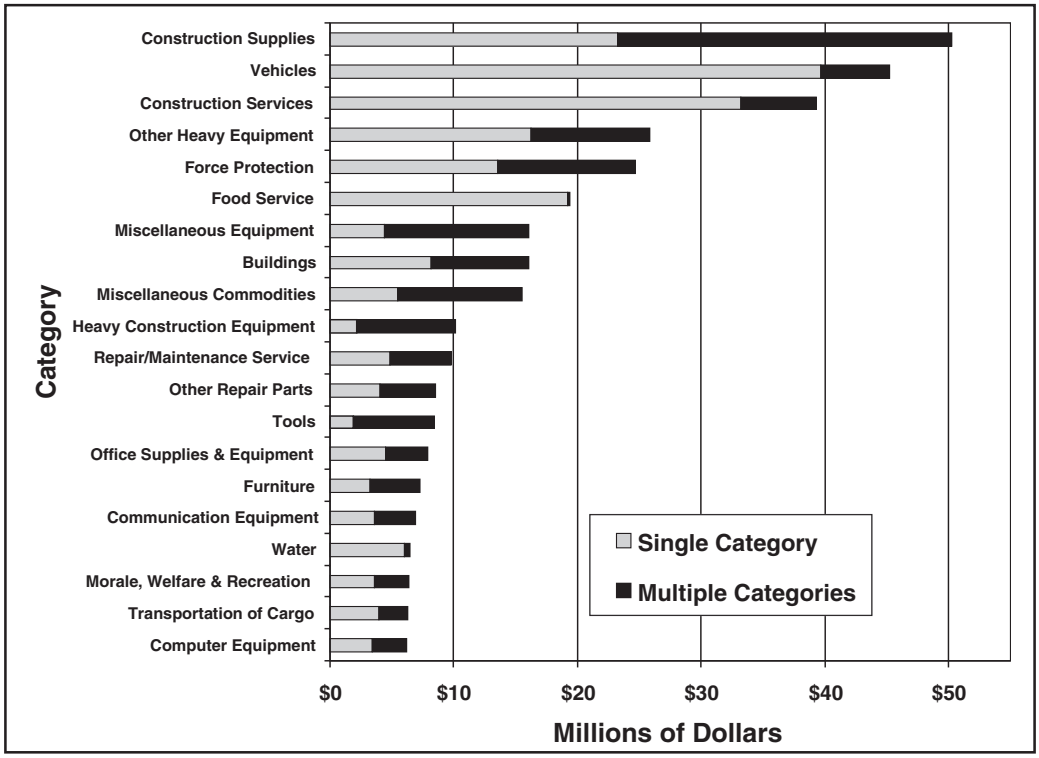



**Figure 2. Obligations for the Top 20 Categories, FY03 and FY04**

Note: the *single category* portion of the horizontal bars shows obligations that clearly belonged in only one category; the *multiple categories* portion shows obligations for transactions that could also be assigned to other categories.

### What

Deployed CCOs purchased a variety of products to support OIF operations during FY 2003 and FY 2004. We created 45 categories of goods and services and used a computer program to assign transactions to these categories based on key words found in the text descriptions of the purchases. After categorizing the transactions as well as possible, we calculated both the total obligations per category as well as the number of transactions per category. The categories with the highest total obligations included construction supplies, vehicles, construction services, and other heavy equipment (see Figure 2).[10] Construction supplies, miscellaneous commodities, and office supplies and equipment represent the largest number of transactions.

### When

Our database also allows analysis of purchases over time. Figure 3 shows that CCO purchases and transactions at these purchasing organizations were higher in FY 2003 than in FY 2004. This could be associated with the decline in the number of active bases or any number of other factors.

We can disaggregate these data to examine how the level of expenditures varied over time at individual bases. Such data can be used to make comparisons across locations according to characteristics such as base population, types of operational missions (for example, special operations, F-16s), existing base infrastructure, or permanency of the operating location.

While our database alone cannot address underlying causes for the observed differences in spending patterns across locations over time, an analyst with additional information about characteristics of locations such

as base population, numbers and types of aircraft, types of missions, types and maturity of base infrastructure, geographic dispersion of facilities, and Service branch responsible for base operating support, could perform more sophisticated evaluations to determine the correlation between these factors and spending patterns over time.[11] The results of such analyses could be used to make programming decisions about new bases, plan transportation requirements, match CCO resources with user requirements, and so forth.

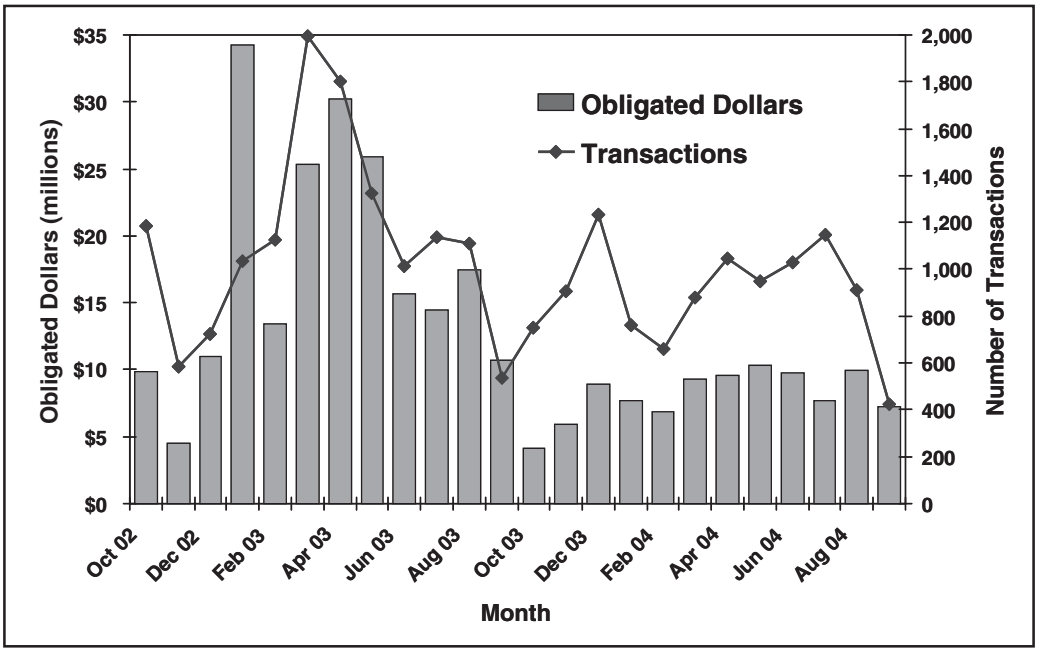



Figure 3. Obligations and Transactions by Month, FY03 and FY04

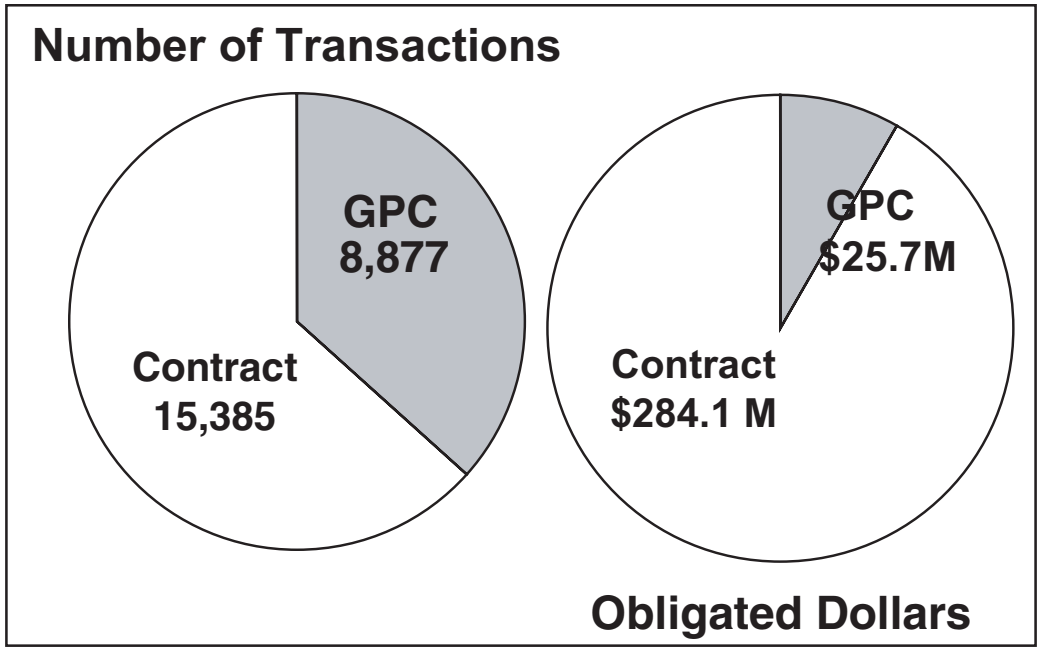



Figure 4. GPC versus Contract Purchases in FY03 and FY04

### How

CCOs have a variety of instruments with which to make purchase payments. Our data allow us to identify two particular types of instruments for further analysis: GPCs (essentially government-issued credit cards) and BPAs. Here, we compare purchases made using GPCs to purchases made through contract instruments that are recorded in USCENTAF comptroller files. As shown in Figure 4, GPC purchases represented more than one-third of the transactions made in fiscal years 2003 and 2004 , but they represented less than one-tenth of the dollars spent.

Since GPCs are designed for purchases of small items, such as office supplies—many of which can be made over the Internet—this is an understandable finding. The dollar amount for the average contract transaction was about 6 times larger than the amount for the average GPC transaction.

Although GPCs are intended for the purchase of small items, it is interesting to note that construction supplies are the largest category for both GPC and contract transactions. Other contract transactions were concentrated in construction services and larger goods, including vehicles and heavy equipment, while GPC purchases included smaller equipment, tools, and office supplies.

### From Whom

Having examined who made what purchases, and when and how the purchases were made, we now turn to the question of from whom goods and services were purchased. We examined the top 10 suppliers (in terms of dollars obligated) in fiscal years 2003 and 2004 by all obligations, for contract obligations alone, and for GPC obligations alone.[12]

Based on firm names, the top firms by contract expenditures appear to be regional firms primarily, whereas GPCs were often used to make purchases from US firms, presumably over the Internet. To get a better sense of what percentage of Air Force CCO purchases were with regional firms, we examined the top 100 firms used in fiscal years 2003 and 2004, which represented 78 percent of the obligations during this period. Of these, 55 were regional firms. Breaking this out by type of transaction, 59 of the top 100 firms for contract transactions were regional, while the number was much smaller for GPC purchases, where only 11 out of 100 were regional.

The top-ranked suppliers provided goods and services from a variety of categories. For each of the top five suppliers in fiscal years 2003 and 2004 (noted as Firms A through E), Figure 5

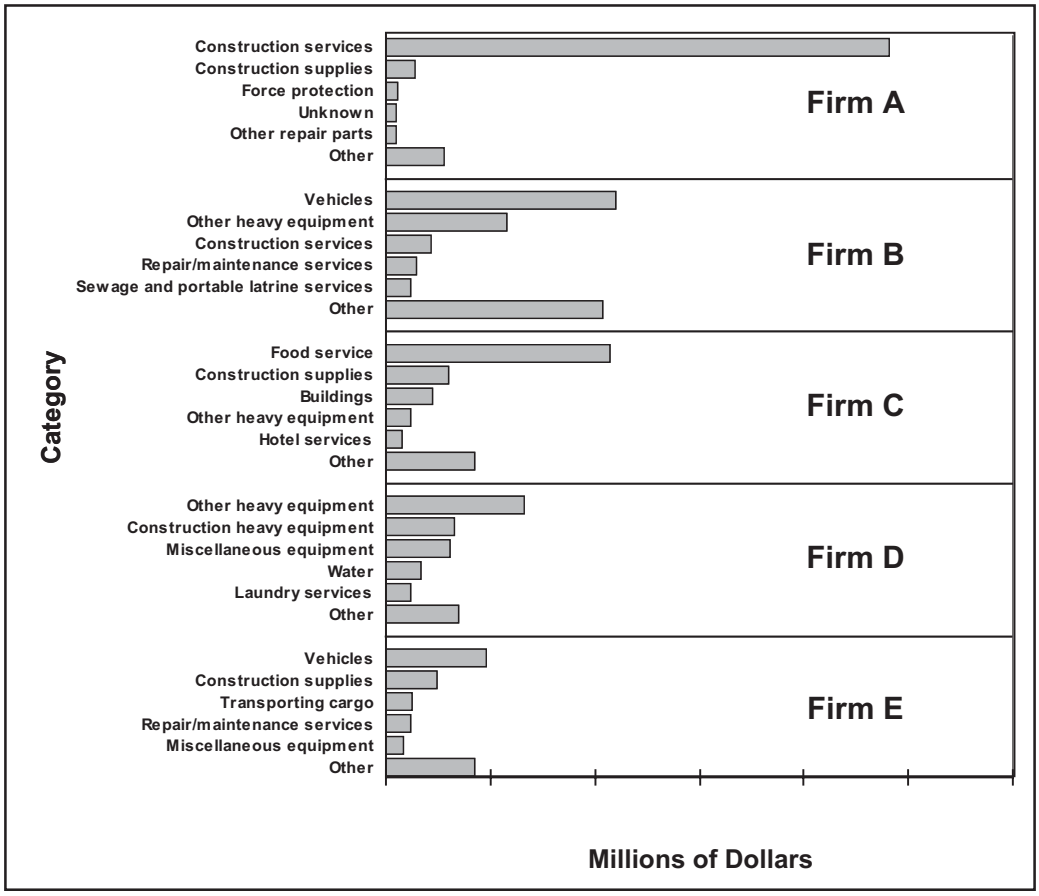



**Figure 5. Top Five Purchase Categories for the Top Five Suppliers**
Note: one of the top categories of purchases from firm A consisted of items that our computer program found difficult to categorize and so they were placed in the *unknown* category.

displays the top five categories of purchases made through the supplier (with all other purchases counted in the bar labeled *Other*).

Top suppliers worked across multiple locations as well. In particular, Firm E supplied goods and services not only in Iraq, but also in Qatar and Oman.

Such detailed information on suppliers' activities across the theater can assist CCOs in planning future acquisitions. While no contracts in our database encompassed more than one purchasing organization, there may be opportunities for the Air Force or the Department of Defense to increase leverage with providers by combining contracts across organizations and encouraging competition among providers. RAND's data analyses of suppliers point to more detailed analyses that could inform such strategic purchasing decisions.

## Implications for Policy Issues

In this section, we use insights from the data and from interviews we conducted in the course of our research to address issues related to CCO staffing, CCO training, combat support planning, and the sharing of lessons within the theater.

### CCO Staffing

Lacking hard data for detailed workload analyses, the Air Force traditionally has used general rules based on perceptions of past experience to determine how many contracting officers to allocate to deployed locations. This approach can lead to the need for adjustments after the fact to reflect real demands on CCOs' time.

One potentially important use of our database could be the systematic assessment of CCO workloads — measured in dollars obligated or transactions executed — across purchasing organizations. While neither measure is perfect (some small-dollar transactions may require more time and attention than do some big-dollar transactions), both measures are potentially important indicators of CCO time requirements. Having received supplemental data from USCENTAF on CCO staffing for selected purchasing organizations for FY 2004, we compared the workload of contracting officers in terms of the average number of transactions per CCO and the average number of dollars obligated per CCO.

Our analyses indicate that there were large differences in CCO activities across locations during fiscal year 2004. However, a better understanding of the nature of activities at individual locations is necessary to draw conclusions. With additional information on the nature of the work within these organizations—such as mission activities supported, types of goods and services purchased, and the number of transactions completed—statistical analyses such as regressions could be used to understand the factors associated with these differences.

### CCO Training

Anecdotes from our interviews indicate that a number of factors make contracing in theater challenging, including differences in the nature of contingency contracting duties as opposed to duties of a contracting officer at a nondeployed location, variation in the contracting environments among countries within the AOR, the short duration of most deployments for contracting personnel,[13] and differences in contracting culture among the military branches operating in a Joint environment.

At first glance, there appears to be abundant guidance available to CCOs to help mitigate any adverse effects associated with these challenges, including AFFARS Appendix CC for Air Force contingency contracting support;[14] Air Force Instruction 10-401, *Air Force Operations Planning and Execution*;[15] the 2003 Air Force Logistics Management Agency contingency contracting handbook;[16] as well as formal training through the Defense Acquisition University[17] and predeployment orientation programs (limited to office chiefs) provided by USCENTAF contracting.

However, one officer we interviewed likened learning CCO procedures from formal training to learning to play golf by reading the rulebook. In contrast, several people mentioned the

importance of providing deploying CCOs with opportunities to engage in training simulations (such as Silver Flag exercises[18]) which present them with scenarios they can expect to encounter when they go into the AOR.

A database of CCO purchases such as the one RAND developed (as described above), could supplement classroom and predeployment training by providing insights into ongoing activities in the theater. Information could be tailored to locations where trainees would be deploying. It also could assist in creating more realistic environments for exercises. In addition, a CCO who is getting ready to deploy could use the database to prepare by becoming familiar with the detailed contracting environment at his or her future location, including the types of purchases made, the predominant types of contracts used for these purchases, and the local supply base. Similar data on contracting for other military branches and coalition partners could be used to better prepare CCOs who will be operating in a Joint requirements environment.

### Combat Support Planning

Combat support planners are responsible for making sure all of the resources the Air Force needs to go to war are in place in time to support contingency operations and associated personnel. After determining all the necessary resources, planners must make choices about where to obtain them and how to get them to the theater to shorten the deployment-to-employment timeline, make the best use of scarce airlift and other transportation resources, and reduce the military footprint in theater.

Since one option that planners consider is the availability of resources in theater, a motivation for the development of the OIF CCO database was that such data could be used to improve combat support planners' ability to make effective, efficient tradeoffs between purchasing items in theater and purchasing them elsewhere and then using scarce transportation resources to bring them to the theater. In addition, these data can be used to describe the local supply base for different types of purchases.

The purchase of bottled water in Iraq provides a simple case study of how a detailed database of CCO purchases can be used to help assess the tradeoffs among options. The US military required a great deal of bottled water for personnel stationed in locations supporting OIF during fiscal years 2003 and 2004. Our database indicates that CCOs in 15 purchasing organizations in theater purchased bottled water through 38 contracts with more than 30 suppliers. Alternatively, planners could have elected to set up contract vehicles for large quantities of water in advance (or purchase and store the water) and then ship the water to appropriate locations in theater as needed. Presumably, such advance planning would result in a lower cost per liter than CCOs were able to negotiate in real time during contingency operations. However, shipments of water into the theater would either delay the transport of troops and other supplies or would require the purchase of additional transportation.[19]

A combat support planner could use RAND's database to determine the best way to meet water requirements in theater during operations. The database would assist the planner by enabling the assessment of costs associated with purchasing water in theater, an analysis of the amount of airlift required for an alternate approach, and the identification of any potential effects on the mission.

In addition, data on Joint contracting in theater, similar to those analyzed in this article, could be used by the combatant commands to construct more realistic and detailed contract support plans. These plans are intended to outline personnel requirements, organizational structures, and so forth, which will be used for Joint contingency contracting to support operations executed by the combatant commands (for example, at what point contracting should transition from a decentralized, Service-specific structure to Joint organizations).

## Sharing Lessons

The nature of particular requirements and the local environment may limit the CCOs' ability to reduce costs. However, awareness of details of purchases made by other CCOs in the theater should assist in negotiating better prices where this is possible. For example, Table 1 shows the maximum, minimum, and average prices paid per liter of water in fiscal years 2003 and 2004 transactions in our database.

The purchase for Baghdad in Table 1 was for 64 pallets of bottled water, which under our assumptions, equates to 110,592 half-liter bottles, or 55,296 liters. If the Baghdad CCO had been able to obtain this water for the price paid at Al Jaber, he or she would have saved more than $53K. Of course, the majority of the cost for the Baghdad purchase may be attributable to the challenges of delivering into that location.

While price information can be a powerful tool for CCOs, additional information about the relative performance of suppliers and other factors related to meeting requirements, such as the urgency, transportation needs, or security threats, would be helpful in interpreting such comparisons.

## Recommendations

In this article, we have described the construction of a database of CCO purchases supporting Air Force activities in OIF during fiscal years 2003 and 2004. We have demonstrated how this database can be a powerful analytic tool to inform and support policy decisions and initiatives for CCO staffing and training, combat support planning, and sharing lessons within the theater.

Based on our experience creating the database and analyzing the CCO data for OIF, we recommend the Air Force (and the Department of Defense more broadly) establish a standardized methodology for collecting contingency contracting data on an ongoing basis to facilitate planning and policy decisions for future contingencies.

To facilitate the types of analyses illustrated here in a timely way, the Air Force needs to systematically gather contingency contracting data on an ongoing basis. To be most useful, the CCO data system must make it possible to quickly access detailed descriptions of individual transactions, as well as aggregate those transactions according to categories of purchases, types of

| Category | Maximum | Minimum | Average |
|---|---|---|---|
| Price per liter ($) | 1.08 | 0.12 | 0.38 |
| Date | March 2004 | June 2003 | |
| Location | Baghdad | Al Jaber | |

**Table 1. Range of Prices CCOs Paid per Liter of Drinking Water, FY03 and FY04**

contract vehicles used, locations of purchases, suppliers dealt with, and so forth.

Table 2 contains our recommendations on the types of data that would be most useful to collect. These recommendations encompass data about the transactions themselves, as well as supplemental information about the activities supported by individual purchasing organizations and the relevant supply bases, that would enhance the types of analyses illustrated in this article and provide a basis for interpreting their results.

We understand the complex and austere conditions in which CCOs often operate. Additionally, we do not propose to overburden these hard-working individuals with new reporting requirements. We do suggest a standardized automated system for transaction-specific data that could be either virtually connected to a master database or regularly downloaded into such a database as a means of recording and cataloging purchases.[20] Such a system should also include an easy method both for categorizing purchases across a wide range of commodities and services and for identifying suppliers in a standardized way. For example, drop-down menus with category options and supplier name options from which to choose would make it easier for CCOs to identify these in a consistent manner. Contingency contracting representatives and logistics planners should work in concert to develop the database, ensuring that one standardized system will satisfy the requirements of both organizations.

The Air Force is in the process of reviewing current contracting organizations, including those overseas, to determine what future organizations should look like. In addition, the Air Force is actively engaged in discussions about how to improve the effectiveness and efficiency of contracting in a Joint contingency environment, in which forces from different military branches are collocated and are operating together. The analytic capabilities recommended in this article as well as the corresponding RAND monograph[21] can provide key inputs to these important organizational and operational decisions.

**Notes**

1. This article is based on the RAND monograph *Contingency Contracting Purchases for Operation Iraqi Freedom (Unrestricted Version)*, MG-559/1-AF, 2008. We thank our RAND colleague Mike Neumann for his help creating this short article.
2. George A. Cahlink, "Send in the Contractors," *Air Force Magazine*, Vol 86, No 1, [Online] Available: http://www.afa.org/magazine/jan2003/0103contract.asp, January 2003.

| TYPE OF DATA | EXPLANATION |
|---|---|
| **Individual Transactions** | **Data to be Entered by Purchasing CCO** |
| Purchasing organization | Organization that purchases the goods or services |
| CCO | Individual responsible for the transaction |
| Recipient | Organization or location that benefited from the purchase, if different from the purchasing organization (such as base that benefited from a RED HORSE repair project) |
| Text description | Description of full range of goods and services purchased through the transaction |
| Units | Number of goods purchased or period of time for which service is to be provided; break out according to types of goods or services covered within the transaction |
| Purchase category | General class(es) of goods or services purchased; break out according to types of goods or services covered within the transaction |
| Price | Price paid for the goods and services; when multiple goods and services are purchased within a single transaction, prices should be broken out by type |
| Supplier | Firm that provides the goods and services |
| Location of supplier | Identifies whether supplier is a local firm, regional firm, or other |
| Transaction ID | Unique identifier for the transaction, such as contract number |
| Payment mechanism | GPC or contract |
| Type of contract | For contracts, type of contract, such as BPA, Form SF44 |
| Date of request | Date on which purchasing organization received the formal request for goods and services |
| Date of payment | Date on which supplier was paid |
| Date of delivery | Date on which goods were delivered or services began |
| Comments | Any explanatory comments CCO deems useful |
| **Activities Supported by Purchasing Organizations** | **Supplemental Data Needed to Explain Purchasing Trends (will vary over time)** |
| Population | Number of personnel supported by the purchasing organization |
| Mission activity | Description of mission activity supported by the purchasing organization's transactions (number and types of aircraft, special operations) |
| Responsibility for base operating support | Service branch responsible for providing base operating support for the location |
| Infrastructure | Number of buildings, acres supported by the purchasing organization |
| Condition of infrastructure | Condition of infrastructure supported by the purchasing organization, particularly for new locations |
| Outlook | Plans for the purchasing organization (temporary operating location) |
| Supply base | Supplemental data to facilitate improved purchasing over time |
| Supplier ratings | Performance ratings of suppliers (perhaps only key suppliers) based on, for example, the quality of goods and services, reliability, and ease of working relationship |

**Table 2. Recommended Data to Be Collected on an Ongoing Basis**

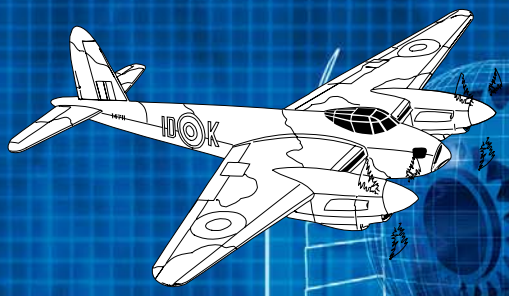
3. Frank Camm and Victoria A. Greenfield, *How Should the Army Use Contractors on the Battlefield? Assessing Comparative Risk in Sourcing Decisions*, Santa Monica, CA: RAND Corporation, MG-296-A, 2005, [Online] Available: http://www.rand.org/pubs/monographs/MG296, as of 7 February 2008.
4. Congressional Budget Office, *Logistics Support for Deployed Military Forces*, Washington, DC, [Online] Available: http://www.cbo.gov/ftpdocs/67xx/doc6794/10-20-MilitaryLogisticsSupport.pdf, October 2005, as of 7 February 2008.
5. *Air Force Federal Acquisition Regulation Supplement*, Appendix CC, paragraph CC-102, 14 March 2007.
6. In most cases, these databases represent all available data on CCO purchases at the identified locations. However, seven of these purchasing organizations recorded some or all of their contract transactions during this period in a centralized electronic database called the BQ system, rather than in the financial management spreadsheets. (The BQ system is the US Air Force's standard base-level general accounting and finance system. Its structure and use are described in DFAS [2000].) Although we were given information about the dollar amount of purchases recorded in BQ, the BQ data do not provide detailed descriptions of these purchases. In addition, we do not know the number of transactions associated with the dollars in the BQ system. Because data for these locations are incomplete, encompassing only GPC expenditures in some cases, we are unable to include them in some of the analyses in this article.
7. As part of the process, we reviewed and corrected several variables, including dates associated with each purchase and information related to contractors.
8. BPA contracts are used to satisfy anticipated recurring requirements for goods or services. They are designed to reduce transaction costs and speed up the procurement process "by establishing *charge accounts* with qualified sources of supply" (Air Force Audit Agency, 2004). The contracts specify the range of goods and services covered by the agreement, price lists, total dollar limits, and time limits. Contracting officers (or other authorized and trained personnel) can then place *calls* against those agreements to meet specific user requirements that fall within the bounds of the agreements.
9. See Footnote 6. In many of the detailed analyses presented in this article, we exclude seven organizations for which we have only partial contracting information; those excluded are Al Dhafra, Al Jaber, Al Udeid, Ali Al Salem, CAOC, Prince Sultan Air Base, and Seeb.
10. In many cases, the description of a purchase clearly fits into only one category. Other transactions included purchases of more than one disparate item or items that were ambiguously described and might, because of the use of key words in the program, fit into more than one category. For example, the text description might include a laptop computer (computer equipment) and a printer (office supplies and equipment), or the purchase may be described as a *desk for chapel* which could be interpreted by the computer program as furniture (the desk) or MWR (the chapel). The *single category* portion of the horizontal bars in Figure 2 shows obligations that clearly belonged in only one category; the *multiple categories* portion shows obligations for transactions that could also be assigned to other categories.
11. Such information would need to be dynamic due to the fluid nature of wartime operations.
12. We cannot list firm names here due to operational security considerations.
13. Typical deployments increased from 3 months to 4 months during our data timeframe, fiscal years 2003 and 2004.
14. *Air Force Federal Acquisition Regulation Supplement*, Appendix CC, paragraph CC-102.
15. AFI 10-401, *Air Force Operations Planning and Execution*, 25 April 2005.
16. James Roloff, *Contingency Contracting: A Handbook for the Air Force CCO*, Maxwell AFB, AL: Air Force Logistics Management Agency, February 2003. [Online] Available: http://www.aflma.hq.af.mil/lgj/contingency%20Contracting%20Mar03_corrections.pdf. In 2007 the AFLMA released a new handbook entiled *Contingency Contracting: A Joint Handbook*.
17. Defense Acquisition University, *2006 Defense Acquisition University Catalog*, Ft Belvoir, VA: DAU Press, October 2005. The course CON 234 (Contingency Contracting) is designed to help develop "skills for contracting support provided to Joint Forces across the full spectrum of military operations" (DAU, 2005, 36). The Defense Acquisition University was updating its contingency contracting curriculum at the time of our research.
18. GlobalSecurity.org, *Silver Flag*, [Online] Available: http://www.globalsecurity.org/military/ops/silver-flag.htm., last updated August 21, 2005. The Silver Flag exercises provide civil engineers, services, and other support personnel training on building and maintaining bare bases in deployed locations.
19. One or more contracts with regional providers that could easily distribute water to multiple locations would reduce the need for airlift.
20. Since the beginning of our study, USCENTAF Contracting and the USCENTAF Comptroller have introduced tools to address some of the data difficulties encountered in our analyses.
21. Laura H.Baldwin, John A. Ausink, Nancy F. Campbell, John G. Drew, and Charles Robert Roll, Jr, *Contingency Contracting Purchases for Operation Iraqi Freedom* (Unrestricted Version), Santa Monica, CA: RAND Corporation, MG-559/1-AF, 2008.

## Napoleon and Logistics Capacity

It should be recognized, however, that the worst shortages were experienced during the first 2 weeks of the advance (that is, precisely the period for which Napoleon had made his most careful and extensive preparations) and that the situation gradually improved afterwards. Also, the *Grande Armee's* problems were at all times, including the retreat from Moscow, largely due to bad discipline. This, of course, was itself partly due to logistics shortages. However, the fact remains that those units with commanders who were strict disciplinarians (for example, Davout's) consistently did better than the rest, while the Guard even managed to keep such good order that, far from running away, the inhabitants enthusiastically welcomed it. Nor is it true, as is so often maintained, that the country as a whole was too poor to support an army. Writing from Drissa early in July, Murat—operating as he was in an area which Pfuel had selected for the erection of his fortified camp precisely because it was supposed to be without resources—informed Napoleon that while the region around was tolerably well provided it would be possible to exploit it only after a proper administration was set up and an end put to the troop's marauding.

That the *Grande Armee* suffered enormous losses during its march to Moscow is true, as is the fact that hunger and its consequences—desertion and disease—played a large part in causing these losses. It would, however, be unwise to attribute this solely to the problems of supply. The need to protect enormously long lines of communication and to leave garrisons behind and the effect of distance *per se* were also factors of major importance. As regards the army's materiel losses, there is reason to believe much, if not most, of the equipment abandoned on the way to Moscow was later retrieved. In 1812, Napoleon's main force marched 600 miles, fought two major battles (at Smolensk and at Borodino) on the way, and still had a third of its number left when entering Moscow. In 1870, as in 1914, the Germans, operating over incomparably smaller distances, in very rich country and supported by a supply organization that became the model for all subsequent conquerors, reached Paris and the Marne respectively with only about half of their effectiveness. Compared with these performances, excellent as they were, the French Army of 1812, for all its supposedly worthless service of supply, did not do too badly.

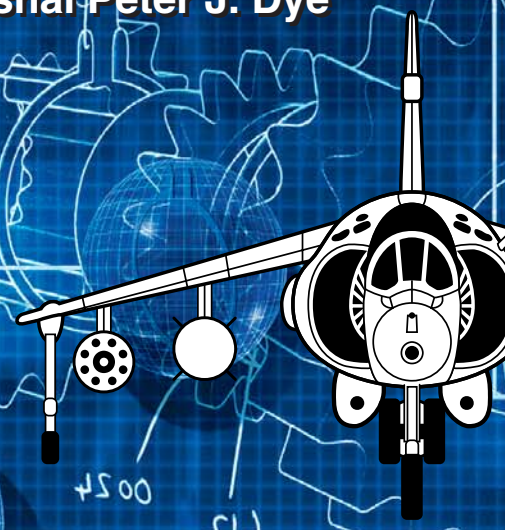
Martin van Crevald, *Supplying War*

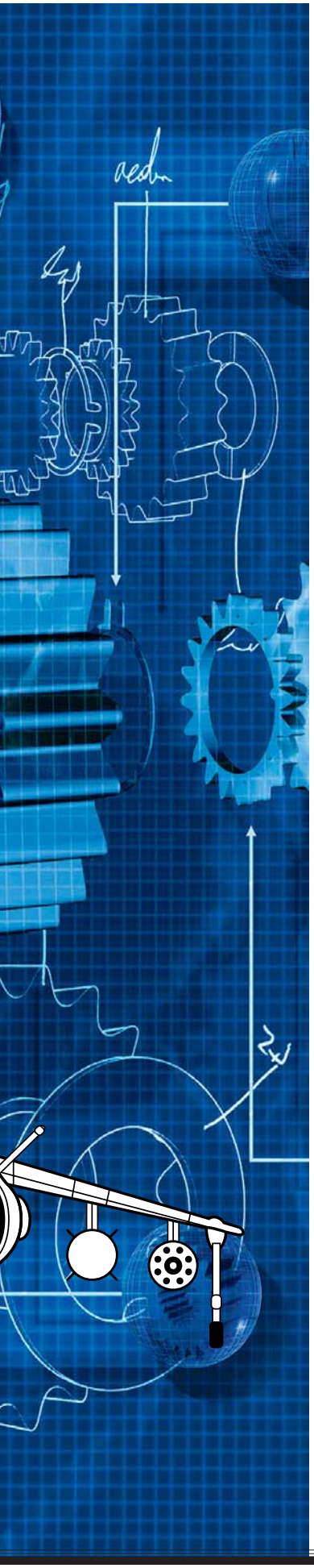


# Sustaining Airpower

## Influence of Logistics on RAF Doctrine

Air Vice-Marshal Peter J. Dye





## Introduction

In 1942, Sir Frederick Sykes, the first commander of the Royal Flying Corps (RFC), and later chief of the Air Staff, briefly outlined how the motto, *Per Ardua ad Astra* (Through Adversity to the Stars), had been selected. Although he noted that some thought it bad Latin, he did not choose to elaborate on why it was the *best possible choice*.[1] For Sykes and his contemporaries, the reasons would have been self-evident. The RFC had emerged in the face of institutional hostility, interservice rivalry, political indifference, and significant technical and environmental challenges. The struggle to master the air had exacted a heavy price. The ethereal (the heavens) had been gained through human (mortal) effort. But, there was perhaps an even deeper message—the paradox that was the aspirational nature of airpower and the laborious, sometimes mundane and frequently complex arrangements needed to support military aviation. Thus, while the bravery and dedication of those individuals who helped to create the RFC was not in question, it was evident that the freedom of the skies (and the boundless military potential they offered) was in stark contrast to the fragility (often literal) of powered flight.

This article explores how the question of sustainability has influenced British thinking on airpower. It explores the often-troubled relationship between support activities, particularly logistics, and the delivery of military capability. The article also touches on organisational and cultural issues, and considers how current paradigms may change with the increasing focus on expeditionary warfare and the development of network-enabled capability.

## Sustainability and Logistics

Logistics and sustainability are not the same thing, although there is sometimes an implication that they are. Strictly speaking, sustainability is the "ability of a force to maintain the necessary level of combat power for the duration required to sustain its objective."[2] Logistics, as the science of planning and carrying out the movement and maintenance of forces, clearly contributes to sustainability, but then so do training, intelligence, planning, and a wide range of other support or enabling activities that are certainly not embraced by the term *logistics*.

Sustainability is now properly regarded as a *principle of war* and, while logistics activities are hugely important in contributing to this core capability, they are subordinate to this end, together with the associated support strategies and organisational arrangements.

## Enabler or Impediment?

Military aircraft spend much of their working lives parked comfortably on the ground, protected from the very elements that they supposedly conquered at the turn of the twentieth century. It is not just gravity that keeps them there. The cost, complexity, and effort needed to sustain military aviation are considerable. Air forces have learned how to manage these activities by focusing on process and organisation, but there remains a suspicion that the logistician is as much an impediment as an enabler in the delivery of airpower. For example, does the supply chain drive the machine forward or drag it back? Current sentiment seems to prefer the latter perspective. The popular press certainly seems unable to employ the word *logistics* without the juxtaposition of *failure*, *shortage,* or *crisis*.

These views are neatly encapsulated in Hoffman Nickerson's observation that "*Airpower is a thunderbolt, launched from an eggshell, invisibly tethered to a base.*"[3] Dramatic effect is balanced by a sense of fragility while still leaving one to wonder whether the tether should be viewed as an umbilical or as a brake.

## Organisational Egg or Doctrinal Chicken?

To address the question of how sustainability has influenced British thinking about airpower we need first to confront the conundrum of what came first, the doctrinal chicken or the organisational egg? The widely used Doctrinal Development Model suggests that the process is best seen as a continuous loop, linking doctrine, output, feedback, and input. While this may be an entirely adequate concept,

# Article Highlights

**The logistics systems deployed by the RAF in both World Wars, and throughout the Cold War, were more than effective—they were winning solutions. These successes should be built on while seeking better ways to meet today's needs. Caution and a degree of humility are called for rather than a relentless dash for the new and untested.**

Royal Air Force (RAF) organizational structures and their associated processes continue to reflect the arrangements developed during the Second World War. The emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the RAF for nearly 90 years.

Air Vice Marshal Peter J. Dye postulates that expeditionary warfare and network enabled capability may be about to shift this particular paradigm. *The End-to-End Logistic Study*, now known as the Logistic Transformation Programme (LTP), and continuing work on station (base) structures offer the prospect of a significant change in the way the RAF is organized. Expenditure on logistic support and on the procurement of aviation and aviation-related equipment continues to represent a significant proportion of the UK defense budget.

According to Dye, the RAF will see fewer uniformed support staff with some functions no longer carried out at station level—and many no longer under the control of the station commander. The four lines of maintenance and repair seen in the RAF for over 50 years will disappear. The effect will be to dilute the status of the station in the overall organization with a greater emphasis on force elements as the RAF's center of gravity. Dye goes on to note that the RAF may need to *unpick* the Binbrook model. The difficulty will be to sustain ethos with the RAF logistics community while creating a more agile and adaptable organization. The basic building block in the new construct may well be the squadron, if not the flight, rather than the station.

The logistic problems faced by the RAF in Iraq are less about quantity and quality, and more about availability. The continuing concern about the inability in the RAF to track individual items, and the debate it does beg the question of what came first? My personal view is that logistics processes have so dominated the delivery of airpower that doctrine has largely followed in their wake. This is as true today as it was when the Royal Air Force (RAF) was created.

## The First World War

On the morning of 7 April 1918, with the airfield at La Gorgue shrouded in heavy fog and the German army advancing, Major Chris Draper ordered the burning of all 16 Sopwith Camel fighters belonging to No 208 Squadron, RAF. Two days later, the squadron had relocated to Serny, over 20 miles to the west, and was actively engaged in the continuous air operations that sought to halt the German march offensive before it could threaten the channel ports. As the squadron commander later recalled, "It says a lot for the supply depots that we got our full complement of 20 new machines within 48 hours."[4]

This small incident, in a long and intensive war, provides some indication of the scale and effectiveness of the logistics system that underpinned the British air effort on the Western Front. The value of the machines burnt at La Gorgue represented £5M at today's prices, yet new aircraft were available almost immediately, as were the technical personnel, ground equipment, spares, fuel, ammunition, vehicles, tools, repair facilities, and hangarage needed to support a frontline squadron. [5]

The First World War and its aftermath largely shaped the twenty-first century. In scale and intensity it was quite different from any other war previously fought. It was also a conflict in which technology dominated events to an unparalleled degree. John Terraine has observed that "the Great War was from the beginning the greatest war of technical innovation ever fought," adding that modern wars had become - as a war of masses with modern weapons sustained by modern mass production - "a matter of organisation and specialist skills in all the complex areas of logistics."[6]

It is arguable that the most complex logistics challenge was faced by the air services as they sought to realize the potential of airpower. Over recent years there has been a gradual recognition of the immense and sophisticated efforts needed to sustain the Western Front, as part of a more balanced and dispassionate analysis. The air war has not attracted the same level of interest, let alone controversy, even though it presaged the great air offensives of the Second World War. In fact, there has been a remarkable lack of debate about how, in a matter of a few years, a pre-war novelty was turned into a weapon capable of influencing the course of battles and ultimately war itself.

Between 1914 and 1918 the air arms of all the major belligerents, with the exception of Turkey, underwent a revolutionary transformation, but none more so than the British Air Services. By the Armistice, the RAF possessed 22,171 aircraft and boasted a total strength of 274,494 personnel compared to the RFC and Royal Naval Air Service combined strength of 270 aircraft and 2,073 personnel on the outbreak of war.[7] The RAF also possessed, according to the author of a post-war study, the most fully developed system of aviation supply amongst the allies.[8]

There is some danger, however, in focusing just on the gross number of aircraft. It masks a fundamental characteristic of airpower—the high ratio of support to operational activities. If

the frontline squadrons were the RAF's cutting edge of the spear, the shaft represented the greater part of the weapon. Of the 22,171 total aircraft, just 6,740 were assigned to operational duties (including the Western Front, home defence and antisubmarine activities). However, only 2,896 could be regarded as effective (13 percent of those on charge)—the remainder being held in store or under repair intheatre. At any one time, a further 10 to 15 percent were unserviceable, leaving just 2,500 aircraft to be employed on active operations. While much of the difference is explained by the need to hold significant reserves against attrition, the number of operational aircraft was unquestionably modest compared to the total inventory (see Figure 1).[9] The scale of the resources needed to sustain this frontline (equivalent to some 200 squadrons in 1918) was unprecedented. Indeed, the national effort was substantially larger than the total uniformed strength of 274,494 implies. When the civilian labour involved in aircraft and aeroengine production, provision of spares and repair is taken into account, the number of personnel required rises to around 630,000 (including trainees, instructors, and support staffs).[10]

By the Armistice, the total cost to the nation, in materiel and human terms, amounted to the equivalent of £200M per year, or 4 percent of the United Kingdom's gross domestic product (GDP). Daily expenditure on the RAF had reached over £0.5M, or 7 percent of Britain's total daily war expenditure (see Figure 2). This was set to rise still further with some £165M of outstanding aviation orders, more than half the production commitments of the Ministry of Munitions, at the time of the Armistice.

The result of this huge investment was the production each month of an average of 4,000 aircraft, 3,900 aeroengines (including those repaired or rebuilt), 1,200 pilots, and 3,000 other ranks. Without this effort, average monthly losses of 2,200 aircraft and 3,000 aeroengines (written off and damaged), and some 800 to 900 pilot casualties would have rapidly curtailed operations.

The logistics system embracing these varied activities had few, if any, parallels in history. By the Armistice, the RAF's technical inventory comprised more than 50,000 separate line items. No business ever had to manage a stock holding of this size or complexity—a challenge made all the more difficult by the delicate nature of much of the equipment and spares involved, rapid obsolescence, and high modification rates.

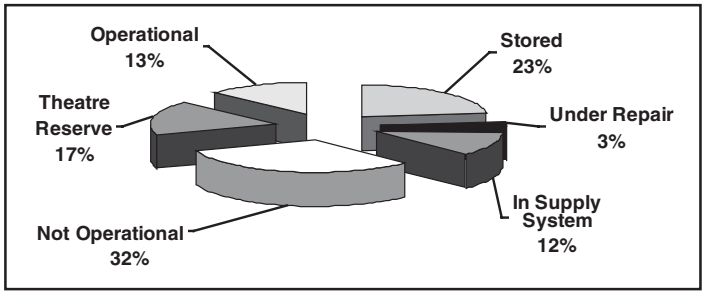



**Figure 1. RAF Aircraft Dispositions November 1918**

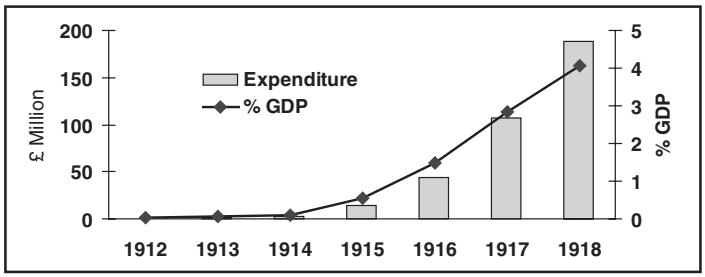



**Figure 2. Aviation Expenditure 1912-1918**

# Article Highlights

about *precision-guided* logistics, presage fundamental changes in the way that supply chains and logistics will be managed in the future.

Dye believes it likely that the RAF will gradually see a transition from a supply chain, built around a hierarchy of organizations, to a distributed network that can respond rapidly to changes in demand.

Dye warns that we must be cautious about what can be quickly achieved. He notes the RAF has toyed with serial number item tracking for at least 30 years and has a vast inventory, support processes, and policies tied to legacy weapons systems. Much as the RAF might wish to move from supporting platforms to supporting military effect, there is a limit to what can be done with our older assets.

The distinguishing characteristics of aviation logistics, as compared to defense logistics in general, are likely to diminish with time as all military equipment becomes more complex and support systems more sophisticated and interdependent.

As warfare moves from the industrial age to the information age, there will be fundamental change in the nature of logistics. Success will be measured by the adaptability of the support organization rather than by its scale or scope. If nothing else, this threatens to transform the relationship between airpower and sustainability that has held sway for nearly 90 years. However, no matter how much logistic processes are transformed, there will continue to be a tension between efficiency and effectiveness. A just-in-time philosophy built around a responsive and agile supply pipeline, a minimum deployment footprint, and extensive host nation support, may not always provide the resilience needed to sustain military capability.

**Editors Note:** British English vice American English spelling has been retained in this article.

## Article Acronyms

**GDP** - Gross Domestic Product
**LTP** - Logistic Transformation Programme
**MAP** - Ministry of Aircraft Production
**RAF** - Royal Air Force
**RFC** - Royal Flying Corps
**RUSI** - Royal United Services Institute
**UK** - United Kingdom

## Organisational Implications

The First World War demonstrated that sustaining an effective air force required significant economic and industrial power allied to a large and complex support organisation. It is not surprising, therefore, to find that the level of increase in resources committed to the air services was significantly greater than to the Army (see Figure 3). Trenchard's strategy of the *relentless and incessant offensive*[11] was only tenable because the necessary human and material resources were made available.

It was known before the war that the arrangements needed to support military aviation possessed quite distinct characteristics. Sefton Brancker described, in June 1914, how the difficulties of maintenance were sometimes lost sight of, and that the fragility of aircraft, the need for repair and large quantities of spares, together with the difficulty of supply meant that "only a small proportion of the aeroplanes in the field will be fit to take to the air at any given moment."[12] In fact, sustainability was a major consideration in the decision to standardise on the squadron as the basic organisational building block for the RFC and, ultimately, for the RAF.[13]

Wastage rates were high as a result of accidents and low reliability, as much as from enemy action. This demanded a constant stream of replacement aircraft and aircrew. The disparity between new production and supply, particularly in aeroengines, meant that salvage, repair, and maintenance made a significant contribution to sustainability. Obsolescence, design and manufacturing shortcomings, and shortages in critical equipment meant that a high level of modification and rework had to be undertaken in the field. A wide range of special equipment, tools, and a myriad of individual parts and components needed to be readily available to the frontline squadrons to support these activities, as well as routine maintenance—under the constant threat of a short-notice move. The result was an extensive ground organisation, employing large numbers of skilled and semi-skilled personnel, underpinned by a supply chain that stretched from the frontline, via the repair depots and air parks, to the factories at home.

Aircraft and their component parts largely populated the supply pipeline, together with a constant flow of technical information, spares, equipment, and personnel. Unlike traditional military logistics systems, it was not dominated by a one way flow of consumables but by scarce, high value items that moved to and from the frontline in a constant cycle of replacement, salvage, and repair.[14] As a result, noncombatants greatly outnumbered combatants. This was no subtle shift in the balance of roles, but a steep change in the *teeth-to-tail* ratio. Thus, of the 51,000 RAF uniformed personnel serving in France by November 1918, only 8 percent were classed as combatants (pilots, observers, air gunners, and so forth) while the majority, some 29,000 (57 percent) were technicians. By comparison, 896,000 personnel (65 percent) of the British Army were classed as combatants (see Figure 4).

The other defining feature was the balance of expenditure between personnel and equipment. During the course of the war over 50,000 aircraft were delivered to the British Air Services, of which only 36 percent remained on charge by the Armistice (see Figure 5). In 1918, squadron frontline establishments were replaced on average every 2 months. Notwithstanding the importance of repair and salvage in helping to recycle aircraft, aeroengines, and components, huge sums had to be committed to sustain the frontline. Throughout the war, between 50 and 60 percent of the budget allocated to the British Air Services was expended on equipment (see Figure 6).

In summary, the RAF was created around a system of interlinked and interdependent logistics activities that moved high value materiel continuously backwards and forwards at a tempo determined by daily attrition, combat operations, and technological advances—John Frederick Charles Fuller's *constant tactical factor*.[15] It was a system unprecedented in both scale and intensity. Moreover, the efficiency and effectiveness of these arrangements directly governed the degree to which air power's potential could be realised. In this sense, logistics acted as air power's *lifeline* and, in so doing, established a dependency that has lasted for 90 years.

**Thus, the expansion of the RAF from 1934 onward, although overtly dominated by the need to match the Luftwaffe's frontline, also sought to provide the resilience needed to fight a modern war.**

## The Creation of the Royal Air Force

Concerns about sustainability also provided the catalyst for the creation of the RAF. The political imperative for an offensive air strategy and secure home defence could only be realised by the deployment of substantial national resources and closer military-industrial cooperation. The Joint War Air Committee formed early in 1916 (and the subsequent Air Board) were direct responses to the squabbling between the Services over the supply of aircraft and engines and the self-evident need to set priorities for the allocation of aeronautical material. Inasmuch as this established a favourable environment for an independent air arm, it may be claimed that the RAF was created as a structural solution to the wartime problem of maintaining an adequate supply of aircraft and aviation personnel.

## Strategic Bombing

The creation of the Air Board and the more effective direction of production under the Ministry of Munitions saw significant improvements in sustainability. Indeed, the expectation of a surplus in aircraft and aeroengine production by the end of 1917 led directly to the creation of the Independent Force intended to attack military and strategic targets in Germany. In the event, the full increase in production was not achieved but by then the Independent Force had been created to employ the notional surplus of men and machines. Eventually, some 10 squadrons

out of the planned 40 were formed. Even if the numbers employed fell short of those planned, and the operational results lacklustre, the experience had a profound influence on RAF doctrine. Thus, an optimistic view of sustainability in 1917 led to the RAF's first steps in strategic bombing and, ultimately, to the Second World War's combined bomber offensive.

## The First World War Legacy

I have laboured the point about the interdependence of airpower and logistics because the nascent RAF, at an organisational level, was designed around the support arrangements needed to sustain operations in war. While there was no *lessons identified* process, the central role of logistics in the delivery of airpower was widely recognised and understood. Air Commodore Robert Brooke-Popham, lecturing shortly after the end of the First World War, stated that,

> It is, therefore, of the highest importance that spare machines and spare parts of every sort shall be instantly available. This means large base depots and an efficient channel of supply between depots and squadrons and on the sound working of this supply system the efficiency of the Air Force in any theatre of war very largely depends.[16]

In the years that followed, Trenchard sought to construct (literally) an air force worthy of the name. The RAF Cadet College and the RAF Apprentice School were the most obvious elements in this strategy, but they were part of a wider programme that enshrined a logistics-centric view of airpower based on a substantial investment in support activities. Speaking in 1944, Trenchard recalled that,

> When we originally formed the Air Force in those days we were told that we were spending all our money on bricks and mortar, and on ground staff and ground personnel. In fact … it was called *the Ground Force* and I believe I was myself once described as *General Officer Commanding Ground Force*.[17]

The importance attached to organisation and process was reflected in the RAF War Manual. "Under the modern conditions in which fighting services are called upon to operate, victory inclines to the force which is most thoroughly and efficiently organized."[18] A recurrent theme in pre-war planning was the high wastage that war would bring. In a paper on *Some Problems of a Technical Service* read at the Royal United Services Institute in 1934 (with Air Marshal Sir Robert Brooke-Popham in the chair), the author stated that the average life of an aircraft in war would be 2 months—based on First World War experience—and that large reserves and high production rates were essential, underpinned by long preparation and skilled repair personnel.[19]

Thus, the expansion of the RAF from 1934 onward, although overtly dominated by the need to match the Luftwaffe's frontline, also sought to provide the resilience needed to fight a modern war. This was not a policy of quantity over quality, although there was some criticism (from even within the Service) that there were dangers in pursuing the mass-production methods employed in the First World War.[20] By and large, new technology was successfully introduced while substantially increasing the size of the frontline and the supporting reserves, consuming some 36 percent of the rearmament budget in the process (see Figure 7).

The result was a vast array of depots and maintenance units, specialising in storage, repair, salvage, and armament, that had no parallel in the Luftwaffe where the doctrine of a short war negated the need for investment on a similar scale. Thus, over a period of 20 years the home-based RAF had been transformed from what was largely a training organisation based around grass airfields and temporary accommodations to a permanent system of stations and maintenance units that would provide the fighting platform for both defensive and offensive action.

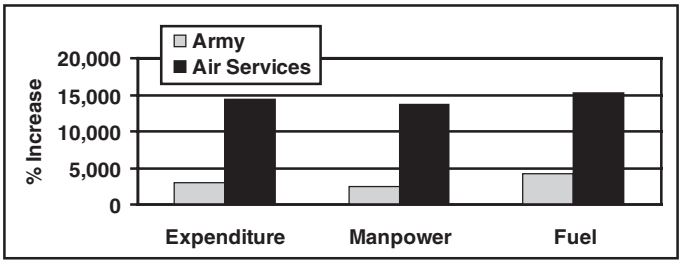



**Figure 3. Relative Increase in Military Resources 1914–1918**

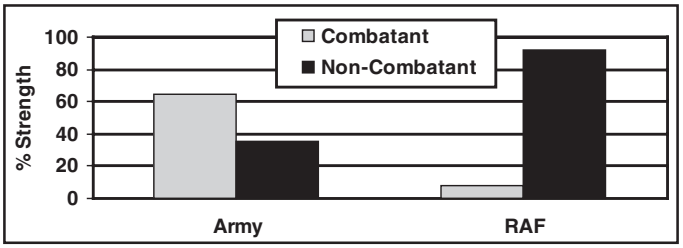



**Figure 4. Relative Proportion of Combatants – France 1918**

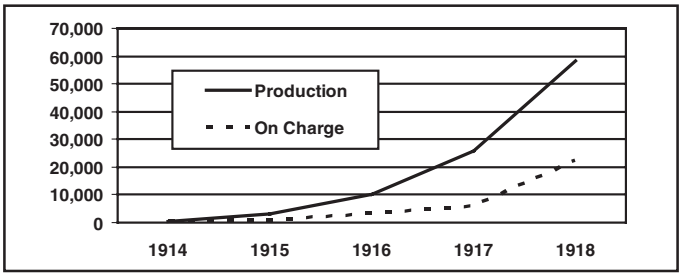



**Figure 5. Aircraft on Charge – British Air Services 1914–1918**

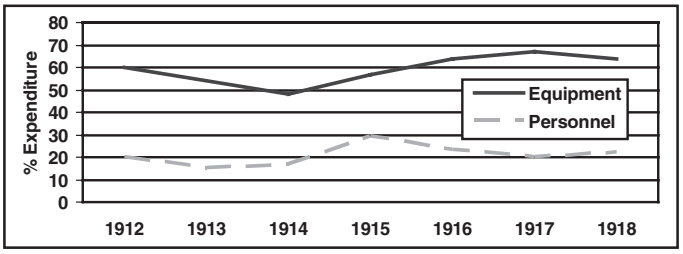



**Figure 6. Air Service Expenditure by Category**

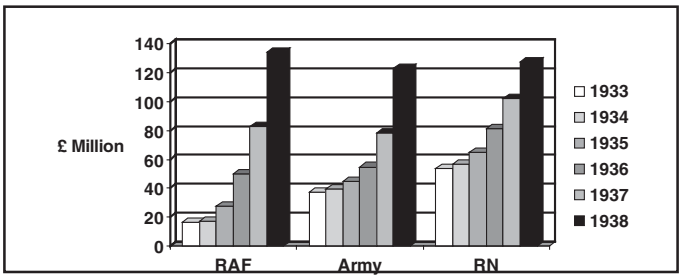



**Figure 7. Comparison of Annual Defence Expenditure 1933–1938**

The impact of this change was deeper than might be imagined, as it touched on that most intangible of issues—ethos and culture. The station became not only the key element in the exercise of command and control, but also a microcosm of the Service itself. In this sense, the station occupied a very different position to the garrison, shore establishment, or dockyard. This was reflected, if nothing else, in the status and authority of the station commander enshrined in King's Regulations and the Air Force Act. While squadrons were the fighting arm, the majority of RAF personnel served on the strength of a station, undertaking the wide range of support activities needed to keep aircraft flying.

To shed some light on the differences between the Services it is interesting to note that in both 1918 and 1945, the RAF possessed more airfields and support units in the UK than frontline squadrons (see Figure 8). The same could certainly not be said about the number of ports versus warships or the number of garrisons versus regiments.

## The Second World War

This massive investment in sustainability came into its own during the Battle of Britain. The disparity in approach to logistics issues between the respective air forces became clearer as the campaign progressed. Fighter Command maintained (if not enhanced) its frontline numbers during the battle, while the Luftwaffe declined in strength as availability fell and aircraft and pilot wastage rose beyond the supply of replacements.

Notwithstanding heavy losses (fighter wastage reached over 50 percent per month during 1940), RAF reserves continued to grow throughout the war. The average number of aircraft in storage awaiting issue to the Metropolitan Air Force rose steadily, reaching over 10,000 by 1944, where it remained until the end of the war (see Figure 9).[21]

While some commentators have criticised the Allies for employing their significant economic and industrial capacity to support a military strategy built on brute force, the attritional nature of modern warfare and the pace of technological change allowed little choice in the matter.[22] While it is true that the RAF and the United States Army Air Force relied on high production rates, an extensive supply system, and comprehensive support arrangements to compensate for high operational wastage, it is also true that these resources were available as a result of careful and detailed planning, driven by what the First World War had demonstrated about sustainability and airpower. Both air forces had long recognised that warfare in an industrial age demanded supply on an industrial scale.

The closest parallel to Trenchard's *incessant offensive*, the combined bomber offensive was founded on a massive industrial effort and a worldwide training programme that produced sufficient heavy bombers and crews to maintain operations in the face of desperate attrition. During the course of the war, Bomber Command lost over 74,000 aircrew (either killed, wounded, or prisoners of war) and 12,330 aircraft to operational and nonoperational causes[23] against a frontline strength that reached 4,384 aircraft by May 1945. During the course of 1944, 12,295 heavy bombers were delivered to Bomber Command—3,285 repaired, and the remainder new production—a wastage rate of 950 percent.[24] [25]

The manufacture, modification, and repair of aircraft had, by 1943, become Britain's largest industrial operation.[26] From 1939 to 1945 over 131,000 aircraft were produced, compared to 55,000 in the First World War. However, the complexity and weight were a magnitude greater, as was the cost. In 1943 alone, expenditure on new production by the Ministry of Aircraft Production (MAP) totalled some £800M (equivalent to £83B at today's prices).[27] Total wartime expenditure on aircraft and related equipment exceeded £3,75M (£385B) while the capital cost expended in creating the necessary industrial capacity amounted to £350M (£36B). Overall, more than 36 percent of wartime defence expenditure (around 20 percent of the UK GDP) was committed to the RAF, of which some 40 to 50 percent comprised equipment costs.[28]

At its peak (in the summer of 1944), more than 3 million personnel were employed in aviation-related activities, including 1.7 million in MAP and over 1 million in uniform (see Figure 10). This compares to a total employment of 630,000 in the First World War. In fact, the remorseless consumption of labour by the RAF and the MAP soon became unsustainable and had to be scaled back in favour of the Army and other critical war industries.

Nightly attacks by hundreds of heavy bombers against targets in Germany and Occupied Europe also demanded a sound and secure infrastructure. From 1939 to 1945, the airfield construction programme was Britain's largest civil engineering project since the building of the railways in the nineteenth century. A total of 444 new airfields were constructed in the UK at a cost of £200M (£20B) and employed over 300,000 men.[29] Approximately 1,800 airfields were constructed worldwide over the same period.[30] Each airfield consumed a vast range and quantity of resources, ranging from hardcore, concrete and bitumen for the runways, taxiways, dispersals and roads, to wood, bricks, and steel for the technical

**RAF organisational structures and their associated processes continue to reflect the arrangements developed during the Second World War. Indeed, the emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the Service for nearly 90 years.**

accommodation and hangars. Stations—and there were 59 distinct designs dependant on functional role[31]—also required dedicated utilities and waste disposal, as well as extensive storage facilities and domestic accommodation. In 1942 over £145M (£16B) was spent on works for the RAF compared to just £4M in 1935, at the start of the expansion programme. [32]

By the end of the war, the RAF frontline comprised some 500 squadrons and 9,250 aircraft.[33] The total inventory was in excess of 55,000 airframes with over 10,000 in store or in reserve in the UK alone, with a further 1,900 under or awaiting repair. New aircraft were being delivered at the rate of some 2,000 per month. As a result, the teeth to tail ratio was remarkably similar to that found nearly 25 years earlier—1 to 6 in 1945, and 1 to 8 in 1918 (see Figure 11).

## Post-War Organisational Models

While the scale of the effort expended on the RAF during the Second World War was impressive, every brick laid and ton of concrete poured, anchored the Service's future to its infrastructure. Demobilisation and substantial reductions in manpower and estate did not alter the emphasis on the station as the RAF's centre of gravity. The Cold War, and the decreasing importance of expeditionary operations, enshrined this perspective, assisted by further infrastructure investment to accommodate heavier and faster aircraft as well as new roles, such as nuclear deterrence.

The early post-war years also saw a succession of studies and trials designed to determine optimum working patterns and organisational structures. This work had commenced during the war with research into improving manpower utilisation and aircraft availability through *planned flying* and *planned servicing*.[34] The focus was very much about treating operational output as a mechanistic process that could be improved using work study methodologies.

A similar effort was expended on determining best practice in the deployment of station manpower and appropriate station structures. An experimental station organisation was tested at RAF Tuddenham in 1946.[35] One of the aims was to relieve the station commander of a mass of administrative work. It was also hoped to weld station personnel into a single unit and thereby foster a good station loyalty and morale. A related study at RAF Binbrook also took place in 1946. It is perhaps the more famous of the two trials. From this latter study emerged the *standard* three-wing station structure (executive, technical, and flying) that has been the foundation of RAF station structures to this day.[36] The subsequent *Benson Experiment*, conducted in 1956, sought to address a number of detailed process and procedural issues largely related to personnel conditions and group cohesion.[37]

The effort put into these studies and related work on squadron structures and alternative models for the management of maintenance (centralised, autonomous and semi-autonomous), was tacit recognition that the station was central to how the RAF went about its business. They might also be seen as *legitimising* the role of sustainability in determining the organisation and management of the Service.

While the Cold War reigned, and with expeditionary warfare a remote prospect, there was little incentive to change structures and certainly no challenge to the station's primacy in the organisational hierarchy. Command of a station remained the aspiration of every ambitious officer and was widely seen as a critical test of an individual's ability and career potential. The station also loomed large in RAF culture, providing the social and domestic focus for the wider Service community. It is hardly surprising, therefore, that attempts to modify the basic station structure or to develop innovative administrative and operational arrangements, such as the Bentwaters/Woodbridge *Twin-Base Concept* in 1991, made little headway.

## Expeditionary Warfare

RAF organisational structures and their associated processes continue to reflect the arrangements developed during the Second World War. Indeed, the emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the Service for nearly 90 years.

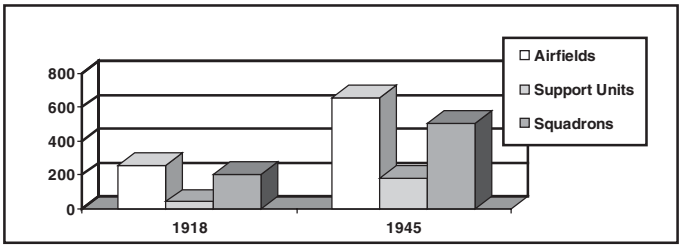



**Figure 8. UK Airfields and Support Units**

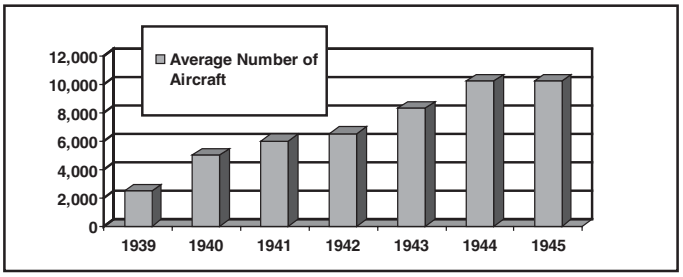



**Figure 9. Aircraft In Storage 1939–1945**

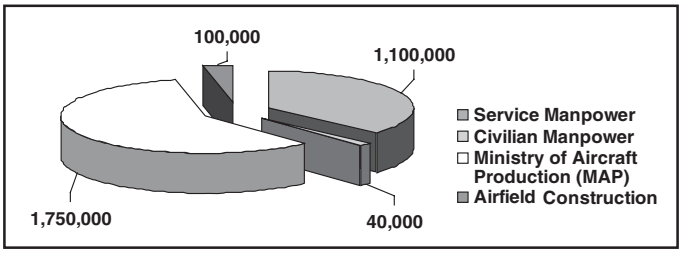



**Figure 10. British Aviation Manpower July 1944**

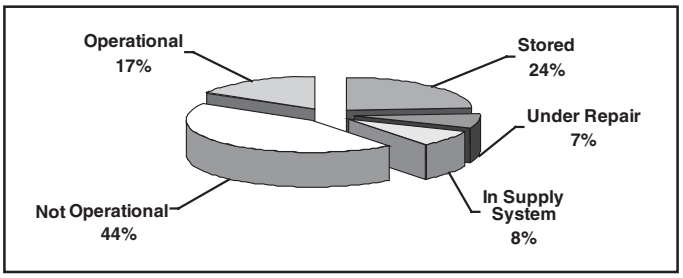



**Figure 11. RAF Aircraft Dispositions May 1945**

Expeditionary warfare and network enabled capability may be about to shift this particular paradigm. The *End-to-End Logistic Study*,[38] now known as the Logistic Transformation Programme (LTP), and continuing work on station structures offer the prospect of a significant change in the way the RAF is organised. Expenditure on aviation logistic support and on the procurement of aviation and aviation-related equipment continues to represent a significant proportion of the defence budget. History teaches us that this is not an unprecedented position, but, while it may prove challenging to reduce substantially the cost of sustaining airpower, the way the frontline is supported will certainly alter in the next few years.

We will see fewer uniformed support staff with some functions no longer carried out at station level—and many no longer under the control of the station commander. The four lines of maintenance and repair that have held good for over 50 years will disappear. The effect will be to dilute the status of the station in the overall organisation with a greater emphasis on force elements as the RAF's centre of gravity. We may therefore need to *unpick* the Binbrook model. The difficulty will be to sustain Service ethos while creating a more agile and adaptable organisation. The basic building block in the new construct may well be the squadron, if not the flight, rather than the station.

There is no doubt that the *brute force* approach to logistics is no longer viable. This approach is unaffordable, and does not provide the flexibility and responsiveness that network-centric warfare demands. The logistics problems faced in Iraq were less about quantity and quality, and more about availability. The continuing concern about the inability to track individual items, and the debate about *precision-guided* logistics, presage fundamental changes in the way that supply chains and logistics will be managed in the future.[39]

It is likely that we will gradually see a transition from a supply chain, built around a hierarchy of organisations, to a distributed network that can respond rapidly to changes in demand. The LTP echoes this approach although it does not (yet) offer the self-synchronisation needed to provide a *sense and respond* network.

We need to be cautious about what can be quickly achieved. After all, the RAF has toyed with serial number item tracking for at least 30 years. We also have a vast inventory, support processes and policies tied to legacy weapons systems. Much as we might wish to move from supporting platforms to supporting military effect, there is a limit to what can be done with our older assets.

Although I have stressed the distinguishing characteristics of aviation logistics, as compared to defence logistics in general, these differences are likely to diminish with time as all military equipment becomes more complex and support systems more sophisticated and interdependent.[40]

As warfare moves from the industrial age to the information age, we will inevitably see a change in the nature of logistics. Success will be measured by the adaptability of the support organisation rather than by its scale or scope. If nothing else, this threatens to transform the relationship between airpower and sustainability that has held sway for nearly 90 years.

But, however much we succeed in transforming our logistics processes, there will continue to be a tension between efficiency and effectiveness. A just-in-time philosophy built around a responsive and agile supply pipeline, a minimum deployment footprint, and extensive host nation support, may not always provide the resilience needed to sustain military capability.

A final word of warning, we must avoid the temptation of believing our predecessors to have been somehow less imaginative or more hidebound than we like to think we are. The logistics systems deployed by the RAF in both World Wars, and throughout the Cold War, were more than effective—they were winning solutions. We should build on these successes while seeking better ways to meet today's needs. To my mind, caution and a degree of humility are called for rather than a relentless dash for the new and untested. Paradigms are rarely *shifted* overnight.

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### Notes

1. Sir Frederick Sykes, *From Many Angles*, London: Harrap & Co., 1942, 97.
2. NATO AAP-6, *NATO Glossary of Terms and Definitions,* 2006, 158.
3. Richard L. Olson, et al., *Gulf War Air Power Survey, Volume 3, Logistics Support*, Washington, DC, 1993, 77.
4. Chris Draper, *The Mad Major*, Letchworth: Aero Publishers, 1962.

5. At 2002 prices using historic gross domestic product.(A Sopwith Camel and its Clerget engine were priced at some £1,700 – *War In The Air*, Volume 6, Appendix XXXII, Oxford University Press, 1935).
6. John Terraine, *Essays on Leadership and War*, Western Frontier Association, Berkshire: Reading Press, 1998, 27-35.
7. H.A. Jones, *The War in the Air*, Oxford: Clarendon Press, 1935. These figures are drawn from Appendix XXXI. Although the data is undoubtedly correct and is supported by extensive and detailed tables, the purpose seems more to provide a flattering comparison with the overall strength of the German and French Air Services (20,000 and 15,342 aircraft respectively).
8. National Archives/Public Record Office, AIR 2/151/290308/20, United Kingdom.
9. A similar position was to be found on the Western Front where, at the time of the Armistice, out of a total 3,522 aircraft on charge, some 1,799 were held by the frontline squadrons with 1,576 in a serviceable condition.
10. National Archives/Public Record Office, AIR 1/686/21/13/2252, United Kingdom, contains a detailed breakdown of this analysis.
11. National Archives/Public Record Office, AIR 1/522/16/12/5, United Kingdom.
12. Sefton Brancker, "The Aeroplane In War," *Flight*, 12 Jun 1914, 632-633.
13. Sir Frederick Sykes, 95.
14. This sort of activity is now described as *reverse logistics*, to distinguish it from *traditional logistics*!
15. Brian Holden-Reid, *J.F.C. Fuller: Military Thinker*, London: Macmillan, 1987, 137-138.
16. Robert Brooke-Popham, "The Air Force," *RUSI Journal*, 1920, 43-70.
17. Hansard House of Lords Proceedings, 1944.
18. Air Publication 1301, *Royal Air Force War Manual, Part II,* Air Ministry, 1939.
19. Wg Cdr GW Williamson, "Some Problems of a Technical Service," *RUSI Journal*, No 513, February 1934, 780-800.
20. John Terraine, *The Right of the Line*, London: Hodder and Stoughton, 1985, 86. Thus Ludlow-Hewitt wrote in 1939 that "I am convinced that the idea that we will be able to fight the next war with mass-produced pilots and crews as we did in the last war is fallacious"
21. National Archives/Public Record Office, AVIA 46/149, *The Storage and Distribution of Aircraft*.
22. John Ellis, *Brute Force*, London: Andre Deutch, 1989, 527.
23. Bill Chorley, *Bomber Command Losses - 1945*, Midland Counties Publications, 1998, 187.
24. National Archives/Public Record Office, AVIA 46/168, *The Repair and Maintenance of Aircraft 1939-1945*.
25. Richard Overy, *Bomber Command*, London: HarperCollins, 1997, 211. Bomber Command's frontline in January 1944 comprised 1,298 heavy bombers. Operational losses in 1944 amounted to just over 3,000 heavy bombers.
26. Correlli Barnett, *The Audit of War*, London: Macmillan, 1986, 145-146.
27. This and subsequent comparisons are based on historic UK GDP.
28. Terraine, 602.
29. Robin Higham, "Bases of Air Strategy," *Airlife*, 1998, 23.
30. Higham, 19.
31. Air Ministry, *Works,* Air Historical Branch, 1956, 112-122.
32. A Cat 'A' airfield cost some £2M to complete.
33. Air Ministry, *Maintenance,* Air Historical Branch, 1954. Average serviceability across all commands in 1945 was approximately 80 percent.
34. Harrop, "Planning for Economy," *Air Clues*, April 1948, 15-20.
35. National Archives/Public Record Office, AIR 20/6617, *Trials of Experimental Station Organisation*.
36. National Archives/Public Record Office AIR 20/6616, *Trial of Experimental Station and Squadron Organisation.*
37. AHB IIR/60/7/13, *The Benson Experiment*.
38. The End-to-End (E2E) Study reviewed aircraft support arrangements and recommended reducing the traditional 4 lines of maintenance to 2 (Forward and Depth), concentrating support facilities at logistics centres of gravity.
39. *Aviation Week & Space Technology*, 12 Jan 2004, 45-46.
40. *Ibid.* The US M-1 Abrams tank has been described as "the world's fastest strategically immobile tank" because of its huge logistics tail.

## The Themes of US Military Logistics

From a historical perspective, ten major themes stand out in modern US military logistics.

- The tendency to neglect logistics in peacetime and expand hastily to respond to military situations or conflict.
- The increasing importance of logistics in terms of strategy and tactics. Since the turn of the century, logistical considerations increasingly have dominated both the formulation and execution of strategy and tactics.
- The growth in both complexity and scale of logistics in the 20th century. Rapid advances in technology and the speed and lethality associated with modern warfare have increased both the complexity and scale of logistics support.
- The need for cooperative logistics to support allied or coalition warfare. Virtually every war involving US forces since World War I has involved providing or, in some cases, receiving logistics support from allies or coalition partners. In peacetime, there has been an increasing reliance on host-nation support and burden sharing.
- Increasing specialization in logistics. The demands of modern warfare have increased the level of specialization among support forces.
- The growing tooth-to-tail ratio and logistics footprint issues associated with modern warfare. Modern, complex, mechanized, and technologically sophisticated military forces, capable of operating in every conceivable worldwide environment, require that a significant portion, if not the majority of it, be dedicated to providing logistics support to a relatively small operational component. At odds with this is the need to reduce the logistics footprint in order to achieve the rapid project of military power.
- The increasing number of civilians needed to provide adequate logistics support to military forces. Two subthemes dominate this area: first, unlike the first half of the 20th century, less reliance on the use of uniformed military logistics personnel and, second, the increasing importance of civilians in senior management positions.
- The centralization of logistics planning functions and a parallel effort to increase efficiency by organizing along functional rather than commodity lines.
- The application of civilian business processes and just-in-time delivery principles, coupled with the elimination of large stocks of spares.
- Competitive sourcing and privatization initiatives that replace traditional military logistics support with support from the private business sector.

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# DLA Forward Stocking: An Economic Analysis

**Captain John A. Flory, USAF**
**Douglas A. Blazer, PhD, LMI**
**Gale Bowman, USAF**

## 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

## 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**

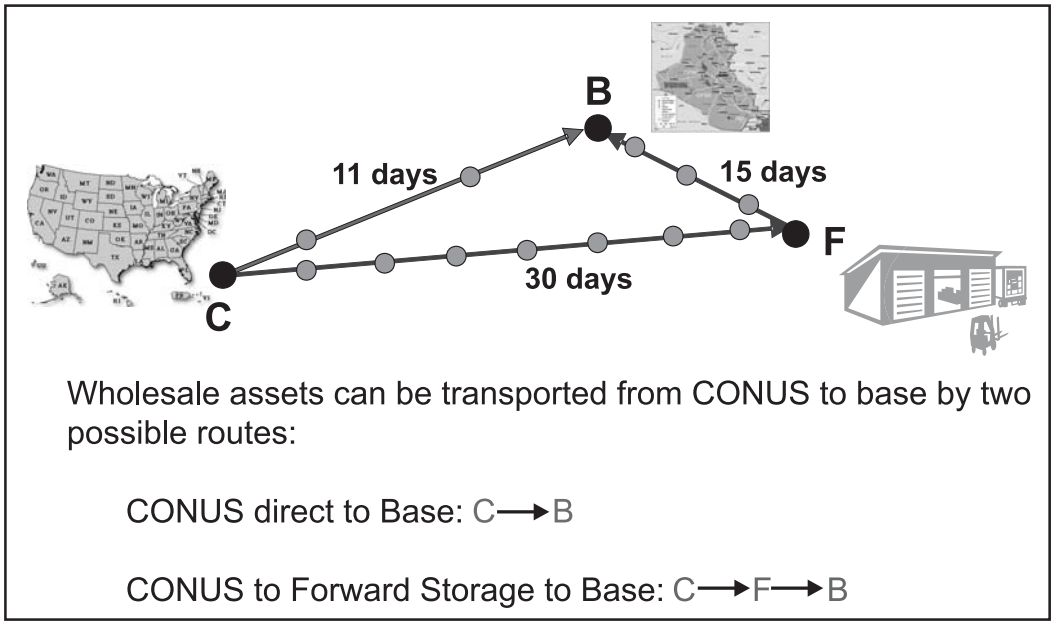



**Figure 1. Forward Stocking Model**

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.

### 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**

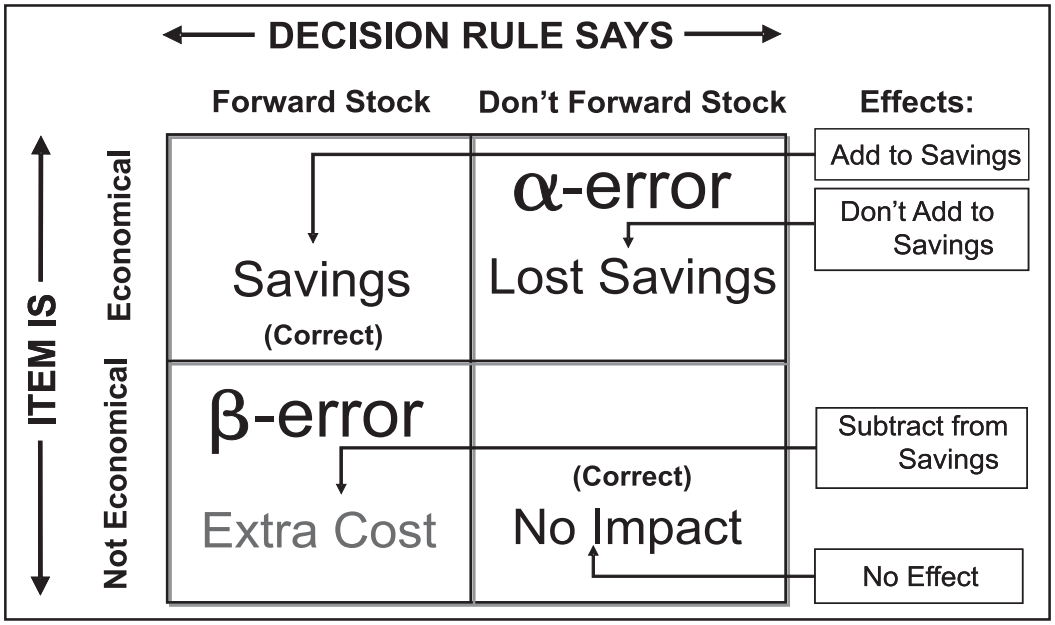



**Figure 2. Performance Outcomes**

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.

| | 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)**

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.

### 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.

### 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.


## Military Logistics and the Warfighter

I think we can all agree there is a relationship between the function of military logistics and the warfighter. What is that relationship, and is it correctly defined? In the early 1960s, there was a stated relationship between logistics and the weapons systems: military logistics "support"' the weapons system. At that time, the subject of military logistics was fairly new and, with little ongoing research, very slow in providing greater *understanding* about it. Therefore, during that period, this definition of relationship seemed appropriate. It was not until the late 1970s that several advocates of military logistics came to the realization that logistics *support* of the weapon system was actually creating and sustaining warfighting capability. This warfighting capability was provided to the combat forces in the form of continuing availability of operational weapon systems (the tools of war). This new awareness set up another definition of the relationship: *military logistics creates and sustains warfighting capability.* While many heard the words, few realized their implications.

The level of warfighting capability that logistics provides the combat forces determines the extent to which war can be waged. This, in turn, limits and shapes how the war will be waged. Warfighting capability is *embedded* in the design of all weapon systems. Advancing technology increases speed, range, maneuverability, ceiling, and firepower, all of which provide more lethal and accurately guided munitions, stealth, and other offensive and defensive warfighting capabilities. They will be embedded into the design of future weapon systems. It is the weapon systems that contain the warfighting capability of military forces. The strength of military forces is no longer measured by the number of men *under arms*. Today, military forces are measured by the number—and warfighting capabilities—of their weapon systems. The Department of Defense has yet to adequately define and manage the total logistics environment (those activities and resources required to create and sustain warfighting capability). While it is said that armies travel on their stomachs, what is usually left unsaid is they perform on the basis of their logistics competency.

Today, as most of you are aware, we have another, more recently defined relationship: *military logistics supports the warfighter*. We know military logistics creates and sustains warfighting capability. We can assume the warfighter fights wars. It would, therefore, appear reasonable to suggest that in order for one to be a warfighter (a pilot in this case) he or she must have the capability to wage war. While weapon systems are designed and created to wage war, people are not. Therefore, in order to become warfighters, pilots must be provided with some level or amount of warfighting capability. I would submit that by providing the pilot with an operational weapon system, which allows him or her to utilize its warfighting capability, *military logistics creates the warfighter*. It does not *support* the warfighter; it *creates* the warfighter. This transformation occurs when a checked-out pilot starts the engine. At that point, the pilot is in control of the weapon system and its warfighting capability. The pilot is now the warfighter. Without the warfighting capability, which the weapons system provides, a pilot is a pilot.

Military logistics creates and sustains warfighting capability; by doing so, military logistics creates and sustains the warfighter.

Colonel Fred Gluck, USAF, Retired

>>>>

# Logistics for the 21st Century

## Deployment Distribution Operations Center, Quick Fix or Long-Term Solution?

**Lieutenant Colonel Patrick Mordente, USAF**
**Paul Needham, PhD**
**Colonel Theodore P. Ogren, USAF**

*Our logistics professionals' achievements in OIF [Operation Iraqi Freedom] were especially spectacular in light of the fact that we supported a 21st century battlefield with a mid-20th century logistics structure.*

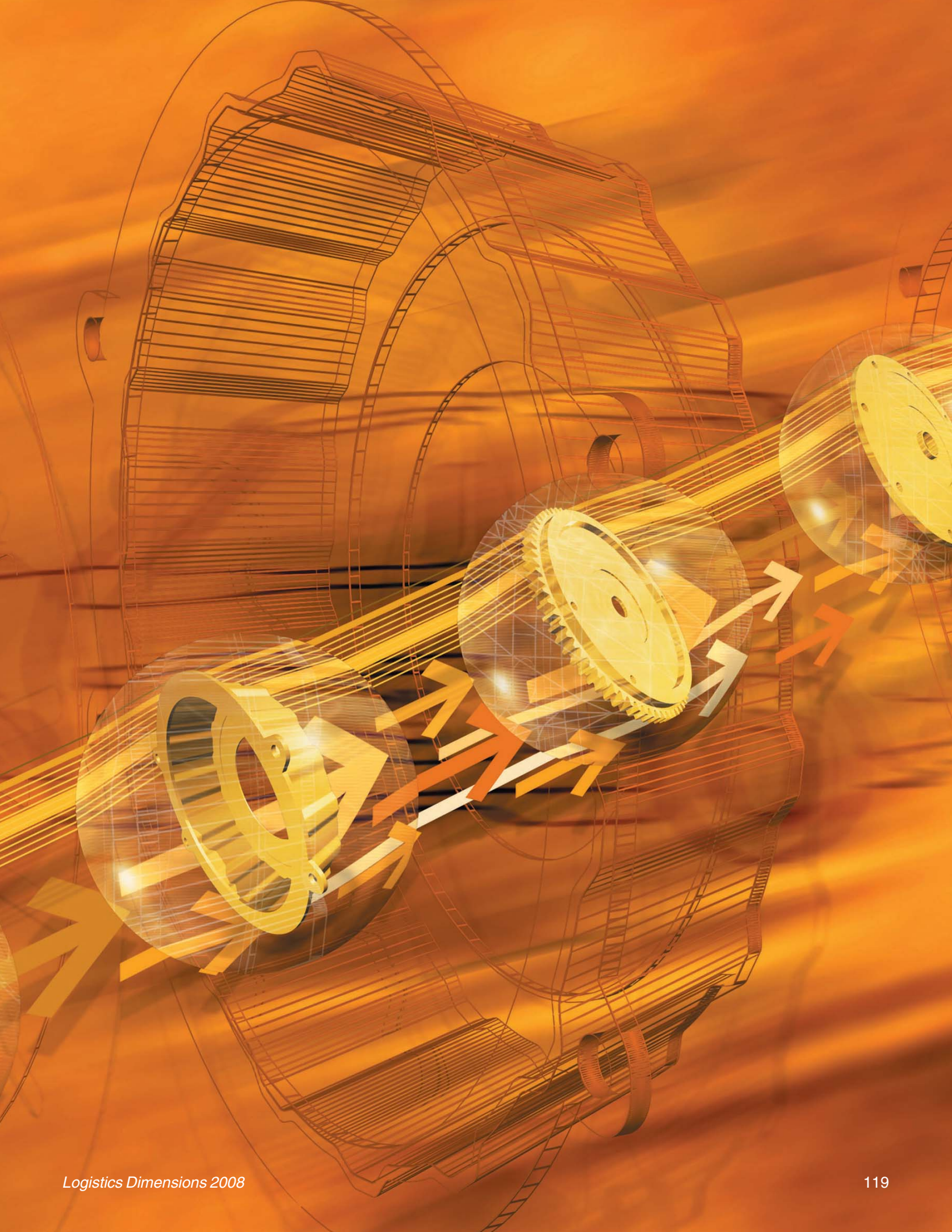
**—Lt Gen C. V. Christianson, *Baghram, February 2002***

February 11, 2002 was a cold night in Baghram, Afghanistan as Lieutenant Colonel Ken Rozelsky recalls.[1] He had just stepped off an Air Force C-130 cargo plane with his eight-man advance team from the 682nd Air Support Operations Squadron (ASOS), which he commanded. Lieutenant Colonel Rozelsky's squadron, a combat communications support unit, had been requested by the 10th Mountain Division and 3rd Army in support of the Joint task force (JTF) Headquarters for Operation Enduring Freedom. His flight into Baghram was the end of a 7 hour flight and the last leg of a long journey which had started several days earlier at Shaw Air Force Base, South Carolina. For most, this would mark the end of a journey and the start of combat operations, but for Lieutenant Colonel Rozelsky it was just the beginning of many challenges with the Joint military logistics system.

Colonel Rozelsky's first obstacle was trying to get approval for his advance team to begin movement towards the Afghanistan theater. The United States Army had requested his unit be deployed into theater due to its unique communications capability and a valid requirement to support the JTF Headquarters. However, as the request for forces (RFF) made its way through the approval system, it was repeatedly denied at the Air Staff level. With little time left to meet the required delivery date, Colonel Rozelsky was ordered to use unit funds and move into theater by any means possible. Ironically, the first leg of the journey to Afghanistan for the 682nd ASOS was supported by the German airline company Lufthansa. Once on the ground in Kuwait, Colonel Rozelsky was able to schedule further movement into Baghram on an Air Force C-130. Three weeks later the RFF was approved.

Colonel Rozelsky began setting up operations as the rest of his team filtered into theater. With little infrastructure and no established supply lines or procedures, Colonel Rozelsky was forced to become self sufficient. He quickly created his own supply line, consisting of a team of airmen positioned in Kuwait, to purchase much needed operating supplies for the squadron. His supply team consisted of five Airmen—one with an Impact card to make the purchase and four to package, ship, and guard the supplies enroute to Baghram.

Lieutenant Colonel Rozelsky's story highlights a military logistics system that was unable to respond rapidly to unit movement and sustainment requirements. Ultimately, it left Colonel Rozelsky, a supply chain customer and combat squadron commander, thinking that there had to be a better way of doing business.



## Introduction

*Who lin'd himself with hope, Eating the air on promise of supply.*

**—William Shakespeare's King Henry IV Part I[2]**

Since the dawn of warfare, the ability to execute a successful campaign has rested squarely on the foundation of military logistics. It is from a well established logistical foundation, one capable of rapid response, flexibility, and ability to meet demand, that combatant commanders have the capacity to execute freedom of maneuver and strike at the enemy with continuous force. It is in the role of meeting the warfighter's logistical requirements that one begins to realize that tacticians are responsible for fighting the battle; but it is the logistician that ensures the battle can be fought. An appreciation for the importance and complexity of the relationship between warfighter and logistician is reflected in the remarks by United States Transportation Command (USTRANSCOM) commander, General John Handy, "Good warfighters always want to know where their logistic experts are well before the battle starts and during the battle."[3] However, the US military's most recent combat and peacekeeping operations in Afghanistan and Iraq have highlighted the need for improvement in the effectiveness and efficiency of the strategic distribution process. Improvements to the strategic distribution process will require a systematic approach that tackles issues from the supply point of origin to the final destination point in theater, and the retrograde of both parts and equipment back to the US mainland. The deployment distribution operations center (DDOC), a Joint logistics initiative by the distribution process owner USTRANSCOM, is a relatively new initiative aimed at improving Joint logistics for the combatant commander.

This article investigates the impact of United States Central Command's (USCENTCOM) DDOC on the military's deployment and distribution system. First, the study will focus the discussion by defining both the players and the processes supporting today's supply chain management as it relates to both deployment and distribution. Second, it will propose a strategic road map for the 21st century Joint logistics system in the form of a balanced scorecard. Third, it will examine the development of the current DDOC concept by defining the DDOC's current mission and organizational structure and how the DDOC concept fits into the balanced scorecard. Finally, by studying key metrics provided by the DDOC's after-action reviews (AAR) and the Logistical Support Agency (LOGSA), it will determine what improvements, if any, were made to the Joint logistics system. Ultimately, this article will answer the question as to whether the implementation of the DDOC into USCENTCOM's theater substantially changed the Joint logistical process or whether the application of logistical expertise simply focused on key problem areas.

**Acronyms**

AAR - After Action Reviews
ASOS - Air Support Operations Squadron
AOR - Area of Responsibility
CDDOC - CENTCOM Deployment Distribution Operations Center
CFLCC - Coalition Forces Land Component Command
CJTF - Combined Joint Task Force
COP - Common Operating Picture
DLA - Defense Logistics Agency
DoD - Department of Defense
DDOC - Deployment Distribution Operations Center
ERP - Enterprise Resource Planning
GAO - Government Accountability Office
ISB - Intermediate Staging Base
ITV - Intransit Visibility
JDDOC - Joint DDOC
JMC - Joint Movement Center
JOPES - Joint Operational Planning and Execution System
JTF - Joint Task Force
LOGSA - Logistical Support Agency
OIF - Operation Iraqi Freedom
RFF - Request for Forces
RSOI - Requisition and Delivery of Personnel, Equipment and Supplies
RWT - Requisition Wait Time
TAA - Tactical Assembly Area
TAV - Total Asset Visibility
TPFDD - Time-Phased Force Deployment Data
USCENTCOM - United States Central Command
USTRANSCOM - United States Transportation Command

## Defining Today's Supply Chain and its Members

When broaching the subject of supply chain management processes within an organization such as the Department of Defense (DoD), one begins to address a broad range of processes and practices that define many different aspects within the military. A basic definition of supply chain management taken from the Global Supply Chain Forum defines the term supply chain management as, "… the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders."[4] As such, the supply chain management processes of today's modern military encompasses an array of organizations within the DoD and affect business practices involving the acquisition, delivery, deployment, sustainment, and final disposition of personnel and equipment in both peacetime and combat.

When evaluating the impact of the DDOC in USCENTCOM's area of responsibility (AOR), we are primarily concerned with that portion of the supply chain that deals with the movement of personnel, equipment, and sustainment from stateside locations to final destination on the battlefield. Therefore, we are concerned with that portion of the supply chain that affects the processes in movement of personnel, equipment, and sustainment from *factory to foxhole* during combat operations. Figure 1 provides a graphical representation.

Figure 1 describes a supply chain environment that moves personnel, equipment, and sustainment through a transportation pipeline, while being supported by a data environment, in order to affect the timely and accurate delivery of requirements to a forward location or tactical assembly area (TAA) for a combatant commander's use in Joint combat operations. The ultimate goal of this process is *the right part at the right place at the right*

*time.* This figure, simple in its design, is complex in its scope. It involves both a strategic movement from the CONUS to some type of port facility or intermediate staging base (ISB) and the follow-on integration, tactical movement, into the forward battle area. It also encompasses the multitude of Joint- and Services-specific information systems and processes that are required to accomplish the requisition and delivery of personnel, equipment, and sustainment (RSOI).

The strategic movement piece involves a triad of transportation assets ranging from airlift to both sealift and prepositioned supply ships. This strategic piece is often referred to as the *strategic mobility triad* and falls under the control of USTRANSCOM with its three subcomponents of Air Mobility Command, Military Sealift Command, and the Surface Deployment and Distribution Command. The onward movement and integration within a theater of operations is accomplished through the use of tactical transportation assets including airlift, ground transportation, and waterway movement. This tactical piece represents a tactical mobility triad that exists within a theater of operation and falls under the responsibility of the combatant commander. In the case of Iraqi Freedom and Enduring Freedom, the tactical mobility triad is the responsibility of United States Central Command (USCENTCOM). However, unlike the strategic mobility triad assets that are controlled and synchronized by a single headquarters, USTRANSCOM, the authority to direct assets that support the tactical mobility triad is dispersed among functional entities at the Joint Task Force (JTF) staff level (Air Mobility Division) and echelons above Corps, as is the case with Army transportation assets. To further illustrate this point, the following quote was taken from the USCENTCOM Deployment Distribution Operations Center (CDDOC) After-Action Report, Spiral 1, dated May of 2004.

> In order to provide the synchronization of the theater for inbound and outbound cargo and passengers, CDDOC needed to have a directive authority. In its position with Coalition Forces Land Component Command (CFLCC), CDDOC did not own any transportation resources and did not exercise the directive authority that it was supposed to have. Directive authority over the transportation assets rested with the CFLCC C-4 and the 143d TRANSCOM.
>
> Recommendation: In order to have true synchronization you need to have a capability that ties the forecasted strategic flow of cargo and passengers to tactical movement. If CDDOC is supposed to represent that capability, it must have the authority to direct lift assets to accomplish this effort within the priority scheme developed by USCENTCOM J-4.[5]

This aspect of tactical level command and control has been highlighted, not to suggest that all military transportation assets should be placed under one commander; but rather, to emphasize the self-imposed complexities of the tactical mobility triad. These very same complexities were overcome in the combat air forces through the use of a Joint forces air component commander responsible for the direction, integration, and synchronization of military airborne assets through the use of an air tasking order process that provided unity of effort and domain-wide visibility for airborne assets operating within a given AOR.[6]

The complexities of the intratheater transportation system are equally matched by the multitude of processes and players involved from the tactical through strategic levels of deployment and distribution. From the start of an operation or contingency when supported and supporting relationships are defined between unified commands, until final redeployment of all military forces, an intricate series of actions is performed within the DoD to enable a combatant commander to effectively execute combat operations. The interactions that take place involve USTRANSCOM and other unified commands in the role of a supporting command, along with the Defense Logistics Agency (DLA), USCENTCOM's Joint task force, and the Services' unique sustainment systems. The processes that define deployment and distribution require all these players to form partnerships and accurately communicate information between the Joint staff, unified commanders, the Joint task force, DoD support agencies, and Service headquarters and their deployed units (to include the Reserve component). See Figure 2, Deployment and Distribution Process and Players

However, the process has been further complicated by the fact that many of the logistical business practices found within the Services are unique and stovepiped. In addition, the information management systems that support the overall process are numerous and not necessarily compatible with each other. What is obvious by this point is that data and information management and integration continue to be major challenges to deployment and distribution operations. A process change that enhances the flow of information would have a positive impact on the current system and would produce a measurable improvement in both the deployment and distribution processes.

With the transportation flow and players defined, the example of Lieutenant Colonel Rozelsky's effort to deploy the 682nd ASOS to Afghanistan and then to sustain his unit in theater stress the challenges within the deployment and distribution system.

In the case of the 682nd ASOS movement, had the deployment and distribution system worked efficiently and effectively, the supported commander (USCENTCOM), would have identified and communicated a capability requirement via the Joint Operational Planning and Execution System (JOPES), a data information management system and process. Then, in concert with the Joint staff, supporting commands and Service components, the 682nd ASOS would have been identified and

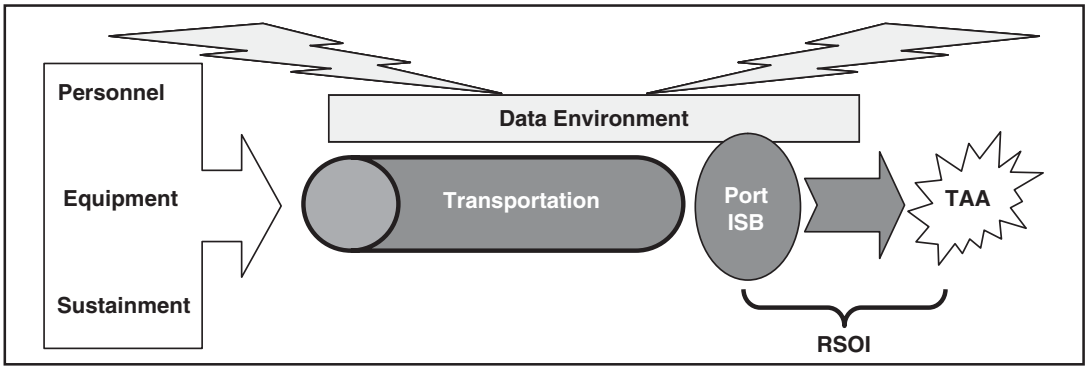



**Figure 1. Idealized Supply Chain – Factory to Foxhole**

designated for deployment. Once validated by the supported commander (USCENTCOM), the 682nd ASOS would be entered into the time-phased force deployment data (TPFDD) and scheduled for movement into theater. Current JOPES directives require that the 682nd ASOS movement be scheduled from a point of embarkation to final destination eliminating Lieutenant Colonel Rozelsky's extended wait time for onward movement and integration into Baghram, Afghanistan. Once in position, the 682nd ASOS should have been able to tap into Service-specific supply processes to meet unit sustainment requirements.

The 682nd ASOS story is just one of many and is anecdotal in nature; however, it does serve to underscore a failure in the Joint deployment and distribution process. Nonetheless, once shortcomings in a current process have been identified, but prior to initiating improvement, an organization must define the vision of what the process should be capable of performing; and ultimately, what the process should look like following improvement efforts. It is relatively easy to identify failure points in a process; it is far more difficult to define a vision that captures what the process should look like and be able to deliver. More importantly, the vision must fully integrate and shape both the processes and players into a future logistics system that meets the needs of a 21st century battlefield.

## The Future Joint Logistics System: A Balanced Scorecard[7]

When looking at today's Joint deployment and distribution process, there are ten defining gaps impacting capability.[8] First, a modern battlefield consists of operations that are widely dispersed and no longer linear in design.[9] This can become challenging when trying to sustain units spread over a wide area. Second, a nonlinear battlefield, such as Iraq, also has a significant impact on the security of main supply routes (MSRs) and requires the logistician to devote resources to protect assets.[10] Third, the US military is becoming more reliant on contractor support due to a reduction in military personnel.[11] The contractor's support is becoming intertwined with military operations, such that it is driving their presence on a nonlinear battlefield. Fourth, the US military is no longer facing the conventional warrior.[12] America's new enemy is highly adaptive and uses unconventional methods to strike at US forces. Fifth, current operations, and those for the foreseeable future, will require the US military to be Joint and work with (or integrate) with interagency and coalition forces.[13] Sixth, the days of financing combat operations through supplementals are more than likely numbered.[14] Therefore, budget pressures will continue to drive the DoD to work smarter and cheaper. Seventh, Title 10 responsibilities of the Services versus the roles given to the combatant commands (COCOMs) are at times, in direct contradiction of each other.[15] The eighth gap concerns Joint logistics functions where agencies, within the DoD, have been assigned as an executive agent for a given logistics requirement.[16] Currently, these functions have difficulty performing optimally due in part to a lack of training between affected Services. This lack of training results in the absence of a habitual relationship, and a task organization that is ad hoc in nature and done on the fly. Ninth, the current distribution process is inadequate.[17] The warfighter requirements are difficult to see, intransit visibility (ITV) is limited, and the current system is not flexible in its response to rapidly moving units. The tenth and final capabilities gap is connectivity.[18] Once units move into contact with enemy forces, they lose connectivity and requirements determination becomes difficult. At one point during Operation Iraqi Freedom, rear area support did not receive requisitions for an entire month, forcing a push system to be put into place. With the gaps in the current process now defined, the next step of defining the future logistics system can be accomplished.

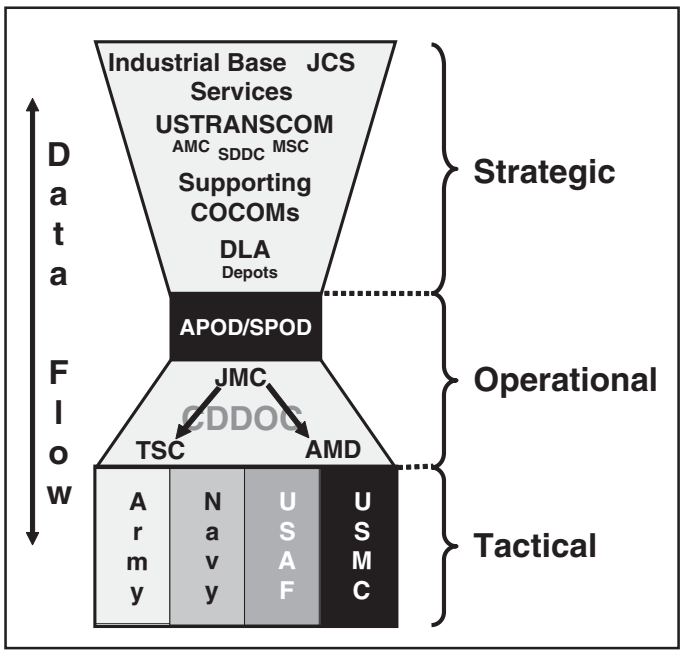



Figure 2. Deployment and Distribution Process and Players

First and foremost, a logistics system designed to meet the requirements for the 21st century battlefield must be customer-focused. The customer for a Joint logistics system is the warfighter, consisting of the combat commander and every sailor, soldier, airman, and marine located on the battlefield. When developing a strategic vision for 21st century logistics, the theme of a warfighter-focused process must be evident throughout its entire development. With that said, a good vision starts with a good foundation.

A warfighter-focused logistics system must set itself on the foundation of a learning and growth perspective[19] which includes the "priorities to create a climate that supports organizational change, innovation, and growth."[20] The four areas within this foundational perspective are organizational structure, technological improvement, professional development, and organizational policy. These four areas are interdependent and begin shaping the organization. The learning and growth perspective leads directly to the next level of an internal perspective.

As the 21st century Joint logistics system begins building upon the foundation of a learning and growth perspective, it must take an internal perspective[21] in order to set "strategic priorities for various business processes, which create customer … satisfaction."[22] This perspective can be developed under two categories, achieving operational excellence and strategic relationships.[23] In order to achieve operational excellence, the deployment and distribution system must be capable of delivering "unity of effort, domain-wide visibility, and rapid and precise response."[24] Under the category of strategic relationships,

the future system must be capable of forming a seamless process from *fort to foxhole* and build trust among the various organizations that comprise the deployment and distribution system. Both of these categories are overlaid with a necessity to accurately forecast end-user requirements, which will enhance operational excellence while building strategic relationships. The objectives of an internal perspective are enablers to the objectives from both a financial perspective[25] and customer (warfighter) perspective.[26] A financial perspective is defined as, "[t]he strategy for growth, profitability, and risk viewed from the perspective of the shareholder."[27] In this case, an argument can be made that the shareholder is not only the DoD, but the American taxpayer. The customer perspective is used to develop, "[t]he strategy for creating value and differentiation from the perspective of the customer."[28] In the case of the DoD, where the majority of logistics is internal to the organization, the emphasis should be on creating value for the warfighter.

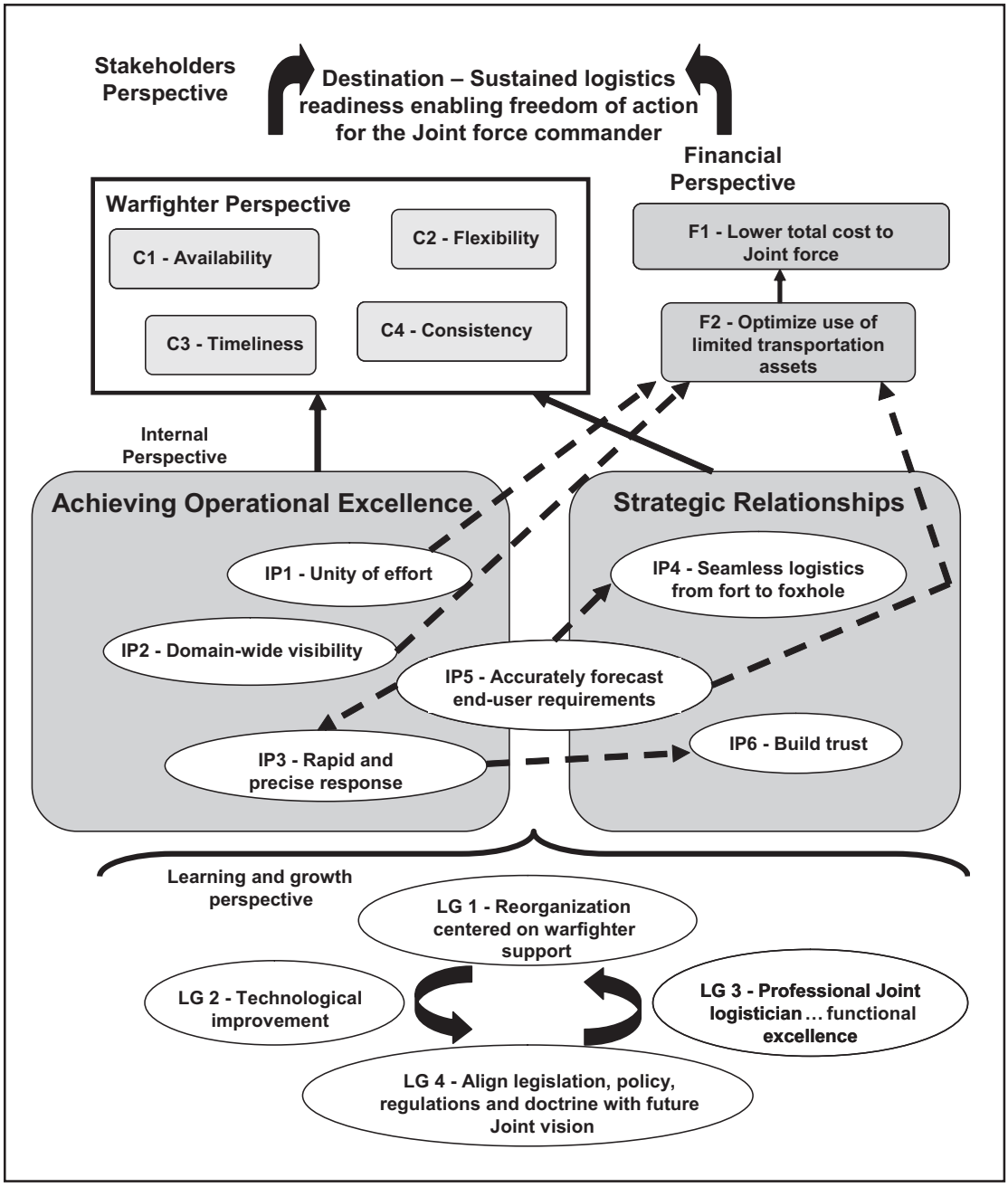



**Figure 3. 21st Century Joint Logistics Balanced Scorecard**

From a financial perspective, unity of effort coupled with both domain-wide visibility and accurate forecasting of end-user requirements will lead to the optimization of limited transportation assets. An efficient and effective use of limited transportation assets will lead to total cost (cost, resources, and money) savings for the Joint force.

Transitioning to the customer (warfighter) perspective, the overarching subcategories of achieving operational excellence and strategic relationships contribute directly to the customer's perception of the value created by a Joint logistics system. The Joint warfighter requires a logistics system that can provide availability, flexibility, timeliness and consistency. These four characteristics of a logistics system allow unhindered operations and freedom of movement and directly feed the stakeholder's perspective,[29] the final destination of a Joint logistics system designed for the 21st century.

From an overall stakeholder's perspective and vision for the future of military logistics, the deployment and distribution system must be capable of delivering, "sustained logistics readiness enabling freedom of action for the Joint force commander."[30] The concepts presented in Kaplan and Norton's book, *The Strategy-Focused Organization*, coupled with the above discussion, lead to a stakeholder's (constituent) scorecard.[31] See Figure 3[32] for the development and management of a 21st century deployment and distribution system.

## How Does the DDOC Fit In?

### DDOC Mission

As stated in the USCENTCOM AAR dated May 2004, the USCENTCOM DDOC mission was to,

> Confirm USCENTCOM deployment and distribution priorities, validate and direct CFACC intratheater airlift requirement support

to components and CJTFs, monitor and direct CFLCC intratheater surface distribution support to components and CJTFs, adjudicate identified USCENTCOM distribution and intratheater shortfalls, coordinate for additional USTRANSCOM support, provide total asset visibility (TAV) and intransit visibility (ITV) for intertheater and intratheater forces and material, and set the conditions for effective theater retrograde.[33]

Figure 2 graphically illustrates where the CDDOC fits into the overall process. The CDDOC was an effort to fill the gaps within the deployment and distribution system between the strategic, operational and tactical levels. In essence, the DDOC formed a physical enterprise resource planning (ERP) environment, vice a virtual environment, that was capable of gathering data from various information systems to enhance the overall common operating picture (COP). The requirement for a physical ERP is necessary due to the vast number of information systems required to formulate a logistics-oriented COP. In addition, the *physical* aspect of the ERP is driven by the fact that much of the data does not exist in systems that are compatible with each other; and therefore, Service and Joint skilled logisticians are required to correlate information feeds.

Future development of the JDDOC (Joint DDOC) concept will take place in each of the geographically aligned unified commands along the same conceptual design as the original CDDOC. Its purpose is:

> A Joint capability solution designed to satisfy the requirements to integrate strategic and theater deployment execution and distribution operations within each of geographic combatant commander's area of responsibility. The JDDOC, under the control, direction and auspices of the geographic combatant commander, directs, coordinates and synchronizes assigned forces' deployment and redeployment execution, and distribution operations … to enhance the combatant commander's ability to execute logistics plans with national partner support.[34]

The DDOC initiative can be used to demonstrate how a concept can be evaluated against the newly developed balanced scorecard for Joint logistics. The DDOC was a doctrinal change (LG 4) to the theater logistical process in the form of a newly developed organization centered on warfighter support (LG 1). It leveraged existing technology (LG 2) and formed a team of professional Joint logisticians (LG 3), with the intent to enhance unity of effort (IP 1) and improve both domain-wide visibility (IP 2) and rapid and precise response (IP 3) of the theater deployment and distribution system. Once established in theater, the DDOC's objective was to provide accurate (C 1), timely (C 3), and consistent (C 4) logistics to the warfighter. With improved visibility, it was also intended for the DDOC to improve the use and optimization of limited transportation assets (F 2). Finally, the ultimate goal of the DDOC is to provide, sustained logistics readiness enabling freedom of action for the Joint force commander.

## Why a DDOC?

*Upon this point a page of history is worth a volume of logic.*

**—Oliver Wendell Holmes, Jr**

As Oliver Wendell Holmes points out, history can teach us a lot. Operations Enduring Freedom and Iraqi Freedom are no exception. US forces had operated in that region in the early 1990's in Operations Desert Storm and Desert Shield. However, a recent Government Accountability Office (GAO) Report reveals that we had not learned much from the not-too-distant past. The following are quotes from the GAO report dated August 2005.

> **Operation Desert Shield and Desert Storm-1991**
>
> The deployment of combat forces to the theater of operations in advance of support units created logistical support difficulties. The military's decision to *push* enormous amounts of equipment to the theater and to deploy combat units before support units in the first 3 months of the campaign contributed to the Army's and Marine Corps' problem of limited capability to store and retrieve equipment and supplies during the initial stages of Operation Desert Storm. A small cadre of logisticians was established to receive incoming equipment, supplies, and personnel; support the combat units that were deployed; and build a logistics infrastructure in an austere environment.[35]
>
> **Operation Iraqi Freedom-2003**
>
> DoD's priority was for combat forces to move into theater first. A study suggested that distribution assets were either deleted from the deployment plan or shifted back in the deployment timeline. As a result, logistics personnel could not effectively support the increasing numbers of combat troops moving into theater. A shortage of support personnel in theater prior to and during the arrival of combat forces was reported, and those who arrived were often untrained or not skilled in the duties they were asked to perform. The shortage resulted in delays in the processing (receipt, sorting, and forwarding) of supplies, and backlogs. Contractors performing distribution functions had become overwhelmed and a Joint contractor military organization quickly evolved. As two divisions entered the theater, the need for a theater distribution center became apparent and an area in the desert was designated as a storage and cross-dock area.[36]

The GAO report cited other similar challenges during Operations Desert Storm, Desert Shield, and Iraqi Freedom. These cited similarities were categorized under the headings of limited communications (as it related to supply), limited asset visibility, misuse of shipment prioritization, shortage of ground transportation assets, and in theater distribution difficulties.[37]

Retired Army Lieutenant General William Pagonis had witnessed the events of Desert Shield and Desert Storm first hand as General Schwarzkopf's head of logistics for the USCENTCOM theater.[38] In his book *Moving Mountains*, he wrote the following:

> Why, in an era of decentralization, is integration the way to go? Because, as I see it, logistics is a field that is particularly prone to suboptimization. Our logistical mission in the Gulf was to protect and provide for our troops, and thereby aid in the liberation of Kuwait. In support of this mission, our stateside shippers made heroic efforts to stuff every Gulf-bound ship absolutely full, … meanwhile, on the receiving end, our port operators were swamped.… What was needed to resolve that conflict and avoid suboptimization was a *kingpin*—someone who could assess the imperative of each functional area and decide upon a solution that best supported the mission. In the Gulf, I was lucky enough to be selected to serve as that person. I would argue that every complex organization that is involved in materials management, handling, and distribution needs my equivalent.[39]

General Pagonis recognized the need for one logistics voice, a kingpin, setting priorities for the warfighter. He also recognized the need for a kingpin due to the many links that make up a supply chain and can lead to its weakness and cause suboptimization in the overall distribution system. The DDOC could be that one voice that sets logistics priorities for the combatant commander.

The bottom line result of the initial stages of Operation Iraqi Freedom was a theater logistics infrastructure that was slow to mature, resulting in the delay of critical logistics functions ("processing, receipt, sorting, and forwarding) of supplies, and backlogs"[40]) that then inhibited the support systems ability to provide optimal support to combat operations. As a result, USTRANSCOM, in its role as the Secretary of Defense-designated distribution process owner (DPO), in concert with USCENTCOM, DLA, and Army Materiel Command, developed the DDOC concept based upon the Joint movement center concept in order to improve the overall theater distribution system. This was an opportunity for USTRANSCOM, in concert with DLA, to move logistics professionals forward as part of the USCENTCOM organization to affect positive change to the overall deployment and distribution system.

Therefore, with an understanding of the challenges facing the deployment and distribution system, based on both historical precedence and current observations, it was time to put a DDOC type concept into action. On 18 January 2004, the USCENTCOM CDDOC began operations collocated with the JTF land component commander in Kuwait.[41] A team of 63 professionals, primarily from USTRANSCOM and the Defense Logistics Agency (DLA) brought the tactical view to the strategic players in an effort to enhance overall deployment and distribution processes within USCENTCOM's AOR.

## DDOC Objectives and Metrics

Metrics drive performance. That is because what is important to an organization is what that organization should be measuring. Therefore, when evaluating performance, the selection of metrics must be accurate, appropriate, and common to all users. That is not to say that all organizations choose the correct metrics to measure their performance. However, what is chosen to be measured, if it has not already shaped an organization or a process, soon will.

When the CDDOC arrived in theater in January of 2004, it came with four well defined objectives.[42]

- Provide total asset visibility and intransit visibility, sustainment, and retrograde (the process of recovering and returning military material and supplies to units, depots, or prepositioned stock)
- Refine theater distribution architecture in coordination with Joint staff and the Services
- Synchronize strategic and operational distribution
- Develop strategic and operational distribution performance measures

These four objectives drove key initiatives such as Single Ticket, Pure Pallet, and Purple/Green Sheeting. From these initiatives came measurements of success (metrics) such as customer wait time (CWT) on personnel during a unit's intermediate stop prior to final destination, TAV of personnel in transit, and requisition wait time (RWT) primarily on Class IX material. Following is a brief description of some of the initial programs implemented by the DDOC and the initial success experienced by those efforts.

The Single Ticket concept is the scheduling of transportation for military units from a stateside aerial port of embarkation (APOE) all the way through to the *foxhole* in one single movement piece.[43] The Single Ticket concept was not a new concept. The Joint Operation Planning and Execution System (JOPES) processes had directed that units be scheduled from point of origin to final destination. However, units moving into USCENTCOM's theater prior to the establishment of the DDOC would be scheduled only to an aerial port of debarkation (APOD), where they would await further coordination on transportation for movement to their final destination. Single Ticket began *marrying up* the strategic movement from the states with the tactical movement within theater. Just some of the highlights of success are listed below.[44]

- Unit loiter time was reduced from 72 to 30 hours.
- Over 130,000 passengers moved with an average ground time of 30 hours.
- As of December 2004, a Single Ticket Tracker was released providing units with 100 percent TAV of all booked passengers.
- During December 2004, the Single Ticket program moved Air Force AEF deployers. The result was 84.8 percent of the passengers moved in 24 hours or less.

**The Single Ticket concept is the scheduling of transportation for military units from a stateside aerial port of embarkation all the way through to the foxhole in one single movement piece.**

The results prompted the Commandant of the United States Marine Corps to state, "Tell all of your supporting staff, including your USCENTCOM DDOC and AMD friends, that they are receiving the highest compliments from the Marine Corps!"[45] As the CDDOC tackled the issues associated with troop movement, they also began looking at cargo movement and palletization, which led them to the Pure Pallet concept.

The CDDOC, in concert with US Army personnel, developed the Pure Pallet initiative to eliminate time and material loss when shippers mixed multiple end-user requirements on a single pallet. The mixed pallets required additional movement time because of the requirement for breakdown and reconfiguration at an intermediate point before continuing on to the final destination.[46] In addition, during breakdown many individual items would lose addressing information and become distressed cargo. The following is an example of suboptimization as cited by General Pagonis.

> Although the pallets moved quickly out of the DLA stateside depots, a DLA metric, the additional time required down range to reconfigure pallets, coupled with the lost material, suboptimized the overall distribution system.

Therefore, the DDOC saw a need to implement the Pure Pallet initiative. A pallet that is designated as a *Pure Pallet* has one end-user location requirement on a single pallet, thus facilitating movement to the final destination.[47] A pure pallet is built at the embarkation or depot points stateside.[48] These pure pallets are then shipped with little to no delay to their final destination.[49] For example, 98 percent of the pallets received at Ballad AB, Iraq, a high demand end-user location, are pure pallets.[50] As a result, throughput velocity was increased.[51] However, the CDDOC realized that a lack of true prioritization in cargo movement was also impacting USCENTCOM's distribution system and as a result, began implementing the Green/Purple Sheet Priority System.

Prior to implementation of the Purple/Green Sheeting Priority System, the distribution process within USCENTCOM was susceptible to a prioritization abuse by end users. The overuse of high priority designation by end users caused confusion in the system and led to truly high priority cargo being impacted by the movement of lower priority requirements. The CDDOC developed a method so that the combatant commander and Services could distinguish regular cargo from that of a higher priority cargo requirement. It was simple in design yet very effective in application. It consisted of *green* sheets, controlled by the Services, and a *purple* sheet, controlled by the combatant commander.[52] A movement requirement that was deemed a high priority by either the Services or combatant commander was designated using these sheets; and moved more quickly in response to a high priority need within theater.[53]

Both the Pure Pallet and Purple/Green Sheeting were two initiatives that focused on increasing the throughput velocity in the distribution system. A study of the data supplied by LOGSA in Figure 4 reveals a steady decline in RWT 5 months after the January 2004 stand up of the CDDOC, with the biggest decline taking place between August and September of 2004. Also, RWT values begin to hold steady at close to the expected 14-day standard by February 2005. A cross comparison of the quantity of requisitions per month shows a cyclical ordering pattern leading this researcher to conclude that the reduction in RWT was as a result of improvements and maturation in the theater distribution system, vice a reduction in the volume of requisitions. However, to assume that the DDOC is solely responsible for the reduction in RWT would be incorrect. There are several factors that must be considered when trying to determine the cause of reduction in RWT. They include the establishment of a DLA warehousing facility in Kuwait, the establishment of a theater distribution center (TDC), the eventual arrival of logistical support units into theater in sufficient quantities, and the fact that many units are on their second or third rotation in the Iraqi theater. The last two points do highlight the fact that, after 3 years, the Iraqi theater is no longer new. In other words, logistics maturation has taken place over time. Infrastructure has been built up and processes have been established. Therefore, one would expect a reduction in RWT over time due to an established operational theater.

## Implications for Senior Leadership and Future Development

In reviewing RWT data, this research concludes that the extended time period to reduce RWT (a metric that focuses on warfighter support) from 23 days to 15 days, a process that took approximately 2 years, was due, in part, to a slow introduction of logistics assets into theater during the initial phases of conflict. Therefore, one would surmise the TPFDD flow should be adjusted to maintain proper logistics support during the early phases of operation and continue to build support in proper proportion to increased operational requirements. However, during this research it has been suggested that the findings of the GAO, which show a late introduction of logistics support elements into the AOR, reflect the realities of how unified commanders choose to phase forces in the TPFDD flow.[54] If the GAO report truly reflects a change in force flow execution, then it is incumbent upon the Joint and Service logistics and operational communities to redefine business processes and shape future development based on a limited logistics footprint during the initial phases of conflict. The development of the DDOC concept suggests an acknowledgement of this situation and signals a need to overcome shortfalls in the current Joint theater logistics system. In addition, the findings of the GAO report, coupled with a need to implement a DDOC concept, signal the obvious. It acknowledges the need for a fundamental change to logistics support structures, from the tactical to strategic level, to better meet the requirements of a post-Cold War military operating under a force projection strategy vice a forward presence strategy. This research also concludes that the introduction of the DDOC concept into USCENTCOM's JTF staff had a positive impact on the theater distribution system; and given the realities of a limited logistics footprint during the initial phases of conflict, is a move in the right direction. The DDOC is an organization capable of voicing deployment and distribution priorities, and through the DDOC organizational structure, setting warfighter-focused logistics objectives, implementing programs, and focusing on problem areas within the deployment and distribution system for a combatant commander. In addition, it can align both strategic and operational players to meet the combatant commander's warfighting needs; however, based on the metrics

**The deployment of the DDOC into USCENTCOM's theater was a result of the shortcomings in the deployment and distribution system that came about due to a conscious delay in the deployment of logistical support into theater despite written doctrine to the contrary.**

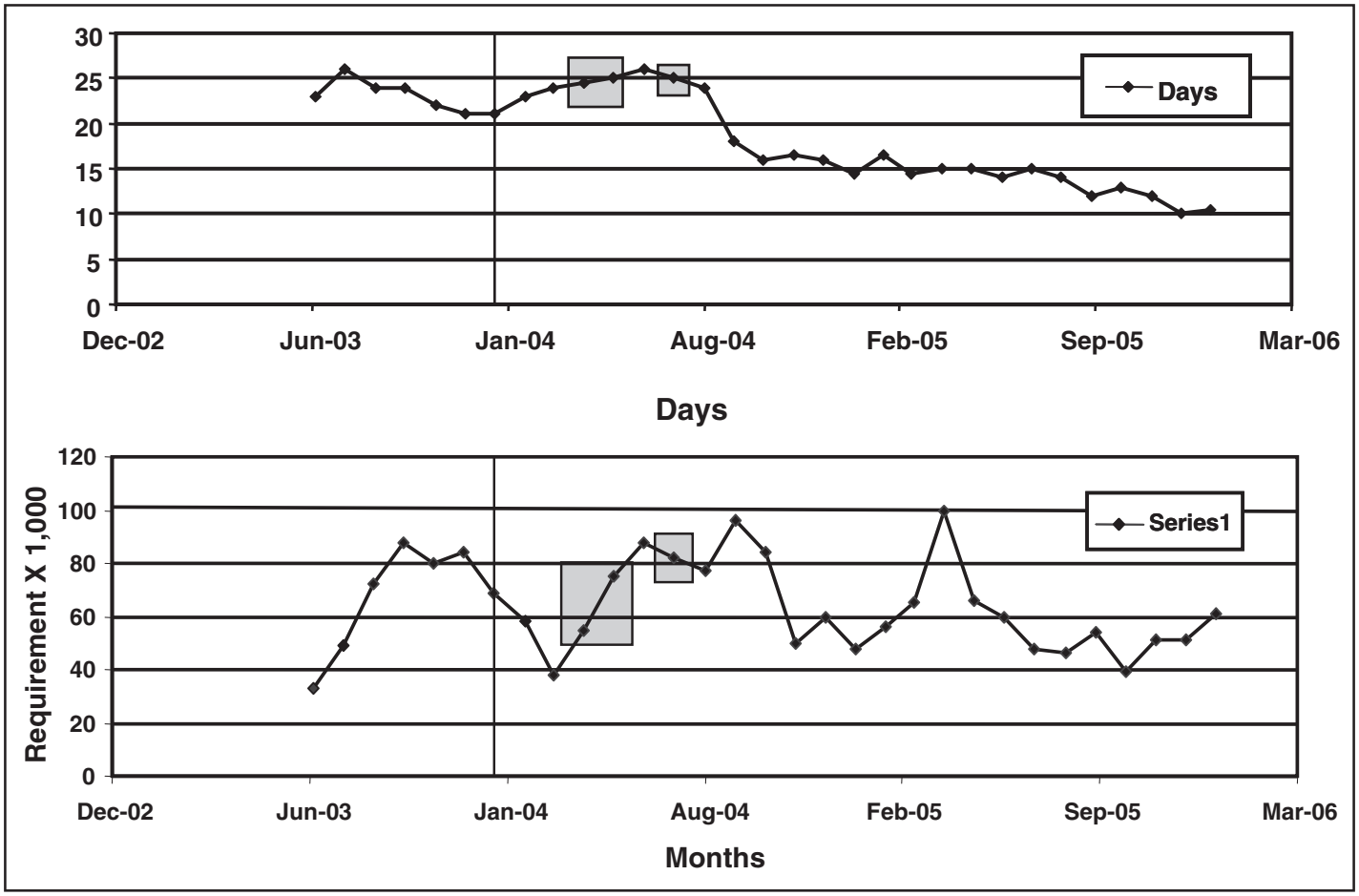



**Figure 4. Top Chart: Requisition Wait Time Values for Iraq per Month June 2003 – January 2006; Bottom Chart: Total Number of Requisitions per Month June 2003 – January 2006; Black Line is DDOC Stand-Up; Gray Squares Denote Missing Data Points (Data Supplied by LOGSA)**

chosen by the DDOC, most initiatives focused on aligning strategic and operational assets to meet warfighter requirements. This research found few, if any, initiatives that directly impacted the processes of the *last tactical mile* with the exception of RFID tagging. In addition, the metrics used to evaluate the DDOC's success were based on programs initiated during the first DDOC rotation in January 2004. This research was unable to find any major initiatives implemented after the rotation of the first DDOC cadre suggesting that the DDOC could be an organization that deploys early in the flow and then those elements that are strategically focused may begin to retrograde back once the logistical infrastructure is established. This would return the theater to a joint movement center (JMC)-focused method for deployment and distribution control.

With these findings in mind, USTRANSCOM should consider future development of the JDDOC to reflect an organization that is used to overcome the realities of a limited movement of logistics assets early in the TPFFD flow. As the Secretary of Defense-designated distribution process owner, USTRANSCOM should maintain primary responsibility for future development and the establishment of standard operating procedures for the various geographically focused JDDOCs. In addition, the development of technology to support an ERP environment should remain with USTRANSCOM in order to ensure standardization across the various unified commands.

Proceeding with the development of JDDOCs in separate unified commands does present a few challenges. The first challenge of allowing DDOC development to take place in separate unified commands has to do with the difficulty in maintaining "habitual relationships and personnel training;" an issue sited as a gap in Joint logistics capability by LTG Christianson, the JS J4. Many of the initial successes of the DDOC were due to habitual relations formed by a relatively small number of Joint logistics professionals. As training packages are developed for future JDDOC implementation, the deployment and distribution community will have to focus on the development of habitual relationships that strengthen the ties between geographic combatant commands and those organizations and unified commands that support the strategic level of deployment and distribution.

## Conclusion

The research conducted within this article attempted to answer the question of whether the implementation of the DDOC into USCENTCOM's theater substantially changed the Joint logistical process, or were improvements simply the result of application of logistical expertise focused on key problem areas. The research finds the latter to be more likely. It is to some degree a fundamental change as to how the deployment and distribution system is focused on warfighter priorities. It is, however, more the application of strategic logisticians brought together to form

a physical ERP to bring a common operating picture to the entire distribution community. The research was unable to answer the fundamental question of, "What if?"

The deployment of the DDOC into USCENTCOM's theater was a result of the shortcomings in the deployment and distribution system that came about due to a conscious delay in the deployment of logistical support into theater despite written doctrine to the contrary. What if US forces had deployed in accordance with doctrine and developed the prescribed logistical infrastructure that is fundamental to military operations? Would the DDOC concept have been necessary had a Theater Support Command and a fully supported joint movement center been put into position from the start of the operation? These two questions will remain unanswered. However, given that this new, doctrinally incorporated concept called a DDOC, was an organizational overlay to the JMC, TSC and air mobility division, and not a fundamental change to the logistics system, then what is to say that doctrine will be followed in the future? The challenge to future Joint military operations will be to maintain discipline in the system and execute Joint doctrine as it is written.

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*Decisive means and results are always to be preferred, even if they are not always possible. We should always be skeptical when so-called experts suggest that all a particular crisis calls for is a little surgical bombing or a limited attack.… History has not been kind to this approach to warmaking.*

**—Gen Colin L. Powell, USA**

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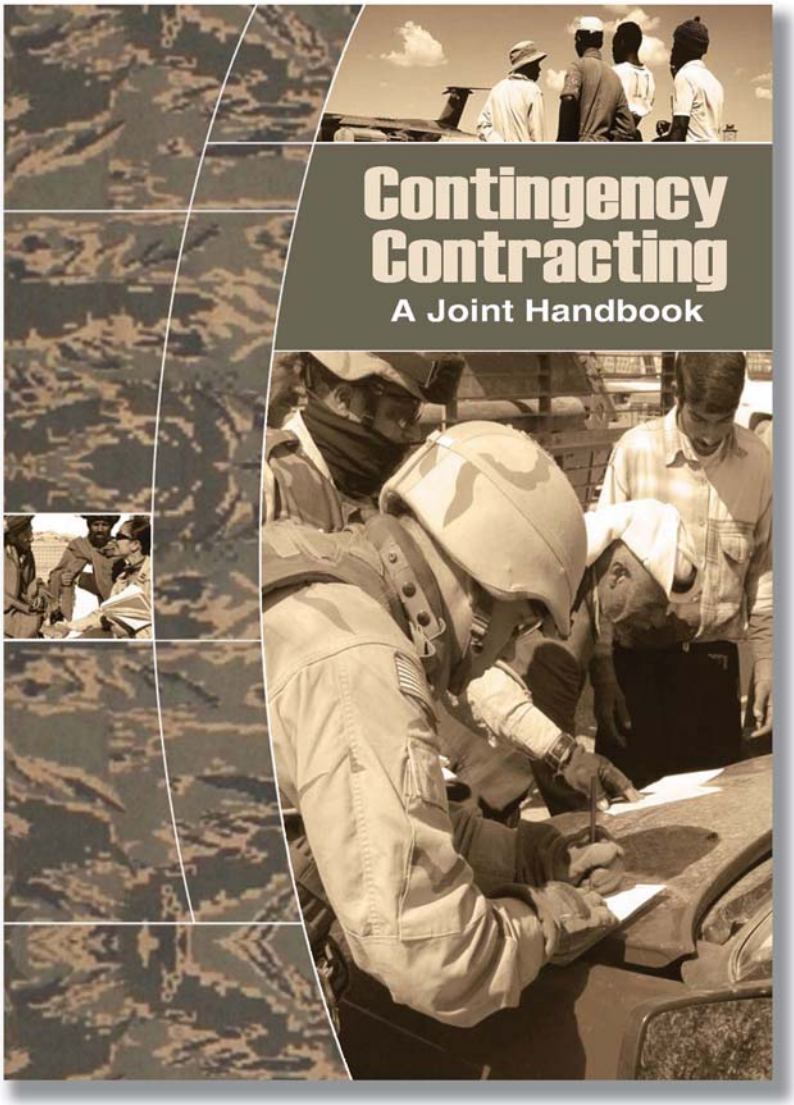


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# Operational-Level Analysis

## DoD's Strategic Mobility and Logistics Support to the Homeland Security Architecture

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### Introduction

On September 11, 2001 (9/11) the United States appeared powerless in the face of a sudden asymmetrical terrorist air attack on several key centers of national power. While the nation rallied in the wake of the attacks, most notably with heroic consequence management efforts in hardest-hit New York City, it also braced itself for follow-on incidents that could range from weapons-laden container ships through the specter of dirty bombs in the American heartland. The US defense establishment was hard pressed to explain how the mightiest military on earth had let the country down. Meanwhile, all departments of the Federal government scrambled to demonstrate resolve in cooperatively *fixing* the apparent breach in civil-military defenses.

Toward this effort, the United States reorganized its homeland support structure, creating the Department of Homeland Security (DHS) and establishing United States Northern Command (USNORTHCOM) as the single unified command for homeland defense and civil support.[1] To better organize itself for emergency response, the DHS integrated the Federal Emergency Management Agency (FEMA) and the United States Coast Guard.[2] These comprehensive changes to the national response structure were designed to increase overall responsiveness to catastrophic events whether caused by an act of terrorism or an act of nature. Yet, although no apparent follow-on deliberate attack has occurred since, the national-level crisis apparatus was tested in the Gulf Coast region of the United States in 2005 with the Hurricane Katrina disaster response, and found wanting—4 full years after 9/11.

The United States homeland security command architecture is extremely complex. Integrating a coherent strategic logistics management process to support this architecture is even more complex. The command architecture is so challenging that very few government officials fully understand how it currently works. Even Department of Defense (DoD) logistics experts are hard-pressed to differentiate parts of problems from parts of solutions. This article examines and synthesizes several essential research areas in order to form a comprehensive analysis of DoD's deployment and distribution architecture to support homeland security. It proposes that the Federal National Response Plan (NRP) is analogous to an interdepartmental coalition operation, and hence can learn from, and possibly model the attributes inherent in a military coalition structure. The analysis culminates with recommendations to enhance DoD's critical role in the homeland security architecture.

This research has three overarching conclusions. First, there is a demarcation of two concentric logistics and mobility

missions. One can be thought of as *tactical relief* operations inside the Joint task force (JTF) Joint operating area (JOA), while the other is the intratheater or *operational and strategic movement* via common user, DoD airlift and other mobility assets. Second, this article concludes that the USNORTHCOM area of responsibility (AOR), in both the Homeland defense and Homeland security support mission realms, has a requirement for operational and strategic logistics and mobility management—these are within the purview of United States Transportation Command (USTRANSCOM). These functions need not be replicated by USNORTHCOM because they are already resident at USTRANSCOM. Third, operational and strategic logistical and mobility planning for incidents of national significance cannot wait until requests are made by overwhelmed lead federal agencies.

**Acronyms**

AEG - Air Expeditionary Groups
AMD - Air Mobility Division
AOC - Air Operations Center
AOR - Area of Responsibility
C2 - Command and Control
C3 - Command, Control, and Communications
COCOM - Combatant Commander
CONUS - Continental United States
CRG - Contingency Response Group
DDOC - Deployment and Distribution Center
DHS - Department of Homeland Security
DIRMOBFOR - Director of Mobility Forces
DoD - Department of Defense
ESF - Energy Support Function
FAA - Federal Aviation Administration
FEMA - Federal Emergency Management Agency
GPMRC - Global Patient Movement Requirements Center
HSOC - Homeland Security Operations Center
HSPD - Homeland Security Presidential Directive
ISR - Intelligence, Surveillance, and Reconnaissance
JFACC - Joint Forces Air Component Commander
JFCOM - Joint Forces Command
JOA - Joint Operating Area
JP - Joint Publication
JTF - Joint Task Force
LFA - Lead Federal Agency
MAF - Mobility Air Force
NDDOC - NORTHCOM Deployment and Distribution Center
NIMS - National Incident Management System
NORAD - North American Air Defense Command
NRP - National Response Plan
SAC - Strategic Air Command
TACC - Tanker Airlift Control Center
TALCE - Tanker Airlift Control Elements
UCP - United Command Plan
USCENTCOM - United States Central Command
USEUCOM - United States European Command
USNORTHCOM - United States Northern Command
USPACOM - United States Pacific Command
USSOCOM - United States Special Operations Command
USSOUTHCOM - United States Southern Command
USSPACECOM - United States Space Command
USSTRATCOM - United States Strategic Command
USTRANSCOM - United States Transportation Command

Analysis begins with a review of the legal foundation that established the framework for the DHS and the rules that guide the federal response architecture. It includes the presidential directives and legal underpinnings most important to DoD support of civilian and military authorities. Next, it lays out the national-level *solution* of federal reorganization designed to foster closer interagency cooperation. It explains the national incident response structure within which DoD is expected to serve as a support functionary.

Next, the article discusses the fundamental differences of the principles of unity of effort and unity of command to explore the limitations on civil-military cooperative command arrangements. The article dwells on the purpose, history, and structure of the unified command plan (UCP) in order to comprehend the military's worldwide organizational architecture and USNORTHCOM's and USTRANSCOM's respective positions within it. The history of the UCP reveals how DoD organization has developed to support operations inside North America, both for homeland defense and for supporting civilian authorities. Further the UCP allows mission-specific divisions inside the United States that are unique to the homeland AOR. It also touches on the distinguishing characteristics of geographic and functional commands in order to highlight the nuances of supporting operations inside sovereign US territory.

Third, it assesses how DoD, USNORTHCOM specifically, integrates into the newly established response system and the interagency unity of effort and unity of command challenges that come with domestic military endeavors. Fourth, for a practical assessment, this article analyzes the military deployment and distribution operations in support of the relief efforts for Hurricane Katrina and Operation Unified Assistance, the US-led international relief effort following the Indian Ocean tsunami of December 2004.

Finally, the article draws conclusions from the striking similarities between the strategic and tactical logistical issues of both the international and domestic relief efforts. It explores the overarching issue of end-to-end strategic logistics management and the associated division of civil-military responsibilities therein, with respect to large-scale catastrophic relief operations.

## National Legal Framework

The national legal framework deliberately places restrictions on the US military for operations outside of overt *defense* in the strictest sense. Operations conducted on US sovereign soil are legally constrained to a significant degree. There are a variety of governing documents that guide homeland security mission areas.[3] Two of the core purposes laid out in the preamble of the United States Constitution state that its very purpose is to ensure domestic tranquility and provide for the common defense. The specific language in the body of the Constitution explicitly divides powers to do so. For example, the Congress has the power

to declare war, raise and support armies, provide and maintain a Navy, and provide for calling forth the militia to execute the laws of the Union, suppress insurrections, and repel invasions. Meanwhile, the President is designated as the Commander in Chief of all the Armed Forces. Therefore, the Constitution itself is the cornerstone justification for the US military's role in homeland defense and homeland security.[4]

## Legal Underpinnings of DoD Support to Homeland Security

The DoD fulfills two baseline missions in support of homeland security. The more straightforward military mission of homeland defense is to defeat conventional threats on the sea, land, and aerospace approaches to the United States under direct orders of the President or Secretary of Defense (SECDEF).[5] By contrast, the homeland security mission of defense support to civil authorities is pursuant to a number of federal legal restrictions designed to safeguard military capabilities from misuse by civilian agencies and military abuse of civilians.[6] In fact, it might surprise the US public to learn what a tiny fraction of its continental United States (CONUS) based military is actively involved in homeland security operations. Moreover, the US public may assume unreasonable expectations of what its military can and cannot do for them—even in crisis.

Over the last two centuries civil and military laws have expanded geometrically. Several pieces of federal legislation and their associated definitions are noteworthy, especially for their impact on the use of the US military for homeland defense and homeland security support. First, the Robert T. Stafford Disaster Relief and Emergency Assistance Act authorizes the Federal government to provide supplemental assistance to state and local governments for relief from major disasters or emergencies.[7] Specifically the President may direct any federal agency, including DoD, to take "special measures, designed to assist the efforts of the affected states in expediting the rendering of aid, assistance, emergency services, and the reconstruction and rehabilitation of devastated areas."[8]

The Stafford Act is the primary legal authority for federal participation in domestic disaster relief. There are three scenarios in which the DoD may be directed to provide assistance.

- A presidential declaration of a *major disaster*
- A presidential order to perform emergency work for the preservation of life and property
- A presidential declaration of an *emergency*[9]

The Stafford Act and the NRP offer detailed definitions for a federal emergency and a major disaster. A federal emergency is:

> Any occasion or instance for which, in the determination of the President, federal assistance is needed to supplement state and local efforts and capabilities to save lives and to protect property and public health and safety, or to lessen (or to avert) the threat of a catastrophe in any part of the United States.[10]

Whereas a major disaster is described as:

> Any natural catastrophe (including hurricane, tornado, storm, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, or drought) or regardless of cause, any fire, flood or explosion, in any part of the United States, which in the determination of the President causes damage in sufficient severity and magnitude to warrant major disaster assistance under this act to supplement the efforts and available resources of the States, local governments, and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby.

In similar fashion, the Homeland Security Presidential Directive (HSPD)-5 establishes threshold criteria for an event to qualify as an *incident of national significance* warranting a coordinated federal response. The NRP defines an incident of national significance as:

> An actual or potential high-impact event that requires a coordinated and effective response by an appropriate combination of federal, state, local, tribal, nongovernment, or private sector entities in order to save lives and minimize damage, and provide the basis for long-term community recovery and mitigation activities.

These federal declarations, and the subsequent level of assistance, are graduated in nature. Emergencies differ from major disasters in that they do not require a specific causal event and are limited in the level of federal assistance rendered. Emergency assistance is limited to $5M without specific Congressional approval to exceed this amount.[11] Major disasters, by definition, are event-related and natural in origin. To qualify as an incident of national significance, an event must meet one of four criteria.

- A responding federal department or agency must request the assistance of the Secretary of Homeland Security.
- The State and local authorities must be overwhelmed and have sought federal assistance through the appropriate channels.
- More than one federal department or agency is substantially involved in responding to the incident.
- The Secretary of Homeland Security has been designated by the President as the manager for the domestic incident.[12]

In addition to the Stafford Act, under certain situations, the Economy Act can be invoked to expedite assistance.[13] The Economy Act allows one federal agency to acquire goods or services from another federal agency provided the requested goods or services cannot be obtained by other means. By invoking this act, a federal agency can request DoD support without a Presidential declaration of an emergency as required by the Stafford Act. Four criteria must be met to invoke the Economy Act.

- The amount (goods) for the purchase must be available.
- The purchase must be in the best interest of the government.
- The goods or services cannot be provided by a contract from a commercial enterprise.
- The agency filling the request must be able to provide or contract for the goods or services.[14]

## The Homeland Security Act

The Homeland Security Act of 2002 and the HSPD-5 established the DHS to be the Federal government's "focal point regarding natural and manmade crises and emergency planning."[15] The Secretary of the DHS is designated as the principal federal official for domestic incident management. In this role, the Secretary is also responsible for "coordinating federal resources utilized in response to or recovery from terrorist attacks, major disasters, or other emergencies" when organic state resources are overwhelmed or as directed.[16] In short, the DHS is termed the

lead federal agency for both planning and response management of homeland security.

The overarching national *solution* to cope with the stove-piped nature of the federal government was the establishment of the DHS itself. Further, the most critical document for achieving forward progress has proven to be HSPD-5. It directed the development and implementation of the NRP, and is predicated on a new "National Incident Management System (NIMS), which aligns the patchwork of federal special-purpose incident management and emergency response plans into an effective and efficient structure."[17] The NRP and NIMS are an ambitious attempt to provide a comprehensive *national framework* for integrating various plans and organizations involved in crisis planning and response.[18] The NRP attempts to put order on the chaotic confluence of agency interrelationships. The NIMS attempts to draw a template for incident response. In a simple example, the NIMS prescribes national standard radio communication language guidelines for all emergency responders to adhere to. This is designed to limit confusing localisms in crisis-situation terminology and to foster interoperability at all levels of government in case an incident expands across multiple jurisdictions.[19]

The NRP assigns lead federal agency (LFA) responsibilities for 15 various types of responses in the form of a matrix containing emergency support function (ESF) annexes which show each applicable *primary agency* (or LFA), and which agencies are tasked to provide support to it.[20] Of the 15 ESFs, DoD is only the LFA for *public works and engineering*, yet DoD is an integral part of the supporting matrix to every other ESF (see Figure 1).[21] In short, DoD will always have a support role regardless of the nature of the emergency.

The ESF annexes are the organizational means for an integrated federal response to incidents of national significance. They provide for federal-to-state, and federal-to-federal interagency support.[22] Each function has a coordinator responsible for all phases of incident management from prevention and preparedness to recovery and mitigation. The coordinator conducts planning and coordination activities on a scheduled basis with support agencies and private sector organizations.[23] The coordinator fills a central role in the organizational foundation of each ESF. A successful response to an incident may very well rest on the level of preparedness and leadership skills at this critical coordination position.

When an incident occurs, the response system activates across the federal and regional levels. The process starts at the Homeland Security Operations Center (HSOC) when the National Response Coordination Center initiates individual ESFs in response to an incident of national significance. The designated ESF primary agencies respond accordingly, activating the appropriate level of responders and support agencies to include the regional echelon through standardized protocols and operating procedures.[24] The goal is a seamless response system implemented across all agencies, primary and support.

## National Response Chain

When an incident becomes a large-scale catastrophe, it will most likely overwhelm state and local emergency responders in short order. In general, these personnel simply do not have the

| Agency | Emergency Support Functions | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #1 - Transportation | #2 - Communications | #3 - Public Works and Engineering | #4 - Firefighting | #5 - Emergency Management | #6 - Mass Care, Housing, and Human Services | #7 - Resource Support | #8 - Public Health and Medical Services | #9 - Urban Search and Rescue | #10 - Oil and Hazardous Materials Response | #11 - Agriculture and Natural Resources | #12 - Energy | #13 - Public Safety and Security | #14 - Long-term Community Recovery and Mitigation | #15 - External Affairs |
| USDA | | | S | | S | S | | S | | S | C/P | S | | P | S |
| USDA/FS | S | S | S | C/P | S | S | S | S | S | S | | | S | | |
| DOC | S | S | S | S | S | | S | | S | S | S | S | S | P/S | S |
| DOD | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| DOD/USACE | | | C/P | S | S | S | | S | S | S | S | S | S | S | |
| ED | | | | | S | | | | | | | | | | S |
| DOE | S | | S | | S | | S | S | | S | S | C/P | S | S | S |
| HHS | | | S | | S | S | | C/P | S | S | S | | | P/S | S |
| DHS | S | S | S | | S | S | S | S | S | S | S | S | C/P/S | S | C |
| DHS/EPR/FEMA | | S | P | S | C/P | C/P | | | C/P | S | | | | C/P | P |
| DHS/IAIP/NCS | | C/P | | | | | | | | | | S | | | |
| DHS/USCG | S | | S | S | | | | S | S | P | | | S | | |
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| DOJ | S | | | | S | S | | S | S | S | S | | C/P/S | | S |
| DOL | | | S | | S | S | S | S | S | S | S | S | | S | S |

C = ESF coordination
P = Primary agency
S = Support agency

Note: Unless a specific component of a department or agency is the ESF coordinator or a primary agency, it is not listed in this chart. Refer to the ESF annexes for detailed supprt by each of these departments or agencies.

**Figure 1. Designation of ESF Coordinator and Primary and Support Agencies**

manpower or equipment to react in a sufficient and timely manner. Federal assistance is obtained through a reactive process triggered by a request for assistance initiated at the state level. The NRP states a governor "requests federal assistance when it becomes clear that state or tribal capabilities will be insufficient or have been exceeded or exhausted."[25]

After an event has occurred, a series of responses and assessments guide the process of obtaining external assistance. First responders to any incident will always be local emergency personnel. These individuals work through the local emergency operations center assessing the extent of the incident in an attempt to determine the level of response required. These initial assessment actions are below the state level with local officials as the incident managers. As the scope of the incident exceeds the capacity of local responders, local authorities request state assistance from the governor through the state emergency operations center. The governor determines if the situation warrants a declaration of a state emergency.[26]

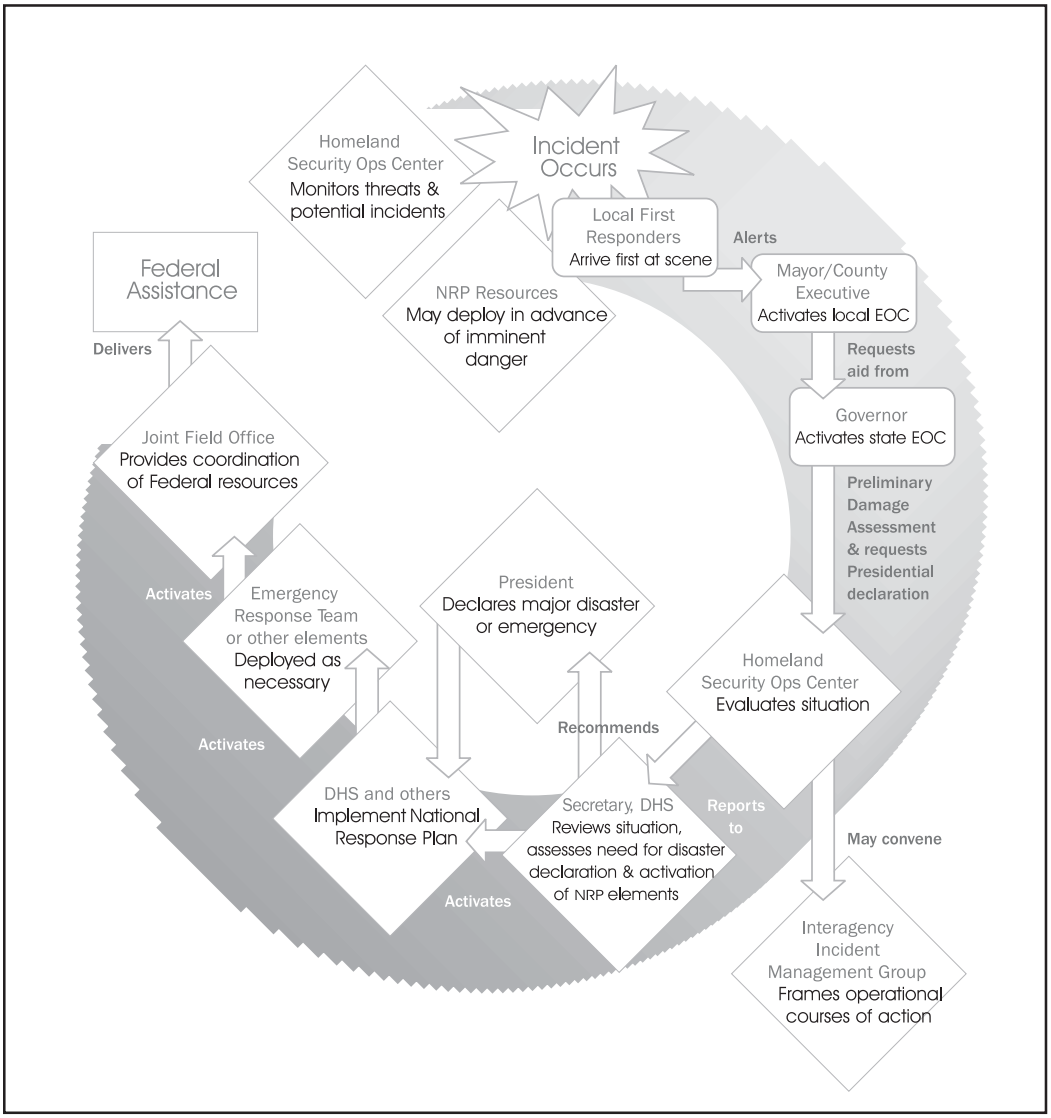


**Figure 2. Federal Involvement Under the Stafford Act**

When the governor declares a state of emergency, he or she also notifies the regional FEMA director, who in turn, notifies the FEMA Director, and in turn, the Secretary of Homeland Security through the HSOC. The operations center evaluates the situation and prepares recommendations for the Secretary and potential presentation to the President. The governor also requests a joint State and DHS Preliminary Damage assessment to determine if the emergency merits a federal emergency or major disaster declaration by the President under the provisions of the Stafford Act (see Figure 2).[27]

It is not inconceivable that a large-scale disaster will overwhelm the capabilities of most organizations. This is where the sheer magnitude and extensive logistics and mobility capabilities of DoD are recognizably unmatched, making it the ideal support element for every ESF of the NRP. Ancillary to its warfighting role, the DoD has a long history of national preparedness and domestic operations often overshadowed by its combat architecture. To further illustrate this point, the next section explores the foundational elements of DoD's strength, the origins of the UCP structure, and the development of USNORTHCOM as a domestic combatant command.

## DoD Framework

### Unity of Command Versus Unity of Effort

Although HSPD-5 and related national guidance describe interdepartment support, cooperation and coordination processes in terms of "unity of effort," only DoD maintains the legal framework for "unity of command." Moreover, DoD is legally bound by Title 10 United States Code authority to always maintain a clear chain of military command regardless of the mission or task being performed. To the military, unity of command is sacrosanct. No Service member can be unattached or take direct orders from a member of another federal agency. Further, the Title 10 chain of command can always be drawn from the airman to the President, or under Title 32 from the airman to his or her Governor. To emphasize this critical point HSPD-5 clarifies: "Nothing in this directive impairs or otherwise affects the authority of … the chain of command for military forces."[28]

The military, unlike its federal partners, holds that "command is central to all military action, and unity of command is central to unity of effort."[29] For the military, it is the essential authority that a military commander "lawfully exercises over subordinates" to assign missions—and to "demand accountability for their attainment."[30] Joint Publication (JP) 0-2, *Unified Action Armed*

*Services,* defines unity of command as the "necessary interlocking web of responsibility" that makes unified action viable.[31] This reflects a difference in perspective between the military and civil servants. Civilian officials certainly rely on unity of effort, yet even law enforcement and firefighters can quit or refuse duty without serious legal repercussion. By contrast, the military member is duty-bound to carry out legal orders. Therefore, who takes orders from whom, matters more inside a purely military hierarchy than in a civilian equivalent. Given the heavy burden of responsibility inherent in such powers, a very clear chain of command is required at all times.

The fact that the civil side of the federal government does not have a clear and codified interdepartmental chain of command, in the Title 10 sense, is a major problem in terms of homeland security. This presents challenges for integrated federal operations where collaborative operations involve both civilian and military personnel. Civilian departments are familiar with this type of interagency environment, despite the obvious inherent inefficiencies. Paradoxically, the DoD, which is most accustomed to clear lines of command and control (C2), is arguably furthest ahead of all federal departments in anticipating disconnects and working within a nonunified command chain. The DoD has gone so far as to codify its wisdom in Joint Publication (JP) 3-08, *Interagency Coordination During Joint Operations*. While not perfect, at a minimum it offers to the DoD Joint community the limitations and nuances of working with external agencies in both planning and execution of complex operations. No such document exists for the federal government in general.

## The Unified Command Plan Architecture

Of all federal departments, the DoD has the most unique structural principles. Doctrine governs that military forces be organized on either a geographic or functional basis.[32] This is spelled out in the UCP, which is the overarching directive that establishes the worldwide architecture of geographic areas of responsibility and functional missions assigned to operational US combatant commanders. The latter alone are given Title 10 combatant command (COCOM) authority to control operational forces.[33] Moreover, the essential role of the Army, Air Force, Navy and Marine Corps Services is to recruit, train, and equip their respective forces for use by the COCOMs. Thus, the Chiefs of Staff of the various Services, all holding the ultimate leadership position achievable for that Service, have in fact no direct role in conducting military operations. Furthermore, the unified commanders themselves only have COCOM of forces assigned to them by a governing DoD *forces for* document. Each command executes operations using standard DoD command, control, and communication (C3) architectures. The current version of the UCP contains five geographic and four functional commands (a new US Africa Command will be created by the end of fiscal year 2008). The geographic commands illustrated in Figure 4 are reminiscent of maps of the Roman Empire, and serve a similar function for US military operations. In short, the commander of each AOR is responsible for all day-to-day Joint operations inside his respective AOR.[35] Additionally, the geographic commands lead planning and political-military *engagement* activities with resident nations. To respond to localized crisis situations or to accomplish specific tasks, combatant commanders are expected to assign either subunified commands or JTFs to concentrate effort without detracting from their broad and continuing AOR missions. For example, US Central Command (USCENTCOM) currently has three JTFs operating simultaneously within its AOR for separate operations inside Afghanistan, Iraq and the Horn of Africa.

By contrast, functional commands control Joint forces performing specific types of continuous military operations without respect to a specific geographic region.[37] The UCP's four current functional command names reflect their unique missions: transportation (USTRANSCOM), special operations (USSOCOM), strategic (USSTRATCOM) and Joint forces (JFCOM). Moreover, each functional command has its own worldwide C3 architecture, and each mutually supports all other unified commands as directed. For example, USTRANSCOM's mission is to "provide air, land and sea transportation for the DoD, both in time of peace and time of war."[38]

Finally, it is important to understand that the President, as commander-in-chief of the armed forces, is granted the establishment authority to reorder the US geographic military *empire* whenever he sees fit.[39] For example, as the UCP map (Figure 3) reveals, prior to 9/11 there was no geographic commander with command of Joint force operations in and around North America. Yet, one year later the UCP architecture had been rapidly adjusted (figure 4).[40] This begs two questions. First, was a catastrophic attack necessary to highlight the American *open gap* in the otherwise comprehensive UCP? Second, why was America initially *uncovered* in the UCP?

### UCP Background

The original goal of the UCP was to preserve the conflict-proven structural framework that was built during the multitheater Second World War. The hard experience of the conflict validated the need for a peacetime military command structure that locked in the wartime proven benefits of *Joint* unity of command. In 1946 the first *UCP* (known as the Outline Command Plan) was approved by President Truman. It established seven unified commands, each with a specific AOR and a set of specified missions. Fifty-nine years later, despite substantial revision and realignment, the basic UCP architectural concept has survived.[41]

The map in Figure 3 shows the delineated AORs of the five geographic commands prior to 9/11: JFCOM, USCENTCOM, US Southern Command (USSOUTHCOM), US European Command (USEUCOM) and US Pacific Command (USPACOM). The two obvious *unassigned* territorial gaps were North America and the former Soviet Union. The latter, comprising the Russian region, remained unassigned as much for its sheer size (it spanned 12 Eurasian time zones) as for its status as a superpower. As the *box* occupied by the very target of the Cold War grand strategy of containment, it was too much of a leviathan to assign to a single geographic command's AOR. In that sense, the pre-9/11 UCP effectively illustrates the military bulwark around the periphery of the Warsaw Pact adversary. Thus, this geographic UCP gap made sense. By contrast the other glaring exception, North America, had no valid military rationale. In fact, it ran counter to the principles of unity of effort and unity of command that were, and are the underpinnings of the UCP architecture.

The North American omission was maintained for a variety of political reasons. First, 60 years ago, there was no viable threat to the secure post-war strategic position of the North American continent. Second, the civil-law legacy of concern over Posse Comitatus and suspicion of military interference with *internal affairs* hampered advocacy of including the continental United States in the plan. Third, the very powerful Armed Services were less than enthusiastic about subjecting their own forces at home, *in garrison*, to a Joint commander from a sister service—especially in the heyday of interservice rivalry. Fourth, the prospect of a *commander in chief* with such an all-important AOR would likely be viewed as first among equals, with responsibilities eclipsing all other combatant commanders. There was also fear that such a position would rival the Chairman of the Joint Chiefs of Staff (CJCS) himself. Yet, in the final analysis, all these reasons (and the list is not exhaustive) prove to be grounded more in internal DoD politics than in any military practicality.[42]

At the UCP's inception, four of the first seven commands (Alaskan, Northeast, Atlantic, and Caribbean Commands) were located in, or tangential to, North America and had collective responsibilities equating to the de facto defense of the continent.[43] While this division was a low-risk proposition in the late 1940s, as time went on the UCP structure was repeatedly forced by *operational military necessity* to be continually adjusted. For example, in 1954, the emerging threat of Russian atomic bomber attack moved the Eisenhower administration and the Joint Chiefs of Staff (JCS) to form the Continental Air Defense Command (CONAD). Three years later in 1957, as a result of Sputnik and the emergence of an intercontinental ballistic missile threat to North America, the North American Air Defense Command (NORAD) was established to extend aerospace early warning and air defense across the CONUS, Canada, and Alaska. Therefore, a Joint force commander with the entire North American continent as an assigned AOR, has been in existence since the 1950s, albeit solely in the realm of air and space *approaches*. Furthermore, hypothetically, had the Soviet threat included a viable land invasion route for massed tank armies across the North pole, a comprehensive air, land, and sea forces Joint command for North America would, of necessity, likely have been organized. In the final analysis then, the reality has been to limit the homeland

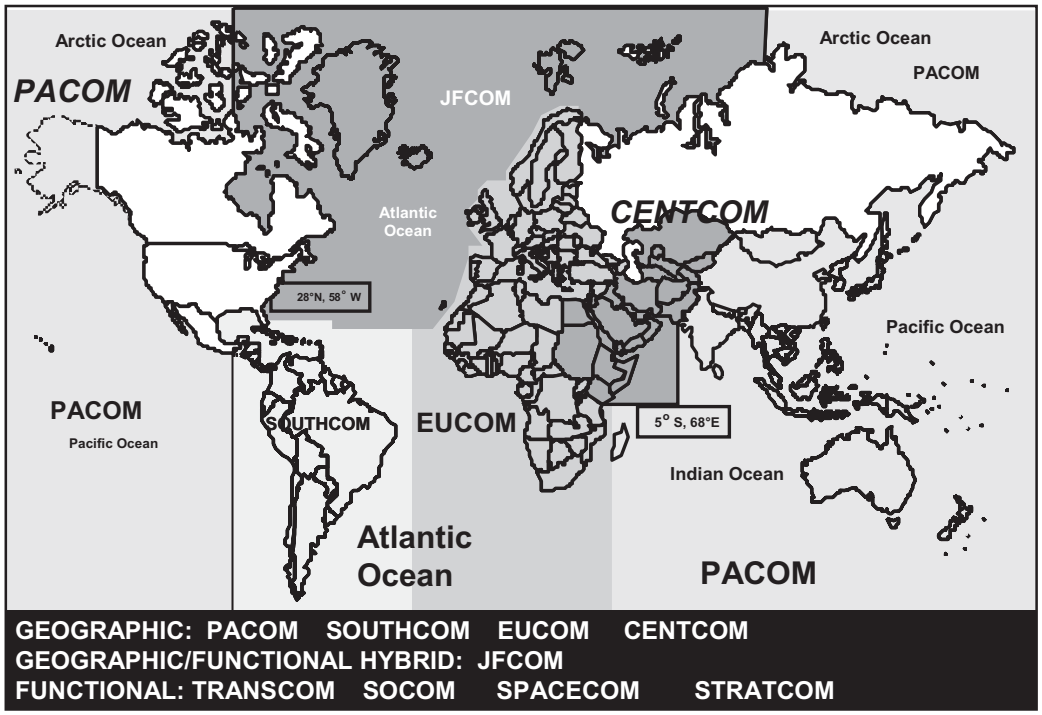


**Figure 3. The Unified Command Plan on 11 Sep 2001[34]**

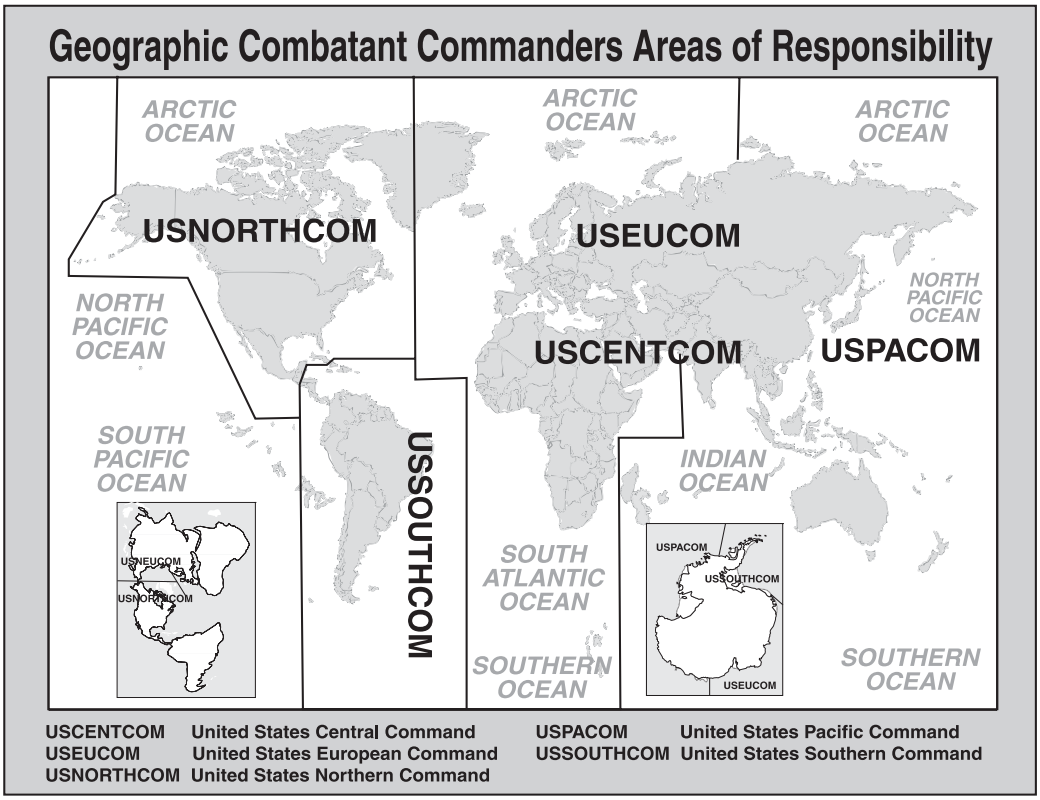


**Figure 4. The Current Unified Command Plan (New US Africa Command to be Created by the End of Fiscal Year 2008)[36]**

UCP geographic region to be organized solely upon defense, and only as a last resort.

Technically, defense is only half of the equation for any geographic commander. The other half is the capability to plan and conduct offensive operations to deter, and failing that, defeat the same enemy you are defending against. For North America in the post-war period, *strategic* offensive power originating in the CONUS equated to the capability to deliver nuclear weapons to any threat-nation on earth, starting with the Soviet Union and later extending to China and elsewhere. Into the mid 1950s, Air Force heavy bombers were the sole delivery systems for atomic weapons. For this reason, the Air Force's Strategic Air Command (SAC) was designated as the first *specified command*—an older concept not in current use that controls only the forces of a single service to accomplish its mission.

The example of SAC is a telling historical lesson in what types of C3 arrangements can be constructed to accomplish a mission deemed critical to national security. As the primary commander charged with offensive strategic weapons delivery prior to the advent of the strategic triad, the Commander-in-Chief, Strategic Air Command (CINCSAC) had awesome (some would argue dangerous) responsibility. In the era of deterrence through *massive retaliation*, an immense responsibility rested on the shoulders of a single-point *offensive* commander who resided inside the CONUS, but whose mission was both global and continuous. Congress and the rest of the Services objected to the disproportionate funding (half of the entire DoD budget) SAC required in the 1950s, but given the gravity of the mission, all understood that a crystal clear, tightly-controlled chain of command was in order. In short, it was once again an operational necessity for such an architecture given the extreme reaction times required to effectively respond to—and thereby deter—a Soviet strategic nuclear attack.

Unfortunately, given the safeguards involved in nuclear offensive operations, and the concomitant requirement for survivable and instantaneous *fail-safe* communications, the C3 architecture of the US offensive forces has been intentionally stove-piped from the C3 of the strategic defense which complements it. The offensive operations of SAC which stood ready to respond in minutes and the defensive operations of NORAD, also postured on alert, were and still are entirely bifurcated and relatively oblivious to each other's operational plans and tactical procedures.

The salient rationale for this self-inflicted disunity of command is the Canadian government's recalcitrance to be integrated into a command that is designed to conduct offensive nuclear operations of any sort. Given the geographical realities of Canada's territorial juxtaposition between the United States and Soviet Union, this price continues to be paid. Yet, it would be ludicrous to divide offensive and defensive military operations in any other theater. For example, would it make sense if the USCENTCOM AOR were divided into an offensive command and a defensive command with entirely separated and stovepiped C3? It would not be logical to order the offensive command to launch a campaign of invasion, while a defensive command dealt only with enemy counter-attacks. Wartime operations would be hopelessly confused and overlap everywhere in the AOR. Yet, that is precisely the structure that existed from the 1950s through to the end of the Cold War. Furthermore, this inherent dichotomy in our strategic planning is essentially invisible. Its fundamental C3 flaws will only be apparent upon execution.

If nothing else, this doomsday scenario illustrates the level of national acceptance in operational design flaws prior to 9/11. Given that the Cold War strategic landscape dictated a strategy of offensive deterrence at the expense of true unified Joint strategic warfighting capability, design flaws in the latter area are at least understandable. However, the baseline assumption to this line of reasoning is that actual real-world execution would never happen. For if *the unthinkable* did happen, the Soviets would suffer unacceptable damage via the nation-ending lethality of the offensive arm. The problem is that the Cold War baseline assumptions have melted away in the face of asymmetric, nonstate actors who have already demonstrated the will and acumen for mounting real-world unthinkable attacks on sovereign American territory. Therefore, the paradigms that allowed military disunity of command and uncentralized Joint coordination at the operational level should have been swept away with the Cold War. In the final analysis, the fall of the Soviet Union did, in fact, drive a relook at the American UCP architecture, but it was done for decidedly nonoperational reasons.

## Closing the North American Gap Prior to 9/11

In the decade prior to 9/11 the JCS began consideration of how to restructure the Cold War UCP to cope with an expected drawdown in forces based overseas. Of immediate concern was how to organize the substantial forces slated to return to permanent CONUS garrisons. This helped to propel a proposal for an all new geographic *Americas Command* that would have included all of North and South America, with the exception of Alaska. USSOUTHCOM was to be disestablished. It proposed to combine Army Forces Command, Tactical Air Command (later Air Combat Command), Atlantic Fleet, and Marine Forces Atlantic as its Service components.[44] However, the proposal was not oriented on missions in and around America, but rather to place all CONUS-based forces under one command as a Joint force manager to support contingencies around the globe. As a functional combatant command it would have responsibility for "Joint training, force packaging, and facilitating deployments of designated CONUS forces."[45] It was also designed to serve as the central manager of Joint force integration and experimentation. The extent of its CONUS operational mission was to lend support to domestic agencies for disaster relief and civil support.[46]

The proposal for an Americas Command eventually resulted in the stand-up of JFCOM, but it faced modification and compromise in the process. Its proposed geographic area was curtailed by the retention of a separate USSOUTHCOM when it was deemed necessary for regional engagement purposes to retain it intact. Also, rather than create an all new command, General Powell, the CJCS at the time, selected the existing Atlantic Command (LANTCOM) as the most favorable alternative to build upon. Because it was a patchwork compromise, the new commander had to add the above-mentioned missions to his existing duties as NATO Supreme Allied Commander Atlantic (SACLANT). Thus, the command was a cobbled together hybrid of geographic and functional missions.[47]

This analysis of the UCP architecture for North America leads to three overall observations. First, the benefits of unity of

command in and around North America have been repeatedly compromised for largely political reasons. Second, true geographic unity of effort and command have been lacking inside North America, given that the missions of homeland defense and the equivalent of *homeland offense* have been assigned to separate commands. Finally, any time there has been proof of operational necessity, substantial adjustments to the North American UCP architecture have been made in order to adapt to emerging mission areas. Of these, the last is the most important. It means that the DoD homeland UCP architecture, and by extension the subsystem constructs within it, have always been malleable. Therefore, when circumstances dictate, there should be no hesitation to make requisite changes as quickly and efficiently as possible.

## Support to the Department of Homeland Security

### Military Architecture in Support of DHS

The 9/11 attacks were followed by political anger and dismay at the lack of federal interagency coordination in both intelligence and counterterrorism. Local agency first responders in both New York City and Washington, DC experienced acute difficulties in communications. The US military, used to meting out precision strikes, received a taste of its own medicine when its central C2 node, the Pentagon, received a direct hit from the air. Even the otherwise quick response launch of NORAD fighters was too little, too late. From local through federal levels, it was apparent that the interagency security apparatus of the United States was in need of critical examination. The President vowed both retribution and rapid reformation of the overall national security infrastructure.

The DoD's game plan for homeland defense was a top down restructuring of its Joint posture. The 9/11 attacks swept away lingering opposition to the idea of an American unified command on US domestic territory. Within weeks all senior DoD officials, including the unified commanders were solicited for recommended changes in the UCP architecture. Multiple proposals were forthcoming, including one for a *North American Command* that would have absorbed both NORAD and STRATCOM to achieve unity of Joint offensive and defensive operations at the national strategic level. However, opposition to this unity of command initiative was a prospective Canadian objection to integrated involvement in a command that was in control of offensive nuclear operations. This may have caused their withdrawal from the critical defensive-only NORAD coalition. Since the actual executive-level deliberations were top secret, it will likely be some years before all considered UCP courses of action are revealed.[48]

In April 2002, President Bush signed the 2002 revision to the UCP. It contained his executive decision to establish US Northern Command (USNORTHCOM) with geographic responsibility for homeland defense and civil support operations. The new command relieved Joint Forces Command of the homeland defense mission and inherited and modified the air sovereignty mission of NORAD.[49] The USNORTHCOM AOR encompassed the continental United States, Alaska, Canada, Mexico, and the air, land, and sea approaches including waters out to approximately 500 nautical miles. It also included the Gulf of Mexico, Cuba, Puerto Rico and the US Virgin Islands. The defense of Hawaii and Pacific territories remains the responsibility of the US Pacific Command (see Figure 4).[50] According to its mission statement USNORTHCOM "conducts operations to deter, prevent, and defeat threats and aggression aimed at the United States, its territories, and interests within the assigned area of responsibility … and, as directed by the President, or Secretary of Defense, provide defense support of civil authorities including consequence management."[51]

The commander of USNORTHCOM is dual billeted as the US commander of NORAD. While not the air component of USNORTHCOM, the NORAD C3 infrastructure effectively functions in both roles as well. By long-standing bilateral agreement, NORAD is confined to only aerospace early warning and enforcing "control of the skies over the United States and Canada" not the above, more extensive USNORTHCOM AOR.[52]

**The DoD homeland UCP architecture, and by extension the subsystem constructs within it, have always been malleable. Therefore, when circumstances dictate, there should be no hesitation to make requisite changes as quickly and efficiently as possible.**

While this arrangement is virtually invisible in the purely defensive role, many of the functions of a standard geographic AOR air component are missing. First, there is a glaring lack of integration with the offensive air component whose C3 belongs to STRATCOM as discussed in the previous section on DoD framework. Second, USNORTHCOM has a severely limited capability for planning and executing its own AOR's intratheater air mobility operations.

With the assignment of Russia to EUCOM and the stand-up of USNORTHCOM, the 2002 UCP finally closed the remaining geographic command AOR gaps. However, it also contained major revisions to the functional commands with equities inside the USNORTHCOM AOR. First, it removed JFCOM's geographic command area responsibilities by transferring it to USNORTHCOM (see Figures 3 and 4).[53] Second, it ordered US Space Command (USSPACECOM) to stand down and transfer its core missions to USSTRATCOM, with the exception of NORAD functions which were transferred to USNORTHCOM. Third, the detachment of NORAD to USNORTHCOM reconfirmed the separation of strategic defensive operations from national strategic offensive operations controlled by USSTRATCOM. In no other AOR are offense and defensive operations intentionally

stovepiped at the operational, planning, execution, and C3 levels. Finally, the 2002 UCP dissolution of USSPACECOM was a matter of choice, not necessity. The expansion of the USSTRATCOM mission set was part of the long-range vision of Defense Secretary Rumsfeld who used the necessity of establishing a headquarters for an all new USNORTHCOM as leverage to disassemble USSPACECOM. The UCP maintained the previous number of nine unified commands, thereby minimizing the costs of associated staff *overhead*.[54]

The sweeping UCP reorganizations also created turbulence at the headquarters of all affected unified commands at the very time the military was ramping up to support the Global War on Terror, including operations in Afghanistan. Meanwhile, USNORTHCOM's initial cadre of Joint staffers were consumed with forming a working organization internally, while keeping abreast of the wider federal homeland security reorganization efforts underway externally.

Further, USNORTHCOM, the command singularly dedicated to homeland security operations, reached operational capability in 2003 with little more than the ex-JFCOM JTF-Civil Support and JTF-6 (counter-drug operations support) as its main tactical units. Although USNORTHCOM is given priority for the forces it requests, it tactically controls very few forces day-to-day. In fact, it technically has no assigned or apportioned forces whatsoever. In this sense, it is very much a *paper command*.[55] Moreover, its Service component commanders are *dual-hatted* with primary duties elsewhere. For example, its 1st Army land component is primarily for training—not for homeland defense or civil support execution.[56]

The USNORTHCOM of 2005 is more robust, but its operations are still relatively narrow in scope. In its defense support to civil authority mission, the command provides support to federal agencies through established Joint task forces. Currently these forces are organized into five distinctive areas or missions: Standing JTF Headquarters North; JTF Civil Support; JTF Alaska; JTF North, and Joint Forces Headquarters, National Capital Region.[57] Unfortunately, USNORTHCOM's task-organized defense and support missions somewhat undermine its basic reason for existing—military unity of command and effort. Due to the dissimilar nature of its unique mission sets, USNORTHCOM's air, land, and sea components must each be independently organized to perform what are disparate missions. For example, the air component is primarily focused on air sovereignty. Its JTF-Civil Support has specific tasks for chemical, biological, radiological, nuclear, and high explosive (CBRNE) detection and consequence management. As a result, rather than training, exercising, and operating as a geographic Joint force, USNORTHCOM forces are spread into specific mission areas, effectively stovepiping their operational C2.

USNORTHCOM is unique in that it either borders with, or is host to the headquarters of, the other eight unified commands. Since all commands are stakeholders in defending the homeland, this should, in theory, foster good *interior lines* of communications. Yet, the intentional *use only as a last resort* language at the heart of its homeland security charter, coupled with the minimum *only as required* force structure, compels USNORTHCOM to compensate with heavy reliance on the four functional commands. JFCOM provides virtually all of its forces. USSOCOM assists with counter-terrorism operations. USSTRATCOM partners in defensive information operations, communications, space support, and missile defense tasks. However, for large-scale consequence management incidents, almost always requiring rapid mobility and logistics support, USTRANSCOM becomes the indispensable functional supporting command.

## Federal Interagency Coalition Concept

The role of USNORTHCOM is difficult to grasp without understanding its role as the military component, or *DoD LFA* piece of the larger national homeland security puzzle. The unique LFA-centric structure of the Federal NRP might best be understood in terms of an interdepartmental coalition operation. Since non-DoD actors cannot be integrated into a true unified command model (in the Title 10 military sense), and given that these operations are predicated upon unity of common effort, a coalition is an accurate description of the myriad of independent federal agencies that are involved in major national emergency response operations. Similar to sovereign nations of varying sizes and capabilities, the numerous federal departments, states, and local agencies are intensely *territorial* about guarding their independent equities and identities, even at the expense of the common objectives of the rest. Yet, all are clearly stakeholders in the same homeland security coalition effort. Moreover, all departments publicly agree that, to be effective, efforts must be coordinated. The DoD might have the hardest time coming to grips with being part of a coalition it does not lead or control.

Therefore, the coalition model can be a useful template for analyzing the federal homeland security *war effort* as it were. The President's own HSPD-5 states, "The objective of the United States Government is to ensure that all levels of government across the Nation have the capability to work efficiently and effectively together, using a national approach to domestic incident management … to prepare for, respond to, and recover from domestic incidents, regardless of cause, size, or complexity."[58]

Putting policy on paper provides only a vision and its intent. Actually executing interagency planning and coordination within the largest and most complex bureaucracy in world history is a bit more of a challenge. According to author Arthur Rice, three elements are essential to coalition success—a lead nation, unity of command, and staff integration.[59] The following macroanalysis applies these three elements to the US civil-military *homeland coalition*.

First, the role of *lead nation* must be bestowed on the DHS, since it is the ultimate LFA with the assignment of coordinating "the Federal Government's resources utilized in response to or recovery from" incidents of national significance.[60] Therefore, only DHS can rightfully assume this role, especially in purely disaster and catastrophic humanitarian relief scenarios. All agencies agree that a surprise, multifaceted event involving critical infrastructure and multiple population centers could occur at any time. Yet the chaos-producing events in New Orleans in 2005 were relatively forgiving in that they were driven by a benign natural enemy and not by a determined and deliberately malicious terrorist organization. If it had been the latter, the careful legal distinctions surrounding what constitutes a DoD-led homeland defense scenario versus a DHS-led civil support scenario could have easily become blurred. In such dire cases, the President will be the ultimate arbiter of categorizing the crisis and assigning an LFA. The two clearly dominant departments—

DoD and DHS—will have to provide mutual support. However, The President's HSPD-5 lays out policy direction, but defaulted to the Secretaries of Defense and Homeland Security to "establish appropriate relationships and mechanisms for cooperation and coordination between their two departments."[61] Although both have technically complied, the less-than-stellar response to Hurricane Katrina, and the extremely negative political fallout has both departments, DoD and DHS, reevaluating all cross-coordination and response mechanisms.[62]

The second essential element of coalition success is unity of command. The departments of the US government are technically parts of a centralized federal government. However, the departments work more as a loose *con*federation than a strongly centralized federalist government.[63] To use the US Civil War as the leading example, a major limitation to the Confederate government's war effort was lack of authority to supersede states rights—insurmountable since it was the root cause of their rebellion. While the Union centrally resourced, planned, and executed under a true unified command structure, the most the Confederacy could do was coordinate efforts for *the cause*. For example, the states could not even be compelled to share uniforms or weapons. State forces cooperated with each other and provided mutual support only on a voluntary basis. The authority granted the Secretary of the DHS by the Homeland Security Act of 2002, and echoed in HSPD-5 makes DHS responsible for *coordinating* federal operations, not controlling them per se.[64] While the Secretary of DHS is certainly not the equivalent of Jefferson Davis, his problems are very much similar in dealing with other interagency actors which include the 50 US state governors who also must be included as independent executives and homeland security coalition *partners*. Federal unity of command is missing and unity of effort is based on a DHS-led confederated architecture. This is the homeland security coalition's Achilles Heel.

The third essential in Rice's coalition model is staff integration. Of the three, this is the most promising to emphasize given the number and complexities of the federal departments and agencies. Interagency information sharing and cross-intelligence will be crucial in managing complex crisis action responses. To formally facilitate this, all combatant commanders, including USNORTHCOM, have created permanently assigned Joint interagency coordination groups (JIACGs) which include experts and liaison officers from other commands, various departments, and state and local authorities. These are supposed to form a "critical bridge between the combatant commander and the appropriate LFA as required."[65] However, exchanging liaisons is not integration of operations. Moreover, the proliferation of command centers within every major department makes it almost impossible to maintain liaison connectivity with every one, and vice versa.

Further, the military paradigm of tactical level tied to operational control, tied to strategic objectives means little to local agencies. Moreover, since incidents of national significance happen only rarely, local, and even federal entities, are willing to wait until an event is underway before devoting the type of planning and training resources that should be required for each ESF scenario. For example, there is no strategic fire chief who can order the training and equipping of hundreds of thousands of firefighters in tens of thousands of localities. Furthermore, even though all US first responders are technically at the *tactical level*, as are DoD forces, they are not beholden to any form of centralized doctrine or a layered C3 system per se. The NIMS is the best attempt to connect C3 in crisis response, but its utility does not directly extend to steady-state planning and coordination efforts. Integration for cooperative and collaborative efforts is better than nothing, but it is far less efficient than strong centralized planning and C3.

The challenges for the DHS Secretary and the inherent difficulties in the DHS system became readily apparent in August 2005 when a catastrophic hurricane devastated the Gulf Coast region of the United States. The ensuing federal response became an excellent case study for all aspects of the federal *coalitional* mechanisms established since 9/11. The following chapter analyzes that domestic hurricane relief effort to identify organizational and logistical challenges and compare these challenges to the international tsunami relief effort of 2004.

## Humanitarian Relief Operations

*It was the largest natural disaster ever to strike the United States—92,000 square miles. Logistics were falling apart.… I should have asked for the military sooner. I should have demanded the military sooner.*

**—(Former) FEMA Director Michael Brown, 18 January 2006**

### Hurricane Katrina

The DHS pressed the previously untested NRP into action on 29 August 2005 when a natural event of immense proportion struck the Gulf Coast. In the latter part of August, a hurricane developed in the Caribbean, cut across southern Florida, and moved northwest into the Gulf of Mexico.[66] The hurricane, named Katrina, intensified, tracked northward and made landfall in the Gulf Coast regions of Louisiana, Mississippi and Alabama. At its peak, the storm developed into a category five event on the Saffir-Simpson scale.[67] At landfall, it was a category four hurricane with winds of 140 miles per hour.[68] The devastation from the storm was beyond any level anticipated. Thousands of Gulf Coast residents across the three states were in dire need of assistance.

In anticipation of the impending relief effort, USNORTHCOM began to position liaison elements well before requests for assistance from any of the states reached the federal level. USNORTHCOM began coordinating with USTRANSCOM, FEMA, and the states a full five days prior. On 24 August, USNORTHCOM sent warning orders to regional and state emergency preparedness officers and the states' senior Army guard advisors.[69] On 28 August, USNORTHCOM positioned a USTRANSCOM liaison officer inside its headquarters.[70] Given that the destructive scale of Hurricane Katrina was yet unknown, these steps were reasonable.

It was not until the Hurricane was actually moving inland that DHS requested DoD assistance per formal NRP process channels. In response, USNORTHCOM established JTF Katrina, a contingency JTF construct built from elements of the command's standing JTF Headquarters North, JTF North, and JTF Civil Support. However, USNORTHCOM chose to deviate from its expected composition by tasking 1st Army at Fort Gillem, Georgia as lead unit, instead of 5th Army at Fort Sam Houston,

Texas, which had been predesignated for the homeland security support mission.

Over the next 7 days staging operations were established at Maxwell Air Force Base, Alabama; Keesler Air Force Base, Mississippi; Barksdale Air Force Base, Louisiana; Naval Air Station Meridian, Mississippi; Alexandria, Louisiana; Fort Polk, Louisiana; and New Orleans International airport. C3 operations were established at the USNORTHCOM JOC located at Peterson Air Force Base, Colorado; Fort Gillem, Georgia (JTF Katrina Headquarters); Camp Shelby, Mississippi (JTF Katrina forward); Baton Rouge (JTF Katrina Southern Louisiana) and aboard the USS Iwo Jima (a second JTF Katrina forward), with an air expeditionary task force (1st AETF) at the Air Operations Center (AOC) located at Tyndall Air Force Base Florida.[71]

The USNORTHCOM-appointed JFACC, Major General M. Scott Mayes, led JTF Katrina air component operations through the Tyndall AOC. General Mayes, a veteran fighter pilot, was commander 1st Air Force, and commander Continental North American Aerospace Defense Command Region. He was also the JFACC for Operation Noble Eagle, responsible for contingency planning and aerospace defense of the continental United States.[72] However, doctrinally the JTF commander selects the JFACC based on the overall mission, concept of operations, the missions and tasks assigned to subordinate commanders, forces available, duration and nature of the operation, and the degree of unity of command required.[73] With JTF Katrina, the clear preponderance of fixed-wing forces were from the mobility air forces (MAF), as was the C3 architecture inherent at the Tanker Airlift Control Center (TACC) and the Global Patient Movements Requirements Center (GPMRC). These factors would have made the 18th Air Force commander, as the MAF's numbered Air Force *warfighting* commander, the most logical candidate for the JTF/JFACC position. Another logical choice would have been a senior ranking helicopter search and rescue airman, from any service including the US Coast Guard. While either of these options would have been a viable solution, USNORTHCOM felt it was more appropriate to use its organic air component commander, and his *inhouse* AOC capability to manage operations.

Under normal conditions the Tyndall AOC operates as the NORAD Southeast Air Defense Sector for Operation Noble Eagle, supporting air defense, air sovereignty, air battle management, radar warning, fighter patrol, and aerial tanker operations.[74] While the standing AOC structure presented a logical C3 center for the JTF Katrina air component, the internal structures and capabilities for support of a humanitarian-type civil support operation were questionable. As a standing AOC, Tyndall has the five standard divisions: strategy, combat operations, combat plans, air mobility (AMD), and intelligence, surveillance, and reconnaissance (ISR). However, unlike AOCs in Korea, Europe, or USCENTCOM, the USNORTHCOM AOC divisions are oriented almost entirely toward the air defense mission, but poorly manned for a major deployment and distribution mission.[75]

To be sure, JTF-Katrina's complex air operations went beyond mobility, but air sovereignty fighter missions were not part of the mission set. The overall air component mission was fourfold—ISR, search and rescue, airspace control, and humanitarian relief operations which were comprised of airlift and aeromedical evacuation missions. The ISR mission was minimal, amounting to one sensor-equipped aircraft that flew less than five times in support of JTF-Katrina. Search and rescue operations were controlled by the Joint Personnel Recovery Center collocated with the AOC at Tyndall AFB.[76] This organization operated parallel and in coordination with the AOC.

Airspace control proved to be a larger challenge due to Federal Aviation Administration (FAA) jurisdiction and the sheer amount of rotary wing assets operating in the recovery area and outside the AOC Air Tasking Order System. The AOC did produce an airspace control plan, however based on reported conflicts, it is doubtful that all military aircraft adhered to the plan. The potential for a mid-air collision operating under a *see-and-avoid* type system requires further research to define responsibilities and mandatory coordination between the FAA and the AOC.

In the final analysis, with virtually independent airlift, aeromedical and search and rescue operations underway throughout the Katrina AOR, the interceptor-centric AOC's Air Tasking Order amounted to controlling the three special use platforms that were under the tactical control of the JFACC—the Scathe View imaging system, the aerial spraying system, and the airborne firefighting system. All of these assets completed

**The organized chaos highlights that requisite coordination, let alone command and control, was never truly attained. Given the disparate organizations employed, one must question if an adequate command and control structure is even feasible under the current response agreements, given the number of *federal coalition* actors. It is, however, apparent that a viable command and control architecture must exist across the span of the DoD responders.**

negligible sorties in comparison to the scope of the aerial relief missions.

On 29 August, 18th Air Force designated Colonel John Gomez as the Director of Mobility Forces (DIRMOBFOR) in support of the aerial relief effort. Later, as the scope of the catastrophe expanded, Brigadier General Mark Zamzow plus two deputy DIRMOBFORs were brought in to help coordinate tasking and validation of airlift and aeromedical missions with USTRANSCOM and the 18AF/AOC, also known as the TACC, at Scott Air Force Base, Illinois.[77] This adjustment reflected not only the change in scale of the emergency, but the major role the DIRMOBFOR would fulfill as the mobility expert in advising the JFACC and directing the actions of his Air Mobility Division (AMD).

The Tyndall AOC's AMD was heavily weighted toward air refueling experts necessary for the AOCs primary fighter-centric NORAD mission, at the expense of operational airlift expertise. This required substantial augmentation of the AMD via deployment of seven airlift specialists from USTRANSCOM. Humanitarian relief operations, specifically airlift support, were coordinated through the AMD to the TACC using a *reachback* concept for tasking and coordination essentially independent of the AOC's Air Tasking Order.[78] Aeromedical evacuation operations were managed in a similar fashion through the Global Patient Movement Requirements Center (GPMRC) at USTRANSCOM.[79]

Requests for assistance from various federal agencies and nongovernmental organizations were validated through USNORTHCOM's Deployment and Distribution Center (NDDOC) at Fort Gillem in coordination with the USNORTHCOM Joint Operations Center/J4. Valid requests were forwarded to the USTRANSCOM DDOC for DoD priority, validation and modal determination. Perhaps most importantly, the *big picture* operational mobility management was performed at USTRANSCOM headquarters DDOC, rather than the USNORTHCOM AOR's NDDOC. Requests from USNORTHCOM were collated and stacked against other worldwide DoD priorities. After USTRANSCOM added their validation stamp to requested movements, it translated them into missions for its component elements in the most efficient and effective way possible—specifically 18th Air Force, the Surface Deployment and Distribution Command, and the Military Sealift Command.

It is noteworthy that the USNORTHCOM validation and tasking process took 5 days to establish as the center was forward located and the command does not normally operate a Deployment and Distribution Center.[80] Moreover, both the USNORTHCOM DDOC and the AOC/AMD at Tyndall were stood up by deploying primarily USTRANSCOM-assigned personnel. Thus, on paper USNORTHCOM provided the operational and *tactical relief* C3, when in actuality it did not have the organic capability to do so. By contrast, the TACC, which normally manages dozens of airlift missions worldwide at any given moment, every day of the year, performed those same C3 duties for airlift missions in support of JTF Katrina in normal stride.

On the ground inside the JTF AOR there were tandem operations. As the magnitude of the crisis became clear, USTRANSCOM coordinated with USNORTHCOM to allow the rapid deployment of its AMC Contingency Response Group (CRG) Elements and Tanker Airlift Control Elements (TALCEs) to establish major aerial ports at Keesler Air Force Base, Mississippi; Jackson International Airport, Mississippi; New Orleans International Airport, Louisiana; Pensacola Naval Air Station and Duke Field, Florida. Each of these elements is specialized in *airfield opening*, or standing up the prerequisite air mobility enabling functions of airfield operations, C3, and aerial port capabilities—all essentials for the reception and handling of inbound platforms, their cargoes, deploying forces, and so forth. Moreover, these elements are arguably the single most critical piece of any airlift operation since they modulate throughput and efficiency inside the disaster relief zone itself. Furthermore, these units are trained, manned, and equipped for short-notice response to austere environments, which means they are essentially tailor-made for reestablishing access to catastrophically-impacted areas—even if those are in the CONUS. Based in California and New Jersey, and maintaining a 12-hour alert-to-launch window, these assets can be rushed to any point in the 50 states well within 24 hours.

These professional mobility experts were, without question, the right teams inserted at the right locations. However, they were the final delivery destinations of the USTRANSCOM system. Therefore, at these same locations, the JFACC established air expeditionary groups (AEGs) to act as functional air bases for the JTF. Reports indicate the USNORTHCOM CRG/TALCEs and AEGs cooperated well; however, they maintained separate command and control lines, presenting obvious challenges for deconfliction and unity of command. The salient point is that the aerial ports were where USTRANSCOM's job technically ended and the USNORTHCOM/JTF-Katrina (or DHS) responsibilities began, in terms of onward movement and distribution of the relief personnel and cargo delivered. Therefore, the span of control of the two major DoD stakeholders was marked out at the boundary between the operational level (USTRANSCOM) and the tactical level (USNORTHCOM).

Unfortunately, USTRANSCOM's controlled and deliberate mobility processes were pitted against a plethora of *coalition partners* external to the official JTF. No less than seven organizations were attempting to respond simultaneously, not always in parallel, or even coordinated.[81] Alongside USNORTHCOM, other DoD, FEMA, state, National Guard, nongovernmental organizations, and private organizations all strived to provide relief as quickly as possible. Unscheduled aircraft began arriving at the relief distribution operations, including various state National Guard actors whose air mobility assets (primarily C-130s) were never formally assigned to the USNORTHCOM or USTRANSCOM. Furthermore, Navy, Army, and Marine Corps fixed-wing assets were not managed by the JTF, since they were *organic* service lift assets. Consequently, the JFACC had no control and very little visibility over these aircraft.[82] Chaotic conditions are as counterproductive in relief operations as they are in war zones. Airfields and ramp space were always at a premium. Finally, the lack of centralized C2 created confusing and potentially dangerous situations for all involved. Scheduling, preventing bottlenecks, and ensuring throughput of lift assets was the goal.

All of the complicating unity of command and unity of effort issues resulted in a far less than optimized logistical operation. Situation reports had multiple examples of poor coordination. At Keesler Air Force Base, "lack of a single point of [overall]

scheduling caused airlift operations to slow considerably." At New Orleans International Airport, "intransit visibility of cargo was nonexistent; unmarked pallets were offloaded [and] ownership was unobtainable."[83]

The organized chaos highlights that requisite coordination, let alone command and control, was never truly attained. Given the disparate organizations employed, one must question if an adequate command and control structure is even feasible under the current response agreements, given the number of *federal coalition* actors. It is, however, apparent that a viable command and control architecture must exist across the span of the DoD responders. And this structure should maximize existing capabilities and capitalize on dedicated expertise from the tactical through operational levels. If nothing else, clearly in this first major *real world* test, both DHS and USNORTHCOM proved they were ill-prepared to effectively manage wide-area logistics with organic capabilities in a large-scale domestic catastrophe. Certainly it underscored their reliance on USTRANSCOM's core competency expertise, assets, and C3 architecture.

### Indian Ocean Tsunami

The similarities of interagency and coalition operations in the Indian Ocean tsunami of 2004 and Hurricane Katrina 2005 are striking. According to the Operation Unified Assistance after actions report, 16 countries and no less than 200 nongovernmental organizations were involved in the international relief operation, operating from multiple countries. Indonesia hosted 68 nongovernment organizations, Thailand 35, Sri Lanka 84, and the Maldives 17. The greatest challenges to overcome were communication and, more importantly, command and control."[84]

The intensive helicopter-centric operations of JTF-Katrina in the United States were mirrored and exaggerated by the severe lack of ground infrastructure in the far-flung Indian Ocean. The fixed-wing airlift operation was equally as complex. US C-5 and C-17 heavy-airlift aircraft were flown into Utaphao, Thailand, making it the strategic distribution hub. From there, C-130 tactical airlift aircraft from a variety of countries and Service components, 19 suboperations in total, delivered relief supplies to forward locations in Sri Lanka, Indonesia, and Thailand. From those forward operating locations, helicopters, the critical key to successful distribution operations, were used to take supplies in, and refugees out of remote disaster areas.[85] The DoD air component commander's concept of operations was a classic strategic logistical management example of hub and spoke operations. While this type of operation is simple in concept, the supporting C3 architecture is not. The US military, specifically USTRANSCOM, has the equipment, communications, and most importantly, the expertise to organize on such a scale. The hundreds of nations and nongovernment organizations that plugged into this US-facilitated system and the victims were the beneficiaries. The alternative would likely have been haphazard in execution and lethally slow in effect.

Of special note, the US military-led coalition originally formed a JTF, however the political implications of a perspective US-dominated C2 structure led to the re-designation of the operation under the guise of *combined support force*s."[86] This structure may forecast the future of international coalition relief operations. It may also be a blueprint for domestic operations given the "coalition" of interagency, active duty, state, local and National Guard operators—especially to effectively coordinate the myriad ground, helicopter, and light fixed-wing relief actors.

Since the operation was multinational and ad hoc, there was ineffective cargo validation and prioritization management, at least in the first critical weeks of the relief operation. After-actions reporting by the JFACC, Major General Deptula, is telling:

> [Relief requirements] assumptions and reality clashed as we all struggled to identify requirements. Initially there was a big push to deliver as much water, food, clothing, plastic, and sheeting, into theater as we could cram onto available aircraft. As the operation progressed and we started to see piled supplies, the requirements definition became critical. Since the US Agency for International Development was the lead organization there was an assumption that they would take the lead, and maybe they did … but the translation of those needs to the JFACC was slow and at times nonexistent.[87]

The associated lessons learned observation made by USPACOM is virtually identical for Katrina operations. It stated there was a need to quickly establish a robust requirements and validation process, based on a common doctrine to ensure the proper flow of cargo requests for airlift. There are also critical needs for a 24 hour, 7 day continuous response capability and for personnel experienced in the requirements process.[88] In every major mobility support operation the essential information is "what, where, how much, and how fast." Requirements absolutely drive the size and scope of the transportation response. However, without this type of accurate and timely data flow from the LFA, the supporting operations, even if led by DoD, are doomed to produce chaos.

## Summary, Conclusions, and Recommendations

This article started with the Presidential directives and legal underpinnings most important to DoD support of civilian and military authorities. Second, it laid out the national-level solution of federal reorganization designed to foster close coordination. It explained the NRP and NIMS graduated incident response structure within which DoD support is expected to function. In order to explain the limitations on forming civil-military cooperative command arrangements, it touched upon the fundamental differences of the principles of unity of effort and unity of command. Next, the article explained the purpose and structure of the UCP in order to enable the reader to understand specifically the military's worldwide organizational architecture and USNORTHCOM and USTRANSCOM's respective positions inside it.

The history of the UCP reveals three key observations. First, the DoD has historically only organized to perform the minimum essential operations required of it both in the military homeland defense and civil-support homeland security missions, a luxury no longer affordable. The DoD must be a full partner in proactively supporting DHS and other government agencies in anticipation of, rather than purely in response to, incidents of national significance. Second, the UCP history reveals that subarchitectures can be reformed any time there is an operational necessity to do so. Finally, the accepted divisions in the offensive and defensive C3 architectures confirm that the single unified commander for the North American AOR does not have to be in control of every traditional mission facet assigned to geographical AOR commanders.

The authors have reached three overarching conclusions based on the above analysis. First, there is a demarcation of two concentric logistics and mobility missions. The first can be thought of as *tactical relief* operations inside the JTF JOA, which includes distribution of relief cargo and services. Both the USNORTHCOM AOR Katrina and the PACOM AOR tsunami relief efforts depended largely on US and *coalition* partners at the tactical level. These forces provided boots on the ground and especially rotor-wing rescue and lift assets which are arguably the most vital assets of all that military capabilities bring to bear in such a crisis. The second is the intratheater, or what can be thought of as the *operational and strategic movement* via common user, DoD airlift and other mobility assets.

Second, this article concludes that the USNORTHCOM AOR, in both the Homeland defense and Homeland security support mission realms, has a requirement for operational and strategic logistics and mobility management. These functions are within the purview of USTRANSCOM. The need not be replicated by USNORTHCOM because they are already resident at USTRANSCOM.

USTRANSCOM's functional core competency mission makes it the only DoD entity capable of strategic logistics management—not only in the sense that its worldwide mobility capabilities are an instrument of national power, but also in the literal sense of using an expert strategy to gain maximum efficiency and effectiveness from the supply chain. The US Council of Logistics Management defines strategic logistics management as:

> The process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements.[89]

In this case, the customers can be defined as either the end users that DoD is trying to supply (like hurricane victims), or to the LFA or DoD command being supported itself—either way the definition fits. The salient point is that USTRANSCOM is the only *federal agency* that can perform the above functions on a grand scale.

According to Joint Publication (JP) 3-26 *Homeland Security*, USTRANSCOM "provides common user and commercial air, land, and sea transportation, common user port management and terminal services … to [USNORTHCOM] and [PACOM] within their respective AORs for homeland defense and civil support mission areas."[90] In addition to this charter to support the two commands whose AORs contain all 50 US states, JP 3-26 also says that USTRANSCOM will do the same for lead federal agencies directly when ordered by the President or Secretary of Defense. Therefore, depending on the situation, LFAs may be directly supported by USTRANSCOM, or they may use USNORTHCOM or PACOM as a DoD intermediary.

USTRANSCOM also provides worldwide patient movement and evacuation, and it now serves as the DoD distribution process owner responsible for the execution of the strategic distribution system."[91] In this last capacity, the command has moved beyond merely transporting personnel and cargo from point to point. USTRANSCOM is now attempting to mirror civilian supply chain management and distribution processes. Its command headquarters, central DDOC, is populated with staff from its Army, Navy and Air Force components which process DoD transportation requests by validating, prioritizing, and choosing the transportation mode given the requirements. Furthermore, USTRANSCOM has unique and distinctive capabilities that need very few layers of bureaucracy to accomplish the effects required. In fact every layer added actually slows down the response unless there is value added in the form of efficiency for the wider effort. For a given movement, say armor for vehicles to USCENTCOM or humanitarian relief supplies to USNORTHCOM, waiting for an opportunity to *bundle* larger aggregates of supplies are examples of overall value-added efficiency delays. On the other hand, simply waiting for another layer of DoD or civilian bureaucracy to rubber stamp an approval is nonvalue added.

In strategic logistics, efficiency equates to effectiveness. This premise is deceptively simple to agree with but much harder to actually orchestrate. At the tactical level each independent operator considers their load of materials *top priority*. The Katrina DIRMOBFOR noted the effectiveness and timeliness of airlift requests "were hampered by the fact that few agencies outside of USTRANSCOM and AMC truly understood distribution processes."[92]

The USNORTHCOM headquarters, by contrast, has a relatively small logistics planning staff by geographic command standards. Day-to-day, it directs its execution through a collocated Joint operations center. In times of crisis in its AOR involving large-scale mobility operations, the command will partner with USTRANSCOM to stand up its own "USNORTHCOM DDOC," or NDDOC, which is essentially a forward deployable DDOC performing a similar function as USTRANSCOM's but on an AOR- or JTF-confined scale. Moreover the NDDOC's operational chain of command runs up to USNORTHCOM, while most of its practical coordination is with USTRANSCOM. Therefore, the overall NDDOC coordination process owner is technically USNORTHCOM, but the de facto process owner, given its worldwide constant C3 of the entire DoD system, is clearly USTRANSCOM.[93]

The third conclusion is that, for incidents of national significance, operational and strategic logistics planning cannot wait until requests are made by overwhelmed LFAs. The rationale for developing the DHS and USNORTHCOM was to increase overall responsiveness to catastrophic events whether caused by an act of terrorism or an act of nature. Trying to do this effectively while in a reactionary mode from a national crisis is next to impossible. In hindsight, the operational response became a reverse engineering project where execution of the mission by USNORTHCOM developed ahead of an adequately robust support architecture.

It is clear that the federal government's lead umbrella organization, DHS, functions more on a coalition operational model that is closer to a *confederacy* than a federal *union*. Therefore, given the uniqueness of the AOR and the myriad agencies operating inside it, the requirement for USNORTHCOM to duplicate the USTRANSCOM functional architecture for large-scale contingency logistics and air mobility is obviated. Moreover, USTRANSCOM needs to be recognized as a discrete, full partner in the federal coalition, confined to its functional, core-competency as the single-point manager for transportation and logistics during large-scale *incidents of national significance*.

While the USNORTHCOM charter clearly defines roles for itself and USTRANSCOM, the limitations placed upon the civil support mission of *respond only when requested*, forces DoD,

and USTRANSCOM especially, to distort the distinctions between who is responsible for what, and when. It is the very nature of the response system that causes confusion and ultimately delays. Planning for in extremis response to incidents of national significance is the most critical missing component. While DoD assistance and resources can only be requested as a last resort for overwhelmed government agencies, *anticipatory,* DoD-guided planning coordination for those events need not be. Moreover, in military parlance, the CONUS is a very *mature theater*. Perhaps hardest to reconcile in terms of the rapid logistical response to Katrina is that there are so many obvious infrastructure advantages of the CONUS. Unlike remote parts of the Indian Ocean or central Africa, the United States enjoys the most robust transportation network on the planet. There is no physical impediment that cannot be overcome to ensure efficient end-to-end movement of relief supplies into, and evacuees out of a JOA like that of JTF-Katrina.

A systematic intermodal logistics chain and its C3 cannot be formed quickly enough to match crisis timelines in most cases. A second 9/11-scale incident or worse could happen at any time. However, while the NRP implores departments and commanders to lean forward in preparation, the current posture of *stand-by for official tasking* from the designated and overwhelmed LFA will guarantee a response system lag. Yet, a tear in the national fabric must be immediately treated via all federal coalition means available. The disaster response sensor-to-reaction mechanisms must be made more efficient. The Homeland Security and Homeland Defense stakeholders must be postured to provide a wide-area *organized* response to domestic catastrophe.

In Thomas Friedman's book *The World is Flat*, he uses UPS as the model corporation that takes the logistics piece over on behalf of less capable companies rather than have them *duplicate the process*.[94] USTRANSCOM is perfectly suited to fulfill this function. It de facto forms an all-modal reachback for domestic incidents of national consequence with USNORTHCOM as the DoD primary C2-agent command.

Planning for rough requirements, pre-siting perspective airfields and cargo ramps, and likely logistics relief hubs and spokes in the USNORTHCOM AOR takes a predictive strategic logistics approach. FEMA certainly has the experience and expertise in defining the baseline relief requirements. These should be prepackaged and ready when a crisis occurs. However, to ensure this working relationship, USTRANSCOM cannot afford to rely on crisis action scenarios. It must devote a sizeable portion of its own expert planning resources to assist USNORTHCOM and the other coalition partners during the preplanning and preparedness phases. No other lead entity can accurately perform shaping functions on size, nature, scope and limitations of the logistics portion of a federal response. In practical terms USTRANSCOM, with its global support to all unified commands, can only afford to treat USNORTHCOM as one of its major warfighter customers. However, the USNORTHCOM/J4 logistics staff's *primary* role needs to be planning and exercising with USTRANSCOM.

The relationship between USNORTHCOM and USTRANSCOM should differ from relationships among the other geographic commanders. Both commands, one functional and one geographic, must team with DHS to develop a more formalized and structured architecture for coordinating all federal, state and private airlift and mobility requirements for relief support. This would entail mandating all responding agencies and organizations to coordinate their airlift needs or operations with a central clearinghouse for deconfliction. This will tie the USNORTHCOM JTF tactical end-user distribution piece with USTRANSCOM's strategic logistical capabilities piece. The latter should be considered a full partner in the federal coalition for exactly that function—its chartered unified command function defined in the UCP.

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